

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
BLIND CREEK WEST CULVERT – WBL  
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/C2**

**Geocres Number: 52A-163**

**Report to**

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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted at the proposed location of the Blind Creek West culvert under the new westbound lanes of Highway 11/17 in the Township of MacGregor, District of Thunder Bay. The new 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 approximately 80 m north of the existing Highway 11/17 alignment.

Blind Creek West flows from north to south at the proposed culvert location. Lands surrounding the culvert site consist of forested areas. Cobbles and boulders were observed within the creek channel and at ground surface at various locations across the site.

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 located near a boundary between mafic to intermediate metavolcanic bedrock and metasedimentary bedrock. Bedrock samples collected during the field investigation confirm that the site is underlain by intermediate metavolcanic rock. Locally, the bedrock is overlain by deposits of sand and gravel, silty sand and sand.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for this project were carried out between November 1 and 6, 2011. Six boreholes, identified as BCWW-1 to BCWW-6, were drilled and sampled at the site.

Boreholes BCWW-1 and BCWW-4 were located near the proposed culvert inlet, Boreholes BCWW-2 and BCWW-5 were located at the centreline of the proposed WBL, and Boreholes BCWW-3 and BCWW-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.

The boreholes were advanced to depths of 6.8 m to 10.7 m (elevations 230.6 to 225.6). Bedrock was proven by coring 3.4 m to 3.8 m into bedrock in all boreholes.

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 during and upon completion of the drilling operations. Groundwater conditions observed after completion of coring were not representative of site conditions as water was introduced into the borehole during coring. A standpipe piezometer was installed in Borehole BCWW-5 for subsequent monitoring of groundwater levels. The completion details of the piezometers and boreholes are summarized in Table 3.1. The piezometer was decommissioned in general accordance with MOE Regulation 903 in late July 2012.

**Table 3.1 – Piezometer and Borehole Completion Details**

<b>Borehole</b>	<b>Borehole Depth/ Elevation (m)</b>	<b>Completion Details</b>
BCWW-1	-	Backfilled with bentonite holeplug to 4.5 m, then auger cuttings to surface .
BCWW-2	-	Backfilled with bentonite holeplug to 5.5 m, then auger cuttings to surface.
BCWW-3	-	Backfilled with bentonite holeplug and auger cuttings to surface.
BCWW-4	-	Backfilled with bentonite holeplug and auger cuttings to surface.
BCWW-5	4.3 / 232.4	Bentonite holeplug from 7.7 m to 4.3 m. Piezometer installed at 4.3 m. Filter sand from 4.3 m to 1.5 m, then bentonite holeplug to surface.
BCWW-6	-	Backfilled with bentonite holeplug and auger cuttings to surface.

#### **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 topsoil overlying a layer of gravelly sand, underlain by various cohesionless deposits of sand and gravel, sand to silty sand, and silt. Cobbles and boulders were encountered within these deposits. Bedrock was encountered below the cohesionless deposits. More detailed descriptions of the individual strata are presented below.

### **5.1 Topsoil**

Topsoil was encountered at the surface in all boreholes. The topsoil is dark brown to black and typically described as silty with some sand. The topsoil thickness varied from 200 mm to 400 mm.

### **5.2 Gravelly Sand**

A layer of gravelly sand was encountered below the topsoil in all boreholes. The gravelly sand is brown, locally dark brown or grey, and contains trace to some silt, and cobbles and boulders. The use of coring methods was required to advance Boreholes BCWW-1 and BCWW-2 through the cobbles and boulders within the gravelly sand.

The gravelly sand layer was 0.3 m to 2.9 m thick. The base of this layer was encountered at depths of 0.6 m to 3.1 m (elevations 236.1 to 234.3).

SPT N-values recorded in the gravelly sand ranged from 26 blows for 0.3 m penetration to 100 blows/0.125 m, indicating a compact to very dense relative density. The higher 'N' values may be associated with the presence of cobbles and boulders. N-values of 6 to 16 blows for 0.3 m were obtained in tests commenced at the ground surface (partially in topsoil and partially in the gravelly sand), indicating a surficially loose to compact condition.

The moisture content of samples of the gravelly sand ranged from 8% to 28%, with the higher values possibly reflecting an organic content.

Two samples of the gravelly sand underwent laboratory gradation analysis. The results of this testing are presented on the Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figure B1, Appendix B. The results are as follows:

Gravel %	21 to 25
Sand %	55 to 71
Silt and Clay %	8 to 20

### **5.3 Sand and Silt**

A layer of sand and silt was encountered below the gravelly sand at 2.1 m depth (elevation 235.4) locally in Borehole BCWW-2. The sand and silt was brown and contained trace gravel and trace clay. The sand and silt layer was 0.8 m thick with a base at 2.9 m depth (elevation 234.6).

An SPT N-value of 31 blows for 0.3 m penetration was recorded in the sand and silt layer, indicating a dense condition. The moisture content of a sample was 16%.

A sample of the sand and silt underwent laboratory gradation analysis, the results of which are summarized below. The results of this test are also presented on the Record of Boreholes sheets in Appendix A and the grain size distribution curve for this sample is plotted on Figure B2, Appendix B.

Gravel %	7
Sand %	43
Silt %	46
Clay %	4

#### **5.4 Sand and Gravel**

A layer of brown to grey sand and gravel with cobbles and boulders was encountered below the gravelly sand in Borehole BCWW-1 and below the sand and silt layer in Borehole BCWW-2. The sand and gravel layer contained some silt. Coring was required to advance the boreholes through the cobbles and boulders within the sand and gravel layer.

The sand and gravel layer was 3.8 m and 3.0 m thick in Boreholes BCWW-1 and BCWW-2, respectively. The base of this layer was encountered at depths of 5.3 m and 5.9 m (elevations 232.2 and 231.6).

SPT N-values recorded in the sand and gravel layer generally ranged from 38 blows for 0.3 m penetration to 100 blows/0.125 m penetration, indicating a dense to very dense relative density and/or the presence of cobbles and boulders. A lower N-value of 17 blows for 0.3 m was obtained near the base of this deposit in Borehole BCWW-1, indicating a compact condition.

The moisture content of samples of the sand and gravel layer ranged from 8% to 16%.

One sample of the sand and gravel underwent laboratory gradation analysis. The results of this testing are presented on the Record of Borehole sheets in Appendix A and the grain size distribution curve is plotted on Figure B3, Appendix B. The results are as follows:

Gravel %	59
Sand %	29
Silt and Clay %	12

#### **5.5 Silt**

A layer of brown to grey silt was encountered below the gravelly sand layer locally in Borehole BCWW-3. The silt contained trace sand and trace to some clay. The silt layer was 4.6 m thick with a lower boundary at 5.5 m depth (elevation 230.8).

SPT N-values recorded in the silt layer ranged from 7 to 21 blows for 0.3 m penetration, indicating a loose to compact relative density. The moisture content of samples of the silt ranged from 21% to 26%.

Two samples of the silt underwent laboratory gradation analysis, the results of which are summarized below. The results of this testing are also presented on the Record of Boreholes sheets in Appendix A and the grain size distribution curves are plotted on Figure B4, Appendix B.

Gravel %	0
Sand %	6 to 9
Silt %	80 to 88
Clay %	6 to 11

## **5.6 Silty Sand**

A layer of silty sand was encountered below the silt in Borehole BCWW-3 and below the gravelly sand in Boreholes BCWW-4 to BCWW-6. The silty sand was brown to grey and contains trace to some gravel and trace clay. This unit became gravelly immediately above the underlying bedrock in Borehole BCWW-3.

The thickness of the silty sand ranged from 0.3 m to 2.9 m, with the lower boundary encountered at depths of 2.1 m to 7.2 m (elevations 234.6 to 229.1).

SPT N-values recorded in the native silty sand typically ranged from 39 to 61 blows for 0.3 m penetration, indicating a dense to very dense relative density. An N-value of 14 blows per 0.3 m (compact) was obtained in the upper part of this layer in Borehole BCWW-5. A higher N-value of 50 blows for 0.15 m penetration was recorded in Borehole BCWW-4 just above the bedrock surface.

The moisture content of samples of the silty sand ranged from 10% to 18%.

Four samples of the silty sand underwent laboratory gradation analysis, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A and are plotted on Figure B5, Appendix B.

Gravel %	5 to 19
Sand %	54 to 55
Silt %	23 to 35
Clay %	4 to 5

## 5.7 Sand

A layer of sand containing trace gravel and some silt was encountered below the silty sand in Boreholes BCWW-5 and BCWW-6. The sand layer was 2.2 m and 1.5 m thick with a lower boundary at depths of 4.3 m and 5.5 m (elevations 232.4 and 230.2). This unit became gravelly immediately above the underlying bedrock in Borehole BCWW-6.

SPT N-values of 4 and 17 blows for 0.3 m penetration were recorded in the sand in Borehole BCWW-5, indicating a loose to compact relative density. An N-value of 100 blows per 0.3 m (very dense) was obtained in Borehole BCWW-6.

The moisture content of samples of the sand ranged from 10% to 14%.

A sample of the sand underwent laboratory gradation analysis, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A and are plotted on Figure B6, Appendix B.

Gravel %	8
Sand %	76
Silt and Clay %	16

## 5.8 Bedrock

Bedrock was proven below the sand and gravel, silty sand and sand by coring in all boreholes. The depths to bedrock are summarized in Table 5.1.

**Table 5.1 – Depth to Bedrock at Borehole Locations**

<b>Borehole</b>	<b>Depth to Bedrock (m)</b>	<b>Top of Bedrock Elevation (m)</b>	<b>Method</b>
BCWW-1	5.3	232.2	Cored
BCWW-2	5.9	231.6	Cored
BCWW-3	7.2	229.1	Cored
BCWW-4	3.4	234.0	Cored
BCWW-5	4.3	232.4	Cored
BCWW-6	5.5	230.2	Cored

The bedrock recovered in the cores was described as greenish grey metavolcanic bedrock. Zones of highly fractured rock (rubble zones) were noted in Boreholes BCWW-1, BCWW-2 and BCWW-5.

Total core recovery typically ranged from 86% to 100%. One run in Boreholes BCWW-2 yielded a lower core recovery of 56% in a highly fractured rock zone.

RQD values recorded for the bedrock core varied widely. RQD values typically ranged from 52% to 100%, indicating fair to excellent rock quality. Four values ranged from 14%

to 47%, indicating a very poor to poor rock quality, and an RQD value of 0% (very poor quality) was recorded in the initial two core runs from Borehole BCWW-2. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, varied from 0 to 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 118 to 197 MPa, indicating a very strong intact rock. Strengths of 32 to 88 MPa were measured on three samples, indicating a medium strong to strong rock. The results are summarized on the Record of Borehole sheets in Appendix A (as average per run).

### 5.9 Water Levels

Groundwater was observed at depths of 0.9 to 1.7 m in the boreholes during drilling. Water was added to the boreholes during coring operations and therefore water levels were not recorded upon completion. A standpipe piezometer was installed in Borehole BCWW-5 following completion of drilling.

The ground water depths and levels measured in the piezometer and in the open boreholes during drilling are summarized in Table 5.2.

**Table 5.2 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
BCWW-1	Nov. 03, 2011	1.7	235.8	During drilling
BCWW-2	Nov. 02, 2011	1.5	236.0	During drilling
BCWW-3	Nov. 01, 2011	1.5	234.8	During drilling
BCWW-4	Nov. 06, 2011	1.4	236.0	During drilling
BCWW-5	Nov. 06, 2011	0.9	235.8	During drilling Piezometer
	Jan. 30, 2012	2.0	234.7	
BCWW-6	Nov. 05, 2011	0.9	234.8	During drilling

The water depth in the creek at the time of the fieldwork was variable but generally in the order of 0.15 m. Based on this observation and the creek invert levels shown on the preliminary design drawings, the creek water level is estimated to be near elevation 236.

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 Mr. Ryan Kromer, E.I.T. 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. R. Palomeque Reyna, P.Eng.

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.

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**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 design of the new culvert carrying Blind Creek West under the Highway 11/17 westbound lanes. The culvert 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 proposed culvert consists of a segmental precast concrete arch with a span of 14.4 m, a rise of 3.7 m and a length of 31.1 m (preliminary General Arrangement drawing dated June 2012). The design top of footing level for the culvert is Elev. 239.0 (north/inlet) to Elev. 237.5 (south/outlet), and the footing thickness is 0.9 m.

The embankment height at the proposed culvert location will be in the order of 9 m with a proposed finished road grade at Elev. 246.1.

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 culvert site is underlain by deposits of gravelly to silty sand, locally silt at the south end, underlying a topsoil layer. Cobbles and boulders are present throughout the native soil deposits. Bedrock was encountered below the cohesionless soils at depths of 3.4 to 7.2 m (elevation 229.1 to 234.0). The groundwater level at the site is expected to be near the water level in the creek, estimated at approximate elevation 236.0 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.

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

The anticipated founding level for spread footings supporting an open footing culvert, assuming 2.2 m of frost cover below the existing ground surface, will range from Elev. 235.3 at the inlet to Elev. 233.5 at the outlet. Based on the borehole information, the soil conditions at this level will consist of the following:

**Table 8.1 – Anticipated Soil Conditions at Founding Level**

Location		Borehole	Founding Level	Anticipated Foundation Subgrade
West Side	Inlet	BCWW-1	235.3	Dense cobbles and boulders
	Middle	BCWW-2	235.3	Dense sand and silt
	Outlet	BCWW-3	234.1	Loose to compact silt
East Side	Inlet	BCWW-4	235.2	Compact gravelly sand
	Middle	BCWW-5	234.5	Loose to compact sand
	Outlet	BCWW-6	233.5	Dense silty sand

The following geotechnical resistances are recommended for design of spread footings founded on the compact to dense native soils at the anticipated founding levels:

Footing Width (m)	<u>0.9</u>	<u>1.2</u>	<u>1.5</u>
Factored Geotechnical Resistance at ULS (kPa)	230	240	250
Geotechnical Resistance at SLS (kPa)	175	160	150

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 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 anticipated founding levels are up to 2.5 m below the approximate creek and groundwater levels. 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, minor excavation below the creek/groundwater levels would be required. 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 0.35 on silt or sand. This value requires 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.

In view of the low available geotechnical resistance and the difficulties associated with construction of footings at frost depth, the use of spread footings founded on native soils is not recommended for support of the currently proposed arch culvert type.

## **8.2 Spread Footings on Rock Fill**

In view of the low geotechnical resistance available in the native soils, 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.

The rock fill must be a minimum 1.0 m thick and be placed on native, compact to very dense silty sand to gravelly sand. 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 1.0 m thickness of rock fill below the base of the footing.

Rock fill placement will generally be carried out above the anticipated creek and groundwater levels, with the exception of the south end of the culvert where excavation to about 1.0 m below the water level may be required to place the rock fill. In this area, rock fill placement 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.

**Table 8.2 – Highest Level for Underside of Rock Fill**

Location		Borehole	Highest Recommended Base Level	Underlying Soil
West Side	Inlet	BCWW-1	236.8	Very dense gravelly sand
	Middle	BCWW-2	236.5	Very dense gravelly sand
	Outlet	BCWW-3	235.6	Compact gravelly sand
East Side	Inlet	BCWW-4	236.7	Compact gravelly sand
	Middle	BCWW-5	236.4	Compact gravelly/silty sand
	Outlet	BCWW-6	235.0	Dense gravelly/silty sand

The recommended gradation of the rock fill is as follows:

<u>Sieve Size</u>	<u>Percent Passing</u>
150 mm	100
106 mm	50 – 100
75 mm	15 – 80
26.5 mm	0 – 15

A minimum 150 mm thick layer of compacted 19 mm clear stone should be placed above rock fill to provide an even founding surface for placement of the footings. Details of footing construction on rock fill are presented in Figure F1, Appendix F.

The geotechnical resistances recommended for design of spread footings founded on a minimum 1.0 m thickness of rock fill are as follows:

Footing Width (m)	<u>0.9</u>	<u>1.2</u>	<u>1.5</u>
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  $31^\circ$  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 exhibit dense to very dense zones and contain cobbles and boulders. Use of rock coring equipment was required to penetrate cobbles and boulders in two of the boreholes. In addition, bedrock was encountered at relatively shallow depths below the culvert level. 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 increase the geotechnical resistance and locally 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.

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 constructed on a minimum 1.0 m layer of rock fill.

## **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)  
 $\gamma$  = 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.

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.

**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 or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	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.

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.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the native sands and silt above the water table may be classed as Type 3 soil. 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 and/or placement of rock fill to prepare the founding surface is expected to extend up to about 1.0 m 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 ( $\Delta K_{AE}$ ) 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 ( $\Delta K_E$ )			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active ( $\Delta K_{AE}$ )*	0.01	0.03	0.01	0.03
At Rest ( $\Delta K_{OE}$ )**	0.02	-	0.03	-
Passive ( $\Delta K_{PE}$ )	-	-	-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. R. Palomeque Reyna, P.Eng.

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

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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

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


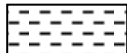



 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (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	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

## EXPLANATION OF ROCK LOGGING TERMS

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

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	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

<u>TERMS</u>	
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.

RECORD OF BOREHOLE No BCWW-1

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 374 511.8 E 374 906.1 Blind Creek West WBL ORIGINATED BY RK  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Casing/NQ Coring COMPILED BY AN  
DATUM Geodetic DATE 2011.11.03 - 2011.11.03 CHECKED BY RPR

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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE				w <sub>P</sub> w      w <sub>L</sub>					
237.5								20	40	60	80	100					
0.0	TOPSOIL, some sand Dark Brown to Black Moist (300mm)		1	SS	9	▽	237										
237.2																	
0.3																	
	Gravelly SAND, trace silt and clay, some cobbles and boulders Loose to Very Dense Brown Moist to Wet	2	SS	100/ 0.125													
236.0	Auger grinding, cored through cobbles and boulder from 0.9m to 1.5m	3	SS	100/ 0.125			236										
1.5	SAND and GRAVEL, some silt and clay, with cobbles and boulders Very Dense to Dense Brown Wet Cored through cobbles and boulders from 1.5m to 2.3m																
			4	SS	38			235									
		Cored through cobbles and boulders from 3.0m to 4.5m Grey	5	SS	43			234									
			6	SS	17		233										
232.2																	
5.3	BEDROCK, metavolcanic, greenish grey Rubble zone from 5.3m to 5.6m    Mechanical breaks from 7.4m to 7.6m		1	RUN			232										
				2	RUN			231									
			3	RUN			230										
228.4							229										
9.1	END OF BOREHOLE AT 9.1m. WATER OBSERVED AT 1.7m DURING DRILLING. BOREHOLE BACKFILLED WITH HOLEPLUG TO 4.5m, THEN AUGER CUTTINGS TO SURFACE.																

ONTMT4S 1182.GPJ 6/28/12

RECORD OF BOREHOLE No BCWW-2

1 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 374 495.5 E 374 912.7 Blind Creek West WBL ORIGINATED BY RK  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Casing/NQ Coring COMPILED BY AN  
DATUM Geodetic DATE 2011.11.02 - 2011.11.02 CHECKED BY RPR

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	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
237.5												
0.0												
237.2												
0.3	TOPSOIL, some sand, occasional rootlets Black to Dark Brown Moist (300mm)		1	SS	9		237					
	Gravelly SAND, trace silt and clay, some cobbles and boulders, Loose to Very Dense Brown Moist to Wet Cored through cobbles and boulders from 0.3m to 2.1m		2	SS	64		236					
235.4												
2.1	SAND and SILT, trace gravel, trace clay Dense Brown Wet		3	SS	31		235					7 43 46 4
234.6												
2.9	SAND and GRAVEL, some silt and clay, cobbles and boulders Very Dense Brown Wet Cored through cobbles and boulders from 3.0m to 5.9m  Frequent boulders and cobbles at 4.5m		4	SS	100/ 0.125		234					
			5	SS	50/ 0.125		233					
							232					
231.6												
5.9	BEDROCK, metavolcanic, greenish grey, occasional vertical joints  Rubble zone from 6.4m to 7.8m  Fresh		1	RUN			231					RUN #1 TCR=86% SCR=0% RQD=0%
			2	RUN			230					RUN #2 TCR=56% SCR=0% RQD=0%
			3	RUN			229					RUN #3 TCR=92% SCR=77% RQD=52% UCS=32MPa (Average)
228.2												
9.3	END OF BOREHOLE AT 9.3m. WATER OBSERVED AT 1.5m DURING DRILLING. BOREHOLE BACKFILLED WITH HOLEPLUG TO 5.5m, THEN											

Continued Next Page

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

RECORD OF BOREHOLE No BCWW-2

2 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 374 495.5 E 374 912.7 Blind Creek West WBL ORIGINATED BY RK  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Casing/NQ Coring COMPILED BY AN  
 DATUM Geodetic DATE 2011.11.02 - 2011.11.02 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100					W <sub>p</sub>	W	W <sub>L</sub>		
	Continued From Previous Page HOLEPLUG AND AUGER CUTTINGS TO SURFACE.																



# RECORD OF BOREHOLE No BCWW-3

1 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 374 478.1 E 374 920.1 Blind Creek West WBL ORIGINATED BY RK  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN  
 DATUM Geodetic DATE 2011.11.01 - 2011.11.01 CHECKED BY RPR

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			SHEAR STRENGTH kPa				
								20 40 60 80 100				
236.3												
0.0	TOPSOIL, occasional rootlets and wood fragments Dark Brown Moist (300mm)		1	SS	6							
236.0												
0.3												
235.4	Gravelly SAND, some silt Loose to Compact Brown Damp		2	SS	12							
0.9												
	SILT, trace sand, trace to some clay Compact to Loose Brown Moist to Wet		3	SS	21							
	Grey		4	SS	7							
			5	SS	8							

Continued Next Page

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

RECORD OF BOREHOLE No BCWW-3

2 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 374 478.1 E 374 920.1 Blind Creek West WBL ORIGINATED BY RK  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN  
DATUM Geodetic DATE 2011.11.01 - 2011.11.01 CHECKED BY RPR




SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100						W <sub>P</sub>	W
	Continued From Previous Page																		
225.6	<b>BEDROCK</b> , metavolcanic, greenish grey, occasional horizontal breaks  Mechanical break from 10.5m to 10.6m						226									3		RUN #4 TCR=100% SCR=93% RQD=83% UCS=123MPa (Average)	
10.7	END OF BOREHOLE AT 10.7m. WATER OBSERVED AT 1.5m DURING DRILLING. BOREHOLE BACKFILLED WITH HOLEPLUG AND AUGER CUTTINGS TO SURFACE.															4			
																1			

# RECORD OF BOREHOLE No BCWW-4

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 374 518.1 E 374 923.5 Blind Creek West WBL ORIGINATED BY RK  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN  
 DATUM Geodetic DATE 2011.11.06 - 2011.11.06 CHECKED BY RPR

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									
								20 40 60 80 100									
237.4																	
0.0																	
0.2	<div>TOPSOIL, silty, some sand, occasional rootlets Dark Brown Moist (200mm)</div>	<div></div>	1	SS	8	<div>▽</div>	237										
	<div>Gravelly SAND, some silt, trace clay Loose to Compact Brown Moist to Wet</div>		2	SS	26		236										
	<div>Very Dense Grey</div>		3	SS	100		235										25 55 12 8
	<div>Compact</div>		4	SS	28		234										
234.3																	
3.1	<div>Silty SAND, some gravel, trace clay</div>	<div></div>	5	SS	50/		234										
234.0	<div>Very Dense Grey Wet</div>				0.150												
3.4	<div>BEDROCK, metavolcanic, greenish grey, occasional horizontal breaks</div>	<div></div>	1	RUN			233										RUN #1 TCR=100% SCR=96% RQD=90% UCS=88MPa (Average)
			2	RUN			232										RUN #2 TCR=100% SCR=39% RQD=14% UCS=140MPa (Average)
			3	RUN			231										RUN #3 TCR=100% SCR=92% RQD=100% UCS=130MPa (Average)
230.6																	
6.8	<div>END OF BOREHOLE AT 6.8m. WATER OBSERVED AT 1.4m DURING DRILLING. BOREHOLE BACKFILLED WITH HOLEPLUG AND AUGER CUTTINGS TO SURFACE.</div>																

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

20  
15  
10

(%) STRAIN AT FAILURE

## METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT						SHEAR STRENGTH kPa				WATER CONTENT (%)				
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>P</sub>	W		
236.7	<b>TOPSOIL</b> , silty, some sand, occasional rootlets Black Moist (300mm) Gravelly <b>SAND</b> , some silt Compact Brown Moist Silty <b>SAND</b> , trace clay, trace gravel Compact to Dense Grey Wet		1	SS	16										GR SA SI C	
236.4																
0.3																
236.1																
0.6																
234.6	<b>SAND</b> , some silt, trace gravel Loose to Compact Grey Wet		2	SS	14									5 55 35 5		
232.4	<b>BEDROCK</b> , metavolcanic, greenish grey, occasional horizontal breaks Rubble zone (125mm) at 4.3m		3	SS	35									FI 1 1 1 1 3 2 1 1 1 1	RUN #1 TCR=100% SCR=73% RQD=73% UCS=193MPa (Average) RUN #2 TCR=100% SCR=93% RQD=92% UCS=57MPa (Average) RUN #3 TCR=100% SCR=90% RQD=78% UCS=133MPa (Average)	
2.1																
229.0	Rubble zone (75mm) at 7.5m		1	RUN												
4.3																
	Rubble zone (75mm) at 7.5m		2	RUN												
	Rubble zone (75mm) at 7.5m		3	RUN												
7.7	END OF BOREHOLE AT 7.7m. WATER LEVEL AT 0.9m BEFORE CORING STARTED. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE      DEPTH (m)      ELEV. (m) Jan. 30/12      2.0      234.7															

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

RECORD OF BOREHOLE No BCWW-6

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 374 485.1 E 374 939.5 Blind Creek West WBL ORIGINATED BY RK  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN  
DATUM Geodetic DATE 2011.11.05 - 0201.11.05 CHECKED BY RPR

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			SHEAR STRENGTH kPa									
								20 40 60 80 100									
235.7								20 40 60 80 100									
0.0	TOPSOIL, silty, occasional rootlets		1	SS	6		235										
235.3	Black																
0.4	Moist (400mm)																
	Gravelly SAND																
234.6	Loose to Dense		2	SS	31												
1.1	Brown to Dark Brown																
	Moist to Wet																
	Silty SAND, some gravel, trace clay		3	SS	61			234									
	Compact to Very Dense																
	Brown to Grey																
	Wet																
231.7			4	SS	42		233										
			5	SS	49		232										
4.0	SAND, medium, trace gravel, some silt																
	Very Dense		6	SS	100		231										
	Grey		1	RUN													
	Wet																
230.2	Gravelly																
5.5	BEDROCK, metavolcanic, greenish grey, occasional horizontal breaks		2	RUN			230										
			3	RUN			229										

ONTM/T4S 1182.GPJ 6/28/12

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

20  
15  
10  
(%) STRAIN AT FAILURE

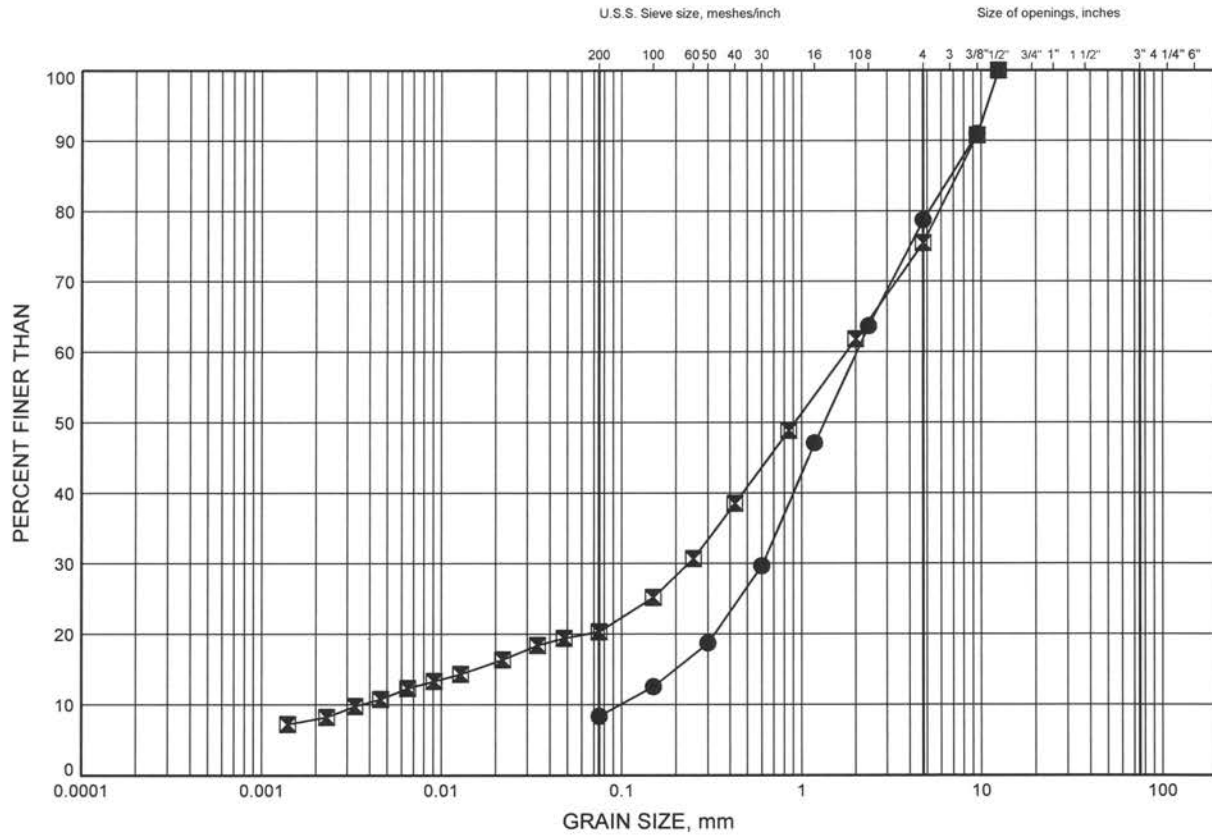
## **Appendix B**

### **Laboratory Test Results**

# Blind Creek West - WBL GRAIN SIZE DISTRIBUTION

FIGURE B1

## GRAVELLY SAND



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

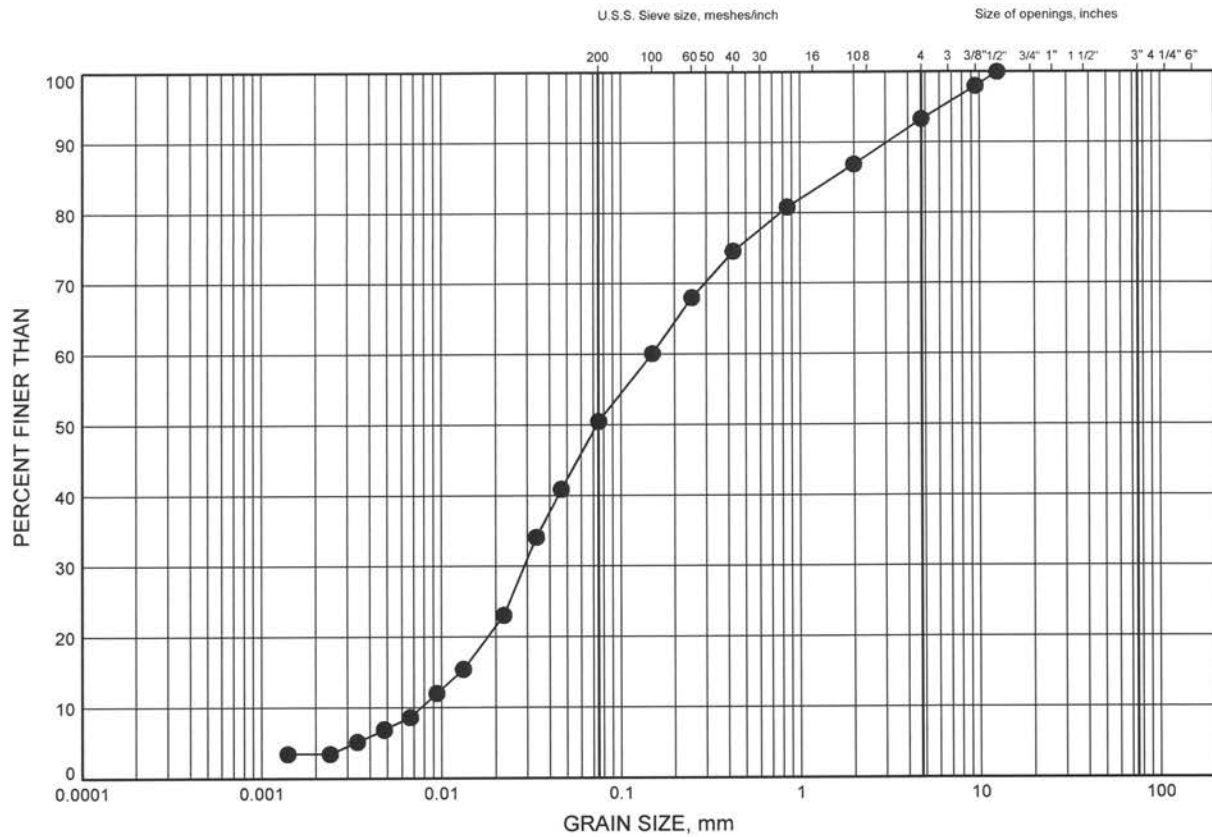
### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWW-1	1.07	236.43
■	BCWW-4	1.83	235.57

# Blind Creek West - WBL GRAIN SIZE DISTRIBUTION

FIGURE B2

## SAND & SILT



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

### LEGEND

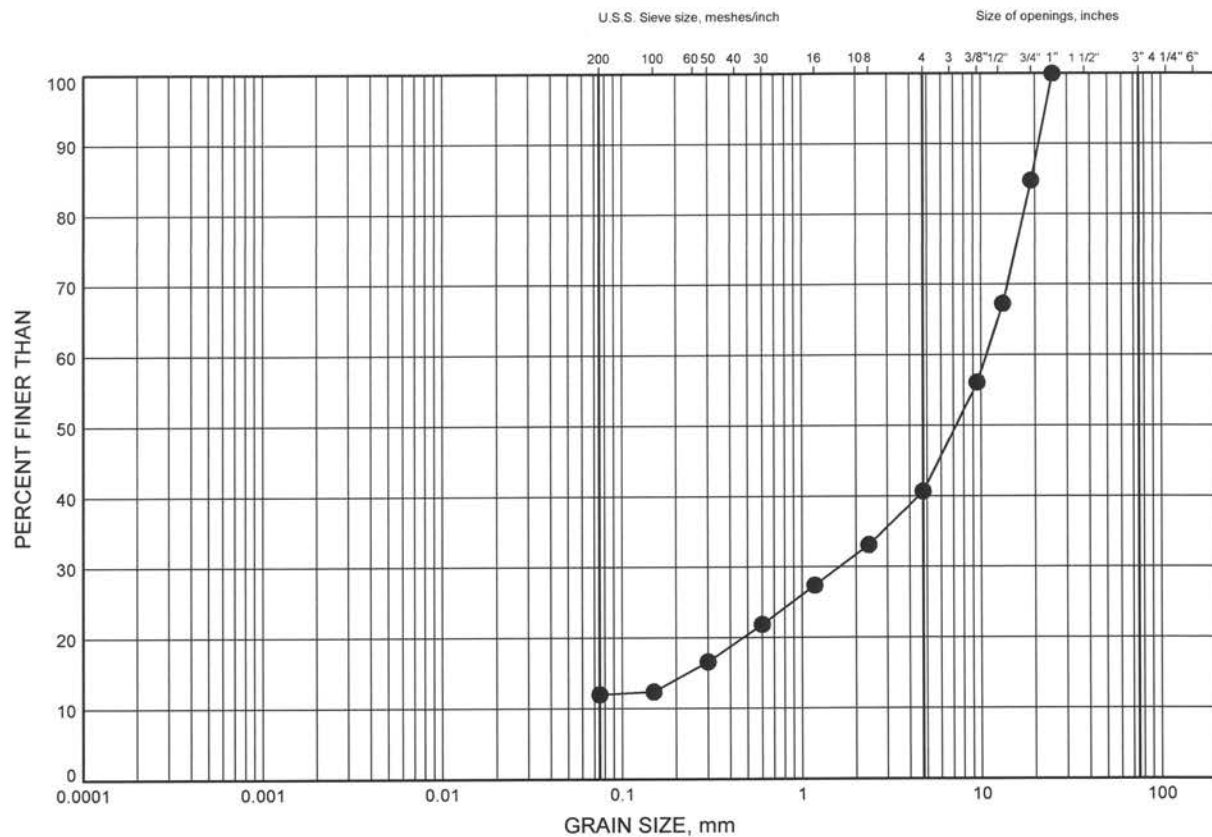
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWW-2	2.59	234.91



# Blind Creek West - WBL GRAIN SIZE DISTRIBUTION

FIGURE B3

## SAND & GRAVEL



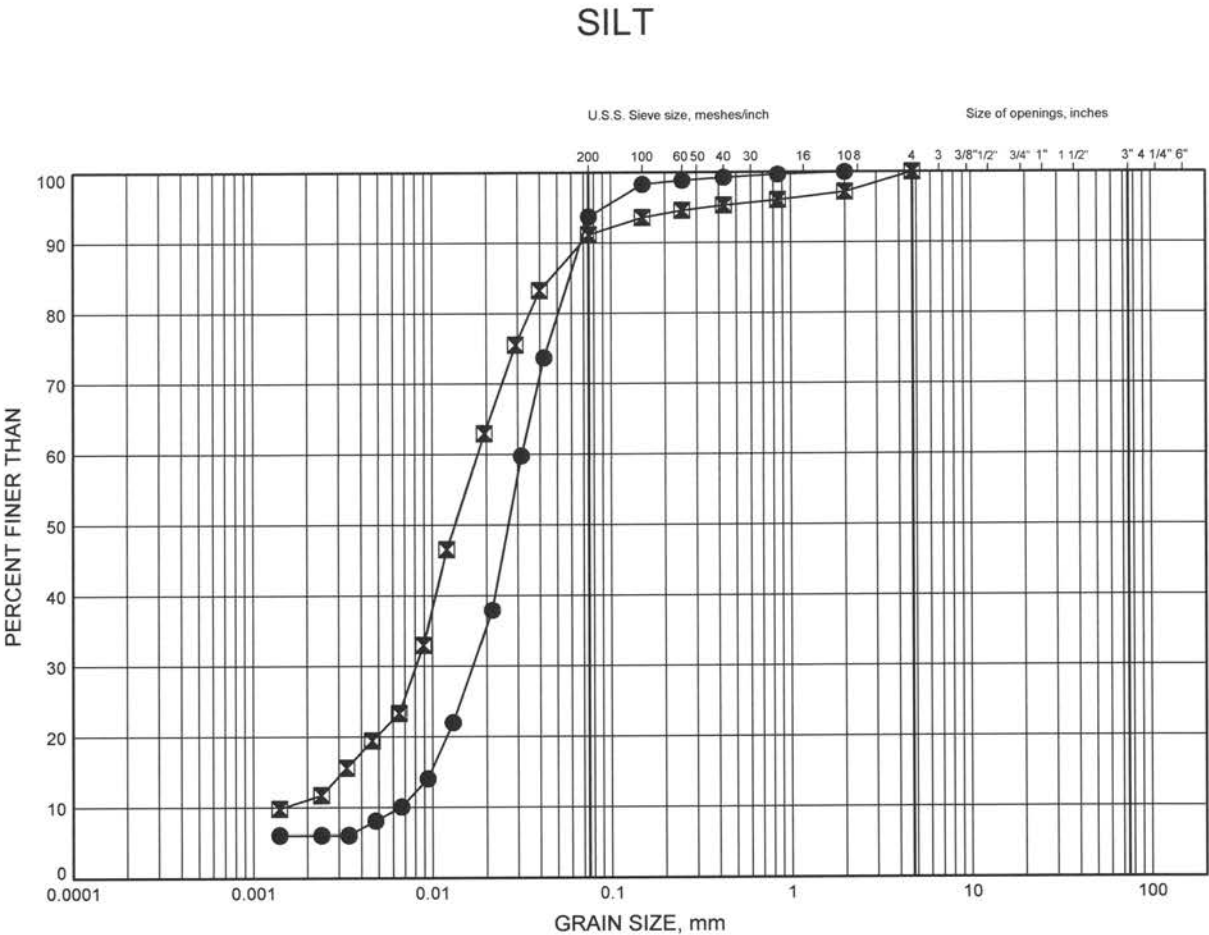
SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWW-1	3.35	234.15

Blind Creek West - WBL  
GRAIN SIZE DISTRIBUTION

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWW-3	3.05	233.25
⊠	BCWW-3	4.72	231.58

GRAIN SIZE DISTRIBUTION - THURBER 1182.GPJ 1/3/12

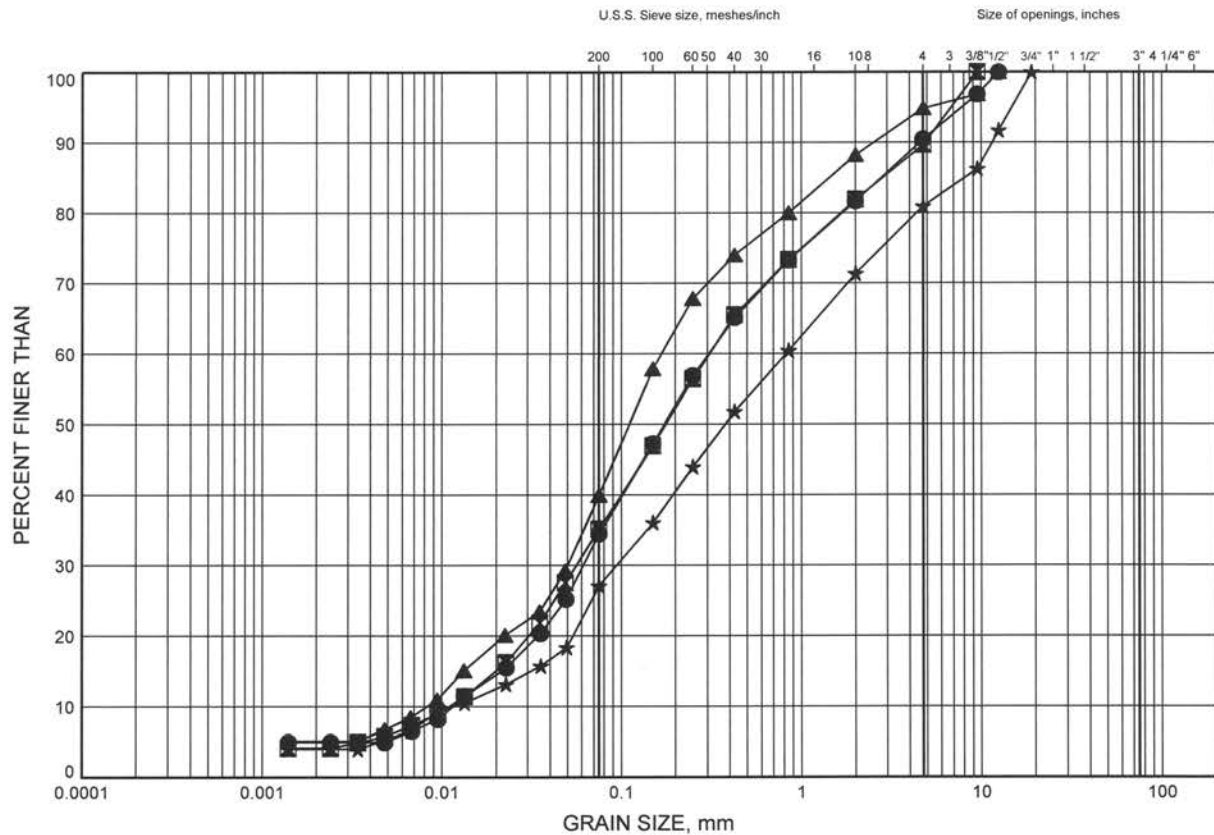
W.P.# 623-89-00  
Prepared By AN  
Checked By LRB



# Blind Creek West - WBL GRAIN SIZE DISTRIBUTION

FIGURE B5

## SILTY SAND



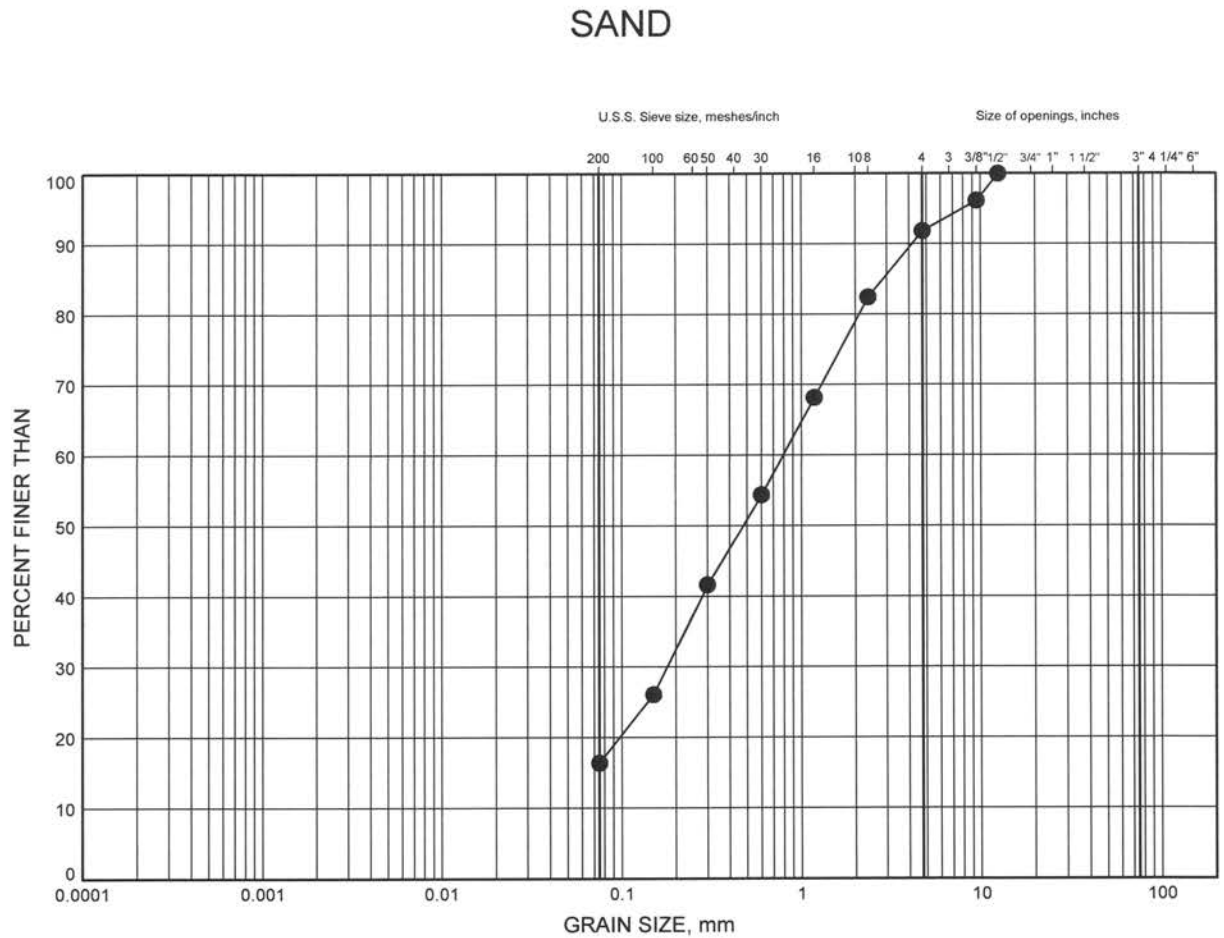
SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWW-3	6.25	230.05
■	BCWW-4	3.24	234.16
▲	BCWW-5	1.83	234.87
★	BCWW-6	1.68	234.02

# Blind Creek West - WBL GRAIN SIZE DISTRIBUTION

FIGURE B6



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCWW-6	4.72	230.98

## **Appendix C**

### **Site Photographs**



**Photograph 1 – Blind Creek West looking north**



**Photograph 2 – Blind Creek West at Borehole BCWW-1**

## **Appendix D**

### **Foundation Comparison**



### COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Rock Fill	Driven Steel Piles	Caissons (Drilled Shaft)
<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> <li>ii. Minimizes excavation depth below groundwater.</li> <li>iii. Rock fill is not required.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> <li>ii. Allows construction of footings above the groundwater level.</li> <li>iii. Higher geotechnical resistances compared to footings on native soil.</li> <li>iv. More uniform support than footings partially on native soil.</li> <li>v. Precast concrete footings may be employed</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistances can be achieved in dense to very dense soils.</li> <li>ii. Installation of piles could continue in freezing weather</li> <li>iii. Excavation below groundwater level may be reduced or eliminated.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistances can be achieved in dense to very dense soils.</li> <li>ii. Installation of caissons could continue in freezing weather</li> <li>iii. Excavation below groundwater level may be reduced or eliminated.</li> </ul>
<p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Low available bearing resistance.</li> <li>ii. Subexcavation below the water level is required.</li> <li>iii. Greater excavation depths would be required for higher resistance values.</li> <li>iv. Potential disturbance of subgrade during excavation.</li> </ul>	<p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Subexcavation below the water level is required to place rock fill.</li> <li>ii. Additional cost of rock fill placement compared to footings on native soil.</li> <li>iii. Rock fill cannot be compacted under water.</li> <li>iv. Potential disturbance of subgrade during excavation.</li> </ul>	<p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Driven piles are expected to encounter refusal on cobbles and boulders at varying depths and often above the bedrock surface.</li> <li>ii. Predrilling through cobbles and boulders will be difficult.</li> <li>iii. Pile lengths will be inadequate at the outlet due to shallow bedrock. Socketing into the bedrock would be required.</li> <li>iv. Higher unit costs than footings.</li> <li>v. Pile lengths may vary.</li> </ul>	<p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Augering and advancement of liner may be obstructed by cobbles and boulders and the very dense nature of the soils at site.</li> <li>ii. Higher cost than spread footings</li> <li>iii. Specialized installation measures such as temporary liners and drilling mud will be required to install caissons in cohesionless soils below the water table.</li> <li>iv. Potential difficulty in cleaning and inspecting bases.</li> </ul>
<b>NOT RECOMMENDED</b>	<b>RECOMMENDED</b>	<b>NOT RECOMMENDED</b>	<b>NOT RECOMMENDED</b>



## **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 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 impede driving of sheet piles, and therefore installation of sheet pile shoring, dewatering of the excavation and construction of culvert footings in the dry is expected to be difficult 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.

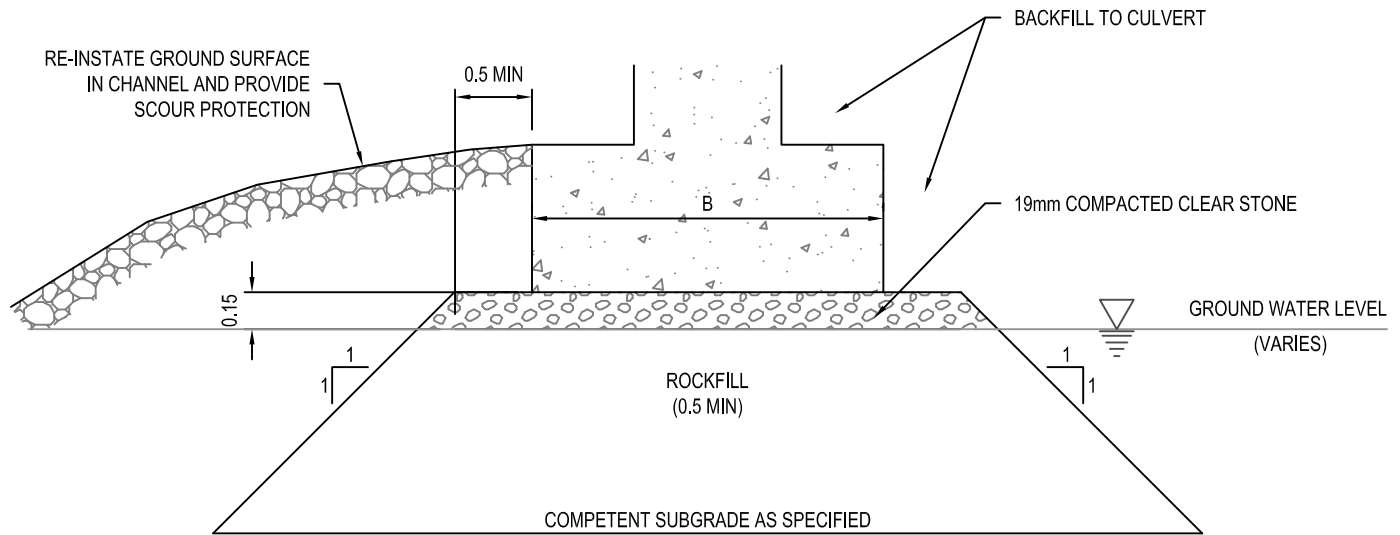
The contractor must carry out the work in a manner which minimizes disturbance to the excavation base and ensure that the excavation does not encroach into the creek by controlling the length of excavation open at any one time, use of shoring, or other suitable means.

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 – Details of Footing on Rock Fill**



## 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 :

MRA

DRAWN :

MFA

APPROVED :

-

DATE :

SEPTEMBER 2012

SCALE :

N.T.S.

DRAWING No.

FIGURE F1

## **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 FOUR LANE  
BLIND CREEK WEST  
CULVERT WEST BOUND LANE  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET  
236



KEYPLAN

LEGEND

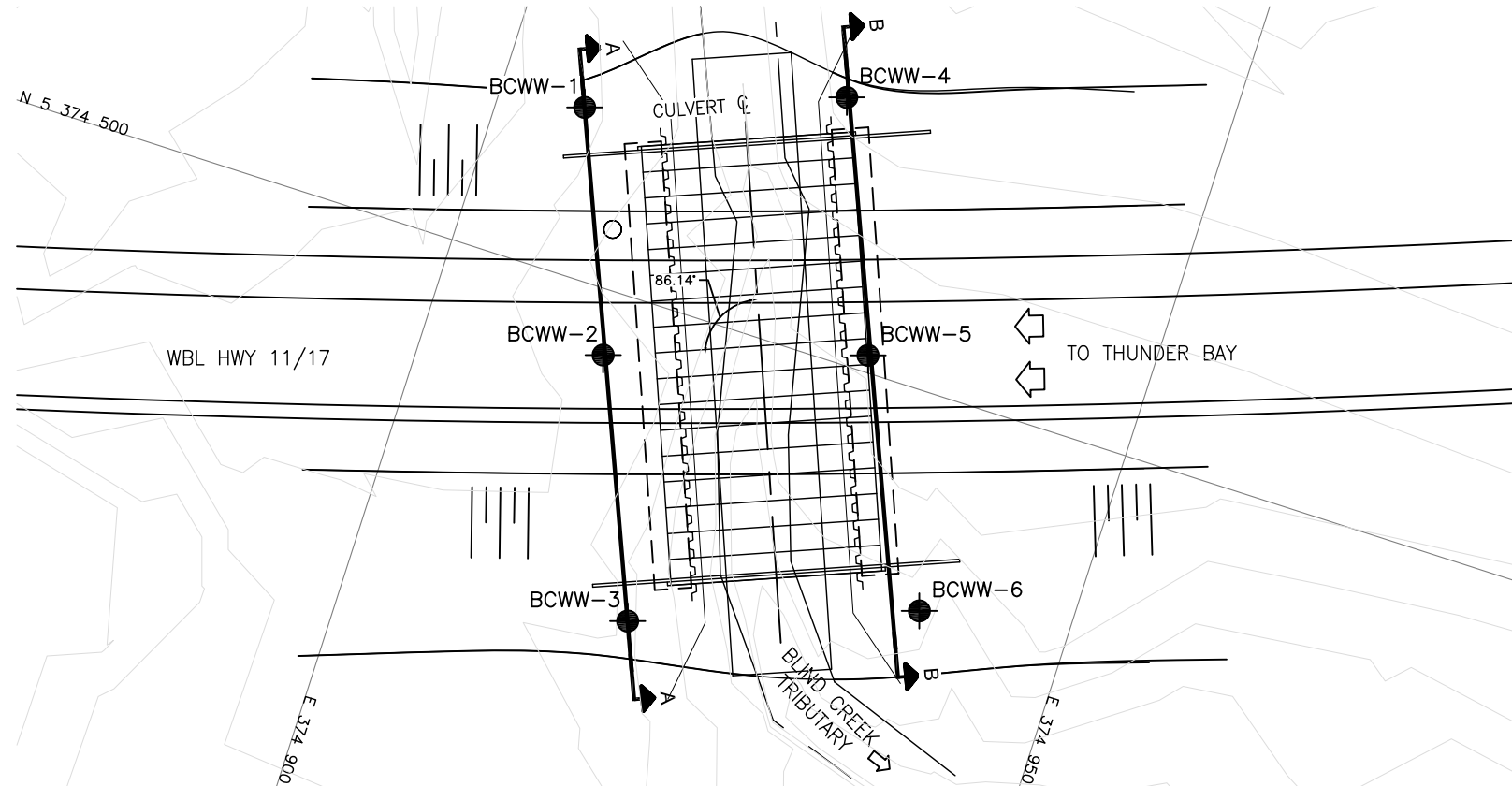
●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊕	Head Artesian Water
⊕	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BCWW-1	237.5	5 374 511.8	374 906.1
BCWW-2	237.5	5 374 495.5	374 912.7
BCWW-3	236.3	5 374 478.1	374 920.1
BCWW-4	237.4	5 374 518.1	374 923.5
BCWW-5	236.7	5 374 501.2	374 930.5
BCWW-6	235.7	5 374 485.1	374 939.5

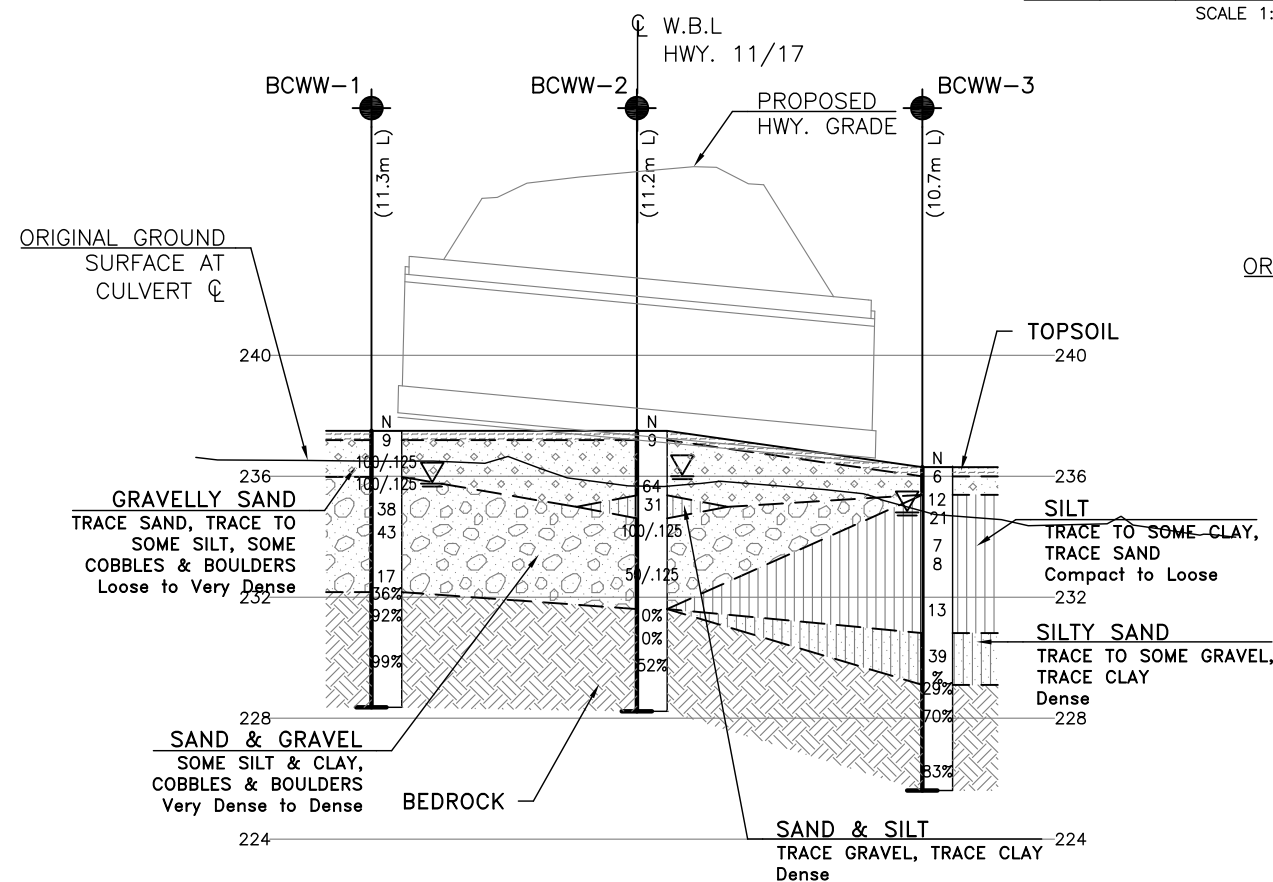
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

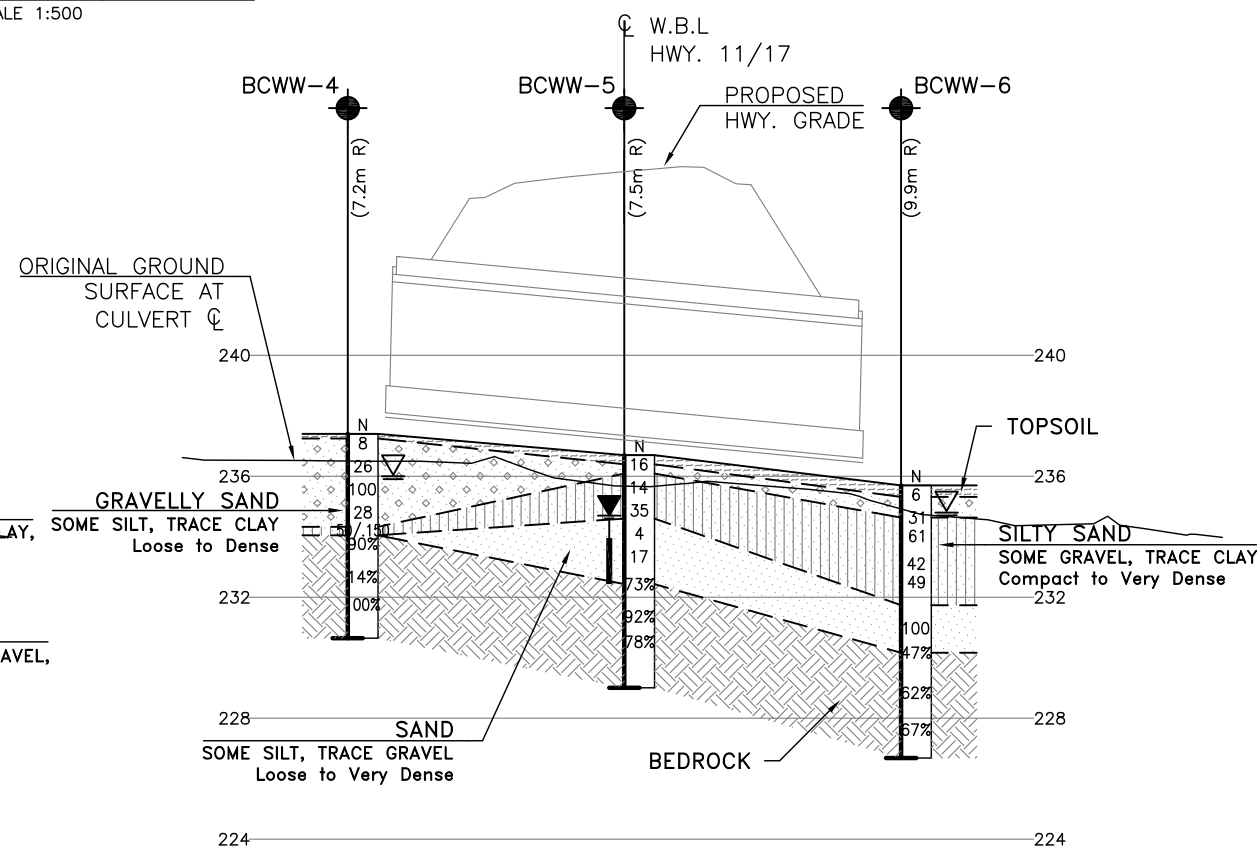
GEOCREs No. 52A-163



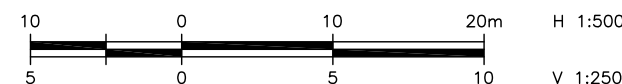
PLAN  
SCALE 1:500



SECTION A-A



SECTION B-B



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	LRB	CHK LRB	CODE CAN/CSA S6-06 [LOAD CL-625-ONT] DATE JUL. 2012
DRAWN	AN	CHK RPR	SITE 48c-350/cz [STRUCT] DWG 1