

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT AND EXTENSION
HIGHWAY 26
FROM SIXTH LINE TO PRETTY RIVER PARKWAY
TOWN OF COLLINGWOOD CONNECTING LINK
COLLINGWOOD, ONTARIO
G.W.P. No. 2002-10-00**

GEOCRES Number: 41A-221

Report to

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November 8, 2011
File: 19-1351-203

H:\19\1351\203 Hwy26 Sixth Line to Pretty River
Pkw\Reports & Memos\191351203 Hwy 26 Culvert
Extension FIDR FINAL_nov08 11.doc

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at the location of a culvert where a new and longer replacement culvert is proposed across Highway 26 which is to be widened from Sixth Line to Pretty River Parkway in the Town of Collingwood.

The purpose of this investigation was to obtain subsurface information at the culvert location and, based on the data obtained, to provide a borehole location plan, a stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions. A model of the subsurface condition was developed from the data obtained at the culvert location during the course of the investigation.

Thurber was retained by McCormick Rankin Corporation (MRC) to carry out this foundation investigation under the MTO Assignment Number 2009-E-0088.

2 SITE DESCRIPTION

The culvert site is located along Highway 26 approximately 40 m west of the intersection with Newport Boulevard. The site is within the Town of Collingwood.

The existing culvert is of the concrete open footing type with an invert slab and has dimensions of 3.00 m wide by 1.9 m high by 15.30 m long. The grade of the existing Highway 26 in the vicinity of the culvert is approximately Elevation 182 m. The embankment fill height at the culvert location is approximately 2.5 m. The general location of the culvert is shown on the key plan on the Borehole Locations and Soil Strata drawing in Appendix C.

The project area is located within the physiographic region known as the Simcoe Lowlands. In the areas bordering Georgian Bay, glacial lacustrine sands and silts overlie shallow limestone bedrock of the Middle Ordovician Age. Drainage in the vicinity of the project area is largely controlled by the



nearby Georgian Bay. Localized drainage is facilitated by creeks, many of which are serviced by culverts located in the flow channel under highway and road embankments.

The land use adjacent to this section of Highway 26 is largely commercial and residential.

3 SITE INVESTIGATION AND FIELD TESTING

The borehole investigation and field testing program was carried out on March 30 and 31, 2011 during which time two boreholes were drilled at this site. One borehole was located on the south shoulder of Highway 26 near the existing culvert outlet and the second one on the shoulder of a gravel road to the south of the existing culvert.

Prior to the start of drilling, the borehole locations were marked/staked in the field and utility clearances were obtained. The drilled borehole locations were subsequently surveyed by McCormick Rankin Corporation (MRC).

A track mounted drill rig was used to drill and sample the boreholes. Hollow stem augers were used to advance the boreholes until practical refusal on the top of bedrock. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). Both boreholes were further advanced by 7.6 to 9.2 m respectively through bedrock using HQ size coring equipment. Groundwater conditions in the open boreholes were observed throughout the drilling operations. A standpipe piezometer was installed in each borehole. The details of piezometer installations and borehole completion are summarized in Table 3.1 below.

Table 3.1
Borehole Completion and Piezometer Installation Details

Borehole Number	Piezometer Installations			Completion Details
	Screen Depth (m)	Screen Elevation (m)	Sand Filter Stratum	
11-01	8.7 – 10.1	172.8 – 171.2	Bedrock	Bentonite to surface
11-02	7.8 – 9.2	172.5 – 171.1	Bedrock	Bentonite to surface

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, secured the recovered soil samples in labelled containers, stored the rock core samples in wooden boxes, and transported the samples to Thurber's laboratory for further examination and testing.

Results of field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.



4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural water content determination. Selected soil samples were subjected to grain size distribution analyses (sieve and hydrometer). All rock cores were logged including the determination of Total Core Recovery (TCR) and Rock Quality Designation (RQD). Point load testing was carried out on selected rock cores for unconfined compressive strength correlation. The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

Reference is made to the Record of Borehole sheets in Appendix A for details of the soil stratigraphy encountered in the boreholes. Stratigraphic profiles for the culvert replacement and extension area is presented on the Borehole Locations and Soil Strata Drawing in Appendix D for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the record of boreholes governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes located on the highway shoulder consist of granular fill overlying bedrock. The Boreholes located south of the highway consisted of thin layers of sandy silt and sand overlying bedrock. More detailed descriptions of the individual stratum are presented below.

5.2 Fill

Embankment fill was encountered in Borehole 11-01. This fill consists of brown sand and gravel. The fill extended to a depth of 2.5 m (Elevation 178.9 m).

SPT N-values measured in the sand and gravel fill ranged from 6 to 25 blows per 0.3 m penetration indicating a loose to compact state. A high blow count of 100 blows for 0.1 m penetration was measured just above bedrock. The moisture contents of the recovered fill samples ranged between 6% and 9%. Grain size analyses conducted on samples of the fill are presented on Figures B1 in Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	35 to 41
Sand	43 to 53
Silt and Clay	12 to 16



5.3 Silt and Sand

A thin layer of sandy silt mixed with organics and underlain by a thin layer of sand was encountered in Borehole 11-02 immediately above the bedrock. The combined thickness of these layers is 0.2 m.

5.4 Bedrock

The soils described above were found to be underlain by limestone bedrock which was proven by coring in both boreholes. The limestone is slightly weathered to fresh and grey to dark grey in colour. Bedrock was found at a depth of 2.5 m (Elevation 178.9 m) in Borehole 11-01 and at a depth of 0.2 m (Elevation 180.1 m) in Borehole 11-02.

The measured Total Core Recovery (TCR) was 100% in both boreholes except in run number one of Borehole 11-02 where 50% was measured. The Rock Quality Designation (RQD) values were recorded at 84 to 100% indicating a typically good to excellent rock quality, except for the first run of Borehole 11-02 where the value of 20% indicated very poor quality.

The estimated Unconfined Compressive Strength (UCS) of the cores ranged from 22 to 87 MPa indicating a medium strong to strong rock. These estimated rock strength values are based on point load tests that were conducted on selected rock cores recovered from the boreholes.

5.5 Groundwater Conditions

Free water was not observed in the boreholes upon completion of drilling. Standpipe piezometers were installed in both boreholes. Measured water levels in these piezometers are presented below.

Borehole (screen location)	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)
11-01	April 7, 2011	2.7	178.7
	July 5, 2011	4.4	177.0
11-02	April 7, 2011	0.5	179.8
	July 5, 2011	2.3	178.0

6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. The MRC surveyed the as-drilled locations, and provided the northing and easting coordinates and ground surface elevations.

Walker Drilling of Utopia, Ontario supplied and operated a track-mounted D50 Turbo drill rig to carry out the drilling, sampling and in-situ testing operations.



The drilling and sampling operations in the field were supervised on a full time basis by Ms. Eckie Siu of Thurber. Laboratory testing was carried out by Thurber in its laboratory.

Overall project management and direction of the field program was provided by Mr. Matthew Boucher, P.Eng.(AB). Interpretation of the field data and preparation of this report was completed by Mr Matthew Boucher, P.Eng.(AB). The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.





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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents foundation recommendations for the design of the replacement and extension of the existing culvert along the same horizontal alignment located at approximate Station 20+275 under Highway 26 in Collingwood, Ontario. The extension is in the order of 10 m to the south to accommodate the highway widening.

The existing culvert is of the concrete open footing type with an invert slab and has dimensions of 3.00 m wide by 1.9 m high by 15.30 m long. There is about 0.2 m of fill covering the box below the highway embankment but the top of the culvert is exposed at both ends. Cast-in-place independent retaining walls currently support the embankment fill at both the inlet and outlet locations. Information from MRC indicates that the replacement culvert will have dimensions of 4.00 m wide by 1.75 m high and the total length is to be confirmed. It is understood that the embankment widening and the extended portion of the culvert would be constructed first, after which the traffic would be detoured onto the new embankment. Demolition of the existing culvert and construction of its replacement would then follow.

The discussions and recommendations presented in this report are based on the information provided by MRC and on the factual data obtained during the course of this investigation.

8 CULVERT FOUNDATIONS

8.1 General

The current project requirements involve a longer replacement culvert with an extended length on the south side where Highway 26 is to be widened. The upstream (north) and downstream (south) inverts of the replacement culvert are at Elevations 179.00 and 178.98 m, respectively. It is understood that these elevations are similar to those of the existing culvert. At the time of the investigation, it was our understanding that the culvert was to be extended



and not replaced. Accordingly, two boreholes numbered 11-01 and 11-02 have been advanced in the area of the culvert extension as shown on the Borehole Location and Soil Strata Drawing.

8.2 Foundation Alternatives

This section presents discussions on available types of culvert replacement, culvert extension and foundation alternatives, and provides recommendations on feasible and/or preferred foundation option(s).

Three common types of culverts are listed as follows:

- Concrete, open footing, culvert
- Concrete box (closed) culvert
- Corrugated Steel Pipe (CSP) culvert

A comparison of the foundation alternatives based on their respective advantages and disadvantages is included in Appendix D.

Both concrete open footing culvert and box culvert are available options for replacing the existing culvert. Environmental factors may dictate the choice of an open footing culvert. It is preferable to use precast concrete sections rather than cast-in-place construction since the former type can be installed more rapidly. CSP's are not suitable for use as permanent culverts.

8.3 Concrete Open Footing Culvert Replacement and Extension

For a concrete open footing culvert replacement and extension, the footings should be founded at similar elevations as the footings for the existing culvert.

It is recommended that the culverts be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

Recommendations on subgrade preparation procedures including sub-excavation, backfilling, bedding and inspection are provided in the following sections.

8.3.1 Geotechnical Resistance

The geotechnical resistances for culvert footing design depend on the subsurface conditions within the culvert footprints. Based on the results of the boreholes, the new footings will be founded on bedrock. Some rock excavation will be required along the southern portion of the extension. Assuming that the rock excavation and subgrade preparation procedures



recommended in this report are followed, the recommended geotechnical resistance at or below Elevation 179 m is as follows:

- The new culvert footings on limestone bedrock with fractured zones may be designed using a factored geotechnical resistance at ULS of 2,000 kPa.
- The SLS condition will not govern design for footings founded on bedrock.

In the vicinity of the northern portion of the culvert where no borehole is drilled, if there is deeper soils overlying bedrock, the soils should be removed and replaced with mass concrete until the founding level is reached.

The above geotechnical resistance is for vertical, concentric loads only. Effects of load inclination and eccentricity should be taken into account as illustrated in the CHBDC (2006) Clause 6.7.3 and Clause 6.7.4.

Resistance to lateral forces/sliding resistance between the concrete footing and the bedrock surface should be evaluated in accordance with the CHBDC (2006) assuming an ultimate coefficient of friction of 0.58.

There is no concern of frost penetration for footings founded on bedrock.

There should be no foundation settlement associated with footings placed on bedrock.

Foundation design for any wingwalls or headwalls associated with the culvert replacement and extension may also be carried out as discussed above.

8.4 Concrete Box (Closed) Culvert

As an alternative and where hydraulic, hydrologic and environmental issues are satisfied, consideration may be given to using pre-cast concrete box sections to construct the replacement culvert.

In order to provide a more uniform foundation subgrade condition, a 300 mm thick layer of bedding material conforming to OPSS Granular A requirements should be provided under the base of box culverts as per OPSD 803.010. The bedding material should be placed following inspection and approval of the final subgrade.

Foundation settlement is not a design issue for box culverts founded on bedrock.

Resistance to lateral forces / sliding resistance between the concrete slab and the underlying Granular A should be calculated assuming an ultimate coefficient of friction of 0.5.

Foundation design for any wingwalls or headwalls associated with the box culvert replacement and extension may also be carried out as outlined in Section 8.3.2 above.



8.5 Excavation and Subgrade Preparation

Soil and rock excavation will be required to widen the existing flow channel to accommodate the new and wider culvert. Rock excavation of 1 m or more below existing rock surface will be required to reach the invert and footing founding elevations within the extension section. It is anticipated that heavy excavating equipment, ripping machinery and rock breakers/splitters will be required to break up the hard limestone slabs. Due to the relatively shallow rock depth and the presence of fractured and/or soil infilled zones within that depth, blasting techniques should not be required.

Following excavation to the design base level of the culvert replacement and extension, any remaining loose and/or shattered rock within the culvert and footing footprint should be removed. The exposed surface must be inspected to confirm that the subgrade is suitable and consists of undamaged rock.

After excavation, the Contractor should scale all loosened rock from the face and the base, and the exposed surface should then be inspected to confirm that the shallow rock cut is stable and that the subgrade is uniform and competent to support the replacement culvert. Where over-breaking occurs, the Contractor should remediate the situation by various means including placement of mass concrete fill. Suggested wording for an NSSP pertaining to these requirements are included in Appendix E.

Within the existing flow channel, all surficial organics, loose/soft soils, alluvium and other debris within the existing flow channel should be stripped from the culvert and adjacent embankment footprints.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

It is recommended that backfill to the culvert and headwalls/wingwalls consists of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of Special Provision No. 110F13, "Amendment to OPSS 1010, April 2004" dated May 2010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01 as appropriate.

All fills should be placed in regular lifts and be compacted in accordance with OPSS 501 "Construction Specification for Compacting" dated November 2010. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should be the same on both sides of the culvert at all times. Heavy compaction equipment must not be used adjacent to the walls and roofs of the culverts.

For rigid structures such as a concrete open frame or box culvert where lateral yielding is not allowed, it is recommended that at-rest horizontal earth pressure co-efficients be used for design.



The active coefficients should be used for any wingwalls, headwalls or otherwise unrestrained walls.

Earth pressures acting on the culvert walls and headwalls/wingwalls may be assumed to impose a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2006 but are generally 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 below)
 γ = 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 walls, headwalls/wingwalls are dependent on the material used as backfill. Recommended unfactored values are shown in the following Table 9.1.

Table 9.1
Earth Pressure Coefficients (K)

Wall 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 (modified) $\phi = 32^\circ; \gamma = 21.2 \text{ kN/m}^3$		Embankment Fill $\phi = 30^\circ; \gamma = 20.0 \text{ kN/m}^3$	
	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 (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-



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

The use of a material with a higher friction angle and lower earth pressure co-efficients (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

The factors in the table above are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.9.1 (a) in the Commentary to the CHBDC 2006.

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

10 EXCAVATION AND GROUNDWATER CONTROL

10.1 General

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the existing fill, native sands and silts at these sites are classified as Type 3 soils. The bedrock is anticipated to be able to stand up within vertical cuts.

10.2 Foundations

Excavation and backfilling for culvert construction must be carried out in accordance with SP 902S01.

10.3 Earth Excavation

Excavations for culvert replacement and extension construction will be carried out through the existing embankment fill, native sands and silts, and limestone bedrock. It is anticipated that unsupported open cutting using a safe temporary slope can be carried out through the fill and native soils overlying bedrock. At locations where there is space restriction or where a slope has to be retained, the excavations may need to be carried out in conjunction with a protection system.

OPSS 539 “Construction Specification for Temporary Protection Systems” dated November 2009 should be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.01.01 (maximum horizontal displacement of 25 mm) be specified for this site.



10.4 Rock Excavation

The bulk of the excavation for installing the replacement culvert will be extended into the limestone bedrock. Heavy excavating equipment, ripping machinery and rock breakers/splitters will be required to break up the hard limestone slabs. The contract documents should contain an NSSP alerting the contract bidders that rock excavation may require the use of such equipment. Suggested wordings for this NSSP are provided in Appendix E.

Any rock excavation should be carried out in accordance with OPSS 902.

Blasting is not required nor an acceptable alternative at this site.

10.5 GROUNDWATER CONTROL

The measured groundwater levels in Boreholes 11-01 and 11-02 were at Elevations 177 and 178 m, respectively. Groundwater perched within the embankment fill will seep into the excavations during culvert construction. Some seepage from the rock joints is also anticipated to occur. Water flow through the creek channel and surface runoff will also tend to accumulate in these excavations. The groundwater level varies between locations but is expected to be governed by the water level of the nearby Georgian Bay. The Contractor must make provisions to control creek water flow, surface runoff, water seepage and ponding by measures including the use of sump pumps to maintain a reasonably dry excavation during the course of construction. Temporary creek water diversion may be considered. Suggested wordings for an NSSP is provided in Appendix E.

11 EMBANKMENT DESIGN AND CONSTRUCTION ADJACENT TO CULVERT

New fill are to be placed adjacent to and over the culvert replacement and extension in order to accommodate the highway embankment widening. Embankment construction should be carried out in accordance with OPSS 206 “Construction Specification for Grading” dated November 2009 (Reissued November 2010). The new embankment fill should consist of Granular A or B Type II materials in compliance with Special Provision No. 110F13, “Amendment to OPSS 1010, April 2004” dated May 2010.

Provided that the foundation subgrade is prepared as recommended in this report, it is recommended that the widening embankment has a slope inclination consistent with the existing embankment and not steeper than 2H : 1V. Consideration may be given to benching the existing earth slope surface as per OPSD 208.010 in order to enhance the keying in of the new fill. Benching is not required for rock surfaces.



In general, all surficial organics, loose/soft soils, alluvium and other debris within the existing flow channel should be stripped from the culvert and adjacent embankment footprints.

12 EROSION CONTROL

Erosion protection should be provided at the culvert inlet and/or outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors 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. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with SP 572S01.

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 at least 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205.

13 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced foundation/geotechnical staff to observe construction activities related to foundation construction, and to inspect and approve the culvert subgrade.

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

- Impact of excavation on the adjacent pavement surface

Daily visual inspection of the adjacent pavement surface must be carried out in the vicinity of culvert construction. Any form of cracks, pavement distress or settlement that are observed must be immediately brought to the attention of the C.A. for determining if remedial action is required.

- Occurrence of bedrock within the culvert construction area

The culvert alignment is underlain by bedrock which characteristically has an uneven surface. It is likely that removal of bedrock will be necessary within the extension (southerly) portion of the culvert. The contract documents must alert bidders to this likelihood and the contract must contain provisional items to cover payment of rock excavation.

- Removal of organics, loose/soft soils, loose/shattered rock, alluvial deposits and debris along the creek channel,
- Confirmation that the culvert and headwall/wingwall backfills and approach fills are adequately placed and compacted to specifications.



It is recommended that provision(s) be included in the contract requiring the Contractor to confirm that the above issues are adequately addressed. Suggested wordings for NSSP's addressing these issues are included in Appendix E.

14 CLOSURE

Preparation of this foundation design report was carried out by Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. who is a Designated Principal Contact for MTO Foundations projects.





Sydney Pang, P.Eng.
Associate, Senior Geotechnical Engineer



P.K. Chatterji, P.Eng.
Principal, Designated MTO Contact



Appendix A

Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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



Water Level

C_{pen}

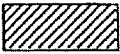
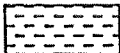



Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
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)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>		
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	Field Estimation of Hardness*
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	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	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m			
Very thinly bedded	20 to 60mm	Strong	50-100	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	Breaks under single blow of geological hammer.
<u>TERMS</u>				
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750
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.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150
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 11-01

1 OF 1

METRIC

G.W.P. 2002-10-00 LOCATION N 4 928 877.6 E 250 160.5 ORIGINATED BY ES
 HWY 26 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2011.03.30 - 2011.03.30 CHECKED BY MAB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
181.4								20	40	60	80	100					
0.0	SAND and GRAVEL , some silt Compact to Loose Brown Moist (FILL)		1	SS	20		181										35 53 12 (SI+CL)
			2	SS	6		180										
	Occasional cobbles		3	SS	25												41 43 16 (SI+CL)
178.9			4	SS	100/		179										
2.5	END OF SAMPLING AT 2.5m AND START CORING. FOR ROCK DETAILS PLEASE REFER TO BH11-01R. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Apr.07/11 2.7 178.7 Jul.05/11 4.4 177.0				0.100												

RECORD OF BOREHOLE 11-01R

PROJECT : Culvert Replacement and Extension
 LOCATION : Hwy 26 Sixth Line to Pretty River Pkwy
 STARTED : March 30, 2011
 COMPLETED : March 30, 2011

Project No. 2002-10-00

INCLINATION: Vertical AZIMUTH: Vertical

SHEET 1 OF 1
 DATUM Geodetic

DEPTH SCALE (metres)	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No.	PENETRATION RATE (mm/min)	COLOUR FLUSH % RETURN	FR-FRACTURE CL-CLEAVAGE SH-SHEAR VN-VEIN				F-FAULT J-JOINT P-POLISHED S-SLICKENSIDED				SM-SMOOTH R-ROUGH ST-STEPPED PL-PLANAR				FL-FLEXURED UE-UNEVEN W-WAVY C-CURVED				Unconfined 50 Compressive Strength (MPa)	FIELD/LABORATORY TESTING RESULTS ● Point Load Test Diametral ▲ Point Load Test Axial ■ Laboratory UCS Test																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
					DEPTH (m)	R.Q.D. %				RECOVERY		FRACT. INDEX PER 3 m	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY k, cm/sec																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
										TOTAL CORE %	SOLID CORE %		DIP wrt Core Axis	TYPE AND SURFACE DESCRIPTION	6 10	5 10	4 10	3 10																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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Bentonite

173.36

Filter Sand

172.75

Slotted Screen

171.22

GROUNDWATER ELEVATIONS

▽ SHALLOW/SINGLE INSTALLATION
 WATER LEVEL (date) 07/05/2011

▼ DEEP/DUAL INSTALLATION
 WATER LEVEL (date)

LOGGED : ES
 CHECKED : MAB



RECORD OF BOREHOLE No 11-02

1 OF 1

METRIC

G.W.P. 2002-10-00 LOCATION N 4 928 861.3 E 250 155.3 ORIGINATED BY ES
HWY 26 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2011.03.31 - 2011.03.31 CHECKED BY MAB

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)						
						20	40	60	80	100	20	40	60				
180.3																	
0.0																	
0.1																	
0.2	Sandy SILT, some clay, trace gravel, mixed with organics Very Dense Brown Damp SAND, some gravel, occasional limestone fragments Very Dense Brown Damp END OF SAMPLING AT 0.2m AND START CORING. FOR CORE LOG PLEASE REFER TO BH10-02R. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Apr.07/11 0.5 179.8 Jul.05/11 2.3 178.0		1	SS	100/ 0.050												

RECORD OF BOREHOLE 11-02R

PROJECT : Culvert Replacement and Extension
 LOCATION : Hwy 26 Sixth Line to Pretty River Pkwy
 STARTED : March 31, 2011
 COMPLETED : March 31, 2011

Project No. 2002-10-00

INCLINATION: Vertical AZIMUTH: Vertical

SHEET 1 OF 1
 DATUM Geodetic

DEPTH SCALE (metres)	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No.	PENETRATION RATE (mm/min)	COLOUR % RETURN	FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX PER 3 m	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY k, cm/sec	Unconfined Compressive Strength (MPa)	FIELD/LABORATORY TESTING RESULTS ● Point Load Test Diametral ▲ Point Load Test Axial ■ Laboratory UCS Test	
				DEPTH (m)	FLUSH					TOTAL CORE %	SOLID CORE %			TYPE AND SURFACE DESCRIPTION	DIP wrt Core Axis	TYPE AND SURFACE DESCRIPTION	DIP wrt Core Axis				
				180.10 0.20																	
2	RUN	LIMESTONE (BEDROCK), slightly weathered to fresh, grey to dark grey, moderately strong to strong Silt or sand seams 75mm broken zone at 1.0m and 1.1m 150mm sub-vertical fracture at 1.2m 25mm sub-vertical fractures at 4.7m Sub-horizontal fractures (between 25mm to 75mm) at 1.7m, 2.0m, 3.0m			1	0.089	100														
	RUN				2	0.101	100														
	RUN				3	0.101	100														
	RUN				4	0.101	100														
	RUN				5	0.095	100														
	RUN				6	0.101	100														
8																					
10		END OF BOREHOLE AT 9.3m.																			

GROUNDWATER ELEVATIONS

▽ SHALLOW/SINGLE INSTALLATION

WATER LEVEL (date) 07/05/2011

▽ DEEP/DUAL INSTALLATION

WATER LEVEL (date)

LOGGED : ES

CHECKED : MAB



Appendix B

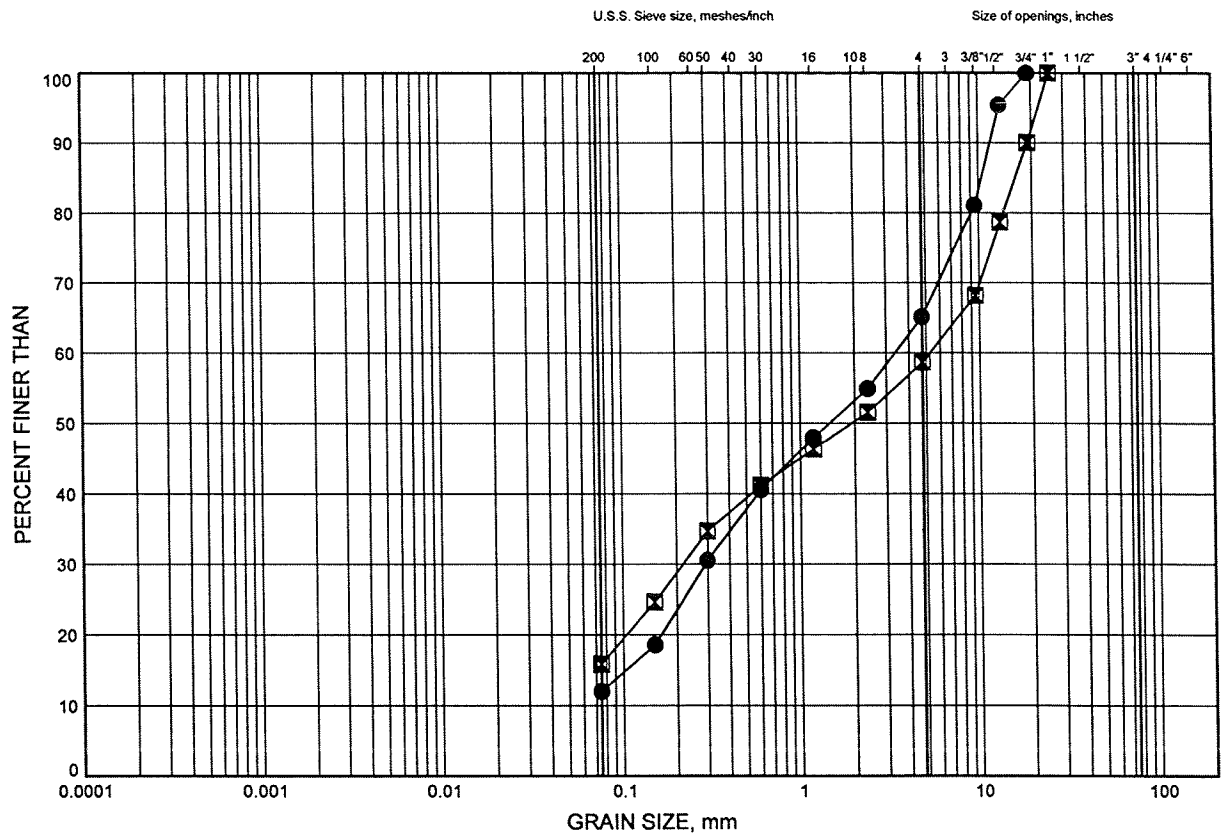
Laboratory Test Results



Hwy 26 Sixth Line to Pretty River Pkwy
GRAIN SIZE DISTRIBUTION

FIGURE C1

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)
●	11-01	0.30	181.11
⊠	11-01	1.83	179.58

GRAIN SIZE DISTRIBUTION - THURBER 1203.GPJ 4/23/11

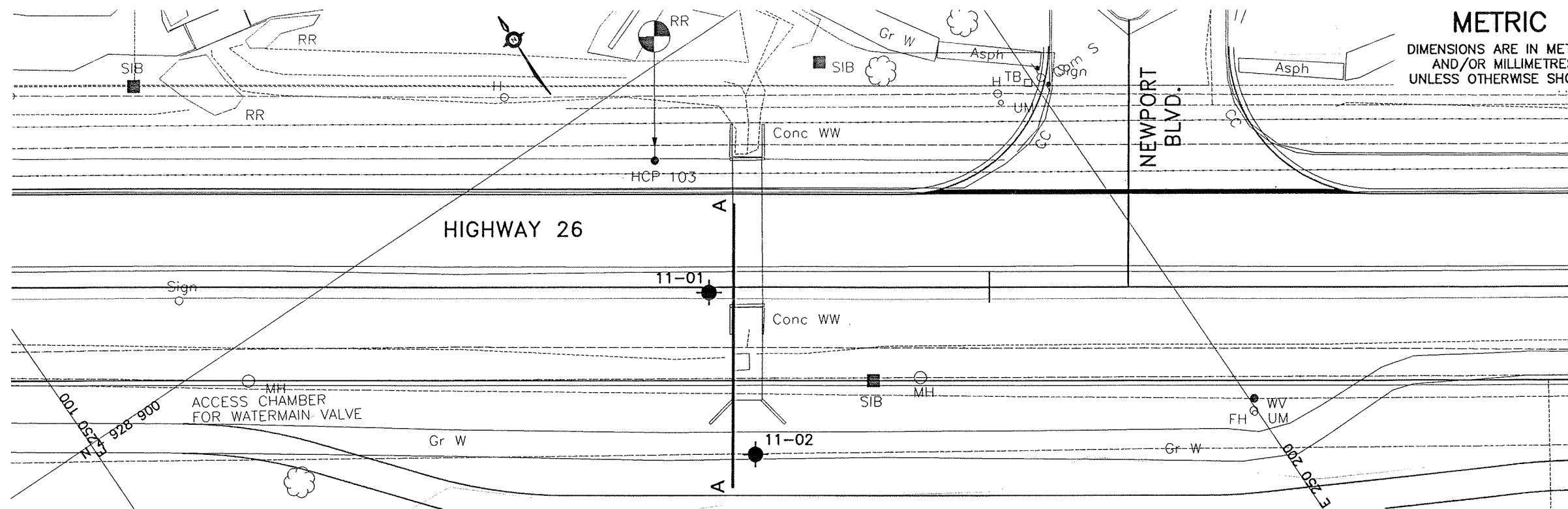
W.P.# 19-1351-203
 Prepared By EA
 Checked By MTB



Appendix C

Borehole Locations and Soil Strata Drawings





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

CONT No
GWP No 2002-10-00

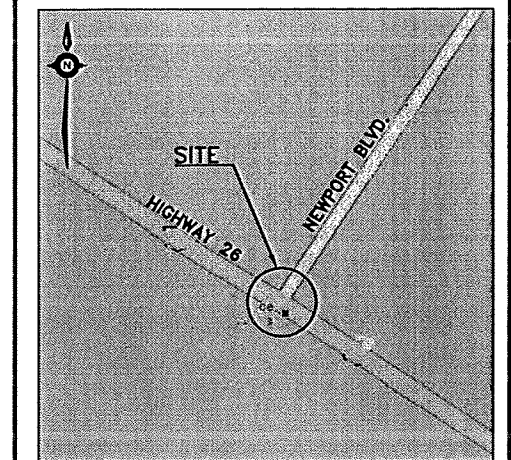
HIGHWAY 26 WIDENING
CULVERT REPLACEMENT &
EXTENSION, COLLINGWOOD
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET

MRC McCORMICK RANKIN
CORPORATION

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



KEYPLAN

LEGEND

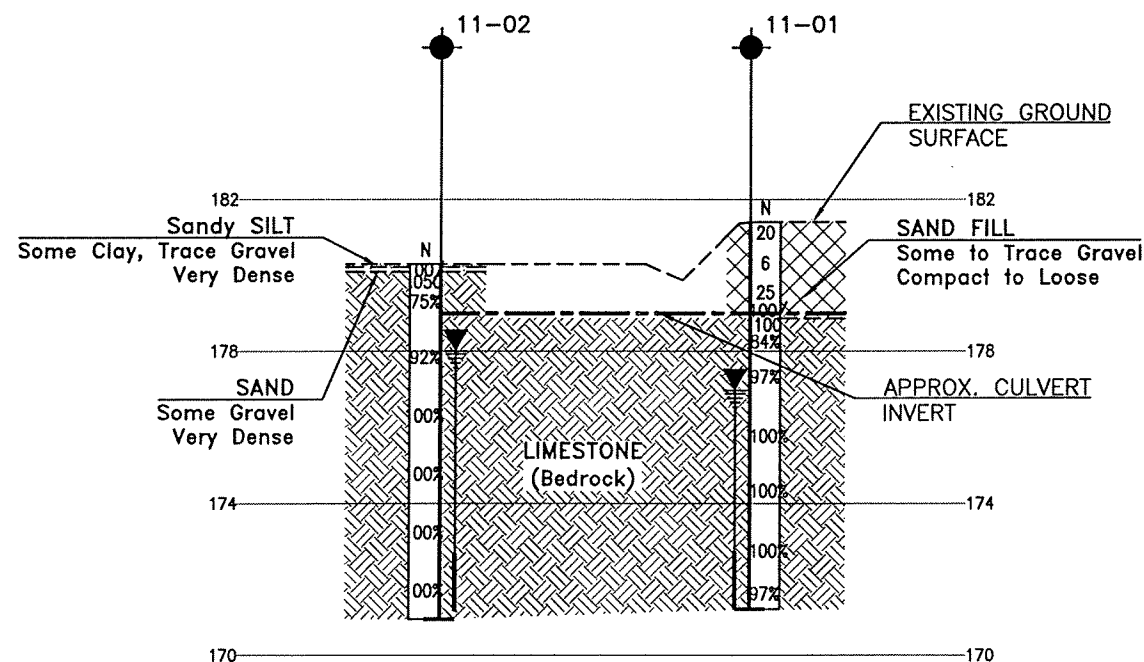
◆	Borehole
◆	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
▽	Head Artesian Water
↑	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
11-01	181.4	4 928 877.6	250 160.5
11-02	180.3	4 928 861.3	250 155.3

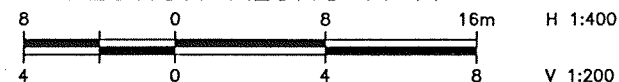
-NOTES-

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

GEOCRES No. 41A-221



SECTION ALONG A-A



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MB	CHK SKP	CODE
DRAWN	AN	CHK PKC	SITE
			LOAD
			DATE NOV. 2011
			STRUCT
			DWG

Appendix D

Foundation Alternatives Comparisons

19-1351-203



COMPARISON OF ALTERNATIVE CULVERT TYPES

Location	Concrete Open Footing Culvert	Concrete Box (Closed) Culvert	Corrugated Steel Pipe (CSP) Culvert
Culvert Extensions And Replacements	<p>Advantages:</p> <ul style="list-style-type: none"> i. Compatible to existing culvert types. ii. Relatively expedient installation if precast units are used. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. May require deeper sub-excavation for footing construction. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Compatible to most existing culvert types. ii May require less sub-excavation than open footing culvert. iii. Relatively expedient installation if precast units are used. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Will require compacted granular pad on subgrade. ii. May create environmental issues such as those involving spawning fish species. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Can tolerate larger foundation settlements than concrete culverts. ii. Lower cost than concrete culverts. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. May only be used as temporary extension during construction since the main purpose of this project is to construct a permanent replacement culvert. ii. Not as durable as concrete culverts.



Appendix E

List of SPs, OPSSs, OPSDs and Suggested NSSP Wordings



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

- SP 110F13
- SP 572S01
- OPSD 208.010
- OPSD 803.010
- OPSD 810.010
- OPSS 206
- OPSS 501
- OPSS 539
- OPSS 902
- OPSS 1205

2. Suggested Text for NSSP on “Excavation and Subgrade Preparation”

- After excavation, the Contractor shall scale all loosened rock from the face and the base, and the exposed surface shall then be inspected to confirm that the shallow rock cut is stable and that the subgrade is uniform and competent to support the replacement culvert. Where over-breaking occurs, the Contractor shall remediate the situation by various means including placement of mass concrete fill.

3. Suggested Text for NSSP on “Rock Excavation”

- The bulk of the excavation for installing the replacement culvert will be extended into the limestone bedrock. The Contractor shall be equipped with heavy excavating equipment, ripping machinery and rock breakers/splitters to break up and remove the hard limestone slabs.

4. Suggested Text for NSSP on “Groundwater Control”

- Groundwater perched within the embankment fill will seep into the excavations during culvert construction. Some seepage from the rock joints is also anticipated to occur. Water flow through the creek channel and surface runoff will also tend to accumulate in these excavations. As such, the Contractor must make provisions to control creek water flow, surface runoff, water seepage and ponding by measures including the use of sump pumps to maintain a reasonably dry excavation during



construction. If necessary, temporary creek water diversion may be carried out subject to approval by relevant authorities.

5. Suggested Text for NSSP on “Impact on Adjacent Roadways”

- It is critical that Contractor’s excavation and construction activities do not undermine or have any adverse impact on the integrity and performance of the travelled lanes of Highway 26. Daily visual inspection of the pavement surface must be carried out in the vicinity of the culvert under construction. Any form of cracks, pavement distress or settlement that are observed must be immediately brought to the attention of the Contract Administrator for determining if remedial action is required.

6. Suggested Text for NSSP on “Culvert Foundation Preparation and Backfill”

- Prior to constructing the replacement culvert, organics, loose/soft soils, loose/shattered rock, alluvial deposits and debris shall be removed along the creek channel. All culvert and headwall/wingwall backfills and approach fills shall be placed and compacted in accordance with OPSS 501.

