February 11, 2015

FOUNDATION INVESTIGATION AND DESIGN REPORT

HIGHWAY 540 WITTY'S CREEK CULVERT AT STA 16+953, SITE 49-071
TOWNSHIP OF ALLAN, MANITOULIN ISLAND, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5057-07-00, WP 5061-07-01

Submitted to:
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REPORT

Report Number: 13-1191-0005-R4

Distribution:

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Golder Associates

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PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 540 WITTY’S CREEK CULVERT AT STA 16+953, SITE 49-071

TOWNSHIP OF ALLAN, MANITOULIN ISLAND, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5057-07-00, WP 5061-07-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the Witty's Creek culvert (Site 49-071) in the Township of Allan on Manitoulin Island, Ontario. The Key Plan showing the general location of this section of Highway 540 and the location of the investigated area are shown on Drawing 1.

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

2.0 SITE DESCRIPTION

The Witty's Creek culvert is located on Highway 540 at STA 16+953 approximately 1.6 km east of Beange Road west of Kagawong. The land use in the area is generally rural (i.e., farm land) with a few residences in the vicinity of the site.

In general, the topography in the area of the overall project limits is flat. The creek flows from north to south. Photographs taken at the site are included following the text of the report.

The existing culvert is 12.4 m long, 3 m wide and 1.5 m high and the highway grade at the culvert site is at about Elevation 231.2 m. The creek water level was measured by Golder on September 26, 2014, at Elevation 229.6 m.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried from September 22 to 30, 2014, during which time a total of four boreholes (Boreholes WC-1 to WC-4) were advanced at the locations shown on Drawing 1. Boreholes WC-1 and WC-2 were advanced using a truck-mounted CME-55 drill rig and Boreholes WC-3 and WC-4 were advanced using a track-mounted CME-55 drill rig. Both drill rigs were supplied and operated by Landcore Drilling 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, 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). Samples of the bedrock were obtained using NW casing and NQ size core barrels in each of the boreholes. 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 (as amended).

The fieldwork was supervised throughout by a member of our technical staff who: located the boreholes; 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 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. Classification testing (water content and grain size distribution) was carried out on one selected soil sample. 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 creek water was obtained using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters.

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		
WC-1	5084090.9	316863.2	231.1	4.7
WC-2	5084094.7	316869.2	231.2	5.2
WC-3	5084102.4	316863.2	229.6	1.6
WC-4	5084084.6	316869.2	229.5	1.9

4.0 REGIONAL GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on surficial geology mapping from the Ministry of Natural Resources[1], the site is located within areas containing post-Precambrian bedrock bordering with lacustrine and glaciolacustrine deposit consisting of silt and clay.

Based on bedrock geology mapping from the Ministry of Natural Resources[2], the bedrock in the area consists of shale, sandstone, dolostone and limestone units of the Clinton-Cataract Group.

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 and bedrock core 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 results of the analytical testing on the sample of creek water are summarized in Table B1 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 rock coring. These boundaries, therefore, represent transitions between soil types rather than exact planes of

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[1] Ministry of Natural Resources, electronic mapping obtained 2014, MRD128, 2006
[2] Ministry of Natural Resources, electronic mapping obtained 2014, MRD219, 2007

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.

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Embankment Fill

The embankment fill at the culvert locations consist of asphalt overlying granular fill.

Asphalt

A 150 mm and 125 mm thick layer of asphalt was encountered at ground surface in Boreholes WC-1 and WC-2, respectively.

Granular Fill

A 1.2 m and 1.8 m thick layer of granular fill was encountered below the asphalt in Boreholes WC-1 and WC-2, respectively. The granular fill consists of brown, moist, gravelly sand, some silt, trace recycled asphalt pavement (RAP).

One split spoon sample was obtained within the gravelly sand fill; however, the split spoon sampler did not penetrate the full sample depth due to the presence of cobbles and/or boulders. NQ coring was required to advance the boreholes through the gravelly sand fill layer.

The natural moisture content measured on a sample of the gravelly sand fill is 6 per cent.

The result of the grain size distribution test completed on a sample of the gravelly sand fill is shown on Figure B1 in Appendix B.

4.2.2 Clayey Silt

A 0.2 m thick layer of brown clayey silt, with sand, trace gravel was encountered below the granular fill in Borehole WC-1. The surface of the clayey silt was encountered at depth of 1.4 m below the existing ground surface, at Elevation 229.7 m.

One split sample was obtained within the clayey silt; however, split spoon refusal (i.e., hammer bouncing) was encountered on the underlying bedrock surface prior to penetrating the full depth of the sampler.

4.2.3 Bedrock/Refusal

Bedrock was cored in all of the boreholes and the depth to the bedrock surface and bedrock surface elevations are presented below.

Borehole No.	Depth to Bedrock (below ground surface) (m)	Bedrock Surface Elevation (m)	Notes
WC-1	1.6	229.5	Bedrock cored for 3.1 m
WC-2	1.9	229.3	Bedrock cored for 3.3 m
WC-3	0.0*	229.6	Bedrock cored for 1.6 m
WC-4	0.0*	229.5	Bedrock cored for 1.9 m

*Exposed bedrock at ground surface

The retrieved bedrock core is described as grey, fine grained, fresh to moderately weathered dolomitic limestone, as presented on 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 of the bedrock cored is 100 per cent and the Solid Core Recovery ranges from 64 per cent to 100 per cent. The Rock Quality Designation (RQD) measured on the core samples generally ranges from 57 per cent to 100 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006)[3]. In Borehole WC-2, an RQD of 0 per cent was measured in the upper 0.3 m of the bedrock core indicating very poor quality rock.

Laboratory Unconfined Comprehensive Strength (UCS) testing was carried out on three representative core samples of the bedrock and the uniaxial compressive strength test results are shown in Table B2 included in Appendix B. The UCS values are presented on the Record of Drillhole sheets and summarized below and the test results indicate that the bedrock is very strong (R5) as per Table 3.5 of the CFEM (2006).

Borehole	Depth/Elevation (m)	UCS (MPa)
WC-1	2.5/228.6	174
WC-2	3.1/228.1	155
WC-4	1.3/228.2	161

4.2.4 Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The water level in the creek was measured at Elevation 229.6 m on September 26, 2014.

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

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
WC-1	1.6	229.5
WC-2	1.6	229.6
WC-3	0.0*	229.6
WC-4	0.1	229.4

*Water level at ground surface

Groundwater and creek water levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field drilling program was supervised by Mr. Trevor Moxam and this report was prepared by Mr. Adam Core, E.I.T. and the technical aspects were reviewed by Mr. David Muldowney, P.Eng. André Bom, P.Eng., carried out an independent review of the report. Mr. Jorge Costa, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.

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PART B

FOUNDATION DESIGN REPORT

HIGHWAY 540 WITTY’S CREEK CULVERT AT STA 16+953, SITE 49-071

TOWNSHIP OF ALLAN, MANITOULIN ISLAND, ONTARIO

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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 Witty's Creek culvert is a 12.4 m long, 3 m wide and 1.5 m high rigid-frame, open-footing culvert, which is to be replaced with a 12 m long, 4.8 m wide and 1.2 m high open footing culvert. Concrete wing walls will be constructed at each of the four corners of the structure extending parallel to Highway 540 for a length of 3.5 m from the ends of the structure. In addition, a 300 mm high, concrete head wall will be constructed at the culvert inlet and outlet. The grade of the highway will essentially remain the same (Elevation 231.2 m) with only a minor grade raise as required for pavement reconstruction.

From a foundations perspective, an open footing culvert is recommended due to the shallow bedrock present at this site. Recommendations for a precast box culvert have been provided in the event that a box culvert is selected as the replacement structure.

6.2 Geotechnical Resistance

6.2.1 Open Footing Culvert

A factored geotechnical axial resistance at Ultimate Limit States (ULS) of 1,000 kPa may be used for design of the strip footings founded directly on the prepared bedrock surface. The geotechnical reaction at SLS for footings founded on the bedrock will be equal to or greater than the factored geotechnical axial resistance at ULS and, therefore, the ULS values will govern for design.

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

6.2.2 Precast Concrete Box Culvert

The factored geotechnical axial resistance at Ultimate Limit State (ULS) for a precast box culvert founded on a granular bedding layer overlying the bedrock may be taken as 1,000 kPa. As the culvert is to be founded on bedrock, the geotechnical reaction at Serviceability Limit State (SLS) (for 25 mm of settlement) does not apply given that the bedrock is an unyielding foundation. Depending on the bedrock surface elevation along the culvert alignment relative to the culvert invert elevation, leveling/lowering of the bedrock may be required to accommodate bedding placement. Details regarding the granular bedding requirement are provided in Section 6.5.

6.2.3 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the concrete culvert or concrete wingwall footings and the bedrock surface should be calculated in accordance with Section 6.7.5 of the CHBDC. For the precast concrete culvert placed on compacted granular material, the coefficient of friction tan $\delta = 0.45$. For cast-in-place wing walls footings (or footings for an open footing culvert) founded directly on bedrock, the coefficient of friction is tan $\delta = 0.7$. These values are unfactored.

6.2.4 Frost Protection

The estimated frost penetration depth at this site is 1.6 m, as per OPSD 3090.101 (Foundation, Frost Penetration Depths for Southern Ontario).

Where the footings are to be founded directly on bedrock, frost protection is not considered necessary.

Closed bottom box culverts are typically not provided with the standard depth of soil cover for frost protection as close bottom box culverts are tolerant to small magnitudes related to freeze-thaw cycles should these occur. The granular bedding placed below the culvert should be kept to a limited thickness to bring the grade from the bedrock surface to founding level.

6.3 Stability, Settlement and Horizontal Strain

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

6.3.1 Stability

Based on the existing/proposed embankment geometry and the subsurface conditions at this site, granular fill embankments at this site will be stable at side slopes not steeper than 2 Horizontal to 1 Vertical (2H:1V).

6.3.2 Settlement

As the proposed culvert will be founded directly on bedrock or on a granular bedding layer over bedrock, total settlement of the culvert is expected to be less than 25 mm.

It is recommended that OPSS.PROV 1010 (Aggregates) Granular ‘A’ or ‘B’ Type I or II be used for embankment reconstruction at the culvert location. Where granular fill will be placed below the groundwater/water level, Granular ‘B’ Type II should be used. The material placed above the water level should be compacted in accordance with OPSS 501 (Compacting). Compression settlement of the granular fill placed below water and from properly compacted embankment fill placed above water is expected to occur during construction.

6.3.3 Horizontal Strain

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

6.4 Lateral Earth Pressures

The lateral earth pressures acting on the side walls, wing walls, and head walls 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 culvert and wing walls and 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 II but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culvert, wing walls and head walls. 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 culvert, wing walls and head walls, in accordance with CHBDC Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501 (Compacting). 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). 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 culvert structure, wing walls and head walls allow for lateral yielding, active earth pressures may be used in the geotechnical design of the structures. If the culvert structure, wing walls and head walls 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.

6.5 Construction Consideration

6.5.1 Excavations, Subgrade Preparation and Backfill

As the proposed culvert and wing walls will be founded on bedrock, a temporary support system comprised of sheet piling will not be feasible at this site. Soldier piles and lagging (with the piles socketted into bedrock or supported by tie backs or rakers) may be used for support of the excavation along the structure, as well as along the roadway for traffic protection. Temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways. Alternatively, the culvert may be installed using open-cut excavations with a maximum temporary side slope of 1.1H:1V or flatter within the existing fill (short-term excavations). The existing fill at this site may be classified as Type 3 soil. All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended). In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of the existing Highway 540.

Given the proposed dimensions of the replacement culvert, it is assumed that the new culvert, and associated wing walls, will be constructed with the same alignment and at the same invert level as the existing culvert. Although the bedrock surface level within the boreholes is fairly consistent, with 0.1 m difference between the boreholes near the inlet and outlet, bedrock excavation may be required to found the culvert and/or wingwall footings at the required depth. As the bedrock is classified as very strong, it would require pre-drilling and hoe ramming to allow it to be excavated.

If a box culvert is selected, the box culvert should be installed in accordance with OPSS 422 as modified by SP 422S01 (Precast Concrete Box Culvert). The box culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV.1010 (Aggregates) Granular ‘A’ or Granular ‘B’ Type II material for bedding purposes. Bedding for the box culvert could be constructed in either dry or wet conditions as follows:

- Where excavations will be unwatered to allow for construction of the culvert in dry conditions (see Section 6.5.3), the bedding should be placed in lifts not exceeding 200 mm loose thickness, and compacted to at least 95 per cent of the Standard Proctor Maximum Dry Density (SPMDD) of the material as specified in OPSS 501 (Compacting). The structural design of the culvert should take into consideration the conditions for bedding placement and compaction in accordance with the requirements of Section 7.8.3.6 of the CHBDC.

- Alternatively, the culvert could be installed in wet conditions depending on the season of construction and water level at the time of installation. The water level should be lower than the proposed surface of the bedding. In this case, the bedding should consist of Granular ‘B’ Type II and be nominally compacted by the construction equipment. The design of the culvert should be based on the bedding having achieved a moderate level of compaction; if a degree of compaction is needed for design, a relative density of 90 per cent of the SPMDD should be assumed.

Groundwater control may be required during installation of the culvert and construction of the wing wall footings as further discussed in Section 6.5.3.

The thickness of fill placed during backfilling should be maintained equal on both sides of the culvert with one side not exceeding the other by more than 400 mm as per OPSS 422 (Concrete Box Culverts). New granular fill should be keyed into the existing embankment side or cut slopes as per the requirements of OPSD 208.010 (Benching of Earth Slopes) to minimize differential settlement between the existing embankment and the newly placed embankment fill.

The structure 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 structure. 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.

Prior to placement of the roadway granular subbase and base courses, the final lift of embankment fill should be compacted to 100 per cent of the SPMDD. 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.

6.5.2 Erosion Protection

If a box culvert is selected, a concrete cut-off or clay seal wall may be required at the culvert inlet and outlet 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). 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.

6.5.3 Control of Groundwater and Surface Water

The creek flow will need to be diverted/piped during construction of the culvert. Surficial water seepage into the excavation should be expected and will be heavier during periods of sustained precipitation. Seepage from the granular fills 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.

An appropriate unwatering strategy will be required for construction of the cast-in-place concrete wing walls footings in the dry. The unwatering strategy will need to consider the water-bearing granular fill and potential seepage from fractures within the dolomitic limestone bedrock. It is recommended that an NSSP be included in the Contract to address unwatering at this site; a sample NSSP is included in Appendix C.

6.5.4 Analytical Testing for Construction Materials

The analytical test results on a sample of creek water taken adjacent to the existing structure 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. Adam Core E.I.T. and Mr. David Muldowney, P.Eng. André Bom, P.Eng., carried out an independent review of the report. Mr. Jorge Costa, 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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Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06. 2006. CSA Special Publication, S6.1-06. Canadian Standard Association.

Ministry of Natural Resources, electronic mapping obtained 2014, MRD128, 2006.

Ministry of Natural Resources, electronic mapping obtained 2014, MRD219, 2007.

STANDARDS

ASTM International:

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

Contract Design Estimation and Documentation (CDED):

SP 422S01	Precast Concrete Box Culvert

Ontario Occupational Health and Safety Act

Ontario Regulation 213	Construction Projects (as amended)

Ontario Provincial Standard Drawing

OPSD 208.010	Benching of Earth Slopes
OPSD 3090.101	Foundation, Frost Penetration 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 422	Construction Specification for Precast Reinforced Concrete Box culverts and Box Sewers in Open Cuts
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Water Resources Act

Ontario Regulation 372/97	Amendment to Ontario Regulation 903

MINISTRY OF TRANSPORTATION, ONTARIO

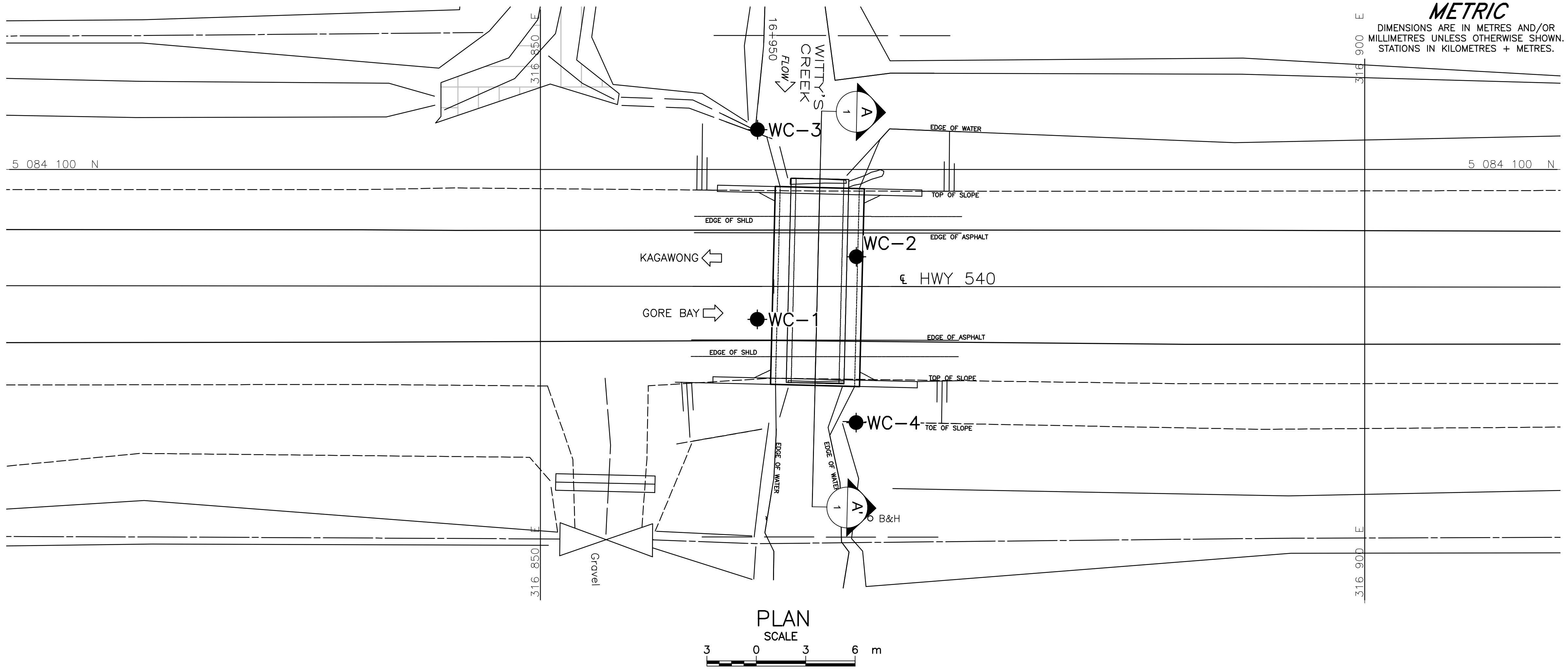
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5061–07–01

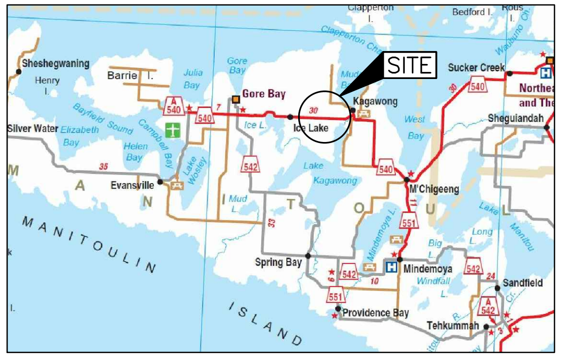
SHEET

HIGHWAY 540
WITTY'S CREEK CULVERT STA 16+953
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates



PLAN



KEY PLAN

LEGEND

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

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
WC–1	231.1	5084090.9	316863.2
WC–2	231.2	5084094.7	316869.2
WC–3	229.6	5084102.4	316863.2
WC–4	229.5	5084084.6	316869.2

NOTES

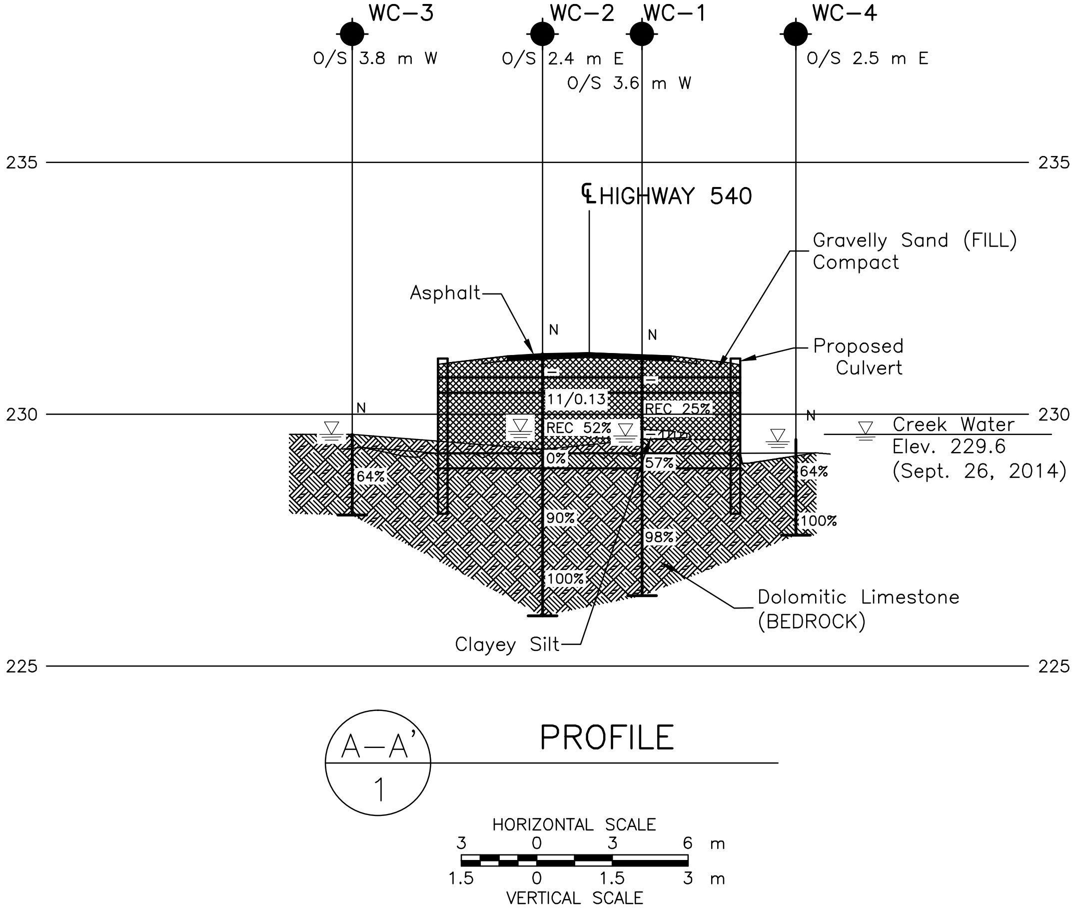
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 AECOM, drawing file nos. GWP 5057–07–00 WITH POINTS ON.dwg, received NOV 06, 2014 and 60302964–S50.dwg, received NOV 06, 2014.



A–A'
1

PROFILE

D.A.MULDOWNEY
100164716
FEB 11, 2015

J.M.A.COSTA
FEB 11, 2015

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 41G–20

HWY. 540		PROJECT NO. 13–1191–0005	DIST. .
SUBM'D. AC	CHKD. .	DATE: FEB 2015	SITE: 49–071
DRAWN: TB	CHKD. DAM	APPD. JMAC	DWG. 1

PLOT DATE: February 11, 2015
FILENAME: \\golder.gds\gal\Sudbury\CAD–GIS\CAD\Projects\2013\13–1191–0005 Manitoulin (Kagawong, Ice Lake)\CIVIL 3D\1311910005AA001.dwg

Photograph 1: Looking South at Culvert Inlet (September 2014)

Photograph 2: Looking East (September 2014)

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
$\sigma_1, \sigma_2, \sigma_3$	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
FLT	Fault
SH	Shear
VN	Vein
FR	Fracture
SY	Stylolite
BD	Bedding
FO	Foliation
CO	Contact
AXJ	Axial Joint
KV	Karstic Void
MB	Mechanical Break
PL	Planar
CU	Curved
UN	Undulating
IR	Irregular
K	Slickensided
PO	Polished
SM	Smooth
SR	Slightly Rough
RO	Rough
VR	Very Rough

PROJECT 13-1191-0005	**RECORD OF BOREHOLE No WC-1**	1 OF 1	**METRIC**
W.P. 5061-07-01	LOCATION N 5084090.9; E 316863.2	ORIGINATED BY TM	
DIST HWY 540	BOREHOLE TYPE 108mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring	COMPILED BY AC	
DATUM GEODETIC	DATE September 22, 2014	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

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
231.1	GROUND SURFACE						
0.0	ASPHALT (150 mm)					231	
0.2	Gravelly sand, some silt, trace RAP (FILL) Brown Moist	1	AS	-			
	Auger refusal at 0.5 m depth. Switched to NQ coring.	-	RC	REC 25%		230	
229.7	A 200 mm cobble recovered at 0.5 m depth.	2	SS	-	▽		
1.6	CLAYEY SILT with sand, trace gravel Brown Wet	1	RC	REC 100%		229	RQD = 57%
	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 1.6 m to 4.7 m depth. For coring details see Record of Drillhole WC-1.	2	RC	REC 100%		228 227	RQD = 98%
226.4 4.7	END OF BOREHOLE						

Note:

1. Water level at a depth of 1.6 m below ground surface (Elev. 229.5 m) upon completion of drilling.

SUD-MTO 001 13-1191-0005.GPJ GAL-MISS.GDT 21/11/14 DATA INPUT:

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

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: WC-1

SHEET 1 OF 1

LOCATION: N 5084090.9 ;E 316863.2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 22, 2014

DRILL RIG: CME 55 Truck Mount

DRILLING CONTRACTOR: Landcore

DATUM: GEODETIC

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

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

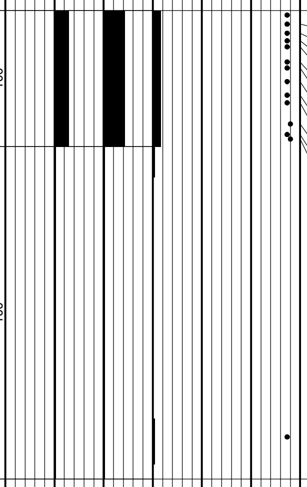
PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

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 % (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)	DISCONTINUITY DATA DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3})	Diametral Point Load Index (MPa) (2 4 6)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK		229.5																
2	CME 55 NW NQ Coring	DOLOMITIC LIMESTONE Fine grained Slightly to moderately weathered Light grey Very strong Clay infill in joints from 1.6 m to 2.5 m depth. Fresh to faintly weathered below 2.5 m depth.		1.6	1	GREY 100							JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo							UCS=174 MPa
3 4				226.4	2	GREY 100							JNIRRo							
5 6 7 8 9 10 11		END OF DRILLHOLE		4.7																



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: TM

CHECKED: DAM

Golder Associates

RECORD OF BOREHOLE No WC-2

1 OF 1 **METRIC**

PROJECT 13-1191-0005
W.P. 5061-07-01
LOCATION N 5084094.7; E 316869.2
ORIGINATED BY TM
DIST
HWY 540
BOREHOLE TYPE 108mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring
COMPILED BY AC
DATUM GEODETIC
DATE September 25, 2014
CHECKED BY DAM

SOIL PROFILE ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
231.2	GROUND SURFACE										
0.0	ASPHALT (125 mm)										
0.1	Gravelly sand, some silt (FILL) Brown Moist		1	AS	-		231		○		25 59 (16)
	Spoon refusal at 1.0 m depth. Switched to NQ coring.		2	SS	11/0.13						
	A 150 mm cobble and 300 mm boulder recovered at 1.0 m and 1.9 m depth, respectively.		-	RC	REC 52%	∇	230				
229.3 1.9	DOLOMITIC LIMESTONE (BEDROCK)		1	RC	REC 100%		229				RQD = 0%
	Bedrock cored from 1.9 m to 5.2 m depth. For coring details see Record of Drillhole WC-2.		2	RC	REC 100%		228				RQD = 90%
			3	RC	REC 100%		227				RQD = 100%
226.0 5.2	END OF BOREHOLE						226				

Note:

1. Water level at a depth of 1.6 m below ground surface (Elev. 229.6 m) upon completion of drilling.

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

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: WC-2

SHEET 1 OF 1

LOCATION: N 5084094.7 ;E 316869.2
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 25, 2014
DRILL RIG: CME 55 Truck Mount
DRILLING CONTRACTOR: Landcore

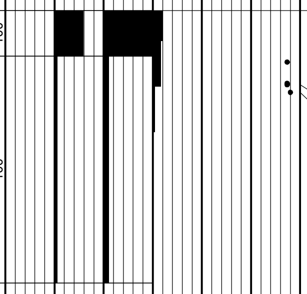
DATUM: GEODETIC

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate
BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage
PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular
PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK	229.3				
2	CME 55 NW	DOLOMITIC LIMESTONE Fine grained Slightly to moderately weathered Grey Very strong Clay infill in joint at 2.2 m depth. Fresh to faintly weathered below 2.4 m depth.	1.9	1	GREY 100	BR	
	NQ Coring					JNIRRo JNIRRo JNIRRo JNIRRo	
3				2	GREY 100		
4				3	GREY 100		UCS=155 MPa
5			226.0 5.2				
		END OF DRILLHOLE					

Additional column headings: SYMBOLIC LOG; RECOVERY (TOTAL CORE %, SOLID CORE %) 80 60 40 20; R.Q.D. % 80 60 40 20; FRACT. INDEX METRES 5 10 15 20; B Angle 0 90 180 270; DIP w.r.t. CORE AXIS 0 30 60 90; Jr Ja Jn; HYDRAULIC CONDUCTIVITY k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}; Diametral Point Load Index (MPa) 2 4 6; RMC -Q' AVG.



Depth scale: 2 3 4 5 6 7 8 9 10 11

DEPTH SCALE
1 : 50

LOGGED: TM
CHECKED: DAM

SUD-RCK 13-1191-0005.GPJ GAL-MISS.GDT 21/11/14 DATA INPUT:

RECORD OF BOREHOLE No WC-3

1 OF 1 **METRIC**

PROJECT 13-1191-0005
W.P. 5061-07-01
DIST HWY 540
DATUM GEODETIC

LOCATION N 5084102.4; E 316863.2
BOREHOLE TYPE NW Casing, NQ Coring
DATE September 29, 2014

ORIGINATED BY TM
COMPILED BY AC
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				
229.6	GROUND SURFACE					▽					
0.0	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from surface to 1.6 m depth. For coring details see Record of Drillhole WC-3.	▨	1	RC	REC 100%		229				RQD = 64%
228.0 1.6	END OF BOREHOLE Note: 1. Water level at ground surface.						228				

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

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

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: WC-3

SHEET 1 OF 1

LOCATION: N 5084102.4 ;E 316863.2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 29, 2014

DRILL RIG: CME 55 Truck Mount

DRILLING CONTRACTOR: Landcore

DATUM: GEODETIC

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

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

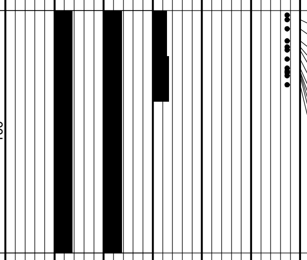
PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

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
		TOP OF BEDROCK		229.6																	
0 1	CME 55 NW NQ Coring	DOLOMITIC LIMESTONE Fine grained Slightly to moderately weathered Grey Clay infill at 0.5 m depth. Fresh to faintly weathered below 0.7 m depth.		0.0 228.0	1	GREY 100								JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo							
2 3 4 5 6 7 8 9 10		END OF DRILLHOLE		1.6																	



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: DAM

RECORD OF BOREHOLE No WC-4

1 OF 1 **METRIC**

PROJECT 13-1191-0005
W.P. 5061-07-01
DIST ______ HWY 540
DATUM GEODETIC
LOCATION N 5084084.6; E 316869.2
BOREHOLE TYPE NW Casing, NQ Coring
DATE September 30, 2014
ORIGINATED BY TM
COMPILED BY AC
CHECKED BY DAM

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
229.5	GROUND SURFACE										
0.0	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from ground surface to 1.9 m depth. For coring details see Record of Drillhole WC-4.	▨	1	RC	REC 100%	▽	229				RQD = 64%
		▨	2	RC	REC 100%		228				RQD = 100%
227.6 1.9	END OF BOREHOLE Note: 1. Water level at a depth of 0.1 m below ground surface (Elev. 229.4 m) upon completion of drilling.										

SUD-MTO 001 13-1191-0005.GPJ GAL-MISS.GDT 21/11/14 DATA INPUT:

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

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

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: WC-4

SHEET 1 OF 1

LOCATION: N 5084084.6 ;E 316869.2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 30, 2014

DRILL RIG: CME 55 Truck Mount

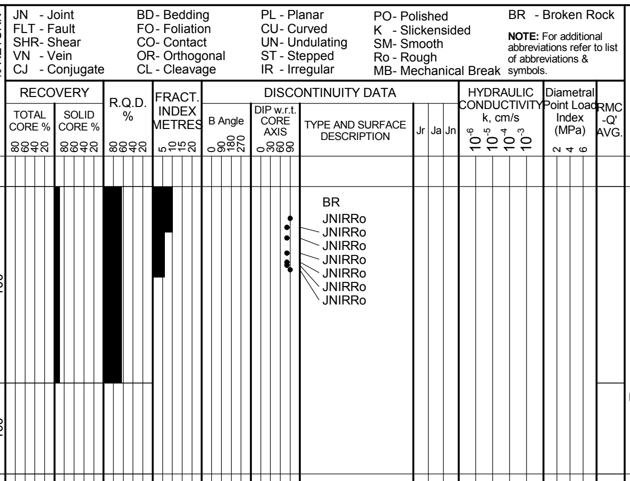
DRILLING CONTRACTOR: Landcore

DATUM: GEODETIC

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
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	

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	TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF BEDROCK		229.5				
0	CME 55 NW	DOLOMITIC LIMESTONE Fine grained Slightly to moderately weathered Grey Very strong		0.0	1	GREY 100	BR JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo	
1	CME 55 NQ Coring	Fresh to faintly weathered below 0.6 m depth.						
				227.6	2	GREY 100		UCS = 161 MPa
2		END OF DRILLHOLE		1.9				
3								
4								
5								
6								
7								
8								
9								
10								



DEPTH SCALE

1 : 50

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LOGGED: TM

CHECKED: DAM

APPENDIX B

Laboratory Test Results

Table B1 - Summary of Analytical Testing of Witty’s Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	2
Dissolved Sulphate	mg/L	1	Not Detected
Conductivity	µmho/cm	1	390
Resistivity	ohm-cm	n/a	2,600
pH	pH	n/a	8.22

Notes: 1. Sample obtained on October 5, 2014.
2. Analytical testing carried out by Maxxam Analytics.

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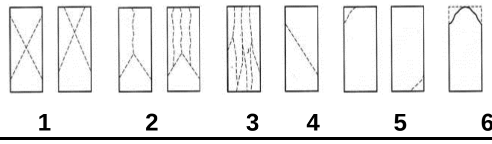
Fax: (705) 524-1984

Table B2 - Summary of Rock Core Test Data

PROJECT NO.: **13-1191-0005 P.2000**
PROJECT NAME: **Witty's Creek Culvert**
TYPE OF UNIT: **Rock Core**
TESTED BY: **S.Albert**

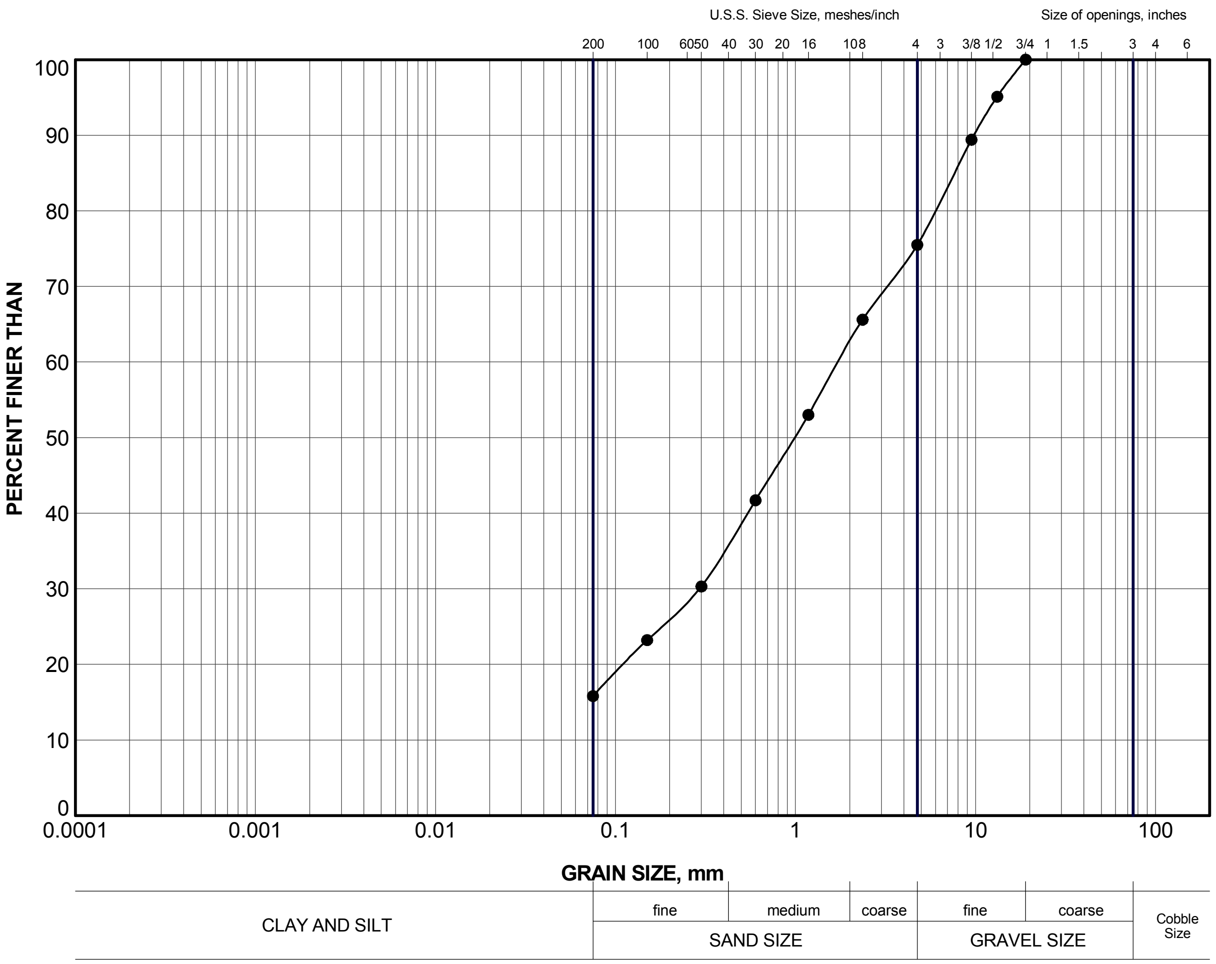
GOLDER LAB NUMBER	G1019	G1020	G1087
BOREHOLE-SAMPLE NUMBER:	WC-1	WC-2	WC4
DATE TESTED	October 16, 2014	October 16, 2014	Nov. 3, 2014
DEPTH OF TESTED CORE (m)	2.5	4.1	1.3
LENGTH AS CUT (mm)	100.0	103.0	100.0
DIAMETER (mm)	47.5	47.5	47.5
DENSITY (kg/m3)	2723	2791	2796
COMPRESSIVE STRENGTH (KN)	307.9	274.9	284.7
CORRECTED STRENGTH (MPa)	**173.8**	**155.1**	**160.7**
TYPE OF FRACTURE	**3**	**3**	**3**

Type of Fracture



COMMENTS:

Reviewed by: **T. Gauthier**



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WC-2	1	230.8

PROJECT

HIGHWAY 540
WITTY'S CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

GRAVELLY SAND (FILL)

PROJECT No.	13-1191-0005		FILE No.	13-1191-0005.GPJ
DRAWN	TB	Nov 2014	SCALE N/A	REV.
CHECK	DAM	Nov 2014		
APPR	JMAC	Nov 2014	**FIGURE B1**	

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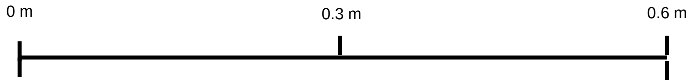
SUD-MTO GSD (NEW) GLDR_LDN.GDT

Borehole WC1
Elevation 229.5 m to 226.4 m

Borehole WC2
Elevation 229.3 m to 226.0 m

Borehole WC3
Elevation 229.6 m to 228.0 m

Borehole WC4
Elevation 229.5 m to 227.6 m



PROJECT
HIGHWAY 540
WITTY CREEK CULVERT

TITLE
BEDROCK CORE PHOTOGRAPHS

PROJECT No. 13-1191-0005			FILE No. ----
DESIGN	AC	Nov. 2014	SCALE AS SHOWN REV.
CADD	--		**FIGURE B2**
CHECK	AB	Nov. 2014	
REVIEW			

APPENDIX C

Non-Standard Special Provisions

GROUNDWATER CONTROL - Item No.

Non-Standard Special Provision

Foundations for the Witty's Creek culvert replacement and wing wall construction will require excavations to extend below the groundwater level at the site. The non-cohesive fill material (gravelly sand) that is present below the groundwater table will slough, run or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate groundwater control system for the culvert site to enable installation of the culvert and construction of the wing walls 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

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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