

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERTS  
HIGHWAY 11/17 FOUR-LANING FROM 1.0 KM WEST OF  
HODDER AVENUE/COPENHAGEN ROAD EASTERLY FOR 5.8 KM  
W.P. 334-94-00**

**Geocres Number: 52A-144**

**Report to**

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## TABLE OF CONTENTS

### **PART 1      FACTUAL INFORMATION**

1	INTRODUCTION .....	1
2	SITE DESCRIPTION .....	1
3	SITE INVESTIGATION AND FIELD TESTING .....	2
4	LABORATORY TESTING .....	4
5	DESCRIPTION OF SUBSURFACE CONDITIONS .....	4
5.1	Culvert 10 (Boreholes 09-62A, 09-62B, 10-62C, 09-63 and 10-63B).....	4
5.2	Culvert 19 (Boreholes 10-100 to 10-103) .....	7
5.3	Culvert 28 (Boreholes 104 to 107A).....	9
6	MISCELLANEOUS .....	10

### **PART 2      ENGINEERING DISCUSSION AND RECOMMENDATIONS**

7	GENERAL.....	11
8	FOUNDATION DESIGN .....	12
8.1	Culvert 10 – Copenhagen Road .....	12
8.2	Culvert 19 – Highway 11/17 Sta. 27+525.....	14
8.3	Culvert 28 – Highway 11/17 Sta. 29+950.....	15
8.4	Box Culverts - General .....	16
8.5	Spread Footings - General .....	16
9	CULVERT BACKFILL AND LATERAL EARTH PRESSURES .....	17
10	SEISMIC CONSIDERATIONS.....	18
11	EROSION CONTROL .....	19
12	EXCAVATION AND GROUNDWATER CONTROL .....	19
13	CONSTRUCTION CONCERNS .....	20
14	CLOSURE .....	21

### **Appendices**

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Foundation Comparison
Appendix D	Special Provisions
Appendix E	Site Photographs
Appendix F	Borehole Locations and Soil Strata Drawings

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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted for three culverts to be installed in connection with the proposed widening of Highway 11/17 in Thunder Bay, Ontario.

Highway 11/17 will be widened from a two-lane undivided highway to a four-lane divided section from 1.0 km west of Hodder Avenue/Copenhagen Road easterly for 5.8 km. The project will include realignment of Copenhagen Road north of the highway. The Savigny Creek culvert under Copenhagen Road and the Catbert Creek and Ishkibibble Creek culverts crossing Highway 11/17 will be replaced.

The purpose of the investigation was to explore the subsurface conditions at the proposed culvert locations and, based on the data obtained, to provide borehole logs, borehole location plans, stratigraphic profiles, and written descriptions of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to McCormick Rankin Corporation, under the Ministry of Transportation Ontario (MTO) Agreement Number 6008-E-0005.

**2 SITE DESCRIPTION**

The project site lies at the northeast limit of the City of Thunder Bay. The Savigny Creek culvert under Copenhagen Road and the Catbert Creek and Ishkibibble Creek culverts crossing Highway 11/17 will be replaced with larger and longer culverts. The culvert locations are as follows:

**Table 2.1 – Culvert Locations**

<b>Culvert Name</b>	<b>Roadway</b>	<b>Station</b>
Savigny Creek	Copenhagen Road	9+572
Catbert Creek	Highway 11/17	27+525
Ishkibibble Creek	Highway 11/17	29+956

The lands surrounding the culvert sites are generally forested with low marshy areas adjacent to the creeks. The ground surface rises sharply north of the culverts on Highway 11/17. Photographs of the culvert sites are included in Appendix E.

Geologically, the site area is located within the physiographic region known as the Canadian Shield, characterized by Pre-Cambrian bedrock typically occurring as rounded knobs and ridges where exposed. At this site, the bedrock consists of the Gunflint Formation, a sequence of limestone, graphitic shale, tuff, taconite, chert-carbonite and chert. Intrusions/sills of diorite are present locally. The bedrock is overlain by a discontinuous layer of glacial till comprising a heterogeneous mixture of clayey silt, silt, sand and gravel.

### 3 SITE INVESTIGATION AND FIELD TESTING

The site investigation was carried out in two stages with an initial three boreholes drilled at the Savigny Creek site on July 13 and 14, 2009 and the remainder of the boreholes drilled between January 22 and 31, 2010. The boreholes were terminated upon auger refusal at depths of 0.7 to 7.2 m. One borehole location (borehole 10-107) could not be accessed by drilling equipment and therefore a hand-shovel was used to confirm bedrock at the surface at this location. A supplementary borehole (borehole 10-107A) was advanced nearby.

The approximate locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawings in Appendix F. The borehole elevations, locations and depths are summarized in Table 3.1.

**Table 3.1 – Borehole Summary**

Culvert	Borehole	Ground Surface Elevation (m)	Location		Total Depth (m)
			Northing	Easting	
Savigny Creek	09-62A	256.2	5 372 403.2	365 250.9	1.5
	09-62B	256.8	5 372 421.6	365 255.9	1.7
	10-62C	256.0	5 372 404.5	365 240.7	2.4
	09-63	256.3	5 372 405.5	365 261.0	1.5
	10-63B	256.5	5 372 428.0	365 280.1	5.4
Catbert Creek	10-100	238.7	5 372 611.3	367 259.0	7.2
	10-101	238.2	5 372 585.6	367 277.1	1.5
	10-101A	238.1	5 372 589.9	367 274.1	4.4
	10-102	240.5	5 372 568.2	367 283.8	7.2
	10-103	237.9	5 372 538.1	367 298.2	3.3
Ishkibibble Creek	10-104	251.7	5 373 948.9	369 222.6	1.4
	10-105	259.9	5 373 970.8	369 208.2	4.2
	10-106	255.8	5 374 013.8	369 231.2	0.7
	10-107	263.6	5 374 060.7	369 235.9	0.0
	10-107A	260.5	5 374 044.2	369 228.7	0.8

Prior to commencing the site investigation, clearance was obtained from utility companies having plant in the area.

Hollow-stem augers were used to advance the boreholes to auger refusal. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the soils.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. In boreholes 10-100 and 10-103, standpipe piezometers consisting of 19 mm PVC pipe with a slotted screen were installed and enclosed in filter sand to permit longer term groundwater level monitoring. The completion details of the piezometers are shown in Table 3.2. Following the final water level reading, the piezometers were decommissioned in accordance with MOE Regulation 903.

The boreholes in which no piezometers were installed were backfilled with bentonite and cuttings. The borehole completion details are shown in Table 3.2.

**Table 3.2 – Borehole Completion Details**

Borehole	Piezometer Tip		Completion Details
	Depth (m)	Elevation (m)	
09-62A	-	-	Borehole backfilled with cuttings to surface
09-62B	-	-	Borehole backfilled with cuttings to surface
10-62C	-	-	Borehole backfilled with cuttings to 1.2 m, then bentonite to surface
09-63	-	-	Borehole backfilled with cuttings to surface
10-63B	-	-	Borehole backfilled with cuttings to 2.1 m, then bentonite to surface
10-100	7.0	231.7	Piezometer with 1.5 m slotted screen installed with sand filter to 4.9 m, bentonite seal from 4.9 m to ground surface
10-101	-	-	Borehole backfilled with cuttings to surface
10-101A	-	-	Borehole backfilled with sand to 0.9 m, then bentonite to surface
10-102	-	-	Borehole backfilled with sand to 3.9 m, then bentonite from 3.9 to 0.2 m, then asphalt to surface
10-103	3.3	234.5	Piezometer with 1.5 m slotted screen installed with sand filter to 1.8 m, bentonite seal from 1.8 m to ground surface
10-104	-	-	Borehole backfilled with cuttings to surface
10-105	-	-	Borehole backfilled with sand to 2.4 m, then bentonite from 2.4 to 0.2 m, then asphalt to surface
10-106	-	-	Borehole backfilled with cuttings to surface
10-107A	-	-	Borehole backfilled with cuttings to surface

#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A.

Selected samples were also subjected to gradation analysis and Atterberg Limits testing. The results of this testing program are shown on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B.

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

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil stratigraphy are presented in these appendices and on the “Borehole Locations and Soil Strata” drawings in Appendix F. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

##### **5.1 Savigny Creek Culvert**

##### **Boreholes 09-62A, 09-62B, 10-62C, 09-63 and 10-63B**

The stratigraphy encountered in the boreholes drilled at Savigny Creek consisted of a layer of peat, organics or topsoil of varying thickness, overlying discontinuous deposits of silt, silty clay and silty sand, underlain by silty sand to sand and silt till.

##### **Peat, Organics and Topsoil**

The surficial organic layer encountered in the boreholes varied from a 200 mm thick topsoil layer in borehole 09-62A, to a 300 mm thick layer of black organics in boreholes 09-62B and 09-63, to a dark brown peat deposit extending to depths of 1.5 and 2.0 m in boreholes 10-62C and 10-63B. The base of the peat layer is at elevation 254.4 to 254.5 m.

Standard Penetration Test ‘N’ values of 0 to 3 blows/0.3 m were recorded in the peat layer. Moisture contents ranged from 87 to 155%.

##### **Silt**

A 2.3 m thick layer of grey silt, some clay, trace sand was encountered below the peat in borehole 10-63B. The lower boundary of the silt was at 4.3 m depth (elevation 252.3 m).

SPT ‘N’ values of 16 and 8 blows/0.3 m were obtained in the silt, indicating a compact to loose condition. Moisture contents ranged from about 23 to 28%.

The results of a laboratory grain size distribution test carried out on a sample of the silt (Figure B1, Appendix B) were as follows:

Gravel (%)	0
Sand (%)	1
Silt (%)	88
Clay (%)	11

### **Silty Clay**

A discontinuous silty clay layer was encountered below the organic layer in borehole 09-62B and below the silt deposit in borehole 10-63B. The clay was described as dark brown with topsoil staining (organics) in borehole 09-62B and grey in borehole 10-63B. The clay layer was 1.1 and 0.6 m thick in the respective boreholes, with a lower boundary at elevation 255.4 and 251.7 m.

SPT 'N' values of 4 and 8 blows/0.3 m were obtained in the clay, indicating a soft to firm consistency. Moisture contents of 70% (borehole 09-62B) and 17% (borehole 10-63B) were determined.

The results of a laboratory grain size distribution test and Atterberg Limits test carried out on a sample of the clay were as follows:

Gravel (%)	5
Sand (%)	19
Silt (%)	57
Clay (%)	19
Liquid Limit	28
Plastic Limit	19

The grains size and Atterberg Limits test results are plotted on Figures B2 and B6 of Appendix B, respectively. The Atterberg Limits indicate that the clay is low plastic (CL).

### **Silty Sand**

A 0.5 m thick layer of loose to compact, grey silty sand was encountered below the clay in borehole 10-63B. Auger refusal was met in this deposit at 5.4 m depth (elevation 251.1 m). A moisture content of 12% was determined.

### **Silty Sand to Sand and Silt Till**

A till deposit consisting of silty sand to sand and silt was encountered below the organic deposits in boreholes 09-62A, 10-62C and 09-63, and below the clay layer in borehole 09-62B. The upper boundary of this unit was encountered at depths of 0.2 to 1.5 m (elevation 254.4 to 256.0 m). Auger refusal was met at depths of 1.5 to 2.4 m in/below the till. Till soils often contain cobbles and boulders.



SPT 'N' values recorded in three of the boreholes ranged from 4 to 17 blows/0.3 m, indicating a loose to compact condition. 'N' values of 50 blows/0.075 m and 100 blows/0.1 m were obtained in two boreholes, reflecting the presence of cobbles or possible bedrock. The moisture content of samples from this deposit ranged from about 10 to 15%, locally 32% in borehole 09-62A.

The results of laboratory grain size distribution tests carried out on samples of the till are shown in Figure B3, Appendix B. The results were as follows:

Gravel (%)	4 to 12
Sand (%)	48 to 57
Silt (%)	23 to 38
Clay (%)	4 to 10

### Auger Refusal

Auger refusal was encountered on possible bedrock or boulders at depths of 1.5 to 5.4 m in all boreholes. The depths to auger refusal are summarized in Table 5.1.

**Table 5.1 – Depth to Auger Refusal**

Borehole	Depth to Refusal (m)	Refusal Elevation (m)
09-62A	1.5	254.6
09-62B	1.7	255.1
10-62C	2.4	253.6
09-63	1.5	254.7
10-63B	5.4	251.1

### Groundwater

The groundwater depths and elevations observed in the boreholes upon completion of drilling are summarized in Table 5.2.

**Table 5.2 – Groundwater Depths and Elevations**

Borehole	Date	Water Level (m)	
		Depth	Elevation
09-62A	13-Jul-09	0.8	255.4
09-62B	14-Jul-09	Dry	-
10-62C	31-Jan-10	1.4	254.6
09-63	13-Jul-09	1.4	254.9
10-63B	31-Jan-10	0.7	255.7

The above water levels reflect the unstabilized conditions in the boreholes upon completion of drilling. The measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected.

## **5.2 Cathbert Creek Culvert**

### **Boreholes 10-100 to 10-103**

The subsurface stratigraphy encountered in the boreholes drilled at Cathbert Creek consisted of a peat layer or existing highway embankment fill overlying sandy silt to silty sand. Auger refusal was met below the sands and silts at depths of 1.5 to 7.2 m.

#### **Fill**

Borehole 10-102 was drilled on the north side of the existing Highway 11/17 embankment and encountered a 75 mm thick asphalt layer overlying sand and gravel fill to 1.5 m depth (elevation 239.0 m), followed by a 0.8 m thick layer of silt and sand fill. The lower boundary of the fill was encountered at a depth of 2.3 m (elevation 238.2 m).

The sand and gravel fill was described as brown, and the sand and silt fill was dark brown.

A Standard Penetration Test 'N' value of 50 blows/0.125 m was obtained in the sand and gravel, reflecting a frozen or very dense condition. An 'N' value of 32 blows/0.3 was recorded in the sand and silt fill, indicating a dense condition.

Moisture contents were approximately 6 and 9 % in the sand and gravel fill, and 12% in the sand and silt fill.

#### **Peat**

A 0.6 to 0.9 m thick layer of peat was encountered in boreholes 10-100, 10-101A and 10-103. The lower boundary of the peat was at elevation 236.9 to 238.1 m, rising to the north. The moisture content of the peat ranged from 34 to 204%.

#### **Sandy Silt to Silty Sand**

A relatively thick deposit of sands and silts, ranging from sandy silt to silty sand, was encountered at the ground surface in borehole 10-101 and below the peat and fill in the remaining boreholes. The sand/silt was described most often as grey, however it was brown in borehole 10-101, dark brown with organics in the upper 0.7 m of this unit in borehole 10-101A, and brown to dark brown to about 5 m depth in borehole 10-102.

Auger refusal was encountered within or below the sand/silt at depths of 1.5 to 7.2 m.

The results of laboratory grain size distribution tests carried out on samples of the sands and silts are illustrated in Figure B4, Appendix B. The results were as follows:

Gravel (%)	1 to 8
Sand (%)	29 to 55
Silt (%)	37 to 65
Clay (%)	4 to 5

SPT 'N' values obtained in the sands and silts were variable. In the upper 0.7 to 1.5 m of this deposit in boreholes 10-101 to 10-103, 'N' values ranged from 1 to 7 blows/0.3 m,

indicating a loose to very loose condition. Below this zone (elevation 235.6 to 236.6 m) and below the peat in borehole 10-100 (elevation 238.1 m), 'N' values ranged from 16 to 100 blows/0.3 m, indicating a variable compact to very dense condition.

The moisture content of samples from this deposit ranged from about 10 to 25%.

#### Auger Refusal

Auger refusal was encountered on possible bedrock or boulders at depths of 1.5 to 7.2 m in all boreholes. The depths to auger refusal are summarized in Table 5.3.

**Table 5.3 – Depth to Auger Refusal**

Borehole	Depth to Refusal (m)	Refusal Elevation (m)
10-100	7.2	231.6
10-101	1.5	236.7
10-101A	4.4	233.7
10-102	7.2	233.3
10-103	3.3	234.5

#### Groundwater

The groundwater depths and elevations observed in the boreholes upon completion of drilling and subsequently in the piezometers installed in two boreholes are summarized in Table 5.4.

**Table 5.4 – Groundwater Depths and Elevations**

Borehole	Date	Water Level (m)		Event
		Depth	Elevation	
10-100	29-Jan-10	2.4	236.3	Upon completion
	31-Jan-10	0.5	238.2	In piezometer
	01-Mar-10	0.9	237.8	In piezometer
10-101	24-Jan-10	1.4	236.8	Upon completion
10-101A	31-Jan-10	0.8	237.3	Upon completion
10-102	26-Jan-10	2.2	238.3	Upon completion
10-103	23-Jan-10	0.0	237.9	Upon completion
	31-Jan-10	0.6	237.3	In piezometer
	01-Mar-10	0.7	237.2	In piezometer

The above water levels reflect the unstabilized conditions in the boreholes upon completion of drilling or the piezometric head at the level of the piezometer tips at the time of the readings. The measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected.

### **5.3 Ishkibibble Creek Culvert Boreholes 104 to 107A**

The subsurface stratigraphy encountered in the boreholes drilled at Ishkibibble Creek consisted of existing embankment fill overlying a relatively thin layer of silty sand. Auger refusal was met at depths of 0.7 to 4.2 m, and bedrock was exposed at the north end of the culvert alignment.

#### **Fill**

Borehole 10-105 was drilled on the north side of the existing Highway 11/17 embankment and encountered a 75 mm thick asphalt layer overlying sand and gravel fill to 1.5 m depth, followed by sand fill to 3.0 m depth (elevation 256.9 m). Borehole 10-104, drilled near the south toe of the highway embankment, encountered 0.8 m of sand and gravel fill.

The sand and gravel fill was described as brown in borehole 10-105, and brown to dark brown in borehole 10-104. The underlying sand fill in borehole 10-105 was dark brown.

Standard Penetration Test 'N' values of 47 and 55 blows/0.3 m were obtained in the sand fill, indicating a dense to very dense condition.

Moisture contents in the fill were approximately 7 to 11 % in borehole 10-105, and 30% in borehole 10-104.

The results of a laboratory grain size distribution test carried out on a sample of the sand fill are shown on Figure B5 in Appendix B and were as follows:

Gravel (%)	20
Sand (%)	60
Silt and Clay (%)	20

#### **Silty Sand**

A thin layer of silty sand was encountered below the fill in boreholes 10-104 and 10-105 and at the ground surface in boreholes 10-106 and 10-107A. The silty sand was described brown to dark brown with occasional roots or organics. Auger refusal was encountered at depths of 0.7 to 4.2 m, indicating a layer thickness of 0.6 to 1.2 m.

SPT 'N' values obtained in the silty sand ranged from 17 to 52 blows/0.3 m, indicating a compact to very dense condition.

Moisture contents of 8 and 20% were determined in this deposit.

#### **Auger Refusal**

Auger refusal was encountered on possible bedrock or boulders at depths of up to 4.2 m in all boreholes. The depths to auger refusal are summarized in Table 5.5.

Table 5.5 – Depth to Auger Refusal

Borehole	Depth to Refusal (m)	Refusal Elevation (m)
10-104	1.4	250.3
10-105	4.2	255.7
10-106	0.7	255.1
10-107A	0.8	259.8
10-107	0.0	263.6

### Groundwater

Groundwater was not observed in the boreholes during or upon completion of drilling. The water level observations are short-term and seasonal fluctuations of the groundwater level are to be expected.

## 6 MISCELLANEOUS

J.D. Barnes Limited determined the co-ordinates and ground elevations at the boreholes following completion of the site investigation.

TBT Engineering Consulting Group of Thunder Bay, Ontario supplied and operated the drilling and sampling equipment for the field program. Full time supervision of the field activities, including obtaining utility clearances, was carried out by Mr. Stephane Loranger and Mr. Jason Mei of Thurber.

Supervision of the field program, interpretation of the field data, and preparation of the report was performed by Mr. Tony Harte and Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 GENERAL**

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for design of the culverts.

Highway 11/17 will be widened from a two-lane undivided highway to a four-lane divided section from 1.0 km west of Hodder Avenue/Copenhagen Road easterly for 5.8 km. Copenhagen Road north of the highway will also be realigned. The work will include replacement of the Savigny Creek culvert under Copenhagen Road and the Catbert Creek and Ishkibibble Creek culverts crossing Highway 11/17.

The locations and approximate invert levels of the proposed structures shown on General Arrangement drawings provided by MTO Northwestern Region (Savigny and Catbert Creeks) and McCormick Rankin Corporation (Ishkibibble Creek) are summarized in Table 7.1.

**Table 7.1 – Proposed Culvert Details\***

Culvert	Roadway	Station	Culvert Type	Approximate Invert Level (m)	
				U/S	D/S
Savigny Creek	Copenhagen Rd	9+572	Open Bottom	~255.0	~255.0
Catbert Creek	Highway 11/17	27+525	Open Bottom	237.6	237.4
Ishkibibble Creek	Highway 11/17	29+956	Box Culvert	260.5	256.0

*\* The current investigations were carried out in anticipation of culvert installation and are considered adequate for open footing or box culvert design. GA drawings for the Savigny and Catbert Creek sites, provided by MTO Northwestern Region subsequent to completion of the investigation, indicate that the structures at these locations will comprise 8 m span bridges supported on steel sheet pile walls driven to bedrock. Additional investigation including coring of bedrock is recommended to provide design recommendations for bridge foundations and assess constructability of the proposed sheet pile structures.*

The discussion and recommendations presented in this report are based on the above information and on the factual data obtained in the course of the investigation.

## 8 FOUNDATION DESIGN

As noted in Table 7.1, open bottom culverts are planned at the Savigny Creek and Catbert Creek sites, and a box culvert is proposed for Ishkibibble Creek.

For the open bottom structures, consideration was given to the use of spread footings on native soil, bedrock or engineered fill as well as deep foundations such as driven piles or augered caissons. A comparison of the technical advantages and disadvantages of the different foundation schemes is provided in Table 8.1, Appendix C.

The box culvert will be constructed on native soil, bedrock or engineered fill.

Further discussion on the feasibility of the alternative foundation types and recommendations for design of foundations for each culvert are presented below.

### 8.1 Savigny Creek

#### Open Footing Culvert

Construction of an open footing culvert on spread footings is considered feasible at this site. Footings for an open footing culvert should be founded on bedrock. Probable bedrock was encountered at elevation 253.6 to 255.1 m in all boreholes except borehole 10-63B.

With the exception of the east end (borehole 10-63B), it is anticipated that the culvert footings will be founded on bedrock above the normal frost depth of 2.2 m (elevation 252.8 m). Excavation of the bedrock to provide the minimum 2.2 m of frost protection is not considered necessary at this site.

At the east end of the culvert (borehole 10-63B), probable bedrock was encountered at elevation 251.1 m, approximately 1.7 m below the normal frost depth. To minimize the potential for differential settlement along the culvert, it is recommended that the culvert footings in this area be extended to the bedrock surface as well.

Approximate 1 to 2 m wide footings founded on bedrock may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	450 kPa
Geotechnical Resistance at SLS	=	300 kPa

Relatively low resistance values (for bedrock) are recommended for design as the bedrock surface was not confirmed by rock coring. These values are also considered suitable for founding on boulders and/or till, and are provided with the intent of minimizing

construction delays in the event that auger refusal in the boreholes was met on boulders in the till.

It is anticipated that a steel sheet pile enclosure in conjunction with a dewatering system will be necessary for footing construction. Prior to excavation, the groundwater level within the enclosure should be lowered to at least 0.5 m below the base of the excavation. A suggested wording for an NSSP on dewatering is included in Appendix D.

The effectiveness of the enclosure and dewatering system may be limited as seepage cutoff between the bottom of the sheet piles and the rock may be incomplete. Considering the increased excavation depth and potential dewatering issues, a box culvert or alternative culvert design should be considered for this site.

### **Box Culvert**

The base level for a box culvert with an invert at elevation 255.0 m is expected to be near elevation 254.5 m. At this level, the anticipated subgrade varies from probable bedrock (boreholes 09-62A, 09-62B and 09-63), to compact sand and silt till (borehole 10-62C), and loose to compact silt (borehole 10-63B).

Placement of a box culvert at the anticipated level is considered feasible, however it is recommended that the subgrade be improved to reduce the potential impacts of the non-uniform support provided by the variable rock, till and silt subgrade. In this regard, the following comments and recommendations pertaining to the east end of the culvert are provided:

- The loose to compact silt encountered in borehole 10-63B, as well as any other areas of loose/soft material below the culvert base, should be subexcavated to a depth of at least 1.5 m below the culvert base.
- It is anticipated that a steel sheet pile enclosure will be required to carry out the excavation. Subexcavation will extend nearly 3 m below the water level observed during drilling, and the loose, saturated silt is prone to disturbance and sloughing when excavated below the water table.
- Prior to excavation, the groundwater level within the enclosure should be lowered to at least 0.5 m below the base of the excavation. A suggested wording for an NSSP on dewatering is included in Appendix D.
- The excavation should be backfilled with rock fill to within 300 mm of the culvert base. The rockfill should be placed in accordance with SP 206S03 and the NSSP for rock fill provided in Appendix D.
- The surface of the rockfill should be chinked with rock fragments and spall. The chinked surface should then be covered with a 300 mm thick layer of Granular A bedding material.



The culvert base founded on a subgrade prepared as outlined above may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	300 kPa
Geotechnical Resistance at SLS	=	200 kPa

Auger refusal was encountered in borehole 09-62B at 0.6 m above the anticipated culvert base level, and therefore rock excavation may be required to establish the culvert level. Coring would be required to determine whether refusal was met on boulders or bedrock.

## 8.2 Catbert Creek

### Open Footing Culvert

Construction of an open footing culvert on spread footings is considered feasible at this site. The anticipated founding level, assuming 2.2 m of frost cover over the footing base, is elevation 235.2 to 235.4 m. Footings for an open footing culvert founded on the compact to very dense sand and silt at this level may be designed using the following resistance values (assuming a 1 to 2 m wide footing):

Factored Geotechnical Resistance at ULS	=	350 kPa
Geotechnical Resistance at SLS	=	250 kPa

### Box Culvert

The base level for a box culvert with an invert at elevation 237.4 to 237.6 m is expected to be elevation 237.0 to 237.2 m. At this level, the subgrade is expected to consist of very loose to dense sands and silts. In general, placement of a box culvert at the anticipated level is considered feasible, however subexcavation and replacement of loose to very loose and/or organic material is recommended to reduce the potential impacts of the non-uniform support conditions.

The recommendation subexcavation levels at the borehole locations are as follows:

Borehole 10-101A	El. 236.5 m
Borehole 10-102	El. 236.0 m
Borehole 10-103	El. 235.5 m

Fill placed below the culvert to re-establish the base level should consist of compacted Granular A or B Type II material.

The culvert base founded on a subgrade prepared as outlined above may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	300 kPa
Geotechnical Resistance at SLS	=	200 kPa

### 8.3 Ishkibibble Creek

#### Box Culvert

The General Arrangement drawing indicates that the culvert invert will fall relatively steeply from elevation 260.5 m at the inlet to elevation 256.0 m at the outlet. The ground surface and probable rock surface also drop towards the south.

The proposed invert level may be above the existing ground surface at the highway median and at the culvert outlet, and fill placement will be required to raise the culvert subgrade in these areas. Bedrock excavation will be required to establish the culvert subgrade level along other sections. The culvert subgrade will therefore vary between bedrock, silty sand and fill.

To reduce the potential for non-uniform support between the bedrock and fill subgrade, it is recommended that rockfill be used to raise the culvert subgrade in low areas. The rockfill should be placed in accordance with SP 206S03 and the NSSP for rock fill provided in Appendix D.

The surface of the rockfill should be chinked with rock fragments and spall. The chinked surface should then be covered with a 300 mm thick layer of Granular A bedding material.

The culvert base founded on a subgrade prepared as outlined above may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	350 kPa
Geotechnical Resistance at SLS	=	250 kPa

#### Open Footing Culvert

Construction of an open footing culvert on spread footings is also considered feasible at this site. It is recommended that all footings for an open footing culvert be founded on bedrock to minimize the potential for differential settlement along the culvert.

Probable bedrock was encountered in the boreholes at elevations ranging from 263.6 m near the inlet to 250.3 m near the outlet. Bedrock excavation will be required to establish the culvert invert near the inlet and possibly under the eastbound lanes. Excavation of the bedrock to provide the minimum 2.2 m of frost protection is not considered necessary.

Approximate 1 to 2 m wide footings founded on bedrock may be designed using the following resistance values:

Factored Geotechnical Resistance at ULS	=	450 kPa
Geotechnical Resistance at SLS	=	300 kPa

Relatively low resistance values (for bedrock) are recommended for design as the bedrock surface was not confirmed by rock coring. These values are also considered suitable for founding on boulders and/or till, and are provided with the intent of minimizing

construction delays in the event that auger refusal in the boreholes was met on boulders in the till.

#### **8.4 Box Culverts - General**

Following excavation to the design base level of the culvert, any remaining fill, topsoil, peat, streambed deposits or soft soils within the culvert footprint should be subexcavated. The exposed surface must be inspected to confirm that the subgrade is uniformly competent. Any fill placed below the culvert to re-establish the founding level should consist of compacted Granular A or B Type II material. This work should be carried out in accordance with SP 902S01.

A minimum 300 mm thick layer of bedding material conforming to OPSS Granular A requirements should be provided under the base of box culverts, as per OPSD 803.010. The bedding material should be placed as soon as practical following inspection and approval of the final subgrade as protection from disturbance during construction.

Use of a precast concrete culvert is preferred over a cast-in-place culvert since installation is likely to be more expedient with less potential for disturbance of the founding soils during construction.

#### **8.5 Spread Footings - General**

Spread footings for open frame culverts should be founded on compact to very dense native deposits or bedrock. Following excavation to the design founding level, any remaining fill, topsoil, peat, streambed deposits or soft soils on the bearing surface should be subexcavated and replaced with concrete of the same class as the footing concrete. Any shattered rock or rock fragments should also be removed from the bearing surface.

The resistance values provided for spread footings 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 Clause 6.7.3 and Clause 6.7.4.

The geotechnical SLS resistance values given above are based on an estimated total settlement not exceeding 25 mm. This settlement is expected to be substantially complete by the end of construction.

The lateral resistance of the footings may be computed using unfactored friction coefficients of 0.4 on compact to dense sands and silts, and 0.7 on sound bedrock. These are “ultimate” values and require a degree of sliding movement to occur to fully mobilize the resistance.

All founding surfaces comprising native sands and silts should be protected from disturbance during construction by placement of a 75 mm mud slab on the prepared bearing surface as soon as practical following inspection and approval.

A frost penetration depth of 2.2 m should be used during foundation and backfill design to provide protection against frost action on the culvert foundations. Frost action is not a concern for footings on bedrock.

## 9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining granular material conforming to OPS Granular A or B Type II specifications. The granular material should be placed to the extents shown in OPSD 803.010.

Backfill should be placed and compacted in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation should be within 400 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. Compaction should be carried out in accordance with SP 105S10.

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

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

where:  $p$  = horizontal pressure on the wall at depth  $h$  (kPa)

$K$  = earth pressure coefficient (see table below)

$\gamma$  = 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 are dependent on the material used as backfill. Recommended unfactored values are shown in Table 9.1. The at-rest coefficients should be employed for restrained culvert walls. Active pressures should be used for any wingwalls or unrestrained walls.

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

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.38*	0.31	0.46*
At Rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-

\* For wing walls.

The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.9.1 (a) of the Commentary to the CHBDC.

In accordance with Clause 6.9.3 of the CHBDC, 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 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II.

The design of the culvert must incorporate measures such as weepholes to permit drainage of the culvert backfill and avoid the potential build-up of hydrostatic pressures behind the walls.

## 10 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.0
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.0
- Peak Horizontal Acceleration 0.02

The soil profile type at this site has been classified as Type I. Therefore, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.0 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 10.1 may be used:

**Table 10.1 – Earth Pressure Coefficient for Earthquake Loading**

Earth Pressure Coefficient (K) for Earthquake Loading				
Wall Condition	Granular A or Granular B Type II $\phi = 35^\circ; \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ; \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active ( $K_{AE}$ )*	0.28	0.41	0.32	0.49
Passive ( $K_{PE}$ )	3.7	-	3.2	-
At Rest ( $K_{OE}$ )**	0.45	-	0.50	-

\* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

\*\* After Woods

The foundation soils at the site are assessed as not being prone to liquefaction.

## **11 EROSION CONTROL**

Erosion protection should be provided at the culvert inlet and outlet areas as applicable. Design of the erosion protection measures must consider hydrologic and hydraulic concerns 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. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in accordance with OPSS 572.

It is recommended that a clay seal or a concrete cut-off wall be used to minimize the potential for erosion near the inlet area. The clay seal should extend above the high water level, have a minimum thickness of 0.5 m, and extend laterally the width of the granular backfill material. The material requirements should be in accordance with OPSS 1205.

## **12 EXCAVATION AND GROUNDWATER CONTROL**

In general, surface vegetation, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the culvert area and embankment footprint prior to culvert installation.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of assessing excavation slope requirements in compliance with the OHSA, the existing fill, till and sands and silts above the water table are classified as Type 3 soil. Below the water table, the cohesionless soils are classified as Type 4 soil.

Temporary shoring may be required to retain the existing embankment fill and subgrade during culvert installation. Based on available subsurface information, a shoring system consisting of steel H-piles with timber lagging may be considered. Temporary shoring should be designed by a licensed Professional Engineer experienced in design of shoring with consideration of adjacent traffic loads and any sloping retained surfaces. Roadway protection should be supplied in accordance with SP 539S01 and designed for Performance Level 2.

Temporary stream diversion measures such as impervious dykes should be provided to divert surface water runoff and stream flow away from the culvert excavations at all times during construction. The Contract Documents should specify that an appropriate dewatering operation shall be provided to maintain a stable and reasonably dry excavation. Although the responsibility for selecting appropriate dewatering methods remains the responsibility of the Contractor, it is anticipated that wellpoints and/or a sheet pile enclosure at Culverts 10 and 19, and pumping from properly filtered sumps at Culvert 28, will be adequate. Suggested wording for an NSSP regarding dewatering is provided in Appendix D.

Decisions regarding dewatering, shoring methods and sequencing should be made by the contractor and submitted to the Contract Administrator for information purposes.

### 13 CONSTRUCTION CONCERNS

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

- Excavation for installation of the culverts may encounter existing approach fill or loose, organic, wet or otherwise deleterious materials requiring flattening of excavation sideslopes or installation of temporary shoring. Shoring should be provided as required to minimize potential movement of the road embankment fill. Temporary shoring systems should be properly designed by a Professional Engineer experienced in such designs.
- Care must be exercised during excavation to avoid disturbing the founding subgrade. The exposed subgrade should be protected from physical disturbance, and the granular bedding and/or a mud slab must be placed on the approved subgrade expeditiously following excavation. Temporary stream diversion, in conjunction with sump pits or wellpoints as required, is essential to maintaining a reasonably dry excavation.
- Soft organic alluvial material may be present to greater depths than encountered at the borehole locations. The subgrade exposed at the design level should be examined and any deleterious materials removed and replaced with compacted granular bedding material. The culvert subgrade must be uniformly competent and should be inspected and approved by the Contractor's QVE as per SP 902S01.
- The probable bedrock surface was defined by auger refusal. Bedrock was not proved by rock coring methods, and therefore refusal may have been encountered on cobbles or boulders in the soils above the bedrock surface.
- The bedrock surface may vary between and beyond the borehole locations. Additional rock excavation may be required where the rock surface is higher than anticipated, or additional subexcavation of soil above the rock may be required where footings are to extend to the rock surface.

The successful performance of the culverts will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified geotechnical personnel during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

## 14 CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.  
Murray R. Anderson, P.Eng., M.Eng.  
Senior Geotechnical Engineer



P.K. Chatterji, P.Eng., Ph.D.  
Review Principal





## **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

$C_{pen}$  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.

# 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
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No 09-062A

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 403.2 E 365 250.9 ORIGINATED BY SLL  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2009.07.13 - 2009.07.13 CHECKED BY TH

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
256.2														
0.0	TOPSOIL, with roots and rootlets													
0.2	Silty SAND, some gravel, trace clay Loose Brown Wet (TILL)		1	SS	4									
254.6														
1.5	END OF BOREHOLE AT 1.5m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN TO 1.1m AND WATER LEVEL AT 0.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.													

# RECORD OF BOREHOLE No 09-062B

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 421.6 E 365 255.9 ORIGINATED BY SLL  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2009.07.14 - 2009.07.14 CHECKED BY TH

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									
256.8								20	40	60	80	100					
0.0	ORGANICS, with roots and rootlets Black																
256.5																	
0.3	Silty CLAY, topsoil stained, trace roots and rootlets Soft to Firm Dark Brown		1	SS	4		256										
255.4																	
1.4	Silty SAND		2	SS	50												
255.1	Very Dense Brown																
1.7	(TILL)				.075												
END OF BOREHOLE AT 1.7m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.																	

+<sup>3</sup> . X<sup>3</sup> : Numbers refer to  
Sensitivity


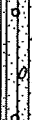
20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 10-062C

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 404.5 E 365 240.7 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.31 - 2010.01.31 CHECKED BY TH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE					
256.0							20	40	60	80	100	PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L		
0.0	PEAT, trace roots Dark Brown Frozen		1	AS												
			1	SS	3											
254.4																
1.5	SAND and SILT, some gravel Compact Grey Moist (TILL)		2	SS	15											
253.6			3	SS	100/											
2.4	END OF BOREHOLE AT 2.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN TO 1.7m, AND WATER LEVEL AT 1.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 1.2m, THEN BENTONITE TO SURFACE.				0.100											

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 09-063

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 405.5 E 365 261.0 ORIGINATED BY SLL  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2009.07.13 - 2009.07.13 CHECKED BY TH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100						
256.3								SHEAR STRENGTH kPa						
0.0	ORGANICS, peat		1	AS				○ UNCONFINED + FIELD VANE						
256.0	Black							● QUICK TRIAXIAL × LAB VANE						
0.3	SAND and SILT, some clay, trace gravel Compact Grey Wet (TILL)		1	SS	17		256	WATER CONTENT (%)						GR SA SI CL
254.7						▽	255							4 48 38 10
1.5	END OF BOREHOLE AT 1.5m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN AND WATER LEVEL AT 1.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.													

# RECORD OF BOREHOLE No 10-063B

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 428.0 E 365 280.1 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.31 - 2010.01.31 CHECKED BY TH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE					
256.5							20	40	60	80	100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>		
0.0	PEAT, trace roots Dark Brown Frozen to Moist		1	AS											125	0 1 88 11
	Occasional silt Very Loose		1	SS	0										90	
			2	SS	0										87	
254.5																
2.0	SILT, some clay, trace sand Loose to Compact Grey Moist		3	SS	16											
			4	SS	8											
252.3																
4.3	Silty CLAY, some sand, trace gravel Firm Grey Moist		5	SS	8											
251.7																
4.9	Silty SAND, trace gravel Loose to Compact Grey Moist															
251.1																
5.4	END OF BOREHOLE AT 5.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN TO 3.7m, AND WATER LEVEL AT 0.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 2.1m, THEN BENTONITE TO SURFACE.															

+<sup>3</sup> . x<sup>3</sup> : Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE


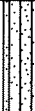


# RECORD OF BOREHOLE No 10-100

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 611.3 E 367 259.0 ORIGINATED BY JM  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2010.01.29 - 2010.01.29 CHECKED BY TH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
							20 40 60 80 100					20 40 60					
238.7																	
0.0	PEAT, some roots Dark Brown Frozen to Wet		1	AS													
238.1																	
0.6	SAND and SILT, trace clay, trace gravel Compact to Very Dense Grey Moist to Wet		1	SS	16												
			2	SS	21												
			3	SS	100/ 300												
			4	SS	48												
			5	SS	38												
			6	SS	57												
231.6																	
7.2	END OF BOREHOLE AT 7.2m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN TO 7.2m, AND WATER LEVEL AT 2.4m UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2010.01.31 0.5 238.2 2010.03.01 0.9 237.8																

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

ONTMT4S 1156.GPJ 3/10/10

# RECORD OF BOREHOLE No 10-101

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 585.6 E 367 277.1 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.24 - 2010.01.24 CHECKED BY TH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE										WATER CONTENT (%)
238.2								20	40	60	80	100						
0.0	Sandy SILT, trace gravel, with organics Moist (FILL)		1	SS	11		238											
			2	SS	3		237											
236.7			3	SS	50													
1.5	END OF BOREHOLE AT 1.5m UPON AUGER REFUSAL ON PROBABLE BEDROCK OR BOULDERS. BOREHOLE OPEN TO 1.5m, AND WATER LEVEL AT 1.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.				025													

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

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 10-101A

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 589.9 E 367 274.1 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.31 - 2010.01.31 CHECKED BY TH

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
238.1														
0.0	PEAT, some roots Dark Brown Frozen to Wet		1	AS			238							
237.3														
0.8	Sandy SILT, trace gravel, mixed with organics Loose Dark Brown Wet		1	SS	7		237							
236.6														
1.5	SAND and SILT, occasional gravel Compact Grey Wet to Moist		2	SS	19		236							
			3	SS	24									
			4	SS	78		235							
233.7							234							
4.4	END OF BOREHOLE AT 4.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN TO 1.7m, AND WATER LEVEL AT 0.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH SAND TO 0.9m, THEN BENTONITE TO SURFACE.													

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

20  
15  
10

(%) STRAIN AT FAILURE






# RECORD OF BOREHOLE No 10-103

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 372 538.1 E 367 298.2 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.23 - 2010.01.23 CHECKED BY TH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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						
237.9								20 40 60 80 100						
0.0	PEAT Dark Brown Wet		1	AS										
236.9														
0.9	Silty SAND, trace gravel Loose Grey wet		1	SS	6									
236.3														
1.5	SAND and SILT, trace clay, trace gravel Loose to Dense Grey Moist		2	SS	7									
			3	SS	17									
			4	SS	50/									
234.5														
3.3	END OF BOREHOLE AT 3.3m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT SURFACE UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 0.91m slotted screen. WATER LEVEL READINGS: DATE      DEPTH (m)    ELEV. (m) 2010.01.31    0.6        237.3 2010.03.01    0.7        237.2													

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

20  
15  
10



(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 10-104

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 373 948.9 E 369 222.6 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.29 - 2010.01.29 CHECKED BY TH

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										
251.7								20	40	60	80	100						
0.0	<b>SAND</b> and <b>GRAVEL</b> , occasional cobbles, trace organics Dark Brown to Brown Frozen to Moist (FILL)		1	AS		251												
250.9																		
0.8	Silty <b>SAND</b> , trace to some gravel, occasional cobbles, occasional roots Compact		1	SS	17													
250.3	Brown																	
1.4	END OF BOREHOLE AT 1.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN TO 1.4m, AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.																	

# RECORD OF BOREHOLE No 10-105

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 373 970.8 E 369 208.2 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.27 - 2010.01.27 CHECKED BY TH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					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						
259.9								20 40 60 80 100						
0.0	ASPHALT: (75mm)													
0.1	SAND and GRAVEL Brown Frozen to Moist (FILL)		1	AS			259							
			2	AS										
258.4														
1.5	SAND, some gravel, some silt Dense to Very Dense Dark Brown Moist (FILL)		1	SS	47		258							
			2	SS	55									
256.9							257							
3.0	Silty SAND, some gravel Very Dense Dark Brown to Brown Moist		3	SS	42		256							
255.7														
4.2	END OF BOREHOLE AT 4.2m UPON AUGER REFUSAL ON PROBABLE BEDROCK OR BOULDERS. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH SAND TO 2.4m, THEN BENTONITE TO 0.2m, THEN ASPHALT TO SURFACE.													

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

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 10-106

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 374 013.8 E 369 231.2 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.22 - 2010.01.22 CHECKED BY TH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			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 (%)				
255.8							20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>			
0.0	Silty SAND, some gravel, trace organics Very Dense Dark Brown Frozen		1	SS	52												
255.1																	
0.7	END OF BOREHOLE AT 0.7m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.						255										

ONTMT4S 1156.GPJ 3/10/10



RECORD OF BOREHOLE No 10-107

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 374 060.7 E 369 235.9 ORIGINATED BY JM  
HWY 11/17 BOREHOLE TYPE Hand Shovel COMPILED BY AN  
DATUM Geodetic DATE 2010.01.23 - 2010.01.23 CHECKED BY TH



SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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 (%)			
						20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>			
263.6 0.0	BEDROCK AT SURFACE.															

# RECORD OF BOREHOLE No 10-107A

1 OF 1

METRIC

G.W.P. 334-94-00 LOCATION N 5 374 044.2 E 369 228.7 ORIGINATED BY JM  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2010.01.23 - 2010.01.23 CHECKED BY TH

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    x LAB VANE									
260.5								20	40	60	80	100					
0.0	Silty <b>SAND</b> , some gravel, occasional roots Compact Brown		1	SS	17												
259.8	Frozen						260										
0.8	END OF BOREHOLE AT 0.8m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.																

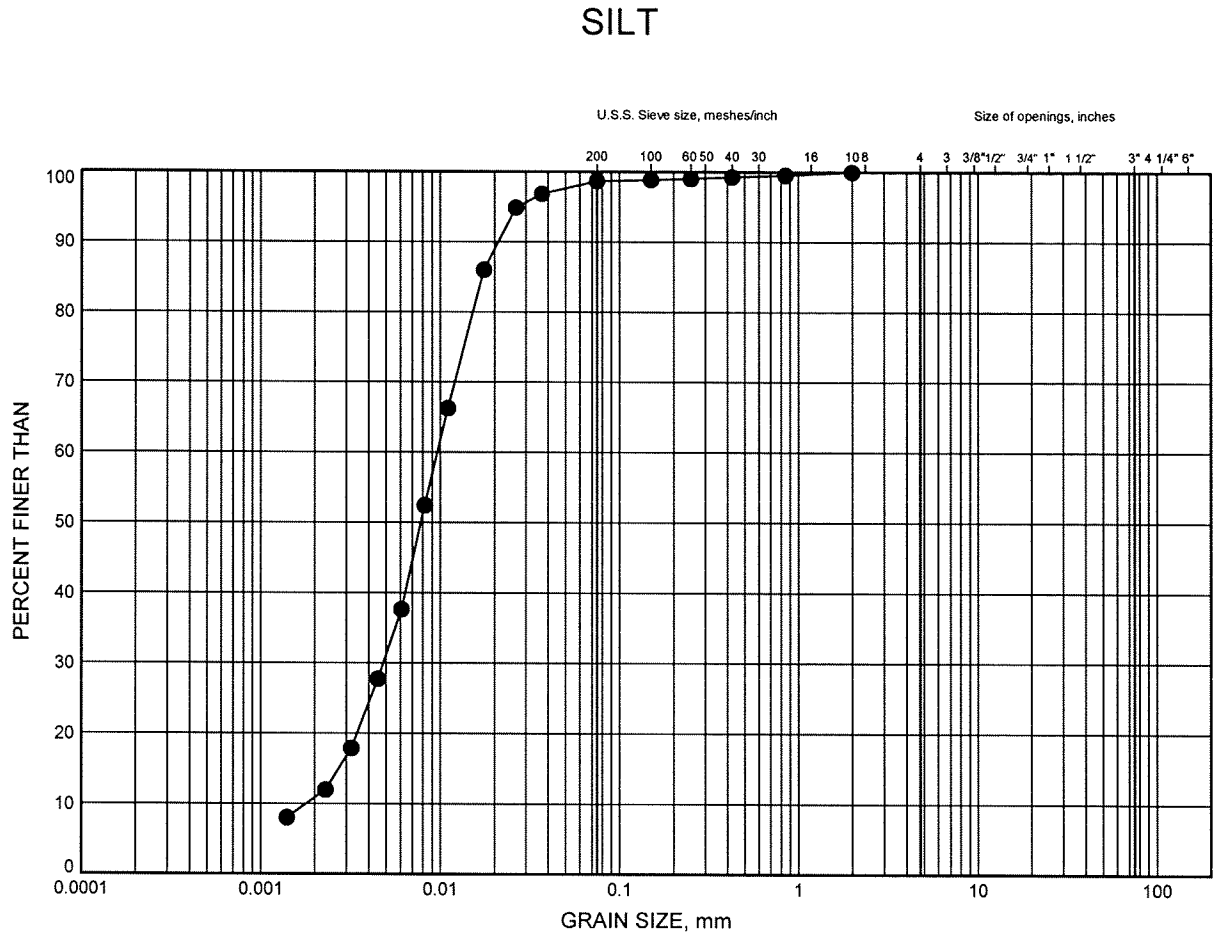
ONTMT4S 1156.GPJ 3/10/10

## **Appendix B**

### **Laboratory Test Results**

# Hwy 11/17 Hodder Avenue 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)
●	10-063B	2.59	253.94

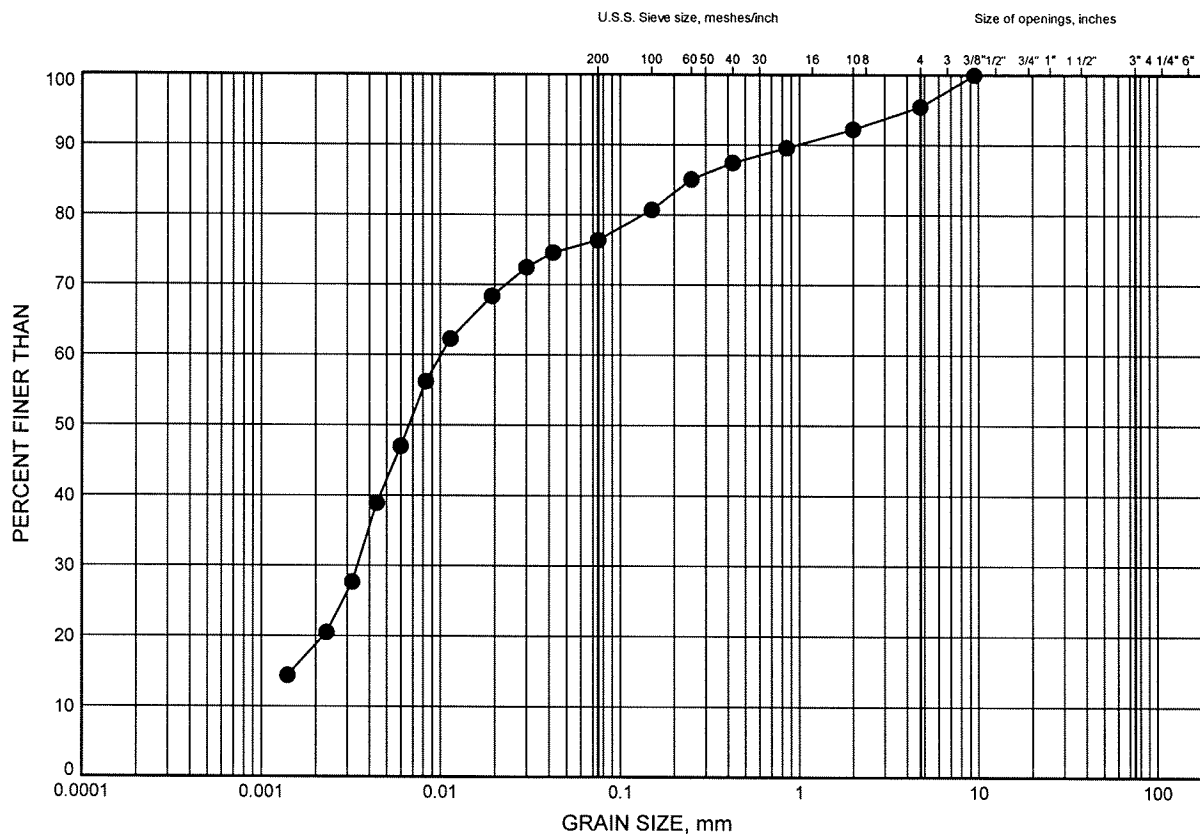


W.P.# 334-94-00  
Prepared By AN  
Checked By MRA

# Hwy 11/17 Hodder Avenue 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)
●	10-063B	4.80	251.73

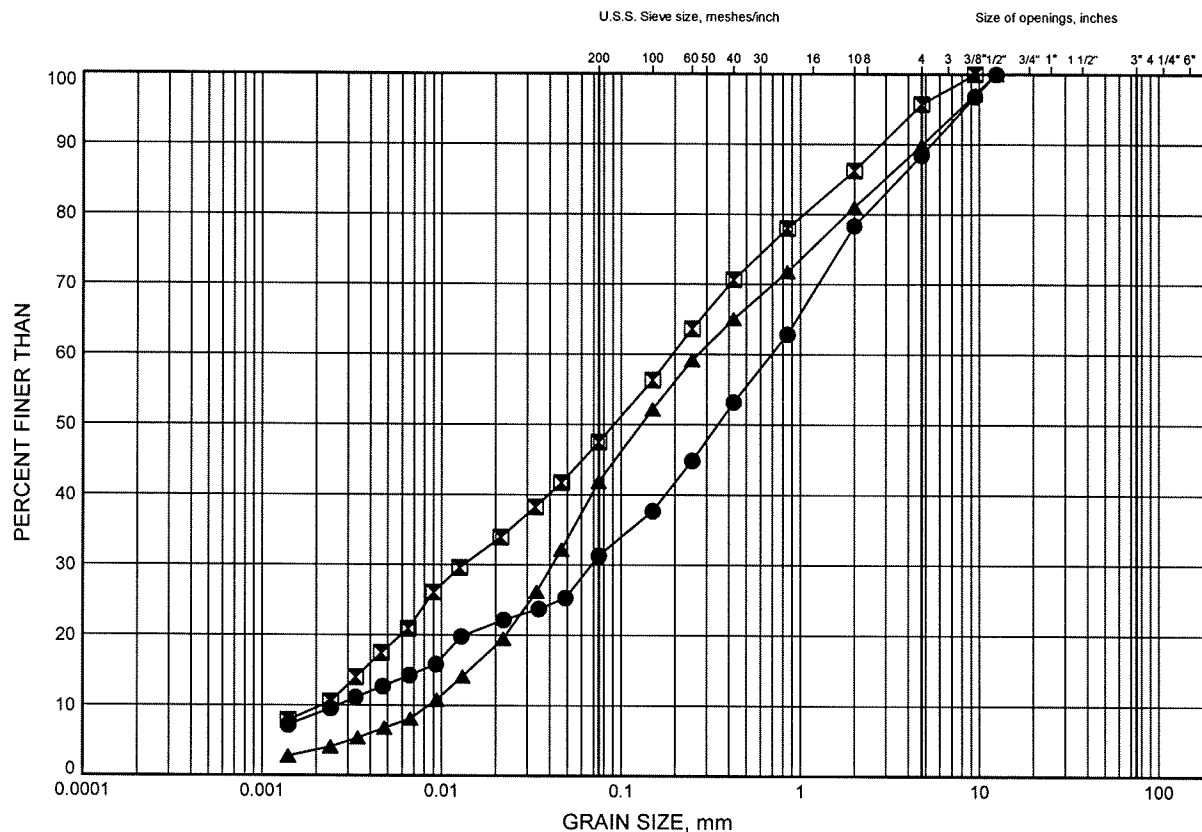


W.P.# .334-94-00.....  
Prepared By .AN.....  
Checked By .MRA.....

Hwy 11/17 Hodder Avenue  
**GRAIN SIZE DISTRIBUTION**

FIGURE B3

**SILTY SAND to SAND & SILT TILL**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	09-062A	1.07	255.11
⊠	09-063	1.07	255.21
▲	10-062C	1.83	254.14

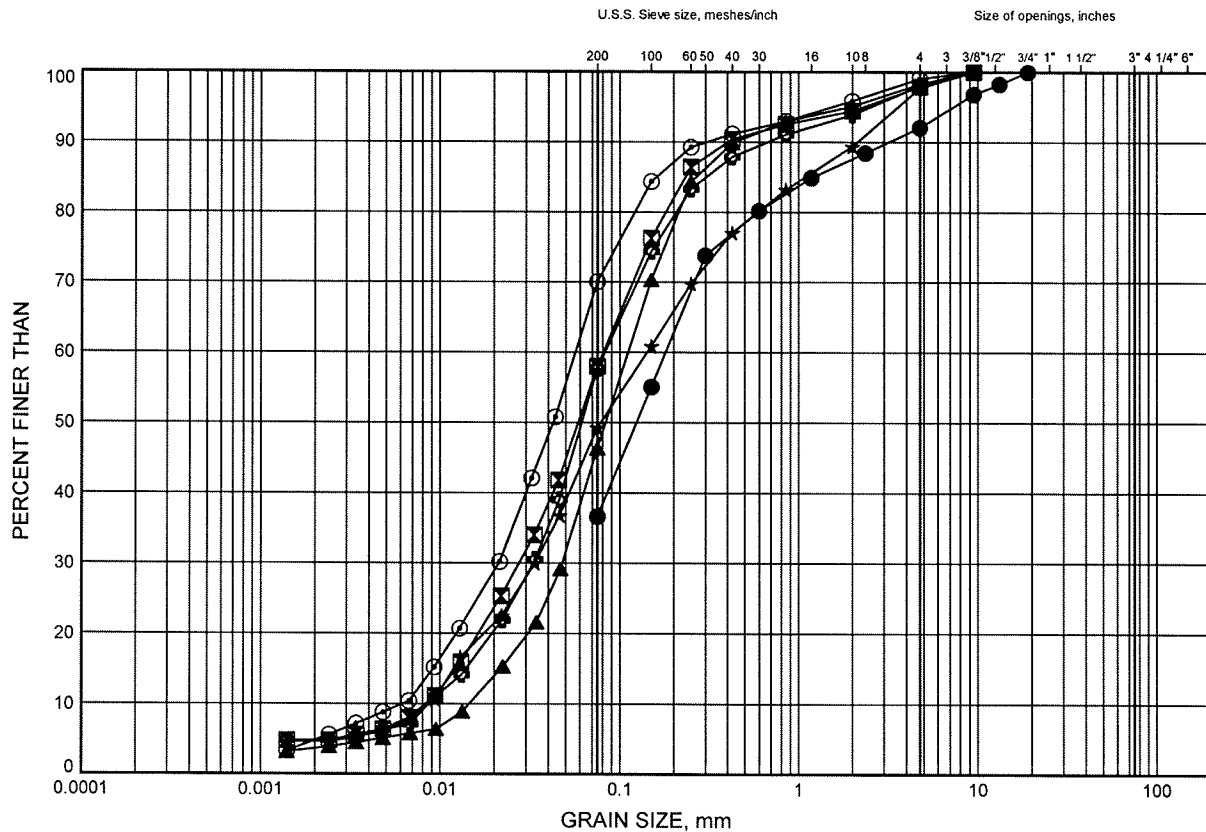


W.P.# 334-94-00  
 Prepared By AN  
 Checked By MRA

# Hwy 11/17 Hodder Avenue GRAIN SIZE DISTRIBUTION

FIGURE B4

## SILTY SAND to SANDY SILT



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	10-100	3.35	235.38
⊠	10-100	6.40	232.33
▲	10-101A	2.59	235.51
★	10-102	2.59	237.94
⊙	10-102	6.40	234.13
⊕	10-103	2.59	235.26

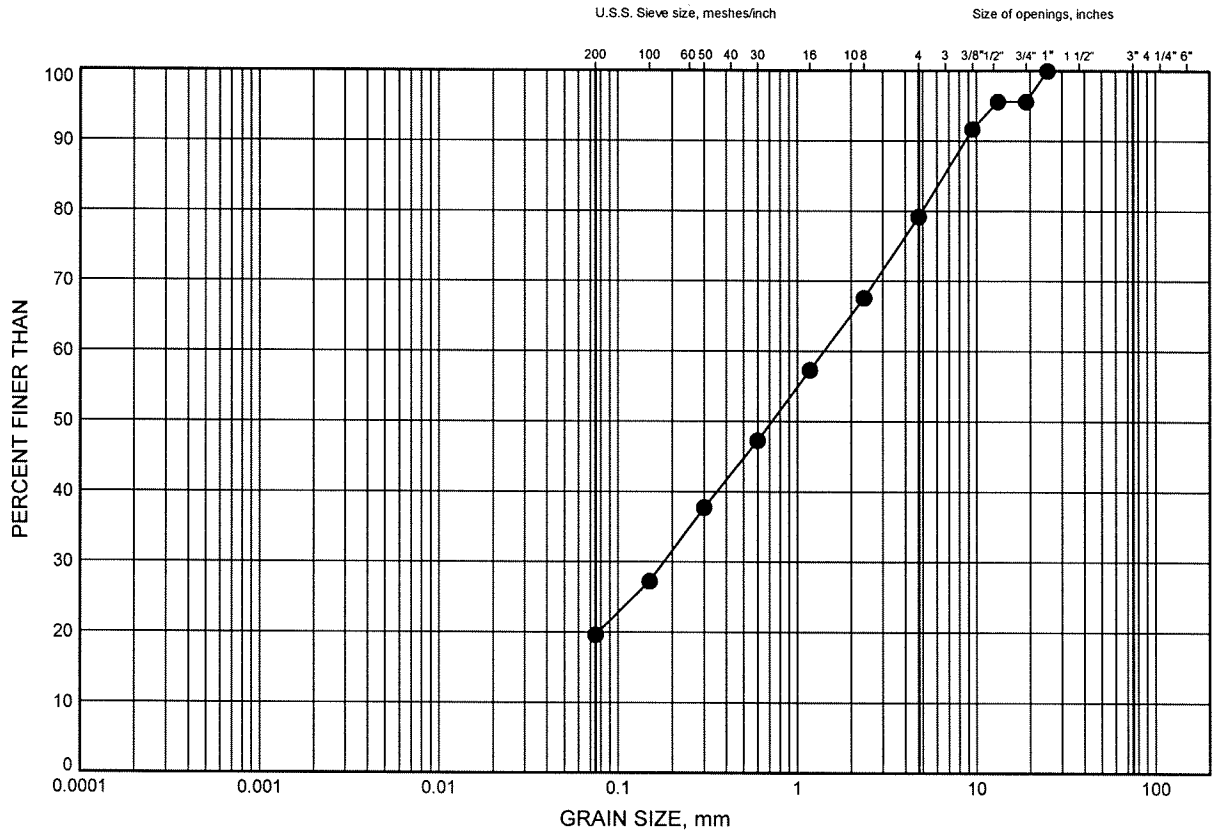


W.P.# .334-94-00.....  
Prepared By .AN.....  
Checked By .MRA.....

Hwy 11/17 Hodder Avenue  
**GRAIN SIZE DISTRIBUTION**

FIGURE B5

**SAND FILL**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	10-105	2.59	258.71

GRAIN SIZE DISTRIBUTION - THURBER 1156.GPJ 3/19/10

W.P.# 334-94-00  
 Prepared By AN  
 Checked By MRA

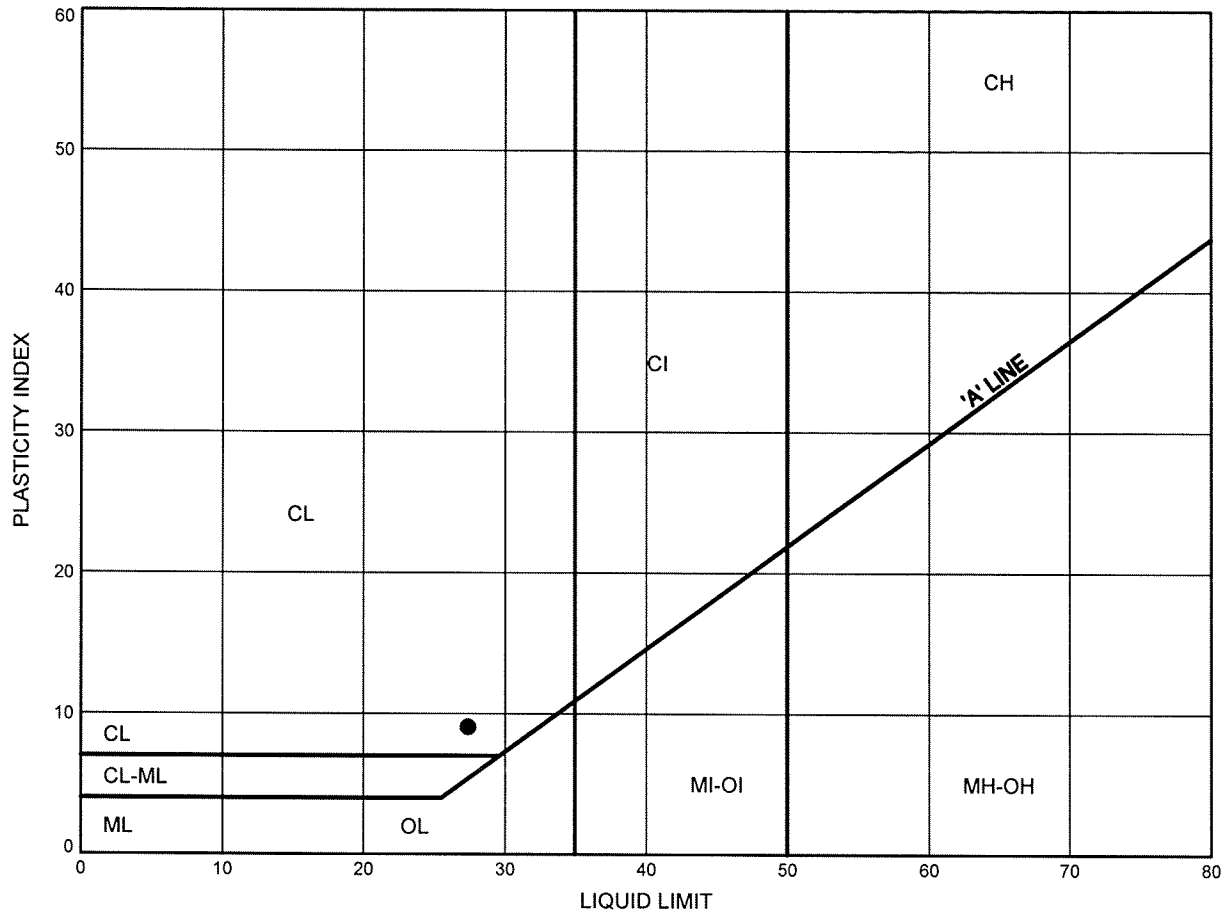




Hwy 11/17 Hodder Avenue  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B6

**SILTY CLAY**



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	10-063B	4.80	251.73

Date March 2010  
 Project 334-94-00



Prep'd AN  
 Chkd. MRA

## **Appendix C**

### **Foundation Comparison**

**TABLE 8.1 - COMPARISON OF FOUNDATION ALTERNATIVES**

<b>Closed Box Culvert</b>	<b>Open Footing Culvert on Native Soil or Bedrock</b>	<b>Footings on Engineered Fill</b>	<b>Deep Foundations (Driven Piles or Caissons)</b>
<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Ease of construction.</li> <li>ii. Minimizes differential settlement.</li> <li>iii. Applies lower bearing pressures on foundation soils.</li> <li>iv. Lower cost than deep foundations.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Requires subexcavation of soft or organic material from streambed if encountered.</li> <li>ii. Potential settlement due to embankment loading must be addressed in culvert design.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Ease of construction.</li> <li>ii. Eliminates bedding requirement.</li> <li>iii. Compared to closed box, potentially less subexcavation required to remove soft organic materials.</li> <li>iv. Lower cost than deep foundations.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Subexcavation may be required to penetrate upper soft or organic material and/or found on bedrock.</li> <li>ii. Dewatering, shoring and roadway protection is required.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Would permit use of higher geotechnical resistance than is available on the native soil.</li> <li>ii. Founding level is not governed by soil conditions.</li> <li>iii. Lower cost than deep foundations.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Cost of constructing engineered fill.</li> <li>ii. Not cost effective on sites with shallow bedrock.</li> <li>iii. Deeper excavation is required, including dewatering, shoring and roadway protection.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High resistance is available for piles or caissons founded on bedrock.</li> <li>ii. Readily installed.</li> <li>iii. Construction could continue in freezing weather.</li> <li>iv. Eliminates potential for foundation settlement.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Much higher cost than shallow footings or box culvert.</li> <li>ii. Possibility of encountering cobbles and boulders in the underlying soils.</li> <li>iii. Pre-augering or coring is required at sites with shallow bedrock.</li> </ul>
<b>FEASIBLE</b>	<b>RECOMMENDED</b>	<b>NOT RECOMMENDED</b>	<b>NOT RECOMMENDED</b>

## **Appendix D**

### **Special Provisions**

**1. List of Special Provisions and OPSS Documents Referenced in this Report**

- SP 105S10
- SP 110F13
- SP 539S01
- SP 902S01
- OPSS 572
- OPSS 1205
- OPSD 803.010

**2. Suggested text for a NSSP on Dewatering**

The soils underlying a number of the sites are predominantly cohesionless and will be readily disturbed by unbalanced water heads or by flow of water. The Contractor shall design, install and operate systems that shall:

- Unwater the excavations.
- Control the flow of groundwater and surface water into the excavations.
- Prevent the disturbance of the base of the excavations.
- Prevent the sloughing of soil into the excavations.

Particular attention must be paid to the design of unwatering systems and shoring systems for foundation construction due to the proximity of the creek and the cohesionless nature of the overburden.

The selection and design of suitable unwatering and shoring systems shall remain the responsibility of the Contractor. Suitable systems that might be employed include:

- Pumping from properly filtered sumps may be suitable to handle the groundwater when excavations extend no more than 0.5 m below the groundwater level.
- The use of vacuum well points for deeper penetration below the groundwater level.
- Sheetpiled cofferdams assisted by vacuum well points at locations near the creek.

Factors that might influence the selection and design of unwatering and shoring systems include, but are by no means limited to:

- The probable water level of the creek during construction. The selected systems must prevent flooding of the work area due to rising creek levels.

**3. Suggested text for a NSSP on Rock Fill**

Rock fill shall be as specified in SP 206S03, and the following:

- Rock fill shall not contain shale or shale fragments.
- Rock fill shall be placed as per clause 206.07.09 Rock Backfill to Structure.

## **Appendix E**

### **Site Photographs**

Culverts  
Highway 11/17 Four-Laning Thunder Bay

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**Photo 1 – West end of existing culvert at Copenhagen Road**



**Photo 2 – East end of existing culvert at Copenhagen Road**





**Photo 3 – North end of Culvert at Hwy 11/17 Sta. 27+525**



**Photo 4 – South end of culvert at Hwy 11/17 Sta. 27+525**





**Photo 5 – South end of culvert at Hwy 11/17 Sta. 29+950**

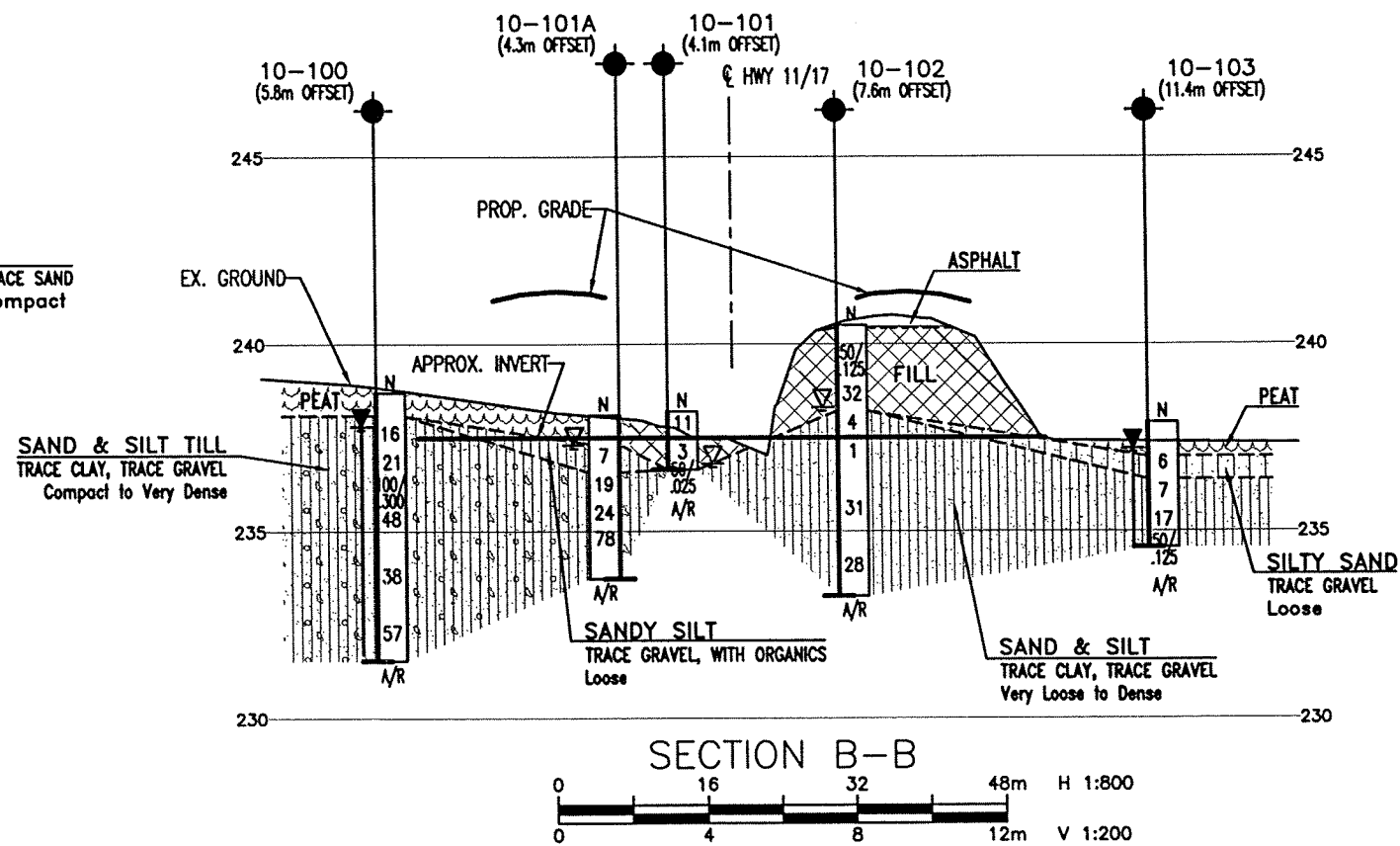
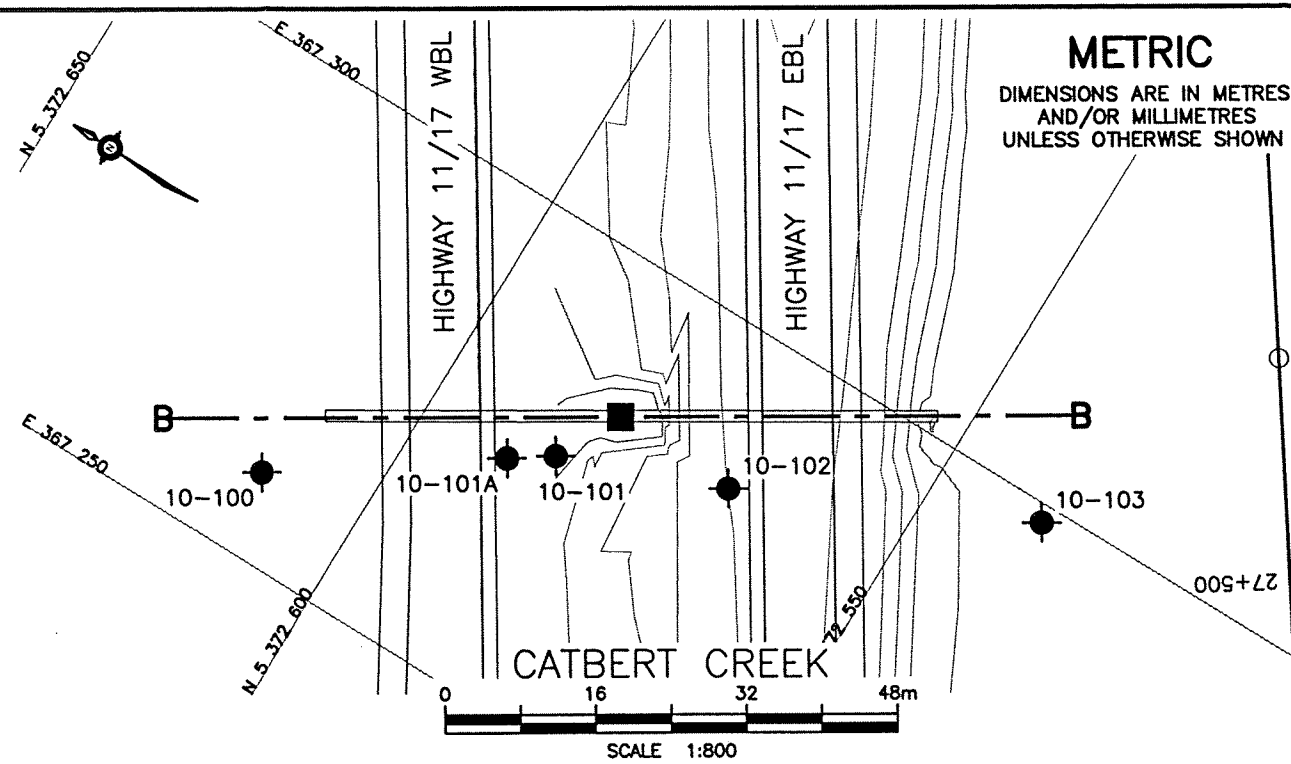




**Photo 6 – North end of culvert at Hwy 11/17 Sta. 29+950**

## **Appendix F**

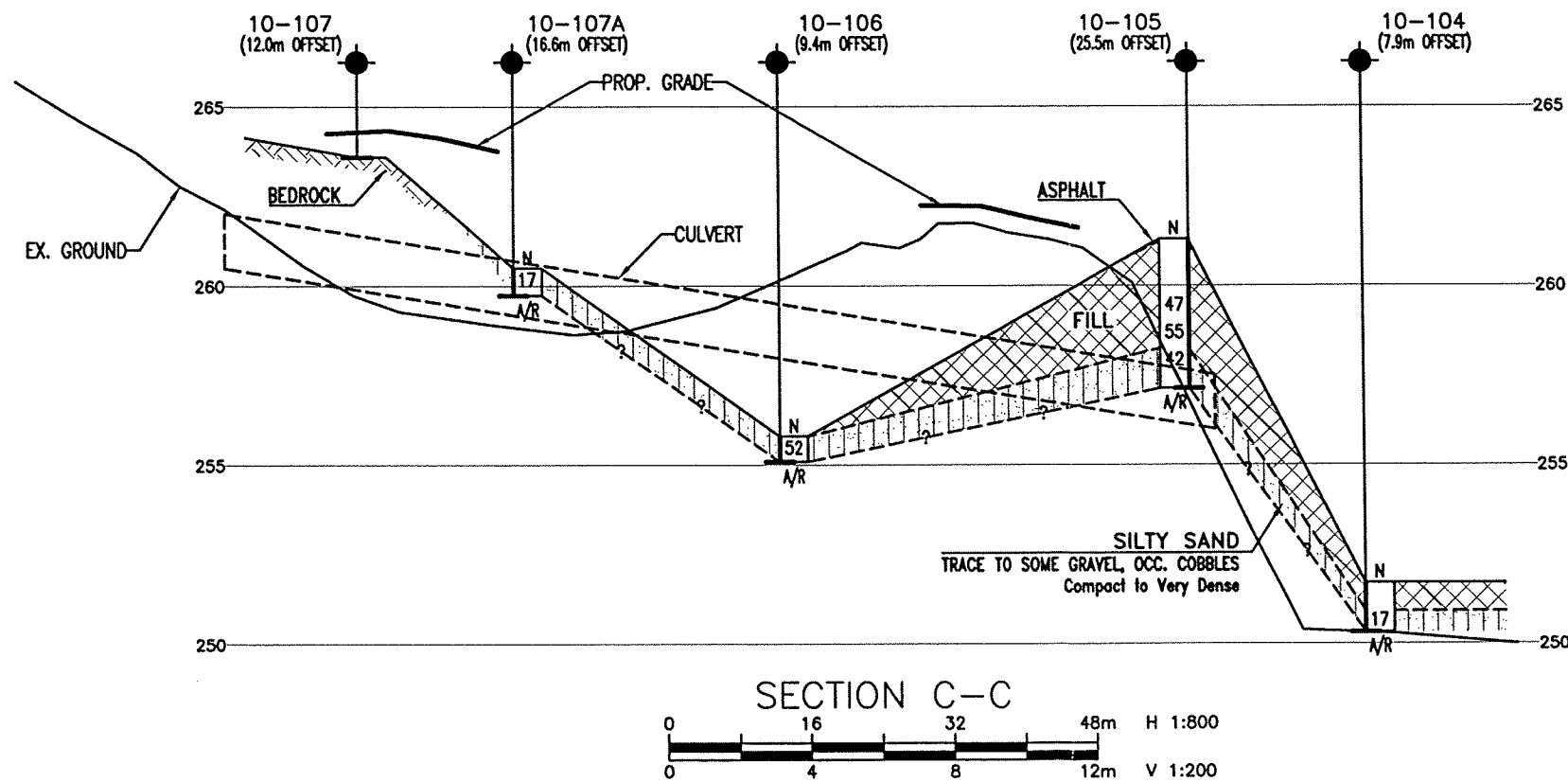
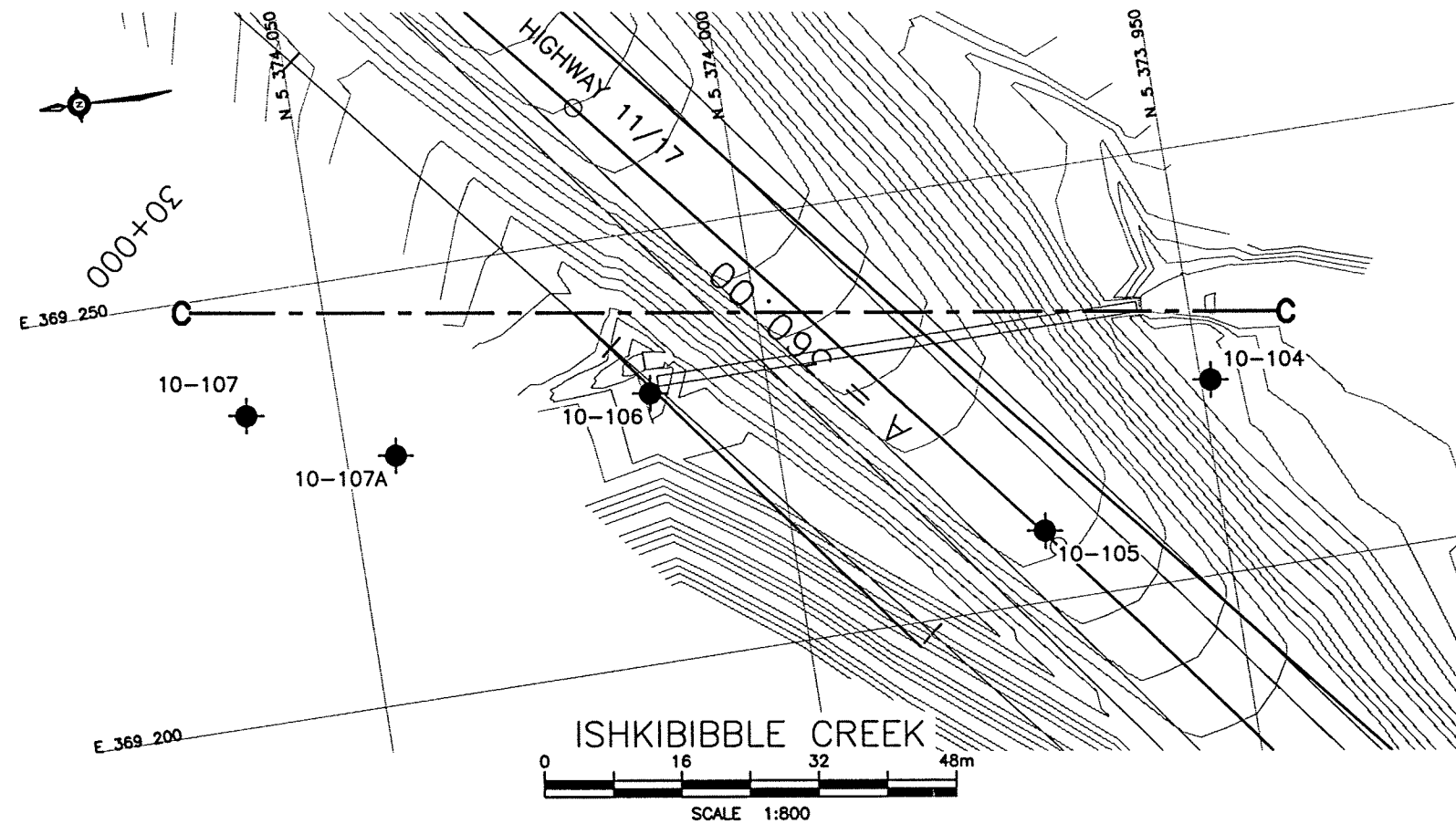
### **Borehole Locations and Soil Strata Drawings**



LICENSED PROFESSIONAL ENGINEER  
 P. K. CHATTERJI  
 PROVINCE OF ONTARIO  
 License No. 12345  
 June 3/10

REVISIONS							
	DATE	BY	DESCRIPTION				
	DESIGN MRA	CHK AEG	CODE	LOAD	DATE MAY 2010		
	DRAWN MFA	CHK PKC	SITE	STRUCT	DWG	1	





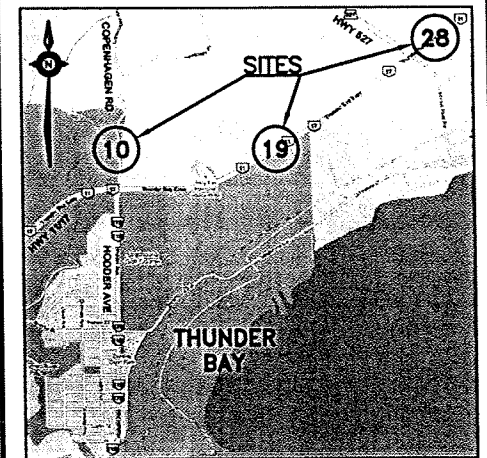
**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 334-94-00  
HIGHWAY 11/17  
HODDER AVENUE TO HWY 527  
CULVERTS  
BOREHOLE LOCATIONS AND SOIL STRATA

**SHEET**

**MRC** McCORMICK RANKIN  
CORPORATION

**THURBER ENGINEERING LTD.**  
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



**KEYPLAN**  
**LEGEND**

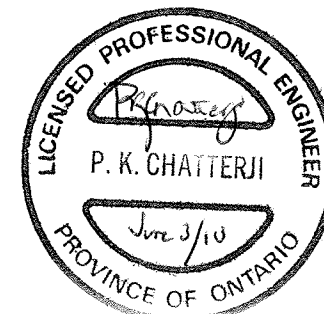
- ◆ Borehole
- ◆ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- HA Head Artesian Water
- PZ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
10-104	251.7	5 373 948.9	369 222.6
10-105	259.9	5 373 970.8	369 208.2
10-106	255.8	5 374 013.8	369 231.2
10-107	263.6	5 374 060.7	369 235.9
10-107A	260.5	5 374 044.2	369 228.7

**-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.

**GEOCRES No. 52A-144**



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MRA	CHK AEG	CODE
DRAWN	MFA	CHK PKC	SITE
			STRUCT
			DWG 2