



**April 2017**

# **FOUNDATION INVESTIGATION AND DESIGN REPORT**

**Culvert Replacement  
Site No. 25-344/C, Highway 23  
Contract 4 Structure Replacements and Rehabilitation  
GWP 3042-11-00  
Ministry of Transportation, West Region**

**Submitted to:**

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**REPORT**



**Report Number: 12-1132-0163-4000-R03**

**Geocres No.: 40P15-47**

**Distribution:**

8 Copies - Stantec Consulting Ltd.  
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## FOUNDATION INVESTIGATION AND DESIGN REPORT CULVERT REPLACEMENT, SITE 25-344/C, HIGHWAY 23

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LIST OF ABBREVIATIONS

LIST OF SYMBOLS

RECORD OF BOREHOLE SHEETS

FIGURE 1 - Key Plan

DRAWING 1 - Borehole Locations and Soil Strata

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Laboratory Test Data

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Suggested Text for NSSP's



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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERT REPLACEMENT, SITE 25-344/C, HIGHWAY 23**

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**PART A**

**FOUNDATION INVESTIGATION REPORT**

**CULVERT REPLACEMENT**

**SITE NO. 25-344/C, HIGHWAY 23**

**CONTRACT 4 STRUCTURE REPLACEMENTS AND REHABILITATION**

**GWP 3042-11-00**

**MINISTRY OF TRANSPORTATION - WEST REGION**



## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detailed design work for GWP 3042-11-00. The project involves the detailed design of the replacement and rehabilitation of several structures along multiple highways in southern Ontario. This report addresses the proposed replacement of the culvert at Site 25-344/C on Highway 23, at about Station 21+870, in Perth County, Geographic Township of Wallace, Ontario.

The purpose of the foundation investigation is to explore the subsurface conditions at the location of the proposed culvert replacement by drilling boreholes and carrying out in situ and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal, in Golder Associates' proposal P2-1132-0163 dated February 25, 2013, and in Change Order 12-1132-0163-4000-C03 dated September 13, 2016. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated March 26, 2013.

## 2.0 SITE DESCRIPTION

The subject culvert is situated at about Station 21+870 across Highway 23, approximately 1 kilometre southwest of the intersection of Perth Road 178/Wellington County Road 4, in the Township of Wallace, Perth County, Ontario. The Town of Palmerston is approximately 3 kilometres northeast of the site. The replacement culvert will be constructed in approximately the same location as the existing culvert. The location of the culvert is shown on the Key Plan, Figure 1.

This section of Highway 23 is currently a two lane, undivided highway with gravel shoulders. It is generally oriented northeast-southwest in the vicinity of the site. An unnamed watercourse flows in the culvert from west to east beneath Highway 23. The existing culvert has an unknown date of construction and is 28 metres (m) long, including extensions of approximately 8.1 m on either side that were constructed circa 1959. The existing culvert is a concrete, non-rigid frame, open footing (NRFO) structure with extensions of the same nature.

Existing Dimensions (m)	Obvert Elevation (m)		Construction
	Lt <sup>1</sup>	Rt <sup>1</sup>	
3.05 x 1.80 x 28.00	388.62	388.63	Concrete NRFO

NOTE: 1. When facing the direction of increasing chainage, Lt and Rt are defined as Left and Right of centreline, respectively.

The banks of the watercourse and the embankments along Highway 23 near the culvert are grass covered. Broken concrete slabs have been placed at the inlet of the culvert and sand bags and broken concrete slabs have been placed at the outlet. The watercourse flows through fields on both sides of Highway 23. Selected site photographs are provided in Appendix B.



## **2.1 Site Geology**

The project area is located within the Teeswater Drumlin Field within the northwestern limb of the Horseshoe Moraine system. This area is characterized as a drumlin field that is not bound by any well-developed terminal moraine, and also intermingled with well-draining gravel terraces, kames, moraines and poor-draining swampy land. The area consists predominately of soil with a loamy texture that is moderately compact and pale brown to yellow-brown in colour, in addition to shallow surface deposits of silty, stone-free material.<sup>1</sup> The overburden in the area of the site generally consists of gravel, gravelly sand, fine sand, stony sandy silt and silt.<sup>2</sup>

The geological mapping indicates that the underlying bedrock consists of cream and tan dolomite of the Bass Islands Formation of Upper Silurian age.<sup>3</sup> The bedrock surface at the site is at about elevation 365 m with the overburden thickness being about 25 m.<sup>4</sup>

## **3.0 INVESTIGATION PROCEDURES**

The geotechnical field investigation was carried out on September 19 and 21, 2016, during which time three boreholes were drilled at the approximate locations shown on the Plan, Drawing 1.

The boreholes were drilled using a track-mounted Dietrich D50T drill rig supplied and operated by a specialist drilling contractor. Samples of the overburden were typically obtained at depth intervals of 0.75 m using 50 millimetre (mm) outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586).

The recorded SPT N-values are noted on the Record of Borehole sheets. The results of the SPT testing, as presented on the Record of Borehole sheets, Drawing 1 and in Section 4.0 of this report, are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.). The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. Larger particle sizes, including cobbles and boulders, are known to be present in the glacial tills as discussed in the text of this report.

Groundwater conditions in the boreholes were observed throughout the drilling operations and a piezometer was installed in borehole BH-302 as indicated on the corresponding Record of Borehole sheet. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The field work was monitored on a full-time basis by an experienced member of our staff who located the boreholes in the field, obtained utility locates, monitored the drilling, sampling and in-situ testing operations and logged the boreholes. The samples were identified in the field, placed in labelled containers and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations, were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

<sup>1</sup> Chapman, L.J., and Putnam, D.F., 1984: Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2, 270p.

<sup>2</sup> Cowan, W.R., et al. 1977: Quaternary Geology: Palmerston, Southern Ontario; Ministry of Natural Resources; Ontario Geological Survey, Map 2382, NTS 40P/15, Scale 1:50,000.

<sup>3</sup> Sanford B.V., 1969: Geology Toronto-Windsor Area, Ontario; Ontario Geological Survey of Canada Map 1263A, Scale 1:250,000.

<sup>4</sup> Davies, L.L., McClymont, W.R., and Karrow, P.F., 1962: Bedrock Topography of the Palmerston Area, Ontario Geological Survey, Ontario Department of Mines Bedrock Topography Series Palmerston Sheet, Prelim. Map No. P.166., Scale 1:50,000.



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The as-drilled borehole locations and ground surface elevations at the borehole locations are shown on the Record of Borehole sheets and on Drawing 1. Table 1, below, summarizes the coordinates, ground surface elevations, and depths of the boreholes.

**Table 1: Geospatial and borehole exploration summary.**

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
BH-301	4 854 725	193 820	389.79	9.60
BH-302	4 854 739	193 815	389.94	9.60
BH-303	4 854 735	193 835	387.98	8.08

## 4.0 SUBSURFACE CONDITIONS

### 4.1 Site Stratigraphy

The subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in-situ and laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered embankment fill materials and buried topsoil overlying layers of silt, sand and gravel, silty clay and clayey silt with clayey silt till at depth in BH-303.

The locations and elevations of the boreholes and the interpreted stratigraphic profile are shown on Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

### 4.2 Soil Conditions

The boreholes encountered topsoil and/or fill materials at the ground surface. A 300 mm thick layer of silty topsoil was encountered at the ground surface in BH-303. Fill materials, consisting of layers of sand and gravel, silty sand and sandy silt, were encountered at the ground surface in BH-301 and BH-302 and beneath the surficial topsoil in BH-303. The fill materials were about 2.1 m thick in BH-301 and BH-302 and about 0.6 m thick in BH-303. The fill had N values, as determined in the standard penetration testing, of 5 to 14 blows per 0.3 m. Buried topsoil layers 0.2 to 0.8 m thick were encountered beneath the fill materials at depths of 2.1 to 2.9 m or between elevation 386.9 and 387.8 m. The topsoil in BH-301 had an SPT-N value of 4 blows per 0.3 m and a water content of about 46 per cent. Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.



Layers of compact to dense silt were encountered beneath the buried topsoil between about elevation 387.6 and 386.9 m. The silt layers were about 0.7 to 1.3 m thick at the borehole locations. The silt had N values of 16 to 19 blows per 0.3 m for tests fully completed in the silt and water contents of about 17 to 18 per cent. Grain size distribution curves for samples of the silt recovered from the standard penetration testing are provided on Figure A-1.

Compact to dense sand and gravel was encountered beneath the silt in all of the boreholes. The sand and gravel was encountered between about elevation 386.1 and 386.3 m. The sand and gravel layers were 0.4 to 1.5 m thick. The sand and gravel had N values of 20 to 46 blows per 0.3 m. A sample of the sand and gravel from BH-302 had a water content of about 9 per cent. A grain size distribution curve for a sample of the sand and gravel is provided on Figure A-2. Although not explicitly encountered during the field work, cobbles and boulders should be expected in the sand and gravel.

Clayey silt was encountered in BH-301 and BH-303 beneath the sand and gravel. The clayey silt was encountered at about elevation 384.6 and 385.9 m in BH-301 and BH-303, respectively, and was about 0.8 and 2.3 m thick. The stiff to very stiff clayey silt had N values of 12 to 18 blows per 0.3 m. A sample of the clayey silt from BH-303 had a water content of about 18 per cent and plastic and liquid limits of about 18 and 33 per cent, respectively. The results of the Atterberg limits testing are shown on Figure A-6. A grain size distribution curve for a sample of the clayey silt is shown on Figure A-3.

Beneath the clayey silt in BH-301 and BH-303 and beneath the sand and gravel in BH-302, silty clay was encountered between about elevation 383.6 and 384.8 m. BH-301 and BH-302 were terminated in the silty clay after exploring it for about 3.7 to 4.4 m. In BH-303, the silty clay was about 2.6 m thick. The stiff to very stiff silty clay had N values of 10 to 22 blows per 0.3 m with water contents ranging from about 31 to 34 per cent. Samples of the silty clay had average plastic and liquid limits of about 23 and 51 per cent, respectively, based on three Atterberg limits determinations indicating silty clay of intermediate to high plasticity. The results of the Atterberg limits testing are shown on Figure A-6. In situ vane testing attempted in BH-303 indicated undrained shear strengths in excess of 144 kilopascals. Grain size distribution curves for samples of the silty clay are shown on Figure A-4.

A layer of clayey silt till was encountered in BH-303 at approximately elevation 381.0 m. BH-303 was terminated in the clayey silt till after exploring it for about 1.1 metres. The clayey silt till had an N value of 25 blows per 0.3 m and a water content of about 17 per cent. Atterberg limits testing carried out on a sample of the clayey silt till indicated plastic and liquid limits of about 15 and 26 per cent, respectively. The results of the Atterberg limits testing are shown on Figure A-6. A grain size distribution curve for a sample of the clayey silt till is provided on Figure A-5. Cobbles and boulders should be expected in the till.

### **4.3 Groundwater Conditions**

Groundwater conditions were observed during drilling, and a piezometer was installed in BH-302 on completion of drilling. The installation details are provided on the corresponding Record of Borehole sheet. Groundwater was encountered during drilling in BH-301 and BH-302 on September 19, 2016, and in BH-303 on September 21, 2016. A summary of the encountered and measured groundwater levels is provided in the table below.





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**Table 2: Encountered and measured groundwater levels.**

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Measured Groundwater Level Elevation (m)	
			September 21, 2016	October 25, 2016
BH-301	389.79	386.9	-	-
BH-302	389.94	386.7	386.74	386.76
BH-303	387.98	386.5	-	-

The above-noted encountered water levels are not considered to be representative of the long-term, stabilized groundwater conditions. Based on the observed groundwater levels, the change in soil colour from brown to grey and the surrounding topography, the groundwater level is inferred to typically be at about elevation 387.0 m. The groundwater levels should be expected to fluctuate seasonally and be higher during periods of sustained precipitation or during spring snow melt conditions.

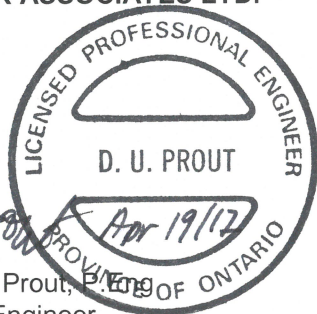


## FOUNDATION INVESTIGATION AND DESIGN REPORT CULVERT REPLACEMENT, SITE 25-344/C, HIGHWAY 23

### 5.0 MISCELLANEOUS

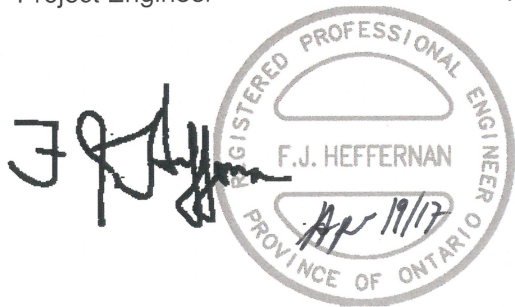
The investigation was carried out using equipment supplied and operated by London Soil Test Limited, an Ontario Ministry of Environment and Climate Change licensed well contractor. The field operations were supervised by Mr. Daniel Hyland, E.I.T. under the direction of the Field Investigation Manager, Mr. Brett Thorner, P.Eng. The laboratory testing was carried out at Golder's London laboratory under the direction of Mr. Michael Arthur. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Ms. Cara Kennedy, E.I.T. under the direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. The report was reviewed by Mr. Michael E. Beadle, P.Eng., an Associate with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, conducted an independent quality review of the report.

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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
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**PART B**

**FOUNDATION DESIGN REPORT**

**CULVERT REPLACEMENT**

**SITE NO. 25-344/C, HIGHWAY 23**

**CONTRACT 4 STRUCTURE REPLACEMENTS AND REHABILITATION**

**GWP 3042-11-00**

**MINISTRY OF TRANSPORTATION - WEST REGION**



## **6.0 ENGINEERING RECOMMENDATIONS**

This section of the report provides recommendations on the foundation aspects of the design of the proposed culvert replacement at Site 25-344/C at about Station 21+870 on Highway 23, about 1 kilometre southwest of the intersection of Highway 23 with Perth Road 178/Wellington County Road 4, in the Township of Wallace, Perth County, Ontario.

The recommendations are based on our interpretation of the factual data obtained from the boreholes advanced during the investigation at this site. The interpretation and recommendations are intended to provide the designers with sufficient information to design the proposed foundations. As such, where comments are made on construction, they are provided only to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, and scheduling.

The existing culvert has an unknown date of construction and is 28 m long, including extensions of approximately 8.2 m on each side that were built circa 1959. The original structure is a concrete, non-rigid, frame open-footing (NRFO) structure with extensions of the same nature. The stream bed elevation at the inlet of the existing open-footing culvert is approximately 386.5 m. Based on the information provided by Stantec, the replacement culvert will be a 27.9 m long precast concrete box culvert with a 4.2 m span and a 2.65 m high opening with an approximate invert elevation of 385.97 m. Recommendations have been included for both a new open footing culvert and a new box culvert. The replacement culvert will be installed at about the same location with respect to Highway 23, at Station 21+870.

### **6.1 Consequence and Site Understanding Classification**

In accordance with Section 6.5 of the Canadian Highway Bridge Design Code (CHBDC version S6-14) and its Commentary, a classification of 'typical' consequence has been assumed for the proposed replacement culvert and foundation system. This consequence classification should be confirmed by Stantec and the MTO.

The degree of understanding based, on the scope of the foundation investigation and proximity of the boreholes to the culvert, is considered 'typical' as described in Clause 6.5.3.2 of the 2014 CHBDC. The appropriate Ultimate Limit States (ULS) and Serviceability Limit States (SLS) consequence factors,  $\Psi$ , geotechnical resistance factors at ULS ( $\phi_{gu}$ ) and SLS ( $\phi_{gs}$ ), respectively, from Tables 6.1 and 6.2 of the CHBDC should be used for design.

### **6.2 Foundations**

The founding soil for a box culvert is expected to consist of compact to dense sand and gravel and/or very stiff clayey silt at the approximate foundation elevation of 385.3 m; the soil type is noted to change and thus variations across the culvert foundation should be expected. The culvert foundations may be designed using a factored geotechnical resistance at Ultimate Limit States (ULS) of 375 kPa and a geotechnical resistance at Serviceability Limit States (SLS) of 250 kPa. The SLS value corresponds to 25 mm of settlement. Bedding for a precast culvert and a levelling pad should be provided as discussed in Section 6.2.3 below. If an open footing culvert is constructed, it must be founded at least 1.4 m (the frost depth) below the invert or at a maximum elevation of 384.6 m. The SLS value for an open footing culvert is based on a minimum footing width of 0.6 metres. Very stiff silty



clay to clayey silt and compact sand and gravel is expected at this elevation. Use of a box culvert is the preferred technical alternative since compared to a cast-in-place (CIP) open footing culvert, it can be more rapidly constructed and will require less dewatering effort.

If the footings or bedding cannot be placed promptly following excavation and inspection, a 100 mm working slab of lean concrete should be provided to protect the integrity of the founding soils.

### 6.2.1 Frost and Scour Protection

Frost treatment in the form of a frost taper symmetrical about the culvert centreline should be provided in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010. The design frost penetration depth for this area is 1.4 m below ground surface. The culvert should also be adequately protected against scour as noted in Section 1.9.5 of the CHBDC. The foundations of open footing culverts are to be provided with soil cover equivalent to the frost depth or insulated with the thermal equivalent. If a box culvert is installed, cut-off walls should be provided in accordance with Clause 1.9.5.6 of the CHBDC and WC-9 of the MTO's Highway Drainage Design Standards.

### 6.2.2 Resistance to Lateral Forces/Sliding Resistance

The resistance to lateral forces/sliding resistance between the base of the culvert and the bedding or the native soils should be calculated in accordance with Section 6.10.5 of the CHBDC.

The factored horizontal geotechnical resistance,  $H_{ri}$  and  $H_{rs}$ , is calculated as follows:

$$H_{ri} = \psi \phi_{gu} (A'c'_i + V_f \tan \delta'_i) > H_f \text{ (for pre-cast elements)}$$

$$H_{rs} = \psi \phi_{gu} (A'c' + V_f \tan \phi') > H_f \text{ (for open footing culverts)}$$

Where:

$\psi$	=	consequence factor, given in Section 6.5.2, Table 6.1 of the CHBDC
$\phi_{gu}$	=	ultimate geotechnical resistance factor, given in Section 6.9.1, Table 6.2 of the CHBDC
$A'$	=	effective contact area, square metres
$c'_i$	=	effective cohesion along the interface between box culvert base and bedding/levelling, nil
$c'$	=	effective cohesion, nil
$\tan \delta'_i$	=	coefficient of friction for interface between box culvert base and bedding/levelling pad
$\tan \phi'$	=	coefficient of friction between footings and native founding soils



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$V_f$  = factored vertical force, kilonewtons

$H_f$  = factored horizontal load, kilonewtons

The factored horizontal resistance may be calculated using the parameters in the following table:

Structure	Interaction	Angle of Friction, $\delta$ (degrees)	Coefficient of Friction, $\tan \delta$
Precast Box Culvert	Precast concrete on Granular A bedding/levelling pad	30	0.58
CIP Open Footing Culvert	Cast-in-place footing	32	0.62
	- sand and gravel - clayey silt to silty clay	30	0.58

### 6.2.3 Bedding, Backfill and Cover

Bedding, backfill and cover for the culvert shall be placed in accordance with OPSS.PROV 501, OPSD 803.010 and Special Provision (SP) 422S01. The backfill should consist of free-draining, non-frost susceptible granular materials such as Ontario Provincial Standard Specifications (OPSS) Granular B Type III, or Granular A placed in 0.3 m thick loose lifts and uniformly compacted. Heavy compaction equipment should not be used immediately adjacent to the walls and roof of the culvert. The height of backfill adjacent to the culvert walls should be maintained as equal as possible on both sides of the culvert during all stages of backfill placement. The height of the backfill on each side of the culvert should differ by no more than 500 mm at any time.

The excavations for this culvert should have a clearance width that exceeds the width of the culvert by at least 1.0 m on each side to allow for good workmanship and effective compaction of the fill. Bedding for a precast box culvert should be placed on properly prepared competent native materials or approved compacted granular materials and should be at least 300 mm thick. At no time should the culvert be constructed on frozen materials. Granular A would be considered suitable for use as bedding material for a precast box culvert. The levelling course can consist of a 75 mm thick layer of Granular A or materials meeting the gradation requirements for fine concrete aggregates.

### 6.2.4 Other Design Considerations

The height of fill over the culvert roof will be less than 4.5 m and no grade raise or widening is planned. The foundation materials consist of granular deposits underlain by very stiff cohesive deposits. Therefore, differential settlement along the length of this culvert is expected to be minor and, thus, camber is not required. Total settlement is also expected to be minor (less than 15 millimetres).

If the results of hydraulic analyses indicate that there will be significant difference in hydraulic head between the inlet and outlet, then the culvert inlet should be provided with a headwall, clay seal or other seepage control measure. The design of the replacement box culvert should include a cut-off wall at the inlet in accordance with Section 1.9.5.6 of the CHDBC.



Erosion protection for the culvert backfill should be provided to protect the roadway, approach embankments and culvert, as appropriate. The erodibility of the founding soils is expected to be low to relatively low. Provided that the backfill is placed as recommended in Section 6.2.3, the backfill materials will also be considered to be relatively non-erodible. Consideration could be given to using suitable non-woven geotextile and rip rap, as required, to provide erosion protection based on hydraulic requirements. Rip-rap treatment at the culvert outlet should be provided in accordance with OPSD 810.010. In addition, sediment control, such as silt fences and erosion control blankets, may be required during construction together with diversion of any flows to mitigate migration of fine soil particles.

Reinstatement of the highway embankment should be carried out using the backfilling recommendations provided above in Section 6.2.3. The side slopes should be trimmed to a maximum final inclination of 2 horizontal to 1 vertical. A Factor of Safety against deep-seated failure of greater than 1.3 is available for embankments constructed on the native sand and gravel and clayey silt subgrade.

### **6.3 Excavations and Groundwater Control**

Excavations will extend through the existing fill and buried topsoil into the underlying silt, sand and gravel and clayey silt. Seepage is anticipated to be such that groundwater control may be achieved by pumping from properly constructed and filtered sumps in the base of the excavation. The groundwater level should be lowered to at least 0.5 m below the underside of footing/founding elevation. However, more aggressive dewatering will be required in the sand and gravel as high seepage volumes should be expected. Sumps should be maintained outside of the actual footing limits. Some seepage from the granular fill or granular topsoil layers should be expected, particularly during and following periods of sustained precipitation.

Surface water runoff should be directed away from the excavations at all times. The existing culvert flows are anticipated to be diverted/piped during construction. A Non Standard Special Provision (NSSP) should be added to the Contract Documents to alert the contractor to the need for dewatering and control of surface water. Suggested text for an NSSP is included in Appendix C.

Temporary open cut slopes within the fill materials should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fill materials and saturated sand and gravel would be classified as a Type 3 soil and the native silty clay and clayey silt would be classified as Type 2 soil. In the absence of proper dewatering or support prior to excavation, the silt is considered to be a Type 4 soil. If properly supported or dewatered, the silt would be classified as a Type 3 soil.





## **6.4 Liquefaction Potential and Seismic Analysis**

### **6.4.1 Seismic Parameters**

For the purposes of this project, Site Class D is appropriate based on the results of the investigation. Seismic performance should be calculated in accordance with Section 4.4.3 of the CHBDC (version S6-14).

The importance category of the replacement culvert is “other” based on the CHBDC. The corresponding Seismic Category for the structure is 1 based on Table 4.10 of the CHBDC. Structures in Seismic Category 1 need not be analysed for seismic loads. However, the minimum requirements as outlined in CHBDC Clause 4.4.5.1 must be followed. It should be noted that the MTO views culverts with spans of 3 m or greater as being similar to bridges. The designer should ensure that the selected culvert design meets the seismic requirements for buried structures as outlined in Clause 7.5.5 of the CHBDC.

### **6.4.2 Seismic Hazard Assessment**

A preliminary screening of the soil stratigraphy was conducted using the procedure outlined in the Federal Highway Administration recommended procedures<sup>5</sup> and Canadian Foundation Engineering Manual (CFEM). The potential for liquefaction occurring at this site is very low to low. Therefore, a detailed evaluation of the liquefaction potential of the foundation soils is not considered warranted.

## **6.5 Lateral Earth Pressures for Design**

The lateral pressures acting on the proposed culvert will depend on the type and method of placement of the backfill materials, on the nature of the soil behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls in accordance with the CHBDC (version S6-14). It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Backfill should be placed in accordance with Section 6.2.3 above.
- A compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for the structural design in accordance with CHBDC Figure 6.6.
- If the wall support does not allow lateral yielding (such is typically the case for a rigid concrete box culvert), at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.4 m behind the culvert walls (Case (a) from commentary on CHBDC Figure C6.20).

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<sup>5</sup> Federal Highway Administration (FHWA). (1997). “Design Guidance: Geotechnical Earthquake Engineering For Highways. Volume I – Design Principles.” *Geotechnical Engineering Circular No. 3: FHWA-SA-97-076*, Washington, D.C.





## FOUNDATION INVESTIGATION AND DESIGN REPORT CULVERT REPLACEMENT, SITE 25-344/C, HIGHWAY 23

- For Case (a), the restrained case, the pressures are based on the existing embankment fill materials; however, since frost tapers will be provided, the pressures will be based on the materials used to construct the tapers; the following parameters (unfactored) may be used:

	<u>GRANULAR A</u>	<u>GRANULAR B TYPE III</u>
Soil unit weight:	22 kN/m <sup>3</sup>	21 kN/m <sup>3</sup>
Coefficients of lateral earth pressure: 'At rest' or restrained, $K_0$	0.47	0.5

- If the wall support allows lateral yielding (unrestrained structure, such as typically the case for open footing culverts), active earth pressures may be used in the geotechnical design of the structure. The granular fill should be placed in a wedged shaped zone with a width equal to at least 1.4 m at the base of foundation level against a cut slope which begins at the footing level and extends upwards at a maximum inclination of 1 horizontal to 1 vertical (case (b) from commentary on CHBDC Figure C6.20).
- For walls backfilled using granular materials in accordance with Case (b), the following parameters (unfactored) may be assumed:

	<u>GRANULAR A</u>	<u>GRANULAR B TYPE III</u>
Fill unit weight:	22 kN/m <sup>3</sup>	21 kN/m <sup>3</sup>
Coefficients of lateral earth pressure:		
'active' or unrestrained, $K_a$	0.31	0.33
'passive', $K_p$	3.3	3.0

### 6.6 Temporary Roadway Protection

It is understood that temporary roadway protection will be required to maintain a single lane of traffic on Highway 23 at the culvert location during construction. Temporary support systems could consist of soldier piles and lagging, or steel sheet piles. Installation of steel sheets through the sand and gravel may be difficult since it can be dense. In addition, cobbles and boulders may be present in the sand and gravel. Cobbles were also encountered in the fill. A NSSP or Notice to the Contractor should be added to the Contract Documents to advise the Contractor of the potential for cobbles and boulders. Suggested text for an NSSP is included in Appendix C.

Excavation support systems should be designed and constructed in accordance with OPSS 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The contractor is responsible for the complete detailed design of the protection system.



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Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution ( $p'$  in  $\text{kN/m}^2$ ; increasing with depth) can be calculated as follows:

$$p' = K_a (H - h_w) \gamma + K_a (\gamma - \gamma_w) h_w + \gamma_w h_w + K_a q$$

where,  $H$  = the height of the excavation at any point in m

$K_a$  = active coefficient of earth pressure

$\gamma$  = soil unit weight

$\gamma_w$  = unit weight of water or  $9.8 \text{ kN/m}^3$

$q$  = surcharge for traffic and other loading

$h_w$  = height of groundwater level above excavation base; inferred groundwater level at time of investigation was 387.0 m

The support systems may be designed using the parameters provided in the table below. These parameters are provided to assist with design for the unfactored ultimate resistance and loading conditions and may not result in a temporary support design that adequately controls ground and structure displacements. Achieving adequate displacement control in accordance with the MTO performance criteria may require designs that result in a system that is stiffer than might otherwise be required based on the soil parameters provided in the table below.

Soil Type	Coefficient of Earth Pressure			Internal Angle of Friction (degrees)	Bulk Unit Weight $\gamma$ ( $\text{kN/m}^3$ )	Effective Unit Weight $\gamma'$ ( $\text{kN/m}^3$ )	Undrained Shear Strength ( $C_u$ , kPa)
	Active, $K_a$	At Rest, $K_o$	Passive, $K_p$				
Fill	0.37	0.55	Nil	27	19	9.0	-
Silt	0.31	0.47	3.3	32	19	9.0	-
Sand and Gravel	0.27	0.43	3.7	35	22	12.0	-
Clayey Silt	0.33	0.50	3.0	30	20	10.0	175
Silty Clay	0.33	0.50	3.0	30	20	10.0	150
Clayey Silt Till	0.27	0.43	3.7	35	21	11.0	200

The earth pressure coefficients identified above may be applied assuming a horizontal ground surface behind the retaining structure. Where the ground surface behind the retaining structure is sloped, the earth pressure coefficients provided in the table above must be increased.



## **6.7 Construction Considerations**

Care should be taken during construction to avoid disturbance of the subgrades prior to constructing foundations or placing bedding. All existing fill and any topsoil, organics and soft or loose soils should be stripped from the proposed founding areas prior to placement of the bedding materials or working mat. Subgrade preparation should be performed and monitored in accordance with OPSS 902 and as modified by these recommendations.

It is recommended that the foundation excavations be carried out such that the final 0.5 m of excavation is completed with a Quality Verification Engineer (QVE) experienced in geotechnical engineering on site. The prepared excavation base should be inspected by the QVE to ensure that the natural soils (sand and gravel, clayey silt and/or silty clay) have been reached and granular base materials or a working mat of lean concrete should be placed immediately after inspection to protect the founding materials. The QVE should assess the foundation conditions to determine if sub-excavation of unsuitable material is required. Sub-excavation, placement and compaction of fill should be carried out under the direction of the QVE. An NSSP or Notice to Contractor should be added to the Contract Documents to advise the Contractor of the possibility for the need for a lean concrete working mat. Suggested text for an NSSP is included in Appendix C.



## FOUNDATION INVESTIGATION AND DESIGN REPORT CULVERT REPLACEMENT, SITE 25-344/C, HIGHWAY 23

### 7.0 MISCELLANEOUS

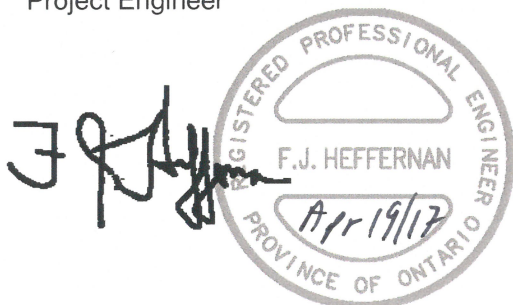
This section of the report was prepared by Ms. Cara Kennedy, EIT, under the direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. The report was reviewed by Mr. Michael E. Beadle, P.Eng., an Associate with Golder Associates, and Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, who conducted an independent quality review of the report.

#### GOLDER ASSOCIATES LTD.



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Project Engineer

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MTO Designated Contact

CK/DUP/WMK/MEB/FJH/cr

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n:\active\2012\1132 - geo\1132-0100\12-1132-0163 stantec-fdns-mega culverts-3011-e-0041\ph 4000-gwp 3042-11-00\rpts\r03 25-344-c hwy 23 wallace\1211320163-4000-r03 apr 19 17  
(final) parts a&b replace clvrt-25-344-c.docx



## LIST OF SYMBOLS

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

<b>(a)</b>	<b>Index Properties</b>
$\rho(\gamma)$	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

### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	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

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$
$$\text{shear strength} = (\text{compressive strength})/2$$



## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

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

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

#### Piezo-Cone Penetration Test (CPT)

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

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

	$C_u, S_u$	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
$SO_4$	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

**Note:** 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

**RECORD OF BOREHOLE No BH-301**

1 OF 1

**METRIC**

PROJECT 12-1132-0163  
W.P. 3042-11-00 LOCATION N 4854724.5 , E 193819.9 ORIGINATED BY DH  
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY ZJB  
DATUM GEODETIC DATE September 19, 2016 CHECKED BY

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  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								WATER CONTENT (%)			
								○ UNCONFINED	+ FIELD VANE										
								● QUICK TRIAXIAL	× LAB VANE										
389.79	GROUND SURFACE						20	40	60	80	100								
0.00	FILL, sand and crushed gravel, trace silt																		
389.45	Brown																		
0.34	FILL, sand and gravel, some silt, with cobbles																		
388.57	Compact Brown		1	SS	11														
1.22	FILL, silty sand, some gravel, with topsoil																		
387.66	Loose Brown		2	SS	5														
2.13	TOPSOIL, silty Loose Black																		
386.89			3	SS	4									46					
2.90	SILT, some sand, trace to some clay, trace gravel																		
386.13	Compact Brown		4	SS	18											1 12 79 8			
3.66	SAND AND GRAVEL, some silt Compact to dense Brown																		
			5	SS	33														
			6	SS	20														
384.61																			
5.18	CLAYEY SILT, some sand, some gravel Very stiff Grey																		
383.85			7	SS	17														
5.94	SILTY CLAY, trace sand, with silt seams Stiff to very stiff Grey																		
			8	SS	14														
			9	SS	11											0 1 27 72			
			10	SS	22														
380.19																			
9.60	END OF BOREHOLE																		
	Groundwater encountered at about elev. 386.9m during drilling on September 19, 2016.																		

## METRIC

ORIGINATED BY DH

COMPILED BY ZJB

\_\_\_\_ CHECKED BY\_\_\_\_

[illegible]



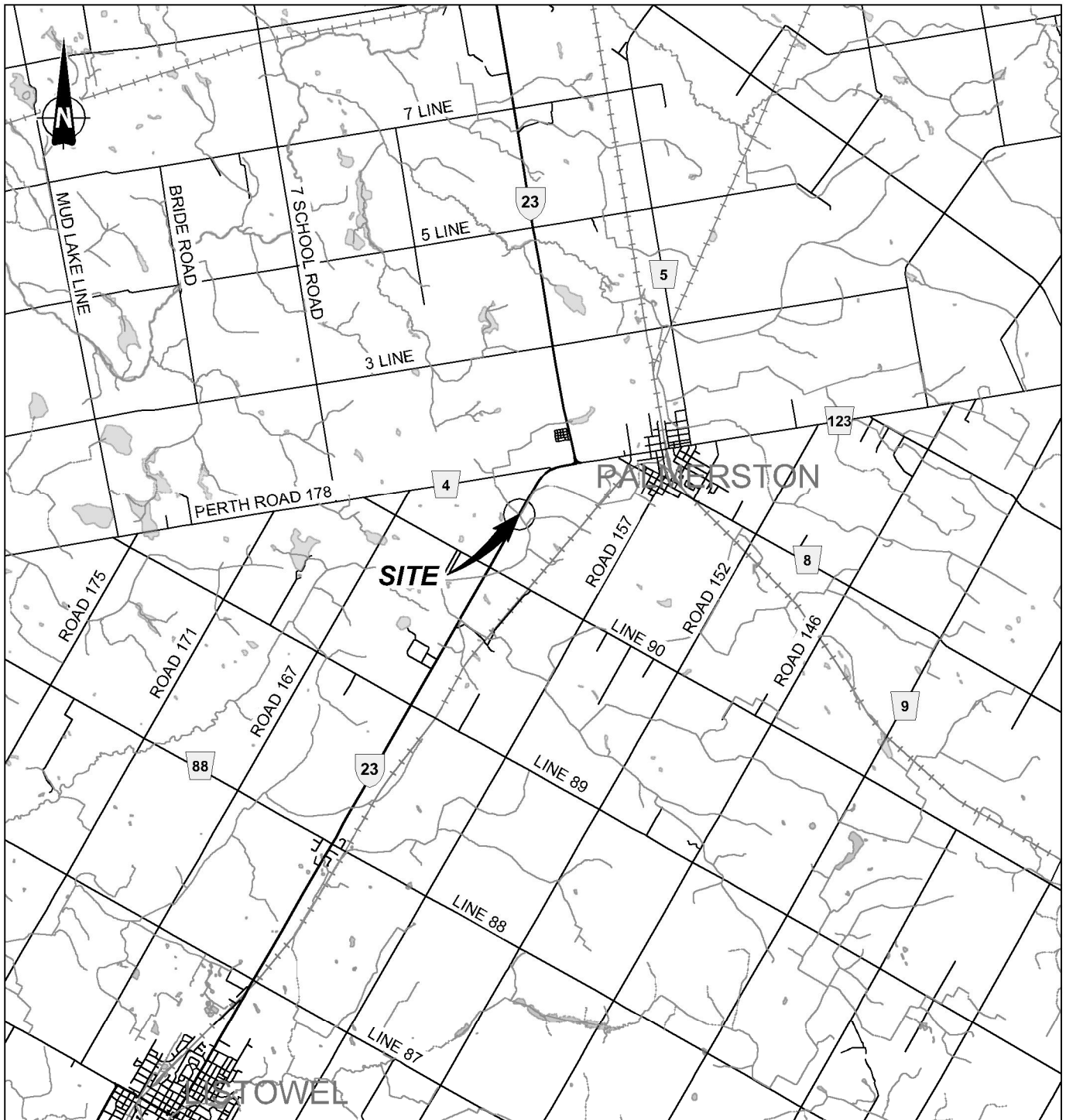
**RECORD OF BOREHOLE No BH-303**

1 OF 1

**METRIC**

PROJECT 12-1132-0163  
W.P. 3042-11-00 LOCATION N 4854734.8 , E 193835.4 ORIGINATED BY DH  
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY ZJB  
DATUM GEODETIC DATE September 21, 2016 CHECKED BY

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 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									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
					WATER CONTENT (%)												
387.98	GROUND SURFACE					20	40	60	80	100	10	20	30				
0.00	TOPSOIL, silty																
387.64	Brown																
0.34	FILL, silty sand, some gravel, some topsoil																
387.22	Brown																
0.76	FILL, sandy silt, some clay, some topsoil		1	SS	10												
0.91	Grey																
1.07	TOPSOIL, silty																
386.21	Compact		2	SS	32												
1.77	Black																
385.85	SILT, some sand, trace clay, trace gravel																
2.13	Compact to dense		3	SS	17										1 14 37 48		
	Brown and grey																
	SAND AND GRAVEL, some silt																
	Dense		4	SS	18												
	Brown																
	CLAYEY SILT, some sand, trace gravel																
	Stiff to very stiff																
	Grey		5	SS	12												
383.56																	
4.42	SILTY CLAY, trace sand																
	Stiff to very stiff		6	SS	11										0 5 31 64		
	Grey																
			7	SS	11												
380.97																	
7.01	CLAYEY SILT TILL, trace to some sand																
	Very stiff																
	Grey																
			8	SS	25										0 6 59 35		
379.90																	
8.08	END OF BOREHOLE																
	Groundwater encountered at about elev. 386.5m during drilling on September 21, 2016.																



## REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

## NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT CULVERT REPLACEMENT, SITE 25-344/C  
HIGHWAY 23  
GWP 3042-11-00

TITLE

## KEY PLAN



PROJECT No. 12-1132-0163			FILE No. 1211320163-4000-F03001	
CADD	ZJB/LMK	Jan. 12/17	SCALE AS SHOWN	REV. 0
CHECK			<b>FIGURE 1</b>	

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

CONT No.  
WP No. 3042-11-00

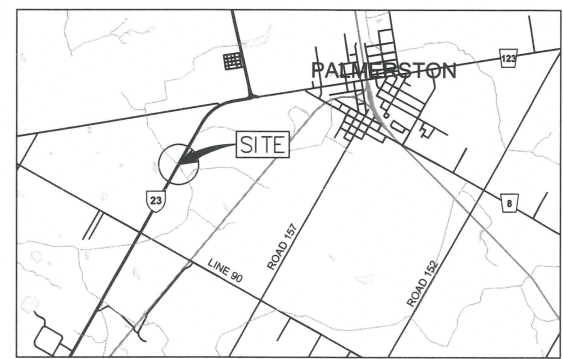


UNNAMED TRIBUTARY  
CULVERT REPLACEMENT  
HIGHWAY 23 SITE No. 25-344/C  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



**Golder Associates Ltd.**  
LONDON, ONTARIO, CANADA



KEY PLAN

SCALE IN KILOMETRES  
0 2

LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL encountered during drilling
- WL measured on October 25, 2016

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
BH-301	389.79	4 854 724.5	193 819.9
BH-302	389.94	4 854 738.8	193 815.3
BH-303	387.98	4 854 734.8	193 835.4

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

REFERENCE

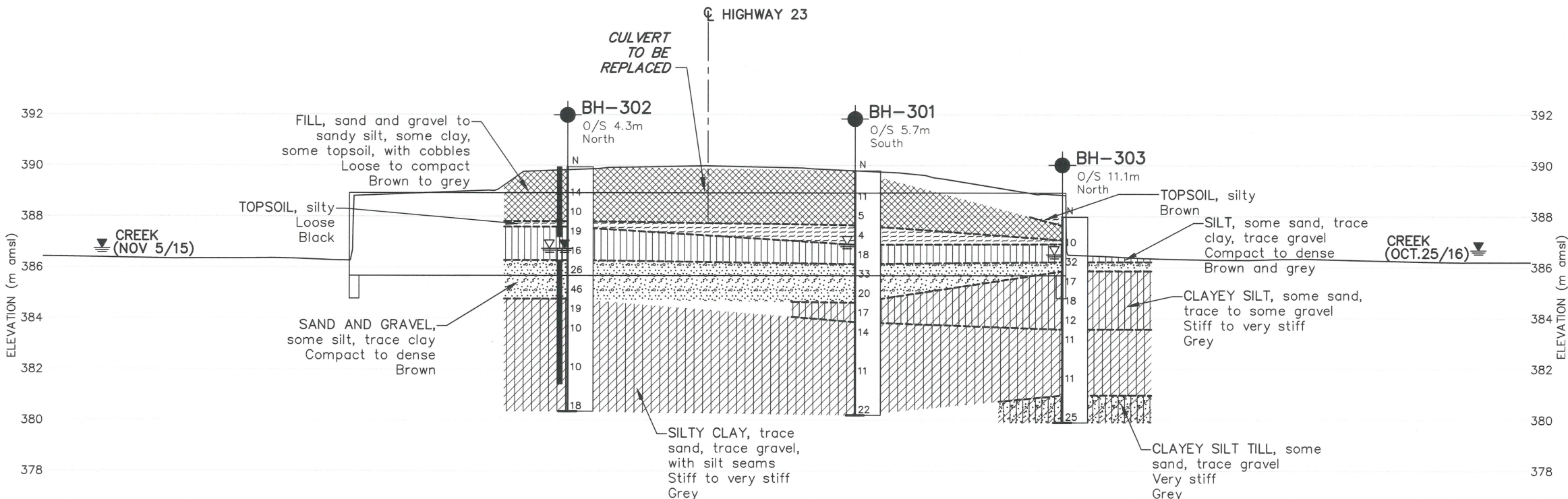
Base plans provided in digital format by Stantec.

NO.	DATE	BY	REVISION
Geocres No.	40P15-47		
HWY.	23	PROJECT NO.	12-1132-0163
SUBM'D.	BT	CHKD.	DH
DATE:	Mar. 22/17	SITE:	25-344/C
DRAWN:	LMK	CHKD.	DUP
APPD.	FJH	DWG.	1



PROFILE ALONG C OF CULVERT

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

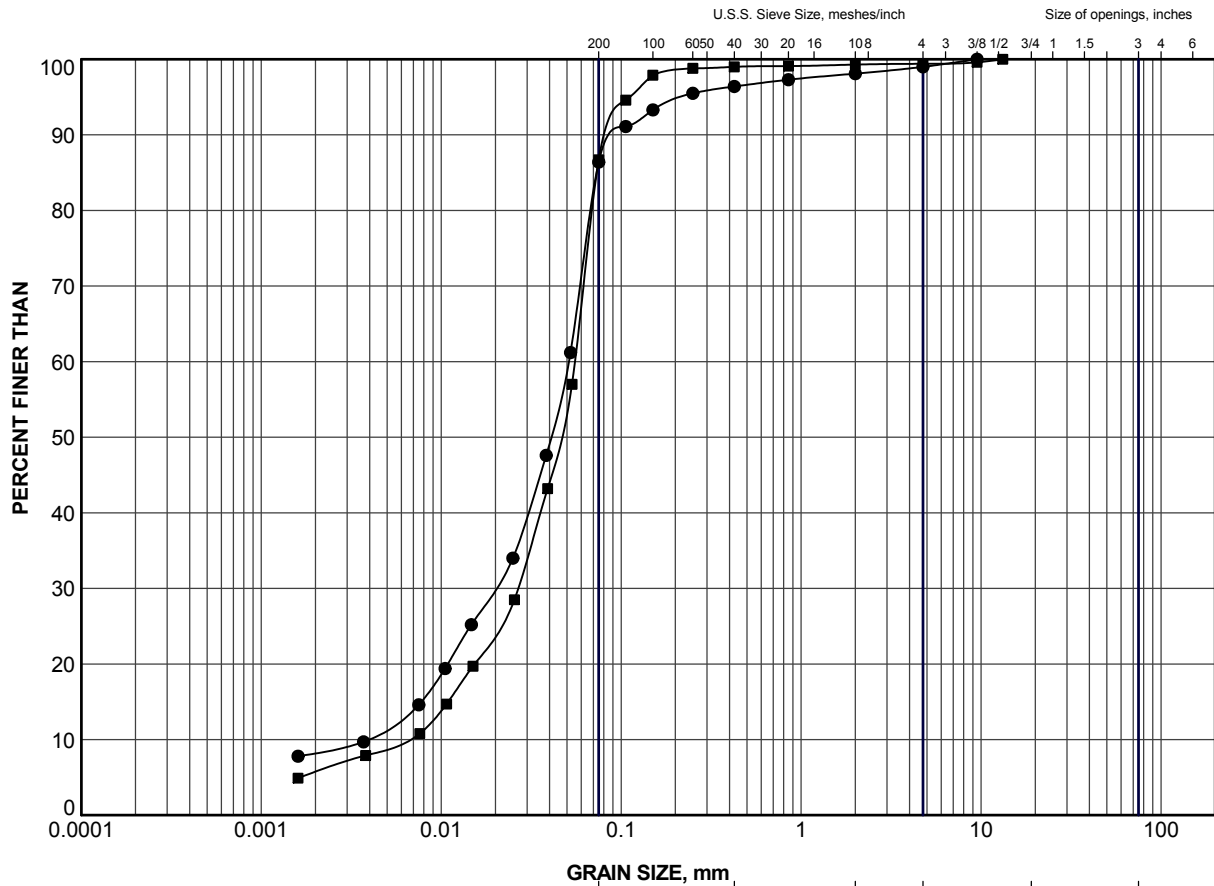




# **APPENDIX A**

## **Laboratory Test Data**




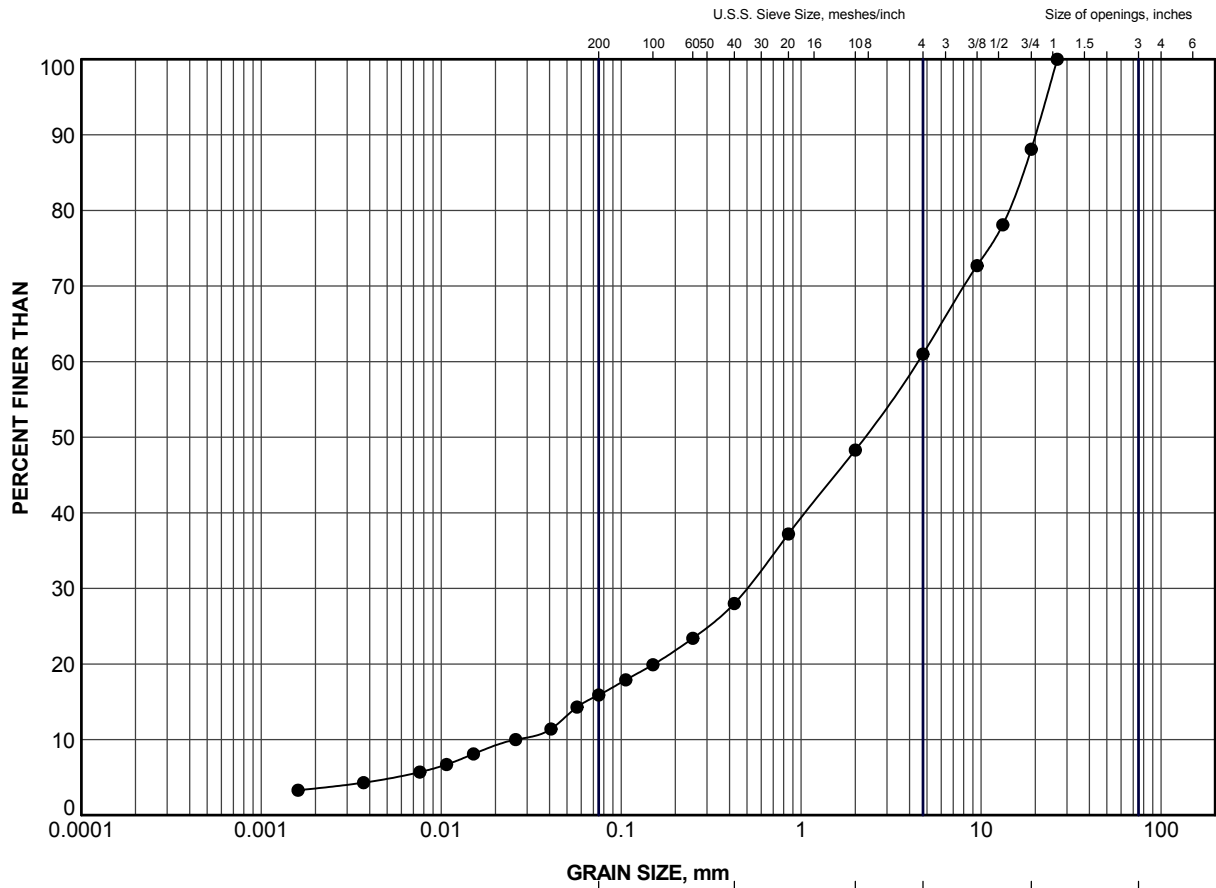


GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-301	4	386.5
■	BH-302	4	386.7

PROJECT				CULVERT REPLACEMENT, SITE 25-344/C HIGHWAY 23 GWP 3042-11-00			
TITLE				GRAIN SIZE DISTRIBUTION SILT			
PROJECT No.		12-1132-0163		FILE No.		1211320163-4000-F030A1	
DRAWN		ZJB		SCALE		N/A	
CHECK				REV.			
				<b>FIGURE A-1</b>			

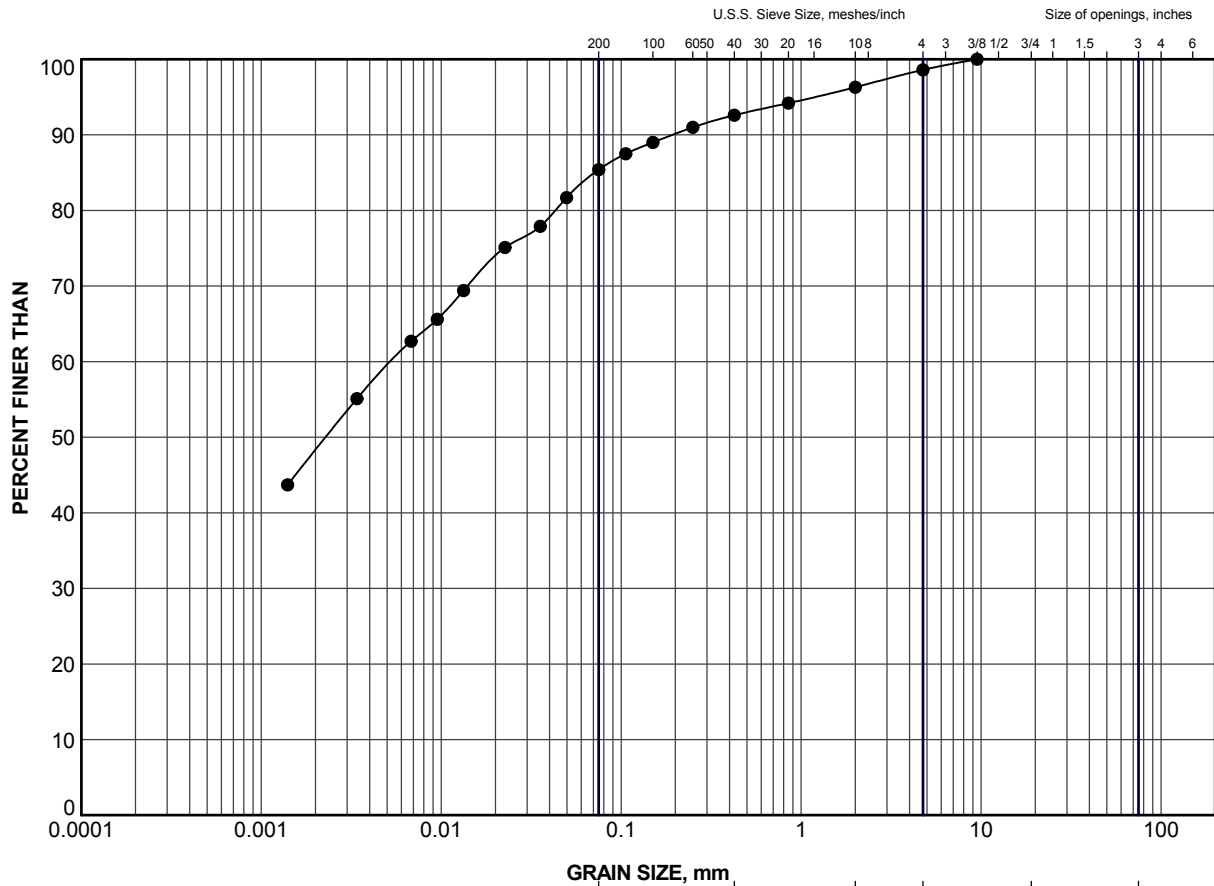


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-302	6	385.1


PROJECT		CULVERT REPLACEMENT, SITE 25-344/C HIGHWAY 23 GWP 3042-11-00			
TITLE		GRAIN SIZE DISTRIBUTION SAND AND GRAVEL			
		PROJECT No.		12-1132-0163	
		FILE No.		1211320163-4000-F030A2	
		SCALE		N/A	
DRAWN		ZJB		Oct 26/16	
CHECK					
		<b>FIGURE A-2</b>			

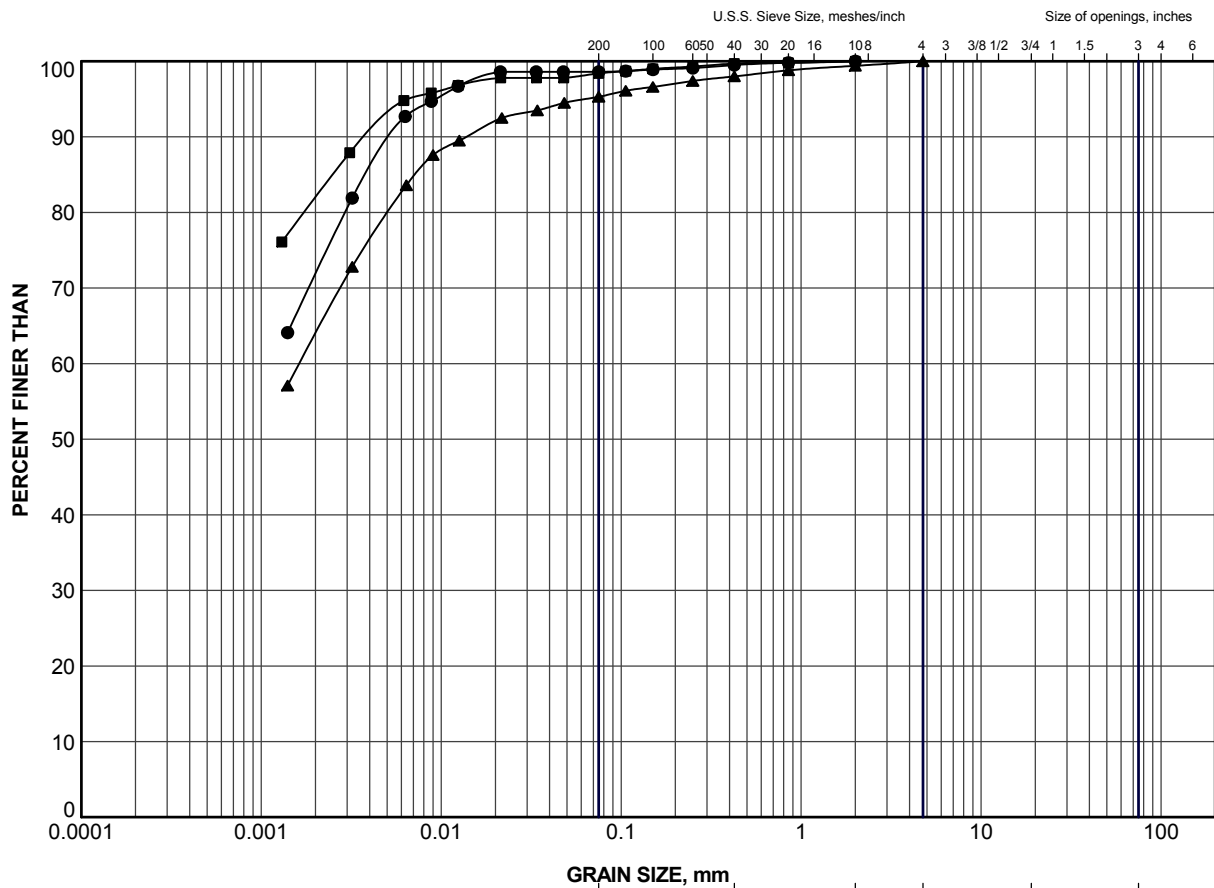


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-303	3	385.5


PROJECT		CULVERT REPLACEMENT, SITE 25-344/C HIGHWAY 23 GWP 3042-11-00			
TITLE		<b>GRAIN SIZE DISTRIBUTION</b> <b>CLAYEY SILT</b>			
PROJECT No.		12-1132-0163		FILE No. 1211320163-4000-F030A3	
DRAWN		ZJB		Oct 26/16	
CHECK					
 <b>Golder Associates</b>		SCALE		N/A	
		REV.			
		<b>FIGURE A-3</b>			



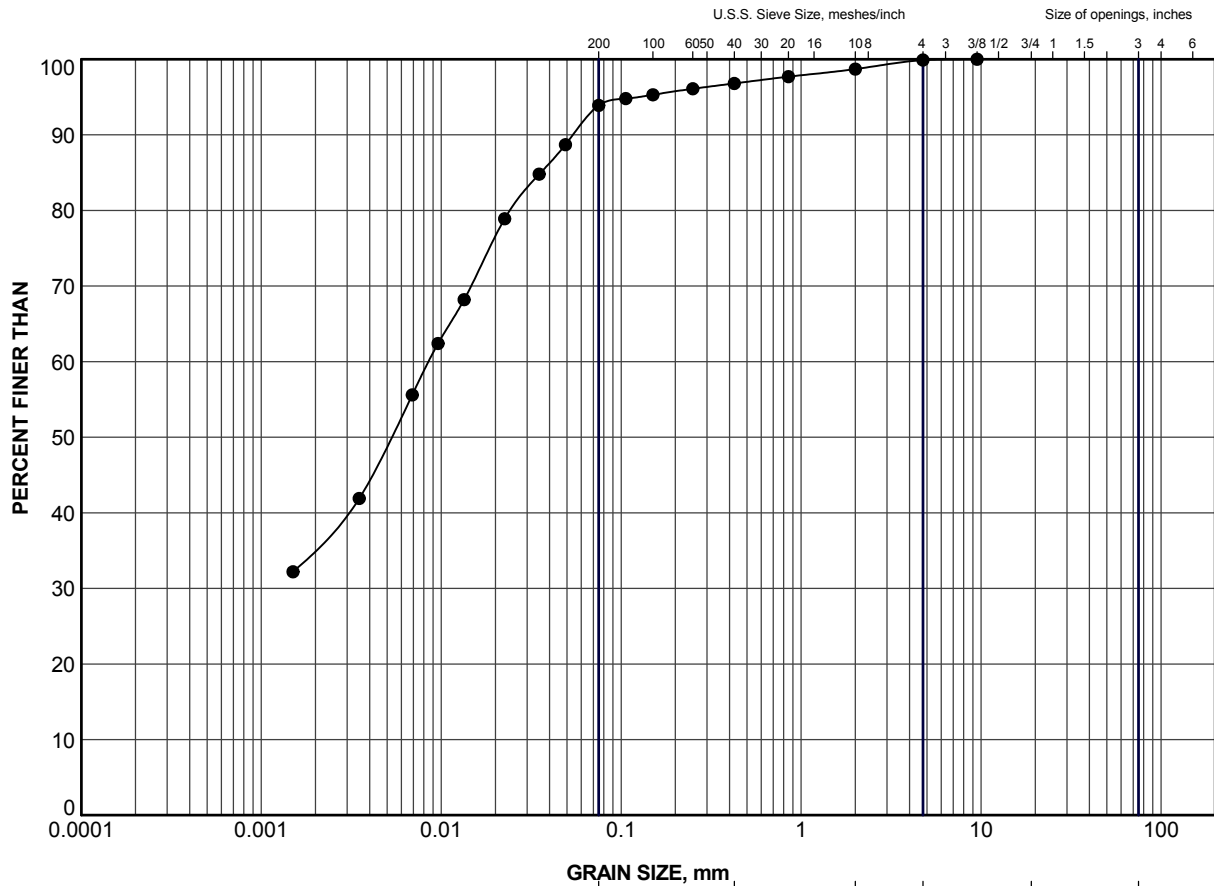
GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-301	9	381.9
■	BH-302	8	383.6
▲	BH-303	6	383.2


PROJECT		CULVERT REPLACEMENT, SITE 25-344/C HIGHWAY 23 GWP 3042-11-00			
TITLE		GRAIN SIZE DISTRIBUTION SILTY CLAY			
		PROJECT No.		12-1132-0163	
		FILE No.		1211320163-4000-F030A4	
		SCALE		N/A	
DRAWN		ZJB		Dec 19/16	
CHECK					
		<b>FIGURE A-4</b>			

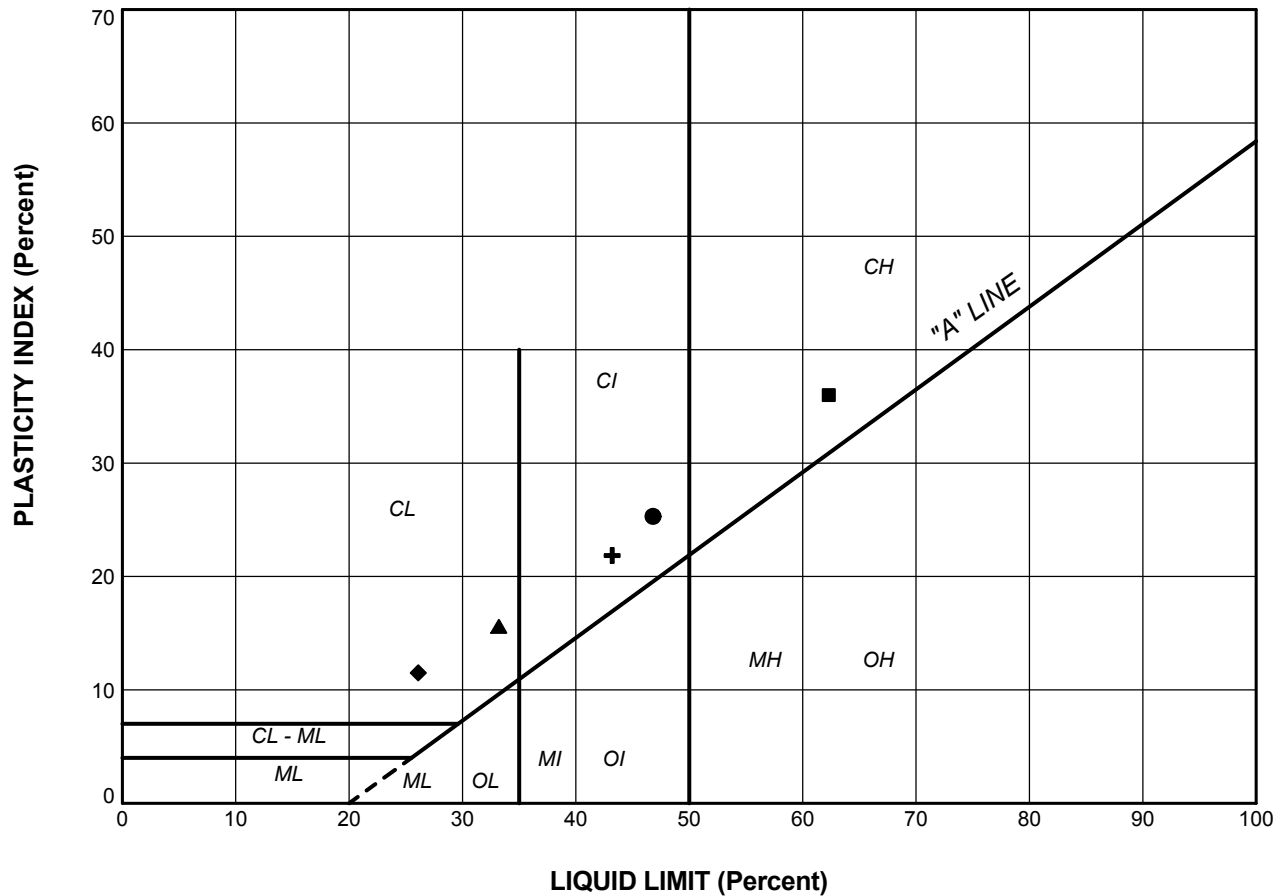




### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-303	8	380.1

PROJECT		CULVERT REPLACEMENT, SITE 25-344/C HIGHWAY 23 GWP 3042-11-00			
TITLE		GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL			
PROJECT No.		12-1132-0163		FILE No. 1211320163-4000-F030A5	
DRAWN		ZJB		Oct 26/16	
CHECK					
 <b>Golder Associates</b>		SCALE		N/A REV.	
				<b>FIGURE A-5</b>	



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
<b>SILTY CLAY</b>					
●	BH-301	9	46.8	21.5	25.3
■	BH-302	8	62.3	26.3	36.0
+	BH-303	6	43.2	21.4	21.9
<b>CLAYEY SILT</b>					
▲	BH-303	3	33.2	17.6	15.6
<b>CLAYEY SILT TILL</b>					
◆	BH-303	8	26.1	14.6	11.5

PROJECT				CULVERT REPLACEMENT, SITE 25-344/C HIGHWAY 23 GWP 3042-11-00			
TITLE							
<b>PLASTICITY CHART</b>							
PROJECT No.		12-1132-0163		FILE No 1211320163-4000-F030A6			
DRAWN	ZJB	Oct 26/16		SCALE	N/A	REV.	
CHECK				<b>FIGURE A-6</b>			





# **APPENDIX B**

## **Site Photographs**



## APPENDIX B SITE PHOTOGRAPHS



Photograph 1: West elevation (inlet) of Culvert Site 25-344/C (February 2, 2016).



Photograph 2: East elevation (outlet) of Culvert Site 25-344/C (February 2, 2016).





## APPENDIX B SITE PHOTOGRAPHS



Photograph 3: Looking northeast from Highway 23, east ditch toward Culvert Site 25-344/C (February 2, 2016).



Photograph 4: Looking southwest from Highway 23, west ditch toward Culvert Site 25-344/C (February 2, 2016).



# **APPENDIX C**

## **Suggested Text for NSSP's**



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## APPENDIX C

### NSSP – COBBLES AND BOULDERS

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#### **NOTICE TO CONTRACTOR – Soil Conditions - Item No.**

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Non-Standard Special Provision

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The Contractor is alerted to the presence of cobbles and boulders within the native granular soils and glacial tills at this site. All associated work relating to this shall be included in the applicable tender items.

#### **BASIS OF PAYMENT**

Payment at the contract price for this Tender Item shall include full compensation for all labour, equipment and material required to do the work.

n:\active\2012\1132 - geo\1132-0100\12-1132-0163 stantec-fdns-mega culverts-3011-e-0041\ph 4000-gwp 3042-11-00\rpts\r03 25-344-c hwy 23 wallace\1211320163-4000-r03 apr 18 17  
(final) app c nssp cobbles and boulders.docx



## APPENDIX C NSSP – WORKING SLAB

### **NOTICE TO CONTRACTOR – Dewatering Structure Excavations, Item No.**

Non-Standard Special Provision

#### **SCOPE**

This Special Provision covers the requirements for the supply, installation and operation of a proactive dewatering system.

#### **CONSTRUCTION**

- The work shall include the dewatering of the structure excavation in order to facilitate subexcavation of organic materials, if required, and placement and compaction of backfill and bedding materials, etc.

#### **BASIS OF PAYMENT**

Payment at the contract price for this Tender Item shall include full compensation for all labour, equipment and material required to do the work.

n:\active\2012\1132 - geo\1132-0100\12-1132-0163 stantec-fdns-mega culverts-3011-e-0041\ph 4000-gwp 3042-11-00\rvpts\rv03 25-344-c hwy 23 wallace\1211320163-4000-r03 apr 18 17  
(final) app c nssp dewatering.docx





## APPENDIX C NSSP – WORKING SLAB

### **NOTICE TO CONTRACTOR - Working Slab, Item No.**

Non-Standard Special Provision

#### **SCOPE**

This Special Provision covers the requirements for the supply and placement of concrete working slab under the structure foundations. The purpose of the working slab is to protect the subgrade from disturbance and loosening due to construction traffic and ponded water and also to provide a level working surface.

#### **CONSTRUCTION**

Protection of Founding Soil

- Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 millimetres shall be placed on the foundation subgrade should the subgrade remain exposed for a prolonged period, as per the contract drawings and documents. The concrete shall have a minimum 28 day compressive strength of 20 MPa.

#### **BASIS OF PAYMENT**

Payment at the contract price for this Tender Item shall include full compensation for all labour, equipment and material required to do the work.

n:\active\2012\1132 - geo\1132-0100\12-1132-0163 stantec-fdns-mega culverts-3011-e-0041\ph 4000-gwp 3042-11-00\rpts\r03 25-344-c hwy 23 wallace\1211320163-4000-r03 apr 18 17  
(final) app c nssp working slab.docx

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