FOUNDATION INVESTIGATION AND DESIGN REPORT

BLIND CREEK WEST CULVERT – EBL

HIGHWAY 11/17 - FOUR LANING

FROM 0.36 km EAST OF HIGHWAY 527 EASTERLY 12.6 km TO 1 km WEST OF MACKENZIE STATION ROAD

G.W.P. 623-89-00, SITE 48C-350/C1

Geocres Number: 52A-160

Report to

McCormick Rankin Corporation

Thurber Engineering Ltd.
2010 Winston Park Drive, Suite 103
Oakville, Ontario
L6H 5R7
Phone: (905) 829 8666
Fax: (905) 829 1166

September 19, 2012
File: 19-1351-182

H:\19\1351\182 Hwy17-Hwy527 east 12.6km\Reports & Memos\1 - Blind Creek West EBL\Blind Creek West EBL - FINAL FIDR.doc

TABLE OF CONTENTS

Appendices

FOUNDATION INVESTIGATION AND DESIGN REPORT

BLIND CREEK WEST CULVERT – EBL

HIGHWAY 11/17 - FOUR LANING

FROM 0.36 km EAST OF HIGHWAY 527 EASTERLY 12.6 km TO 1 km WEST OF MACKENZIE STATION ROAD

G.W.P. 623-89-00, SITE 48C-350/C1

Geocres Number: 52A-160

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the location of the Blind Creek West culvert under existing Highway 11/17 in the Township of MacGregor, District of Thunder Bay. Replacement of the existing culvert is planned as part of the proposed Highway 11/17 four-laning project extending from 0.36 km east of Highway 527 to 1 km west of MacKenzie Station Road. The existing Highway 11/17 will become the new eastbound lanes of the four-lane divided highway.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic sections, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to McCormick Rankin Corporation, under the Ministry of Transportation Ontario (MTO) Agreement Number 6009-E-0017.

2 SITE DESCRIPTION

The proposed Blind Creek West culvert is located approximately 11 km east of Thunder Bay, Ontario and approximately 6.8 km east of Highway 527. The new culvert will be situated at the location of the existing culvert under the existing Highway 11/17 alignment. The existing roadway embankment is approximately 1.5 to 3.5 m in height.

The existing culvert comprises twin 1.4 m diameter corrugated steel pipes (CSP) with lengths of 34.7 and 33.8 m. The invert level of the existing culverts ranges from approximate elevation 232.5 at the inlet (north end) to elevation 230.8 at the outlet (south end). The CSPs are suspended approximately 300mm above the water level at the outlet, and bedrock is exposed along the sides of the adjacent plunge pool.

Lands surrounding the culvert site consist of forested areas with bedrock outcrops. Cobbles and boulders line the creek channel.

Photographs in Appendix C show the general nature of the site.

The site lies near the border of the Superior and Southern Geological Provinces of the Canadian Shield. According to bedrock geology maps produced by the Ontario Geological Survey, the culvert site is underlain by mafic to intermediate metavolcanic rocks consisting of basaltic and andesitic flows, tuffs, breccias, chert, iron formation, minor metasedimentary and intrusive rock, and related migmatites. Locally, the overburden generally consists of deposits of silty sand to sand and gravel with cobbles and boulders.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between October 20 and 22, 2011 and consisted of drilling and sampling six boreholes identified as BCWE-1 to BCWE-6.

Boreholes BCWE-1 and BCWE-4 were located near the proposed culvert inlet, Boreholes BCWE-2 and BCWE-5 were located on the existing highway embankment, and Boreholes BCWE-3 and BCWE-6 were located near the culvert outlet. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata drawing included in Appendix G.

Boreholes BCWE-1, BCWE-2, BCWE-4 and BCWE-5 located at the north and central part of the culvert were advanced to depths of 9.0 m to 10.7 m (elevations 225.9 to 224.0), including rock coring. Borehole BCWE-3 located at the culvert outlet was completed by manual excavation to expose the bedrock surface at 60 mm depth (Elev. 232.6), and Borehole BCWE-6 was documented by visual examination of the embankment slope surface and exposed bedrock at the toe.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. Clearing and access preparation were required prior to commencement of the borehole drilling. Silt fencing was installed between the drill area and the creek to prevent migration of core water sediment into the adjacent creek.

A track mounted CME 45 drill rig was used at this site and a combination of hollow-stem augers, casing and NQ coring techniques were used to advance the boreholes. Overburden samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). All rock cores were logged, and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

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 and rock cores for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed in the open boreholes upon completion of the drilling operations. The completion details of the boreholes are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole	Borehole Depth/ Elevation (m)	Completion Details
BCWE-1	10.7 / 224.0	Backfilled with holeplug to 3.6 m, then auger cuttings to surface.
BCWE-2	9.1 / 225.9	Backfilled with bentonite holeplug to 3.0 m, then sand and gravel to surface.
BCWE-3	0.1 / 232.6	Filled in with gravel.
BCWE-4	9.0 / 224.2	Backfilled with bentonite holeplug to 1.5 m, then cuttings to surface.
BCWE-5	9.2 / 225.4	Backfilled with holeplug to 3.0 m, then auger cuttings to surface.
BCWE-6	1.4 / 232.1	Visual inspection only.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to gradation analysis. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

Point load tests were carried out on selected samples of intact bedrock upon arrival at the laboratory to evaluate the unconfined compressive strength (UCS) of the bedrock. The UCS values of the rock assessed from the point load data are reported on the borehole logs.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented in these sheets and on the "Borehole Locations and Soil Strata" drawing included in Appendix G. 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.

In general, the subsurface stratigraphy encountered at the site consisted of sand and gravel embankment fill overlying native deposits of silty sand to sand and gravel, which in turn were underlain by cobbles and boulders. Cobbles and boulders were also encountered at the fill/native soil interface and within the native deposits. Bedrock was encountered below the layer of cobbles and boulders. The bedrock is exposed at the ground surface at the culvert outlet. More detailed descriptions of the individual strata are presented below.

5.1 Topsoil

A 25 mm thick veneer of topsoil was encountered at the ground surface in Borehole BCWE-4.

5.2 Sand and Gravel Fill

Sand and gravel fill was encountered in Boreholes BCWE-1, BCWE-2 and BCWE-5 drilled on the existing roadway embankment, and below the topsoil veneer in Borehole BCWE-4. Sand and gravel fill was visually documented at the location of Borehole BCWE-6 on the embankment side slope. The sand and gravel fill was brown and contained trace silt and clay and occasional cobbles.

The thickness of the sand and gravel fill ranged from 1.4 m to 3.1 m, with the base of the fill at elevations 232.8 to 231.7.

SPT N-values recorded in the fill typically ranged from 28 to 56 blows for 0.3 m penetration, indicating a compact to very dense relative density. SPT 'N' values of 50 blows per 0.1 m and 100 blows for no penetration were obtained on probable cobbles in Boreholes BCWE-2 and BCWE-5.

The moisture content of samples of the sand and gravel fill ranged from 3% to 12%.

Selected samples of the sand and gravel fill underwent laboratory gradation analysis. The results of these tests are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figure B1, Appendix B. The results of the three gradation analyses are as follows.

Gravel%	37 to 76
Sand%	22 to 56
Silt and Clay%	2 to 7

5.3 Cobbles and Boulders

Rock coring equipment was required to advance the boreholes through a layer of cobbles and boulders below the sand and gravel fill in Boreholes BCWE-1, BCWE-2, BCWE-4 and BCWE-5. The cobbles and boulders either form the base of the embankment fill or represent native materials lining the original stream channel.

The layer of cobbles and boulders was 0.7 m to 1.2 m thick, with the lower boundary encountered at depths of 2.3 m to 4.2 m (elevation 231.7 to 230.8).

5.4 Sand and Gravel

Native sand and gravel was encountered below the cobbles and boulders in Boreholes BCWE-2 and BCWE-4. The sand and gravel was brown and contained trace silt and clay as well as cobbles and boulders.

The sand and gravel layer was 1.1 m thick in Borehole BCWE-2 and 3.0 m thick in Borehole BCWE-4. The base of the sand and gravel layer was encountered at a depth of 5.3 m in both boreholes (elevations 229.7 and 227.9).

SPT N-values recorded in the native sand and gravel ranged from 26 blows for 0.3 m penetration to 50 blows for 0.05 m penetration, indicating a compact to very dense relative density. SPT N-values recorded for penetration less than 0.3 m can be attributed to the presence of cobbles and boulders.

One sample of the native sand and gravel was selected for laboratory grain size analysis. The results of this test are summarized below and plotted on Figure B2, Appendix B.

Gravel%	56
Sand%	41
Silt and Clay%	3

A thin layer (100mm) of gravel containing some sand was encountered overlying bedrock at Borehole BCWE-3.

5.5 Sand

Orange brown sand with some silt and trace of gravel was encountered beneath the cobbles and boulders in Borehole BCWE-1. The sand layer was 1.5 m thick with a lower boundary at 4.5 m depth (elevation 230.2).

A SPT ‘N’ value of 22 blows for 0.3 m penetration was recorded in the sand, indicating a compact condition. A moisture content of 19% was measured

5.6 Silty Sand

Native silty sand was encountered beneath the sand layer in Borehole BCWE-1 and below the cobbles and boulders in Borehole BCWE-5. The silty sand was grey and contained trace to some gravel and trace clay. A gravelly zone with cobbles was encountered within the silty sand in Borehole BCWE-5 at a depth of 4.6 m.

The silty sand was 2.2 m thick in both boreholes. The base of the silty sand was encountered at depths of 6.7 m and 5.2 m (elevations 228.0 and 229.4) in Boreholes BCWE-1 and BCWE-5, respectively.

SPT N-values recorded in the native silty sand ranged from 35 blows for 0.3 m penetration to 50 blows for 0.075 m penetration, indicating a dense to very dense relative density.

The moisture content of samples of the silty sand ranged from 7% to 15%.

One sample of the silty sand underwent laboratory gradation analysis, the results of which are summarized below and are plotted on Figure B3, Appendix B.

Gravel%	10
Sand%	52
Silt%	29
Clay%	9

5.7 Cobbles and Boulders

A layer of cobbles and boulders was encountered overlying bedrock in Boreholes BCWE-1, BCWE-2, BCWE-4 and BCWE-5. The thickness of the layer of cobbles and boulders ranged from 0.2 m to 0.8 m, with the base of the layer encountered at depths of 5.5 m to 7.4 m (elevations 228.9 and 227.3).

5.8 Bedrock

Bedrock was encountered in all boreholes. The depths to bedrock proven by coring, manual excavation or visual assessment are summarized in Table 5.1. The bedrock surface rises to the south and outcrops at the culvert outlet.

Table 5.1 – Depth to Bedrock at Borehole Locations

Borehole	Depth to Bedrock (m)	Top of Bedrock Elevation (m)	Proving Method
BCWE-1	7.4	227.3	Cored
BCWE-2	6.1	228.9	Cored
BCWE-3	0.1	232.6	Manual excavation
BCWE-4	5.5	227.7	Cored
BCWE-5	5.8	228.8	Cored
BCWE-6	1.4	232.1	Visual inspection

The bedrock recovered from the cores was described as intermediate metavolcanic rock with occasional quartz veins. The bedrock is grey in colour with white bands.

Core recovery was typically high, between 93% and 100%. Lower core recovery values of 49% and 57% were obtained in the initial core run in Boreholes BCWE-1 and BCWE-5, advanced partially in the cobbles and boulders overlying the bedrock. RQD values typically ranged from 83% to 100%, indicating good to excellent rock quality. Lower RQD values of 23% to 58% were measured in Run #1 of Boreholes BCWE-1, BCWE-4 and BCWE-5, reflecting the presence of cobbles and boulders in the initial run. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, was generally less than 5 with occasional values over 5.

The unconfined compressive strength of the rock, estimated from the results of point load tests conducted on the rock core samples, typically ranged from 75 to 135 MPa, indicating a strong to very strong intact rock. Individual values of 21 MPa (weak) and 195 MPa (very strong) were obtained in Boreholes BCWE-4 and BCWE-1, respectively. The results are summarized on the Record of Borehole sheets in Appendix A (as average per run).

5.9 Water Levels

Water levels measured in the open boreholes upon completion of the drilling operations are summarized in Table 5.2. Water was added to the boreholes during coring operations and therefore the measured water levels may not be indicative of stabilized groundwater conditions at the site.

Table 5.2 – Water Level Measurements

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
BCWE-1	Oct. 20, 2011	1.1	233.6	Upon completion
BCWE-2	Oct. 21, 2011	2.1	232.9	Upon completion
BCWE-4	Oct. 22, 2011	0.8	232.4	Upon completion
BCWE-5	Oct. 20, 2011	1.3	233.3	Upon completion

The water level in the creek at the time of the fieldwork was in the order of 0.1 m above the culvert invert level. Based on this observation and the culvert invert levels shown on the preliminary design drawings, the creek water level is estimated to be between elevation 232.6 at the inlet and 230.9 at the outlet. These water levels are consistent with water levels of 232.6 and 231.1 shown on preliminary plan plates (June 2010). The water falls approximately 0.3 m upon exiting the CSPs.

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall, and will reflect the water level in the creek.

6 MISCELLANEOUS

The borehole locations were selected by Thurber Engineering Ltd. and staked in the field by McCormick Rankin Corporation (MRC). The co-ordinates and ground surface elevations at the boreholes were surveyed by MRC. Where boreholes required relocation from the staked location, field measurements were recorded and the surveyed coordinates and elevations adjusted accordingly.

Thurber obtained utility clearances for the borehole locations prior to drilling.

Eastern Ontario Diamond Drilling Ltd. from Hawkesbury, Ontario supplied a track mounted CME 45 drill rig and conducted the drilling, sampling and in-situ testing operations.

The field program was supervised on a full time basis by Ms. Eckie Siu of Thurber.

Routine laboratory testing was carried out by Thurber Engineering Ltd.

Overall supervision of the field program was conducted by Mr. Mark Farrant, P.Eng. Interpretation of the data and preparation of this report were carried out by Ms. Lindsey Blaine, E.I.T. and Ms. Mei T. Cheong, M.Phil.

The report was reviewed by Mr. Murray R. Anderson, M.Eng., P.Eng. and Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd

Lindsey Blaine, E.I.T.
Project Manager

L. Blaine
Sept. 19/12

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Sept 19/12
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Sep 19/12
PROVINCE OF ONTARIO

Murray R. Anderson, P.Eng., M.Eng.
Senior Foundations Engineer

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

FOUNDATION INVESTIGATION AND DESIGN REPORT

BLIND CREEK WEST CULVERT – EBL

HIGHWAY 11/17 - FOUR LANING

FROM 0.36 km EAST OF HIGHWAY 527 EASTERLY 12.6 km TO 1 km WEST OF MACKENZIE STATION ROAD

G.W.P. 623-89-00, SITE 48C-350/C1

Geocres Number: 52A-160

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for replacement of the culvert carrying Blind Creek West under Highway 11/17. The culvert replacement is part of the Highway 11/17 four-laning project, in which the existing highway will become the new eastbound lanes of the four-lane divided highway.

The existing culvert consists of twin 1.4 m diameter CSPs with lengths of 34.7 and 33.8 m. The invert level of the existing culverts ranges from approximate elevation 232.5 at the inlet (north end) to elevation 230.8 at the outlet (south end).

Two concepts have been proposed for the replacement culvert: a rigid frame steel box culvert with a span of 9.5 m (preliminary General Arrangement drawing dated January 2012), and a sheet pile wall culvert with concrete cap and span of 6.4 m (preliminary General Arrangement drawing dated June 2012). The culvert design alternatives were selected on the basis of considerations other than foundations.

The design top of footing level for the steel box culvert is Elev. 231.9 (north/inlet) to Elev. 230.2 (south/outlet), and the footing thickness is 0.6 m. The piles for the sheet pile concept would be driven to bedrock.

The embankment height at the proposed culvert location will be in the order of 1.5 to 3.5 m with a proposed finished road grade at Elev. 234.8 (essentially unchanged).

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the investigation. The preliminary General Arrangement drawings used for preparation of this report were provided by Hatch Mott MacDonald.

8 CULVERT FOUNDATIONS

The existing highway embankment consists of sand and gravel fill and is underlain by native deposits of silty sand to sand and gravel, which in turn overlie a layer of cobbles and boulders. Cobbles and boulders were encountered at the fill/native soil interface and within the native deposits. Bedrock was encountered below the layer of cobbles and boulders at depths of 0.1 to 7.4 m (elevation 227.3 to 232.6), rising to the south. The bedrock is exposed at the ground surface at the culvert outlet.

The groundwater level at the site is expected to be near the water level in the creek, estimated to be between elevation 232.6 at the inlet and 230.9 at the outlet at the time of drilling.

Foundation recommendations for design of poured in-place or precast spread footings to support the proposed culvert are provided in the following sections. Comments regarding alternative foundation systems (steel piles, augered caissons) are also presented in the event that the design concept changes.

It must be noted that driven sheet piles are expected to encounter refusal on cobbles and boulders in the native soils above the bedrock surface and therefore use of the proposed sheet pile wall culvert design is not recommended.

A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Appendix D. A foundation scheme preferred from a foundations perspective is recommended.

8.1 Spread Footings on Native Soils or Bedrock

The anticipated founding level for spread footings on native soils supporting an open footing culvert, assuming 2.2 m of frost cover between the footing base and the finished ground surface within the culvert (top of footing from preliminary GA drawing), would range from Elev. 229.7 at the inlet to Elev. 228.0 at the outlet. However, bedrock was encountered above these levels in the south half of the culvert envelope and the founding levels for footings on bedrock will be higher. Based on the borehole information, the founding conditions will consist of the following:

Table 8.1 – Anticipated Conditions at Founding Level

Location		Borehole	Founding Level	Anticipated Foundation Subgrade
West Side	Inlet	BCWE-1	229.7	Very dense silty sand
	Middle	BCWE-2	228.9	Bedrock
	Outlet	BCWE-3	232.6	Bedrock
East Side	Inlet	BCWE-4	229.7	Very dense sand and gravel
	Middle	BCWE-5	229.0	Cobbles, boulders, bedrock
	Outlet	BCWE-6	232.1	Bedrock

The following geotechnical resistances are recommended for design of spread footings founded on the bedrock or very dense native soils at the above founding levels:

	Silty Sand/Gravel			Bedrock
Footing Width (m)	0.9	1.2	1.5	
Factored Geotechnical Resistance at ULS (kPa)	450	525	600	2,000
Geotechnical Resistance at SLS (kPa)	450	425	400	N/A

The width of footing must be designed based on the load demand from the culvert structure and overlying embankment fill.

The geotechnical resistances are based on a footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance used in the design must be reduced in accordance with the CHBDC Clause 6.7.3 and 6.7.4.

The geotechnical resistance at SLS provided for footings on native soil is based on an estimated total settlement not exceeding 25 mm. The SLS values take into consideration the potential for some disturbance of the founding surface during excavation for footing construction “in the wet”. The geotechnical resistance at SLS will not govern design of footings founded on bedrock, and negligible settlement is expected.

Differential settlement may occur between sections of the culvert founded on soil and sections founded on rigid bedrock. To smooth the transition and reduce the potential for differential settlement and cracking of footings at the transition between the soil and bedrock subgrade, placement of a rock fill transition zone is recommended. The recommended transition treatment is shown on Figure F1, Appendix F.

The anticipated founding levels are up to 2.9 m below the approximate creek and groundwater levels at the north end of the culvert. In view of the proximity of the footings to the creek, the high permeability of the soils, and the presence of cobbles and boulders potentially obstructing installation of sheet pile shoring, dewatering of the excavation and construction of the culvert footings in the dry at the design founding level is likely to be impractical. Therefore, construction of spread footings will require subexcavation to the design level below water (“in the wet”) in short sections of about 2 m length followed by immediate placement of concrete using tremie methods.

Consideration could be given to raising the founding levels and providing frost protection for the founding surfaces using equivalent thermal insulation. However, the use of insulation is generally not practical for culvert foundations. Further, excavation through cobbles and boulders to depths of about 1.7 m below the creek/groundwater levels would still be required to extend the footings to competent native soils. From this viewpoint, use of higher founding levels is not the recommended option.

The lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.55 on silty sand, sand and gravel, and cobbles and boulders. For footings on bedrock, an unfactored friction coefficient of 0.7 is recommended. These values require a degree of sliding movement to occur to fully mobilize the resistance.

The structural designers must ensure that the geometry of the proposed footing and the limits of subexcavation do not encroach into the creek.

8.2 Spread Footings on Rock Fill

In view of the high groundwater conditions, the high permeability of the soils, and the impracticality of dewatering excavations for footing construction, placement of spread footings on compacted rock fill may be considered as an option to establish the top of footing level above the water level along the north part of the culvert.

Where constructed on soil, the rock fill must be a minimum 0.5 m thick and be placed on native, compact to very dense sand/till. Accordingly, the base of the rock fill must be placed no higher than the elevations indicated in Table 8.2, and deeper as required to provide a minimum 0.5 m thickness of rock fill below the base of the footing. The minimum thickness requirement does not apply to rock fill or footings placed directly on bedrock anticipated at the south end of the culvert.

Table 8.2 – Highest Level for Underside of Rock Fill

Location		Borehole	Highest Recommended Base Level	Underlying Soil
West Side	Inlet	BCWE-1	232.4	Cobbles and boulders
	Middle	BCWE-2	231.9	Cobbles and boulders
	Outlet	BCWE-3	N/A	Bedrock
East Side	Inlet	BCWE-4	231.7	Cobbles and boulders
	Middle	BCWE-5	232.8	Cobbles and boulders
	Outlet	BCWE-6	N/A	Bedrock

Rock fill placement will generally be carried out below the water level, and should involve subexcavation in short sections followed by immediate backfilling to above the water level to permit placement of the footings in the dry. The rock fill should be placed in accordance with OPSS 206 including compaction by several passes of heavy tracked equipment once the rock fill surface is above the water level.

A minimum 150 mm thick layer of compacted 19 mm clear stone should be placed above the rock fill to provide an even founding surface for placement of the footings. Details of footing construction on rock fill are presented in Figure F2, Appendix F.

The recommended gradation of the rock fill is as follows:

Sieve Size	Percent Passing
150 mm	100
106 mm	50 – 100
75 mm	15 – 80
26.5 mm	0 – 15

The geotechnical resistances recommended for design of spread footings founded on a minimum 0.5 m thickness of rock fill are as follows:

Footing Width (m)	0.9	1.2	1.5
Factored Geotechnical Resistance at ULS (kPa)	450	525	600
Geotechnical Resistance at SLS (kPa)	450	425	400

The width of footing must be designed based on the load demand from the culvert structure and overlying embankment fill.

The geotechnical resistances are based on a footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance used in the design must be reduced in accordance with the CHBDC Clause 6.7.3 and 6.7.4.

The geotechnical resistance at SLS provided is based on an estimated total settlement on the culvert structure not exceeding 25 mm.

The lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.6 assuming a friction angle of 31° between the footing concrete and underlying clear stone. This value requires a degree of sliding movement to occur to fully mobilize the resistance.

8.3 Driven Steel Piles

The native soils at this site are typically dense to very dense and contain cobbles and boulders. Use of rock coring equipment was required to penetrate cobbles and boulders in each borehole drilled. In addition, bedrock was exposed at the ground surface at the culvert outlet. The use of driven steel H-piles or sheet piles is not recommended in these conditions and these alternatives have not been further developed.

8.4 Augered Caissons

Installation of caissons at this site is not recommended due to the presence of cobbles and boulders as well as the potential for base and sidewall instability in the cohesionless soils below the groundwater level. In view of these factors, this alternative has not been further developed.

8.5 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, spread footings on rock fill placed to raise the founding level above the groundwater level are considered the most cost effective and practical foundation option for supporting the culvert type selected for this site. This option will enable footing construction above the water level, reduce excavation and dewatering requirements, and provide a more uniform founding surface than footings on native soils. Footings at the south end of the culvert will be placed on bedrock.

Alternative culvert types (ie., box culvert) may be preferable at this site based solely on foundation design and construction considerations. However, selection of the proposed culvert type was based on considerations other than foundations.

8.6 Frost Cover

The depth of frost penetration at this site is 2.2 m. The base of all footings on native soil must be provided with a minimum of 2.2 m of earth cover as protection against frost action. Frost protection is not required for footings on bedrock or for footings constructed on a minimum 0.5 m layer of rock fill placed to establish founding levels above the groundwater level.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Culvert backfill should consist of free-draining granular material conforming to OPSS Granular A, Granular B Type II or Granular B Type III specifications.

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 OPSS 501.

In general, 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 9.1)
γ = bulk unit weight of retained soil (see Table 9.1)
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 $\phi = 35°, \gamma = 22.8\ kN/m^3$		OPSS Granular B Type I or Type III $\phi = 32°, \gamma = 21.2\ kN/m^3$	
	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 C6.16 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 at a depth of 1.7 m for Granular A or Granular B Type II.

The design of the culvert must incorporate measures such as weepholes or subdrains to permit drainage of the culvert backfill, or alternatively the culvert walls should be designed to withstand the potential build-up of hydrostatic pressures behind the walls.

10 EROSION CONTROL

Erosion and scour protection must be provided for the culvert foundations. In general, this will involve placing the footings below the level of potential scour and/or providing rock protection over the footings to prevent erosion and undermining of the foundations. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

11 EXCAVATION AND GROUNDWATER CONTROL

The excavation and backfilling for foundations must be carried out in accordance with OPSS 902. Construction staging will include temporary detouring of traffic onto the new WBL during culvert construction and therefore roadway protection will not be required.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the native silty sand to sand and gravel above the water table may be classed as Type 3 soils. This classification is based on the lack of cohesion in the soils. The cohesionless soils below the water table are classified as Type 4 soil.

Excavation for footing construction or placement of rock fill to prepare the founding surface is expected to extend up to about 2.9 or 0.9 m, respectively, below the groundwater levels within cohesionless soils containing cobbles and boulders. In these conditions, installation of sheet pile shoring, dewatering of the excavation and construction of culvert footings in the dry within close proximity to the creek is considered impractical.

The recommended procedure for preparation of the founding surface entails subexcavation in the wet to the depths outlined in Section 8 in short sections of about 2 m length followed by immediate backfilling with rock fill to the required founding level (allowing for the clear stone layer) and/or placement of tremie concrete. The contractor must ensure that the excavation does not encroach into the creek by controlling the length of excavation open at any one time.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. The Contract Documents should contain a NSSP advising the Contractor of the high groundwater levels, cohesionless soils and cobbles and boulders at this site that may impact foundation construction. Suggested wording is provided in Appendix E.

12 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 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 earth pressure coefficients that incorporate the effects of earthquake loading. The seismic component of the earth pressure distribution is additional to the static earth pressure distribution and may be taken as an inverted triangle with the maximum pressure at the top of the wall and the minimum pressure at the toe. The seismic earth pressure parameters (ΔK_{AE}) recommended for determining the seismic component are presented in Table 12.1:

Table 12.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Seismic Earth Pressure Coefficient (ΔK_E)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3		OPSS Granular B Type I or Type III $\phi = 32°, \gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (ΔK_{AE})*	0.01	0.03	0.01	0.03
At Rest (ΔK_{OE})**	0.02	-	0.03	-
Passive (ΔK_{PE})	-	-	-0.1	-

* 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.

13 CONSTRUCTION CONCERNS

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

- Preparation of the founding surfaces for spread footings will require excavation below the groundwater level within cohesionless soils containing cobbles and boulders. This work will require excavation in short sections (in the wet) followed by immediate backfilling with rock fill or tremie concrete. Driving of sheet piling is not considered feasible.
- Large boulders may be encountered within the excavation depth. Removal of these boulders will require suitable excavating equipment, and may result in areas of over-excavation requiring additional rock fill to backfill.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

14 CLOSURE

Engineering analysis and preparation of the report were carried out by Ms. Mei T. Cheong, M.Phil.

The report was reviewed by Mr. Murray R. Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd

Mei T. Cheong, M.Phil.
Geotechnical Specialist
Sept 19, 12

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Sept 19/12
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Sep 19/12
PROVINCE OF ONTARIO

Murray R. Anderson, P.Eng., M.Eng.
Senior Foundations Engineer

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

THURBER

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(1) '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.

<u>UNIFIED SOILS CLASSIFICATION</u>

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			

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS

- CLAYSTONE
- SILTSTONE
- SANDSTONE
- COAL
- Bedrock (general)

DISCONTINUITY SPACING

Bedding	**Bedding Plane Spacing**
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

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 percentage 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.

STRENGTH CLASSIFICATION

Rock Strength	**Approximate Uniaxial Compressive Strength**		**Field Estimation of Hardness***
	(MPa)	**(psi)**	
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

THURBER

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BCWE-1

METRIC

W.P. 623-89-00 LOCATION N 5 374 467.1 E 375 003.6 Blind Creek West EBL ORIGINATED BY ES

HWY 11/17 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2011.10.20 - 2011.10.20 CHECKED BY LRB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
234.7 / 0.0	**SAND** and **GRAVEL**, trace silt and clay; Dense to Compact; Brown; Damp; (FILL)	1	GS				
		1	SS	49	∇		
	Moist to Wet; Occasional cobbles	2	SS	28			37 56 7 (SI+CL)
232.4 / 2.3	Cored through **COBBLES** and **BOULDERS**						
231.7 / 3.0	**SAND**, fine grained, some silt, trace gravel; Compact; Orange Brown; Wet	3	SS	22			
230.2 / 4.5	Silty **SAND**, trace gravel; Very Dense; Grey; Wet	4	SS	50/ 0.075			
228.0 / 6.7	Cored through **COBBLES** and **BOULDERS**	1	RUN			FI: >25, >10	RUN #1 TCR=49% SCR=24% RQD=24%
227.3 / 7.4	**BEDROCK**, metavolcanic, grey with white bands, occasional quartz interbeds; Occasional mechanical breaks; Sub-vertical fracture (25mm) at 9.1m, 9.4m, 9.5m, 9.9m: 75mm at 8.0m	2	RUN			1, 1, 1, 2, 1, 1	RUN #2 TCR=100% SCR=100% RQD=100% UCS=195MPa (Average)
		3	RUN			2, 2, 1	RUN #3 TCR=100% SCR=100% RQD=100% UCS=93MPa (Average)

Elevation scale: 234, 233, 232, 231, 230, 229, 228, 227, 226, 225

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

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

ONTMT4S 1182.GPJ 6/5/12

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BCWE-1

METRIC

W.P. 623-89-00 LOCATION N 5 374 467.1 E 375 003.6 Blind Creek West EBL ORIGINATED BY ES

HWY 11/17 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2011.10.20 - 2011.10.20 CHECKED BY LRB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
224.0	**BEDROCK**, metavolcanic, grey with white bands, occasional mechanical breaks									1 0	
10.7	END OF BOREHOLE AT 10.7m. WATER LEVEL AT 1.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO 3.6m, THEN AUGER CUTTINGS TO SURFACE.										

ONTMT4S 1182.GPJ 6/5/12

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

20 / 15 -⊕- 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BCWE-2

METRIC

W.P.	623-89-00	LOCATION	N 5 374 463.3 E 375 020.7 Blind Creek West EBL	ORIGINATED BY	ES
HWY	11/17	BOREHOLE TYPE	Casing/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.10.21 - 2011.10.21	CHECKED BY	LRB

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
235.0								
0.0	**SAND** and **GRAVEL**, trace silt and clay Very Dense to Compact Brown Damp (FILL)	1	GS			235		
		1	SS	56		234		
	Occasional cobbles Moist	2	SS	31	∇	233		
	Wet	3	SS	50/ 0.100				76 22 2 (SI+CL)
231.9 3.1	Cored through **COBBLES** and **BOULDERS**					232		
230.8 4.2	**SAND** and **GRAVEL**, with cobbles and boulders, trace silt and clay Compact Brown Wet	4	SS	26		231 230		56 41 3 (SI+CL)
229.7 5.3	Cored through **COBBLES** and **BOULDERS**					229	FI	
228.9 6.1	**BEDROCK**, metavolcanic, occasional quartz interbeds, grey with white bands, occasional vertical and mechanical bands Sub-vertical fracture (25mm to 100mm) at 6.4m, 6.6m, 6.8m, 7.0m and 7.1m Sub-horizontal fracture at 6.9m	1	RUN			228	3 >5 4 >5 1	RUN #1 TCR=93% SCR=88% RQD=88% UCS=97MPa (Average)
	Sub-vertical fracture (25mm to 75mm) at 8.2m, 8.3m, 8.8m 125mm at 8.4m	2	RUN			227 226	1 0 1 2 >5	RUN #2 TCR=100% SCR=90% RQD=90% UCS=81MPa (Average)
225.9 9.1	END OF BOREHOLE AT 9.1m. WATER LEVEL AT 2.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 3.0m, THEN SAND AND GRAVEL TO							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity   20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BCWE-2

METRIC

W.P.	623-89-00	LOCATION	N 5 374 463.3 E 375 020.7 Blind Creek West EBL	ORIGINATED BY	ES
HWY	11/17	BOREHOLE TYPE	Casing/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.10.21 - 2011.10.21	CHECKED BY	LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	SURFACE.										

ONTMT4S 1182.GPJ 12/14/11

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

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BCWE-3

METRIC

W.P. 623-89-00 | LOCATION N 5 374 459.7 E 375 036.8 Blind Creek West EBL | ORIGINATED BY ES

HWY 11/17 | BOREHOLE TYPE Manual Excavation & Visual Inspection | COMPILED BY AN

DATUM Geodetic | DATE 2011.10.21 - 2011.10.21 | CHECKED BY LRB

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	SAMPLES – TYPE	SAMPLES – "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
232.7											
0.0 / 0.1	**GRAVEL**, some sand, mixed with organics Brown (60mm)										
	END OF BOREHOLE AT 0.06m ON BEDROCK.										

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BCWE-4

METRIC

W.P. 623-89-00 | LOCATION N 5 374 476.8 E 375 005.7 Blind Creek West EBL | ORIGINATED BY ES

HWY 11/17 | BOREHOLE TYPE Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2011.10.22 - 2011.10.22 | CHECKED BY LRB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
233.2								
0.0	**TOPSOIL:** (25mm)							
	SAND and **GRAVEL**, trace silt and clay, occasional organics, occasional cobbles, Dense, Brown, Damp to Moist (FILL)	1	SS	46		233		
					▽ (water level)			
		2	SS	30		232		62 34 4 (SI+CL)
231.7 / 1.5	Cored through **COBBLES** and **BOULDERS**	3	SS	50/ 0.050				
230.9 / 2.3	**SAND** and **GRAVEL**, with cobbles and boulders, trace silt and clay, Very Dense, Brown, Wet. Cored through cobbles and boulders from 2.6m to 4.6m	4	SS	82/ 0.175		231, 230, 229		
	No recovery	5	SS	50/ 0.050				
227.9 / 5.3	Cored through **COBBLES** and **BOULDERS**					228	FI	
227.7 / 5.5	**BEDROCK**, metavolcanic, grey with white bands, mechanical and vertical breaks, occasional quartz interbeds. Sub-vertical fracture (50mm to 100mm) at 5.7, 5.8m. Vertical fracture (75mm) at 5.7m, 5.9m, 125mm at 5.8m. Sub-horizontal fracture at 5.5m, 6.0m	1	RUN				>25, >5, >5	RUN #1 TCR=100% SCR=64% RQD=58% UCS=21MPa (Average)
	Vertical fractures at: 125mm at 6.0m, 175mm at 6.1m, 100mm at 8.7m	2	RUN			227, 226	>5, 4, 1, 1, 2	RUN #2 TCR=100% SCR=100% RQD=89% UCS=78MPa (Average)
	Sub-vertical fractures (25mm to 100mm) at 6.5m, 6.6m, 6.7m, 7.2m, 7.3m, 7.6m, 7.9m, 8.0m, 125mm at 8.3m. Highly broken (125mm) at 8.8m	3	RUN			225	3, 4, 2, 5	RUN #3 TCR=100% SCR=91% RQD=83% UCS=122MPa (Average)
224.2 / 9.0	END OF BOREHOLE AT 9.0m. WATER LEVEL AT 0.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.5m, THEN CUTTINGS TO SURFACE.							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ◯ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BCWE-5

METRIC

W.P.	623-89-00	LOCATION	N 5 374 473.9 E 375 018.8 Blind Creek West EBL	ORIGINATED BY	ES
HWY	11/17	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.10.20 - 2011.10.20	CHECKED BY	LRB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT	UNIT WEIGHT / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
234.6 / 0.0	**SAND** and **GRAVEL**, Dense, Brown, Damp (FILL)	1	GS			234	o		
		1	SS	42	▽		o		
232.8	No recovery	~~2~~	~~SS~~	~~100/~~ 0.0		233			
1.8	Cored through **COBBLES** and **BOULDERS**					232			
231.6 / 3.0	Silty **SAND**, some gravel, trace clay, Dense, Grey, Moist	3	SS	35		231	o		10 52 29 9
229.4	Becoming gravelly, occasional cobbles, Wet	4	SS	40		230	o		
5.2	Cored through **COBBLES** and **BOULDERS**	1	RUN			229		FI: >25, >15, >10	RUN #1 TCR=57% SCR=36% RQD=23% UCS=135MPa (Average)
228.8 / 5.8	**BEDROCK**, metavolcanic, grey with white bands, quartz interbeds. Sub-vertical fractures (50mm) at 6.6m, 7.3m, 7.4m	2	RUN			228		2, 1, 2, 2, >5	RUN #2 TCR=100% SCR=100% RQD=97% UCS=84MPa (Average)
	Highly broken zone (75mm) at 7.6m					227		1, 1	
225.4	Sub-vertical fractures (25mm to 50mm) at 8.3m, 8.5m, 8.6m, 8.7m, 9.1m	3	RUN			226		2, >5, 3	RUN #3 TCR=100% SCR=100% RQD=97% UCS=75MPa (Average)
9.2	END OF BOREHOLE AT 9.2m. WATER LEVEL AT 1.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 3.0m,								

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 1182.GPJ 6/5/12

RECORD OF BOREHOLE No BCWE-5

METRIC

W.P. 623-89-00
LOCATION N 5 374 473.9 E 375 018.8 Blind Creek West EBL
ORIGINATED BY ES

HWY 11/17
BOREHOLE TYPE Hollow Stem Augers/NQ Coring
COMPILED BY AN

DATUM Geodetic
DATE 2011.10.20 - 2011.10.20
CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	THEN AUGER CUTTINGS TO SURFACE.										

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

15-⊕-5 (20 / 10) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BCWE-6

METRIC

W.P. 623-89-00 LOCATION N 5 374 469.3 E 375 039.0 Blind Creek West EBL ORIGINATED BY ES

HWY 11/17 BOREHOLE TYPE Visual Inspection of Embankment Slope Surface COMPILED BY AN

DATUM Geodetic DATE 2011.10.21 - 2011.10.21 CHECKED BY LRB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
233.5											
0.0	**SAND** and **GRAVEL**, some cobbles and boulders Brown (FILL)						233				
232.1 / 1.4	BEDROCK EXPOSED AT TOP OF EMBANKMENT SLOPE ADJACENT TO BOREHOLE LOCATION.										

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

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

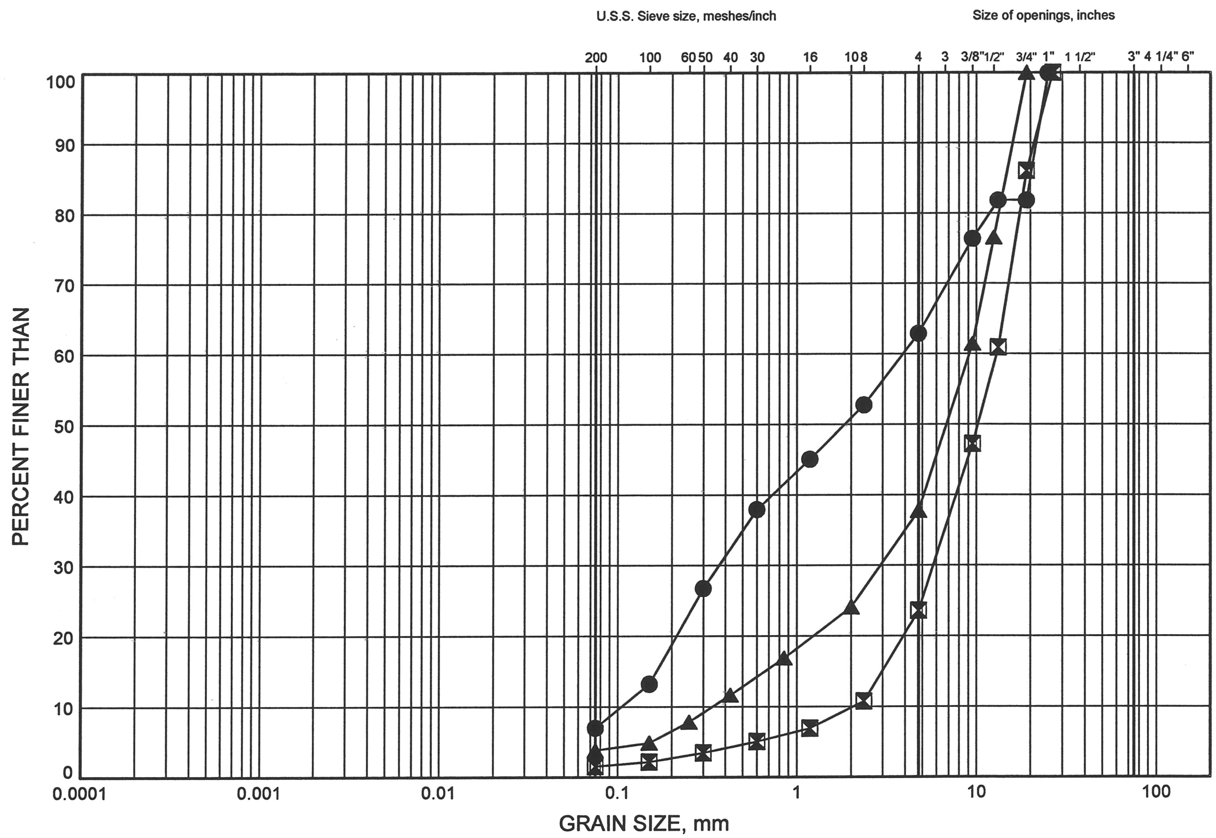
Laboratory Test Results

Hwy 17 - Hwy 527 easterly 12.6km

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND & GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWE-1	1.83	232.83
⊠	BCWE-2	2.44	232.54
▲	BCWE-4	1.07	232.12

W.P.# 623-89-00
Prepared By AN
Checked By LRB

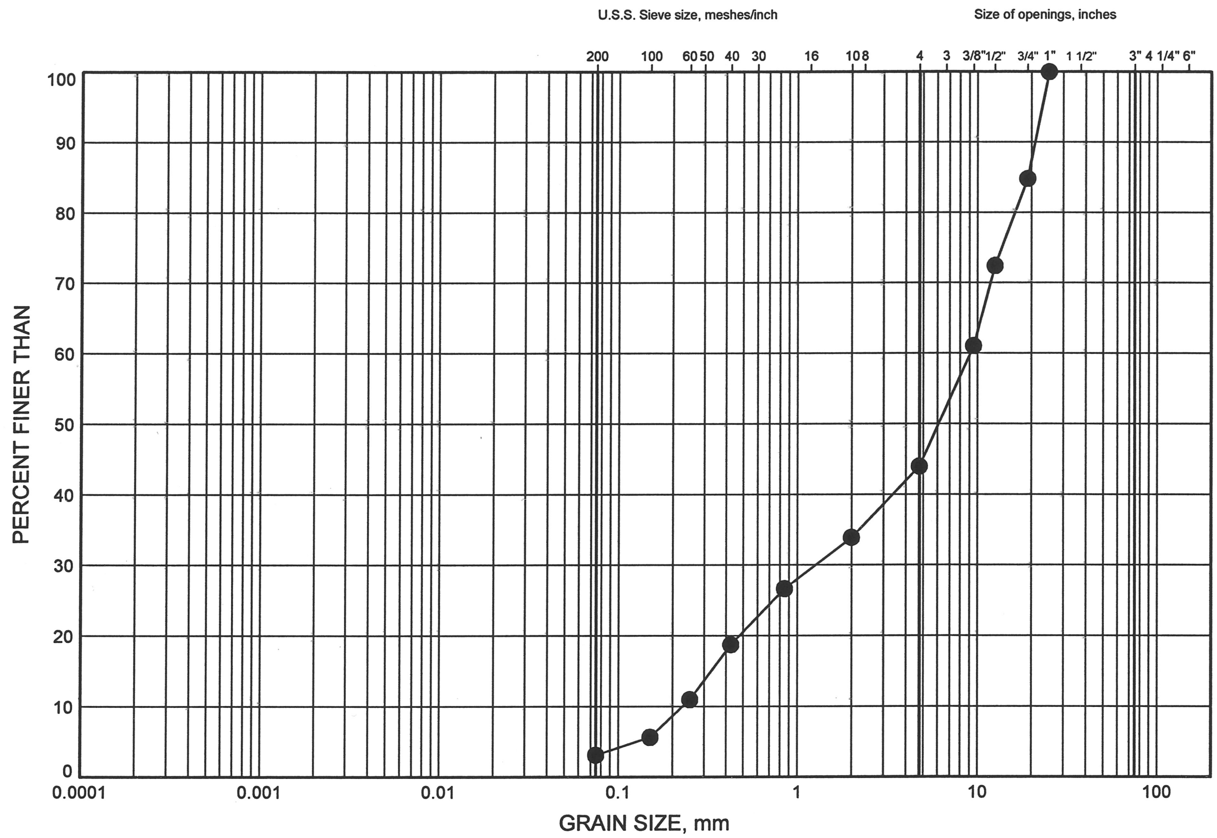
THURBER

Hwy 17 - Hwy 527 easterly 12.6km

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND & GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWE-2	4.88	230.10

W.P.# 623-89-00

Prepared By AN

Checked By LRB

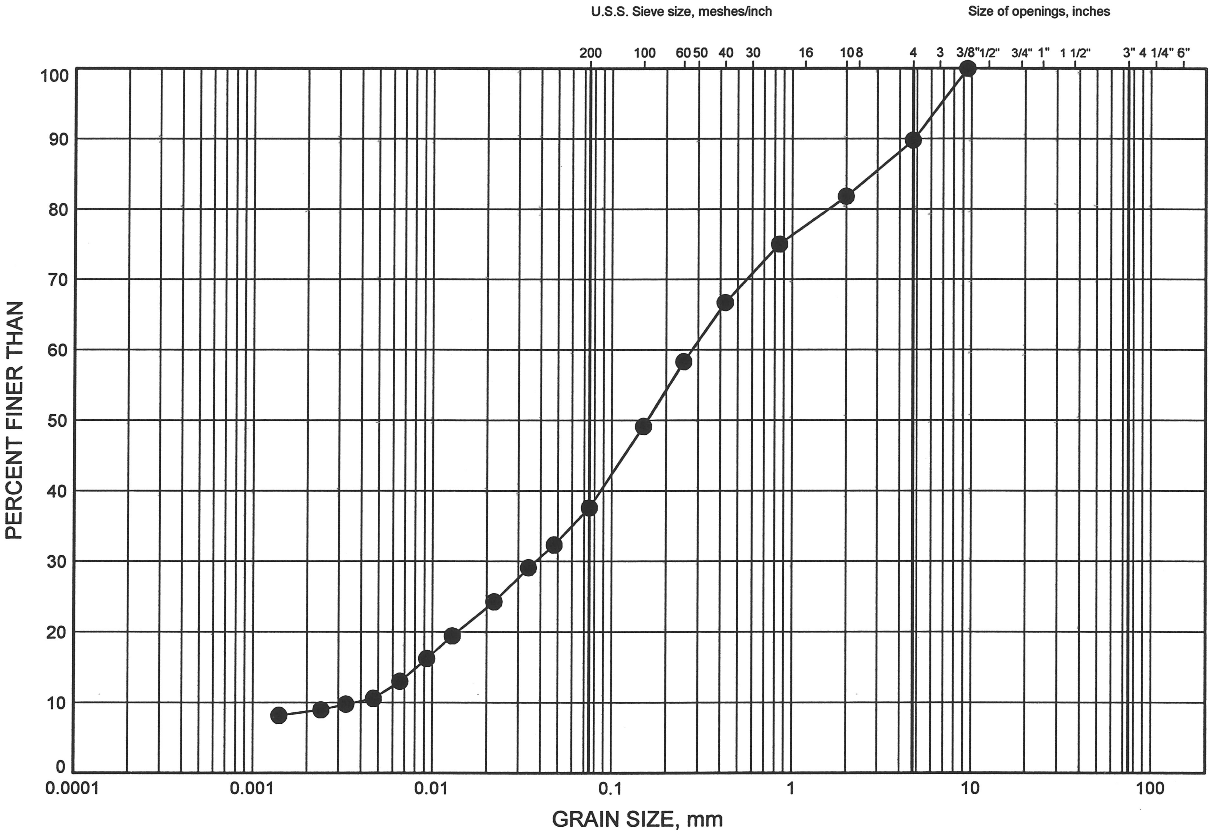
THURBER

Hwy 17 - Hwy 527 easterly 12.6km

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWE-5	3.96	230.60

W.P.# 623-89-00
Prepared By AN
Checked By LRB

THURBER

GRAIN SIZE DISTRIBUTION - THURBER 1182.GPJ 12/1/11

Appendix C

Site Photographs

Photograph 1 – Blind Creek West EBL Culvert Inlet

Photograph 2 – Blind Creek West EBL Culvert Outlet

Appendix D

Foundation Comparison

THURBER

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Rock Fill	Driven Steel Piles	Caissons (Drilled Shaft)
Advantages: i. Generally less costly construction than deep foundation elements. ii. Rock fill is not required.	***Advantages:*** i. Generally less costly construction than deep foundation elements. ii. Allows construction of footings above the groundwater level. iii. Higher geotechnical resistances compared to footings on native soil. iv. More uniform support than footings partially on native soil. v. Precast concrete footings may be employed	***Advantages:*** i. High geotechnical resistances can be achieved in dense to very dense soils. ii. Installation of piles could continue in freezing weather iii. Excavation below groundwater level may be reduced or eliminated.	***Advantages:*** i. High geotechnical resistances can be achieved in dense to very dense soils. ii. Installation of caissons could continue in freezing weather iii. Excavation below groundwater level may be reduced or eliminated.
Disadvantages: i. Subexcavation below the water level is required. ii. Footings must be placed using tremie concrete, which may not be compatible with proposed culvert type. iii. Greater excavation depths would be required for higher resistance values. iv. Potential disturbance of subgrade during excavation.	***Disadvantages:*** i. Subexcavation below the water level is required to place rock fill. ii. Additional cost of rock fill placement compared to footings on native soil. iii. Rock fill cannot be compacted under water. iv. Potential disturbance of subgrade during excavation.	***Disadvantages:*** i. Driven piles are expected to encounter refusal on cobbles and boulders at varying depths and often above the bedrock surface. ii. Predrilling through cobbles and boulders will be difficult. iii. Pile lengths will be inadequate at the outlet due to bedrock at the ground surface. Socketing into the bedrock would be required. iii. Higher unit costs than footings. iv. Pile lengths may vary.	***Disadvantages:*** i. Augering and advancement of liner may be obstructed by cobbles and boulders and the very dense nature of the soils at site. ii. Higher cost than spread footings iii. Specialized installation measures such as temporary liners and drilling mud will be required to install caissons in cohesionless soils below the water table. iv. Potential difficulty in cleaning and inspecting bases.
FEASIBLE	**RECOMMENDED**	**NOT RECOMMENDED**	**NOT RECOMMENDED**

Appendix E

List of SPs and OPSS, and Suggested Text for Selected NSSP

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

- OPSS 206
- OPSS 501
- OPSS 804
- OPSS 902

2 Suggested Text for NSSP on Foundation Excavation

The Contractor is advised that groundwater levels are high at this site and the soils consist of cohesionless silty to gravelly sands containing cobbles and boulders. Preparation of the founding surfaces for spread footings will require excavation below the groundwater level within these deposits.

Excavation sidewalls in the cohesionless deposits will generally be unstable and sloughing due to groundwater inflow must be anticipated. The presence of cobbles and boulders is likely to preclude the use of driven sheet piles, and therefore installation of sheet pile shoring, dewatering of the excavation and construction of culvert footings in the dry is considered impractical at this site.

In view of the site conditions, preparation of the founding surface is to entail subexcavation in the wet to the specified depths (compact to dense native soils) in short sections of about 2 m length followed by immediate backfilling with rock fill to above the groundwater level, followed by placement of clear stone to the design founding level as per the Contract Drawings.

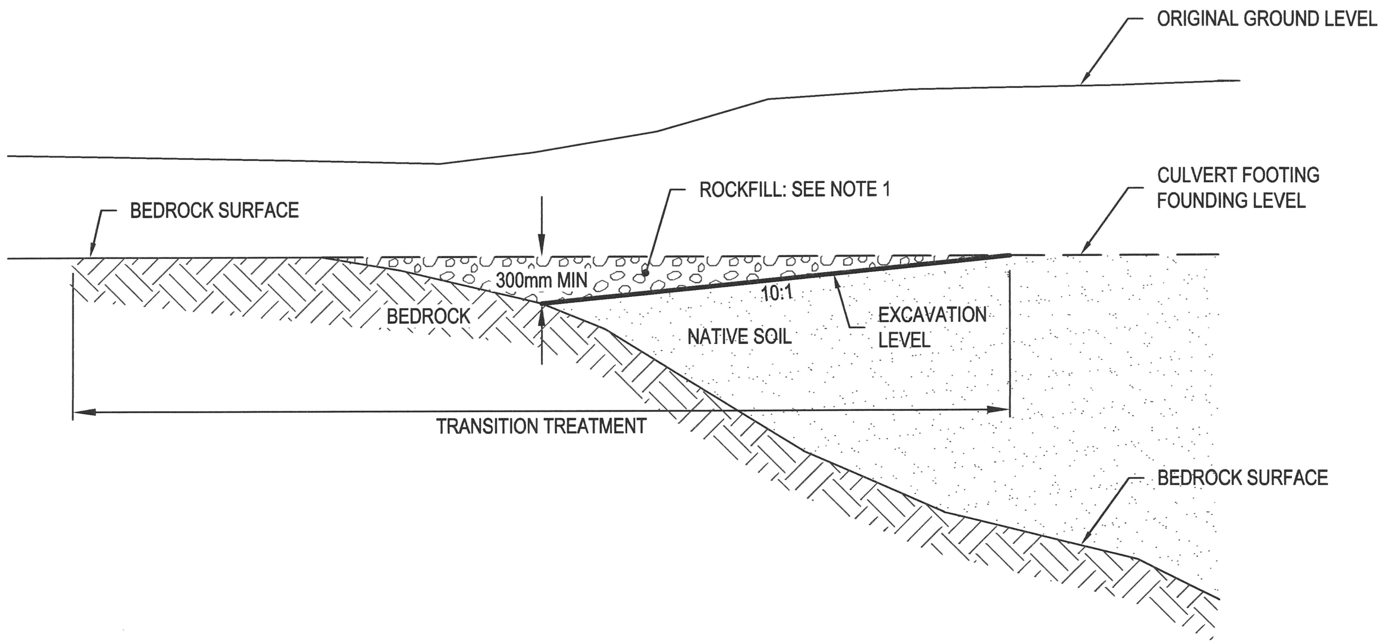
The contractor must carry out the work in a manner which minimizes disturbance to the excavation base and ensure that the excavation does not encroach into the creek by controlling the length of excavation open at any one time, use of shoring, or other suitable means.

Large boulders may be encountered within the excavation depth. Removal of these boulders will require appropriate excavating equipment, and may result in areas of over-excavation requiring additional rock fill to backfill.

Selection of the equipment and methodology to excavate and prepare the founding surface remains the responsibility of the Contractor, and should be based on his interpretation of the subsurface conditions presented in the Foundation Investigation Report as well as the surface conditions exposed at the site.

Appendix F

Figure F1 – Transition Treatment for Footings
Figure F2 - Details of Footing on Rock Fill



LONGITUDINAL SECTION

NOTE:

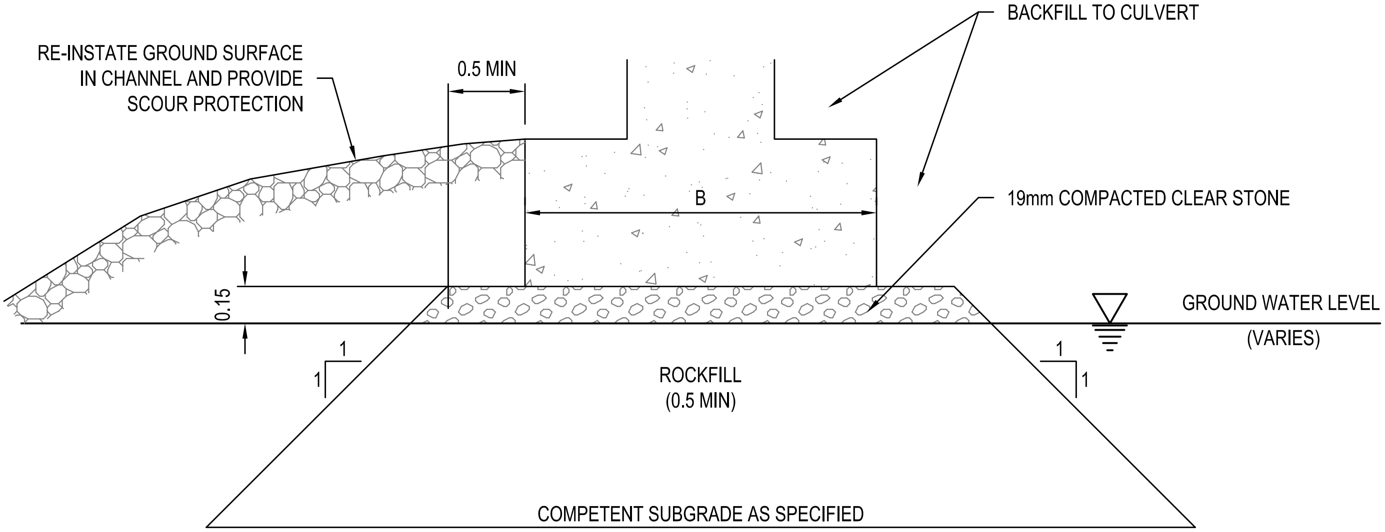
1. ROCKFILL SHALL HAVE PARTICLE SIZE NO GREATER THAN 150mm.

TRANSITION TREATMENT FOR FOOTINGS
BEDROCK TO NATIVE SOIL

THURBER ENGINEERING LTD.

ENGINEER:	DRAWN:	APPROVED:
MC	MFA	-
DATE:	SCALE:	DRAWING No.
JUNE 2012	N.T.S.	FIGURE F1

H:\Drafting\19\13511182\FootingTransition.dwg - 6/5/2012 2:13 PM



CROSS-SECTION

NOTES:

1. REMOVE ANY TOPSOIL AND SOFT/LOOSE SUBSOIL UNDER AREA OF ROCKFILL TO COMPETENT SUBGRADE LEVEL AS SPECIFIED.
2. PLACE ROCKFILL TO ABOVE GROUNDWATER LEVEL. ROCKFILL TO HAVE PARTICLE SIZE NO GREATER THAN 150mm.
3. ROCKFILL SURFACE SHOULD BE COMPACTED WITH SEVERAL PASSES OF A DOZER/ROLLER AFTER ROCKFILL IS ABOVE WATER LEVEL.
4. PLACE CLEAR STONE TO BASE OF FOOTING LEVEL AND COMPACT THE CLEAR STONE.
5. PLACE CONCRETE FOOTING.
6. RE-INSTATE GROUND SURFACE IN CHANNEL AND PROVIDE SCOUR PROTECTION.

FOOTING ON ROCKFILL CORE

THURBER ENGINEERING LTD.

ENGINEER :	DRAWN :	APPROVED :
MRA	MFA	-
DATE : SEPTEMBER 2012	SCALE : N.T.S.	DRAWING No. FIGURE F2

H:\Drafting\19\13511182\FootingonRockfill2.dwg - 9/24/2012 11:30 AM

Appendix G

Borehole Locations and Soil Strata Drawing

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No 2012–6010
WP No 623–89–00

HIGHWAY 11/17
BLIND CREEK WEST EBL
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

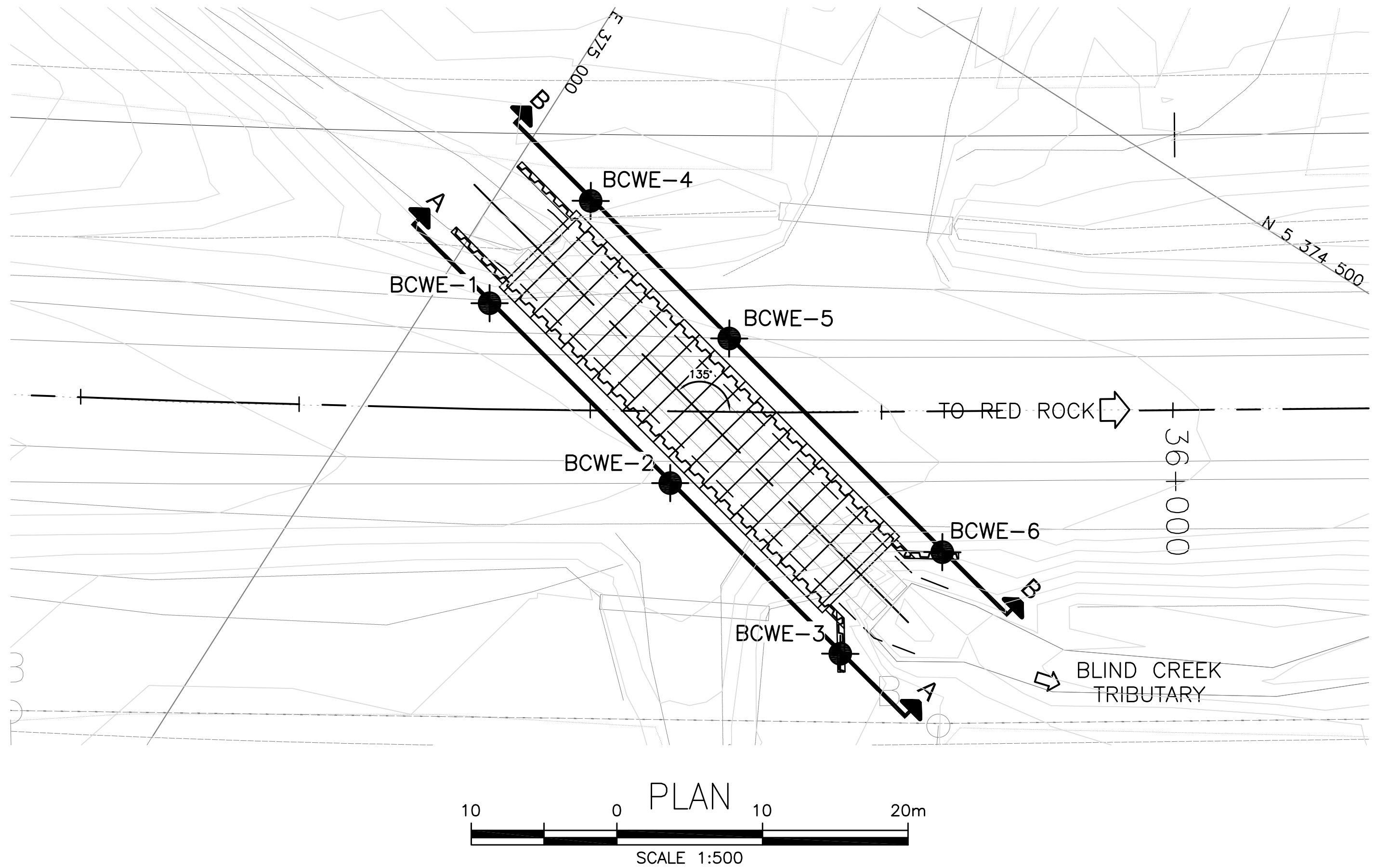
SHEET 240

Hatch Mott MacDonald

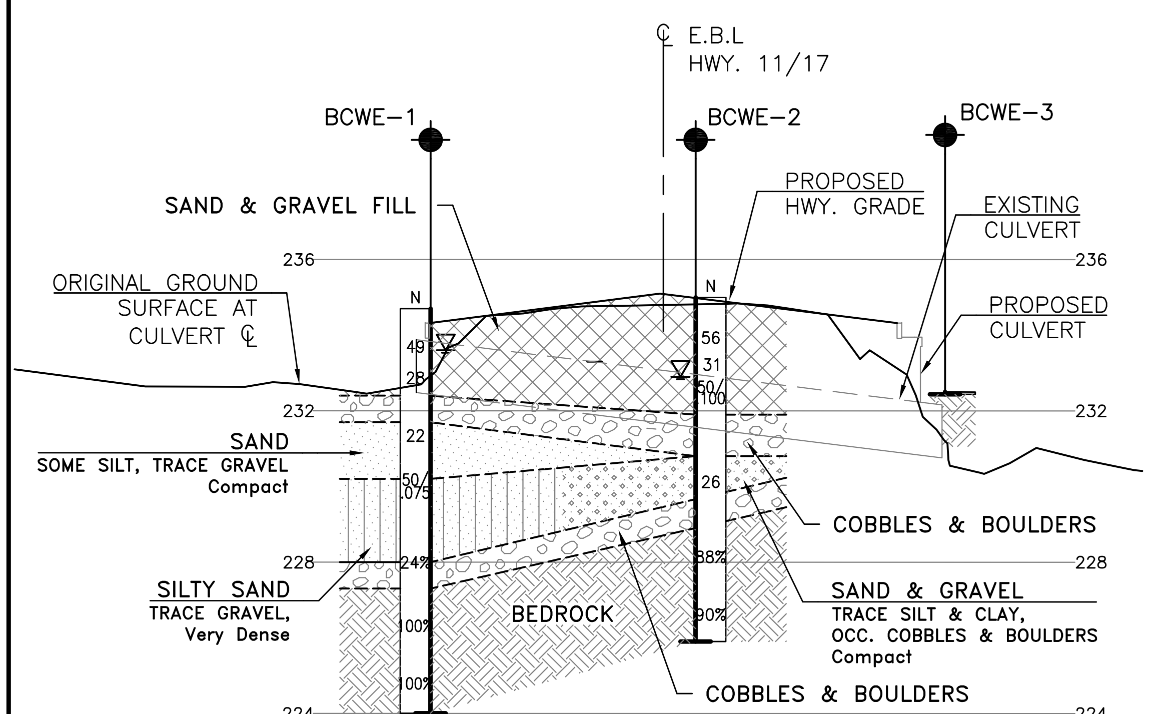
THURBER ENGINEERING LTD.

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Sep 19/12
PROVINCE OF ONTARIO

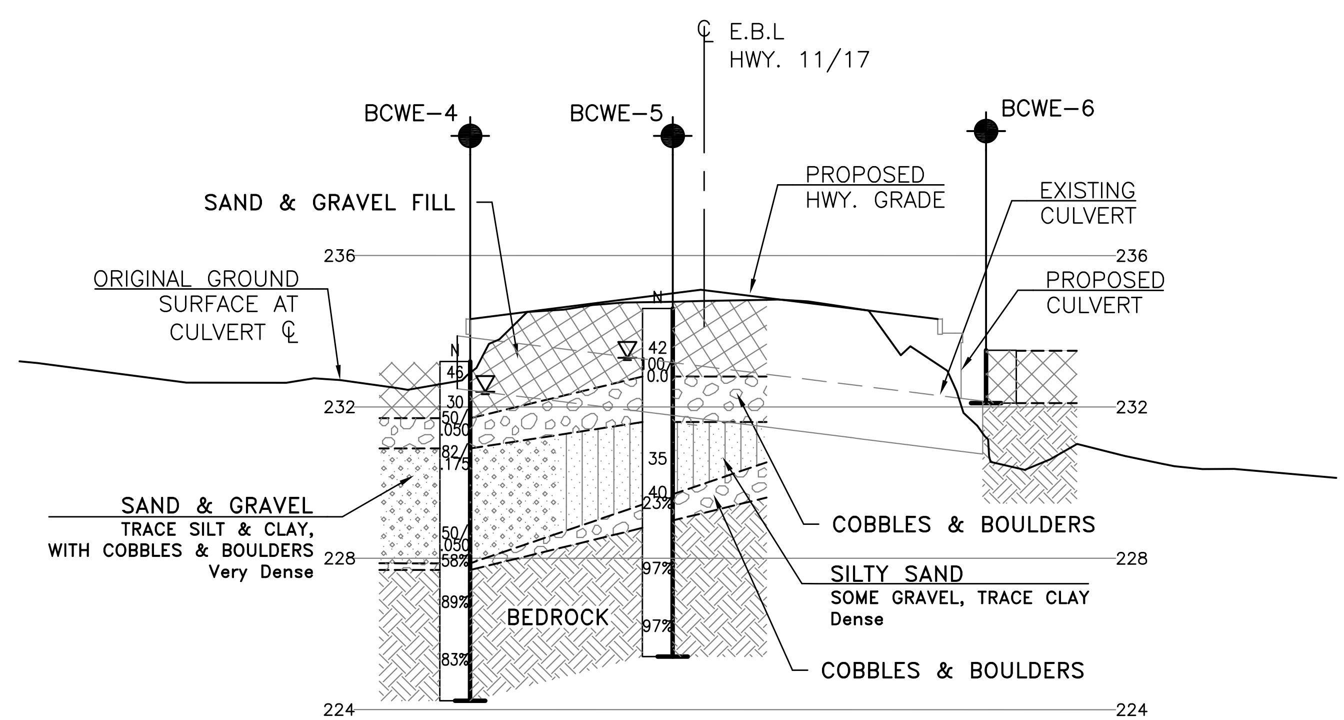
LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Sep 19/12
PROVINCE OF ONTARIO



PLAN



SECTION A–A



SECTION B–B

10 0 10 20m H 1:500

4 0 4 8 V 1:200

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
▼	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BCWE–1	234.7	5 374 467.1	375 003.6
BCWE–2	235.0	5 374 463.3	375 020.7
BCWE–3	232.7	5 374 459.7	375 036.8
BCWE–4	233.2	5 374 476.8	375 005.7
BCWE–5	234.6	5 374 473.9	375 018.8
BCWE–6	233.5	5 374 469.3	375 039.0

-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-160

REVISIONS	DATE	BY	DESCRIPTION

DESIGN LRB	CHK LRB	CODE CAN/CSA S6–06	LOAD CL–625–ONT	DATE JULY 2012
DRAWN AN	CHK LRB	SITE 48C–350/C1	STRUCT	DWG 2

FILENAME: H:\Drafting\19\1351\182\ted1182–BlindCreekWest(EBL)Revise.dwg
PLOTDATE: 9/26/2012 9:50 AM