

**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**CENTERLINE CULVERT REPLACEMENT**

**NEW LISKEARD DISTRICT, ONTARIO**

**G.W.P. No. 5196-13-00, W.P. No. 5141-14-01**

**Geocres Number: 42A-108**

**Report to**

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## TABLE OF CONTENTS

SECTION	PAGE
<b>PART 1     FACTUAL INFORMATION</b>	
1   INTRODUCTION.....	1
2   SITE DESCRIPTION.....	1
3   SITE INVESTIGATION AND FIELD TESTING .....	2
4   LABORATORY TESTING .....	3
5   DESCRIPTION OF SUBSURFACE CONDITIONS .....	3
5.1   General .....	3
5.2   Topsoil.....	3
5.3   Asphalt .....	3
5.4   Fill .....	4
5.5   Silty Clay.....	4
5.6   Clayey Silt.....	5
5.7   Sand to Sand and Silt Till.....	5
5.8   Groundwater Conditions .....	6
6   CORROSIVITY AND SULPHATE TEST RESULTS .....	7
7   MISCELLANEOUS.....	7
<b>PART 2     ENGINEERING DISCUSSION AND RECOMMENDATIONS</b>	
8   GENERAL .....	9
9   CULVERT FOUNDATIONS .....	9
9.1   General.....	9
9.2   Foundation Alternatives.....	10
9.3   Foundation Design for Culverts.....	10
9.3.1   Concrete Box Culvert.....	11
9.3.2   Concrete Pipe or Corrugated Steel Pipe (CSP) Culverts.....	12
9.3.3   Depth of Frost Penetration .....	12
9.3.4   Subgrade Preparation .....	12
9.4   Construction Considerations.....	12
10   CULVERT BACKFILL AND LATERAL EARTH PRESSURES .....	13
11   EMBANKMENT RE-CONSTRUCTION .....	14
12   EROSION CONTROL.....	15

13	EXCAVATION AND GROUNDWATER CONTROL .....	15
14	PROTECTION SYSTEM DESIGN .....	16
15	CORROSION AND SULPHATE ATTACK POTENTIAL .....	16
16	CONSTRUCTION CONCERNS .....	17
17	CLOSURE.....	18

**Appendices**

Appendix A	Record of Borehole Sheets
Appendix B	Geotechnical and Analytical Laboratory Test Results
Appendix C	Selected Site Photographs
Appendix D	Borehole Locations and Soil Strata Drawing
Appendix E	List of Relevant OPSS and OPSD Documents
Appendix F	Comparison of Foundation Alternatives

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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at the Centerline Culvert on Highway 572, located on the border of the Hislop and Guibord Townships, New Liskeard District, Ontario.

The purpose of this investigation was to obtain subsurface information at the culvert location and, based on the data obtained, to provide borehole location plans, stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by MMM Group Limited to carry out this foundation investigation under the MTO Assignment Number 5014-E-0019.

**2 SITE DESCRIPTION**

The culvert site is located on Highway 572, approximately 450 m north of the Pike River Bridge in the Township of Hislop/Guibord, New Liskeard District, Ontario. This culvert facilitates the flow of an unnamed creek, from west to east, under Highway 572. Highway 572 is oriented in the north-south direction at the culvert site.

Based on the terms of reference, the existing structure consists of a 2.4 m diameter and 23.4 m long corrugated steel pipe (CSP) culvert. The embankment fill at the culvert location is between 5.5 m and 6 m in height. The culvert is proposed for full replacement.

The grade level of Highway 572 at the existing culvert is at approximate Elevation 288.0 m.

The site is located approximately 14 km southwest of Matheson. Naturally elevated areas slope downwards towards the creek with vegetation consisting of tall grass and shrubs and frequent trees. The local topography is generally of low relief with no visible bedrock outcrops.

Based on published geological information, the general area of the project is covered by glaciolacustrine sediments of clays and silts deposited during the Pleistocene period. These deposits are mostly varved

clays, but massive clays are also present in some areas. Below the clays are glacial outwash deposits of silts, sands and gravel underlain by Precambrian ultramafic to metavolcanic bedrock.

### 3 SITE INVESTIGATION AND FIELD TESTING

The borehole investigation and field testing program was carried out between February 20 and March 9, 2016. The program consisted of drilling and sampling 4 boreholes, numbered CC-01 to CC-04, to depths ranging from 5.2 to 15.4 m. Dynamic Cone Penetration Tests (DCPTs) were carried out below the sampled portion of Boreholes CC-01 and CC-02 to depths of 7.3 and 6.4 m respectively. Borehole CC-01 was located near the culvert inlet, and Borehole CC-04 was located near the culvert outlet, Boreholes CC-02 and CC-03 were located on the road embankment.

Prior to the start of drilling, the borehole locations were marked/staked in the field and utility clearances were obtained. The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided to Thurber by MMM Group Limited. The approximate borehole locations are shown on the Borehole Locations and Soil Strata drawing included in Appendix D.

A track-mounted CME 45 drill rig was used to advance Borehole CC-02 and CC-03 to the target depth using NW casing/wash boring techniques. A portable tripod drill rig was used to advance Boreholes CC-01 and CC-04 to the target depth due to difficult access for a conventional drill rig beyond the road embankment. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). Groundwater conditions in the open boreholes were observed throughout the drilling operations. Upon completion of drilling and final water reading, the boreholes were decommissioned in general accordance with O.Reg. 903. The details regarding borehole completion are summarized in Table 3.1.

**Table 3.1 - Borehole Completion and Backfilling Details**

<b>Borehole</b>	<b>Borehole Depth/ Elevation (m)</b>	<b>DCPT Depth/ Elevation (m)</b>	<b>Borehole Backfilling Details</b>
CC-01	6.7 / 276.3	7.3 / 275.7	Bentonite holeplug from 7.3 m to ground surface.
CC-02	15.4 / 272.6	N/A	Bentonite holeplug and cuttings from 15.4 m to 0.1 m and asphalt cold patch to ground surface.
CC-03	14.0 / 274.0	N/A	Bentonite holeplug from 14.0 m to 0.2 m and asphalt cold patch to ground surface.
CC-04	5.2 / 278.0	6.4 / 276.8	Bentonite holeplug from 6.4 m to ground surface.

The results of the field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, secured the recovered soil samples in labelled containers, and transported the samples to Thurber's laboratory for further examination and testing.

#### **4 LABORATORY TESTING**

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected soil samples were subjected to grain size distribution analyses (sieve and hydrometer) and plasticity testing (Atterberg Limits). The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix A and on Figures in Appendix B.

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

##### **5.1 General**

Reference is made to the Record of Borehole sheets in Appendix A for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for this culvert site are presented on the Borehole Locations and Soil Strata Drawing in Appendix D for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the records of boreholes governs any interpretation of the site conditions. The subsurface conditions may vary between and beyond borehole locations.

The boreholes were drilled at the locations shown on the Borehole Location and Soil Strata drawing. It was not feasible to investigate the ground conditions immediately under the existing culvert and these may vary from the conditions encountered in the boreholes.

In general, underlying the embankment fill is a deposit of silty clay which grades with depth to a clayey silt. The clayey silt is underlain by a cohesionless till ranging in composition from a silty sand to sand and silt. Near the culvert inlet and outlet, a thin veneer of topsoil overlies the silty clay and subsequent layers. More detailed descriptions of the encountered strata are presented below.

##### **5.2 Topsoil**

A layer of topsoil with a thickness of 150 mm was encountered at the ground surface in Boreholes CC-01 and CC-04, near the culvert inlet and outlet. The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating topsoil quantities.

##### **5.3 Asphalt**

Asphalt was encountered at the ground surface in Boreholes CC-02 and CC-03. The thickness of the asphalt ranged from 30 to 75 mm at the borehole locations.

## 5.4 Fill

Embankment fill was encountered in Boreholes CC-02 and CC-03 underlying the asphalt. This fill consisted of brown sand to sand and gravel with trace to some silt and occasional cobbles. Large size rock fill protection was observed at the outlet of the culvert and frequent cobbles were noted at the culvert inlet. The thickness of the embankment fill was 5.5 m with a lower boundary at depths of 5.5 to 5.6 m (base Elevations 282.4 to 282.5 m).

SPT N-values measured in the fill ranged from 1 blow per 0.3 m penetration to 50 blows per 0.15 m penetration indicating a typically very loose to very dense relative density. The high 'N' values may be attributed to the presence of cobbles in the fill. Measured moisture contents of the recovered fill samples ranged between 1% and 34%.

Grain size analyses conducted on samples of the fill are presented on Figure B1 in Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	0 to 41
Sand	54 to 95
Silt and Clay	4 to 14

## 5.5 Silty Clay

Silty clay was encountered in all boreholes drilled at the site either underlying the topsoil or the embankment fill. The fill was brown to grey and contained trace sand and gravel and occasional rootlets and wood fibres at shallow depths. The thickness of the silty clay ranged from 1.7 to 3.1 m with a lower boundary at depths of 2.4 to 8.7 m (Elevations 280.8 to 279.3).

SPT N-values measured in the silty clay typically ranged between 5 and 23 blows per 0.3 m penetration, with most values lying between 10 and 14 blows which indicates a typically stiff consistency with occasional firm and very stiff zones. The measured water contents of samples recovered of the silty clay typically ranged from 14% to 43% with most values between 27% and 43%.

Grain size analyses conducted on samples of the silty clay are presented on Figure B2 and Atterberg Limits test results are presented on Figure B6 in Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	0 to 3
Silt	46 to 49
Clay	51

Soil Property	%
Liquid Limit	38 to 44
Plasticity Index	22 to 24

The results of the Atterberg Limits tests indicate that the silty clay is typically of intermediate plasticity (CI).

## 5.6 Clayey Silt

Clayey silt with trace to some sand and gravel was encountered in Boreholes CC-01, CC-03 and CC-04 underlying the silty clay. The thickness of the clayey silt ranged from 1.3 to 3.0 m with a lower boundary at depths of 4.0 to 10.2 m (Elevations 279.0 to 277.8).

SPT N-values measured in the clayey silt typically ranged between 9 and 32 blows per 0.3 m penetration, indicating a stiff to hard consistency. The measured water contents of the clayey silt samples typically ranged from 27% to 39%.

Grain size analyses conducted on samples of the clayey silt are presented on Figure B3 and Atterberg Limits test results are presented on Figure B7 in Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0 to 20
Sand	0 to 14
Silt	46 to 76
Clay	20 to 24
Soil Property	%
Liquid Limit	24
Plasticity Index	6

The results of the Atterberg Limits tests indicate that the clayey silt is low plasticity (CL-ML).

## 5.7 Sand to Sand and Silt Till

A sand to sand and silt till deposit was encountered underlying the silty clay deposit in Borehole CC-02 and the clayey silt in Boreholes CC-01, CC-03 and CC-04. The till contained trace to some gravel, trace clay and occasional cobbles and boulders. All boreholes were terminated in this till at depths ranging from 5.2 m to 15.4 m (Elevations 278.0 to 272.6).

SPT N-values measured in the till typically ranged from 13 blows per 0.3 m penetration to more than 100 blows per 0.3 m penetration, indicating a compact to very dense relative density. The measured water contents of samples recovered of the deposit typically ranged from 9% to 21%.



A grain size analysis conducted on a sample of the sand and silt till is presented on Figure B4 in Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	18
Sand	39
Silt and Clay	43

A layer of sand and gravel with trace silt was encountered in Borehole CC-02 within the sand to sand and silt deposit. Boulders were noted in this layer. The thickness of this layer was 1.4 m with a base depth of 11.2 m (Elevation 276.4). One SPT value recorded in this deposit was 35 blows per 0.3 m penetration indicating a dense relative density. One measured water content in the layer was 15%.

A grain size analysis conducted on a sample of the sand and gravel layer is presented on Figure B5 in Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	49
Sand	41
Silt and Clay	10

Below the sampled depth in Boreholes CC-01 and CC-04, a DCPT was carried out within the till to depths of 7.3 and 6.4 m respectively (Elevation 275.7 and 276.8). Practical refusal was encountered in the DCPT in Borehole CC-04 (100 blows per 0.3 m penetration).

## 5.8 Groundwater Conditions

Free water was observed in most of the boreholes upon completion of drilling and are presented below.

**Table 5.1 – Water Level Measurements in Open Boreholes**

Borehole	Date of Reading	Water Level	
		Depth (m)	Elevation (m)
CC-01	March 4, 2016	1.2	281.8
CC-03	March 9, 2016	5.4	282.6
CC -04	March 4, 2016	2.1	281.1

These are short term observations and the groundwater level should be assumed to coincide with the local creek water level.

The surveyed water level in the creek was at Elev. 282.3 at the east end of the culvert and at Elev. 281.7 at the west end of the culvert on June 2015.

The groundwater levels and water level in the creek are expected to vary seasonally in response to severe weather events.

## 6 CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the surface water from the creek was submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

**Table 6.1 – Analytical Test Results**

Parameter Units	Units	Centerline (Creek Water)
Sulphide	mg/L	<0.05
Chloride	mg/L	4.86
Sulphate	mg/L	1.49
pH	pH Units	7.73
Electrical Conductivity	µS/cm	175
Resistivity	ohm.cm	5710
Redox Potential	mV	385

## 7 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by MMM Group Limited.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated a track-mounted CME-45 hi-torque drill rig and portable tripod drill rig to carry out the drilling, sampling and in-situ testing operations for two boreholes on the road embankment, one borehole at the culvert inlet and one borehole at the culvert outlet. The drilling and sampling operations in the field were supervised on a full time basis by Mr. Amir Fereidouni and Mr. George Azzopardi of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET.

Ms. Deanna Pizycki, EIT, interpreted the data and prepared the report. The report was reviewed by Ms. Anna Piascik, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8 GENERAL**

This report presents interpretation of the geotechnical data in the factual report and provides foundation recommendations for the design of replacement of the existing Centerline Culvert on Highway 572, located approximately 450 m north of the Pike River Bridge in the Township of Hislop/Guibord, New Liskeard District, Ontario.

Based on the terms of reference, the existing culvert consists of a 2.4 m diameter and 23.4 m long corrugated steel pipe (CSP). The embankment fill at the culvert location is approximately 5.5 m to 6 m in height. The culvert is proposed for full replacement. It is anticipated that no grade raise will be required at the culvert location. However, temporary embankment widening may be required for staged construction to accommodate traffic.

The discussions and recommendations presented in this report are based on information provided by MMM Group Limited (MMM) and on the factual data obtained during the course of this investigation. No information on the proposed replacement culvert alternatives was available at the time of preparation of this report. The discussion and geotechnical recommendations presented are intended to provide the designer with sufficient information to assess feasible foundation alternatives and to carry out the design of the structure foundations.

**9 CULVERT FOUNDATIONS**

**9.1 General**

For the purpose of this report it was assumed that the replacement culvert will be installed along the same alignment as the existing culvert, and that staged construction will be required for the culvert replacement.

In general, the boreholes encountered 5.5 m to 5.6 of embankment fill consisting of sand to sand and gravel with the base at approximately Elev. 282.4. Underlying the fill was a deposit of silty clay grading with depth to clayey silt. At the borehole locations, this cohesive deposit extended to depths ranging from 4.0 m to 10.2 m (Elev. 279.3 to 277.8). The silty clay/clayey

silt was underlain by a till consisting of sand to sand and silt. The cohesionless till was encountered to depths 5.2 m to 15.4 m (Elev. 278.0 to 272.6) investigated in the boreholes.

The water level in open boreholes located near the ends of the culvert were measured at depths of 1.2 m and 2.1 m (Elev. 281.8 and 281.1) upon completion of drilling. The water level was measured at a depth of 5.4 m (Elev. 282.6) in the open borehole advanced from the top of the highway embankment. These water levels indicate the short time observations after completion of drilling and may not indicate the stabilized ground water level at this site.

The surveyed water level in the creek was at Elev. 282.3 at the east end of the culvert and at Elev. 281.7 at the west end of the culvert on June 2015.

## **9.2 Foundation Alternatives**

This section presents discussions on available types of replacement culverts and foundation alternatives, and provides recommendations on preferred foundation options.

Several common culvert types that may be considered for this site are listed below:

- Concrete box (closed) culvert
- Concrete, open footing, culvert
- Concrete pipes or corrugated steel pipes (CSP).

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix F.

The existing culvert consists of a corrugated steel pipe (CSP). Given the subsurface conditions and anticipated construction sequencing, we consider that box culvert, concrete pipe or corrugated CSP would be technically feasible alternatives from a foundation engineering standpoint.

A concrete, open footing culvert option is not considered favourable, as deeper excavation will be required for footing construction below the creek water level involving significant dewatering effort. Moreover, the subgrade soils are relatively weak and are not likely to provide the geotechnical resistances required to support strip footings of reasonable width.

The report provides foundation recommendations for the design and construction of box culvert and pipe culvert.

## **9.3 Foundation Design for Culverts**

It is anticipated that the invert level of the replacement culverts will be similar to the invert of the existing culvert. There is approximately 3.0 m of fill above the existing culvert. Foundation design aspects for the replacement culvert includes discussion and recommendations on geotechnical capacities, settlement of founding soils, lateral earth pressures, protection system design, groundwater control, staged construction, and re-construction of the roadway embankment.

### 9.3.1 Concrete Box Culvert

Since the replacement culvert will be constructed on the same alignment as the existing culvert with no grade raise, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading, other than due to the weight of the concrete box structure.

In order to provide a uniform foundation subgrade condition, a min 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements must be provided under the base of the box culvert, similar to as shown on OPSD 803.010. The bedding material should be placed on the approved subgrade as soon as practical, following its inspection and approval. The surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A. Construction specifications outlined in OPSS PROV 422 should be followed. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 282.4 on firm to stiff silty clay. For culvert replacement on the existing alignment, the underside of the bedding will be likely lower than Elev. 282.4.

The following geotechnical capacities could be used for design of the box culvert 3 m in width and founded at or below Elev. 282.4 on firm to stiff silty clay:

Factored Geotechnical Resistance at ULS of 175 kPa

Geotechnical Resistance at SLS (less than 25 mm settlement) of 125 kPa.

The ULS resistance and settlement are dependent on the footing/culvert size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert width or founding elevation differs significantly from that given above.

The geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance between the concrete slabs and the underlying Granular A or B Type II should be calculated assuming an ultimate coefficient of friction of 0.5.

Culvert should be designed to resist external loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

### **9.3.2 Concrete Pipe or Corrugated Steel Pipe (CSP) Culverts**

Replacement of the culvert with a concrete pipe or steel pipe (CSP) on the same alignment as the existing culvert or on an alignment adjacent to the existing can be considered for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

The concrete pipe or CSP culvert should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements, as per OPSD 802.010 or 802.020 respectively. The bedding material should be placed on the approved subgrade as soon as practicable following its inspection and approval. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. The bedding should be placed on undisturbed, native stiff silty clay, which will place its underside at Elev. 282.4, or lower along the existing culvert alignment.

The modulus of subgrade reaction “k” of 30 MN/m<sup>3</sup> could be used in the design of the culvert placed on the subgrade prepared as noted above.

### **9.3.3 Depth of Frost Penetration**

The depth of frost penetration at this site is approximately 2.3 m.

### **9.3.4 Subgrade Preparation**

After the excavation reaches the subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, creek bed deposits, disturbed soils and any deleterious materials within the culvert replacement footprint should be removed and replaced with well compacted bedding.

This work should be carried out in accordance with OPSS PROV 902 and construction should be carried out in the dry.

## **9.4 Construction Considerations**

The construction of the Centerline Culvert replacement may involve either a total road closure or staged construction. If the construction of the culvert replacement is part of the contract for replacements of the bridges to be carried out in the area, a total road closure will likely be implemented. However, if one lane of traffic is to be maintained, a staged construction will be required.

Staged construction sequencing will likely require the following:

- Diversion of the creek for construction. Cofferdams will be required, as well as pumping from sumps, to permit construction in the dry.
- Roadway protection system will be required during all stages of construction. Excavation and installation of the new culvert and backfilling should be carried out within the

temporary protection systems. If required, removal of the old culvert should be carried out inside the protection system

- All culvert subgrade preparation and installation should be carried out in the dry.

Since the excavation and culvert installations will be conducted within the existing creek channel, all works will have to be carried out within a water-tight enclosure/cofferdam. For this site, the use of interlocking steel sheetpiles may be utilized. Sump pumping will be required to maintain dry excavations. The dewatering during construction should be effective to maintain the water level below the final subgrade level. The design of the dewatering system is the responsibility of the contractor. The contractor should retain a dewatering specialist to design the appropriate cofferdam and dewatering system.

## 10 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01, 802.010, or 802.031, as appropriate.

All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of a culvert, and the top of backfill elevation should not differ more than 200 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert.

Earth pressures acting on the culvert walls may be assumed to impose a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2014, but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where	$p_h$	=	horizontal pressure on the wall at depth h (kPa)
	$K$	=	earth pressure coefficient (see table below)
	$\gamma$	=	bulk unit weight of retained soil (see table below)
	$h$	=	depth below top of fill where pressure is computed (m)
	$q$	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in the following Table 9.1. For rigid structures such as concrete box culvert, it is recommended that at-rest horizontal earth pressures be used for design. Active pressures should be used for any unrestrained wall.



**Table 9.1**  
**Earth Pressure Coefficients (K)**

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ$ ; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$ ; $\gamma = 21.2 \text{ kN/m}^3$		Embankment Fill $\phi = 30^\circ$ ; $\gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or Granular B Type II.

## 11 EMBANKMENT RE-CONSTRUCTION

The existing highway embankment is between 5.5 and 6 m in height at the culvert location. It is anticipated that no grade raise is proposed at this site.

Embankment reconstruction after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206. The embankment material may consist of imported Granular A or B Type II material.

For slope stability purposes, it is generally recommended that the side slopes of embankments be constructed at an inclination of 2H:1V. However, the existing slopes locally at the culvert are as steep as 1.7H:1V and appear to be stable and performing satisfactory. Accordingly, at this specific site, it is considered to be acceptable to re-construct the slopes to match the existing slope inclination. This approach is expected to simplify the construction and will avoid potential settlement issues at the ends of the culverts that could arise from extending the loaded area under the embankment.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel should be conducted.

If widening of the embankment is required for the staged construction, the settlement in the temporarily widened embankment areas (not previously loaded) is estimated to be in the order of 50 mm, and the majority of the settlement will occur during construction.

## **12 EROSION CONTROL**

The existing embankment in the vicinity of the culvert experienced erosion as evident on the enclosed photographs in Appendix C. Properly design erosion protection works should be implemented at this site.

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. Treatment at the outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

A clay seal or a concrete cut-off wall should be used to minimize the potential for erosion or piping around the box culvert. The clay seal should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.

## **13 EXCAVATION AND GROUNDWATER CONTROL**

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill, native silt, and native silty clay at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits that are anticipated in the inlet and outlet areas should be classified as Type 4 soils.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS PROV 902.

Excavations for culvert replacement will be carried out through the existing embankment fill and extended into the native silty clay deposit. The work will need to be carried out within a protection system, if staged construction is implemented.

Groundwater perched within the embankment fill and surface runoff will seep into the excavation during culvert replacement. The groundwater level is expected to be largely governed by the water level in the creek. As discussed in the previous sections, a combination of the use of cofferdams at the inlets and outlets, creek water diversion, protection systems such as sheetpiled enclosures and pumping from filtered sumps will be required to maintain dry excavations during the course of staged construction. A water-tight, sheetpile enclosure is recommended since all excavation and culvert installation works will

be conducted within the existing creek channel. Reference should be made to OPSS PROV 517 and OPSS PROV 518 for specifications for dewatering and control of water from dewatering.

#### **14 PROTECTION SYSTEM DESIGN**

Roadway protection system will be required during various stages of construction. The design of the protection system is typically the responsibility of the Contractor, as per OPSS PROV 539.

If required, the protection system should be design for Performance Level 2 (maximum 25 mm horizontal deflection). One option that is considered to be suitable for use at this site is steel interlocking sheetpile enclosures which are also anticipated to provide an effective groundwater cut-off. It is anticipated that the sheetpiles will need to be driven into the firm native silty clay/clayey silt or deeper into the cohesionless till to develop the required toe resistance. It is anticipated that the protection system may be stiffened by corner and cross bracings, where applicable.

An interlocking sheetpiled wall may be designed using the parameters given below:

$\gamma$	=	20 kN/m <sup>3</sup> (embankment fill and native soils)
$\gamma_w$	=	10 kN/m <sup>3</sup>
$K_a$	=	0.33 (road embankment fill)
	=	0.39 (silty clay/clayey silt)
$K_p$	=	2.6 (silty clay/clayey silt)

Full hydrostatic pressure should be considered assuming a water level at least equal to the design creek water level.

The actual pressure distribution acting on the protection system is a function of the construction sequence and the relative flexibility of the wall, and these factors should be considered when designing the shoring system. Typically, a triangular earth pressure distribution similar to the one used for culvert lateral pressure design could be used for a cantilevered sheetpiled wall.

All shoring systems should be designed by a Professional Engineer experienced in such designs.

#### **15 CORROSION AND SULPHATE ATTACK POTENTIAL**

The results of the corrosivity and sulphate analytical tests conducted on the creek water indicates the following:

- The potential for corrosion or sulphate attack on concrete treatment systems from the surrounding surface water is considered to be negligible due to the low concentration of sulphate in the samples tested.
- The potential for surface water corrosion on metal is considered to be mild.
- Appropriate protection measures are recommended to address the mild potential for corrosion on metal structural rehabilitation elements.

## **16 CONSTRUCTION CONCERNS**

Potential construction concerns include, but are not necessarily limited to, the following:

- All subgrade and foundation preparation works for the replacement culvert and any wingwalls should be carried out in the dry
- Possible presence of cobbles and boulders within the embankment fill materials, and in underlying native soils, especially in cohesionless till. Presence of rock fill was noted surrounding outlet of the culvert.
- Impact of excavation on the existing roadway surface; re-grading and resurfacing of the roadway surface will be required after construction.
- Possible presence of variable thickness of peat, organic soils, soft soils and alluvial deposits within the footprint of the replacement culvert. Careful inspection of the founding strata should be carried out and any deleterious materials should be removed from below the culvert.

## 17 CLOSURE

Preparation of this foundation design report was carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng, a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

Anna Piascik, P.Eng.  
Senior Foundation Engineer



Alastair Gorman, M.Sc., P.Eng.  
Senior Geotechnical Engineer/Senior Associate



P.K. Chatterji, Ph.D., P.Eng.  
Review Principal, Designated MTO Contact

**Appendix A**  
**Record of Borehole Sheets**

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

### 1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

### 2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 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	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT      Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

## EXPLANATION OF ROCK LOGGING TERMS


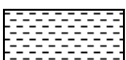

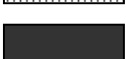

### ROCK WEATHERING CLASSIFICATION

<b>Fresh (FR)</b>	No visible signs of weathering.
<b>Fresh Jointed (FJ)</b>	Weathering limited to the surface of major discontinuities.
<b>Slightly Weathered (SW)</b>	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
<b>Moderately Weathered (MW)</b>	Weathering extends throughout the rock mass, but the rock material is not friable.
<b>Highly Weathered (HW)</b>	Weathering extends throughout the rock mass and the rock is partly friable.
<b>Completely Weathered (CW)</b>	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.

### DISCONTINUITY SPACING

<b>Bedding</b>	<b>Bedding Plane Spacing</b>
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

### SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

### STRENGTH CLASSIFICATION

<b>Rock Strength</b>	<b>Approximate Uniaxial Compressive Strength (MPa)</b>	<b>Approximate Uniaxial Compressive Strength (psi)</b>	<b>Field Estimation of Hardness*</b>
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

### TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.



# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ( $W_L < 30\%$ ).
		CI	Inorganic clays of medium plasticity, silty clays. ( $30\% < W_L < 50\%$ ).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

# RECORD OF BOREHOLE No CC-01

1 OF 1

METRIC

GWP# 5196-13-00 LOCATION Centerline Culvert N 5 374 041.1 E 358 351.9 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE Tripod/NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.04 - 2016.03.04 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  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					
283.0	GROUND SURFACE												
0.0	TOPSOIL: (150mm)												
0.2	Silty <b>CLAY</b> , trace sand, trace gravel, trace organic matter (rootlets) Stiff Dark Brown to Grey Moist		1	SS	14							122	
			2	SS	10		282						
			3	SS	10		281						
280.6													
2.4	Clayey <b>SILT</b> , some sand, some gravel Stiff Grey Moist		4	SS	12		280						
			5	SS	9								20 14 46 20
279.0							279						
4.0	<b>SAND</b> and <b>SILT</b> to Silty <b>SAND</b> , some gravel, trace clay Compact Grey Wet (TILL)		6	SS	16		278						18 39 43 (SI+CL)
							277						
			7	SS	20								
276.3													
6.7	End of sampling at 6.7m upon casing refusal. Start of DCPT						276						
275.7													
7.3	END OF DCPT AT 7.3m UPON CONE REFUSAL. BOREHOLE OPEN TO 7.3m AND WATER LEVEL AT 1.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.												

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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No CC-02

1 OF 2

METRIC

GWP# 5196-13-00 LOCATION Centerline Culvert N 5 374 027.1 E 358 365.7 ORIGINATED BY AHF  
 HWY 572 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2016.02.20 - 2016.02.20 CHECKED BY DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$  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						
								20 40 60 80 100						
288.0	GROUND SURFACE													
0.0 0.1	ASPHALT: (75mm)													
	SAND and GRAVEL, trace silt Very Loose to Compact Brown Moist (FILL)		1	SS	28		287							41 54 5 (SI+CL)
			2	SS	7		286							
			3	SS	1		285							
			4	SS	2									
283.9							284							
4.1	SAND, trace silt Loose Brown Wet (FILL)		5	SS	7		283							0 95 5 (SI+CL)
282.4							282							
5.6	Silty CLAY, trace sand, trace gravel, occasional cobbles Stiff Grey Moist		6	SS	11		281							
			7	SS	10		280							
279.3							279							
8.7	Silty SAND to SAND, some to trace gravel, occasional sand and gravel layer, occasional cobbles and boulders Compact to Very Dense Grey Wet (TILL)		8	SS	13									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15 10 5 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No CC-02

2 OF 2

METRIC

GWP# 5196-13-00 LOCATION Centerline Culvert N 5 374 027.1 E 358 365.7 ORIGINATED BY AHF  
 HWY 572 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2016.02.20 - 2016.02.20 CHECKED BY DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL LIQUID      MOISTURE CONTENT			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							<div>20   40   60   80   100</div> <div>○ UNCONFINED      + FIELD VANE</div> <div>● QUICK TRIAXIAL      × LAB VANE</div>				<div>W<sub>P</sub>      W      W<sub>L</sub></div> <div>WATER CONTENT (%)</div>			kN/m <sup>3</sup>	GR   SA   SI   CL
	300mm boulder at 10.4m	0 4 0														
	500mm sand and gravel layer at 10.7m	0 4 0	9	SS	35		277						○		49   41   10 (SI+CL)	
	300mm boulder at 11.6m	0 4 0					276									
		0 4 0	10	SS	180/ 0.200								○			
	Cobbles and boulders from 13.1m to 13.6m	0 4 0					275									
		0 4 0	11	SS	100/ 0.075		274						○			
	Cobbles and boulders from 14.0m to 14.9m	0 4 0					273									
272.6		0 4 0	12	SS	100/ 0.125								○			
15.4	END OF BOREHOLE AT 15.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT COLD PATCH TO SURFACE.															

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No CC-03

1 OF 2

METRIC

GWP# 5196-13-00 LOCATION Centerline Culvert N 5 374 035.5 E 358 369.6 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.09 - 2016.03.09 CHECKED BY AMP

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 (%)					GR	SA	SI	CL
								20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>					
288.0	GROUND SURFACE																			
0.0	ASPHALT: (30mm)																			
	SAND, trace to some gravel, trace to some silt, occasional cobbles Dense to Very Dense Brown Moist (FILL)		1	SS	59													12 74 14 (SI+CL)		
			2	SS	89															
			3	SS	50/ 0.150															
			4	SS	40															
			5	SS	20													14 82 4 (SI+CL)		
	100mm cobble at 4.0m		6	SS	16															
282.5																				
5.5	Silty CLAY, trace sand, trace rootlets and wood fibres in upper 1.0m zone Stiff Grey Moist		7	SS	11													0 3 46 51		
280.8																				
7.2	Clayey SILT Very Stiff to Hard Grey Moist		8	SS	18															
			9	SS	32															

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No CC-03

2 OF 2

METRIC

GWP# 5196-13-00 LOCATION Centerline Culvert N 5 374 035.5 E 358 369.6 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.09 - 2016.03.09 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ 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							
								20 40 60 80 100							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
Continued From Previous Page							WATER CONTENT (%)								
277.8															
10.2	Silty <b>SAND</b> to <b>SAND</b> , some gravel, trace to some clay, occasional cobbles Very Dense Grey Wet (TILL)		10	SS	92		277								
							276								
			11	SS	114/ 0.150		275								
274.0			12	SS	124		274								
14.0	END OF BOREHOLE AT 14.0m. BOREHOLE OPEN TO 14.0m AND WATER LEVEL AT 5.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPUG TO 0.5m, CONCRETE TO 0.2m, THEN ASPHALT PATCH TO SURFACE.														

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No CC-04

1 OF 1

METRIC

GWP# 5196-13-00 LOCATION Centerline Culvert N 5 374 030.4 E 358 388.1 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE Tripod/NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.04 - 2016.03.04 CHECKED BY AMP

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 (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)					
								<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>					
								<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>					
283.2	GROUND SURFACE					<div><div></div><div></div><div></div><div></div><div></div></div>									
0.0	TOPSOIL: (150mm)														
0.2	Silty <b>CLAY</b> , trace sand, occasional rootlets Firm to Very Stiff Grey Moist		1	SS	6		283								
			2	SS	7		282								
			3	SS	23										
			4	SS	5										
280.2						<div><div></div><div></div><div></div><div></div><div></div></div>									
3.0	Clayey <b>SILT</b> Very Stiff Grey Moist		5	SS	24		280								
278.9						279									
4.3	Silty <b>SAND</b> to <b>SAND</b> , some gravel, trace clay Dense Grey Wet (TILL)		6	SS	39										
278.0						278									
5.2	End of sampling at 5.2m upon casing refusal. Start of DCPT														
276.8						277									
6.4	END OF DCPT AT 6.4m UPON CONE REFUSAL. BOREHOLE OPEN TO 6.4m AND WATER LEVEL AT 2.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.														

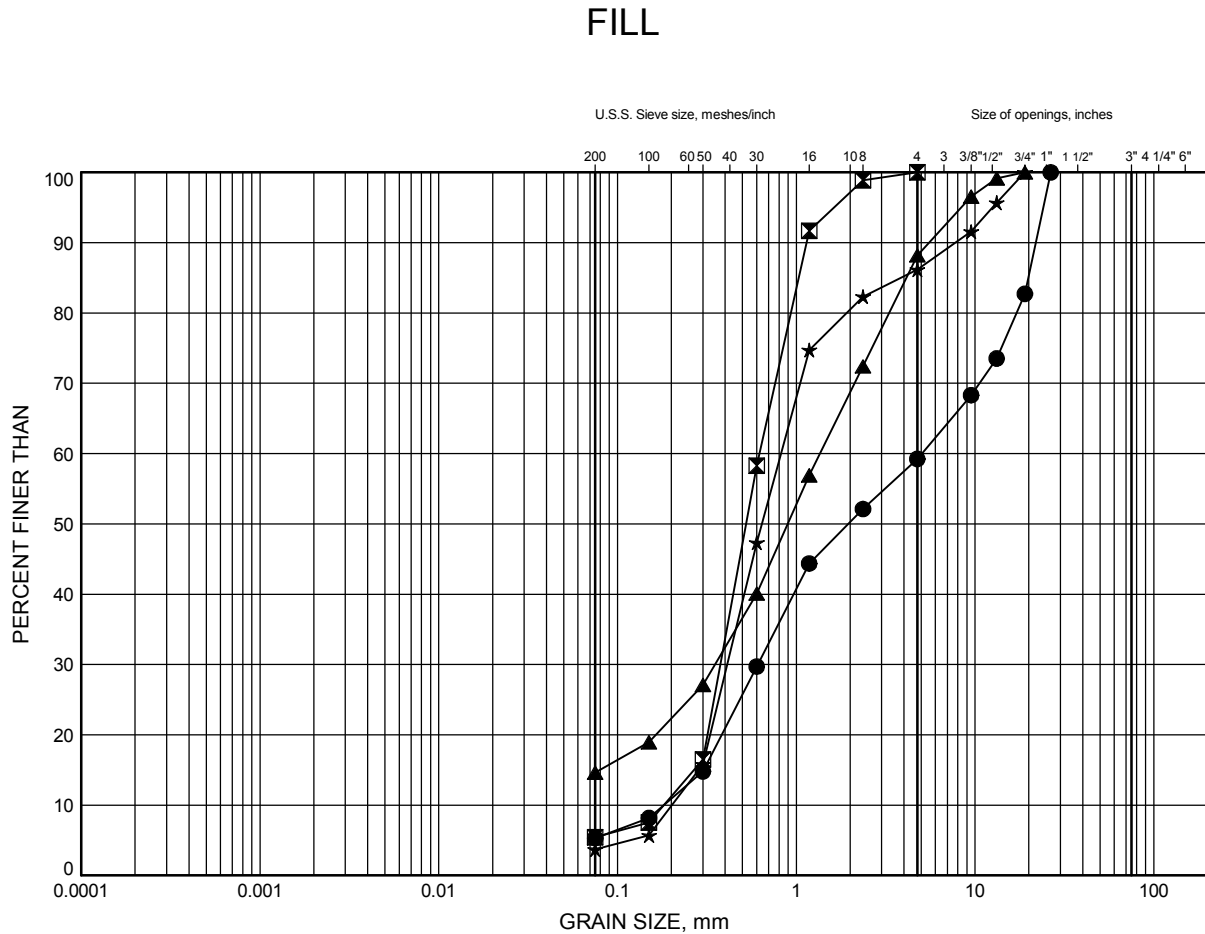
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**Appendix B**  
**Geotechnical and Analytical Laboratory Test Results**



# Centerline Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CC-02	1.07	286.93
⊠	CC-02	4.88	283.12
▲	CC-03	0.30	287.69
★	CC-03	3.35	284.64

Date April 2016  
GWP# 5196-13-00

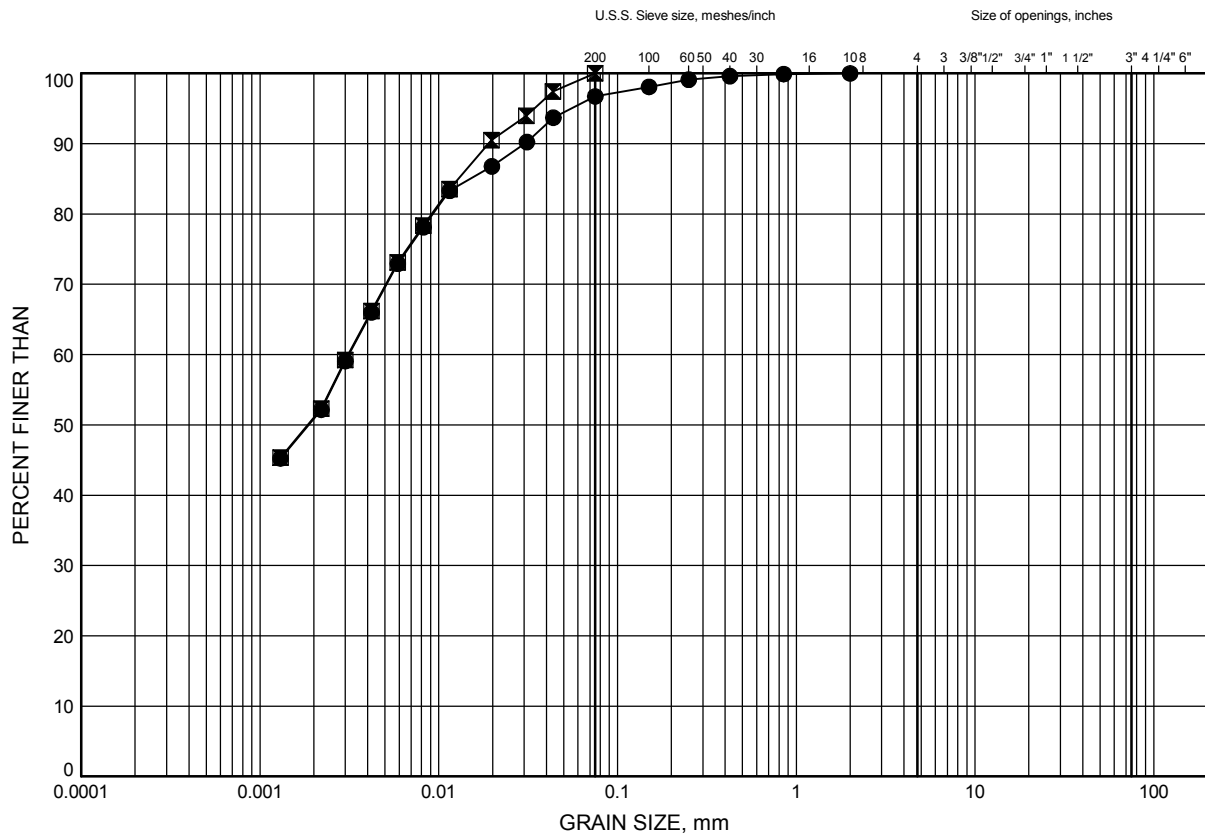


Prep'd MFA  
Chkd. DJP

# Centerline Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CC-03	6.40	281.60
⊠	CC-04	1.83	281.37

Date April 2016  
GWP# 5196-13-00

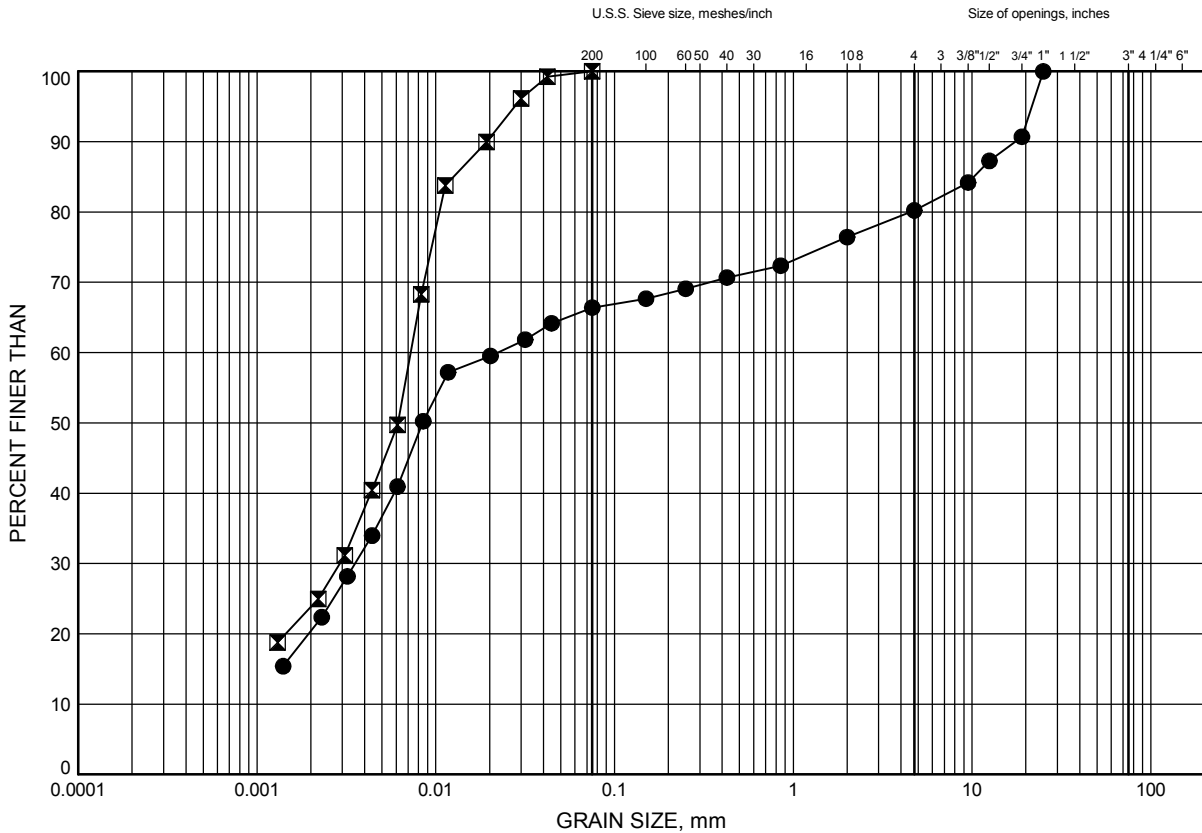


Prep'd MFA  
Chkd. DJP

# Centerline Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

## Clayey SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CC-01	3.35	279.64
⊠	CC-04	3.35	279.84

Date April 2016  
GWP# 5196-13-00

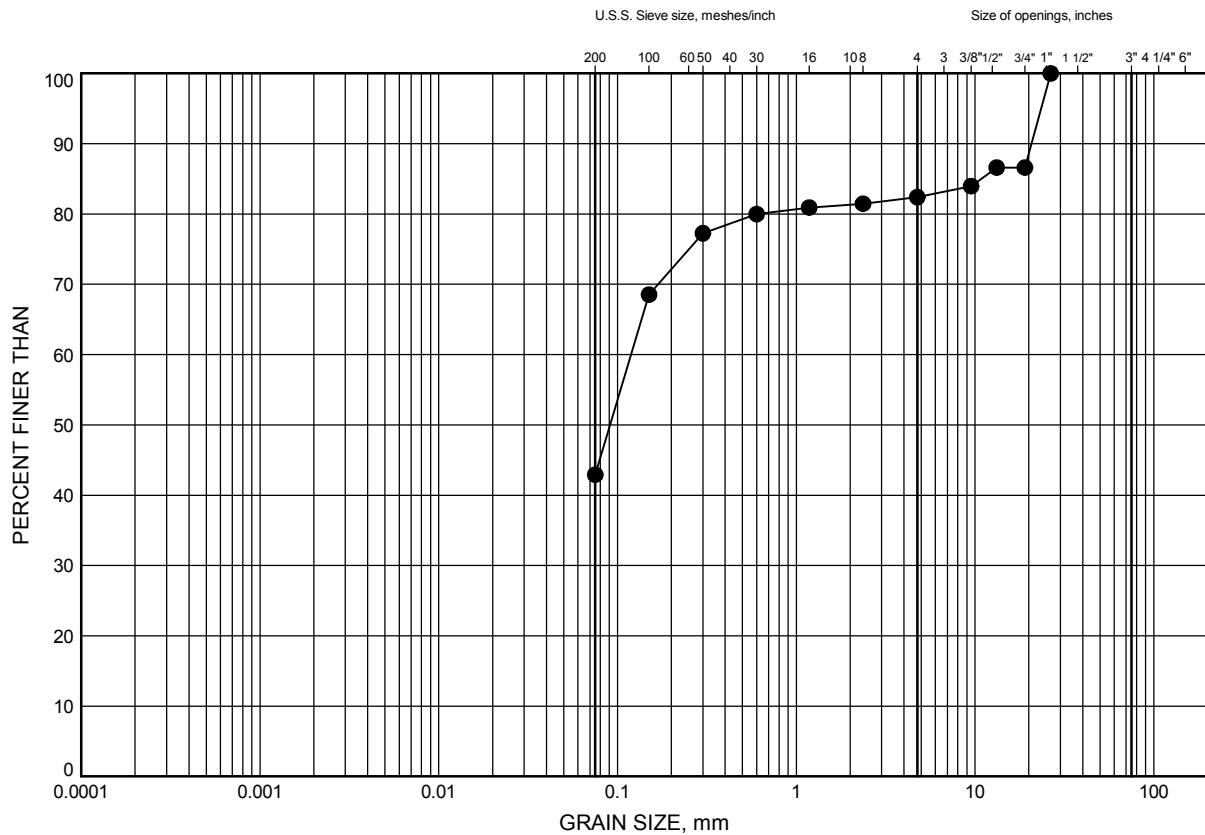


Prep'd MFA  
Chkd. DJP

# Centerline Culvert GRAIN SIZE DISTRIBUTION

FIGURE B4

## SAND & SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CC-01	4.88	278.12

Date April 2016  
GWP# 5196-13-00

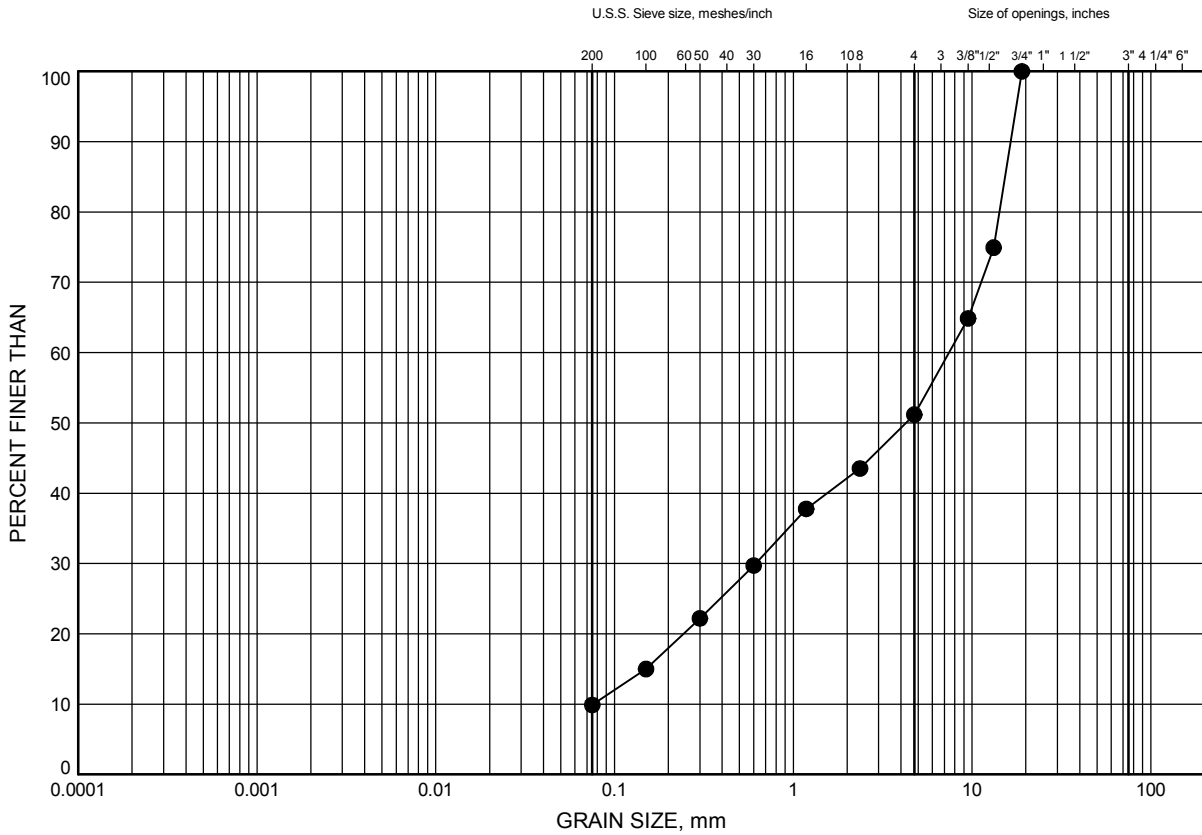


Prep'd MFA  
Chkd. DJP

# Centerline Culvert GRAIN SIZE DISTRIBUTION

FIGURE B5

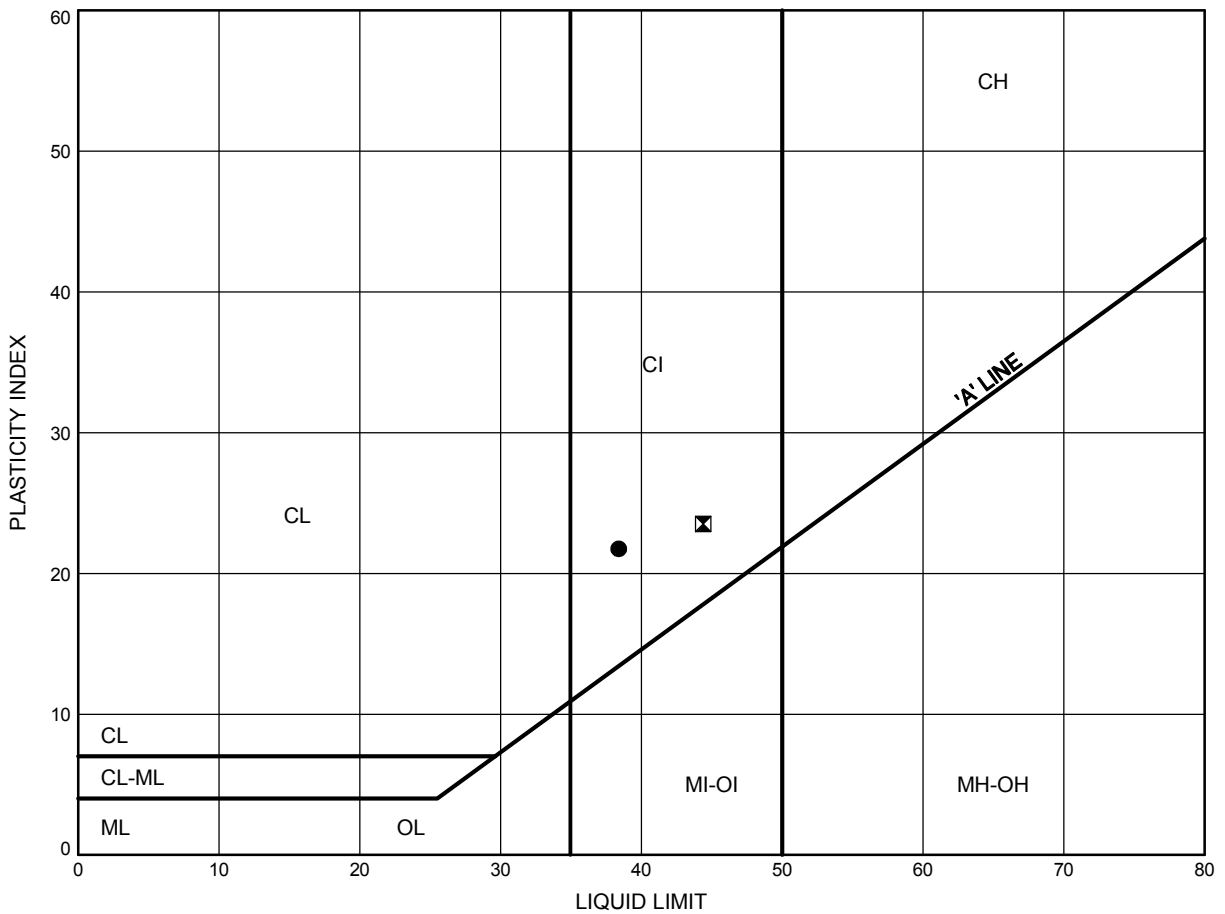
## SAND & GRAVEL



Centerline Culvert  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B6

Silty CLAY



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CC-03	6.40	281.60
⊠	CC-04	1.83	281.37

Date April 2016  
GWP# 5196-13-00

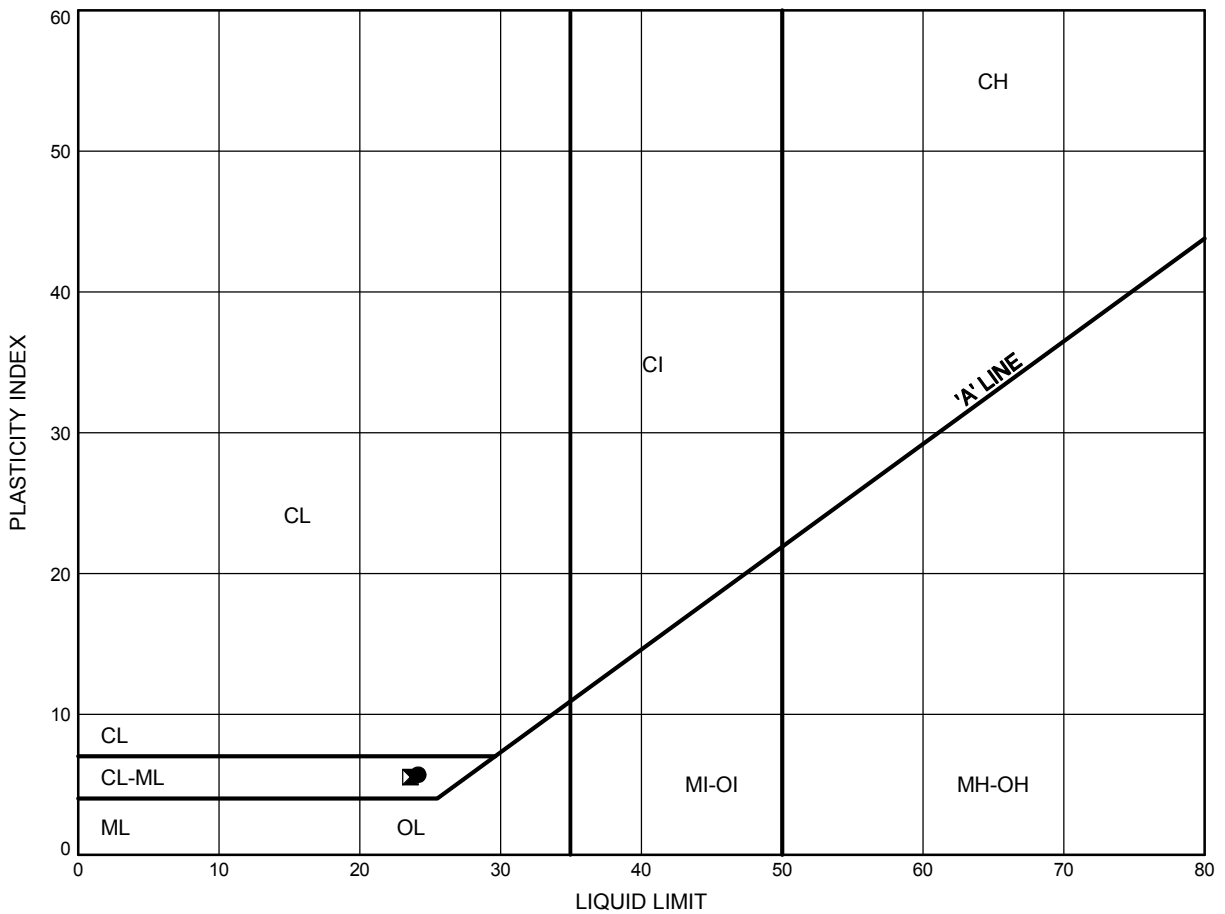


Prep'd MFA  
Chkd. DJP

Centerline Culvert  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B7

Clayey SILT



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CC-01	3.35	279.64
⊗	CC-04	3.35	279.84

Date April 2016  
 GWP# 5196-13-00



Prep'd MFA  
 Chkd. DJP

CLIENT NAME: THURBER ENGINEERING LTD  
SUITE 103, 2010 WINSTON PARK DRIVE  
OAKVILLE, ON L6H5R7  
(905) 829-8666

ATTENTION TO: Deanna Pizycki

PROJECT:

AGAT WORK ORDER: 16T076149

WATER ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: Mar 18, 2016

PAGES (INCLUDING COVER): 5

VERSION\*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

\*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.





**AGAT** Laboratories

## Certificate of Analysis

AGAT WORK ORDER: 16T076149

PROJECT:

5835 COOPERS AVENUE  
MISSISSAUGA, ONTARIO  
CANADA L4Z 1Y2  
TEL (905)712-5100  
FAX (905)712-5122  
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: Deanna Pizycki

SAMPLING SITE:

SAMPLED BY:GA

### Corrosivity Package (Water)

DATE RECEIVED: 2016-03-11

DATE REPORTED: 2016-03-18

		SAMPLE DESCRIPTION:		Centre Line
		SAMPLE TYPE:		Cul.572
		DATE SAMPLED:		Water
				3/9/2016
Parameter	Unit	G / S	RDL	7435578
Sulphide	mg/L		0.05	<0.05
Chloride	mg/L		0.10	4.86
Sulphate	mg/L		0.10	1.49
Electrical Conductivity	uS/cm		2	175
pH	pH Units		NA	7.73
Redox Potential	mV		5	385
Resistivity	ohms.cm			5710

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

Certified By:

*Amanjot Bhela*



## Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 16T076149

PROJECT:

ATTENTION TO: Deanna Pizycki

SAMPLING SITE:

SAMPLED BY:GA

Water Analysis															
RPT Date: Mar 18, 2016			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Corrosivity Package (Water)															
Sulphide	7430656		<0.05	<0.05	NA	< 0.05	100%	80%	120%	102%	85%	115%	102%	70%	130%
Chloride	7435391		149	148	0.7%	< 0.10	108%	90%	110%	110%	90%	110%	114%	80%	120%
Sulphate	7435391		10.0	10.0	0.0%	< 0.10	107%	90%	110%	109%	90%	110%	108%	80%	120%
Electrical Conductivity	7436969		2740	2750	0.4%	< 2	104%	80%	120%	NA			NA		
pH	7436969		8.07	8.03	0.5%	NA	99%	90%	110%	NA			NA		
Redox Potential	7435580	7435580	395	395	0.0%	< 5	109%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By:

*Amanjot Bhela*



## Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 16T076149

PROJECT:

ATTENTION TO: Deanna Pizycki

SAMPLING SITE:

SAMPLED BY:GA

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Water Analysis			
Sulphide	INOR-93-6054	SM 4500 S2- D	SPECTROPHOTOMETER
Chloride	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Sulphate	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Electrical Conductivity	INOR-93-6000	SM 2510 B	PC TITRATE
pH	INOR-93-6000	SM 4500-H+ B	PC TITRATE
Redox Potential		SM 2510 B	REDOX POTENTIAL ELECTRODE
Resistivity		SM 2510 B	EC METER



5835 Coopers Avenue  
Mississauga, Ontario L4Z 1Y2  
Tel: 905.510.5100 Fax: 905.713.5133

**If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water intended for human consumption)**

2. Email:

☐ 3 Business Days

## AGAT Quote

Please note: If quotation number is not provided, client will be billed full price for analysis

Bill To Same: Yes ☒ No ☐

Sample Matrix Legend	
B	Biota
GW	Ground Water
O	Oil
P	Paint
S	Soil
SD	Sediment
SW	Surface Water

**Scirpus maritima**  
**Lotond**

**Report Guideline on  
Certificate of Analysis**

☐ Yes ☐ No

Work Order #: 110710149

Custody Seal Intact: ☐ Yes ☐ No ☐ N/A

**Rush TAT**  
(Rush Surcharges Apply)

☐ 3 Business Days ☐ 2 Business Days ☐ 1 Business Day

**OR Date Required (Rush Surcharges May Apply):**

**Please provide prior notification for rush TAT**  
\*TAT is exclusive of weekends and statutory holidays

[illegible]

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16/11/3	1
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Date of

samples relinquished by (Print Name and Sign)

Date \_\_\_\_\_

Samples Received By (Print Name and Sign):

Date	Time
------	------

No.	T	O	O	O	O
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**Appendix C**  
**Selected Site Photographs**



Centerline Culvert Replacement  
Highway 572

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**Photograph 1: Culvert Inlet Looking West**



**Photograph 2: Culvert Outlet Looking East**



Centerline Culvert Replacement  
Highway 572

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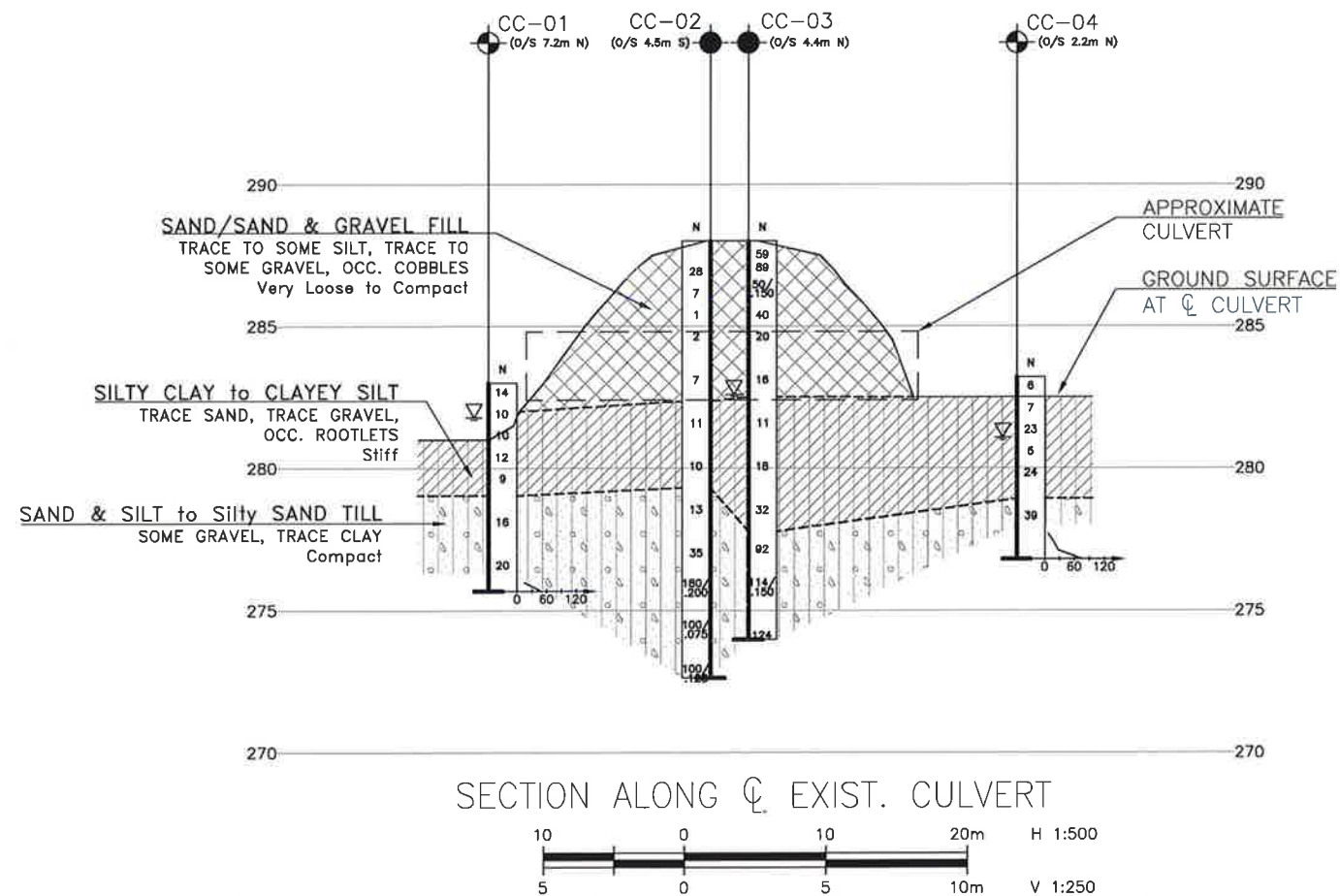
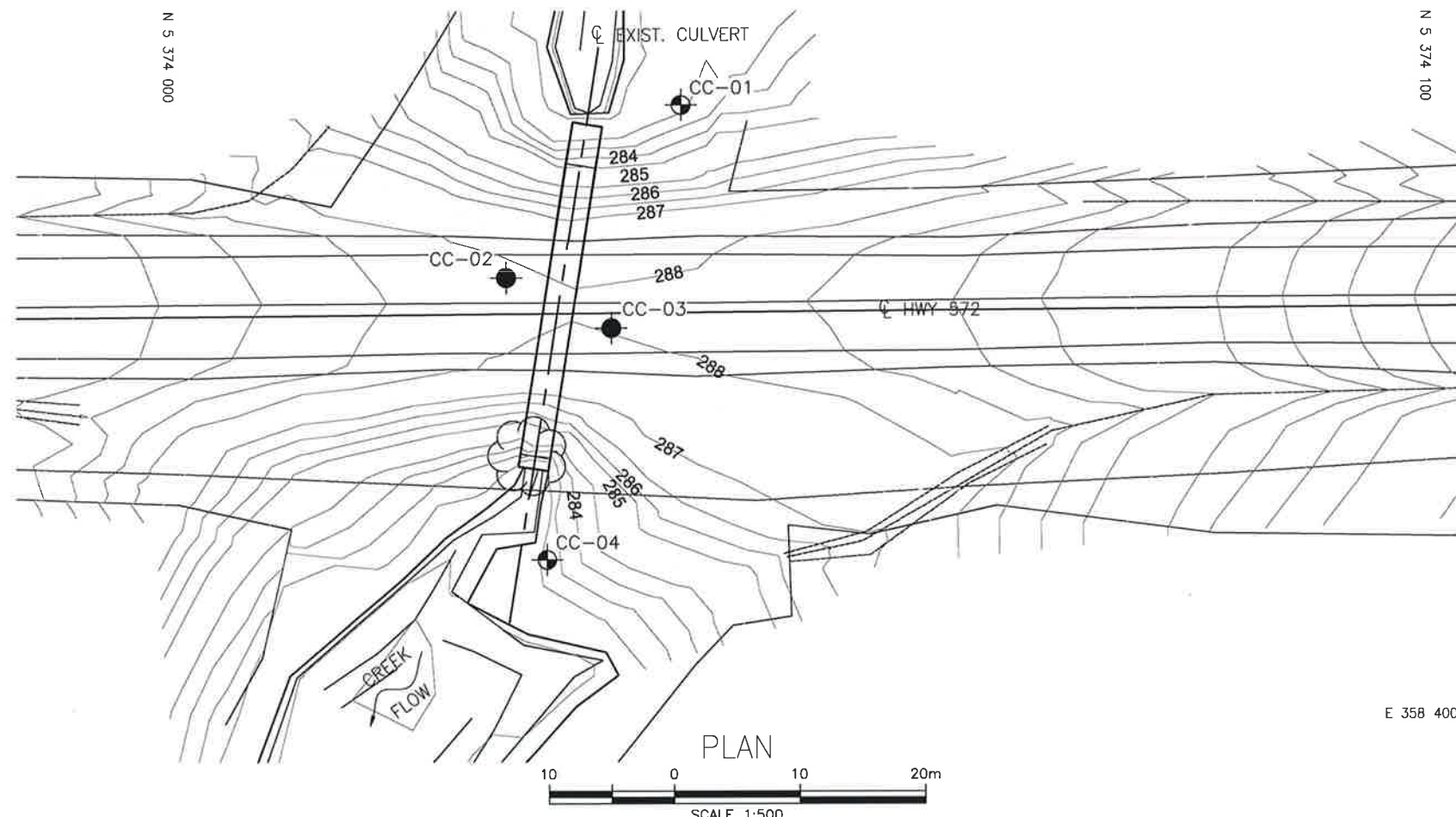
**Photograph 3: Creek - Looking East**



**Photograph 4: Creek - Looking West**

**Appendix D**  
**Borehole Locations and Soil Strata Drawing**





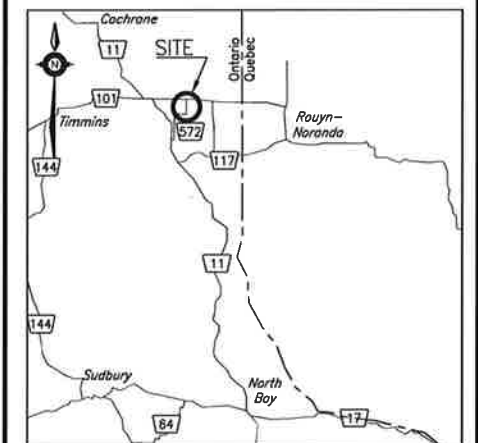
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
GWP No 5196-13-00

HIGHWAY 572  
CENTRELINE CULVERT  
REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

◆	Borehole
◆	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
↑	Water Level in Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
CC-01	283.0	5 374 041.1	358 351.9
CC-02	288.0	5 374 027.1	358 365.7
CC-03	288.0	5 374 035.5	358 369.6
CC-04	283.2	5 374 030.4	358 388.1

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) MTM, Zone 12 co-ordinate system was used to obtain boreholes Northings and Eastings.

GEOCREs No. 42A-108



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DJP	CHK	AMP
DRAWN	AN	CHK	DJP
CODE			
LOAD			
DATE	JUL 2016		
STRUCT			
DWG	1		

## **Appendix E**

### **List of Relevant OPSS and OPSD Documents**

**1. List of OPSS and OPSD Documents Relevant to this Project**

- OPSS PROV 206
- OPSS PROV 422
- OPSS PROV 501
- OPSS PROV 517
- OPSS PROV 518
- OPSS PROV 539
- OPSS PROV 804
- OPSS PROV 902
- OPSS PROV 1010
- OPSS PROV 1205
- OPSD 810.010
- OPSD 802.010
- OPSD 803.010
- OPSD 803.031

## **Appendix F**

### **Comparisons of Foundation Alternatives**

**COMPARISON OF FOUNDATION ALTERNATIVES**

Proposed Works	Concrete Box Culvert	Concrete or Corrugated Steel Pipe Culvert	Concrete Open Footing Culvert
Culvert Replacement	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Relatively rapid installation and less disturbance to subgrade soils if precast units are used.</li> <li>ii. Less requirement for soil geotechnical resistances as loading is spread over a larger width.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. More expensive than pipe culvert alternative.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Concrete or steel pipes may be more cost effective than concrete box or open footing culverts.</li> <li>ii. Relatively rapid installation.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Steel pipes could have shorter design life than concrete culverts</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. May have less environmental issues related to spawning fish species.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Requires higher soil geotechnical resistances to support strip footings.</li> <li>ii. Requires deeper excavation for strip footing construction.</li> <li>iii. Potentially more difficult unwatering requirements.</li> </ul>
	<b>FEASIBLE</b>	<b>FEASIBLE</b>	<b>NOT RECOMMENDED</b>