

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
BEAVER CREEK BRIDGE REPLACEMENT  
HIGHWAY 594, DISTRICT OF KENORA  
G.W.P. 6047-08-00, STRUCTURE NO. 41S-56**

**Geocres Number: 52F-35**

**Report to  
McCormick Rankin Corporation**

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

February 7, 2012  
File: 19-1351-197

## TABLE OF CONTENTS

### **PART 1        FACTUAL INFORMATION**

1	INTRODUCTION .....	1
2	SITE DESCRIPTION .....	1
3	SITE INVESTIGATION AND FIELD TESTING .....	2
4	LABORATORY TESTING .....	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS .....	3
5.1	Pavement Structure .....	3
5.2	Silty Clay Fill .....	4
5.3	Silty Clay .....	4
5.4	Sand to Gravelly Sand .....	5
5.5	Silt .....	5
5.6	Bedrock .....	6
5.7	Water Levels .....	6
6	MISCELLANEOUS .....	7

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

7	INTRODUCTION .....	8
8	STRUCTURE FOUNDATIONS .....	8
8.1	Steel H-Pile Foundations .....	9
8.1.1	Pile Lateral Resistance .....	10
8.2	Spread Footings on Native Soil .....	11
8.3	Caissons .....	11
8.4	Recommended Foundation .....	11
8.5	Frost Cover .....	11
9	SHEET PILE WALLS .....	12
10	EROSION CONTROL .....	13
11	EXCAVATION AND GROUNDWATER CONTROL .....	13
12	SEISMIC CONSIDERATIONS .....	14

13 CONSTRUCTION CONCERNS ..... 15

14 CLOSURE..... 15

**Appendices**

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Photographs and Tables
Appendix D	List of Special Provisions and OPSS References
Appendix E	Drawing titled “Borehole Locations and Soil Strata”



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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a geotechnical investigation conducted at the location of the bridge carrying Highway 594 over Beaver Creek in the District of Kenora, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the bridge location and, based on the data obtained, to provide a borehole location plan, borehole logs, stratigraphic profile, cross-sections, laboratory test results and a written description of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to McCormick Rankin Corporation under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0011.

**2 SITE DESCRIPTION**

The site is located on Highway 594 approximately 75 m east of Griffith Road and 15 km west of Dryden in the Geographic Township of Aubrey, District of Kenora, Ontario.

Highway 594 at the bridge location is a two-lane surface treated roadway. The existing Beaver Creek Bridge has a total span of 18.9 m and is supported on four timber pile bents. Archive drawings indicate that the timber piles have lengths of 9 to 15 m. The approach embankments are in the order of 2.5 m high. Photographs of the site are presented in Appendix C.

The surrounding lands consist of a mix of grass and brush covered floodplain adjacent to the creek, heavily wooded areas, and occasional agricultural fields. The ground surface has a flat to gently undulating topography.

The site lies within the Canadian Shield, characterized by low, rounded hills of Pre-Cambrian bedrock mantled by varying thicknesses of overburden. At this site, the overburden primarily consists of glaciolacustrine silts and clays. The thickness of this geologic stratum is in the order of 30 m. The bedrock comprises a metasedimentary granitic complex of the Ghost Lake Batholith.

### 3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out during the period June 1 to 24, 2011. Six sampled boreholes were drilled at the site: four boreholes (BCB-2 to BCB-5) were advanced adjacent to the existing bridge abutments to depths of 27.3 to 32.2 m (bedrock/probable bedrock), and two boreholes (BCB-1 and BCB-6) were drilled in the approaches 20 m from the abutments to a depth of 11.9 m. Two of the abutment boreholes were advanced a further 3.1 to 3.4 m into bedrock by rock coring.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing in Appendix E. The coordinates and elevations of the boreholes are given on the drawings and on the individual Record of Borehole Sheets in Appendix A.

Prior to commencement of drilling, utility clearances were obtained for all borehole locations.

Hollow stem augers and wash-boring with casing were used to advance the boreholes. Samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). In situ vane shear testing was carried out using an MTO 'N' vane to evaluate the undrained shear strength of the cohesive deposits.

A member of Thurber's engineering staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, visually examined the recovered samples, and transported them to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Where artesian conditions were encountered, drill casing was extended above the ground surface to measure the pressure head. Standpipe piezometers were not installed due to the artesian conditions and the locations of the boreholes within the roadway. The boreholes were backfilled with bentonite, cement and auger cuttings upon completion. The borehole completion details are shown in Table 3.1.

**Table 3.1 – Borehole Decommissioning Details**

<b>Borehole</b>	<b>Completion Details</b>
BCB-1	Portland cement from 11.9 to 0.1m, then cold patch asphalt to surface.
BCB-2	Bentonite from 35.3 to 24.3m, sand from 24.3 to 21.3m, auger cuttings from 21.3 to 9.1m, bentonite from 9.1 to 0.1m, then cold patch asphalt to surface.
BCB-3	Peltonite from 32.2 to 30.5m, cement from 30.5 to 25.2m, auger cuttings from 25.2 to 9.1m, bentonite from 9.1 to 6.0m, cement from 6.0 to 1.5m, sand and gravel from 1.5 to 0.2m, then cold patch asphalt surface.
BCB-4	Cement from 28.0 to 24.1m, bentonite from 24.1 to 19.2m, auger cuttings from 19.2 to 9.4m, bentonite from 9.4 to 4.3m, sand and gravel from 4.3 to 0.2m, then cold patch asphalt to surface.
BCB-5	Bentonite from 30.7 to 24.3m, auger cuttings from 24.3 to 6.1m, bentonite from 6.1 to 0.1m, then cold patch asphalt to surface.
BCB-6	Portland cement from 11.9 to 0.1m, then cold patch asphalt 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 grain size distribution analyses (sieve and hydrometer) and Atterberg Limits testing where appropriate. The results of this testing program are shown on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B.

Point load testing was conducted on rock core samples retrieved from the boreholes. The results of the point load tests are shown on the borehole logs in Appendix A.

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

Reference is made to the Record of Borehole sheets in Appendix A for details of the encountered soil stratigraphy. A stratigraphic profile is presented on the Borehole Locations and Soil Strata Drawing in Appendix E, for illustrative purposes. Overall descriptions of the stratigraphy are given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations.

The soil stratigraphy encountered at the borehole locations typically consists of a roadway pavement structure overlying silty clay fill (embankment fill), underlain by a deep deposit of silty clay. The silty clay is underlain by a discontinuous sand/gravel/silt layer and bedrock.

More detailed descriptions of the individual strata are presented below.

##### **5.1 Pavement Structure**

A pavement structure consisting of 13 to 25 mm of asphaltic surface treatment over sand to sand and gravel fill was encountered in all boreholes. The sand/gravel extended to depths of 1.0 to 1.3 m (Elev. 346.8 to 347.3 m).

SPT 'N' values obtained in the lower portion of the sand/gravel fill ranged from 8 to 16 blows/0.3 m penetration, indicating a loose to compact condition. Moisture contents typically varied from 2 to 5%, with one value of 19% from Borehole BCB-1.

Grain size distribution curves for two samples of the sand fill are presented on the Record of Borehole sheets and on Figure B1 of Appendix B. The results of the laboratory tests are summarized as follows:

Gravel %	20 to 38
Sand %	52 to 65
Silt & Clay %	10 to 15

## 5.2 Silty Clay Fill

A layer of silty clay fill was encountered below the pavement structure in all boreholes except Borehole BCB-1. The fill was variously described as brown, dark brown and blackish brown, and contained wood fibres and organics. In Borehole BCB-3, a 200 mm thick layer of organics was encountered at the base of the fill.

The thickness of the silty clay fill was 0.4 to 2.0 m. The depth to the base of the silty clay fill ranged from 1.6 to 3.1 m (Elev. 345.3 to 346.7 m).

The consistency of the cohesive fill was firm to stiff, based on SPT 'N' values ranging from 6 to 12 blows/0.3 m. The moisture content varied from 23 to 35%. A moisture content of 4% was obtained in a sample with mixed sand and gravel in Borehole BCB-3.

## 5.3 Silty Clay

Native silty clay was encountered below the pavement structure in Borehole BCB-1 and below the clay fill in the remaining boreholes. The upper 0.7 to 2.3 m of the clay typically contained wood fibres, rootlets and other organic material, and the colour varied between grey, dark grey, dark brown and brown. Below this depth, the clay was grey, with a reddish brown zone between approximate depths of 14.7 and 17.8 m.

The thickness of the silty clay deposit ranged from 21.9 to 26.6 m. The lower boundary was at depths of 25.0 to 28.9 m (Elev. 319.4 to 323.4 m). Boreholes BCB-1 and BCB-6 were terminated in the silty clay at 11.9 m depth (Elev. 336.1 to 336.4 m).

SPT 'N' values obtained in the silty clay generally decreased with depth in the upper 1.0 to 4.0 m of this deposit, ranging from 14 blows/0.3 m to 1 blow/0.3 m, indicating a stiff to very soft consistency. Below approximately 5.5 m depth (4.0 m in Borehole BCB-5), the sampling equipment generally sank under self-weight, resulting in 'N' values of zero.

The undrained shear strength determined by in situ vane testing typically ranged from 18 to 46 kPa, indicating a soft to firm consistency. Shear strengths of 60 to 90 kPa (stiff) were measured below about 15 m depth in Boreholes BCB-2 and BCB-5 and at about 27 m depth in Borehole BCB-3. The apparent increase in shear strength with depth measured by vane testing in Boreholes BCB-2 and BCB-5 is not consistent with the recorded 'N' values and tactile descriptions.

Moisture contents in the silty clay ranged from 25 to 44% in samples obtained from within 3 to 5 m below the ground surface. Below this depth, the moisture contents ranged from 50 to 89%. A single value of 18% was measured at 26.2 m depth in Borehole BCB-3.

The results of grain size distribution analyses conducted on samples of the silty clay are presented on the Record of Borehole sheets and on Figures B2 to B5 of Appendix B. The results of Atterberg Limits testing are plotted on the logs and on Figures B8 to B10. A summary follows:

	<u>In upper 0.7 to 2.3 m</u>	<u>Remainder</u>
Gravel %	0	0
Sand %	4 to 10	0 to 1
Silt %	35 to 42	16 to 38
Clay %	48 to 61	61 to 84
Liquid Limit	56	44 to 70
Plastic Limit	29	21 to 26

The results of the laboratory testing indicate that the silty clay is typically of high plasticity with a designation of CH. Two tested samples from Borehole BCB-5 indicated medium plasticity (CI).

#### **5.4 Sand to Gravelly Sand**

A layer of sand to gravelly sand was encountered below the silty clay in Boreholes BCB-2, BCB-3 and BCB-5 at depths of 25.0 to 28.9 m (Elev. 319.4 to 323.4 m). The sand layer was 2.1 to 3.4 m thick with a lower boundary at depths of 27.1 to 32.2 m (Elev. 316.0 to 321.3 m). In Borehole BCB-5, a 200 mm thick layer of cobbles and gravel was encountered at the base of the sand layer.

SPT 'N' values in the sand ranged from 15 to 20 blows/0.3 m, indicating a compact relative density. 'N' values of 50 blows for 50 to 125 mm of penetration were obtained at the surface of the underlying bedrock in Boreholes BCB-2 and BCB-3. The moisture contents varied from 12 to 21%.

Grain size distribution curves for the sand are presented on the Record of Borehole sheets and on Figure B6 of Appendix B. The results of the laboratory tests are summarized as follows:

Gravel %	3 to 28
Sand %	53 to 84
Silt & Clay %	13 to 19

#### **5.5 Silt**

A layer of silt was encountered below the silty clay in Borehole BCB-4 at 26.3 m depth (Elev. 322.1 m). The silt layer was 1.7 m thick with a lower boundary at 28.0 m depth (Elev. 320.4 m).

An SPT 'N' value of 9 blows/0.3 m was obtained at the upper boundary of the silt, indicating a loose condition. A moisture content of 22% was measured.

A grain size distribution curve for the silt is presented on the Record of Borehole sheet and on Figure B7 of Appendix B. The results of the laboratory tests are summarized as follows:



Gravel %	0
Sand %	6
Silt %	82
Clay %	12

## 5.6 Bedrock

Bedrock and probable bedrock were encountered below the sand and silt layers in Boreholes BCB-2 to BCB-5. The depths to bedrock proved by coring or inferred by auger refusal are summarized in Table 5.1.

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

Location	BH Number	Depth to Bedrock (m)	Top of Bedrock Elevation (m)	Cored/ Inferred
West Abutment	BCB-2	32.2	316.0	Cored
	BCB-3	32.2	316.1	Inferred
East Abutment	BCB-4	28.0	320.4	Inferred
	BCB-5	27.3	321.1	Cored

The bedrock recovered in the cores was described as dark grey granite. Core recovery was between 88 and 100%. RQD values ranged from 77 to 100% indicating good to excellent rock quality. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, was generally less than 3.

The unconfined compressive strength of the rock, estimated from the results of point load tests conducted on the rock core samples, ranged between 78 and 134 MPa, indicating a strong to very strong intact rock. The point load test results are included on the borehole logs in Appendix A.

## 5.7 Water Levels

Groundwater was measured at 3.9 and 4.4 m depth in Boreholes BCB-1 and BCB-6 upon completion of drilling. An artesian groundwater condition was encountered in the sand, gravelly sand and silt layer underlying the silty clay deposit in Boreholes BCB-2 to BCB-5. The water levels measured in the open boreholes, referenced to the ground surface, are summarized in Table 5.2.

It is noted that in Borehole BCB-5, artesian water continued to flow from augers extended 1.8 m above the ground surface, and the full artesian head was not determined.

The water level in Beaver Creek was at Elev. 346.2 m in July 2011.

**Table 5.2 – Water Level Measurements**

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
BCB-1	June 24, 2011	3.9	344.1	In open borehole
BCB-2	June 3, 2011	-3.1*	351.3*	In drill casing
BCB-3	June 21, 2011	-3.0*	351.3*	In drill casing
BCB-4	June 22, 2011	-2.7*	351.1*	In augers
BCB-5	June 2, 2011	-1.8*	>350.2*	Flowing from augers
BCB-6	June 24, 2011	4.4	343.9	In open borehole

\*Indicates water level above ground surface, artesian conditions.

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

## 6 MISCELLANEOUS

The borehole locations were established in the field by Thurber Engineering. The coordinates and ground surface elevations at the boreholes were subsequently determined by MMM Group Limited survey personnel.

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

Eastern Ontario Diamond Drilling Ltd. supplied truck-mounted drilling equipment and conducted the drilling, sampling and in-situ testing operations for the boreholes drilled.

The field program was supervised on a full time basis by Ms. Eckie Siu of Thurber Engineering Ltd. Overall supervision of the field program was provided by Mr. Alastair E. Gorman, P.Eng. and Ms. Lindsey Blaine, E.I.T.

Interpretation of the data and preparation of the report was carried out by Mr. Murray R. Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundations Projects.

### Thurber Engineering Ltd.

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



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

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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 bridge to replace the existing bridge at Beaver Creek.

The existing bridge is a three-span structure with a concrete-capped timber deck supported on timber piles. The overall length of the bridge is 18.9 m and the width is 9.75 m.

The proposed bridge (as shown on the preliminary General Arrangement drawing dated July/11) consists of a single span structure with a deck of precast box girders supported on a single row of H-pile foundations. The abutments will comprise steel sheet pile walls. The new bridge will have a span of 16.4 m and a width of 10.9 m.

Existing road grades over the bridge (approximate Elev. 348.7 m) will be maintained. The embankment height is about 2.5 m.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the investigation. The plans and profiles used for preparation of this report were provided by McCormick Rankin Corporation.

**8 STRUCTURE FOUNDATIONS**

In general, the site is underlain by a 21.9 to 26.6 m thick deposit of very soft to stiff silty clay, underlain by a relatively thin layer of sand or silt, overlying bedrock at depths 27.3 to 32.2 m. The existing embankment consists of sand/gravel fill over silty clay fill extending to depths of 1.2 to 3.1 m. An artesian groundwater condition was encountered in the sand/silt layer at the site, with a head of up to 3.1 m above the ground surface (Elev. 351.3 m). The water level in the creek was at Elev. 346.2 m in July 2011.

Geotechnical recommendations for design of the proposed H-pile foundation system are presented in the following sections. Foundation alternatives together with corresponding geotechnical design parameters for feasible options are also presented in the event that the foundation concept changes.

A comparison of the technical advantages and disadvantages of alternative foundation schemes (driven steel H-piles, spread footings on native soil, and caissons/drilled shafts) is presented in Appendix C. A foundation scheme preferred from a foundations perspective is recommended.

### 8.1 Steel H-Pile Foundations

The geotechnical conditions encountered at this site are considered suitable for driven steel H-pile foundations. The piles must be driven to bedrock and are expected to encounter refusal on bedrock at the elevations given in Table 8.1.

**Table 8.1 – Anticipated Pile Tip Elevation**

Location	Borehole Number	Depth to Bedrock (m)	Anticipated Pile Tip Elevation (m)
West Abutment	BCB-2	32.2	316.0
	BCB-3	32.2	316.1
East Abutment	BCB-4	28.0	320.4
	BCB-5	27.3	321.1

The recommended axial geotechnical resistance of an HP 310x110 pile driven to bedrock is 2,000 kN per pile at factored ULS. The SLS condition will not govern design of piles bearing on bedrock. The structural resistance of the pile must be checked by the structural designer.

The pile tip elevations are presented for estimating purposes only and may vary along the abutment locations.

Pile installation should be in accordance with OPSS 903. For piles installed for the tolerances shown in Clause 903.07.05.01 of the Specification, the foundation drawing should include the note “Piles to be driven to bedrock”.

We understand however that the proposed bridge design may require that the lateral deviation at the pile head be limited to 12 mm. To reduce the potential for misalignment resulting from hard driving on bedrock, it is recommended that the pile driving note on the foundation drawing be modified as follows:

“Piles to be driven to bedrock. Upon initial contact with the bedrock:

1. Apply 10 blows at 10% of the hammer energy. Record the penetration.
2. Apply 10 blows at 50% of the hammer energy. If the penetration under 10 blows is less than 12.5 mm, the pile is set.
3. If the penetration under 10 blows at 50% hammer energy is greater than 12.5 mm, refer the issue to the design team for resolution.”

A driving template or other means may also be required to achieve the specified maximum deviation.

The tips of all piles should be fitted with H-section rock points from an approved manufacturer such as Titus Steel (Standard H-point), Pruyn Points or approved equivalent. Rock points are recommended for setting the piles on bedrock.

Since the highway grades will not be revised, downdrag on the piles is not considered to be an issue at this site.

An artesian groundwater condition was encountered at the site, with a head of up to 3.1 m above the ground surface. It is expected that the thick clay layer above the artesian zone will act as a seal to prevent artesian flow up along the pile shaft. If residual artesian flow is observed adjacent to the pile, measures such as placement of a bentonite seal or a gravel/geotextile filter at the ground surface may be required. The CA should refer this issue to the design team for resolution.

#### 8.1.1 Pile Lateral Resistance

The geotechnical lateral resistance acting on an H-pile in silty clay may be calculated using a value for the coefficient of horizontal subgrade reaction ( $k_s$ ) and ultimate lateral resistance ( $p_{ult}$ ) as follows:

$$\begin{aligned} k_s &= 67 S_u / D \quad (\text{kN/m}^3) \\ p_{ult} &= 9 S_u \text{ (kPa) at and below a depth of } 3D \\ &\quad \text{reduced to zero at the ground surface} \end{aligned}$$

where

$$\begin{aligned} S_u &= \text{undrained shear strength} \\ &= 25 \text{ kPa for stiff to very soft silty clay} \\ D &= \text{pile width in metres} \end{aligned}$$

The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.

The spring constant,  $K_s$ , for analysis may be obtained by the expression,  $K_s = k_s \times L \times D$  (kN/m), where  $k_s$  is the coefficient of horizontal subgrade reaction (kN/m<sup>3</sup>),  $D$  is the pile width (m) and  $L$  is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance,  $P_{ult}$ , may be obtained from the expression,  $P_{ult} = p_{ult} \times L \times D$ . This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements. It is recommended, however, that the total lateral resistance assumed in one pile be limited to no more than 120 kN at ULS and 35 kN at SLS.

The modulus of subgrade reaction may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the

direction of loading are provided in Table 8.2. Intermediate values may be obtained by linear interpolation.

**Table 8.2 – Subgrade Reaction Reduction Factors for Pile Spacing**

Condition	Pile Spacing, Centre to Centre*	Reduction Factor
Pile group oriented <i>perpendicular</i> to direction of loading	4D	1.0
	1D	0.5
Pile group oriented <i>parallel</i> to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

\* where D is the width of pile

Alternatively, horizontal loads may be resisted by means of battered piles.

## 8.2 Spread Footings on Native Soil

Spread footings are not recommended at this site in view of the very low geotechnical resistance available in the native silty clay and the potential for excessive long-term settlement resulting from consolidation of the deep cohesive deposits. This alternative has not been developed further.

## 8.3 Caissons

The silty clay deposit at this site is unsuitable as a caisson bearing material and caissons would need to be extended to the underlying bedrock encountered at depths of 27.3 to 32.2 m. A sand/silt layer with artesian water pressures was encountered immediately above the bedrock surface.

Caisson construction would require specialized construction techniques such as the use of drilling mud and a caisson liner to support the sidewalls and counter the artesian pressure. Sealing the bottom of the caisson liner to exclude groundwater would be difficult and unwatering of the caissons would be impractical. In view of these factors, the use of caissons is not recommended and this alternative has not been developed further.

## 8.4 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, steel H-piles driven to bedrock are the recommended foundation type for the replacement bridge at this site.

## 8.5 Frost Cover

The depth of frost penetration at this site is 2.5 m. The base of all pile caps must be provided with a minimum of 2.5 m of earth cover as protection against frost action.

## 9 SHEET PILE WALLS

Steel sheet pile walls will be driven adjacent to the H-pile foundations at each abutment. The sheet piles will provide containment and resistance to lateral earth pressures from the approach fill.

Driving of the sheet piles through the existing approach fill and into the underlying stiff to very soft silty clay is considered feasible based on the borehole data.

Backfill to the sheet pile walls should be in accordance with OPSS 902. Granular backfill should be placed to the extents shown in OPSD 3101.150. All granular material should meet the specifications of OPSS 1010 as amended by Special Provision 110S13. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.

Earth pressures acting on the sheet pile walls may be assumed to be triangular and to be governed by the characteristics of the abutment backfill and the existing silty clay and silty clay fill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

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

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

$K$  = earth pressure coefficient (see Table 9.1)

$\gamma$  = 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 abutment wall are dependent on the material used as backfill and the existing material adjacent to the wall. Typical values are given in Table 9.1.

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

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		Silty Clay Fill of Silty Clay $\phi = 27^\circ, \gamma = 18.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	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*	0.38	0.76*
At Rest (Restrained Wall)	0.43	-	0.47	-	0.55	-
Passive	3.7	-	3.3	-	2.7	-

\* For wing walls.

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

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

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.

## **10 EROSION CONTROL**

In general, earth fill embankment slopes must be provided with erosion protection in accordance with OPSS 804.

Erosion protection must be provided at the toe of any embankment slopes that are potentially in contact with the creek flow. We understand that the existing creek banks are not to be disturbed during construction.

## **11 EXCAVATION AND GROUNDWATER CONTROL**

Excavation for construction of the new bridge and removal of exposed sections of the existing timber bents is expected to be limited to the existing sand backfill adjacent to the structure and potentially the silty clay fill. Excavation will be carried out above the water level in the creek.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the sand fill and silty clay fill forming the existing embankment may be classified as Type 3 soils. The native silty clay is a Type 4 soil based on the soft to very soft consistency.

Roadway protection should be supplied in accordance with OPSS 539 and designed for Performance Level 2. The protection systems should be designed by a licensed Professional Engineer experienced in design of shoring with consideration of adjacent traffic loads and any sloping retained surfaces. Based on available subsurface information, a shoring system consisting of steel sheet piles may be considered. The design of the roadway protection should be the responsibility of the Contractor.

An artesian groundwater condition was encountered at the site. This condition is not expected to impact on shallow excavations for installation of the new bridge. It is recommended that the existing timber piles be left in place to avoid creating a pathway for artesian water to escape to the surface.



The Contractor should be prepared to pump from sumps to remove any seepage water or surface water collecting in an excavation.

The excavation and backfilling for foundations must be carried out in accordance with OPSS 902.

## 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 IV based on a silty clay thickness of 21.9 to 26.6 m. Therefore, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 2.0 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 12.1 may be used:

**Table 12.1 – Earth Pressure Coefficients for Earthquake Loading**

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	Existing Sand Fill or OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Silty Clay $\phi = 27^\circ$ $\gamma = 18 \text{ kN/m}^3$
Active ( $K_{AE}$ )*	0.28	0.32	0.38
Passive ( $K_{PE}$ )	3.7	3.2	2.7
At Rest ( $K_{OE}$ )**	0.45	0.50	0.57

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

\*\* After Woods

The site overlies stiff to very soft silty clay. A cursory review of the subsurface conditions indicates that a potential for liquefaction does not exist at this site. During a seismic event, local toe failure or minor embankment settlement may occur, but is expected to be readily repairable.

### 13 CONSTRUCTION CONCERNS

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

- Although not encountered in the boreholes, buried obstructions may be encountered in the existing embankment fill during excavation or interfere with driving of piles.
- An artesian condition was encountered at this site. If artesian groundwater flow is observed adjacent to the piles, the contractor or QVE must immediately advise the CA. The CA should refer this issue to the design team.
- Roadway protection must be provided to maintain traffic during construction. Temporary shoring systems should be properly designed by a Professional Engineer experienced in such designs.

### 14 CLOSURE

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

#### Thurber Engineering Ltd.

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



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



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

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

### 1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

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

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

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

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

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

### 5. LEGEND FOR RECORDS OF BOREHOLES

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

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



Water Level

C<sub>pen</sub>

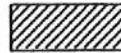




Shear Strength Determination by Pocket Penetrometer

- (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

ROCK WEATHERING CLASSIFICATION		SYMBOLS			
Fresh (FR)	No visible signs of weathering.				
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE		
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE		
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE		
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL		
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)		
DISCONTINUITY SPACING		STRENGTH CLASSIFICATION			
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.
TERMS		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
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 BCB-1

1 OF 2

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 406.4 E 301 298.6 ORIGINATED BY ES  
 HWY 594 BOREHOLE TYPE Hollow Stem Augers/Casing COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.24 - 2011.06.24 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
348.0	ASPHALT: (25mm)		1	GS			348						
346.8	SAND and GRAVEL Brown Damp (FILL)		1	SS	12		347						
1.2	Silty CLAY, trace sand, organics, occasional wood fibres Stiff to Soft Brown to Dark Brown		2	SS	8		346						
	Dark Brown to Grey		3	SS	6		345						0 7 38 55
344.5			4	SS	2		344						
3.5	Silty CLAY, trace sand Very Soft Grey		5	SS	1		343						0 1 38 61
			6	SS	0		342						
			7	SS	0		341						
			8	SS	0		340						0 0 23 77
							339						

Continued Next Page

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BCB-1

2 OF 2

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 406.4 E 301 298.6 ORIGINATED BY ES  
 HWY 594 BOREHOLE TYPE Hollow Stem Augers/Casing COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.24 - 2011.06.24 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 (%)  GR SA SI CL		
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>				
	Continued From Previous Page					20 40 60 80 100	20 40 60 80 100	20 40 60									
							338										
			9	SS	0		337										
336.1																	
11.9	END OF BOREHOLE AT 11.9m. WATER LEVEL AT 3.9m UPON COMPLETION. BOREHOLE BACKFILLED WITH PORTLAND CEMENT TO 0.07m, THEN ASPHALT TO SURFACE.																

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No BCB-2

1 OF 4

METRIC

W.P. 6048-08-00 LOCATION Beaver Creek Bridge N 5 516 407.8 E 301 307.0 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.02 - 2011.06.03 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	20 40 60 80 100	20 40 60 80 100		
348.2	ASPHALT: (25mm)		1	GS			348					* 3.1m above ground surface
347.2	SAND and GRAVEL, trace silt Brown Moist (FILL)		1	SS	8		347					38 52 10 (SI+CL)
1.0	Silty CLAY, some sand, trace gravel, trace rootlets Firm Brown (FILL)		2	SS	6		346					
345.7	Silty CLAY, trace sand, occasional wood fibres, trace peat Firm to Soft Dark Grey		3	SS	6		345					0 10 42 48
2.5			4	SS	5		344					
343.6	Silty CLAY, trace sand Very Soft Grey		5	SS	2		343					
			6	SS	0		342					0 0 20 80
			7	SS	0		341					
			8	SS	0		340					
							339					

Continued Next Page

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BCB-2

2 OF 4

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 407.8 E 301 307.0 ORIGINATED BY ES  
 HWY 594 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.02 - 2011.06.03 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	PLASTIC LIMIT w <sub>p</sub> NATURAL MOISTURE CONTENT w LIQUID LIMIT w <sub>L</sub>		
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE		WATER CONTENT (%) 20 40 60		
	Silty CLAY Very Soft Grey		9	SS	0		338	3				
							337					
			1	TW			336					
			10	SS	0		335	2				
							334					
333.5 14.7			11	SS	0		333					
	Reddish Brown						332	2				
			12	SS	0		331					0 0 16 84
330.5 17.8							330					
			13	SS	0		329	2				

Continued Next Page

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

# RECORD OF BOREHOLE No BCB-2

3 OF 4

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 407.8 E 301 307.0 ORIGINATED BY ES  
 HWY 594 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.02 - 2011.06.03 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE      LIQUID CONTENT      LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE		● QUICK TRIAXIAL      x LAB VANE					w <sub>p</sub> w      w <sub>L</sub>		
								20   40   60   80   100				20   40   60					
	Continued From Previous Page		14	SS	0		328										
	Silty <b>CLAY</b> Very Soft Grey						327		+ <sub>3</sub>								
							326										
			15	SS	0		325						○				
							324		+ <sub>3</sub>								
							323										
			16	SS	0		322					○					
							321		+ <sub>5</sub>								
							320										
319.4							319					○					
28.8	<b>SAND</b> , trace gravel, some silt Compact Grey Wet		17	SS	15												

Continued Next Page

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

METRIC

W.P.	6047-08-00	LOCATION	Beaver Creek Bridge N 5 516 407.8 E 301 307.0	ORIGINATED BY	ES
HWY	594	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.06.02 - 2011.06.03	CHECKED BY	RPR

[illegible]

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

# RECORD OF BOREHOLE No BCB-3

1 OF 4

METRIC

W.P. 6048-08-00 LOCATION Beaver Creek Bridge N 5 516 402.6 E 301 306.8 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.21 - 2011.06.21 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								WATER CONTENT (%)				
348.3							20 40 60 80 100	20 40 60				GR SA SI CL
0.8	ASPHALT: (25mm)											* 3.0m above ground surface
	SAND, some gravel Damp Brown (FILL)		1	GS								
347.1			1	SS	9							
1.1	Silty CLAY, some sand, trace gravel Stiff Brown (FILL)											
	With sand and gravel		2	SS	9							
346.1												
346.0	ORGANICS											
2.3	Dark Brown Damp		3	SS	6							
	Silty CLAY, trace sand, occasional wood fibres Firm Grey Damp											0 4 35 61
344.8			4	SS	7							
3.5	Silty CLAY, trace sand Soft to Very Soft Grey											
			5	SS	2							
			6	SS	0							
			7	SS	0							
			8	SS	0							

Continued Next Page

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

# RECORD OF BOREHOLE No BCB-3

2 OF 4

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 402.6 E 301 306.8 ORIGINATED BY ES  
 HWY 594 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.21 - 2011.06.21 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>	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X LAB VANE	WATER CONTENT (%) 20 40 60			GR SA SI CL
	Silty CLAY, trace sand Very Soft Grey		9	SS	0		338					
							337	+ <sup>4</sup>				
			10	SS	0		336					0 0 24 76
							335					
			11	SS	0		334					
	Grey to Reddish Brown						333					0 0 22 78
			12	SS	0		332					
							331					
			1	TW			330					
							329					
			13	SS	0							

Continued Next Page

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BCB-3

3 OF 4

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 402.6 E 301 306.8 ORIGINATED BY ES  
HWY 594 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2011.06.21 - 2011.06.21 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>	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60			
	Silty CLAY, trace sand Very Soft Grey		14	SS	0		328					
							327					
							326					
			15	SS	0		325					0 0 26 74
							324					
							323					
			16	SS	1		322					
							321					
							320					
319.4 28.9	Gravelly SAND, some silt Compact Grey Wet		17	SS	20		319					28 53 19 (SI+CL)

Continued Next Page

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

# RECORD OF BOREHOLE No BCB-3

4 OF 4

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 402.6 E 301 306.8 ORIGINATED BY ES  
 HWY 594 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.21 - 2011.06.21 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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
	Continued From Previous Page													
317.8							318							
30.5	SAND, coarse grained, trace gravel Very Dense Brown Wet						317							
316.1			18	SS	50/									
32.2	END OF BOREHOLE AT 32.2m UPON REFUSAL TO AUGER ON PROBABLE BEDROCK. ARTESIAN GROUND WATER WITH HEAD AT 3.0m ABOVE GROUND SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH PELTONITE FROM 32.2m TO 30.5m, CEMENT FROM 30.5m TO 25.2m, CUTTINGS FROM 25.2m TO 9.1m, HOLEPLUG FROM 9.1m TO 6.0m, CEMENT FROM 6.0m TO 1.5m, SAND AND GRAVEL FROM 1.5m TO 0.2m, THEN ASPHALT TO SURFACE.				0.050									



# RECORD OF BOREHOLE No BCB-4

1 OF 3

METRIC

W.P. 6048-08-00 LOCATION Beaver Creek Bridge N 5 516 407.1 E 301 331.2 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.22 - 2011.06.22 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
348.4	ASPHALT: (25mm)  SAND, some gravel, some silt Brown Damp (FILL)		1	GS			348					* 2.7m above ground surface
347.1			1	SS	10							20 65 15 (SI+CL)
1.3	Silty CLAY, trace sand, trace rootlets, occasional wood fibres, mixed with organics Stiff Dark Brown (FILL)		2	SS	10		347					
345.7			3	SS	10		346					
2.7	Silty CLAY, trace sand, occasional oxide staining Stiff to Soft Brown/Grey to Dark Brown		4	SS	8		345					
343.5			5	SS	3		344					
4.9	Silty CLAY, trace sand Very Soft Grey		6	SS	0		343	2 +				
			7	SS	0		342					0 0 17 83
			8	SS	0		341					
							340					
							339					

Continued Next Page

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

20  
15 5  
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BCB-4

2 of 3

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 407.1 E 301 331.2 ORIGINATED BY ES  
HWY 594 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2011.06.22 - 2011.06.22 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 (%)
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>	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				
	Silty CLAY, trace sand Very Soft Grey		9	SS	0		338					
							337					
			10	SS	0		336					
							335					
			11	SS	0		334					
333.6 14.8							333					
	Reddish Brown		12	SS	0		332					
							331					
330.6 17.8			13	SS	0		330					
							329					
			14	SS	0							

Continued Next Page



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

# RECORD OF BOREHOLE No BCB-4

3 OF 3

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 407.1 E 301 331.2 ORIGINATED BY ES  
 HWY 594 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.22 - 2011.06.22 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					WATER CONTENT (%)		
								20 40 60 80 100					20 40 60		
	Continued From Previous Page		1	TW											
	Silty <b>CLAY</b> Very Soft Grey Wet														
			15	SS	0										
322.1			16	SS	9										
26.3	<b>SILT</b> , some clay, trace sand Loose Grey Wet														
320.4															
28.0	END OF BOREHOLE AT 28.0m UPON REFUSAL TO AUGER ON PROBABLE BEDROCK. ARTESIAN GROUND WATER WITH HEAD AT 2.7m ABOVE GROUND SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH CEMENT FROM 28.0m TO 24.1m, BENTONITE FROM 24.1m TO 19.2m, CUTTINGS FROM 19.2m TO 9.4m, BENTONITE FROM 9.4m TO 4.3m, SAND AND GRAVEL FROM 4.3m TO 0.15m, THEN ASPHALT TO SURFACE														

0 6 82 12

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BCB-5

1 OF 4

METRIC

W.P. 6048-08-00 LOCATION Beaver Creek Bridge N 5 516 402.7 E 301 330.8 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/Casing COMPILED BY AN  
 DATUM Geodetic DATE 2011.06.01 - 2011.06.02 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  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 ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	w <sub>p</sub> w      w <sub>L</sub>					
348.4							20 40 60 80 100								GR SA SI CL
0.8	ASPHALT: (13mm)		1	GS											* Flowing from casing extended 1.8m above ground surface.
	SAND, some gravel, trace silt Brown Moist (FILL)														
347.3			1	SS	9										
1.1	Silty CLAY, trace sand, trace gravel, occasional burnt wood fibres Stiff to Firm Blackish Brown (FILL)		2	SS	12										
			3	SS	6										
345.3			4	SS	3										
3.1	Silty CLAY, trace sand Soft to Very Soft Grey														0 1 26 73
			5	SS	0										
			6	SS	0										
			1	TW											
			2	TW											

Continued Next Page

+<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 γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI C
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	W <sub>P</sub>	W		
Continued From Previous Page													
	Silty CLAY Very Soft Grey Wet		7	SS	0								0 0 24 76
			8	SS	0								
			9	SS	0								
333.7 14.7	Reddish Brown		10	SS	0								
			11	SS	0								
330.6 17.8			12	SS	0								

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

## METRIC

[illegible]

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

ONTMT4S 1197.GPJ 9/9/11

RECORD OF BOREHOLE No BCB-5

4 OF 4

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 402.7 E 301 330.8 ORIGINATED BY ES  
HWY 594 BOREHOLE TYPE Hollow Stem Augers/Casing COMPILED BY AN  
DATUM Geodetic DATE 2011.06.01 - 2011.06.02 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		
	Continued From Previous Page		3	RUN			318							
317.7														
30.7	END OF BOREHOLE AT 30.7m. ARTESIAN GROUND WATER CONDITION WITH HEAD GREATER THAN 1.8m ABOVE GROUND SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE TO 24.3m, CUTTINGS TO 6.1m, BENTONITE TO 0.04m, THEN ASPHALT TO SURFACE.													

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

20  
15  
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BCB-6

1 OF 2

METRIC

W.P. 6047-08-00 LOCATION Beaver Creek Bridge N 5 516 406.0 E 301 338.9 ORIGINATED BY ES  
HWY 594 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2011.06.24 - 2011.06.24 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>		
348.3	ASPHALT: (25mm)												
	SAND, some gravel Brown Damp (FILL)		1	GS			348						
347.1			1	SS	16								
1.2	Silty CLAY, some sand, trace gravel Stiff						347						
346.7	Brown (FILL)		2	SS	14								
1.6	Silty CLAY, some sand, trace rootlets Stiff						346						
346.0	Grey		3	SS	10								
2.3	Silty CLAY, trace sand Stiff to Very Soft		4	SS	4		345						
	Grey												
			5	SS	5		344						
							343						
			6	SS	0		342						
							341						
			7	SS	0		340						
			8	SS	0		339						

Continued Next Page

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

20  
15  
10  
(%) STRAIN AT FAILURE



METRIC

W.P.	6047-08-00	LOCATION	Beaver Creek Bridge N 5 516 406.0 E 301 338.9	ORIGINATED BY	ES
HWY	594	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.06.24 - 2011.06.24	CHECKED BY	RPR

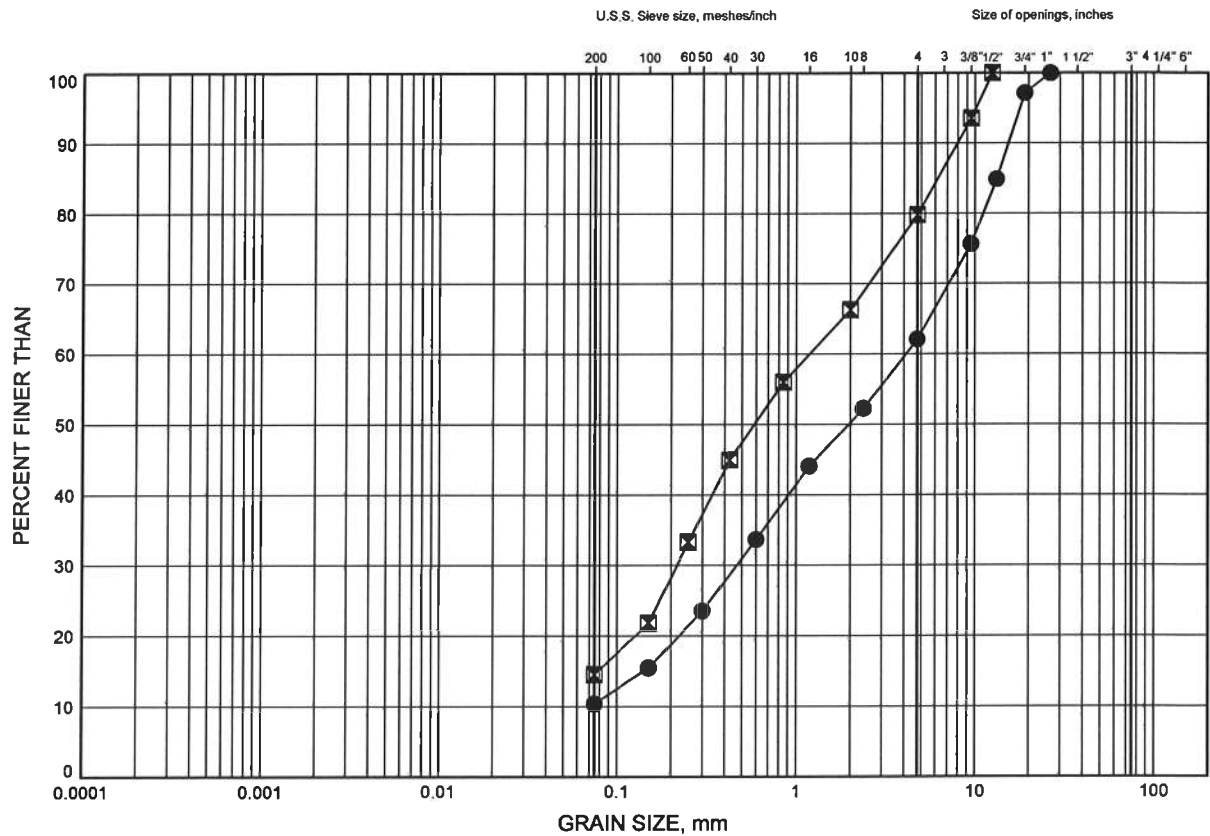
[illegible]

**Appendix B**  
**Laboratory Test Results**

# NWR 32 Rehabs GRAIN SIZE DISTRIBUTION

FIGURE B1

## SAND and GRAVEL FILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCB-2	0.46	347.76
⊠	BCB-4	1.07	347.35

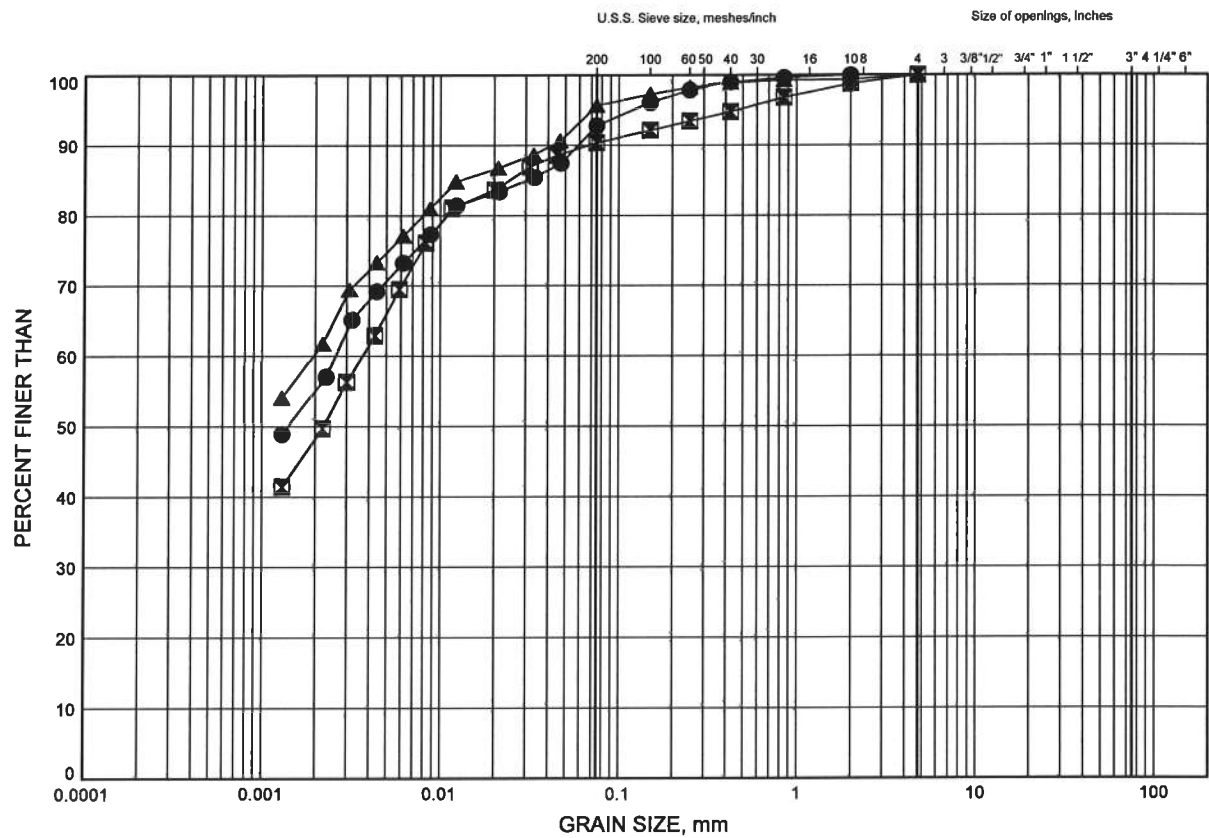


W.P.# 6047-08-00  
Prepared By AN  
Checked By MRA

# NWR 32 Rehas GRAIN SIZE DISTRIBUTION

FIGURE B2

## SILTY CLAY



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCB-1	2.59	345.39
⊠	BCB-2	2.51	345.71
▲	BCB-3	2.59	345.67

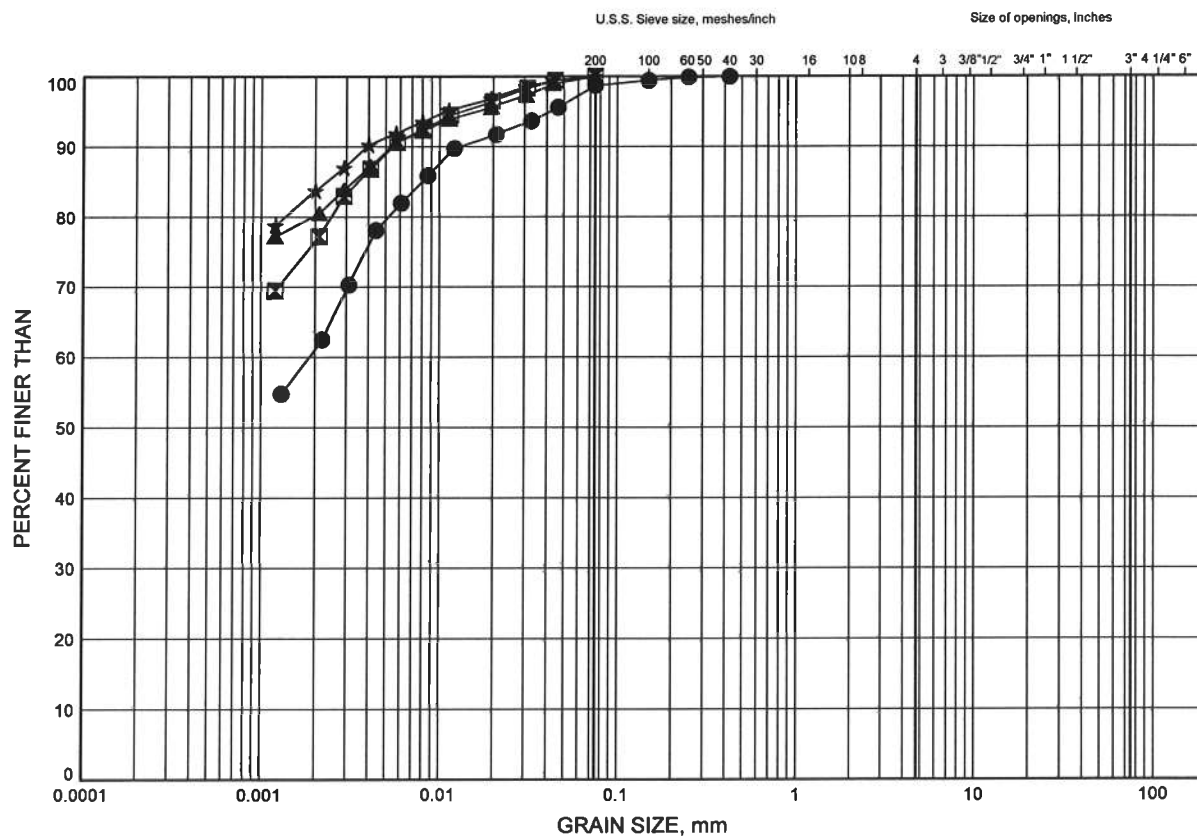


W.P.# 6047-08-00  
Prepared By AN  
Checked By MRA

# NWR 32 Rehas GRAIN SIZE DISTRIBUTION

FIGURE B3

## SILTY CLAY



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

### LEGEND

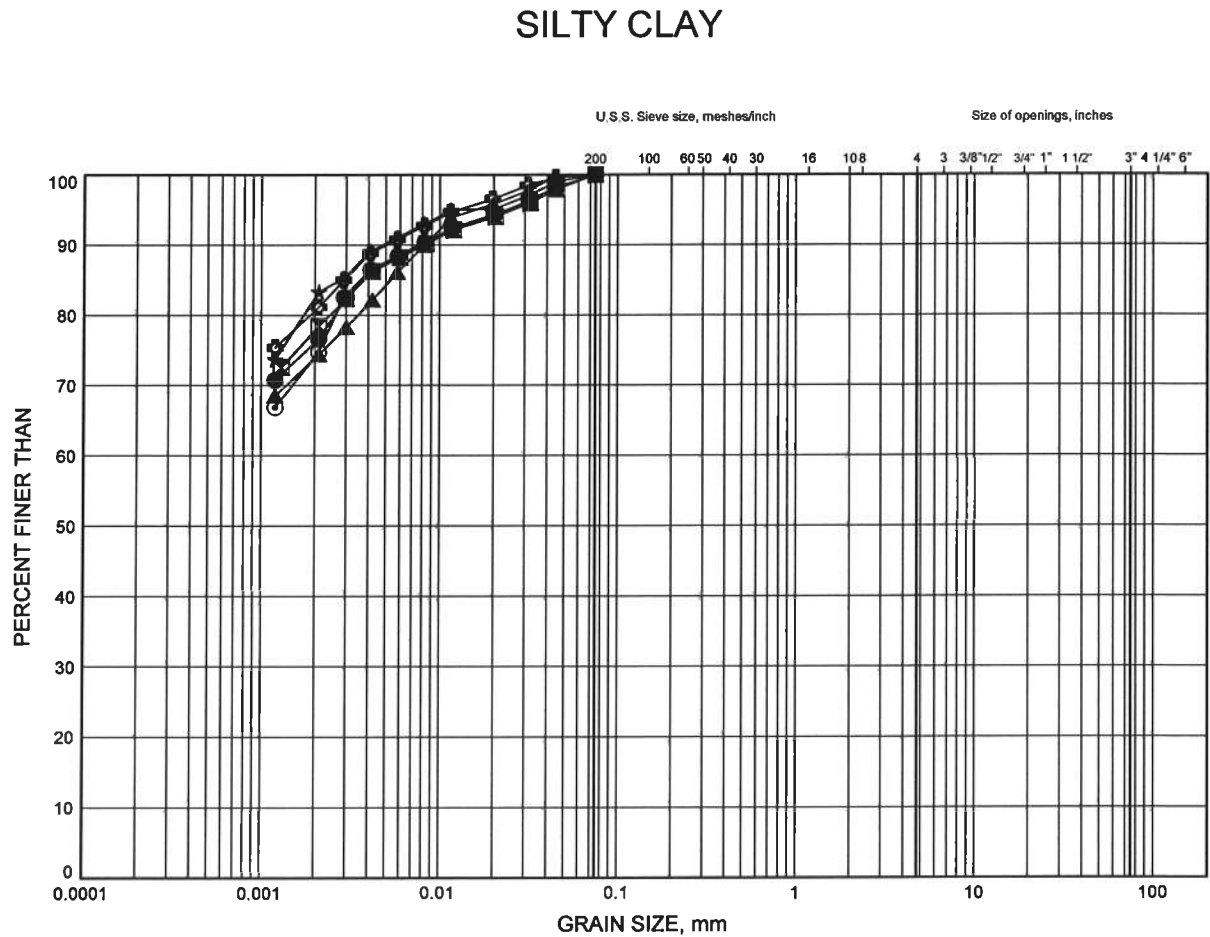
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCB-1	4.88	343.11
⊠	BCB-1	7.92	340.06
▲	BCB-2	6.32	341.90
★	BCB-2	16.99	331.23



W.P.# 6047-08-00  
Prepared By AN  
Checked By MRA

# NWR 32 Rehas GRAIN SIZE DISTRIBUTION

FIGURE B4



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCB-3	12.50	335.76
⊠	BCB-3	15.54	332.71
▲	BCB-3	23.16	325.09
★	BCB-4	6.40	342.02
⊙	BCB-4	14.02	334.40
⊕	BCB-4	18.59	329.82



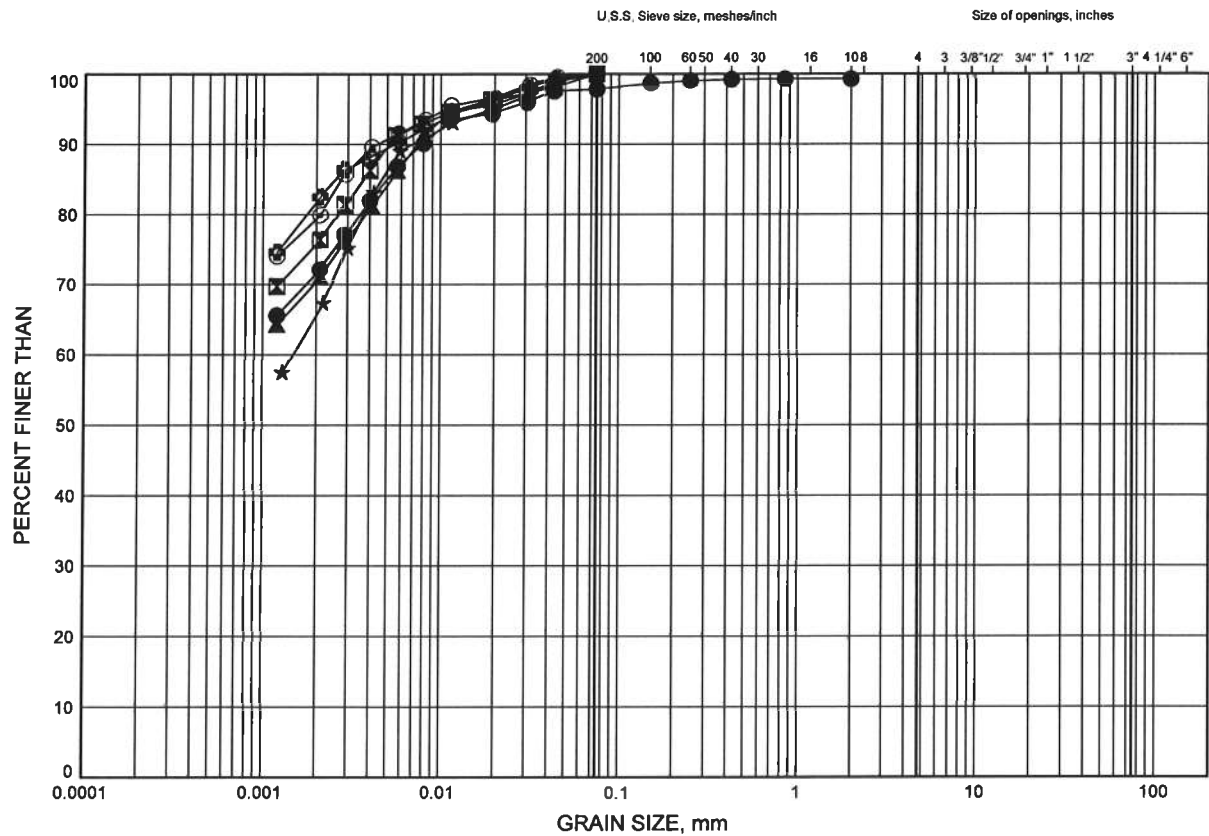
W.P.# 6047-08-00  
Prepared By AN  
Checked By MRA

# NWR 32 Rehas

## GRAIN SIZE DISTRIBUTION

FIGURE B5

### SILTY CLAY



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCB-5	3.28	345.13
⊠	BCB-5	10.97	337.43
▲	BCB-5	20.04	328.36
★	BCB-6	2.59	345.73
⊙	BCB-6	6.40	341.92
⊕	BCB-6	10.97	337.34

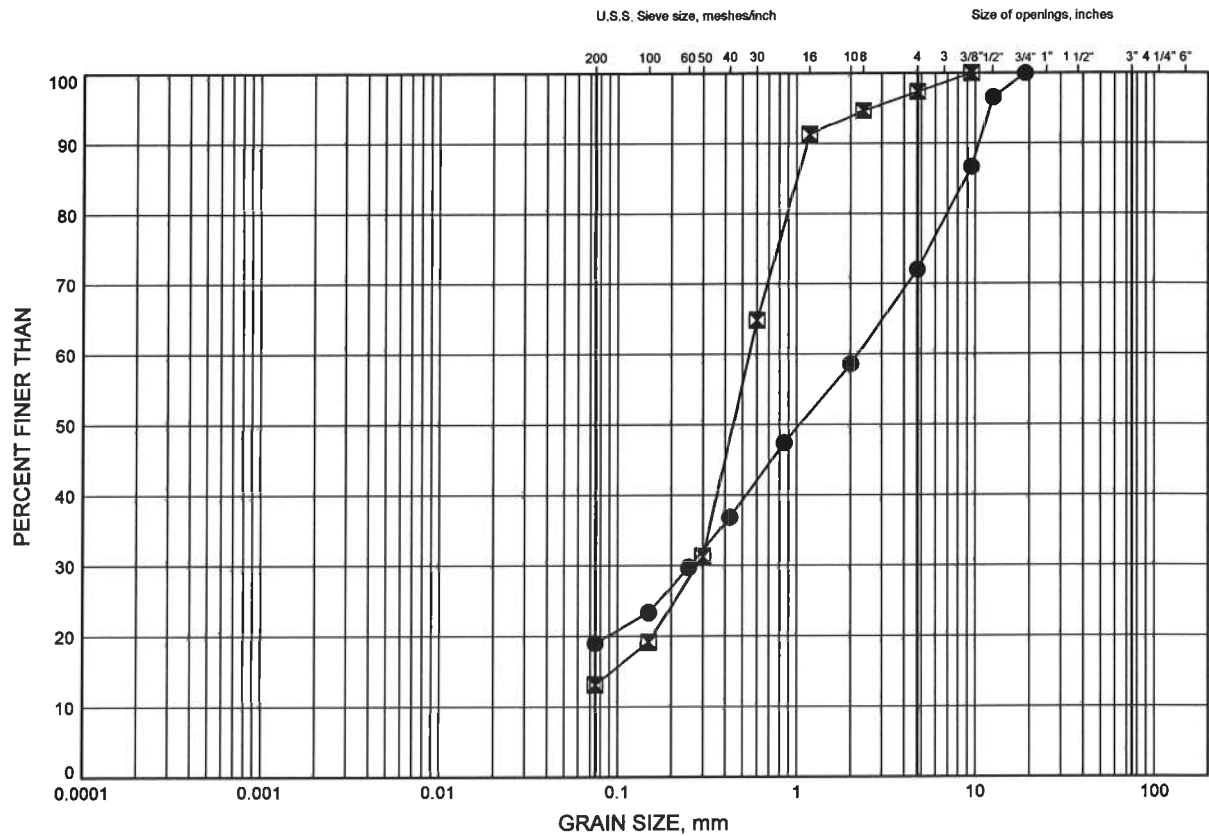


W.P.# 6047-08-00  
 Prepared By AN  
 Checked By MRA

# NWR 32 Rehas GRAIN SIZE DISTRIBUTION

FIGURE B6

## SAND to GRAVELLY SAND



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCB-3	29.26	319.00
⊠	BCB-5	26.75	321.66



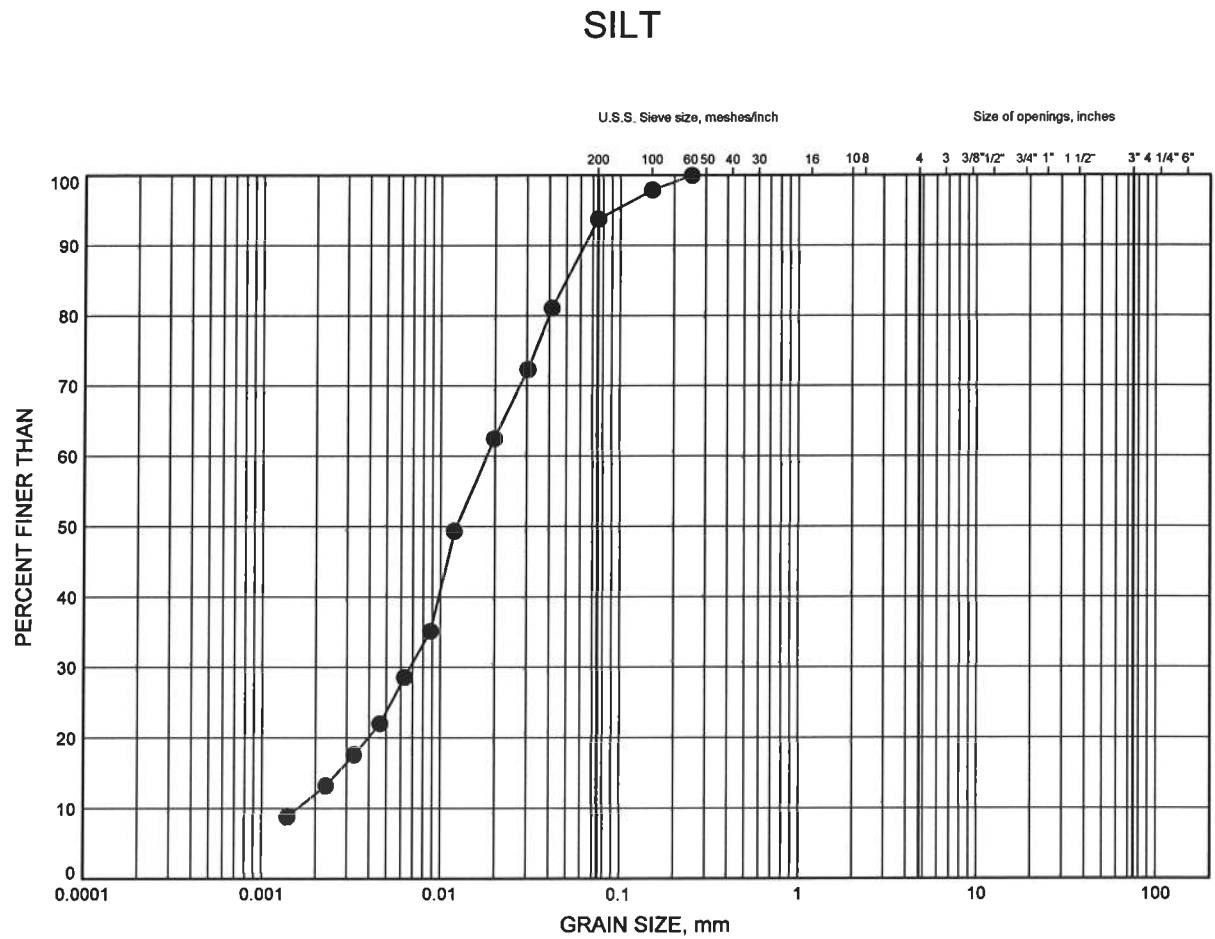
W.P.# 6047-08-00  
Prepared By AN  
Checked By MRA



# NWR 32 Rehas

## GRAIN SIZE DISTRIBUTION

FIGURE B7



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCB-4	26.21	322.20



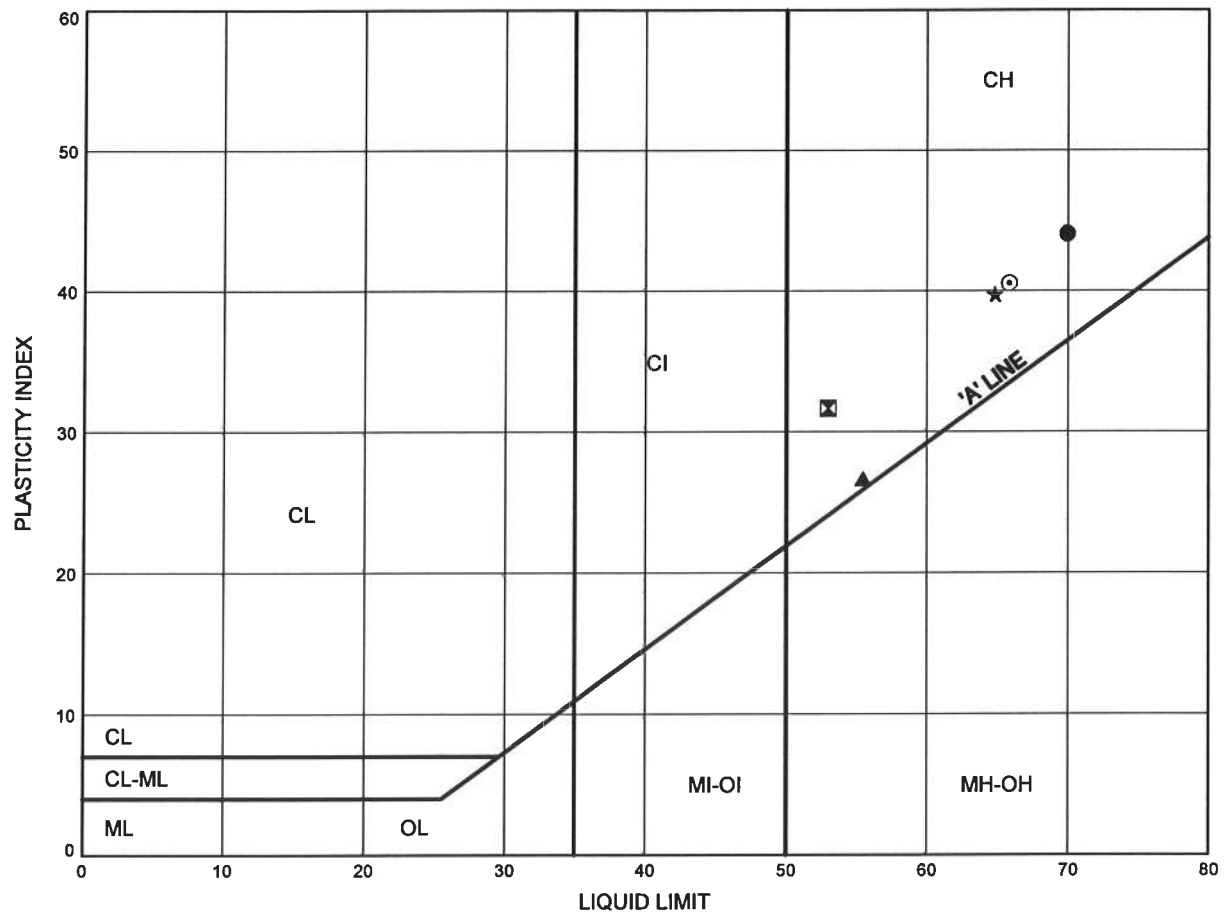
W.P.# 6047-08-00  
 Prepared By AN  
 Checked By MRA

NWR 32 Rehabs

# ATTERBERG LIMITS TEST RESULTS

FIGURE B8

## SILTY CLAY



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BCB-1	4.88	343.11
⊠	BCB-1	7.92	340.06
▲	BCB-2	2.51	345.71
★	BCB-2	6.32	341.90
⊙	BCB-2	16.99	331.23

Date September 2011  
 Project 6047-08-00

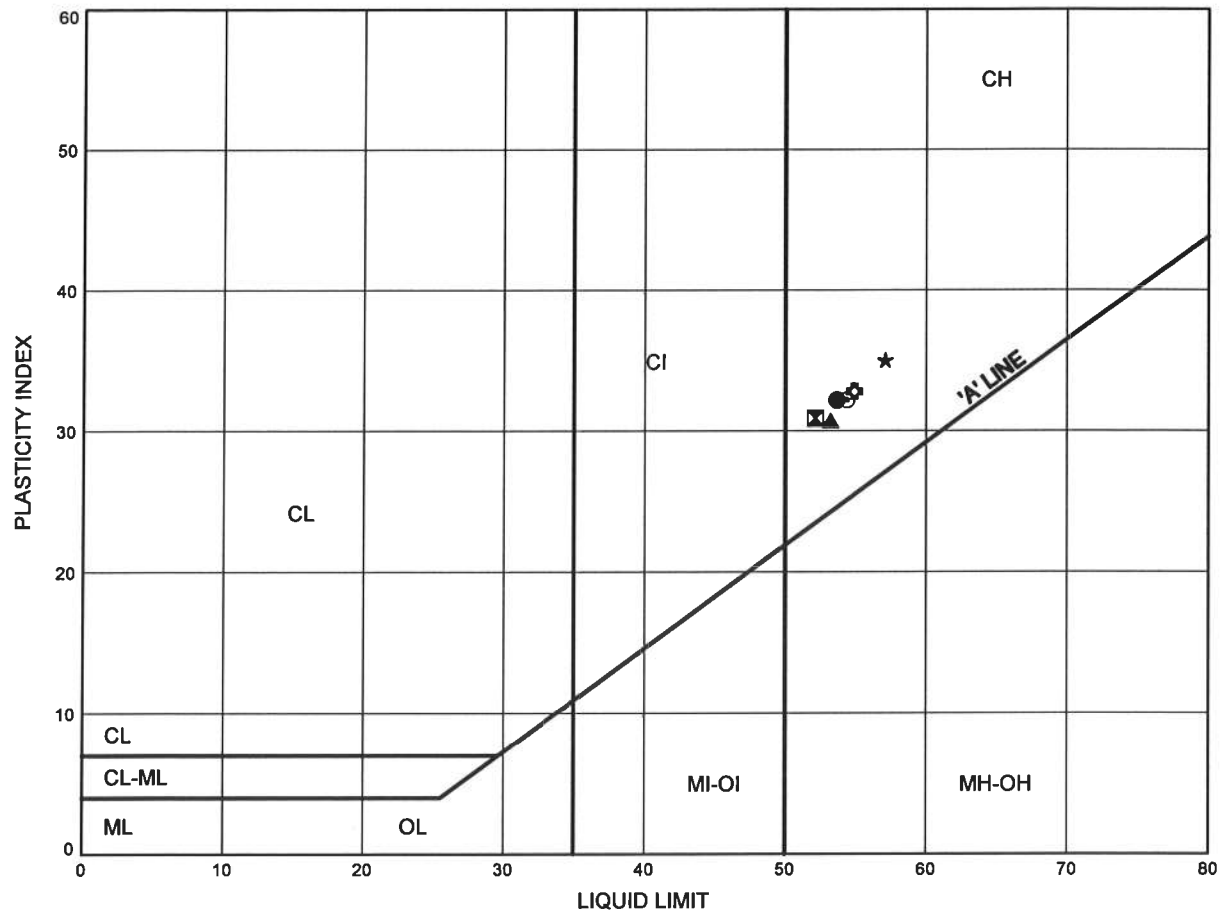


Prep'd AN  
 Chkd. MRA

NWR 32 Rehabs  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B9

**SILTY CLAY**



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BCB-3	12.50	335.76
⊠	BCB-3	15.54	332.71
▲	BCB-3	23.16	325.09
★	BCB-4	6.40	342.02
⊙	BCB-4	14.02	334.40
⊕	BCB-4	18.59	329.82

Date September 2011  
 Project 6047-08-00

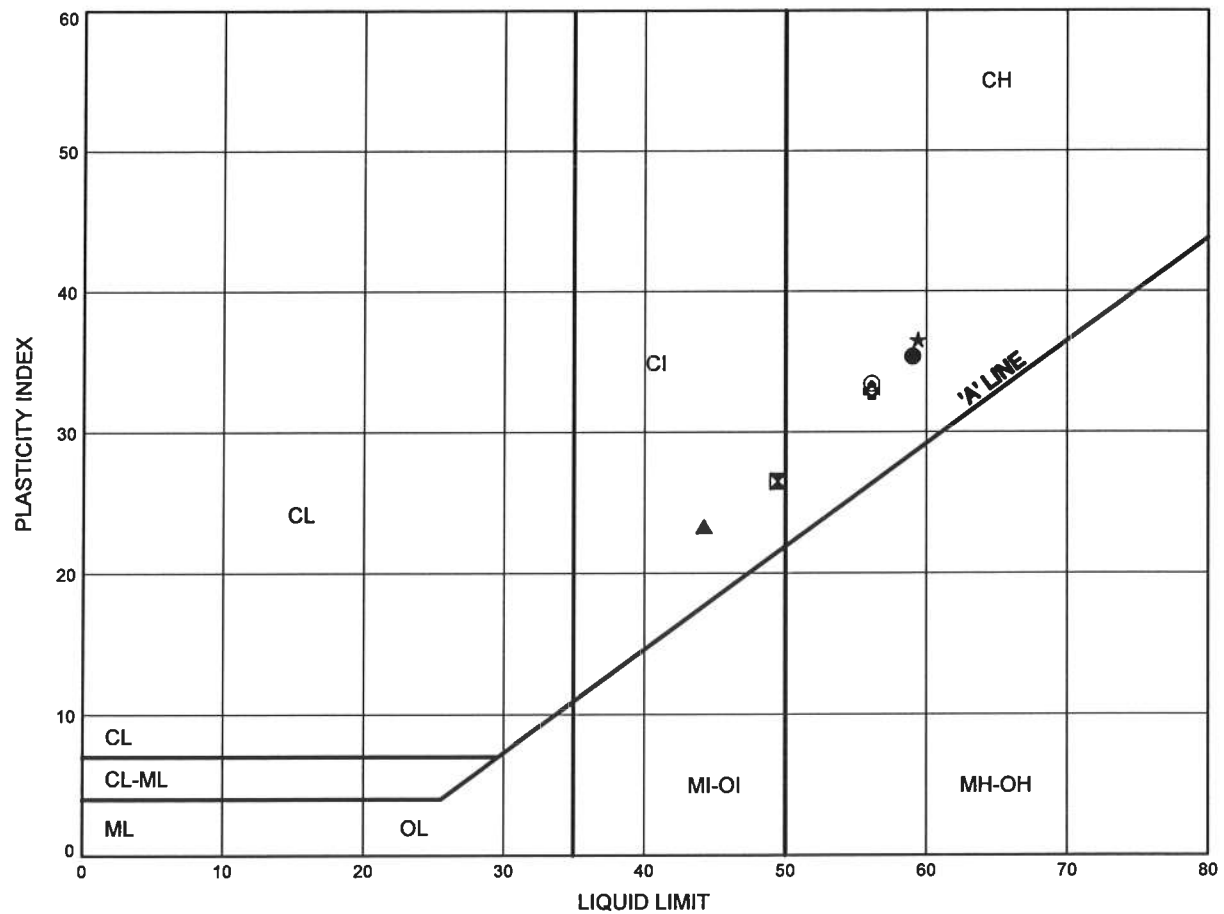


Prep'd AN  
 Chkd. MRA

NWR 32 Rehabs  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B10

**SILTY CLAY**



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BCB-5	3.28	345.13
⊠	BCB-5	10.97	337.43
▲	BCB-5	20.04	328.36
★	BCB-6	2.59	345.73
⊙	BCB-6	6.40	341.92
⊕	BCB-6	10.97	337.34

Date September 2011  
 Project 6047-08-00



Prep'd AN  
 Chkd. MRA

**Appendix C**  
**Photographs and Tables**



Photograph 1: Beaver Creek Bridge looking east.



Photograph 2: South side of Beaver Creek Bridge.

**TABLE C1 - COMPARISON OF FOUNDATION ALTERNATIVES**

Driven H-Piles	Footings on Native Soil	Caissons
<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance is available for piles driven to bedrock.</li> <li>ii. Installation of piles could continue in freezing weather</li> <li>iii. Foundation construction may require less volume of excavation than footings.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher unit costs than footings.</li> <li>ii. Relatively long pile lengths will be required to contact bedrock.</li> <li>iii. Pile lengths required to achieve design resistance may vary.</li> <li>iv. Limiting deviation at pile head for site specific bridge design may require use of driving template and/or modified driving procedure.</li> </ul> <p><b>RECOMMENDED</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> <li>ii. Conventional bridge abutment design is feasible.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>iii. Low available geotechnical resistance in native clay deposit.</li> <li>iv. Excavation to base of existing roadway embankment is required for footing construction.</li> <li>v. Dewatering and stream diversion will be required.</li> <li>vi. Potential disturbance of creek during excavation.</li> </ul> <p><b>NOT RECOMMENDED</b></p>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance is available for caissons extended to bedrock.</li> <li>ii. Construction of caissons could continue in freezing weather.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher cost than spread footings</li> <li>ii. Specialized installation measures such as temporary liners and drilling mud will be required to install caissons in artesian groundwater conditions.</li> <li>iii. Cleaning and inspecting of caisson bases will not be practical.</li> </ul> <p><b>NOT RECOMMENDED</b></p>

## **Appendix D**

### **List of Special Provisions and OPSS References**

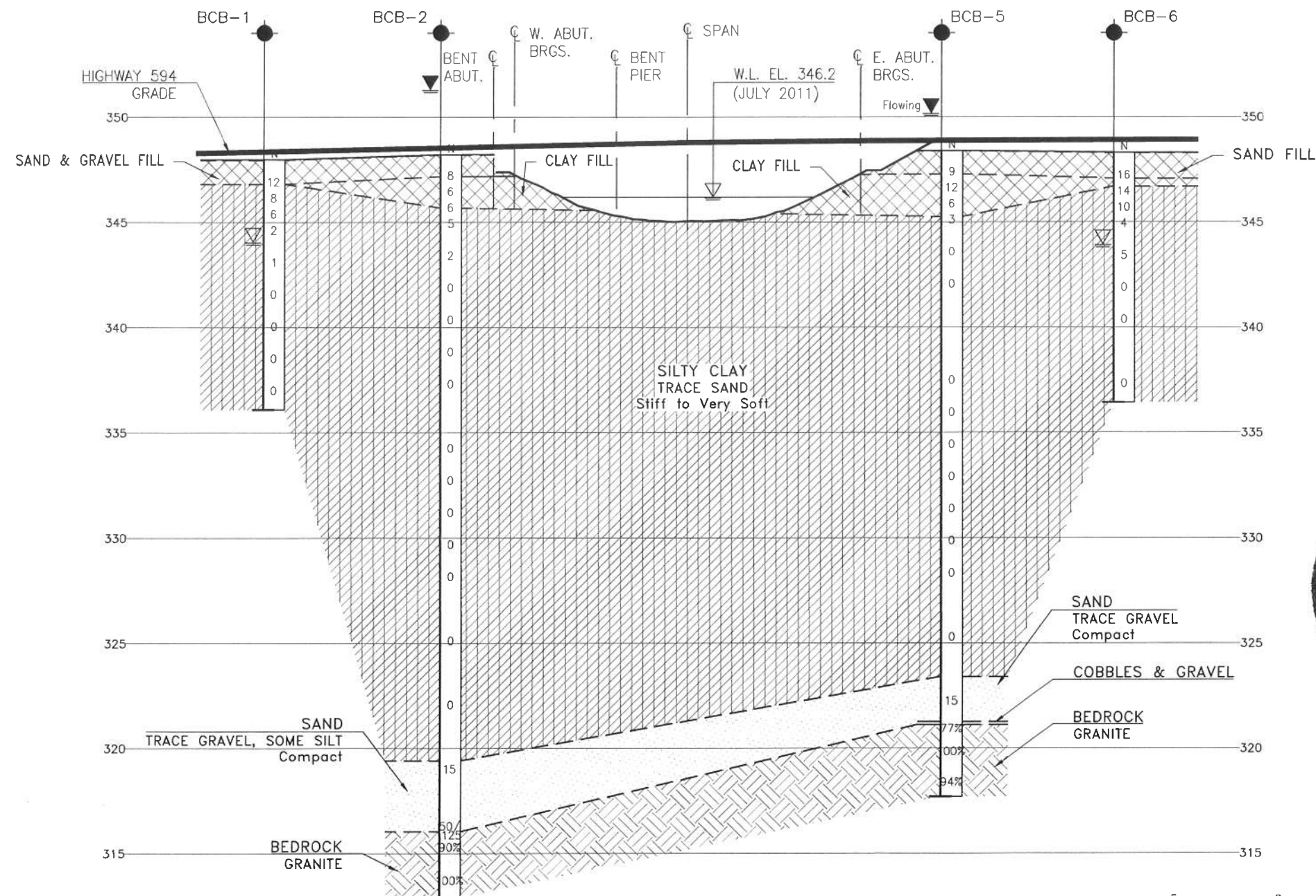
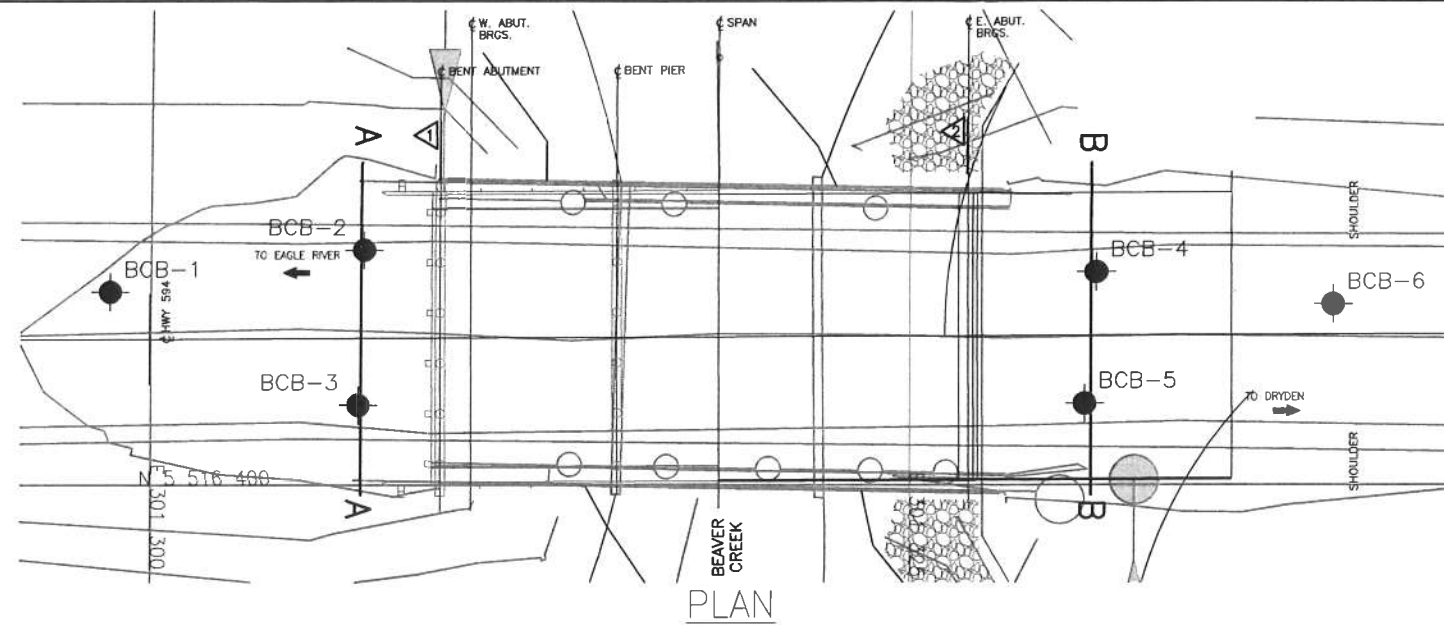


**1. List of Special Provisions and OPSS Documents Referenced in this Report**

- SP 110S13
- OPSS 501
- OPSS 539
- OPSS 804
- OPSS 902
- OPSS 903
- OPSS 1010
- OPSD 3101.150

**Appendix E**

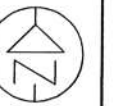
**Drawing titled “Borehole Locations and Soil Strata”**



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

CONT No  
WP No 6047-08-00

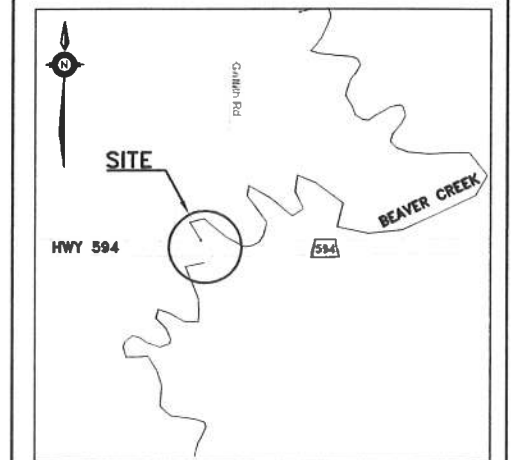
BEAVER CREEK BRIDGE  
REPLACEMENT HWY 594  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET

**MRC** McCORMICK RANKIN  
CORPORATION

**THURBER ENGINEERING LTD.**



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 upon completion
- ▽ Head Artesian Water
- | Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BCB-1	348.0	5 516 406.4	301 298.6
BCB-2	348.2	5 516 407.8	301 307.0
BCB-3	348.3	5 516 402.6	301 306.8
BCB-4	348.4	5 516 407.1	301 331.2
BCB-5	348.4	5 516 402.7	301 330.8
BCB-6	348.3	5 516 406.0	301 338.9

**-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. 52F-35**



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MRA	CHK	MRA
DRAWN	AN	CHK	SITE
LOAD			
STRUCT			
DWG			
DATE	FEB. 2012		



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

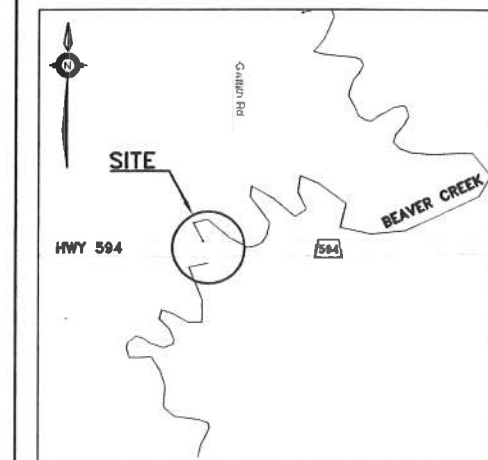
CONT No  
WP No 6047-08-00

BEAVER CREEK BRIDGE  
REPLACEMENT HWY 594  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

MRC McCORMICK RANKIN  
CORPORATION

THURBER ENGINEERING LTD.



### KEYPLAN LEGEND

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

NO	ELEVATION	NORTHING	EASTING
BCB-1	348.0	5 516 406.4	301 298.6
BCB-2	348.2	5 516 407.8	301 307.0
BCB-3	348.3	5 516 402.6	301 306.8
BCB-4	348.4	5 516 407.1	301 331.2
BCB-5	348.4	5 516 402.7	301 330.8
BCB-6	348.3	5 516 406.0	301 338.9

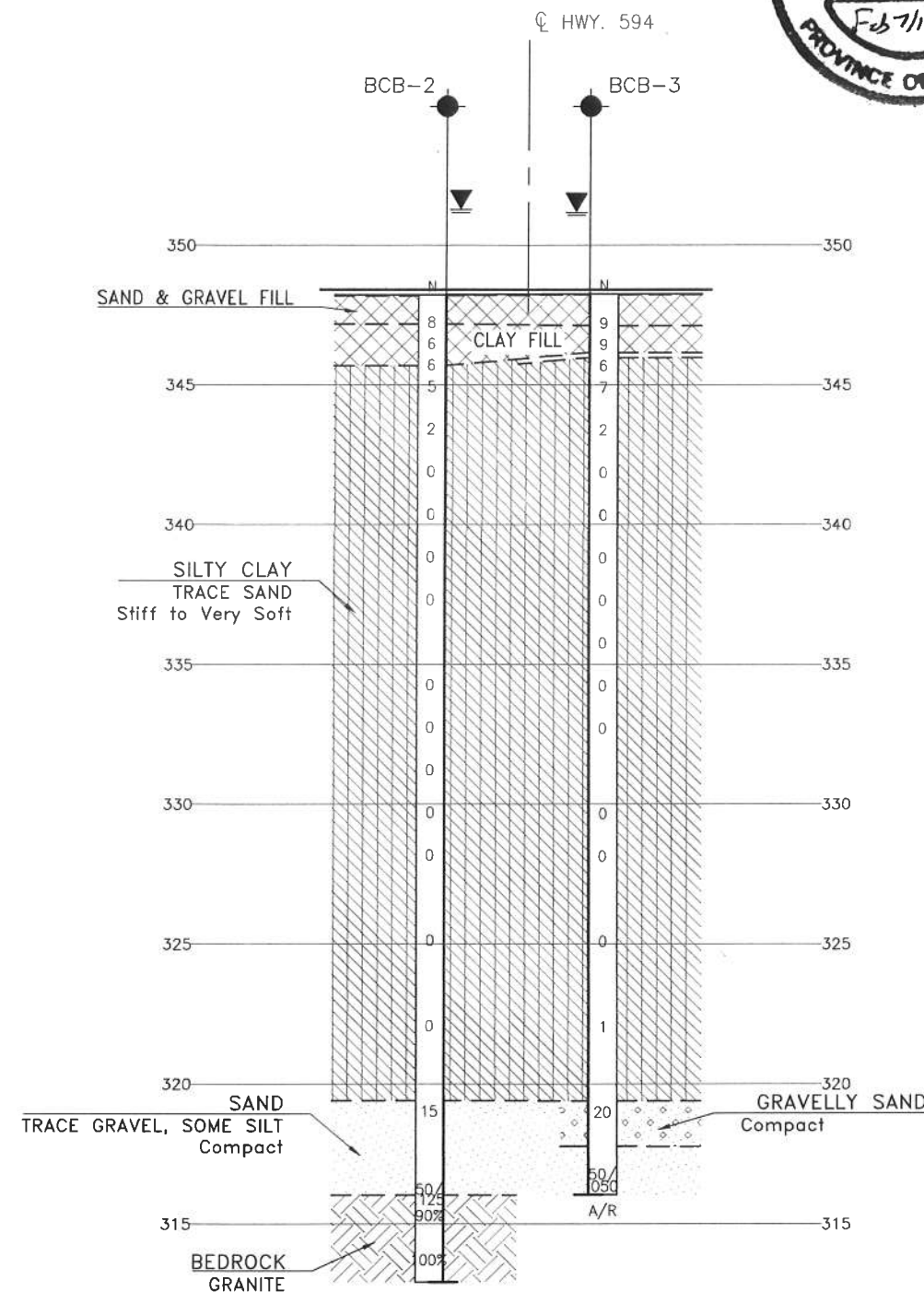
### -NOTES-

- 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.

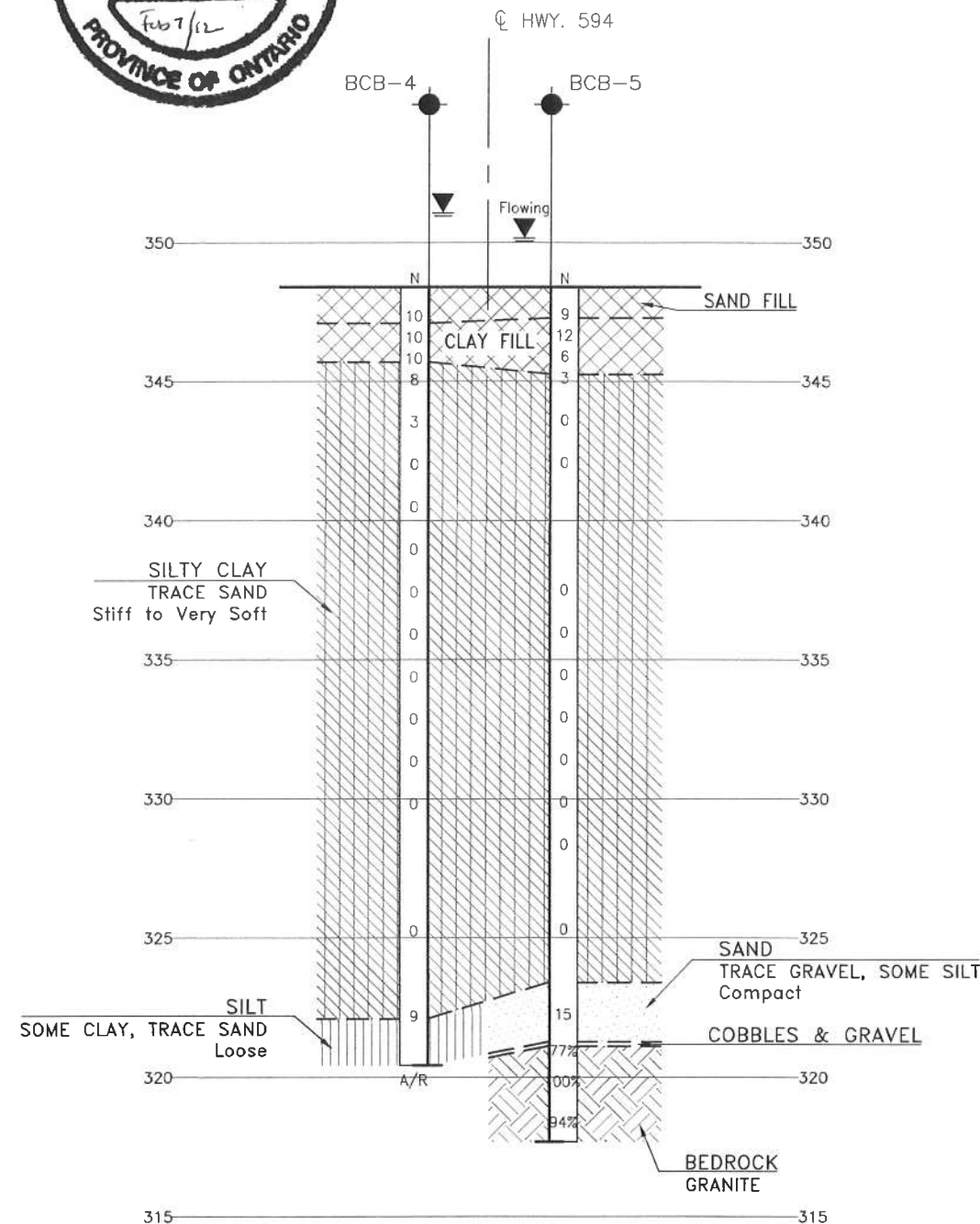
GEOCREs No. 52F-35

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MRA	CHK	MRA
DRAWN	AN	CHK	SITE
LOAD			
DATE	FEB. 2012		
DWG	2		

FILENAME: H:\Drafting\19\1351\197\1ed1197-BeaverCreekRiver(BCB)(Plan&Profile).dwg  
PLOTDATE: 2/7/2012 2:05 PM



SECTION A-A



SECTION B-B

