



**FINAL REPORT**

**Foundation Investigation and Design  
Replacement of Culvert CV-0416-000185  
Highway 416  
Ottawa, Ontario**

*G.W.P. 4113-16-00*

*W.P. 4045-18-01*

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**PART A**

Foundation Investigation  
Replacement of Culvert CV-0416-000185  
Highway 416  
Ottawa, Ontario

## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with the detailed design of replacement of a non-structural culvert on Highway 416 and a structural culvert on Highway 417 under Assignment No. 7, of the Eastern Region Retainer Mega 10 (Assignment No. 4017-E-0019).

This report presents the results of the foundation investigation carried out for the replacement of the non-structural Culvert CV-0416-000185. The replacement of the structure is to be carried out in accordance with the current version of the Canadian Highway Bridge Design Code, S6-14 (CHBDC).

The scope of work for the foundation engineering services associated with the replacement was outlined in Golder's Change in Scope Memorandum dated May 8, 2019. The investigation program was developed to meet the requirements of Work Item Quote Form for Agreement No. 4016-E-0019, Assignment 7, as well as the structural requirements of Dillon to complete the design. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for the project dated August 2019.

## 2.0 SITE DESCRIPTION AND GEOLOGY

### 2.1 Site Description

Culvert CV-0416-000185 is located at Station 26+926 under the northbound lanes of Highway 416, approximately 1.0 km north of Ventnor Road near Spencerville, Ontario. The location of the culvert is shown on the Key Plan on Drawings 1 and 2. Site photographs showing the general conditions at the site are presented in Appendix D.

At this location, Highway 416 is a divided highway with two travel lanes in each direction separated by a wide, vegetated median ditch. Steel cable guiderails are present along both side of the highway in the vicinity of the culvert.

Information provided in the Work Order for this assignment indicates that the existing culvert is a structural-plated corrugated steel pipe arch (SPCSPA) culvert with a vertical dimension of 1,850 mm and a horizontal dimension of 2,620 mm at the base of the arch and is 28.3 m long. There are no headwalls at this location. The elevation of the culvert invert ranges from 93.4 to 93.5 m and creek flow through the culvert is from west to east.

The base plan mapping provided by Dillon for this project and the ground surface elevations at the borehole locations surveyed during the field investigation indicate that the top of pavement elevation of Highway 416 in the vicinity of the culvert ranges from 98.6 to 99.0 m and the top of culvert elevation ranges from 95.2 to 95.4 m corresponding to cover over the culvert from the shoulder to the top of the culvert ranging from about 3.2 to 3.8 m. Based on a visual observation at the time of the site investigation, no signs of foundation settlement were observed, and the existing slopes appear to be performing satisfactorily.

The culvert was last inspected in 2013 and identified as a fisheries culvert with the presence of species at risk turtles.



## 2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*<sup>1</sup>, this section of Highway 416 lies within the minor physiographic region known as the Edwardsburg Sand Plain, which lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Edwardsburg Sand Plain region is characterized by a slightly undulating sand plain that overlies boulder clay and bedrock. The sand is likely glaciofluvial in origin, probably deposited in the late stages of the Champlain Sea with a few morainic structures remaining.

The site falls within the Western Québec (WQ) seismic zone according to the Geological Survey of Canada. The WQ zone constitutes a large area which encompasses the urban areas of Montreal, Ottawa-Hull and Cornwall. Within the WQ zone recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. The two major earthquakes that have recently occurred in the WQ zone are the 1935 Témiscaming event, which had a magnitude (i.e., a measure of the intensity of the earthquake) of 6.2, and the 1944 Cornwall-Massena event, which had a magnitude of 5.6.

## 3.0 INVESTIGATION PROCEDURES

### 3.1 Current Investigation

The field work for the 2019 investigation was carried out between July 11 and July 18, 2019 and August 6 and 7 2019, and included advancing six boreholes, numbered 19-7001 to 19-7005 and 19-7015, with three located within the highway platform and one each at the culvert inlet and outlet. Borehole 19-7015 was advanced approximately 1.5 m south of Borehole 19-7005 due to the presence of boulders encountered within the embankment fill at Borehole 19-7005.

Table 1 below further outlines the locations of the boreholes with respect to the existing culvert.

Boreholes 19-7001 and 19-7002 were advanced at the inlet and outlet of the culvert respectively using portable rotary drilling equipment employing a half weight hammer lifted manually and dropped from the Standard Penetration Test (SPT) height. Where a half weight hammer was used, the N values presented on the Record of Boreholes are corrected for the lower energy drive. The highway boreholes were advanced with CME55 truck-mounted drilling equipment. The drilling equipment was supplied and operated by CCC Geotechnical & Environmental Drilling Ltd. (CCC) of Ottawa, Ontario.

Traffic control required to close the driving lanes of Highway 416 while carrying out field operations was provided by Beacon Lite Ltd. of Ottawa, Ontario.

Soil samples in the highway boreholes were obtained at vertical sampling intervals of about 0.76 m, using a 50 mm outer diameter split-spoon sampler in general accordance with the procedure Standard Penetration Test (ASTM D1586). Soil samples from Boreholes 19-7001 and 19-7002, which were advanced with the portable drilling equipment, were obtained in nearly continuous vertical increments of about 0.6 m.

<sup>1</sup> 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. Ontario Ministry of Natural Resources.

Bedrock core samples were obtained in all boreholes, except Borehole 19-7005, using NQ sized diamond drilling equipment at the highway boreholes (Boreholes 19-7003, 19-7004A and 19-7015) and 63 mm outside diameter thin wall coring equipment at the boreholes advanced using a portable drill rig (Boreholes 19-7001 and 19-7002).

The boreholes were backfilled with bentonite within the bedrock, and bentonite mixed with soil cuttings within the overburden. The boreholes were then capped with either asphaltic concrete cold patch or granular material, depending on the surrounding surface cover. The boreholes were backfilled in general accordance with the intent of O.Reg 903, as amended. The site conditions were restored following completion of the field work.

The field work was supervised on a full-time basis by members of Golder's staff who located the boreholes in the field, directed the drilling, sampling, and in-situ testing operations, logged the boreholes and examined and cared for the samples. The soil and bedrock samples were identified in the field, placed in labelled containers, and transported to Golder's laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations, grain size distribution analyses, and Atterberg Limits testing were carried out on selected soil samples at Golder's Ottawa laboratory. Unconfined compressive strength testing was carried out on select samples of the dolostone bedrock at Golder's Mississauga laboratory. The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

Two soil samples were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

The borehole locations and elevations were surveyed by Golder using a Trimble R8 GPS unit referenced to the NAD83 CSRS CBNv6-2010.0 MTM Zone 9 geodetic datum. The borehole locations, including northing and easting coordinates, ground surface elevations, and drilled depths are summarized in Table 1.

**Table 1: Summary of Borehole Locations**

Borehole	Location	NAD83 CSRS CBNv6-2010.0 MTM Zone 9		Ground Surface Elevation (m)	Drilled Depths (m)
		Northing (m)	Easting (m)		
19-7001	Culvert Inlet	4971040.4	379081.6	95.3	8.1
19-7002	Culvert Outlet	4971059.1	379102.1	95.7	8.2
19-7003	Highway 416 North of Culvert	4971065.2	379084.4	98.7	10.9
19-7004A	Highway 416 South of Culvert	4971043.6	379099.6	98.6	11.8
19-7005	Highway 416 South of Culvert	4971027.6	379101.6	99.0	3.6 <sup>1</sup>
19-7015	Highway 416 South of Culvert	4971026.4	379102.4	99.0	12.1

**Notes:** <sup>1</sup>Borehole terminated at auger refusal within the embankment fill

## 4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

### 4.1 General

The subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in-situ testing from the current investigation are given on the Record of Borehole, and Drillhole sheets presented in Appendix A. The results of the laboratory testing carried out during the investigation are presented on the Record of Borehole sheets as well as on Figures B1 to B7 in Appendix B. The borehole locations and the interpreted stratigraphic profile projected along the highway and along the alignment of the existing culvert and are provided on Drawings 1 and 2, respectively.

Photographs of the core recovered from the underlying bedrock are shown on Figures A1 to A10, provided in Appendix A. The results of basic chemical analysis completed on select soil samples are provided in Appendix C.

The stratigraphic boundaries shown on the borehole sheets and on the interpreted stratigraphic sections from Drawings 1 and 2, are inferred from observations of the drilling progress and noncontinuous sampling and therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

### 4.2 Site Stratigraphy Overview

At the boreholes, the subsurface conditions generally consist of asphaltic concrete pavement or topsoil, overlying fill materials containing cobbles and boulders, overlying native sand and silt, which in turn overlies clayey silt, overlying glacial till, all underlain by dolostone bedrock. Buried topsoil and peat were encountered below the embankment fill in Boreholes 19-7002, 19-7004A and 19-7015.

A more detailed description of the overburden soil deposits, and bedrock geology conditions encountered during the field investigation is provided in the following sections.

### 4.3 Highway 416 Embankment

#### 4.3.1 Surface Cover / Surficial Materials

Boreholes 19-7003 to 19-7005 and 19-7015 were advanced through the Highway 416 pavement structure. Asphaltic concrete pavement with thicknesses ranging from 90 to 200 mm was encountered at the surface of the four highway boreholes.

Topsoil with a thickness of 0.2 m was encountered at surface at Boreholes 19-7001 and 19-7002.

#### 4.3.2 Pavement Structure and Embankment Fills

Pavement structure fill consisting predominantly of sand and gravel with varying amounts of silt was encountered below the asphaltic concrete pavement at the highway boreholes. The thickness of the pavement structure fill ranges from 0.3 to 0.6 m. The measured moisture content of a single sample tested was 2 percent. The results of grain size analysis testing carried out a single sample of the pavement structure fill are provided on Figure B1 in Appendix B.

Fill consisting predominantly of sand with varying amounts of silt and gravel was encountered below the pavement structure fill in the highway boreholes. The top of this layer was encountered at elevations ranging from 98.1 to 98.2 m. The thickness of the fill ranges from 3.6 to 4.0 m. Cobbles and boulders were noted in this layer at the highway boreholes. Borehole 19-7005 was terminated at auger refusal within the embankment fill after coring through boulders at a depth of about 2.8 m below the pavement surface.

The SPT N values of the sand fill ranged from 5 to greater than 100 blows per 0.3 m of penetration, but were more typically were 13 to 39, indicating a compact to dense state of packing. The higher blow count (i.e., greater than 100) noted on the Record of Boreholes for the embankment may have been influenced by the presence of cobbles or boulders within the fill, rather than the state of packing of the soil matrix. The measured moisture content of the samples tested ranged from 4 to 7 percent. The results of grain size analysis testing carried out on two samples of this material are provided on Figure B2 in Appendix B.

Silty sand and gravel and gravelly silty sand was encountered underlying the surficial topsoil at the boreholes advanced at the culvert ends. The fill is about 1.7 and 0.9 m in thickness at the inlet and outlet, respectively. The SPT N values ranged from 11 to greater than 100 blows per 0.3 m of penetration but were more typically 11 to 28 indicating a compact state of packing. . The measured moisture content of a single sample tested was 9 percent. The results of grain size analysis testing carried out a single sample of this material are provided on Figure B3 in Appendix B.

### **4.3.3 Buried Topsoil and Peat**

Buried topsoil and peat were encountered below the embankment fill material in Boreholes 19-7002, 19-7004A and 19-7015 at elevations ranging from 94.0 to 94.6 m. The thickness of the buried topsoil and peat at these locations ranges from 0.1 to 0.2 m.

### **4.3.4 Sand, Sand and Silt to Silty Sand**

Sand with varying amounts of silt and gravel was encountered in all boreholes at elevations ranging from 93.4 to 94.5 m. The thickness of the sand layer at these locations ranges from 0.6 to 2.2 m. The SPT N values ranged from 9 to 24 blows per 0.3 m of penetration, indicating a loose to compact state of packing.

The measured moisture content of the samples tested ranged from 24 to 29 percent. The results of grain size analysis testing carried out on three samples of this material are provided on Figure B4 in Appendix B.

### **4.3.5 Clayey Silt – Silt**

Clayey silt – silt was encountered below the sand and silt material in all boreholes at elevations ranging from 92.1 to 92.8 m. The thickness of the clayey layer ranges from 1.2 to 1.8 m. The SPT N values ranged from 4 to 22 blows per 0.3 m of penetration, indicating a stiff to very stiff consistency.

The measured moisture content of the samples tested ranged from 19 to 22 percent. The results of grain size analysis testing carried out on three samples of this material are provided on Figure B5 in Appendix B. The results of Atterberg Limits testing completed on three samples of the clayey silt – silt indicates liquid limits ranging from 19 to 27, plastic limits ranging from 15 to 18, and plasticity indexes ranging from 4 to 10. Atterberg Limits analysis results are illustrated on Figure B6 in Appendix B and indicate a Clayey silt – silt (CL-ML to CL).

### **4.3.6 Glacial Till**

Glacial till was encountered below the clayey silt to silty clay in all boreholes except Borehole 19-7015, where the clayey silt overlies bedrock. The glacial till generally consists of a heterogeneous mixture of cobbles and boulders within a soil matrix of silt, clay or sand, with trace gravel. The thickness of the till layer at the borehole locations ranges from 0.1 to 0.8 m. The SPT N values ranged from 36 to 57 blows per 0.3 m of penetration, indicating a dense to very dense state of packing.

The measured moisture content of a single sample tested was 18 percent. The results of grain size analysis testing carried out on two samples of glacial till are provided on Figure B7 in Appendix B. Atterberg Limits test results on a single sample indicate a non-plastic silt till (ML).

## 4.4 Bedrock

The overburden materials are underlain by dolostone bedrock with shale partings and interbeds.

Bedrock core samples were obtained in all boreholes, except Borehole 19-7005, using a combination of NQ sized diamond drilling equipment at the highway boreholes (Boreholes 19-7003, 19-7004A and 19-7015) and 63 mm outside diameter thin wall coring equipment at the portable boreholes advanced using a portable drill rig (Boreholes 19-7001 and 19-7002)..

Table 2 summarizes the depths and the elevations of the bedrock surface as encountered at the borehole locations.

**Table 2: Summary of Bedrock Surface Depths and Elevations**

Borehole	Location	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
19-7001	Culvert Inlet	95.3	4.8	90.5
19-7002	Culvert Outlet	95.7	4.9	90.8
19-7003	Highway 416 North of Culvert	98.7	8.0	90.7
19-7004A	Highway 416 South of Culvert	98.6	8.3	90.3
19-7015	Highway 416 South of Culvert	99.0	8.7	90.3

The bedrock encountered was slightly weathered to fresh and medium bedded. Thin shale interbeds were present in the bedrock core. Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 54 to 98 percent, but were more typically 65 to 90 percent, indicating a good to excellent rock quality.

Results of unconfined compressive strength (UCS) testing carried out on three bedrock core samples are presented on Figure B8 provided in Appendix B. The samples tested had UCS values ranging from 55 to 270 MPa, but more typically 137 to 230 percent, indicating a very strong bedrock.

## 4.5 Groundwater Conditions

The groundwater level was measured in the open boreholes prior to carrying out coring operations and the measured depths to the water levels ranged from 1.9 to 5.3 m below existing grade, corresponding to elevations ranging from 93.2 to 94.0 m.

The groundwater level in the area of the culvert is expected to reflect the creek water level.

The water level in the creek was measured at the time of Golder's field investigation at a depth of 1.3 m below the top of the culvert at the invert; corresponding Elevation 93.9 m.

It is expected that the groundwater levels will be subject to fluctuations both seasonally and as a result of precipitation events.

## 4.6 Steel Corrosion and Sulphate Attack, Chemical Analysis

Two soil samples were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The test results are provided in Appendix C and are summarized in Table 3.

**Table 3: Steel Corrosion and Sulphate Attack, Chemical Analysis**

Borehole	Sample	Sample Depth (m)	Sample Type	Chloride (%)	Sulphate (%)	Electrical Conductivity (mS/cm)	pH	Resistivity (ohm-cm)
19-7002	SS5	2.7	Silty Sand	0.007	0.02	0.24	7.9	4,120
19-7004A	SS5	3.3	Sand Fill	0.006	<0.01	0.12	8.7	8,700

## 5.0 CLOSURE

This report was prepared by Mr. Kenton Power, P.Eng. It was reviewed by Mr. Bill Cavers, P.Eng., a Senior Geotechnical Engineer and Associate with Golder. Mr. Fintan Heffernan, P.Eng. a Senior Consultant with Golder and the Designated MTO Foundations Contact for this project, carried out an independent quality control review of this report.

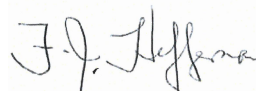
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**PART B**

Foundation Design  
Replacement of Culvert CV-0416-000185  
Highway 416  
Ottawa, Ontario



## 6.0 FOUNDATION ENGINEERING RECOMMENDATIONS

### 6.1 General

This section of the report provides geotechnical guidance for the replacement of non-structural Culvert CV-0416-000185 (W.P. 4045-18-01). The guidance provided herein is based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation and in accordance with the current Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC).

No previous foundation investigation information for the subject culvert was available. Base plan mapping was provided by Dillon for the preparation of this report.

The foundation investigation report, discussion, and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

### 6.2 Existing Conditions

Information provided in the Work Order for this assignment indicates that the existing culvert is a structural-plated corrugated steel pipe arch (SPCSPA) culvert with a vertical dimension of 1,850 mm and a horizontal dimension of 2,620 mm at the base of the arch and is 28.3 m long. There are no headwalls at this location. The elevation of the culvert invert ranges from 93.4 to 93.5 m and creek flow through the culvert is from west to east.

At this location, Highway 416 is a divided highway with two travel lanes in each direction separated by a wide, vegetated median ditch. Steel cable guiderails are present along both side of the highway in the vicinity of the culvert.

The base plan mapping provided by Dillon for this project and the ground surface elevations at the borehole locations surveyed during the field investigation indicated that the top of pavement elevation of Highway 416 in the vicinity of the culvert ranges from 98.6 to 99.0 m and the top of culvert elevation ranges from 95.2 to 95.4 m corresponding to cover over the culvert from the shoulder to the top of the culvert ranging from 3.2 to 3.8 m. Based on a visual observation at the time of the site investigation, no signs of foundation settlement were observed, and the existing slopes appear to be performing satisfactorily.

The culvert was last inspected in 2013 and identified as a fisheries culvert with the presence of species at risk turtles.

### 6.3 Proposed Structure

Based on the information provided by Dillon, the existing culvert is to be replaced with either a concrete box, open footing rigid frame concrete culvert or a new steel CSP culvert. Both a new alignment or the existing alignment are being considered for this replacement project. The top of streambed elevation is to remain the same as the existing culvert at about 93.5 m. Also, no headwalls or wingwalls are proposed for this project. It is understood that an offset distance from the existing culvert for a new alignment has yet to be finalized.

It is anticipated that the creek flow will be maintained using a dam and pump or dam and divert system during construction of the new culvert. The existing culvert may either be removed as part of the construction program or, if a new alignment is selected, it may be abandoned in place and filled with concrete or grout after installation of the new culvert.

## 6.4 Seismic Design

### 6.4.1 Seismic Hazard and Importance Category

The CHBDC states that the seismic hazard values associated with the design earthquakes should be those established for the National Building Code of Canada (NBCC) by the Geological Survey of Canada (GSC). The current seismic hazard maps (referred to as the 5<sup>th</sup> generation seismic hazard maps) were developed by the GSC and were made available for public use in December 2015.

In accordance with Section 4.4.2 of the CHBDC, it is understood that the Highway 416 at this location has been given an importance category of “Major Route”.

### 6.4.2 Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy below the founding elevation. Based on the soil conditions encountered below the anticipated culvert founding elevation, the site is classified as a Seismic Site Class D in accordance with Table 4.1 of the CHBDC.

### 6.4.3 Spectral Response Values and Seismic Performance Category

In accordance with Section 4.4.3.1 of the CHBDC and based on the location of the culvert (latitude 44.88 N longitude 75.56 W), the values provided in Table 4 are the reference Site Class C (reference) peak seismic hazard values based on data obtained from Earthquakes Canada ([www.earthquakescanada.nrcan.gc.ca](http://www.earthquakescanada.nrcan.gc.ca)).

**Table 4: Site Class C Spectral Values for Subject Site**

Parameter	2% Probability of Exceedance in 50 Years (2,475-year) (g)
PGA	0.253
T ≤ 0.2 s	0.394
T = 0.5 s	0.214
T = 1.0 s	0.108
T = 2.0 s	0.052
T = 5.0 s	0.014
T ≥ 10.0 s	0.005

The values given above are for the reference ground condition Site Class C and must be modified to the site-specific seismic site classification given in Section 6.4.2 (Site Class D) in accordance with Section 4.4.3 of the CHBDC. As indicated in Section 4.4.3.3 of the CHBDC, the value of  $PGA_{ref}$  for use with Tables 4.2 to 4.9 shall be taken as 80 percent of the PGA for Site Class C where  $S_a(0.2)/PGA$  is less than 2.0. Based on this requirement a  $PGA_{ref}$  value of 0.202 was used for the 2,475-year return period. The corresponding site-specific Site Class D seismic hazard values given in Table 5 can be used for design.

**Table 5: Site Class D Spectral Values for Subject Site**

Parameter	2% Probability of Exceedance in 50 Years (2,475-year) (g)
PGA	0.278
$T \leq 0.2$ s	0.429
$T = 0.5$ s	0.278
$T = 1.0$ s	0.150
$T = 2.0$ s	0.075
$T = 5.0$ s	0.021
$T \geq 10.0$ s	0.007

## 6.4.4 Liquefaction Assessment

The soils beneath the anticipated founding elevation of 93.0 m consist of compact sands and silts, stiff to very stiff clayey silts and compact to dense glacial till, which are not considered to be susceptible to liquefaction under earthquake loading using the site-specific PGA value of 0.278g.

## 6.5 Foundation Options

### 6.5.1 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the CHBDC and its Commentary, Highway 416 may be classified as having large traffic volumes and its performance as having potential impacts on other transportation corridors, hence having a “typical” consequence level associated with exceeding limits states design. Given the level of foundation investigation completed to date as presented in Sections 3.0 and 4.0, in comparison to the degree of site understanding in Section 6.5 of CHBDC, the level of confidence for design is considered to be a “typical degree of site and prediction model understanding” for this site. Accordingly, the appropriate corresponding ULS and SLS consequence factor,  $\psi$  of 1.0, and geotechnical resistance factors from Tables 6.1 and 6.2 of the CHBDC have been used for design, as indicated in the following sections.

For seismic design, the consequence factor,  $\Psi$ , and resistance factor,  $\phi_{gu}$ , should be taken as unity, as per Section 4.6.3 of the CHBDC.

### 6.5.2 Frost Protection

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*), the frost penetration depth at the site is 1.8 m below the existing ground surface. Footings constructed at this site (i.e., for an open footing rigid frame concrete culvert) should have a minimum embedment depth of 1.8 m below the top of streambed elevation for frost protection purposes.

### 6.5.3 Culvert Type/Foundation Alternatives

At present the hydraulic opening has yet to be determined for the new culvert. For preliminary design an inner span of 3.0 m, the minimum required for a structural culvert and a height of 2.0 m, similar to the existing culvert opening, has been assumed in the geotechnical design and recommendations provided in the following sections.

Common culvert and foundation types are listed below, along with a comparison of these alternatives, from a foundation perspective. Their respective advantages and disadvantages are outlined below and are summarized in Table 6 following the text of this report.

### **6.5.3.1 Closed Box (Concrete) Culvert**

From a geotechnical perspective, the replacement could be achieved with a closed bottom culvert. Since the base of the closed box does not need to be founded below frost depth, the base of the excavation for a closed box would be at a higher elevation than required for the footings of an open bottom culvert. The shallower excavation would have the advantages of a shorter duration for dewatering, reduced dewatering effort, construction staging and reduced material and handling.

Based on the existing invert elevation ranging from approximately 93.4 to 93.5 m, and allowing for 350 mm thick layer of interior substrate, a 260 mm thick concrete base and a 300 mm thick layer of Granular A bedding, the founding elevation is expected to be around Elevation 92.5 m. The anticipated founding subgrade material would be within the compact sand and silt or stiff to very stiff clayey silt.

### **6.5.3.2 Open Bottom Concrete Rigid Frame Culvert**

With the design stream bed elevation ranging from approximately 93.4 to 93.5 m, an open bottom culvert founded at elevations ranging from 91.6 m to 91.7 m (1.8 m below top of streambed elevation) is considered feasible at this site from a foundation standpoint. At this elevation, it is expected that the replacement culvert will be founded on the stiff to very stiff clayey silt or compact to very dense till. In order to meet frost protection requirements, the founding elevation for the open bottom structure will be lower than for the closed box or CSP options, thereby requiring deeper excavations. The deeper excavations would require increased dewatering effort, longer construction duration and result in increased material and handling costs.

### **6.5.3.3 Corrugated Steel Pipe (CSP) or Steel Arch Culvert**

From a foundation perspective, the replacement can also be carried out with the installation of new steel pipe or arch type culvert with invert elevations ranging from 93.4 to 93.5 m. A bedding layer consisting of Granular A with a thickness of 300 mm is recommended. The base of excavation is expected to be at an approximate elevation between 93.1 and 93.2 m. This shallower excavation (than for an open footed culvert) would have the advantages of a shorter duration for dewatering, construction staging and reduced material and handling.

## **6.5.4 Construction Methodology Alternatives**

This section presents discussions from a foundation perspective on alternative replacement methods for the proposed culvert. Further comparison of these options is summarized in the Table 7 following the text of this report.

### **6.5.4.1 Open Cut with a Full Road Closure**

Installation of a new culvert using open cut techniques during a full road closure with a detour route is a feasible alternative from a foundation perspective. This option would allow for an expedient construction schedule and reduced costs associated with roadway protection; however, it is understood that a detailed review including the availability of detour routes has yet to be undertaken and may not be feasible from a traffic operations perspective.

### **6.5.4.2 Trenchless Techniques**

Trenchless techniques have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment. However, the presence of cobbles and boulders within the embankment fill means that many common trenchless techniques such as jack and bore are not feasible. In addition, the cover over the existing culvert is less than two culvert diameters at some locations and there is limited area to construct entry/exit pits within the median ditchline. The geometry is therefore not conducive to tunnelling.

Based on the above, trenchless techniques for the installation of the new culvert are not considered suitable for this replacement project.

### **6.5.4.3 Open Cut with Staged Construction and Temporary Protection Systems**

The culvert could be replaced using open cut techniques with staged construction (half and half). The use of temporary protection systems parallel to the highway and possible platform widening would be required in order to keep at least one lane of northbound traffic open throughout the construction period.

Temporary embankment widening to the east could be considered, however, this would require realigning of the existing creek and possible temporary extension of the existing culvert during construction. Also, with the presence of species at risk turtles constructing beyond the highway platform may be restricted.

The presence of boulders within the embankment fill and glacial till and relatively shallow depth to bedrock below the founding elevation will make the installation of temporary protection systems challenging, increasing cost and the risk of construction related issues.

Sheet pile systems are not considered feasible at this site due to the relatively shallow depth to bedrock and hence limited embedment depth below the base of the excavation. One feasible option is the use of steel H-piles and timber lagging with the H-piles installed in pre-drilled holes into the bedrock.

### **6.5.5 Recommended Approach for the Culvert Replacement**

From a foundation engineering perspective, replacement of the culvert with a concrete closed box culvert using open cut techniques with temporary roadway protection to maintain traffic flow is the recommended culvert type and construction methodology for this project.

Both a steel CSP culvert or a concrete open footed culvert are also considered feasible from a foundation perspective.

## **7.0 FOUNDATION DESIGN RECOMMENDATIONS**

### **7.1 Culvert Foundation Bearing Resistances**

#### **7.1.1 Box Culvert / Open Footed Design**

As noted in Section 6.5.3, the design top of substrate is noted to be between Elevations 93.4 to 93.5 m with a minimum thickness of 0.35 m. Assuming a culvert base thickness of 0.26 m, a closed concrete box culvert will be founded at approximately Elevation 92.8 m.

A closed box culvert structure may be founded on native, undisturbed silt and sand or clayey silt. A culvert with a base width between 2.5 and 4.0 m founded at Elevation 92.8 m on a concrete mud slab or a granular pad at least 0.3 m thick, can be designed with the following geotechnical resistances:

- A factored geotechnical resistance of ULS 250 kPa
- A factored geotechnical resistance of SLS 150 kPa

An open footing culvert structure founded on native, undisturbed clayey silt or glacial till at a minimum depth of 1.8 m (frost depth) below top of stream bed elevation (Elevation 91.6 m) with a footing with between 1.0 and 2.5 m in width may be designed based on the following geotechnical resistances:

- A factored geotechnical resistance at ULS 250 kPa
- A factored geotechnical resistance at SLS 150 kPa

The factored geotechnical resistances include the following factors:

- The factored geotechnical resistance at Serviceability Limit State (SLS) corresponds to a maximum settlement of 25 mm
- Consequence factor (  $\Psi$  ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
  - Bearing (ULS),  $\phi_{gu} = 0.5$  (static analysis; typical degree of understanding)
  - Settlement (SLS),  $\phi_{gs} = 0.8$  (static analysis; typical degree of understanding)

The geotechnical resistances provided above are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4.

### 7.1.2 Steel CSP or Arch Culverts

A steel pipe or arch type culvert installed with invert elevations ranging from 93.4 to 93.5 m and a 300 mm bedding layer consisting of Granular A are considered feasible at this site. The base of excavation is expected to be at an approximate elevation between 93.1 and 93.2 m.

Design and installation of CSP culverts should be carried out in accordance with the height of fill tables in the OPSD 800 drawing series.

It is noted that construction will extend below the creek water level. Creek diversion and dewatering will be required to prepare the subgrade and to place the bedding material and install the culvert in the dry.

## 7.2 Sliding Resistance

Resistance to lateral forces through sliding resistance between concrete and native till or Granular A bedding materials should be evaluated using an unfactored coefficient of friction of 0.55 for cast-in-place concrete and 0.45 for pre-cast concrete and 0.4 for steel culvert.

## 7.3 Site Preparation and Construction

### 7.3.1 General

Excavation and backfilling for installation of the new concrete culvert should be carried out in accordance OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*) and MTO Special Provision (SP) No. 109S12, Amendment to OPSS 902, August 2018.

Construction for the installation of new pipe culverts should be carried out in accordance with OPSS.PROV 421 (*Construction Specification for Pipe Culvert Installation in Open Cut*).

### 7.3.2 Subgrade Preparation and Backfilling

Subgrade preparation for the culvert structure should include excavation and removal of the existing culvert, culvert foundations and backfill materials from beneath the founding elevation. The existing fill and any soft or organic materials must be removed from within the influence zone of the foundations and replaced with compacted Granular B Type II. The native subgrade for the concrete box culvert or pipe culvert foundation is anticipated to be silt and sand or clayey silt. Any boulders encountered at the subgrade elevation should be removed and the excavation backfilled with Granular B Type II.

If peat is encountered at the design subgrade elevation it should be excavated and removed in accordance with OPSS 902.

The native subgrade will be easily disturbed and should be protected with a concrete working slab promptly after excavation and inspection. The exposed subgrade could be covered with a 100 mm thick concrete working slab. After the concrete for the working slab has set, the box culvert could then be constructed directly on the working slab without the need for a granular pad or bedding material. Suggested wording for an NSSP to alert the Contractor to the requirement for a working slab has been provided in Appendix E.

Backfill for the culvert should consist of compacted free-draining granular material. It is recommended that the backfill detailing of OPSD 803.010 (*Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m*) be utilized with a frost penetration line above the top of the culvert. The frost treatment depth,  $k$ , should be set at 1.8 m. The depth of roadbed granulars,  $d$ , should be set at a minimum of 0.6 m as indicated in OPSD 803.010.

### 7.3.3 Embankment Design and Reinstatement

The existing embankments have slopes that are at approximately 2H:1V. Embankment reinstatement, after culvert replacement, should be carried out in accordance with OPSS.PROV 206 (*Construction Specification for Grading*) and should match the adjacent slope geometry. The new embankment material should consist of imported Granular B Type II material. Excavated granular fill may also be reused as embankment fill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction. Excavated granular fill must not be used as culvert bedding or backfill.

Granular fill should be placed and compacted in accordance with OPSS.PROV 501 (*Construction Specification for Compacting*). Where new embankment fill is placed against existing embankment slopes the existing earth or fill slope must be benched in accordance with OPSD 208.010 (*Benching of Earth Slopes*).

Provided the subgrade is prepared as outlined and embankment fill is placed as recommended herein, an embankment slope inclined at 2H:1V or flatter, will remain stable.

## 7.4 Construction Considerations

### 7.4.1 Open-Cut Excavations

Excavations should be carried out in accordance with the guidelines outlined in the latest edition of the Occupational Health and Safety Act (OHSA) for Construction Activities.

Excavations to depths of up to about 5.5 and 6.5 m below the existing Highway 416 grade through the existing fill and native materials are anticipated for the installation of a box culvert. The groundwater level in the area of the culvert is expected to reflect the creek water level.



The soils at this site would be generally classified as Type 3 soils (compact to loose fill material above groundwater level) in accordance with the OHSA. Accordingly, excavations should be made with side slopes no steeper than 1H:1V. Any fill and silts and sands which extend below the water table would be classified as Type 4 soil and excavations in these materials should be sloped no steeper than 3H:1V. As indicated in OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation.

#### 7.4.2 Temporary Protection Systems

If the required safe side slopes for the open cut excavations cannot be accommodated, then temporary roadway protection (i.e., excavation shoring) will be required to facilitate excavation to the foundation level for the replacement of the culvert and removal of the existing culvert.

The design of the shoring will be entirely the responsibility of the contractor. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*), and the lateral movement should meet Performance Level 2 provided that any existing adjacent utilities can tolerate this magnitude of deformation. Traffic loading should be included as a surcharge. Traffic loading does not account for construction equipment loadings which may be higher; the contractor's shoring designer should confirm those load requirements.

Increased difficulty with the installation of temporary protection systems should be anticipated due to the presence of boulders within the fill materials and till and the relatively shallow depth to the bedrock surface. For preliminary assessment purposes, the use of sheet piles is not considered feasible. One option is to use H-piles and timber lagging with the H-piles installed in pre-drilled holes into the bedrock. Recommended wording for an NSSP alerting the Contractor to this condition and the requirement to use appropriate equipment and installation techniques is provided in Appendix E.

#### 7.4.3 Groundwater and Surface Water Control

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the proposed culvert replacement to be constructed in a dry and stable excavation. The groundwater level for the site at the time of the proposed replacement should be taken as the water level in the creek. It is recommended that the replacement be conducted during a drier season such as after the spring freshet or prior to the fall season.

A temporary flow passage system will be required to replace the culvert in the dry. It is anticipated that a dam and pump or dam and divert system will be used during construction of the new culvert. The existing culvert may either be removed as part of the construction program or may be abandoned in place by filling with concrete or grout.

Excavations below the groundwater level are anticipated for preparing the subgrade, installing the new culvert and the removal of the existing culvert, if required. All dewatering measures including creek and surface water diversion, must always remain operational and effective during the construction period.

However, the selection and design of temporary unwatering/dewatering system is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with MTO SP FOUN0003 (Dewatering Structure Excavations), dated January 2020, which amends OPSS 902. A copy the SP FOUN0003 (SP3) is provided in Appendix E along with the appropriate Designer Fill-ins.



#### 7.4.4 Erosion Protection

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS.PROV 805 (*Temporary Erosion and Sediment Control Measures*).

To reduce erosion of the embankment side slopes due to surface water runoff, placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments. The erosion protection should be in accordance with OPSS.PROV 804 (*Seed and Cover*).

#### 7.4.5 Corrosion and Cement Type

Two soil samples were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The test results are provided in Appendix C.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The sulphate results in Table 3 of this report, were compared with Table 3 of Canadian Standards Association Standards A23.1-14 (CSA A23.1) and generally indicate a low degree of sulphate attack potential on concrete structures at this site. Accordingly, GU cement could be specified for concrete in below grade applications.


The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. Generally, the test results provided in Table 3 indicate a moderate to high potential for corrosion of exposed ferrous metal at the site which should be considered in the design.

## 8.0 CLOSURE

This report was prepared by Mr. Kenton Power, P.Eng. It was reviewed by Mr. Bill Cavers, P.Eng., a Senior Geotechnical Engineer and Associate with Golder. Mr. Fintan Heffernan, P.Eng. a Senior Consultant with Golder and the Designated MTO Foundations Contact for this project, carried out an independent quality control review of this report.

**Golder Associates Ltd.**




  
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KCP/WC/FJH/hdw

[https://golderassociates.sharepoint.com/sites/25312g/deliverables/7000 - hwy 416\\_417 culverts/01 - hwy 416 culvert/3-final hwy 416/1899802-7000 final 416 culvert replacement 2020-03-17.docx](https://golderassociates.sharepoint.com/sites/25312g/deliverables/7000-hwy_416_417_culverts/01-hwy_416_culvert/3-final_hwy_416/1899802-7000_final_416_culvert_replacement_2020-03-17.docx)

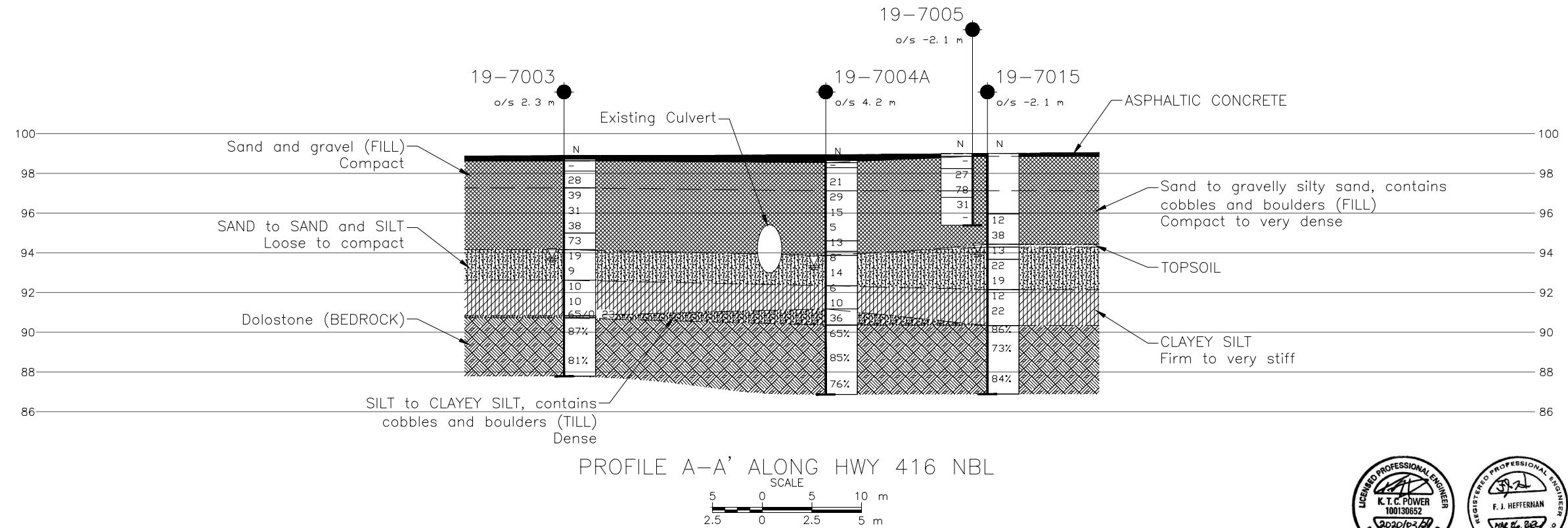
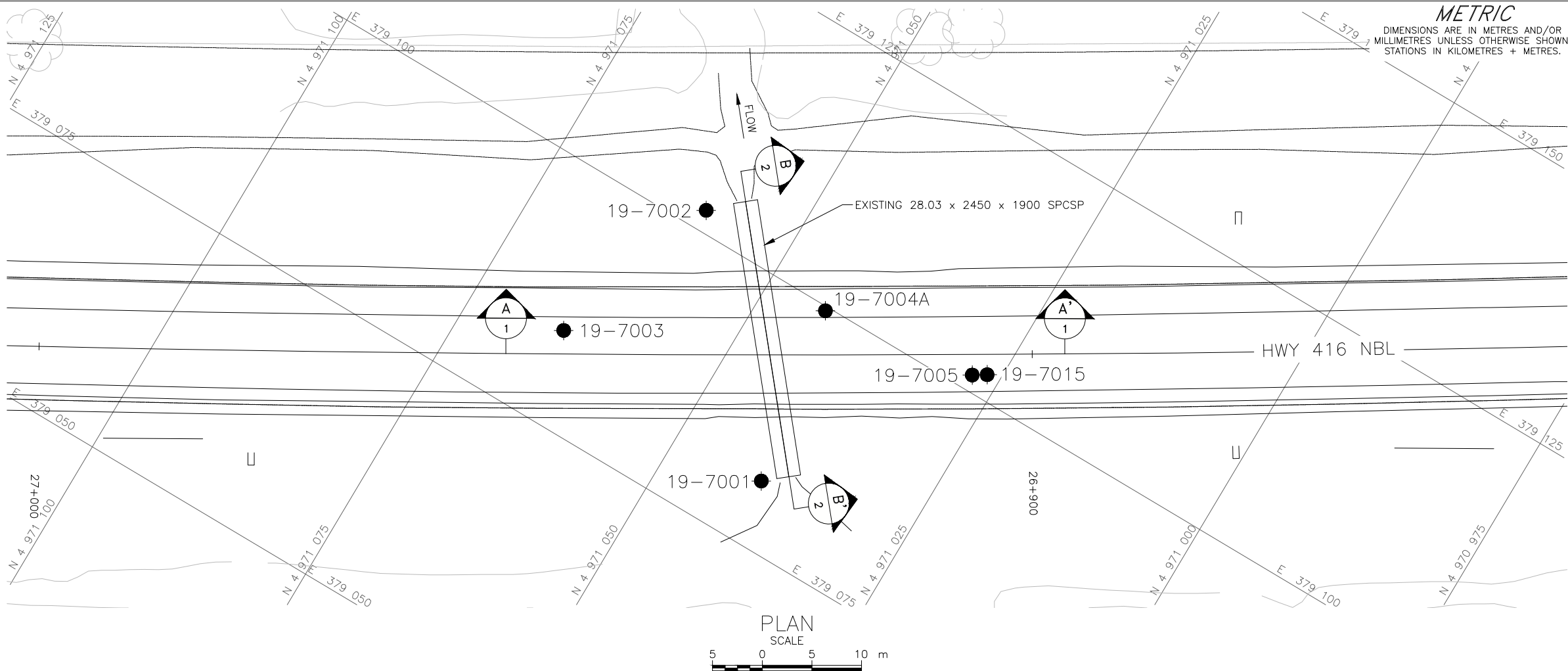
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Table 6 – Comparison of Foundation Alternatives

Culvert Design Alternatives	Feasibility	Advantages	Disadvantages	Relative Costs	Constructability/Risks
Closed Concrete Box Culvert	<ul style="list-style-type: none"><li>Preferred option from a foundation perspective</li><li>Feasible</li></ul>	<ul style="list-style-type: none"><li>Wide base reduces bearing pressures</li><li>Base of the closed box does not need to be founded below frost depth reducing excavation depths and dewatering requirements due to the shallower excavation</li><li>Less prone to effects of scour and erosion</li></ul>	<ul style="list-style-type: none"><li>Requires temporary roadway protection and cofferdam systems to be installed prior to carrying out excavation and to facilitate construction of the culvert.</li></ul>	<ul style="list-style-type: none"><li>Low to moderate</li></ul>	<ul style="list-style-type: none"><li>Potential for base disturbance if groundwater not controlled, leading to added cost and schedule delays</li></ul>
Open Footing Concrete Culvert	<ul style="list-style-type: none"><li>Feasible</li></ul>	<ul style="list-style-type: none"><li>More flexibility for installation of temporary flow passage system</li></ul>	<ul style="list-style-type: none"><li>Founding elevation is deeper than with closed box culvert, requiring deeper excavations and increased dewatering requirements.</li><li>Greater probability of encountering bedrock during footing excavation.</li><li>More susceptible to effects of scour and erosion</li><li>Requires deeper and more costly temporary roadway protection and cofferdam systems with minimal embedment above bedrock.</li></ul>	<ul style="list-style-type: none"><li>Moderate</li></ul>	<ul style="list-style-type: none"><li>Deeper excavation increases excavation volume and dewatering requirements leading to added cost and schedule delays</li><li>Potential for base disturbance if groundwater not controlled leading to added cost and schedule delays</li></ul>
Corrugated Steel Pipe Culvert	<ul style="list-style-type: none"><li>Feasible</li></ul>	<ul style="list-style-type: none"><li>Wide base reduces bearing pressures</li><li>Base of the steel pipe culvert does not need to be founded below frost depth reducing excavation depths and dewatering requirements due to the shallower excavation</li></ul>	<ul style="list-style-type: none"><li>Generally lower durability compared to a concrete option and therefore potentially has a shorter service life</li><li>Requires temporary roadway protection and cofferdam systems to be installed prior to carrying out excavation and to facilitate construction of the culvert.</li></ul>	<ul style="list-style-type: none"><li>Low to moderate</li></ul>	<ul style="list-style-type: none"><li>Potential for base disturbance if groundwater not controlled leading to added cost and schedule delays</li></ul>

Table 7 – Construction Methodology Options

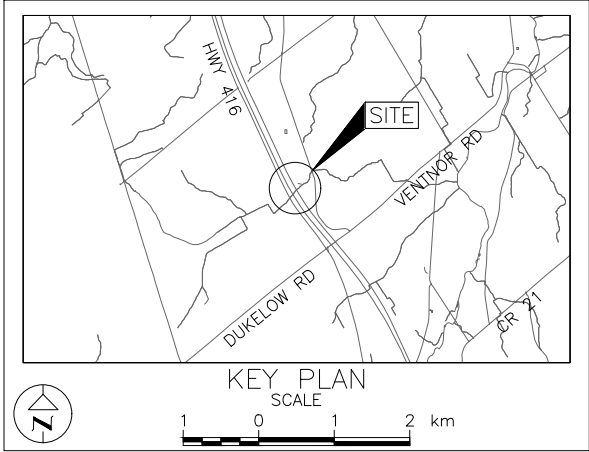
Culvert Methodology Alternatives	Feasibility	Advantages	Disadvantages	Relative Costs	Constructability/Risks
Open Cut with Staged Construction and Temporary Protection Systems	<ul style="list-style-type: none"><li>■ Feasible</li><li>■ Preferred option from a foundation perspective</li></ul>	<ul style="list-style-type: none"><li>■ Does not require full traffic closure</li><li>■ Limits volume of earthwork compared to platform lowering/widening</li></ul>	<ul style="list-style-type: none"><li>■ Traffic impacts</li><li>■ Requires platform widening to accommodate a single lane of traffic during construction</li><li>■ Potentially large volumes of earthwork required for widening</li><li>■ Temporary extension of the existing culvert may be required during construction to allow for widening</li><li>■ The presence of species at risk turtles may restrict construction beyond the current highway platform</li></ul>	<ul style="list-style-type: none"><li>■ Moderate</li></ul>	<ul style="list-style-type: none"><li>■ Settlement of widened portion of embankment leading to increased maintenance, even over short term</li></ul>
Open Cut with a Full Road Closure	<ul style="list-style-type: none"><li>■ Feasible</li></ul>	<ul style="list-style-type: none"><li>■ Quicker installation than with staged construction</li></ul>	<ul style="list-style-type: none"><li>■ Traffic impacts</li><li>■ Requires a long detour around project site to be setup and maintained throughout construction</li></ul>	<ul style="list-style-type: none"><li>■ High</li></ul>	<ul style="list-style-type: none"><li>■ Delays in construction could increase length of time highway is closed.</li><li>■ Detour maintenance could increase costs further</li></ul>
Trenchless Installation	<ul style="list-style-type: none"><li>■ Not Recommended</li></ul>	<ul style="list-style-type: none"><li>■ Avoids open cut.</li><li>■ Does not require traffic staging – minimal traffic impact</li><li>■ Relatively well-known technology and readily available.</li></ul>	<ul style="list-style-type: none"><li>■ Limited depth of cover over tunnel obvert</li><li>■ High mobilization costs</li><li>■ Difficult ground conditions with boulders in fill and till</li><li>■ Relatively large hydraulic opening may require multiple pipes</li></ul>	<ul style="list-style-type: none"><li>■ Very High</li></ul>	<ul style="list-style-type: none"><li>■ Potential impacts to roadway (settlement, loss of ground) due to limited cover</li><li>■ Obstructions within the fill and till materials delay, or potentially halt, the drive</li></ul>



CONT No.  
WP No.4045-18-01

CULVERT CV-0416-000185  
REPLACEMENT  
HIGHWAY 416  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 44.875536 LONG. -75.559694

SHEET



LEGEND

Borehole - Current Investigation

N

Standard Penetration Test Value

16

Blows/0.3m unless otherwise stated  
(Std. Pen. Test, 475 j/blow)

100%

Rock Quality Designation (RQD)

WL upon completion of drilling

BOREHOLE CO-ORDINATES NAD 83 (CSRS)/MTM ZONE 9			
No.	ELEVATION	NORTHING	EASTING
19-7001	95.3	4971040.4	379081.6
19-7002	95.7	4971059.1	379102.1
19-7003	98.7	4971065.2	379084.4
19-7004A	98.6	4971043.6	379099.6
19-7005	99.0	4971027.6	379101.6
19-7015	99.0	4971026.4	379102.4

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.

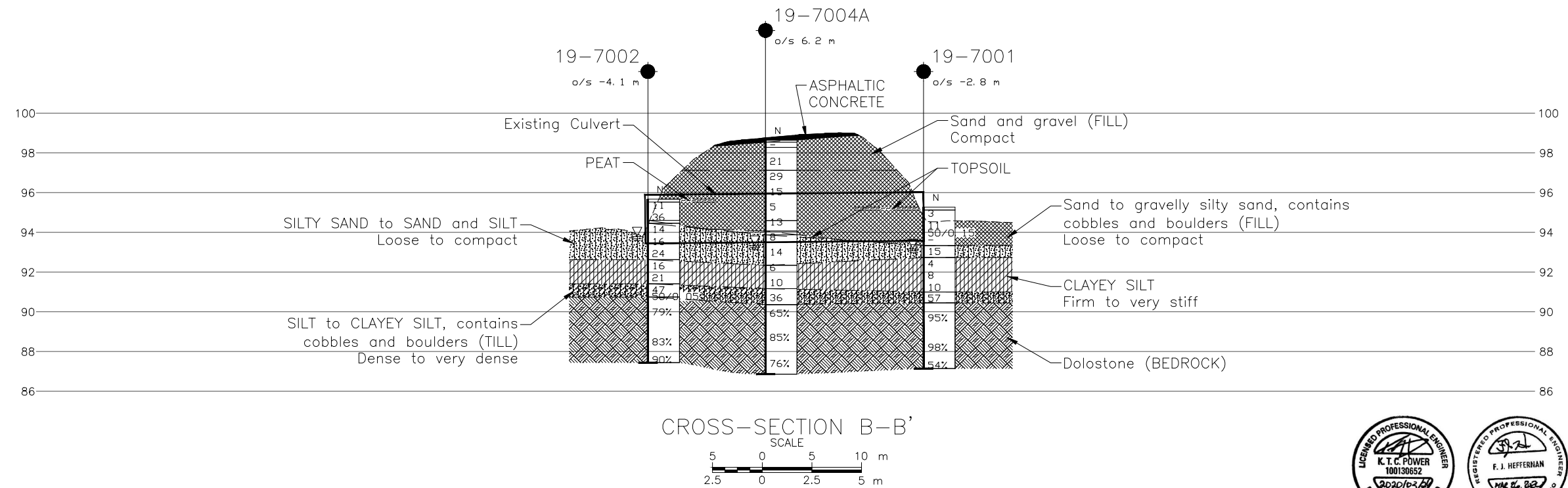
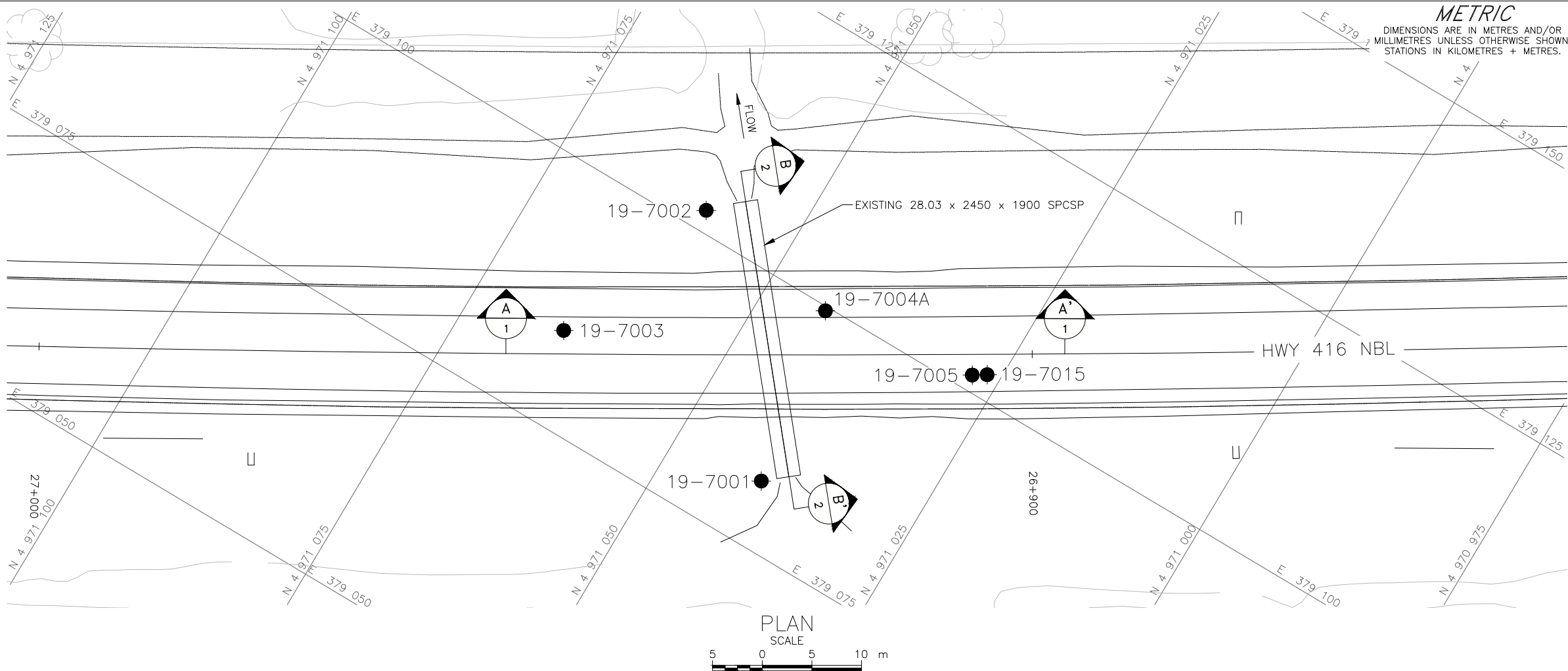
Although not shown it is anticipated that backfill material exists around the culvert.

REFERENCE

Base plans provided in digital format by Dillon Consulting Limited, drawing file no. Hwy 416 Edwardsburgh Culvert 000185.dwg, received JULY 22, 2019.

NO.	DATE	BY	REVISION
Geocres No. 31B-096			
HWY. 416		PROJECT NO. 1899802	
SUBM'D. KCP		CHKD. KCP	DATE: 3/30/2020
DRAWN: JM		CHKD. FJH	APPD. FJH
		DIST. EASTERN	
		SITE: -	
		DWG. 1	





CONT No.  
WP No.4045-18-01

CULVERT CV-0416-000185  
REPLACEMENT  
HIGHWAY 416  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 44.875536 LONG. -75.559694

KEY PLAN  
SCALE  
0 1 2 km

**LEGEND**

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

BOREHOLE CO-ORDINATES NAD 83 (CSRS)/MTM ZONE 9			
No.	ELEVATION	NORTHING	EASTING
19-7001	95.3	4971040.4	379081.6
19-7002	95.7	4971059.1	379102.1
19-7003	98.7	4971065.2	379084.4
19-7004A	98.6	4971043.6	379099.6
19-7005	99.0	4971027.6	379101.6
19-7015	99.0	4971026.4	379102.4

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.

Although not shown it is anticipated that backfill material exists around the culvert.

REFERENCE

Base plans provided in digital format by Dillon Consulting Limited, drawing file no. Hwy 416 Edwardsburgh Culvert 000185.dwg, received JULY 22, 2019.

NO.	DATE	BY	REVISION
Geocres No. 31B-096			
HWY. 416	PROJECT NO. 1899802		DIST. EASTERN
SUBM'D. KCP	CHKD. KCP	DATE: 3/30/2020	SITE: -
DRAWN: JM	CHKD. FJH	APPD. FJH	DWG. 2



**APPENDIX A**

**Record of Boreholes**

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 19-7001 to 19-7005 and 19-7015

Bedrock Core Photographs, Figures A1 to A10



# ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

## MINISTRY OF TRANSPORTATION, ONTARIO

### PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
	Coarse Medium	2.00 to 4.75	(10) to (4)
SAND	Medium	0.425 to 2.00	(40) to (10)
	Fine	0.075 to 0.425	(200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

### MODIFIERS FOR SECONDARY COMPONENTS<sup>1,2</sup>

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (i.e., SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (i.e., some sand)
≤ 10	trace (i.e., trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

### 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.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

#### Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q<sub>t</sub>), porewater pressure (u) and sleeve friction (f<sub>s</sub>) are recorded electronically at 25 mm penetration intervals.

#### Dynamic Cone Penetration Resistance (DCPT); N<sub>d</sub>:

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

### SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

### SOIL TESTS

w	water content
PL, w <sub>p</sub>	plastic limit
LL, w <sub>L</sub>	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
D <sub>R</sub>	relative density (specific gravity, G <sub>s</sub> )
DS	direct shear test
GS	specific gravity
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 <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
Y	unit weight

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

### COARSE-GRAINED SOILS

#### Compactness<sup>1</sup>

Term	SPT 'N' (blows/0.3m) <sup>2</sup>
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

3. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

### FINE-GRAINED SOILS

#### Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' <sup>1,2</sup> (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

### Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.



# LIST OF SYMBOLS

## MINISTRY OF TRANSPORTATION, ONTARIO

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

### I. GENERAL

$\pi$	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

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta\sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	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  $\rho$ . Unit weight symbol is  $\gamma$  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 $= (w_l - w_p)$
NP	non-plastic
$w_s$	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
$C_\alpha$	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
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	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  
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$

## 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, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

### DISCONTINUITY DATA

#### Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

#### Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

#### Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

#### Abbreviations

JN Joint	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	

PROJECT		1899802-7000		RECORD OF BOREHOLE No 19-7001		SHEET 1 OF 2		METRIC										
G.W.P.		4045-18-01		LOCATION		N 4971040.4; E 379081.6 NAD 83 MTM ZONE 9 (LAT. 44.875490; LONG. -75.559840)		ORIGINATED BY										
DIST		Eastern HWY 416		BOREHOLE TYPE		Wash Boring, BW Casing, Portable Rotary Drill, AW Casing		COMPILED BY										
DATUM		Geodetic		DATE		August 6, 2019		CHECKED BY										
								KCP										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
95.3	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL																	
0.2	(SM) Silty sand and gravel, contains cobbles and boulders (FILL) Loose to compact Brown Moist		1	SS	3													
			2	SS	11													
	- Cobbles and boulders from 1.3 m to 1.9 m		3	SS	50/0.15													
			4	RC	-													
93.4	(ML) SANDY SILT Compact Grey Wet		5	SS	15													
92.8	(CL-ML) CLAYEY SILT-SILT, trace sand Stiff to very stiff Grey Wet		6	SS	4													
			7	SS	8													
			8	SS	10													
91.0	(CL) CLAYEY SILT, some gravel, contains cobbles (TILL) Very dense Grey Wet		9	SS	57													
90.5	Dolostone (BEDROCK)		10	RC	-													
4.8	Bedrock cored from depths 4.8 m to 8.1 m  For bedrock coring details refer to Record of Drillhole 19-7001		1	RC	REC 100%													
			2	RC	REC 100%													
			3	RC	REC 100%													
87.2	END OF BOREHOLE																	
8.1	NOTES:  1. Manual half-weight hammer used for all split spoon samples. SPT N-values are corrected to approximate expected values that would be obtained using a standard weight hammer.  2. Water level in open borehole at 2.1 m depth below ground surface (Elev. 93.2 m), upon completion of drilling.																	

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTD\HWY417BRIDGES\02\_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

PROJECT: 1899802-7000

**RECORD OF DRILLHOLE: 19-7001**

SHEET 2 OF 2

LOCATION: N 4971040.4 ;E 379081.6

DRILLING DATE: August 6, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
					DEPTH (m)	RECOVERY				FRACT. INDEX PER	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY K, cm/sec			WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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DEPTH SCALE

1 : 50



LOGGED: RI

CHECKED: KCP

GTA-RCK 031 N:\ACTIVE\SPATIAL\_IMMTO\HWY417\BRIDGES\02\_DATA\GINT\1899802\1899802.GPJ GAL-MISS.GDT 20-3-19 ZS



STA-MTO 001 N:\ACTIVE\SPATIAL IM\MT0\HWY417BRIDGES\02 DATA\GINT\1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

PROJECT: 1899802-7000

**RECORD OF DRILLHOLE: 19-7002**

SHEET 2 OF 2

LOCATION: N 4971059.1 ;E 379102.1

DRILLING DATE: August 7, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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5	Rotary Drill AW Casing	Continued from Record of Borehole 19-7002		90.75																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						

DEPTH SCALE

1 : 50

**GOLDER**

LOGGED: RI

CHECKED: KCP


GTA-RCK 031 N:\ACTIVE\SPATIAL\_IMMTO\HWY417\BRIDGES\02\_DATA\GINT\1899802\1899802 GPJ GAL-MISS.GDT 20-3-19 ZS

PROJECT		1899802-7000		<b>RECORD OF BOREHOLE No 19-7003</b>		SHEET 1 OF 3		<b>METRIC</b>								
G.W.P.		4045-18-01		LOCATION		N 4971065.2; E 379084.4 NAD 83 MTM ZONE 9 (LAT. 44.875710; LONG. -75.559800)		ORIGINATED BY JS								
DIST		Eastern HWY 416		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, HW Casing		COMPILED BY JM								
DATUM		Geodetic		DATE		July 11-12, 2019		CHECKED BY KCP								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
98.7	GROUND SURFACE							20	40	60	80	100				
0.0	ASPHALTIC CONCRETE															
0.1	(SM/GM) Silty sand and gravel (FILL) Grey Damp		1	GRAB	-											37 43 (20)
98.1	(SW) Sand and gravel, some silt, contains cobbles (FILL) Compact Brown Damp		2	SS	28											
97.3	(SP) Sand, some silt (FILL) Dense Brown Moist		3	SS	39											
95.0	(SW) Gravelly sand (FILL) Very dense Brown Moist		6	SS	73											
94.1	(SM/ML) SAND and SILT, contains clayey silt seams Compact to loose Grey Wet		7	SS	19											
92.6	(CI) CLAYEY SILT Very stiff Grey Wet		9	SS	10											0 1 76 23
90.8	SAND and GRAVEL (TILL) Dolostone (BEDROCK)		11	SS	65/0.23											
8.0	Bedrock cored from depths 8.0 m to 10.9 m  For bedrock coring details refer to Record of Drillhole 19-7003		1	RC	REC 100%											RQD = 87%
			2	RC	REC 100%											RQD = 81%

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTD\HWY417BRIDGES\02\_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

PROJECT		RECORD OF BOREHOLE No 19-7003				SHEET 2 OF 3		METRIC									
G.W.P. 4045-18-01		LOCATION N 4971065.2; E 379084.4 NAD 83 MTM ZONE 9 (LAT. 44.875710; LONG. -75.559800)				ORIGINATED BY JS											
DIST Eastern HWY 416		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, HW Casing				COMPILED BY JM											
DATUM Geodetic		DATE July 11-12, 2019				CHECKED BY KCP											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100						
87.8	Dolostone (BEDROCK)		2	RC	REC 100%	88											RQD = 81%
10.9	Bedrock cored from depths 8.0 m to 10.9 m  For bedrock coring details refer to Record of Drillhole 19-7003																
	END OF BOREHOLE																
	NOTES:  1. Water level in open borehole at 5.0 m depth below ground surface (Elev. 93.7 m), upon completion of drilling.																

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IM\MTOWHY417BRIDGES\02\_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS



PROJECT: 1899802-7000

**RECORD OF DRILLHOLE: 19-7003**

SHEET 3 OF 3

LOCATION: N 4971065.2 ;E 379084.4

DRILLING DATE: July 11-12, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr		Ja	W1	W2	W3	W4	W5		W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
8		Continued from Record of Borehole 19-7003		90.72																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								

DEPTH SCALE

1 : 50

**GOLDER**

LOGGED: JS

CHECKED: KCP


GTA-RCK 031 N:\ACTIVE\SPATIAL\_IMMTO\HWY417\BRIDGES\02\_DATA\GINT\1899802\1899802.GPJ GAL-MISS.GDT 20-3-19 ZS

PROJECT		1899802-7000		RECORD OF BOREHOLE No 19-7004A		SHEET 1 OF 3		METRIC							
G.W.P.		4045-18-01		LOCATION		N 4971043.6; E 379099.6 NAD 83 MTM ZONE 9 (LAT. 44.875525; LONG. -75.559614)		ORIGINATED BY JS							
DIST		Eastern HWY 416		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, NQ Core		COMPILED BY JM							
DATUM		Geodetic		DATE		July 11, 2019		CHECKED BY KCP							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
98.6	GROUND SURFACE														
0.0	ASPHALTIC CONCRETE														
98.2	(SW) Gravelly sand (FILL) Grey Damp		1	GRAB	-										
0.4	(SW) Sand and gravel, some fines (FILL) Compact Grey brown Damp		2	SS	21										
97.1															
1.5	(SP) Sand, trace fines (FILL) Compact to loose Brown Moist		3	SS	29										
			4	SS	15										
			5	SS	5										
94.6	(GW) Sandy gravel (FILL) Brown Wet		6	SS	13										
94.0															
93.8	(SM) Silty sand (TOPSOIL) Black Moist to wet		7	SS	8										
4.8	(SM/ML) SAND and SILT, contains rootlets Compact Grey brown Wet		8	SS	14										
92.3	(CL-ML) CLAYEY SILT Very stiff Grey Wet		9	SS	6										
6.3			10	SS	10										
91.1	(ML) SILT, contains clayey silt seams, cobbles and boulders (TILL) Dense Grey Wet		11	SS	36										
7.5															
90.3	Dolostone (BEDROCK)														
8.3	Bedrock cored from depths 8.3 m to 11.8 m  For bedrock coring details refer to Record of Drillhole 19-7004A		1	RC	REC 82%										RQD = 65%
			2	RC	REC 100%										RQD = 85%

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IM\IMTO\HWY417\BRIDGES\02\_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

PROJECT		RECORD OF BOREHOLE				No 19-7004A		SHEET 2 OF 3		METRIC							
G.W.P. 4045-18-01		LOCATION				N 4971043.6; E 379099.6 NAD 83 MTM ZONE 9 (LAT. 44.875525; LONG. -75.559614)				ORIGINATED BY JS							
DIST Eastern HWY 416		BOREHOLE TYPE				Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, NQ Core				COMPILED BY JM							
DATUM Geodetic		DATE				July 11, 2019				CHECKED BY KCP							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
	Dolostone (BEDROCK)		2	RC	REC 100%												RQD = 85%
	Bedrock cored from depths 8.3 m to 11.8 m  For bedrock coring details refer to Record of Drillhole 19-7004A		3	RC	REC 98%												
86.8 11.8	END OF BOREHOLE																
	NOTES:  1. Water level in open borehole at 5.3 m depth below ground surface (Elev. 93.3 m), upon completion of drilling.																

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMITO\HWY417BRIDGES\02\_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

PROJECT: 1899802-7000

**RECORD OF DRILLHOLE: 19-7004A**

SHEET 3 OF 3

LOCATION: N 4971043.6 ;E 379099.6

DRILLING DATE: July 11, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
				DEPTH (m)	FLUSH RETURN		RECOVERY		R.Q.D. %	FRACT. INDEX PER	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY K, cm/sec			WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
							TOTAL CORE %	SOLID CORE %			DIP w.r.t CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	10°	10°	10°	W1	W2	W3		W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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UCS = 230 MPa

DEPTH SCALE

1 : 50

**GOLDER**

LOGGED: JS







CHECKED: KCP

GTA-RCK 031 N:\ACTIVE\SPATIAL\_IMMTO\HWY417\BRIDGES\02\_DATA\GINT\1899802\1899802.GPJ GAL-MISS.GDT 20-3-19 ZS

PROJECT <u>1899802-7000</u>		<b>RECORD OF BOREHOLE No 19-7005</b>		SHEET 1 OF 1		<b>METRIC</b>	
G.W.P. <u>4045-18-01</u>		LOCATION <u>N 4971027.6; E 379101.6 NAD 83 MTM ZONE 9 (LAT. 44.875382; LONG. -75.559591)</u>		ORIGINATED BY <u>JS</u>			
DIST <u>Eastern</u> HWY <u>416</u>		BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>		COMPILED BY <u>JM</u>			
DATUM <u>Geodetic</u>		DATE <u>July 12, 2019</u>		CHECKED BY <u>KCP</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub> W                      W <sub>L</sub>				
								○ UNCONFINED                      + FIELD VANE ● QUICK TRIAXIAL                      × REMOULDED					WATER CONTENT (%)				
99.0	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALTIC CONCRETE																
0.2	(GW) Silty gravel and sand (FILL) Grey to brown Moist		-	GS	-												
98.2																	
0.8	(SM) Silty sand, some gravel, contains cobbles (FILL) Compact Brown Moist		1	SS	27												
97.1			2	SS	78												
1.9	(SP) Sand (FILL) Brown Moist																
96.8																	
2.2	(SM) Silty sand, some gravel, contains cobbles and boulders (FILL) Dense Brown, mottled Moist		3	SS	31												
			4	RC	-												
	- Boulder from 2.8 m to 3.6 m																
95.4																	
3.6	END OF BOREHOLE AUGER REFUSAL																


GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMITO\HWY417\BRIDGES\02\_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

PROJECT		1899802-7000		<b>RECORD OF BOREHOLE No 19-7015</b>		SHEET 1 OF 3		<b>METRIC</b>								
G.W.P.		4045-18-01		LOCATION		N 4971026.4; E 379102.4 NAD 83 MTM ZONE 9 (LAT. 44.875370; LONG. -75.559581)		ORIGINATED BY JS								
DIST		Eastern HWY 416		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, NQ Core		COMPILED BY JM								
DATUM		Geodetic		DATE		July 18, 2019		CHECKED BY KCP								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
99.0	GROUND SURFACE															
0.0	For soil descriptions from 0.0 m to 3.1 m refer to Record of Borehole 19-7005															
96.0																
3.1	(SM/ML) Gravelly sand and silt, contains cobbles and boulders (FILL) Brown Moist		1	SS	12											27 37 (36)
			2	SS	38											
94.4																
4.7	(SM) Silty sand (TOPSOIL) Black Moist		3	SS	13											
	(SP) SAND, some silt Grey brown Wet															
93.7																
5.3	(SM) SILTY SAND, trace gravel Compact Grey Wet		4	SS	22											6 71 (23)
			5	SS	19											
92.1																
6.9	(CL) CLAYEY SILT Very stiff Grey		6	SS	12											0 2 72 26
			7	SS	22											
90.3																
8.7	Dolostone (BEDROCK)		1	RC	REC 100%											RQD = 86%
	Bedrock cored from depths 8.7 m to 12.1 m		2	RC	REC 100%											RQD = 73%
	For bedrock coring details refer to Record of Drillhole 19-7015															

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IM\MTOWHY417BRIDGES\02\_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

PROJECT		RECORD OF BOREHOLE No 19-7015				SHEET 2 OF 3		METRIC									
G.W.P. 4045-18-01		LOCATION N 4971026.4; E 379102.4 NAD 83 MTM ZONE 9 (LAT. 44.875370; LONG. -75.559581)				ORIGINATED BY JS											
DIST Eastern HWY 416		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem), Rotary Drill, NQ Core				COMPILED BY JM											
DATUM Geodetic		DATE July 18, 2019				CHECKED BY KCP											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100						
	Dolostone (BEDROCK)		2	RC	REC 100%												RQD = 73%
	Bedrock cored from depths 8.7 m to 12.1 m  For bedrock coring details refer to Record of Drillhole 19-7015		3	RC	REC 97%												RQD = 84%
86.9 12.1	END OF BOREHOLE																
	NOTES:  1. Water level in open borehole at 5.0 m depth below ground surface (Elev. 94.0 m), upon completion of drilling.																

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IM\MTOWHY417BRIDGES\02\_DATA\GINTV1899802\1899802.GPJ GAL-GTA.GDT 20-3-19 ZS

SHEET 3 OF 3

DATUM: Geodetic

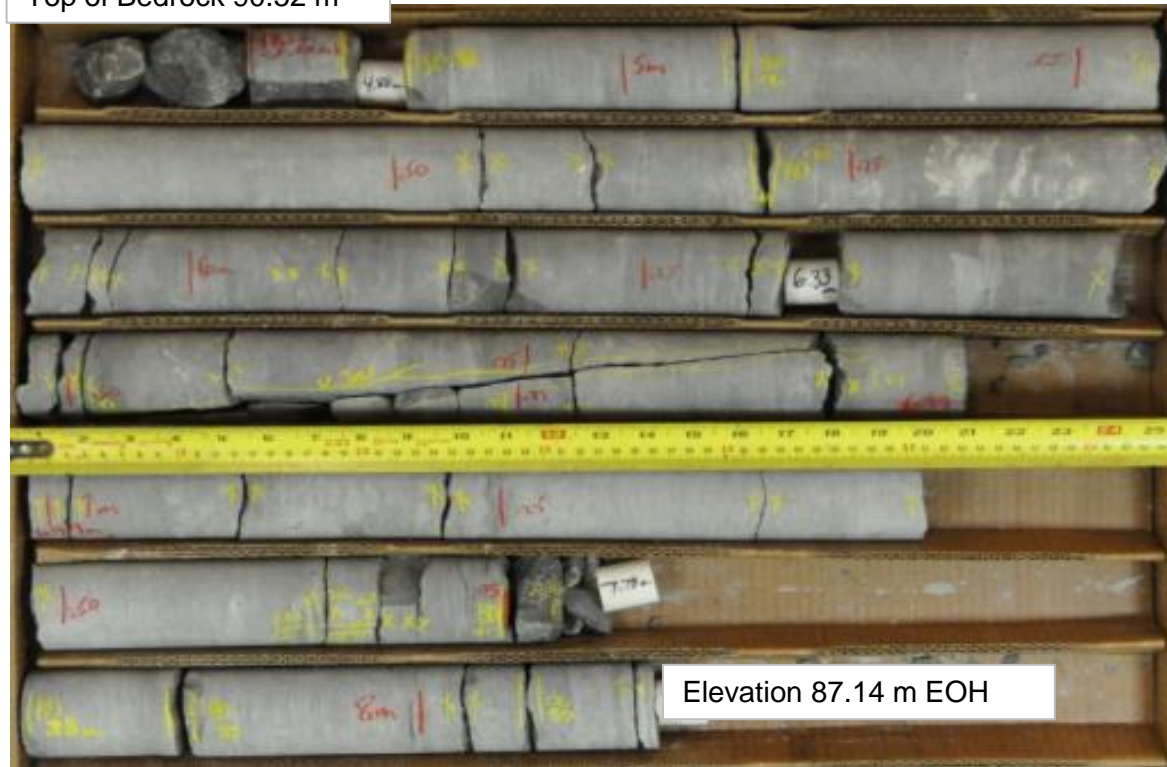
DRILLING CONTRACTOR: CCC

CHECKED: KCP



**BH 19-7001 (Dry)**  
**Core Box 1 and 2 of 2**

Top of Bedrock 90.52 m



Elevation 87.14 m EOH



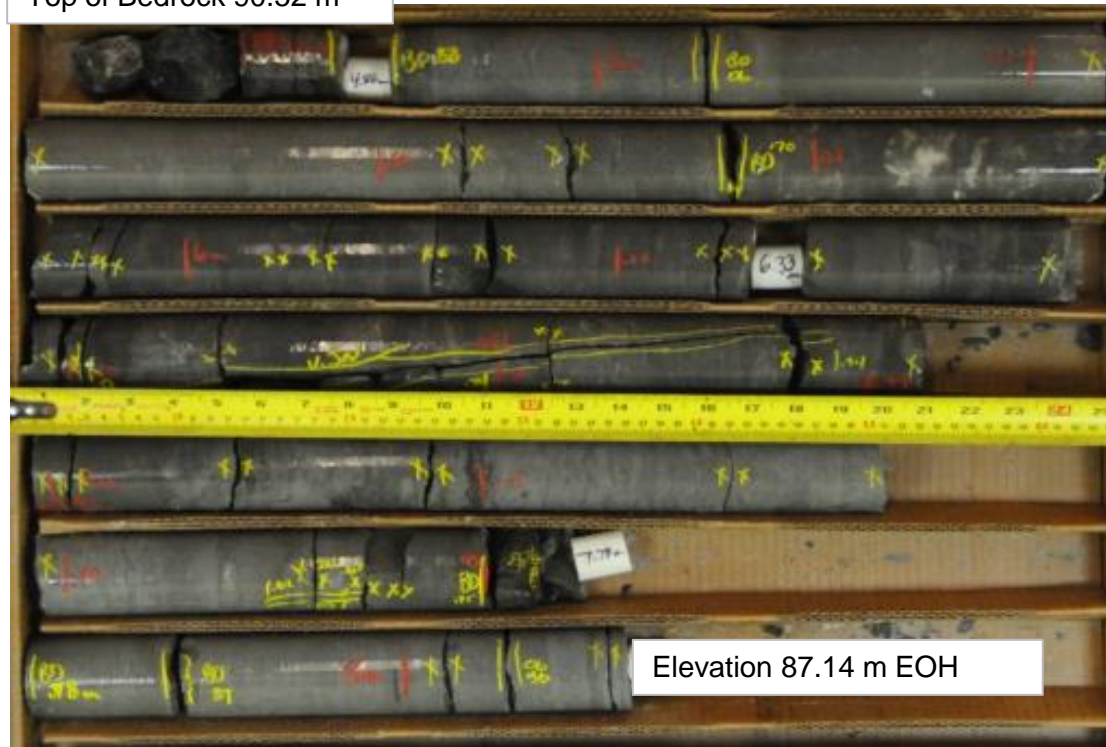
**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A1**

**BH 19-7001 (wet)**  
**Core Box 1 and 2 of 2**

Top of Bedrock 90.52 m



Elevation 87.14 m EOH



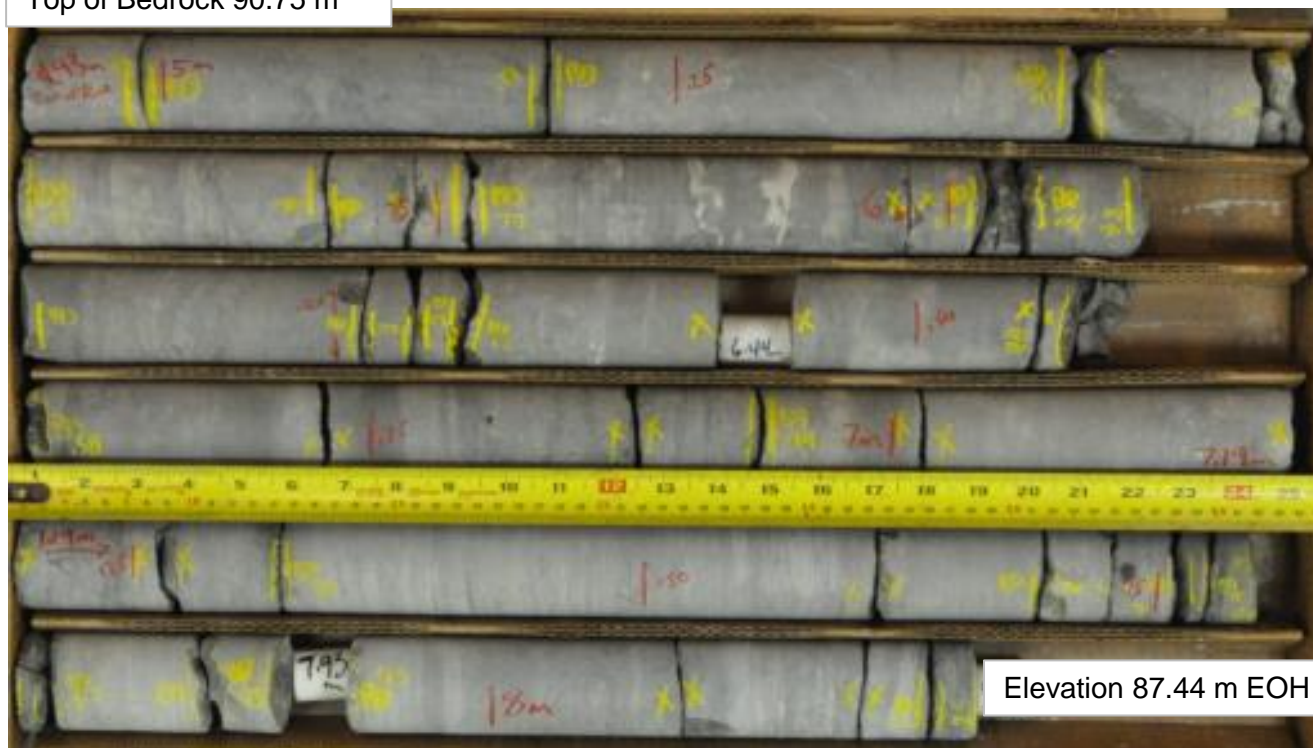
**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A2**

**BH 19-7002 (Dry)**  
**Core Box 1 of 1**

Top of Bedrock 90.75 m



Elevation 87.44 m EOH



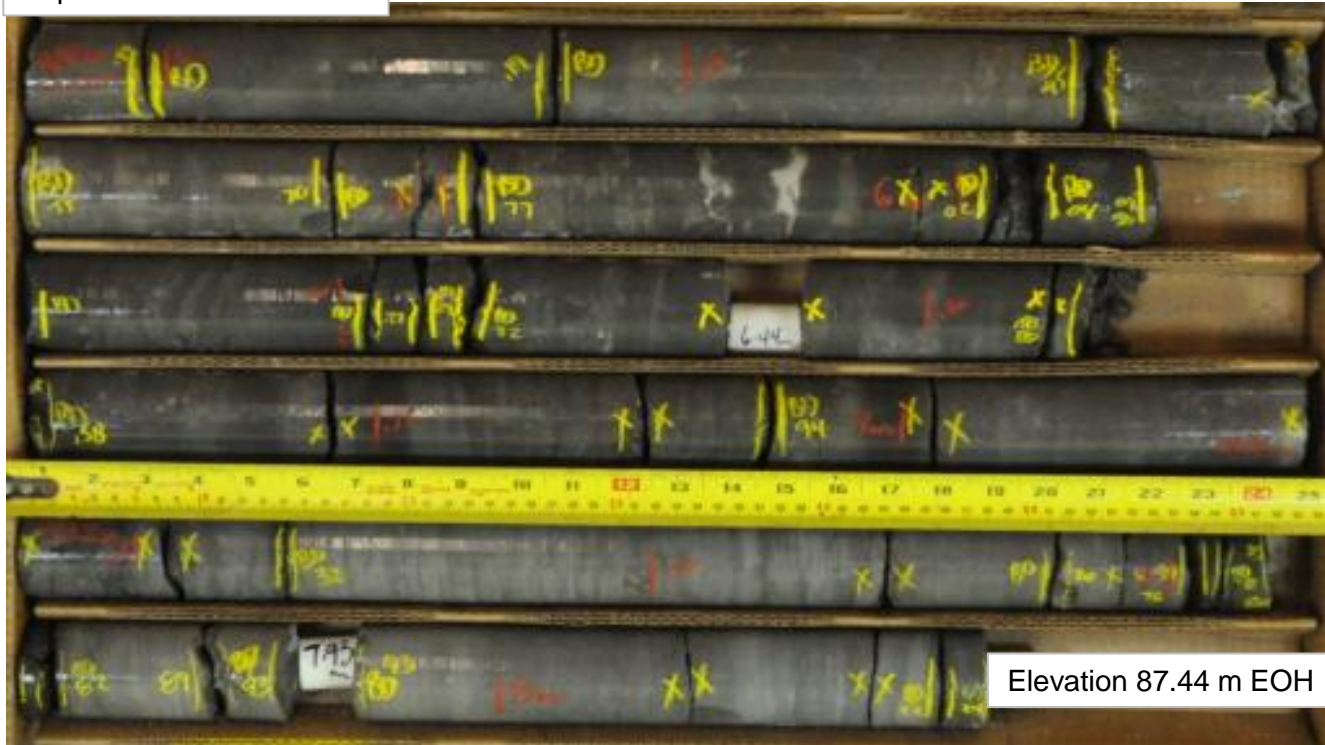
**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A3**

**BH 19-7002 (wet)**  
**Core Box 1 to 2 of 2**

Top of Bedrock 90.75 m



Elevation 87.44 m EOH



**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

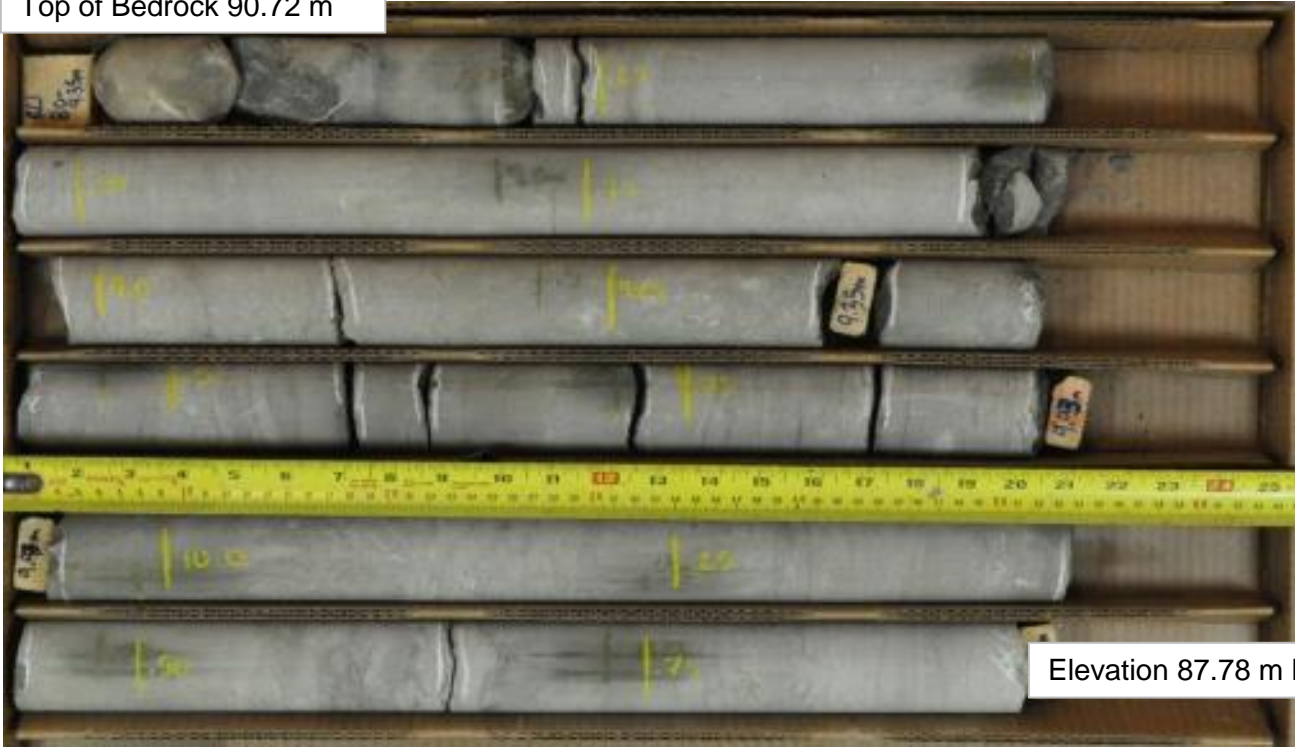
Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A4**



BH 19-7003 (Dry)  
Core Box 1 of 1

Top of Bedrock 90.72 m



Elevation 87.78 m EOH



**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A5**

**BH 19-7003 (Wet)**  
**Core Box 1 and 2 of 2**

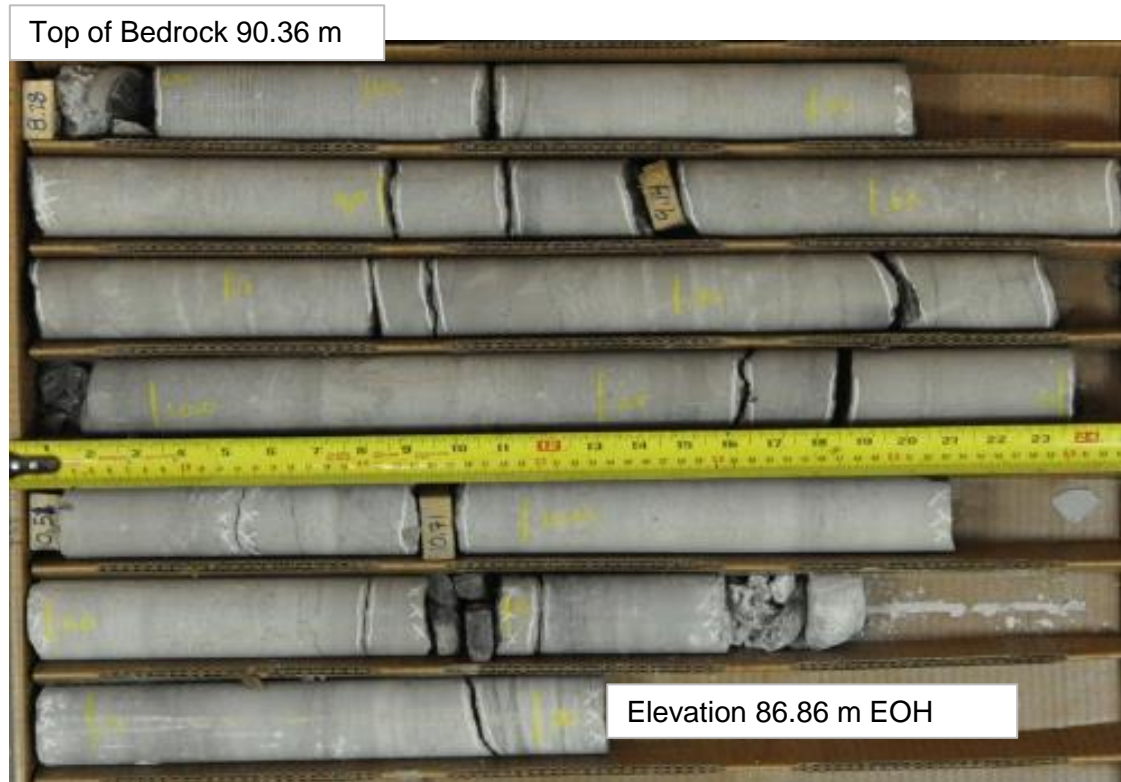


**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A6**

**BH 19-7004A (Dry)**  
**Core Box 1 and 2 of 2**



**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A7**

**BH 19-7004A (wet)**  
**Core Box 1 and 2 of 2**

Top of Bedrock 90.36 m



Elevation 86.86 m EOH



**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A8**



**BH 19-7015 (Dry)**  
**Core Box 1 and 2 of 2**

Top of Bedrock 90.33 m



Elevation 86.88 m EOH



**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A9**

**BH 19-7015 (Wet)**  
**Core Box 1 and 2 of 2**

Top of Bedrock 90.33 m



Elevation 86.88 m EOH



**Geotechnical Investigation**  
**Replacement of Culvert CV-0416-000185**  
**Highway 416, Ottawa, Ontario**

Project No.	1899802 / 7000
Drawn:	MS
Date:	2019-07-23
Checked:	KCP
Review:	FJH

**Figure A10**

## APPENDIX B

# Laboratory Test Results

Figure B1 – Grain Size Distribution Test Results – Sand and Gravel (Fill)

Figure B2 – Grain Size Distribution Test Results – Sand to Sand and Gravel (Fill)

Figure B3 – Grain Size Distribution Test Results - Silty Sand and Gravel (Fill)

Figure B4 – Grain Size Distribution Test Results – Sand and Silt to Silty Sand

Figure B5 – Grain Size Distribution Test Results – Clayey Silt – Silt

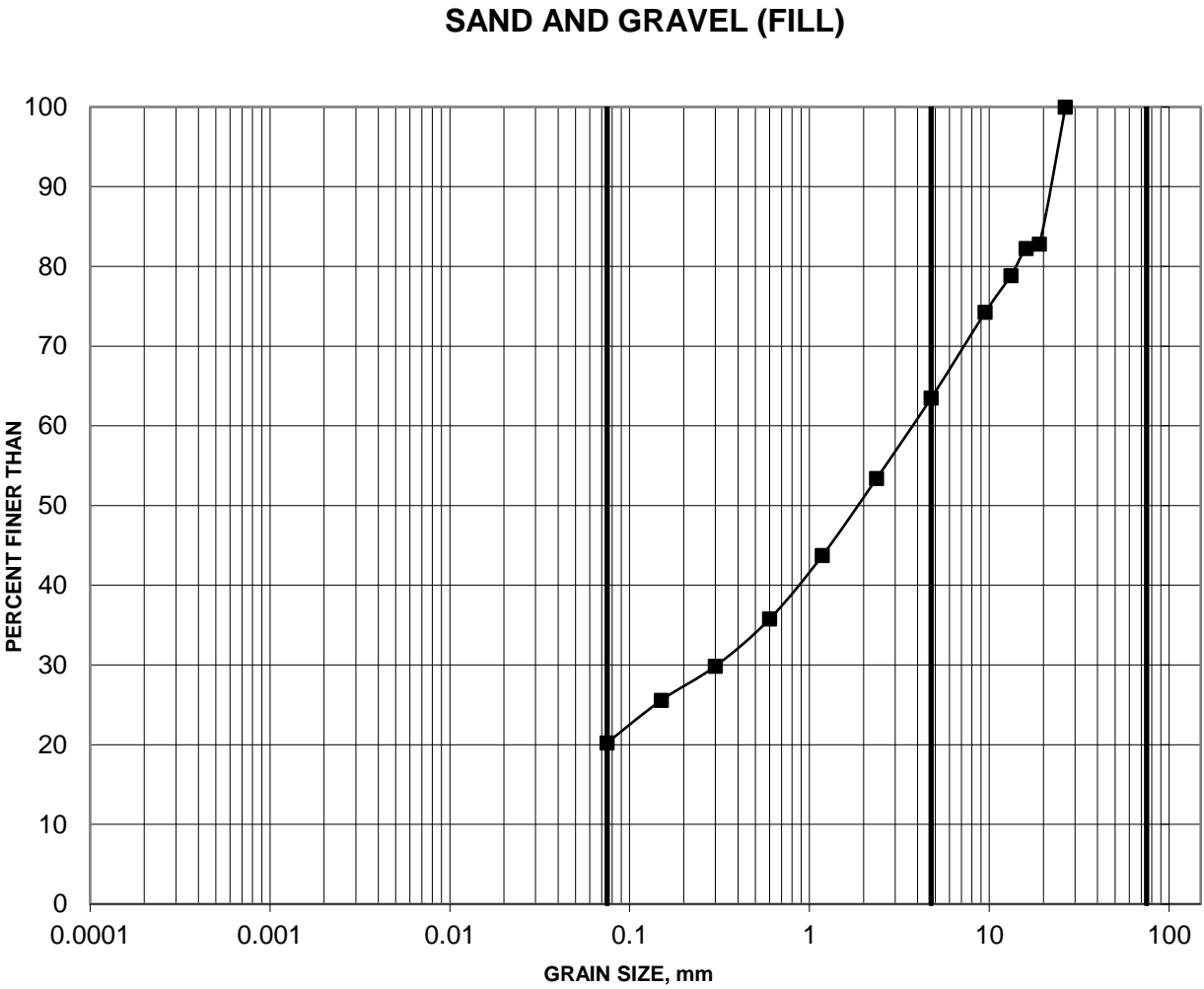
Figure B6 – Plasticity Chart – Clayey Silt – Silt

Figure B7 – Grain Size Distribution Test Results – Silt (Till)

Figure B8 – Summary of Laboratory Compressive Strength Unconfined  
Compression Test

GRAIN SIZE DISTRIBUTION

FIGURE B1



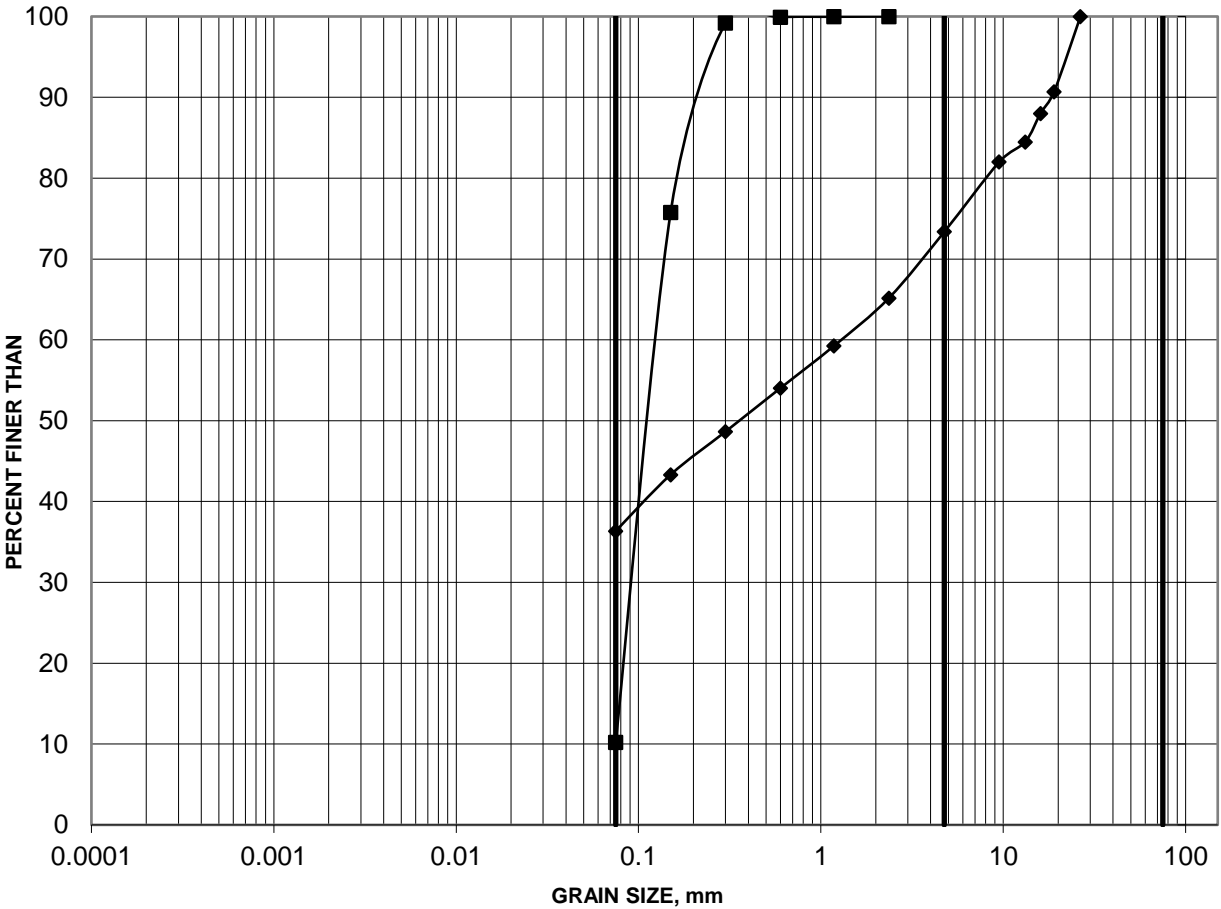
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

	Borehole	Sample	Depth (m)
■	19-7003	1	0.33-1.67

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND TO SAND AND GRAVEL (FILL)



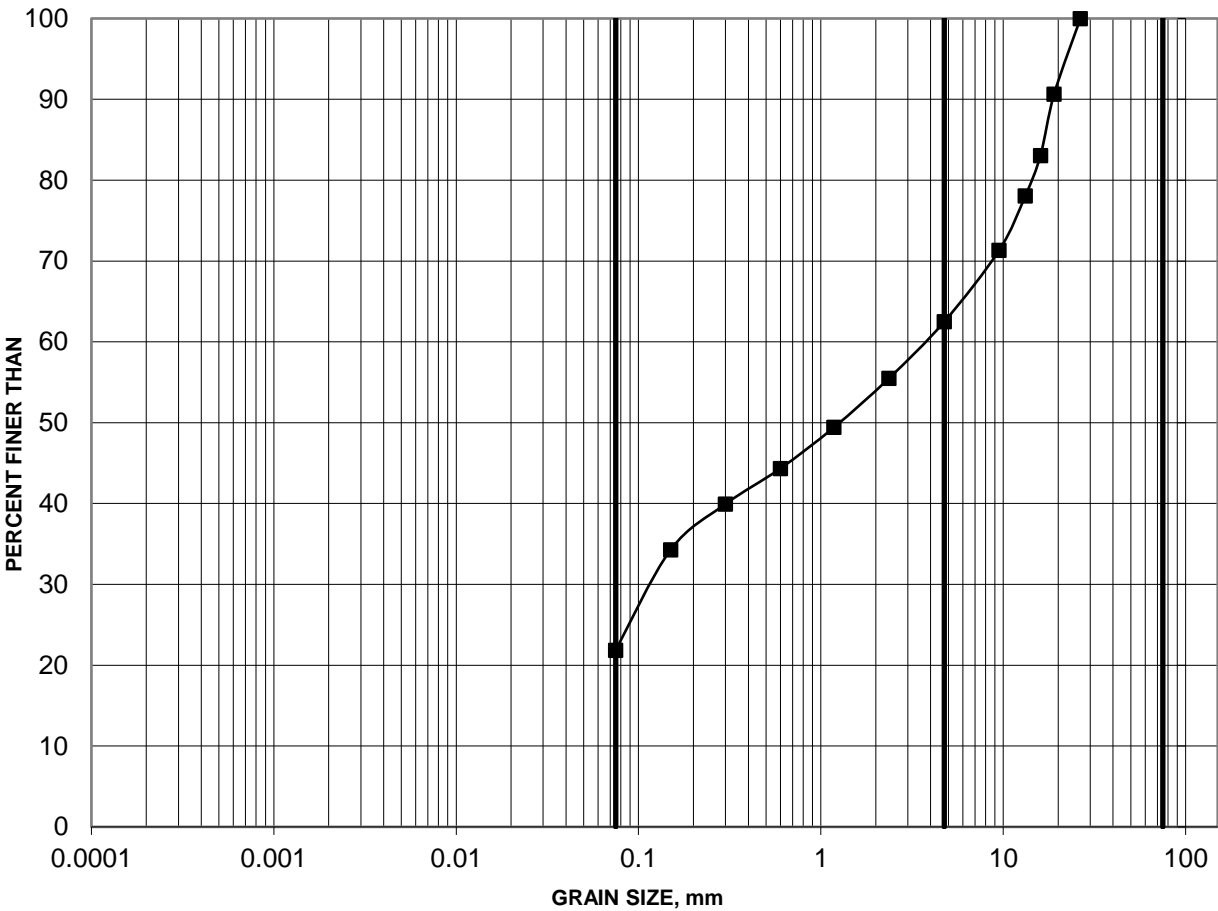
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
19-7003	4	2.29-2.90
19-7015	1	3.05-3.66

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY SAND AND GRAVEL (FILL)



SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
■ 19-7001	2	0.61-1.22

Project: 1899802/7000

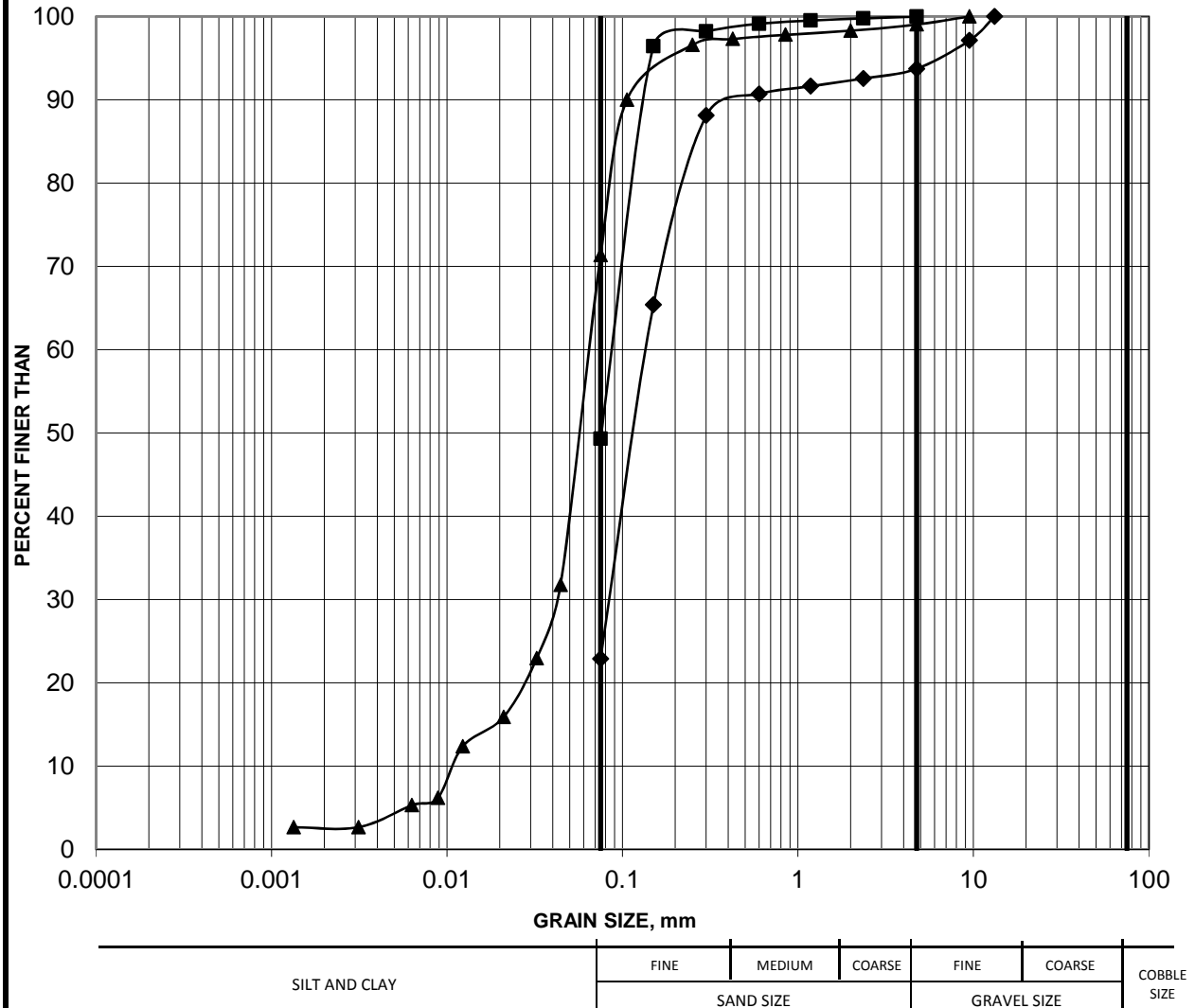
Golder Associates

Created by: KCP  
Checked by: MI

# GRAIN SIZE DISTRIBUTION

FIGURE B

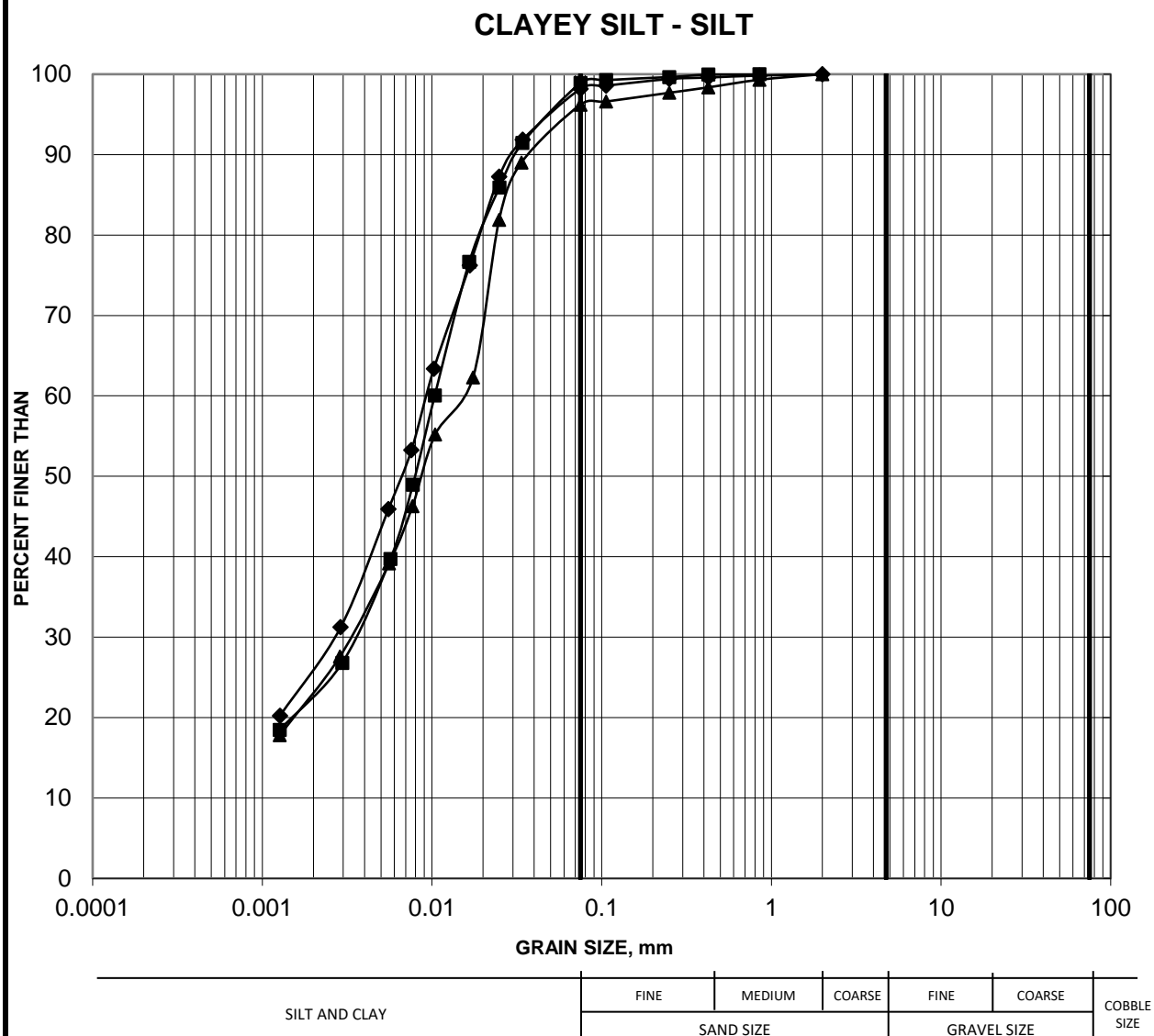
## SAND AND SILT TO SILTY SAND



Borehole	Sample	Depth (m)
19-7001	5	1.92-2.53
19-7004A	8	5.33-5.94
19-7015	4	5.33-5.94

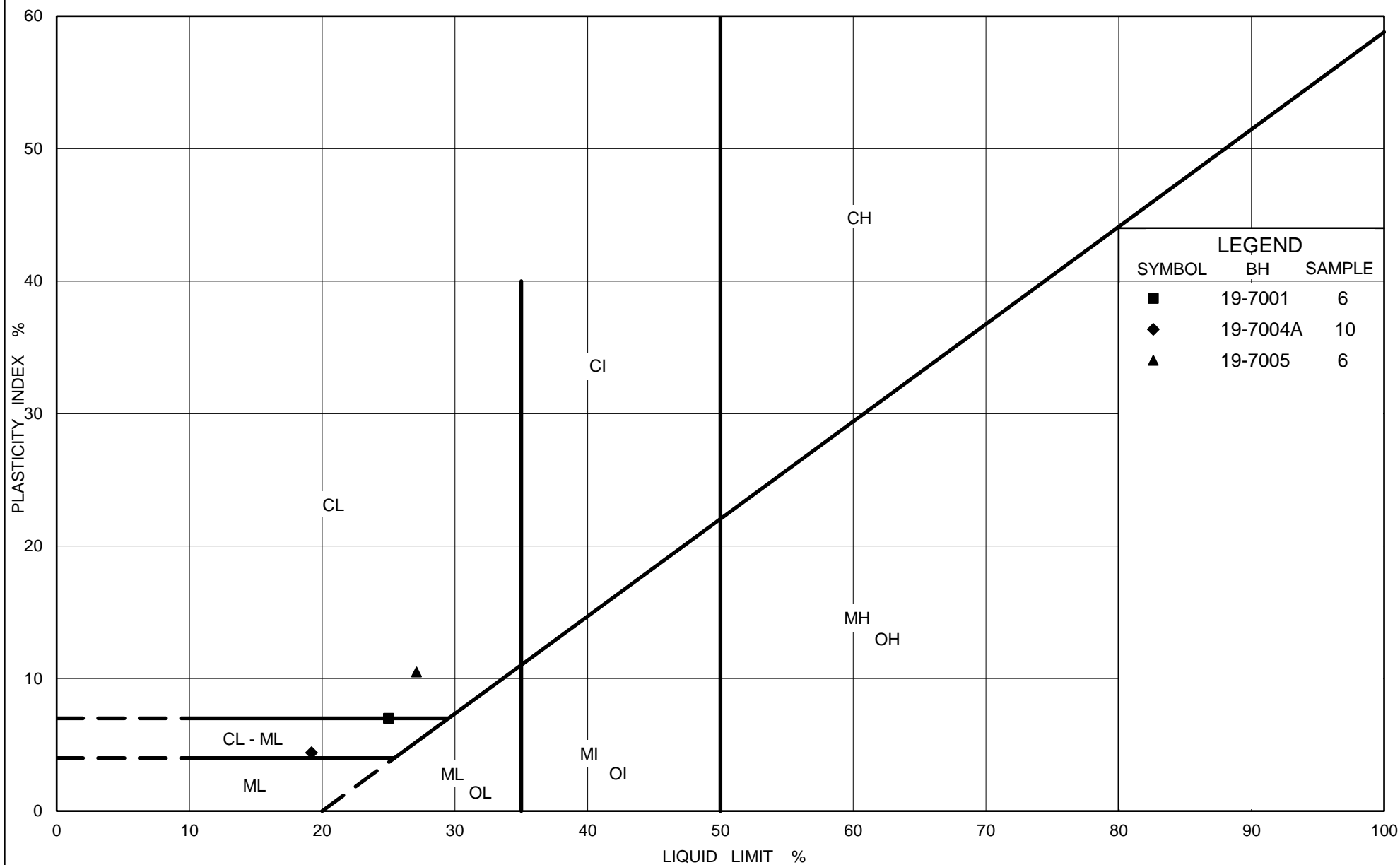
# GRAIN SIZE DISTRIBUTION

FIGURE B



Borehole	Sample	Depth (m)
▲ 19-7001	6	2.53-3.14
■ 19-7003	9	6.10-6.71
◆ 19-7015	6	6.86-7.47





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# PLASTICITY CHART CLAYEY SILT - SILT

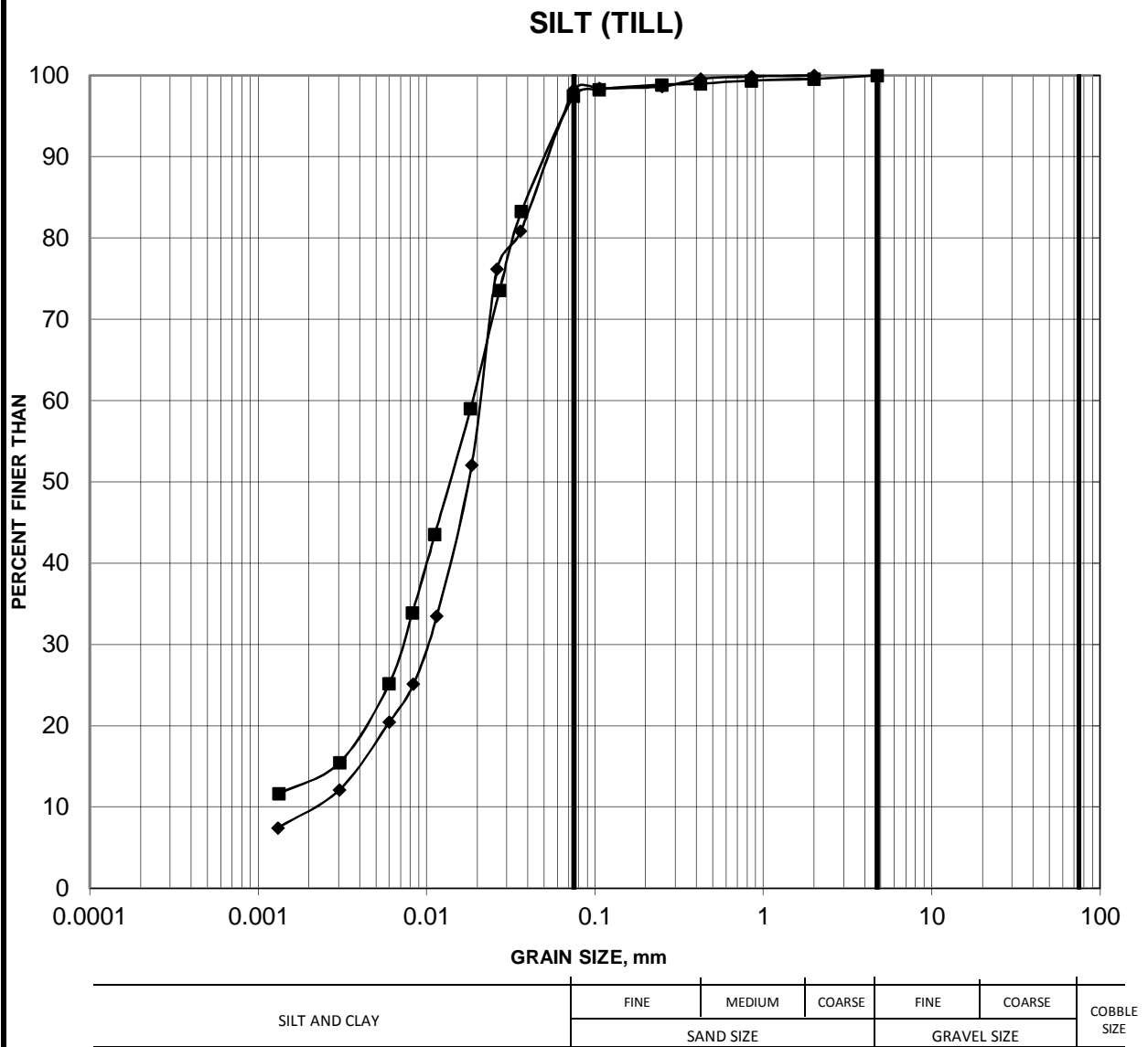
FIG No. B6

Project No. 1899802/7000

Compiled By : KCP Checked By : MI

# GRAIN SIZE DISTRIBUTION

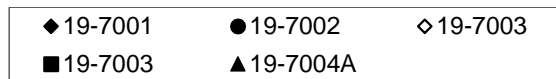
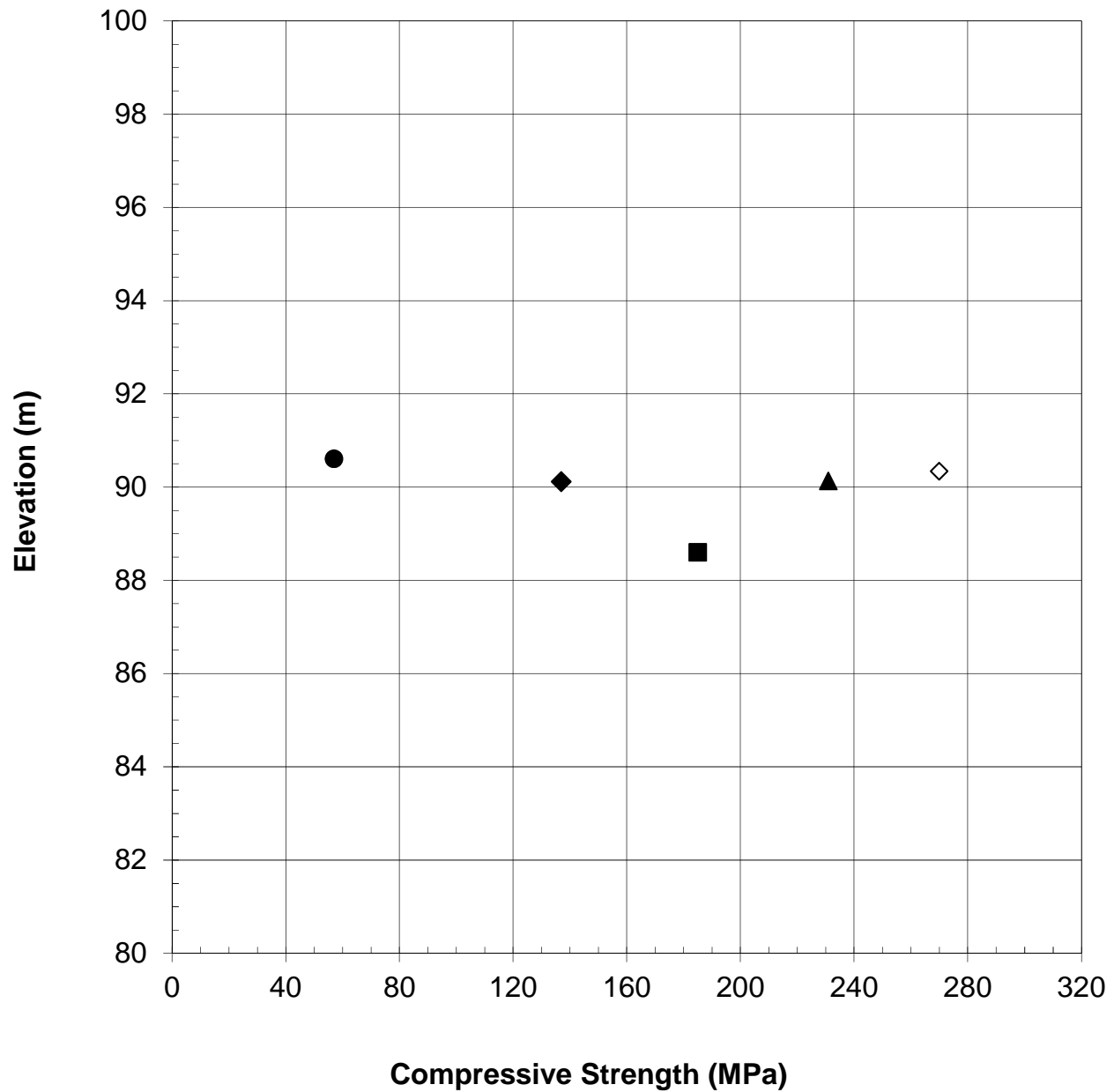
FIGURE B



Borehole	Sample	Depth (m)
19-7002	8	4.27-4.88
19-7004A	11	7.62-8.23

# SUMMARY OF LABORATORY COMPRESSIVE STRENGTH UNCONFINED COMPRESSION TESTS

FIGURE B



**APPENDIX C**

# **Results of Chemical Analysis**

Eurofins Environment Testing Report No. 1913683 and 1915176



## Environment Testing

## Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)  
1931 Robertson Road,  
Ottawa, Ontario

Attention: Kenton Power

PO#:

Invoice to: Golder Associates Ltd

Report Number: 1913683  
Date Submitted: 2019-07-31  
Date Reported: 2019-08-08  
Project: 1899802/7000  
COC #: 847133

					Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1444568 Soil  2019-07-11 19-7004 sa5	1444569 Soil  2019-07-15 19-7006B sa5	1444570 Soil  2019-07-16 19-7009 sa3
Group	Analyte	MRL	Units	Guideline				
Anions	Cl	0.002	%			0.006	0.067	0.006
	SO4	0.01	%			<0.01	<0.01	<0.01
General Chemistry	Electrical Conductivity	0.05	mS/cm			0.12	0.64	0.16
	pH	2.00				8.66	8.06	8.56
	Resistivity	1	ohm-cm			8700	1570	6130

Guideline =

\* = Guideline Exceedence

Results relate only to the parameters tested on the samples submitted.  
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range



## Environment Testing

### Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)  
1931 Robertson Road,  
Ottawa, Ontario  
K2L 4G1  
Attention: Kenton Power  
PO#:  
Invoice to: Golder Associates Ltd

Report Number: 1915176  
Date Submitted: 2019-08-21  
Date Reported: 2019-08-29  
Project: 1899802 pH 7000  
COC #: 847895

					Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.
Group	Analyte	MRL	Units	Guideline	1448940 Soil  2019-08-07 19-7002 SS 5
Anions	Cl	0.002	%		0.007
	SO4	0.01	%		0.02
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.24
	pH	2.00			7.98
	Resistivity	1	ohm-cm		4120

**Guideline =**

**\* = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.  
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

**APPENDIX D**

# Site Photographs



**Photograph 1: Highway 416 platform looking north at culvert crossing; 2019-06-26**



**Photograph 2: Looking west upstream from culvert inlet towards Highway 416 southbound; 2019-06-26**





**Photograph 3: Looking east downstream from culvert outlet; 2019-06-18**



**Photograph 4: Looking north along west embankment / ditchline; 2019-06-26**



**Photograph 5: Looking north along east embankment / ditchline; 2019-06-26**

**APPENDIX E**

**NON-STANDARD SPECIAL PROVISIONS**

Excavation

Concrete Working Slab

Protection of Sensitive Foundation Soils

Temporary Protection System

FOUN0003 Dewatering Structure Excavations



## **NON-STANDARD SPECIAL PROVISIONS**

### **RECOMMENDED WORDING FOR “NSSP – 902.07.05 EXCAVATION”**

Subsection 902.07.05 of OPSS 902 is amended by the addition of the following:

Excavations at the site may be impeded by obstructions within the existing fill and glacial till. The contractor shall be prepared to dislodge and remove these obstructions and extend the excavations to the design depths

### **RECOMMENDED WORDING FOR “NSSP – A CONCRETE WORKING SLAB”**

This Non-standard Special Provision covers the requirements for the supply and placement of a concrete working slab to protect the sand and silt subgrade to provide a proper working surface for the installation of the culvert/culvert foundations.

Excavation for the working slab shall be according to OPSS 902. Within four hours following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents. Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

### **RECOMMENDED WORDING FOR “NSSP – PROTECTION OF SENSITIVE FOUNDATION SOILS”**

The Contractor is advised that the soil that will be exposed at the subgrade during the construction of the foundation of the culvert is moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personal traffic, freeze thaw actions, ingress or ponding water. The Contractor shall be responsible for implementing adequate groundwater control measures and to minimize construction and personnel traffic on the founding subgrade.

### **.RECOMMENDED WORDING FOR “NSSP – TEMPORARY PROTECTION SYSTEM”**

Temporary protection system will be installed in ground conditions that include cobbles, boulders and relatively shallow depth to bedrock. Such obstructions may lead to increased difficulty with the installation of temporary protection systems and may impede installation to the required designed depths. The Contractor's installation method and temporary protection system design shall take into account existing, soil and bedrock conditions and the Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the installations to the design depths.

## **DEWATERING STRUCTURE EXCAVATIONS - Item No.**

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Special Provision No. FOUN0003 January 23, 2020

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### **Amendment to OPSS 902, November 2019**

#### **902.02 REFERENCES**

Section 902.02 of OPSS 902 is amended by the addition of the following:

##### **Ontario Provincial Standard Specifications, Construction**

OPSS 517 Dewatering

OPSS 805 Temporary Erosion and Sediment Control Measures

#### **902.03 DEFINITIONS**

Section 902.03 of OPSS 902 is amended by the addition of the following:

**Automatic Transfer Switch** means as defined in OPSS 517.

**Cofferdam** means as defined in OPSS 539.

**Cut-Off Wall** means as defined in OPSS 517.

**Design Storm Return Period** means as defined in OPSS 517.

**Groundwater Control System** means as defined in OPSS 517.

**Plug** means as defined in OPSS 517.

**Sediment** means as defined in OPSS 517.

**Sediment Control Measure** means as defined in OPSS 517.

**Temporary Flow Passage System** means as defined in OPSS 517.

**Unwatering** means as defined in OPSS 517.

**Vegetated Discharge Area** means as defined in OPSS 517.

**Waterbody** means as defined in OPSS 517.

**Watercourse** means as defined in OPSS 517.

#### **902.04 DESIGN AND SUBMISSION REQUIREMENTS**

##### **902.04.01 Design Requirements**

##### **902.04.01.01 Dewatering**

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a [\* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

#### **902.04.02 Submission Requirements**

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

##### **902.04.02.01 Preconstruction Survey**

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of **0 m** [\*\* Designer Fill-In, See Notes to Designer] metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

##### **902.04.02.02 Working Drawings**

Working Drawings for the dewatering system shall be according to OPSS 517.

#### **902.07 CONSTRUCTION**

##### **902.07.04 Dewatering Structure Excavation**

Subsection 902.07.04 of OPSS 902 is amended by the addition of the following clauses:

##### **902.07.04.01 General**

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

#### **902.07.04.02                      Discharge of Water**

The discharge of water shall be according to OPSS 517.

#### **902.07.04.03                      Monitoring**

Monitoring shall be according to OPSS 517.

#### **902.07.04.04                      System Amendments**

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

#### **902.07.04.05                      Removal**

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

#### **NOTES TO DESIGNER:**

\* Fill in the design storm return period according to MTO Drainage Design Standard TW-1.

\*\* Fill in the preconstruction survey distance as recommended by the foundation engineer.

**WARRANT:** Include with this standard tender item **only** on the recommendation of a foundation engineer.

**CUSTODIAN:** Tony Sangiuliano, MERO - Foundation Group



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