

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
BLACK CREEK CULVERT  
STATION 13+975 MACHAR TOWNSHIP  
HIGHWAY 11, BURK'S FALLS TO SOUTH RIVER  
G.W.P. 759-93-00**

**Geocres Number: 31E-248**

**Report to**

**Marshall Macklin Monaghan**

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

March 31, 2006

File: 19-1423-12

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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted at the site of a proposed culvert to carry Black Creek under the new four-lane Highway 11 north of the village of South River, Ontario. The culvert will be located at Station 13+975 Machar Township.

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, borehole logs, stratigraphic profile, and a written description of the subsurface conditions. A model of the subsurface conditions was developed to describe the geotechnical conditions influencing design and construction of the foundations and backfill for the structure.

Thurber carried out the investigation as a sub-consultant to Marshall Macklin Monaghan, under the Ministry of Transportation Ontario (MTO) Agreement Number 5005-A-000188.

**2 SITE DESCRIPTION**

The site is located approximately 1.5 km west of existing Highway 11 and approximately 1.0 km north of the Village of South River, in Machar Township. In general, the area is heavily wooded with occasional open meadows.

The general site area is located within the physiographic region known as the Canadian Shield, characterized by Pre-Cambrian bedrock typically occurring as rounded knobs and ridges where exposed. Locally however, the site lies in an area infilled with relatively deep deposits of glacio-fluvial sands and silts, overlying the bedrock. Swamp deposits have developed in poorly drained areas, including adjacent to the Black Creek channel at the site.

**3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for this project were carried out during the period November 25 to December 1, 2005, and consisted of three boreholes drilled along the proposed culvert alignment. One borehole was drilled at each end of the culvert and one borehole was drilled at the

centreline of proposed Highway 11. The approximate locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix C.

The boreholes were drilled to refusal at depths of 10.5 to 13.3 m, and extended an additional 3.1 to 3.3 m by coring to prove bedrock. The boreholes were supplemented by dynamic cone penetration testing (DCPT) adjacent to each location.

Prior to the start of drilling, the borehole locations were staked in the field and utility clearances were obtained. The coordinates and elevations of the boreholes are given on the Borehole Locations and Soil Strata Drawing in Appendix C and on the individual Record of Borehole Sheets in Appendix A.

Hollow stem augers supplemented by drilling mud and NW casing were used to advance the boreholes to bedrock. Samples were obtained using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Bedrock cores were recovered using NQ coring equipment.

A member of Thurber's engineering staff supervised the drilling and sampling operations on a full time basis. The inspector logged the boreholes, secured the recovered samples in labelled containers, and transported the samples to Thurber's laboratory.

#### **4 LABORATORY TESTING**

All recovered soil samples were subjected to visual identification and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A.

Selected samples were subjected to gradation analysis (sieve and hydrometer) and the results are shown on the Record of Borehole sheets in Appendix A and on the charts in Appendix B. A total of seven samples were selected for this testing.

The rock core descriptions were confirmed in the laboratory and Point Load Tests were conducted to assess the compressive strength of the rock.

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

##### **5.1 General**

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, Appendix C, for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the borehole logs governs any interpretation of the site conditions.

The soil stratigraphy encountered at this site consists of a topsoil layer or peat deposit overlying cohesionless silts and fine sands, underlain by bedrock. More detailed descriptions of the individual strata are presented below.

## **5.2 Topsoil**

A 50 mm thick topsoil layer was identified in borehole BC-1 drilled at the west end of the proposed culvert. The topsoil thickness was established only at the borehole location and may vary between and beyond the borehole locations. The data is not intended for the purpose of estimating quantities.

## **5.3 Peat**

A deposit of sandy fibrous peat was encountered in boreholes BC-2 and BC-3 drilled at the centre and east end of the proposed culvert. The peat extended to depths of 2.7 and 3.0 m (elevation 328.4 and 328.6 m). SPT N-values of 2 to 5 were obtained in the peat, indicating a loose to very loose condition. Moisture contents of 53 to 90% were determined in this material.

## **5.4 Silt, Sandy Silt, Silty Sand and Sand**

The site is underlain by cohesionless soils grading from silt to fine to medium-grained sand. The results of grain size distribution analyses conducted on the soils are presented in Appendix B. These deposits extend to bedrock encountered at depths of 10.5 to 13.3 m (elevation 318.4 to 320.7 m). At the east end of the culvert (BC-3), a boulder and cobble layer was encountered in the sand between 9.0 and 10.0 m depth, requiring coring to penetrate.

SPT N-values obtained in the silt/sand typically ranged from 11 to 29 blows/0.3 m penetration, indicating a generally compact condition. In the upper 4.6 m of borehole BC-1 at the west end of the culvert and at two isolated occasions in the other boreholes, a loose condition was indicated by N-values of 5 to 10 blows/0.3 m. In addition, a dense condition was indicated by N-values of 32 and 37 on two occasions. DCPT testing was generally consistent with these findings. Moisture contents ranged from 13 to 26%.

## **5.5 Bedrock**

The soils described above were found to be underlain by bedrock of the Pre-Cambrian Canadian Shield. The bedrock was proved by coring 3.1 to 3.3 m at each borehole location. The rock is described as fresh to slightly weathered, pink gneiss with black banding and occasional vertical to subvertical joints. The Fracture Index was generally 0 to 2, with values of 3 to 5 in the upper 0.9 m at the east end of the culvert.

The core recovery was 100% in each core run. With the exception of the initial run in borehole BC-3, RQD values ranged from 96 to 100%, indicating an excellent quality rock. A lower RQD value of 55% was obtained in the initial 1.5 m of core from borehole BC-3 at the east end of the culvert, indicating a fair quality rock.

Based on Point Load Testing, the unconfined compressive strength of the bedrock at the north abutment was estimated to range from 161 to 209 MPa. Based on these strength

values and the classification system given in the Canadian Foundation Engineering Manual, the rock was classified as very strong.

## 5.6 Water Levels

The site is located in a poorly drained marshy area adjacent to the Black Creek. Water was observed at depths of 0.8 and 0.6 m (elevation 330.6 and 331.1 m) in the boreholes drilled at the west and east ends of the proposed culvert.

In borehole BC-2 drilled near the centreline of the proposed highway, an artesian condition was encountered in the underlying bedrock, with the water level rising to 1.2 m (elevation 332.4 m) above the ground surface at the borehole. The borehole was sealed and grouted to plug the artesian flow.

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.

## 6 MISCELLANEOUS

Marshall Macklin Monaghan completed field layout for the site investigation and provided borehole coordinates and ground surface elevations.

All-Terrain Drilling Limited supplied and operated the drilling and sampling equipment used for the investigation. Full time supervision of the field activities, including obtaining utility clearances, was carried out by Mr. George Azzopardi of Thurber.

Interpretation of the field data and preparation of the investigation report was completed by Mr. Murray Anderson, P.Eng. Overall supervision of the field program and review of the report was performed by Mr. Alastair E. Gorman, P.Eng. The report was also reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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



Alastair E. Gorman, P.Eng., M.Sc.  
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 selection and design of the proposed culvert foundation.

The proposed Black Creek crossing will be constructed at approximate Station 13+975, Township of Machar, under the new twinned Highway 11 west and south of Eagle Lake Road. A box culvert, approximately 98 m long, 5.0 m wide and 4.0 m high, is proposed. The base of the culvert will be placed near elevation 329.2 to 329.5 m. The maximum embankment height at the culvert location will be approximately 5.5 m above existing grade, and 3 m above the top of the culvert.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigation.

## **8 STRUCTURE FOUNDATIONS**

The subsurface stratigraphy revealed in the boreholes drilled at the culvert location consists of a topsoil layer or peat deposit overlying cohesionless silts and fine sands, underlain by bedrock at depths of 10.5 to 13.3 m. The peat thickness was 2.7 and 3.0 m at the centre and east end of the culvert, respectively. The silts/sands are typically compact with occasional loose and dense zones. The site is located in a swampy area with a high water table.

The proposed culvert base level ranges from elevation 329.2 to 329.5 m at the west and east ends, respectively. These elevations are approximately 2.2 m below the existing ground surface at the borehole locations. The soil at this level consists of loose to compact sand at the west end of the proposed culvert, peat over loose to compact sand near the centre, and peat over compact silt at the east end. It is recommended that all peat and loose sand be subexcavated and replaced with engineered fill to support the culvert.

Considering the relatively low and variable bearing resistance available on the native soils at the site, it is recommended that a closed box culvert be employed to reduce the bearing pressure applied to the foundation soils and minimize the potential effects of any differential settlement.



Further, design of spread footings based on the resistance values recommended below is likely to result in an impractical footing width if an open footing culvert is used. Use of a precast concrete culvert may be preferred over a cast-in-place culvert since installation is likely to be more expedient, reducing the duration of dewatering operations required during construction.

The engineered fill pad placed under the culvert should be at least 1.5 m thick below the culvert base. For the proposed culvert base levels, the underside of the fill will be at or below elevation 327.7 and 328.0 m at the west and east ends, respectively. The engineered fill must consist of OPSS Granular A placed in 150 mm lifts and compacted to 100% of its SPMDD at  $\pm 2\%$  of optimum moisture content. The fill should extend laterally at least 1.5 m beyond the edges of the culvert.

For a 5 m wide culvert bearing on an engineered fill pad as outlined above, a concentric, vertical geotechnical resistance of 550 kPa at factored ULS and a resistance of 150 kPa at SLS may be employed for design.

Settlement of the culvert is expected to be controlled primarily by the settlement of the subgrade under the embankment loading. Embankment heights of approximately 5.5 m are planned. The estimated settlement along the culvert resulting from the embankment loading is provided in Table 8.1:

**Table 8.1 – Estimated Settlement at Culvert**

Highway 11	Estimated Foundation Settlement (mm)		
	Embankment Centreline	Shoulder Rounding	Embankment Toe
Northbound Lanes	50	45	15
Southbound Lanes	50	45	15

The predicted settlements are considered to be immediate in nature and should be essentially completed by the end of construction. The culvert design should include appropriate cambering and articulated joints, if necessary, to accommodate the differential settlement along the culvert. The culvert settlement could be reduced by constructing the embankment fill in advance of culvert installation, then excavating as necessary to construct the culvert. A delay of four weeks between the initial fill construction and excavation for culvert installation is considered adequate.

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

A frost penetration depth of 1.9 m should be used during foundation and backfill design to provide protection against frost action on the culvert foundations.

## 9 CULVERT BEDDING, BACKFILL AND LATERAL EARTH PRESSURES

All topsoil, peat and excessively loose material should be stripped/subexcavated from the culvert subgrade prior to placement of the engineered fill/bedding material. As indicated previously, subexcavation for fill construction will extend to elevation 327.7 and 328.0 m at the west and east ends of the culvert, respectively.

Culvert bedding and backfill should be placed to the extents shown in OPSD 803.010. The backfill should consist of free-draining granular material conforming to OPS Granular A or B 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.

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

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

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

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

$\gamma$  = bulk unit weight of retained soil (see table below)

$h$  = depth below top of fill where pressure is computed (m)

$q$  = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert are dependent on the material used as backfill. Recommended unfactored values are shown in Table 9.1. The at-rest coefficients should be employed for closed box culvert walls. Active pressures shall be used for any wingwalls or unrestrained walls.

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

Condition	Earth Pressure Coefficient (K)			
	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 (Unrestrained Wall)	0.27	0.40*	0.31	0.43*
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

\* For wing walls, if employed.

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

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II.

The design of the culvert must incorporate measures such as weepholes 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 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 1
- Zonal Velocity Ratio 0.05
- Acceleration Related Seismic Zone 1
- Zonal Acceleration Ratio 0.05
- Peak Horizontal Acceleration 0.08

The Soil Profile Type at this site has been classified as Type I. Thus, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient “S” of 1.0 should be used in seismic design.

The seismic earth pressure coefficients for active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) conditions to be used in design at this site are shown in Table 10.1. In accordance with Clause 4.6.4 of the CHBDC, structures should be designed using earth pressure coefficients that incorporate the effects of earthquake loading.

**Table 10.1 – Earth Pressure Coefficients (K) for Seismic Design**

Condition	Earth Pressure Coefficient (K) for Earthquake Loading					
	OPSS Granular A or OPSS Granular B Type II  $\phi = 35^\circ, \delta = 17^\circ$		OPSS Granular B Type I  $\phi = 32^\circ, \delta = 16^\circ$		Rock Fill (Limited to 300 mm size)  $\phi = 42^\circ, \delta = 21^\circ$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active*, $K_{AE}$ (Unrestrained Wall)	0.30	0.45	0.33	0.54	0.23	0.31
At rest**, $K_{OE}$ (Restrained Wall)	0.59	-	0.63	-	0.43	-
Passive*, $K_{PE}$ (Movement Towards Soil Mass)	6.3	-	5.4	-	12.0	-

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

\*\* After Woods

In Table 10.1, the angle of friction between the wall and the backfill,  $\delta$ , is taken as 50% of the angle of internal friction of the backfill,  $\phi$ .

The potential for liquefaction of the foundation soils has been assessed using the Seed and Idriss (1971) method<sup>1</sup>. Using this method, it was determined that the foundation soils at the abutments are not in danger of liquefaction under earthquake loading.

## 11 EROSION CONTROL

Erosion protection should be provided at the culvert inlet and outlet areas as applicable. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rip-rap should be provided over all surfaces with which creek water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in accordance with OPSS 572.

<sup>1</sup> Seed, H.B. and Idriss, I.M. 1971, "Simplified Procedure for Evaluating Soil Liquefaction Potential" *Journal of Soil Mechanics and Foundations Division, ASCE*, Vol. 101, No. SM9, pp. 1249 – 1273.

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

## **12 EXCAVATION AND GROUNDWATER CONTROL**

Excavation for culvert installation will penetrate up to 3.6 m below the groundwater levels observed in the boreholes. Excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause boiling and sloughing of the soil below the water table making it difficult to maintain a dry, sound base on which to work.

Accordingly, dewatering in advance of excavation is recommended. Prior to excavation below the natural groundwater level, the groundwater must be depressed to a level below the deepest excavation level sufficient to maintain a stable base and prevent soil disturbance by construction.

Temporary stream diversion measures such as impervious dykes should be provided to divert surface water runoff and stream flow away from the culvert excavation at all times during construction.

The Contract Documents should contain a NSSP alerting the bidders that the near surface soils at the site are subject to boiling and sloughing under conditions of unbalanced hydrostatic head, and effective dewatering is recommended prior to excavating below the groundwater level. Suggested wording for the NSSP is provided in Appendix D.

The design of the dewatering system that may be required is the responsibility of the Contractor, and the Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist. While the responsibility for dewatering remains with the Contractor, suitable systems that might be employed include pumping from filtered sumps for penetration of no more than 0.5 m below the groundwater level and the use of vacuum wellpoints for deeper penetration below the groundwater level.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the soils at this site may be classed as Type 3 soils above the water table, and Type 4 below the water table. This classification is based on the lack of cohesion in the soils and the resulting possibility that excavation slopes will slough if excavated vertically for the lower 1.2 m. Excavation slopes should not exceed 1V:1H above the groundwater level.

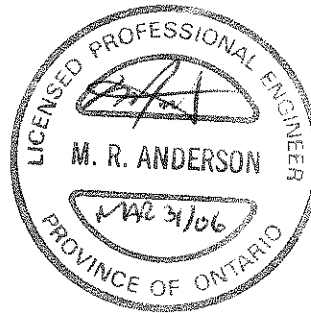
### 13 CONSTRUCTION CONCERNS

- The site is located in a swampy area with a high water table. Excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause boiling and sloughing of the soil below the water table. Prior to excavation, the groundwater must be depressed to a level below the deepest excavation level to maintain a stable base and prevent soil disturbance.
- Care must be exercised during excavation to avoid disturbing the founding subgrade. The exposed subgrade should be protected from physical disturbance and the granular pad placed on the approved subgrade expeditiously following excavation.

### 14 CLOSURE

Engineering analysis and preparation of the foundation design report was conducted by Mr. Murray Anderson, P.Eng. The report was reviewed by Mr. Alastair E. Gorman, P.Eng. The report was also reviewed by Dr. P.K. Chatterji, Ph.D., a Designated Principal Contact for MTO Foundations Projects.

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



Alastair E. Gorman, P.Eng., M.Sc.  
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  
 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			

# RECORD OF BOREHOLE No BC-1

1 OF 2

METRIC

W.P. 759-93-00 LOCATION N 5 078 811.2 E 312 948.8 Black Creek Culvert ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY WM  
 DATUM Geodetic DATE 25.11.05 - 25.11.05 CHECKED BY MRA

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 (%)		
331.4																	
0.9	TOPSOIL (50 mm)		1	SS	7												
	SAND, fine to medium grained, trace silt, occasional oxide staining Loose to Compact Brown Wet		2	SS	15												
			3	SS	8												
			4	SS	12									0 94 6 (SI+CL)			
			5	SS	10												
326.8																	
4.6	SILT, trace sand, trace clay Compact Brown Wet		6	SS	23									0 5 86 8			
325.3																	
6.1	SAND, fine to medium grained, trace silt Compact Brown Wet		7	SS	16												
323.7																	
7.6	Sandy SILT, trace clay Compact Brown Wet		8	SS	25									0 22 75 3			
322.2																	
9.1	SAND, fine to medium grained, trace silt, trace gravel Compact Brown Wet		9	SS	22												

Continued Next Page

+<sup>3</sup> ×<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			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)
								UNCONFINED	FIELD VANE	QUICK TRIAXIAL			
318.6	Becoming Very Dense		10	SS	15							1 90 9 (SI+CL)	
12.8	<b>GNEISS BEDROCK</b> Fresh to slightly weathered, thinly bedded, pink, with black banding, very strong		11	SS	50/.100							RUN 1# TCR=100%, SCR=100%, RQD=96%, UCS=209MPa	
			1	RUN								RUN 2# TCR=100%, SCR=100%, RQD=100%, UCS=176MPa	
			2	RUN								RUN 3# TCR=100%, SCR=100%, RQD=100%, UCS=187MPa	
315.3	END OF BOREHOLE AT 16.10 m. BOREHOLE OPEN TO BOTTOM AND WATER LEVEL AT 0.76 m UPON COMPLETION. BOREHOLE GROUTED WITH BENTONITE TO SURFACE.		3	RUN									

# RECORD OF BOREHOLE No BC-2

1 OF 2

METRIC

W.P. 759-93-00 LOCATION N 5 078 769.7 E 312 968.4 Black Creek Culvert ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY WM  
 DATUM Geodetic DATE 01.12.05 - 01.12.05 CHECKED BY MRA

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		
331.2 0.0	Sandy PEAT, some silt, fibrous, occasional rootlets and wood fibers Very Loose to Loose Black Wet		1	SS	2		331					
			2	SS	4		330					
			3	SS	5		329					
328.4			4	SS	5		328					
2.7	SAND, fine grained, trace silt Loose to Dense Brown Wet		5	SS	5		327					
			6	SS	25		326					
			7	SS	29		325					
			8	SS	32		324					
322.7							323					
8.5	Silty SAND, trace gravel Compact Brown Wet		9	SS	25		322					

Continued Next Page

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BC-2

2 OF 2

METRIC

W.P. 759-93-00 LOCATION N 5 078 769.7 E 312 968.4 Black Creek Culvert ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY WM  
 DATUM Geodetic DATE 01.12.05 - 01.12.05 CHECKED BY MRA

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	60	80	100					
320.7							321										
10.5	<b>GNEISS BEDROCK</b> Fresh to slightly weathered, thinly bedded, pink, with black banding, very strong subvertical joints from 12.1 m to 12.3 m, green staining at subvertical joint, artesian pressure observed during drilling		SS	100/	.100		320										
			1	RUN			319										
			2	RUN			318										
317.5																	
13.7	END OF BOREHOLE AT 13.72 m. BOREHOLE OPEN TO BOTTOM UPON COMPLETION. WATER LEVEL AT 1.2 m ABOVE GROUND DUE TO ARTESIAN PRESSURE BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 10.4 m TO SEAL ARTESIAN PRESSURE. BOREHOLE GROUTED WITH BENTONITE FROM 10.4 m TO SURFACE.																

ONTMT4S 414.GPJ 01/03/06

# RECORD OF BOREHOLE No BC-3

1 OF 2

METRIC

W.P. 759-93-00 LOCATION N 5 078 721.7 E 312 988.3 Black Creek Culvert ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY WM  
 DATUM Geodetic DATE 30.11.05 - 30.11.05 CHECKED BY MRA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>			WATER CONTENT (%)
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60 80 100	20 40 60	20 40 60	20 40 60			
331.7															
0.0	Sandy PEAT, some silt, fibrous, occasional rootlets and wood fibers Very Loose to Loose Black		1	SS	2										
			2	SS	3										
			3	SS	4										
			4	SS	2										
328.6															
3.0	SILT, trace sand, trace clay Compact Grey Wet		5	SS	11									0 3 88 9	
			6	SS	12										
325.6															
6.1	SAND, fine grained, trace silt Loose to Compact Grey Wet		7	SS	5										
			8	SS	19										
322.7															
9.0	BOULDER														
321.7															

Continued Next Page

+ 3, x 3. Numbers refer to 20  
Sensitivity 15 5  
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BC-3

2 OF 2

METRIC

W.P. 759-93-00 LOCATION N 5 078 721.7 E 312 988.3 Black Creek Culvert ORIGINATED BY GA  
HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY WM  
DATUM Geodetic DATE 30.11.05 - 30.11.05 CHECKED BY MRA

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		
321.6 10.0	COBBLES													
10.1	SAND, fine to medium grained, some silt, trace gravel Dense to Compact Brown Wet		9	SS	37		321							0 78 22 (SI+CL)
							320							
			10	SS	25		319							
318.4														
13.3	GNEISS BEDROCK Fresh to slightly weathered, thinly bedded, pink, with black banding, very strong, vertical joint at 13.6 m to 13.8 m subvertical joint at 13.8 m to 13.9 m		1	RUN			318							RUN 1# TCR=100%, SCR=77%, RQD=55%, UCS=161MPa
							317							
			2	RUN			316							RUN 2# TCR=100%, SCR=100%, RQD=100%, UCS=180MPa
315.3														
16.4	END OF BOREHOLE AT 16.41m. BOREHOLE OPEN TO BOTTOM UPON COMPLETION AND WATER LEVEL AT 0.6 m. BOREHOLE GROUTED WITH BENTONITE TO SURFACE.													

## **Appendix B**

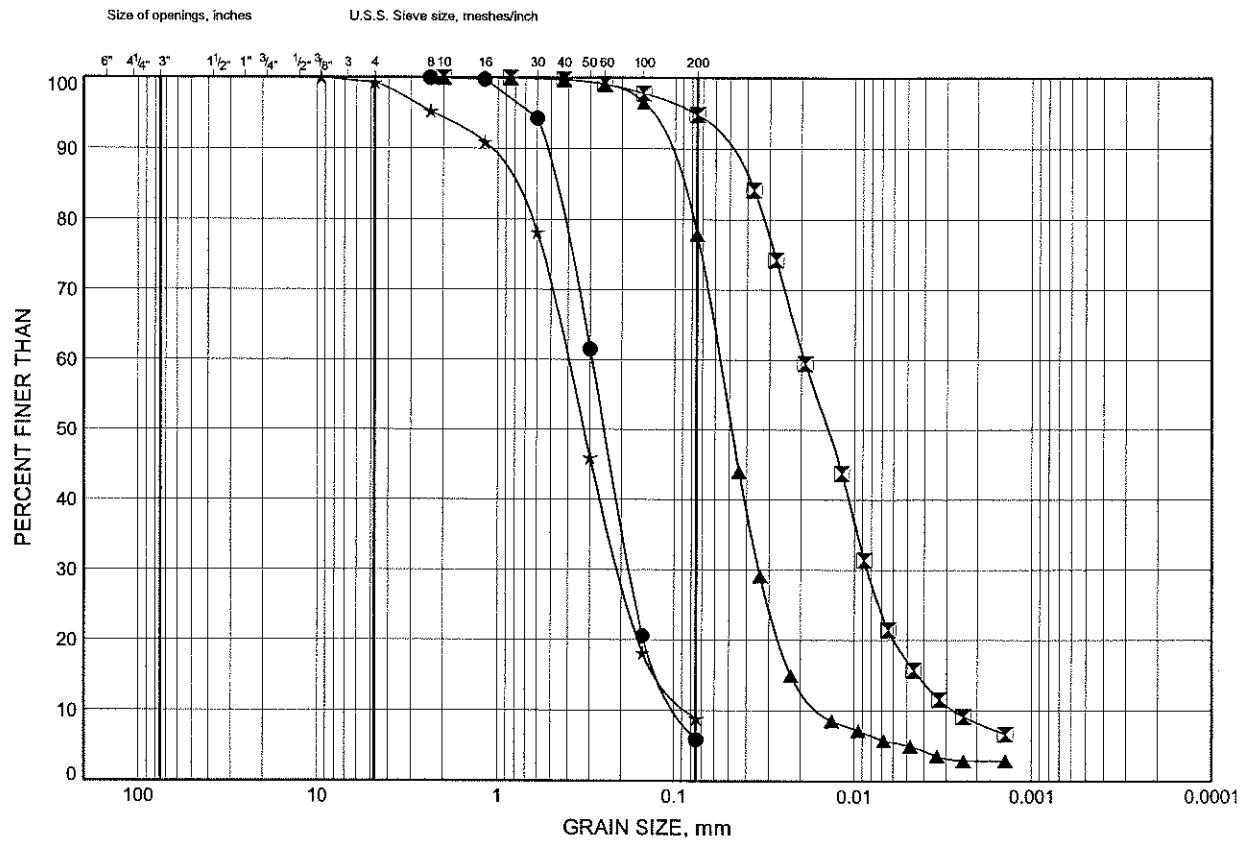
### **Laboratory Test Results**



# Hwy 11 Four Laning GRAIN SIZE DISTRIBUTION

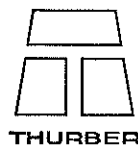
FIGURE B1

## SILT, Sandy SILT, and SAND



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BC-1	2.59	328.78
⊠	BC-1	4.80	326.57
▲	BC-1	7.85	323.52
★	BC-1	10.90	320.47

Date February 2006  
Project 759-93-00

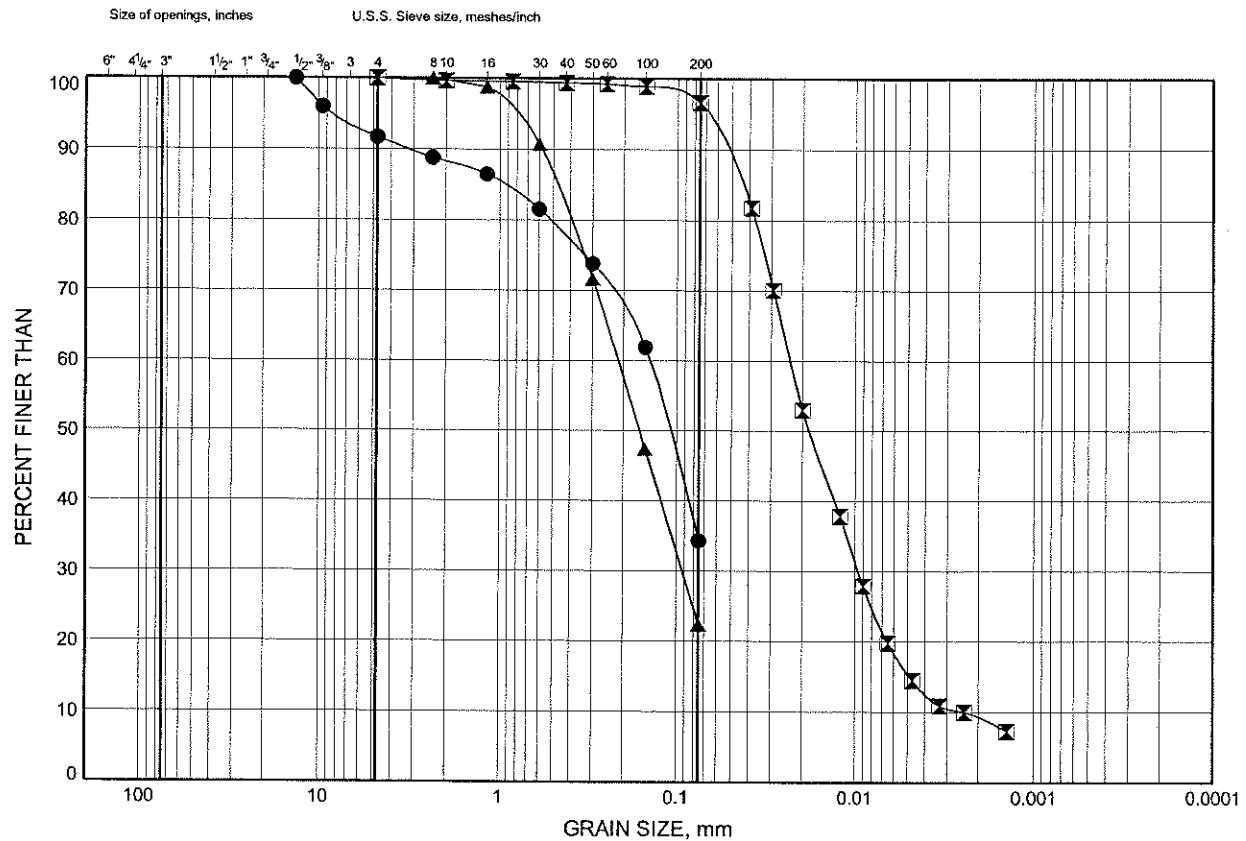


Prep'd JL  
Chkd. MEF

# Hwy 11 Four Laning GRAIN SIZE DISTRIBUTION

FIGURE B2

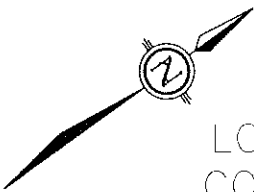
## SILT, Silty SAND, and SAND



**Appendix C**

**Drawings**





DIST OF PARRY SOUND  
GEOG TWP MACHAR

LOT 7  
CON 4

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

HWY 11  
CONT No  
GWP No 759-93-00

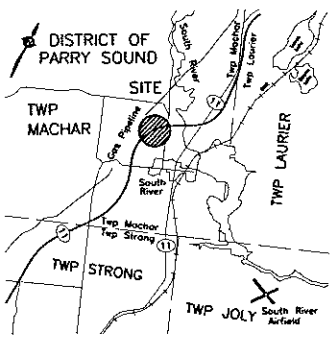


HIGHWAY 11 MAINLINE  
MACHAR TOWNSHIP  
PROPOSED CROSSING  
AT BLACK CREEK  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



THURBER ENGINEERING LTD.



KEYPLAN

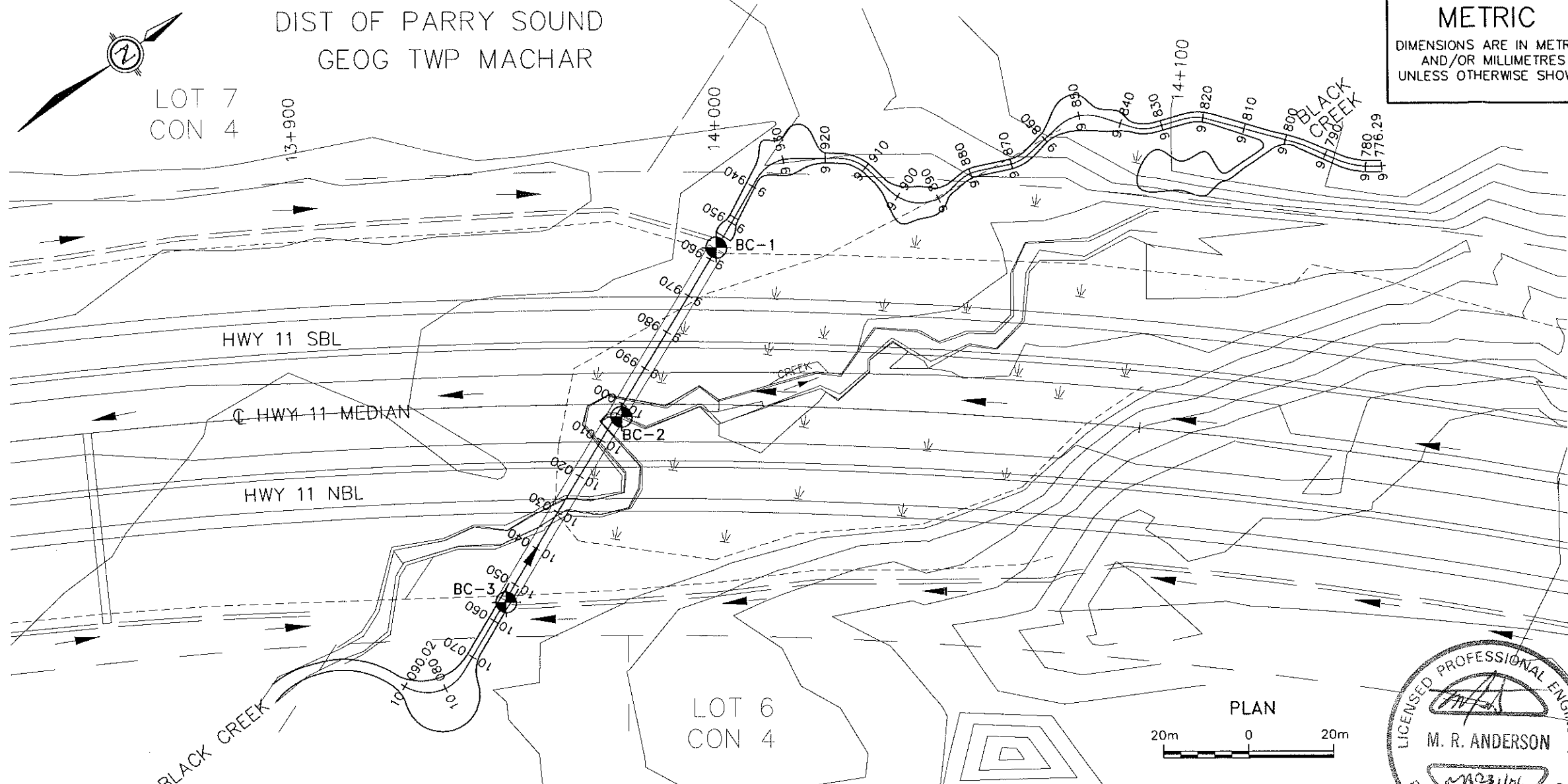
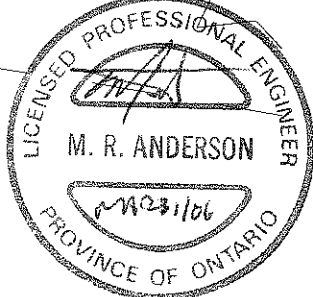
LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (cone)
- ⊕ Bore Hole & Cone
- N Blows/0.3m (Std pen Test, 475J/blow)
- CONE Blows/0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- WL in Piezometer at Time of Investigation (Date)
- Head Artesian Water
- Piezometer
- WL in Open Borehole Upon Completion of Drilling
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal
- C/R Cone Refusal

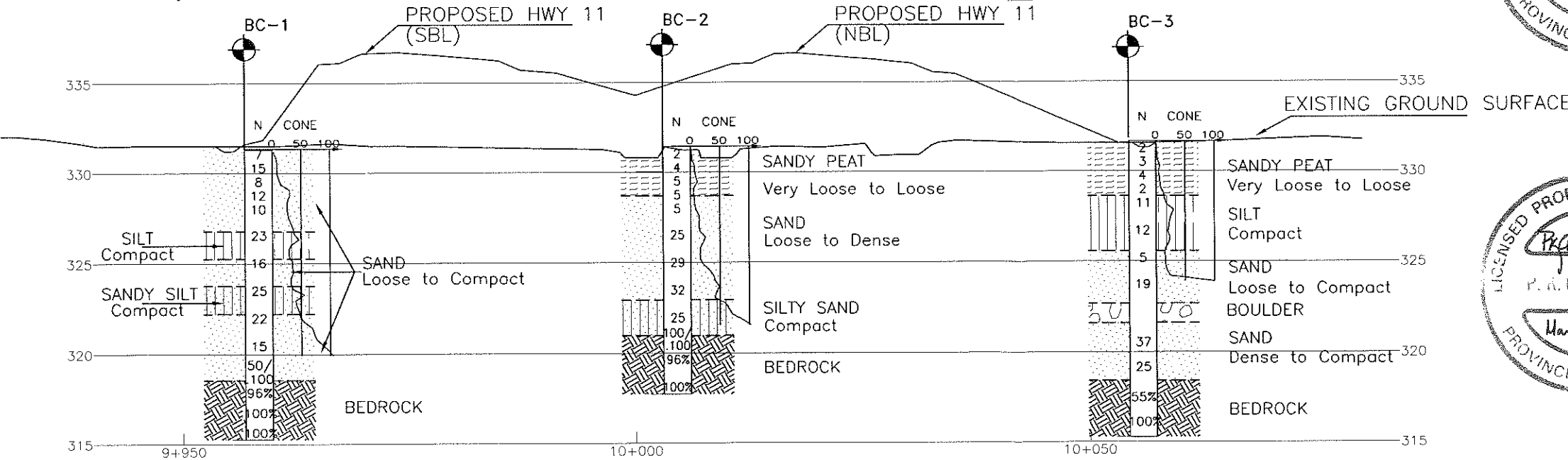
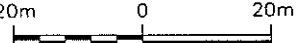
NO	NORTHING	EASTING	ELEVATION (m)
BC-1	5078811.2	312948.8	331.4
BC-2	5078769.7	312968.4	331.2
BC-3	5078721.7	312988.3	331.7

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.



PLAN



PROFILE OF REALIGNED BLACK CREEK



DRAWING NOT TO BE SCALED  
100 mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	DESCRIPTION
FEB 06/MRA			ISSUED AS DRAFT FOR REVIEW
DESIGN MRA	CHK AEG	CODE	LOAD
DRAWN SLL	CHK MRA	SITE	STRUCT
			SCHEME
			DWG A1

## **Appendix D**

### **Non Standard Special Provision**

Suggested text for a NSSP on Excavation Dewatering should contain the following:

*“The soils underlying this site are cohesionless in nature and the observed groundwater table lies close to the surface. Excavation below the groundwater level is expected to lead to instability and slough of the sides of the excavation and boiling of the base, accompanied by loss in geotechnical resistance of the soils. If excavation is required to be carried out below the groundwater level prevailing at the time of construction, appropriate means of dewatering must be implemented to depress the groundwater level sufficiently far below the base of the excavation to prevent any instability, sloughing, or boiling and so as to preserve the stability of the excavation and to allow the work to proceed in the dry.”*