

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
WILD GOOSE CREEK 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-214/C2**

**Geocres Number: 52A-162**

**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 location of a proposed culvert planned to carry the new westbound lanes of Highway 11/17 over Wild Goose Creek. The new westbound lanes will be constructed 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 in the Township of MacGregor, District of Thunder Bay.

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 Wild Goose Creek culvert is located approximately 9.5 km east of Thunder Bay, Ontario and approximately 5.7 km east of Highway 527. The culvert for the WBL will be situated approximately 30 m north of the existing Highway 11/17 alignment. Wild Goose Creek flows from north to south at the site.

Lands surrounding the proposed culvert site consist of forested areas with cobbles and boulders strewn within and along the creek channel. A large bedrock outcrop was observed west of the creek and south of the proposed culvert site, towards the existing Highway 11/17. Photographs in Appendix C show the general nature of the surrounding land.



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. Core samples obtained from boulders encountered in boreholes suggest presence of basaltic rock in the area. Locally, the overburden generally consists of deposits of silty sand, gravelly sand and sandy silt with occasional cobbles and boulders as well as silty clay till.

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

The site investigation and field testing for this project were carried out between November 24 and 29, 2011 and consisted of drilling and sampling six boreholes identified as WGW-1 to WGW-6. The boreholes were advanced to depths of 3.7 m to 12.2 m (elevations 247.5 to 239.7).

Boreholes WGW-1 and WGW-4 were located at the proposed culvert inlet, while Boreholes WGW-2 and WGW-5 were located at the proposed centreline of the new WBL embankment, and Boreholes WGW-3 and WGW-6 were located at the proposed culvert outlet. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata drawing included in Appendix G.

At several locations where rock coring methods were required to penetrate cobbles and boulders, the borehole depths were limited as it was necessary to terminate coring to avoid infiltration of core water and sediment into the adjacent creek. Silt fencing was installed between the drill area and the creek.

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.

A track mounted CME 45 drill rig was used at this site and a combination of hollow-stem augers, casing and 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).

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

Groundwater conditions were observed in the open boreholes upon completion of the drilling operations. One standpipe piezometer was installed at this site. The completion details of the piezometer 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>Piezometer Tip Depth/ Elevation (m)</b>	<b>Completion Details</b>
WGW-1	-	Backfilled with bentonite holeplug to 0.9 m, then auger cuttings to surface.
WGW-2	-	Backfilled with bentonite holeplug to 0.9 m, then auger cuttings to surface.
WGW-3	-	Backfilled with auger cuttings to surface.
WGW-4	-	Backfilled with bentonite holeplug to surface.
WGW-5	12.2 / 239.7	25 mm diameter PVC standpipe installed. Slotted from 12.2 m to 10.7 m. Filter sand from 12.2 m to 9.8 m, then bentonite holeplug to surface. Piezometer protrudes 0.6 m above ground level
WGW-6	-	Backfilled with bentonite holeplug 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 and Atterberg Limits testing, where appropriate. 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.

#### **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 a surficial topsoil layer overlying deposits of silty sand, gravelly sand and sandy silt, interrupted by a stratum of silty clay till at the central and northern part of the culvert location. Cobbles and boulders were encountered throughout these deposits. More detailed descriptions of the individual strata are presented below.

##### **5.1 Topsoil**

Topsoil was encountered at surface in all of the boreholes. The topsoil was dark brown and contained occasional cobbles. The thickness of the topsoil varied from 100 mm to

200 mm on the west side of the culvert alignment and from 600 mm to 1100 mm on the east side.

SPT N-values of 13 to 23 blows for 0.3 m penetration were recorded in the topsoil on the east side of the culvert, reflecting a frozen condition. Moisture contents of 36%, 58% and 112% were measured.

## **5.2 Silty Sand**

A layer of silty sand was encountered below the topsoil in all boreholes except Borehole WGW-5. In Borehole WGW-4, a second layer of silty sand was encountered below a gravelly sand unit. The silty sand was generally dark brown, locally brown and grey in Borehole WGW-4, and contained trace to some gravel and trace clay. Occasional rootlets mixed with organics were noted near the top of the layer.

The thickness of the silty sand ranged from 0.4 m to 1.3 m. The base of the layer is at depths of 0.5 m to 1.6 m (Elev. 250.0 to Elev. 251.2), locally 3.3 m (Elev. 249.2) for the lower layer in Borehole WGW-4.

SPT N-values recorded in the silty sand layer typically ranged from 4 to 22 blows for 0.3 m penetration, indicating a loose to compact relative density. SPT N-values in the lower layer of silty sand in Borehole WGW-4 were 50 blows for 0.15 m and 0.05 m penetration, indicating a very dense relative density or the presence of cobbles and boulders. Coring was required to advance the borehole through this layer.

Moisture contents of the silty sand typically ranged from 17% to 33%. One value of 60% was measured in a sample from Borehole WGW-6, possibly indicating an organic component. In the lower layer of silty sand in Borehole WGW-4, moisture contents of 10% and 15% were measured.

One sample of the silty sand underwent laboratory grain size analysis testing. These results are presented on the Record of Borehole sheets included in Appendix A and the grain size distribution curve for this sample is presented on Figure B1, Appendix B. The grain size analysis results are as follows:

Gravel%	2
Sand%	62
Silt%	30
Clay%	6

## **5.3 Gravelly Sand**

A gravelly sand layer was encountered below the silty sand at depths of 0.5 m to 1.6 m (Elev. 250.0 to Elev. 251.2) in all boreholes except Borehole WGW-5. Gravelly sand was

also encountered below silty clay till in Boreholes WGW-1 and WGW-2 at depths of 3.7 m and 3.0 m (Elev. 248.8 and 249.2), and below sandy silt in Boreholes WGW-4 to WGW-6 at depths of 6.1 m to 7.6 m (Elev. 245.4 to 244.3). The gravelly sand was brown to grey and contained trace to some silt and occasional cobbles and boulders.

The upper layer of gravelly sand encountered in Boreholes WGW-1, WGW-2, WGW-4 and WGW-6 was 0.7 m to 0.8 m thick with a lower boundary at depths of 2.0 m to 2.4 m (Elev. 249.3 to 250.5). Borehole WGW-3 was terminated on a probable boulder in the gravelly sand at 3.7 m depth (Elev. 247.5). Boreholes WGW-1, WGW-2, WGW-4 and WGW-6 were terminated in the lower layer of gravelly sand generally on probable boulders at depths of 5.7 m to 9.2 m (Elev. 242.3 and 246.8), indicating a thickness of at least 1.6 m and 3.1 m. In Borehole WGW-5, the lower gravelly sand layer was 1.5 m thick with a lower boundary at 9.1 m depth (Elev. 242.8).

SPT N-values recorded in the upper gravelly sand layer typically ranged from 16 to 32 blows for 0.3 m penetration, indicating a compact to dense relative density. SPT 'N' values of 67 blows per 0.28 m to 100 blows per 0.1 m penetration were recorded in Borehole WGW-6 and the lower part of Borehole WGW-3, indicating a very dense condition or cobbles.

SPT 'N' values in the lower gravelly sand were between 87 blows per 0.3 m penetration to 100 blows for no penetration. These values suggest a very dense relative density and may indicate presence of cobbles and/or boulders within the gravelly sand. Coring techniques were required to advance the boreholes through occasional cobbles and boulders encountered within the gravelly sand.

The moisture content of samples of the gravelly sand ranged from 9% to 19%.

Selected samples of the gravelly sand underwent laboratory gradation analysis testing, the results of which are summarized below. These results are plotted on Figure B2, Appendix B.

Gravel%	25 to 34
Sand%	45 to 73
Silt and Clay%	2 to 22

#### **5.4 Silty Clay Till**

A layer of silty clay till was encountered at depths of 2.0 m to 3.3 m (Elev. 249.2 to 250.5) in Boreholes WGW-1, WGW-2, WGW-4 and WGW-5. The silty clay till was grey and contained some sand to sandy, trace gravel and occasional cobbles.

The thickness of the silty clay till ranged from 0.8 m in Borehole WGW-2 to 3.7 m in Borehole WGW-5. The lower boundary was encountered at depths of 3.0 m to 6.1 m (Elev. 249.2 to 245.8).

SPT N-values recorded in the silty clay till ranged from 41 blows for 0.3 m penetration to 106 blows for 0.25 m penetration, indicating a hard consistency. Occasional cobbles were encountered within the till requiring the use of coring techniques to advance the borehole.

Moisture contents of samples of the silty clay till ranged from 9% to 19%.

Four samples of the clay till were selected for grain size analysis testing. The results of these tests are plotted on Figure B3, Appendix B. One Atterberg Limits test was also performed. Figure B5 illustrates the results of the Atterberg Limits test. The test results are summarized below:

Gravel%	0 to 5
Sand%	16 to 22
Silt%	43 to 61
Clay%	21 to 32
Liquid Limit%	28
Plastic Limit%	15
Plasticity Index%	13

The results of the Atterberg Limits test indicate that the silty clay till is of low plasticity with a group symbol CL.

## 5.5 Sandy Silt

A sandy silt layer was encountered below the silty clay till in Boreholes WGW-4 and WGW-5, and below cobbles and boulders in Borehole WGW-6. A second, lower deposit of sandy silt was encountered below gravelly sand in Borehole WGW-5. The sandy silt was typically grey, locally brown, and contained some clay, trace to some gravel and occasional cobbles and boulders.

The sandy silt layer was 1.4 m to 3.1 m thick with a lower boundary at depths of 6.1 m to 7.6 m (Elev. 244.3 to 245.4). Borehole WGW-5 was terminated in the lower sandy silt deposit at 12.2 m depth (Elev. 239.7).

SPT 'N' values recorded in the sandy silt ranged from 50 blows per 0.125 m penetration to 50 blows per 0.025m penetration, indicating a very dense relative density and/or the presence of cobbles and boulders. Cobbles and boulders encountered within the sandy silt required the use of coring techniques to advance the borehole.

Moisture contents of the sandy silt ranged from 9% to 16%.

One sample of the sandy silt was selected for grain size analysis testing. Results of the test are summarised below and plotted on Figure B4, Appendix B.

Gravel%	1
Sand%	33
Silt%	54
Clay%	12

### 5.6 Cobbles and Boulders

Cobbles and boulders were encountered throughout the sand, sandy silt and clay till deposits in the boreholes. In Boreholes WGW-5 and WGW-6, a layer consisting primarily of cobbles and boulders was encountered at depths of 1.1 m and 1.5 m (Elev. 250.8 and 249.3), and rock coring equipment was required to advance the boreholes through this zone.

The layer of cobbles and boulders in Boreholes WGW-5 and WGW-6 was 1.3 m and 0.8 m thick, with the lower boundary encountered at depths of 2.4 m and 3.0 m (elevation 249.5 and 248.4).

### 5.7 Water Levels

Water levels were observed in the open boreholes during drilling and one standpipe piezometer was installed at the site for long-term monitoring of groundwater. The water levels measured in the open boreholes during drilling and in the piezometer are summarized in Table 5.1.

**Table 5.1 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
WGW-4	Nov. 25, 2011	0.6	251.9	Open borehole
WGW-5	Nov. 25, 2011	0.7	251.2	Open borehole
	Dec. 2, 2011	0.3	251.6	Piezometer
WGW-6	Nov. 27, 2011	0.5	251.0	Open borehole

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 also reflect the water levels 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.

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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 a new culvert which will carry Wild Goose Creek under the new WBL of Highway 11/17.

The proposed culvert (as shown on the Preliminary General Arrangement drawing dated June 2012) consists of a concrete arch culvert supported on precast concrete footings. The new structure will have a span of 10.9 m, a rise of 3.4 m, and a total length of 38.4 m with RSS wing walls at the culvert inlet and outlet. The design top of footing level for the culvert is Elev. 253.3 (north/inlet) to Elev. 252.4 (south/outlet), and the footing thickness is 1.1 m. The proposed culvert design was selected on the basis of considerations other than foundations.

The embankment height at the proposed culvert location will be in the order of 11 m with a proposed finished road grade at Elev. 263.4.

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 drawing used for preparation of this report was provided by Hatch Mott MacDonald.

**8 CULVERT FOUNDATIONS**

The site is underlain by a topsoil layer overlying deposits of silty sand, gravelly sand and sandy silt, interrupted by a stratum of silty clay till at the central and northern part of the culvert location. Cobbles and boulders are present at the ground surface and were encountered throughout the boreholes. Bedrock was not encountered within the exploration depths.



The groundwater level at the site was measured at depths of 0.3 m to 0.7 m (Elev. 251.0 to 251.9) below the ground surface during borehole drilling and in the piezometer.

Foundation recommendations for design of 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. 250.3 at the inlet to Elev. 249.0 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	WGW-1	250.3	Hard silty clay till
	Middle	WGW-2	250.0	Hard silty clay till
	Outlet	WGW-3	249.0	Very dense gravelly sand
East Side	Inlet	WGW-4	250.3	Very dense gravelly/silty sand
	Middle	WGW-5	249.7	Cobbles/boulders, hard silty clay till
	Outlet	WGW-6	249.3	Cobbles/boulders

The following geotechnical resistances are recommended for design of spread footings founded on the hard/very dense native soils at the recommended founding levels presented in the above table:

Factored Geotechnical Resistance at ULS	500 kPa
Geotechnical Resistance at SLS	350 kPa

The geotechnical resistances are considered applicable to 1.5 to 3.0 m wide footings 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 width of footing must be based on the load demand from the culvert structure and overlying embankment fill.

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 2.0 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, excavation to depths of up to 1.0 m below the creek/groundwater levels would still 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 0.45 on clay till, sand, and cobbles and boulders. 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.

## 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.

The rock fill must be a minimum 1.0 m thick and be placed on native, compact to 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.

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

Location		Borehole	Highest Recommended Base Level	Underlying Soil
West Side	Inlet	WGW-1	251.2	Dense gravelly sand
	Middle	WGW-2	251.5	Compact silty sand
	Outlet	WGW-3	250.7	Compact gravelly sand
East Side	Inlet	WGW-4	250.9	Compact gravelly sand
	Middle	WGW-5	250.8	Cobbles and boulders
	Outlet	WGW-6	250.9	Compact silty sand

Rock fill placement will be carried out below the water level locally, and in these areas 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 F1, Appendix F.

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

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>1.5</u>	<u>3.0</u>
Factored Geotechnical Resistance at ULS (kPa)	525	600
Geotechnical Resistance at SLS (kPa)	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 very dense/hard and contain frequent cobbles and boulders. The use of driven steel piles is not recommended in these conditions and this alternative has 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.

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 placed to establish founding levels.

## **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.

**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.

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.

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 and gravelly sand 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 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 silty and gravelly sands 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 (compact to dense native soils) in short sections of about 2 m length followed by immediate backfilling with rock fill to the design founding level (to above the groundwater level). 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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	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. 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

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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


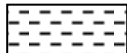



$C_{pen}$  Shear Strength Determination by Pocket Penetrometer

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

# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ( $W_L < 30\%$ ).
		CI	Inorganic clays of medium plasticity, silty clays. ( $30\% < W_L < 50\%$ ).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	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	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
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 WGW-1

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 374 402.7 E 373 956.9 Wild Goose Creek WBL ORIGINATED BY ES  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Casing COMPILED BY AN  
 DATUM Geodetic DATE 2011.11.28 - 2011.11.28 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						
252.5														
0.0 0.1	TOPSOIL: (100mm)		1	SS	4		252							
	Silty SAND, trace gravel and clay, mixed with organics, occasional rootlets Loose Dark Brown Moist		2	SS	6									2 62 30 6
251.2							251							
1.3	Gravelly SAND		3	SS	32									
250.5	Dense Brown Wet													
2.0	Silty CLAY, some sand, trace gravel		4	SS	41		250							
	Hard Grey (TILL)		5	SS	50/ 0.125									0 16 55 29
248.8	Auger grinding from 3.6m to 3.8m						249							
3.7	Gravelly SAND, some silt		6	SS	50/ 0.125		248							
	Very Dense Grey Moist													
246.8	Auger refusal at 5.3m Cored through boulder from 5.3m to 5.7m						247							
5.7	END OF BOREHOLE AT 5.7m UPON AUGER REFUSAL ON PROBABLE BOULDER. BOREHOLE BACKFILLED WITH HOLEPLUG TO 0.9m, THEN AUGER CUTTINGS TO SURFACE.													

# RECORD OF BOREHOLE No WGW-2

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 374 384.6 E 373 955.0 Wild Goose Creek WBL ORIGINATED BY ES  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2011 11 28 - 2011 11 28 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							
252.2							20	40	60	80	100	PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	
0.0	TOPSOIL: (200mm)														
0.2	Silty <b>SAND</b> , trace gravel, occasional roots and rootlets Loose to Compact Dark Brown Moist		1	SS	4										
			2	SS	21										
250.7															
1.5	Gravelly <b>SAND</b> , some silt and clay, occasional cobbles Compact Brown Wet		3	SS	22										29 55 16 (SI+CL)
250.0															
2.2	Silty <b>CLAY</b> , some sand, trace gravel Hard Grey (TILL)		4	SS	52										
249.2															
3.0	Gravelly <b>SAND</b> , some silt and clay, occasional cobbles Very Dense Moist		5	SS	87										33 45 22 (SI+CL)
	Auger refusal at 4.0m Cored through boulder (150mm)														
	Cored through a boulder from 4.6m to 5.7m		6	SS	100/ 0.0										
246.5															
5.7	END OF BOREHOLE AT 5.7m UPON AUGER REFUSAL ON PROBABLE BOULDER. BOREHOLE BACKFILLED WITH HOLEPLUG TO 0.9m, THEN AUGER CUTTINGS TO SURFACE														

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

20  
15 5  
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No WGW-3

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 374 367.5 E 373 951.8 Wild Goose Creek WBL ORIGINATED BY ES  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2011.11.29 - 2011.11.29 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  7  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
251.2								20   40   60   80   100						
0.0	TOPSOIL: (125mm)							20   40   60   80   100						
0.1	Dark Brown		1	SS	13		251							
250.7	Frozen													
0.5	Silty SAND, trace gravel, mixed with organics													
	Compact		2	SS	16		250							
	Dark Brown													
	Moist													
	Gravelly SAND, occasional cobbles													
	Compact to Very Dense													
	Brown to Grey		3	SS	31		249							
	Wet to Damp													
	Some silt		4	SS	105/ 0.200									
			5	SS	100/ 0.100		248							
247.5														
3.7	END OF BOREHOLE AT 3.7m UPON AUGER REFUSAL ON PROBABLE BOULDER. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.													

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

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No WGW-4

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 374 403 3 E 373 968.8 Wild Goose Creek WBL ORIGINATED BY ES  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2011 11 25 - 2011 11 25 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					
								20 40 60 80 100					
						<div><div>○ UNCONFINED</div><div>● QUICK TRIAXIAL</div></div>	<div><div>+ FIELD VANE</div><div>× LAB VANE</div></div>		<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div>				
									<div><div>W<sub>P</sub></div><div>W</div><div>W<sub>L</sub></div></div>				
									WATER CONTENT (%)				
									20 40 60				
252.5	0.0		1	SS	23		252						34 57 9 (SI+CL)
251.7	0.8			2	SS		12	251					
250.9	1.6			3	SS		27	250					
250.1	2.4			4	SS		50/ 0.150	249					
249.2	3.3			5	SS		50/ 0.050	248					
				6	SS		102/ 0.250	247					
246.4	6.1			7	SS		50/ 0.025	246					
245.0	7.5			8	SS		50/ 0.125	245					
243.4	9.1			9	SS		50/ 0.0	244					

ONTMT4S 1182 GPJ 5/29/12

+<sup>3</sup>, x<sup>3</sup> Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE



RECORD OF BOREHOLE No WGW-5

1 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 374 385 6 E 373 965 4 Wild Goose Creek WBL ORIGINATED BY ES  
HWY 11/17 BOREHOLE TYPE Casing COMPILED BY AN  
DATUM Geodetic DATE 2011 11 24 - 2011 11 24 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40					
251.9 0.0	TOPSOIL, occasional wood fibres, occasional cobbles Dark Brown Moist		1	SS	13									
250.8 1.1	Cored through COBBLES and BOULDERS from 1.1m to 2.4m													
249.5 2.4	Silty CLAY, some sand to sandy, trace gravel Hard Grey (TILL)		2	SS	106/ 0.250									5 22 43 30
	Cored through occasional cobbles from 3.7m to 4.6m													
245.8 6.1	Sandy SILT, some clay Very Dense Brown Cored through occasional cobbles from 6.3m to 7.6m		4	SS	100/ 0.100									1 17 61 21
244.3 7.6	Gravelly SAND Very Dense Grey Wet		5	SS	50/ 0.075									
242.8 9.1	Cored through cobbles and boulders from 7.9m to 9.1m		6	SS	50/ 0.050									
	Sandy SILT, trace gravel Very Dense Grey Damp Cored through occasional cobbles and boulders from 9.2m to 12.2m													

Continued Next Page

+ 3 × 3 : Numbers refer to  
Sensitivity 20 15 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No **WGW-5**

2 OF 2

**METRIC**

W.P. 623-89-00 LOCATION N 5 374 385.6 E 373 965.4 Wild Goose Creek WBL ORIGINATED BY ES  
 HWY 11/17 BOREHOLE TYPE Casing COMPILED BY AN  
 DATUM Geodetic DATE 2011 11 24 - 2011 11 24 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
	Sandy SILT, trace gravel Very Dense Grey Damp to Wet  No recovery		7	SS	50/	0.025	241							
							240							
239.7			8	SS	50/									
12.2	END OF BOREHOLE AT 12.2m. WATER LEVEL AT 0.7m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV (m) Dec. 02/11 0.3 251.6					0.050								

ONTMT4S 1182.GPJ 1/27/12

# RECORD OF BOREHOLE No WGW-6

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 374 367 8 E 373 964 6 Wild Goose Creek WBL ORIGINATED BY ES  
 HWY 11/17 BOREHOLE TYPE Casing COMPILED BY AN  
 DATUM Geodetic DATE 2011.11.27 - 2011.11.27 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 w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	
251.5												
0.0	TOPSOIL, trace sand, occasional roots and rootlets		1	SS	17		251					
250.9	Dark Brown Frozen											
0.6	Silty SAND, trace to some gravel		2	SS	22							
	Compact Dark Brown Moist											
250.0							250					
1.5	Gravelly SAND Very Dense Brown Wet		3	SS	67/ 0.275							
249.3												
2.2	Cored through COBBLES and BOULDERS from 1.9m to 3.0m		4	SS	50/ 0.125		249					
248.4												
3.0	Sandy SILT, trace to some gravel, occasional cobble Very Dense Grey Moist		5	SS	50/ 0.125		248					
	Occasional boulders, cored from 3.2m to 4.6m											
			6	SS	50/ 0.075		247					
							246					
245.4			7	SS	50/ 0.075		245					
6.1	Gravelly SAND, occasional cobbles Very Dense Grey Moist to Wet Cored through occasional cobbles and boulders from 6.1m to 9.1m											
			8	SS	50/ 0.050		244					
							243					
242.3			9	SS	50/ 0.100							
9.2	END OF BOREHOLE AT 9.2m WATER LEVEL AT 0.5m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE											

25 73 2  
(SI+CL)

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

## **Appendix B**

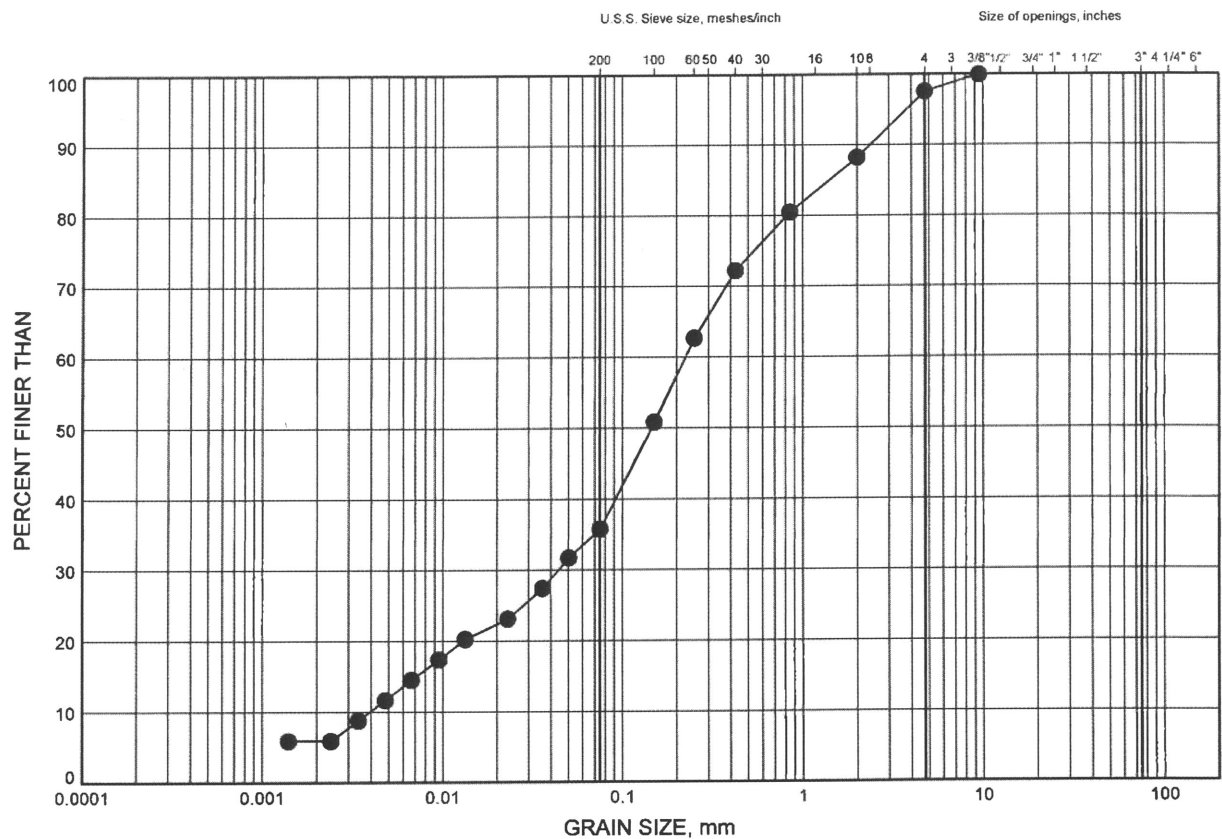
### **Laboratory Test Results**

# Wild Goose Creek Culvert - WBL

## GRAIN SIZE DISTRIBUTION

FIGURE B1

SILTY SAND



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

### LEGEND

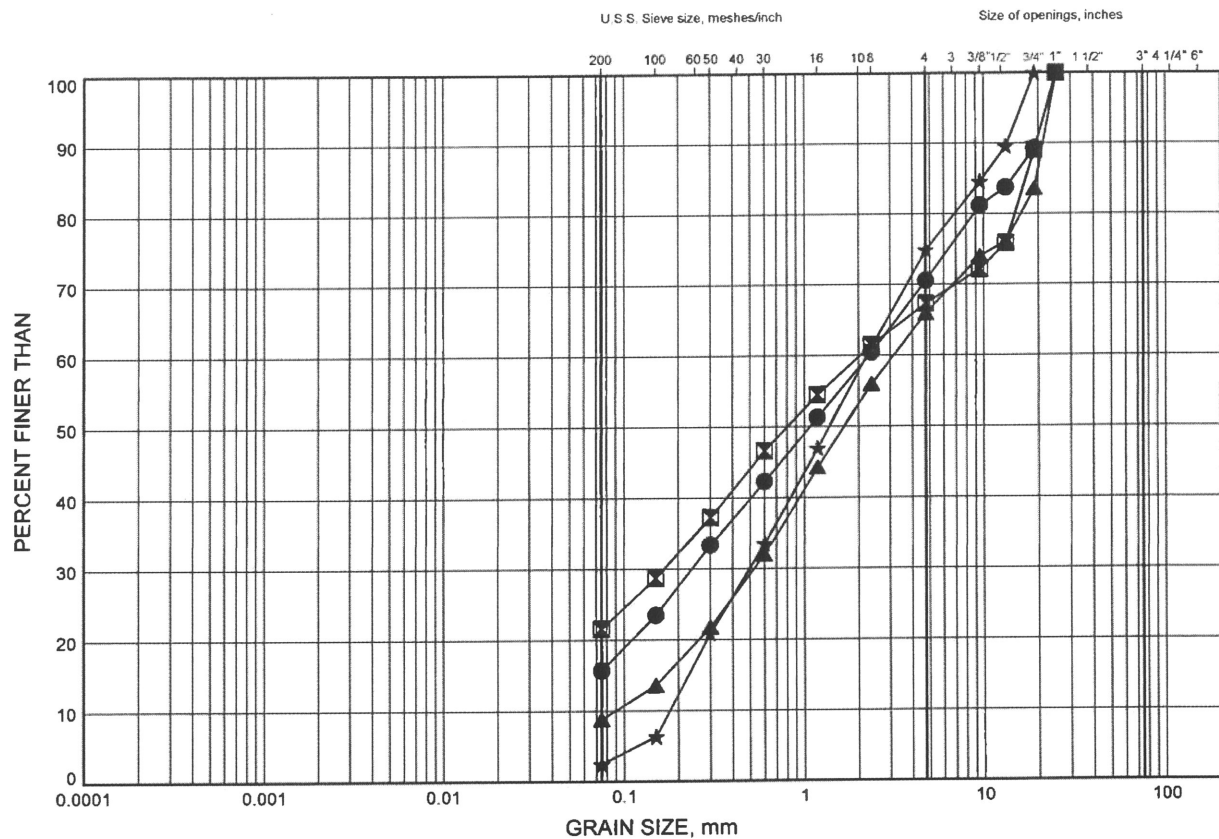
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WG-1	1.07	251.43



# Wild Goose Creek Culvert - WBL GRAIN SIZE DISTRIBUTION

FIGURE B2

## GRAVELLY SAND



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

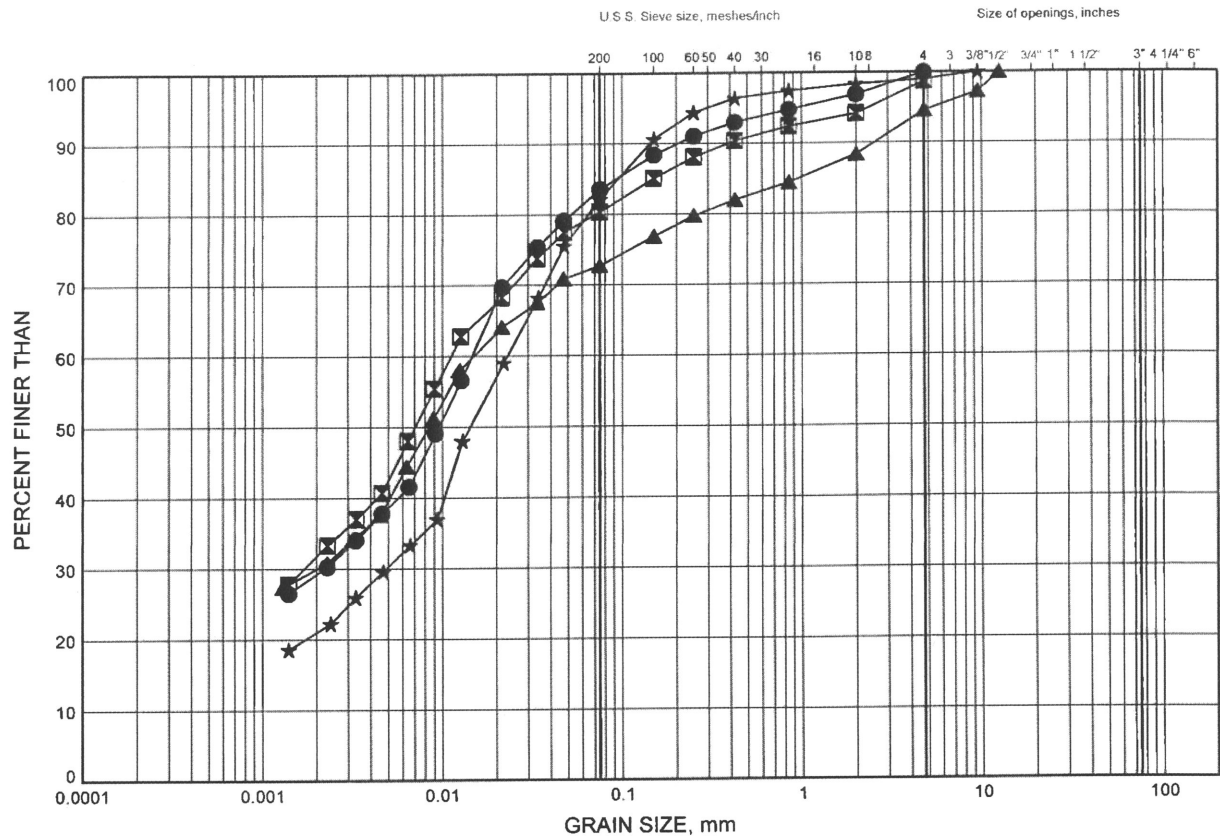
### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WGW-2	1.83	250.37
■	WGW-2	3.35	248.84
▲	WGW-4	1.83	250.67
★	WGW-6	6.40	245.10

# Wild Goose Creek Culvert - WBL GRAIN SIZE DISTRIBUTION

FIGURE B3

## SILTY CLAY TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WGW-1	3.11	249.39
⊠	WGW-4	4.78	247.72
▲	WGW-5	3.35	248.54
★	WGW-5	4.88	247.02



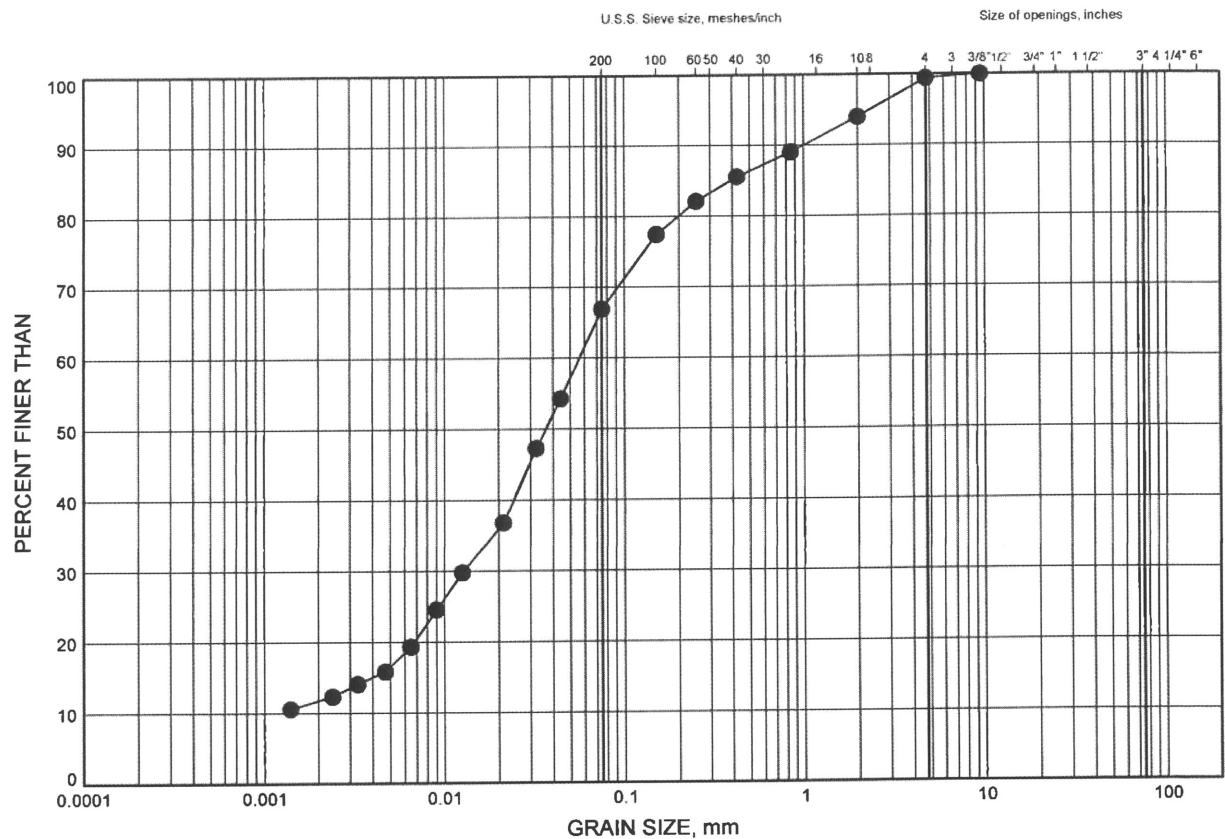
W.P.# 623-89-00  
Prepared By AN  
Checked By LRB

# Wild Goose Creek Culvert - WBL

## GRAIN SIZE DISTRIBUTION

FIGURE B4

### SANDY SILT



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	WGW-4	6.40	246.10



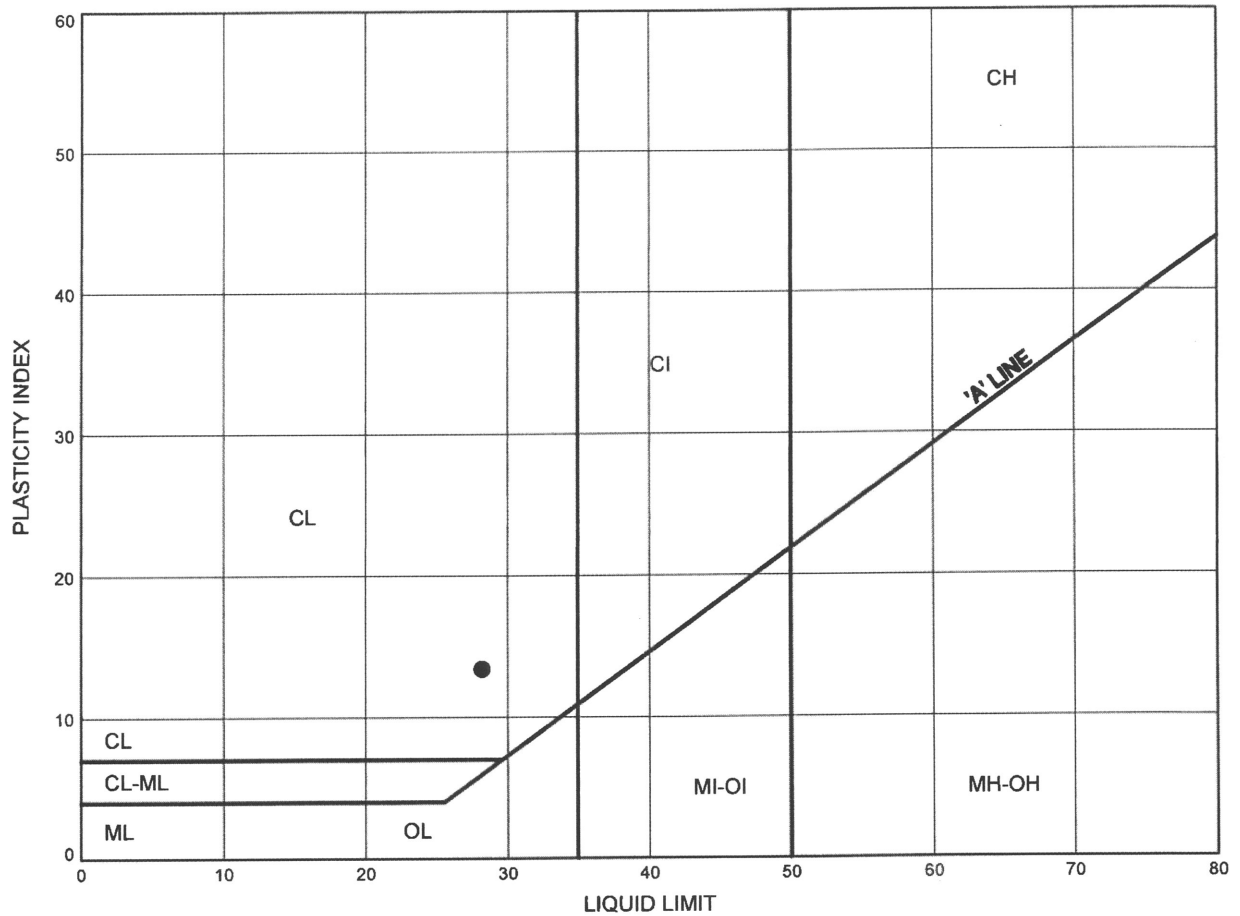
W.P.# 623-89-00  
 Prepared By AN  
 Checked By LRB



Wild Goose Creek Culvert - WBL  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B5

**SILTY CLAY TILL**



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	WGW-4	4.88	247.62

## **Appendix C**

### **Site Photographs**



**Photograph 1 – Looking west at proposed culvert inlet. Borehole WGW-4 is in the foreground and Borehole WGW-1 is in the background.**



**Photograph 2 – Wild Goose Creek, looking north from existing Wild Goose Creek culvert.**

## **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. Precast concrete footings may be employed provided rock fill is placed to re-establish the founding level above groundwater.</li> <li>iii. Minimizes rock fill quantity.</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. Subexcavation below the water level is required to remove topsoil and loose soils.</li> <li>ii. Available geotechnical resistances are lower compared to footings on rock fill pad.</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 remove topsoil and loose soils.</li> <li>ii. Cost of rock fill.</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. Presence of cobbles and boulders makes driven piles impractical and predrilling difficult.</li> <li>ii. Higher unit costs than footings.</li> <li>iii. 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>FEASIBLE</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 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.

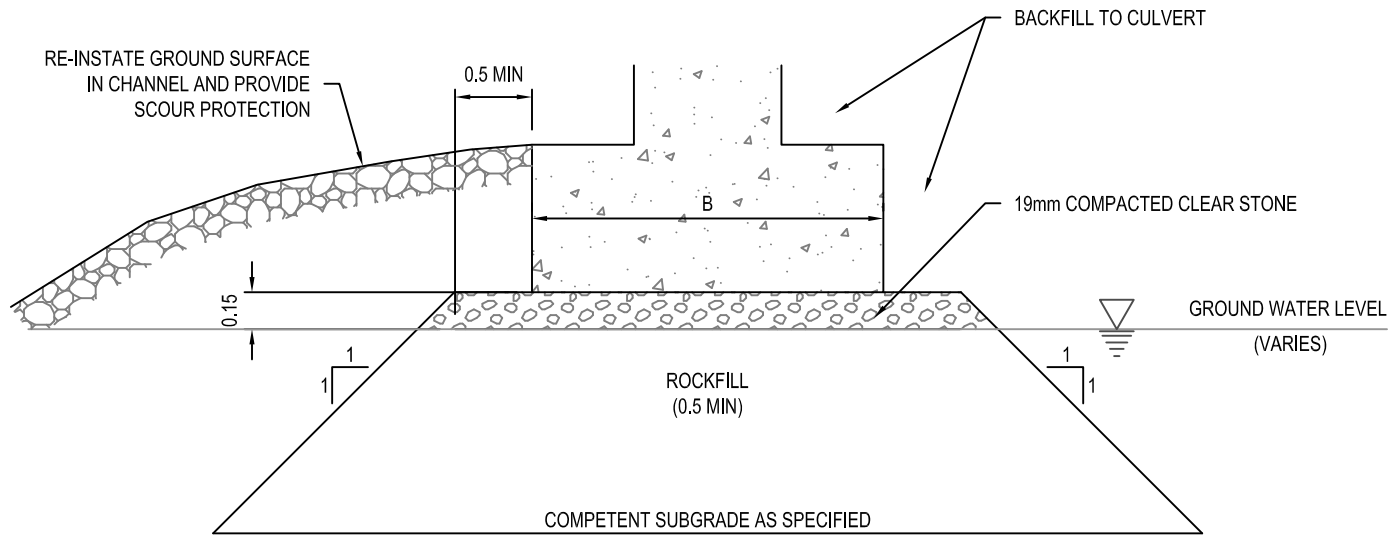
Large boulders may be encountered within the excavation depth. Removal of these boulders will require appropriate excavating equipment, and may result in areas of over-excavation requiring additional rock fill to backfill.

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 - 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

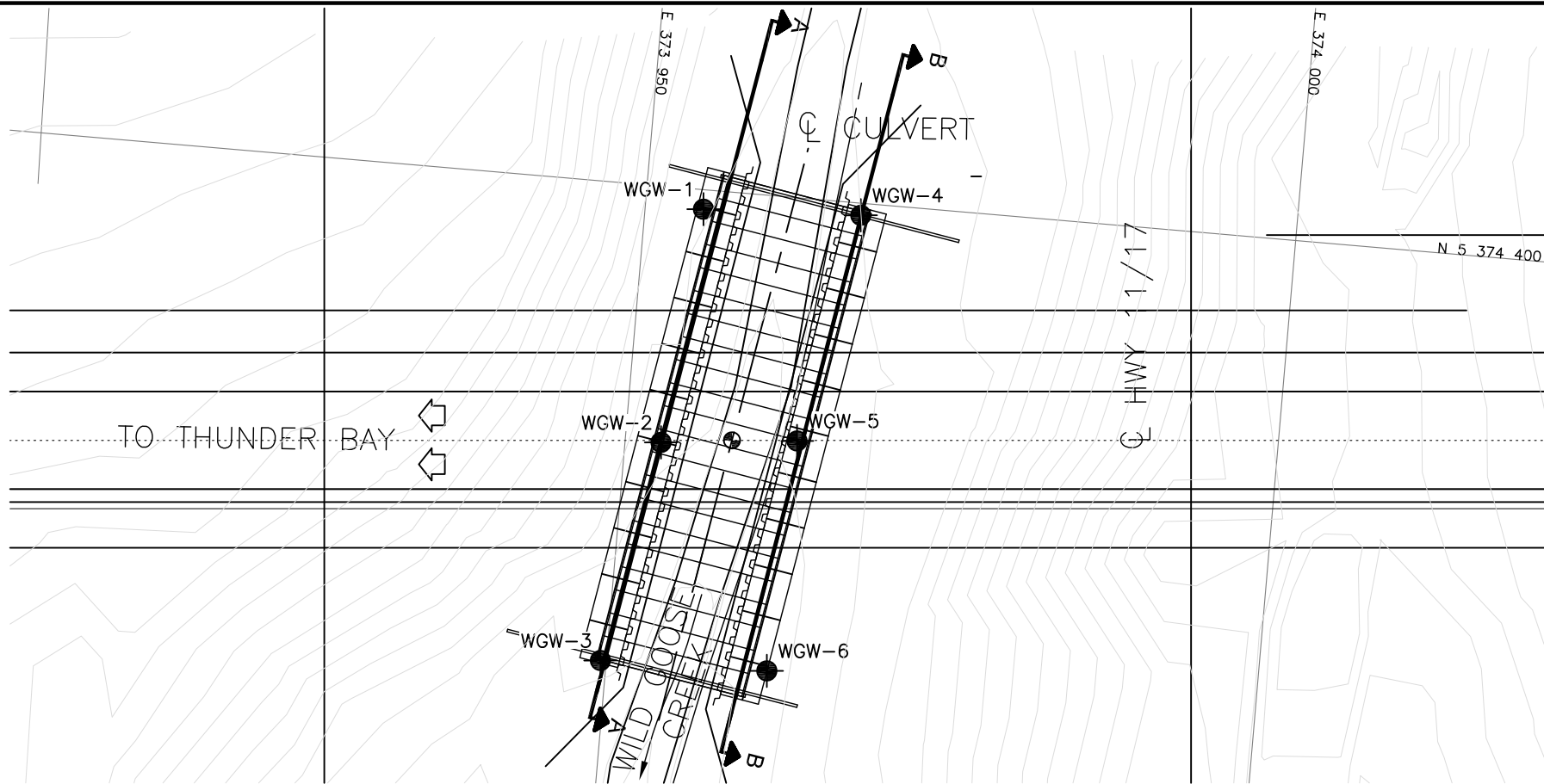


**THURBER ENGINEERING LTD.**

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 201-6010  
WP No 623-89-00

HIGHWAY 11/17 WIDENING  
WILD GOOSE CREEK  
CULVERT WESTBOUND LANES  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET  
217



KEYPLAN

LEGEND

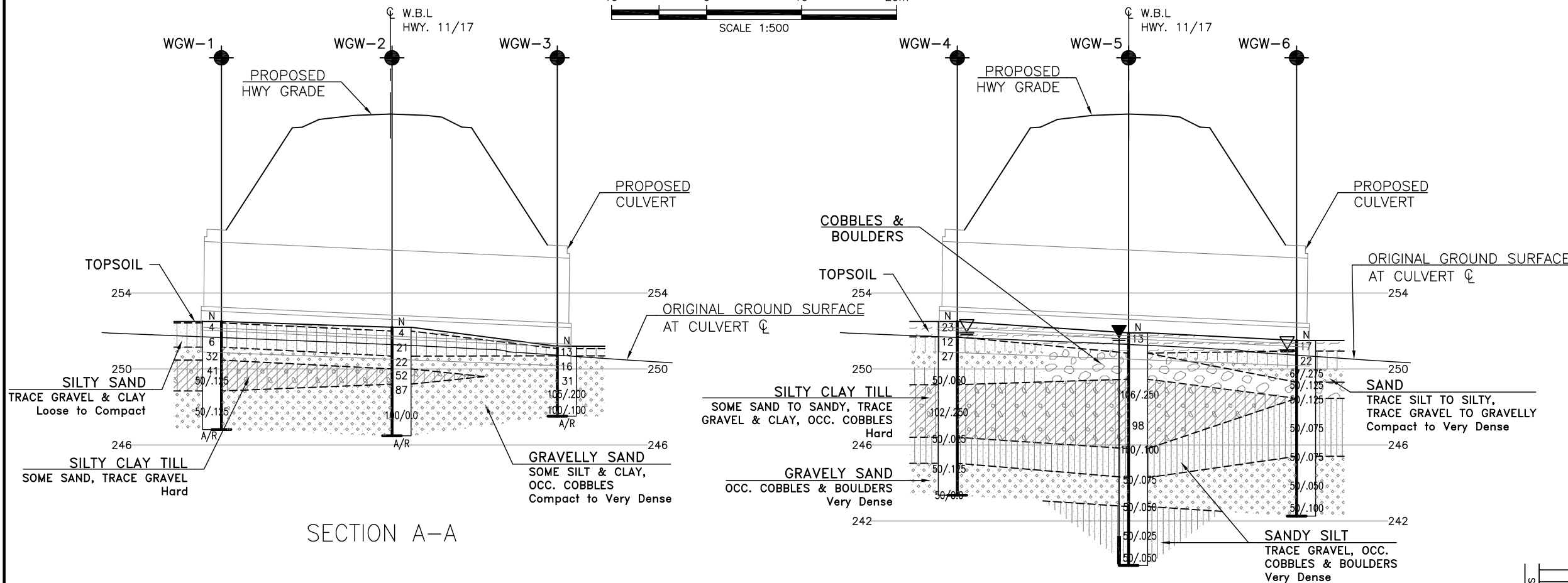
•	Borehole
•	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
↑	Head Artesian Water
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
WGW-1	252.5	5 374 402.7	373 956.9
WGW-2	252.2	5 374 384.6	373 955.0
WGW-3	251.2	5 374 367.5	373 951.8
WGW-4	252.5	5 374 403.3	373 968.8
WGW-5	251.9	5 374 385.6	373 965.4
WGW-6	251.5	5 374 367.8	373 964.6

-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-162



SECTION A-A

SECTION B-B

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	LRB	CHK	LRB
DRAWN	AN	CHK	RPR
CODE	CAN/CSA	SE-06	LOAD CL-625-ONT
DATE	JULY	2012	
SITE	48C-214/C2	STRUCT	DWG 2