



THURBER ENGINEERING LTD.

**FOUNDATION DESIGN REPORT
WESTOVER CREEK CULVERT REPLACEMENT
HIGHWAY 11, ROSEBERRY TOWNSHIP
RAINY RIVER DISTRICT, ONTARIO
W.P. 6944-10-01, SITE NO. 45-137/C
Geocres Number: 52C-49**

Report to

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TABLE OF CONTENTS

SECTION	PAGE
1 INTRODUCTION	1
2 SUBSURFACE CONDITIONS	2
3 CULVERT FOUNDATIONS	3
3.1 Concrete Box Culvert on Native Soils.....	3
3.2 Corrugated Steel Arch or Open Footing Concrete Culvert.....	4
3.3 Corrugated Steel Pipe (CSP) Culvert.....	5
3.4 Frost Cover	6
4 CULVERT BACKFILL AND LATERAL EARTH PRESSURES	6
5 SEISMIC CONSIDERATIONS.....	7
6 WINGWALLS	8
7 EMBANKMENT RESTORATION.....	9
8 EROSION CONTROL.....	9
9 EXCAVATION AND GROUNDWATER CONTROL	9
10 CONSTRUCTION CONCERNS	10
11 CLOSURE.....	11

Appendices

Appendix A	Record of Borehole Sheets and Borehole Location Plan, Geocres No. 52C-34
Appendix B	Comparison of Foundation Alternatives
Appendix C	List of OPSSs and OPSDs, and Suggested Wording for NSSP

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1 INTRODUCTION

This report provides foundation design recommendations for the replacement of the existing Westover Creek Culvert located on Highway 11, 6.6 km west of Highway 71 in the Township of Roseberry in the Rainy River District, Ontario.

The existing Westover Creek culvert is a cast-in-place concrete box structure approximately 5.7 m in width, 1.75 m in height and 37.5 m in length. The culvert crosses the highway embankment on a skew from the north to the south. The highway embankment is estimated to be between 3.5 and 4.0 m in height with approximately 1.8 m of earth fill cover above the culvert.

It is understood that the culvert requires replacement due to deterioration including delamination and cracking in the floor, walls and soffit, as well as tilted walls and a 200 mm sag in the middle of the culvert. An embankment grade raise will not be required for culvert replacement, and construction will be carried out in stages to maintain traffic on Highway 11.

The report was prepared based on interpretation of the geotechnical data in the factual report prepared by DST Consulting Engineers Inc. (DST) titled "Foundation Investigation Report, Westover Creek Culvert, Township of Roseberry in District of Rainy River, Agreement No.: 6013-E-0023, Assignment No. 2, Site No. 45-137/C, W.P No. 6944-10-01, Geocres No.: 52C-34", dated August 8, 2014, which was provided by MTO/Hatch Mott MacDonald.

Reference should be made to the above report for a written description of the subsurface conditions, borehole location plan, stratigraphic profile, record of borehole sheets and laboratory test results. It should be noted that DST is solely responsible for the subsurface information provided in the Foundation Investigation Report. The Borehole Location Plan and Record of Borehole sheets from the investigation report have been enclosed in Appendix A of this report for reference.

The discussion and recommendations presented in this report are based on information provided by Hatch Mott MacDonald (HMM) on preliminary General Arrangement drawings dated January 2016 (box and open footing options) and September 2016 (CSP), and on the factual data presented in the Foundation Investigation Report noted above. The recommendations are intended to provide the

designer with sufficient information to assess feasible foundation alternatives and to carry out the design of the foundations for the replacement culvert.

2 SUBSURFACE CONDITIONS

The foundation investigation carried out at this site consisted of four boreholes numbered BH1 to BH4. Boreholes BH1 and BH2 were advanced to a depth of 9.7 m from the top of the roadway embankment, and Boreholes BH3 and BH4 were advanced using portable hand augers to depths of 3.0 and 3.1 m at the outlet and inlet of the culvert. The locations are shown on the Borehole Location Plan in Appendix A.

A temporary local benchmark was assumed for preparation of the borehole logs presented in the investigation report. Based on topographic information shown on the preliminary General Arrangement drawing, the approximate ground surface elevations at the borehole locations have been referenced to Geodetic Datum as follows:

Borehole Number	Approximate Ground Surface Elevation	
	Assumed Local Datum	Geodetic Datum (m)
BH1	101.5	336.3
BH2	101.4	336.2
BH3	97.4	332.2
BH4	98.1	332.9

In summary, the soil stratigraphy encountered in the boreholes drilled from the roadway consisted of a pavement structure and embankment fill overlying a deposit of silty clay extending to the borehole termination depth. In the shallow hand-auger holes at the inlet and outlet, a 200 mm thick topsoil layer was encountered over the clay deposit.

The pavement structure encountered in Boreholes BH1 and BH2 consisted of 75 mm of asphalt underlain by approximately 0.7 m of sand and crushed gravel. The underlying embankment fill consisted of sand with some silt and gravel. Standard Penetration Test (SPT) N-values of 27 to 29 blows/0.3 m were obtained above depths of 1.5 and 3.0 m, indicating a compact condition. N-values of over 50 and 100 blows/0.3 m were recorded in the lower part of the fill, possibly reflecting the presence of cobbles in the embankment material. The underside of the fill was encountered at 3.8 m depth (Elev. 332.5 and 332.4).

The embankment fill and topsoil are underlain by native firm to stiff silty clay of low to high plasticity. SPT N-values obtained in the clay ranged from 5 to 10 blows/0.3 m, and the undrained shear strength measured by field vane testing ranged from 65 to 135 kPa. All boreholes were terminated in the silty clay at depths between 3.0 m and 9.7 m (Elev. 329.9 and Elev. 326.5).

It is noted that the clay above 2.0 m depth in the hand auger holes was described as sandy, some gravel, with cobbles. In addition, the grain size distribution curve for a sample of this material recovered from 0.5 m depth in Borehole BH3 was similar to those obtained for the sand embankment

fill. This may indicate mixing of sand fill and clay during sampling or previous culvert construction, and/or the presence of alluvial material.

Water was measured at a depth of 3.5 m below the road grade (Elev. 332.8 and 332.7) during the field investigation conducted in May 2014. The water level will generally be governed by the water level in the creek.

3 CULVERT FOUNDATIONS

Based on the preliminary General Arrangement drawings, the replacement culvert will be installed along the same alignment as the existing culvert. It is understood that staged construction is envisioned for the culvert replacement.

Culvert types that may be considered for this site are listed below:

- Concrete box (closed) culvert composed of pre-cast segments
- Corrugated steel arch culvert
- Open footing concrete culvert
- Round corrugated steel pipe (CSP)

A comparison of the advantages and disadvantages of the various culvert types is presented in Appendix B. From a foundations and constructability perspective, use of a pre-cast box culvert or CSP culvert is preferred based on the following considerations:

- A pre-cast box or CSP culvert can be installed relatively quickly, and segmental installation is amenable to staged construction;
- The depth of excavation and groundwater control requirements will be minimized; and
- A segmental pre-cast structure or CSP can accommodate potential differential settlement along the culvert axis.

A sheet pile wall culvert could also be considered at this site. Additional drilling to greater depths will be required to confirm design parameters if this type of culvert will be considered.

Recommendations for design and installation of a box culvert, steel arch, open footing concrete culvert, and a CSP are presented below.

3.1 Concrete Box Culvert on Native Soils

The preliminary General Arrangement drawing indicates that the replacement culvert will have an approximate width of 6.5 m, height of 3.0 m and length of 38.5 m. The base of the culvert will be placed at approximate Elev. 331.7 (inlet) to 330.6 (outlet).

Based on the borehole information, the subgrade at the level of the culvert base will consist of native firm to stiff silty clay. The firm to stiff clay subgrade is considered suitable for support of the replacement culvert.

In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements should be provided on the approved subgrade under the base of the box culvert, as per OPSS 422 and OPSD 803.010. A 75 mm thick levelling course should be placed on top of the bedding material as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The factored geotechnical resistance at the Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS) for a 6.7 m wide box culvert founded on bedding placed on firm to stiff silty clay as described above can be assumed as follows:

Factored Geotechnical Resistance at ULS of 200 kPa

Geotechnical Resistance at SLS (less than 25 mm settlement) of 150 kPa.

The resistance values provided are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clause 6.10.3 and Clause 6.10.4.

Preparation of the culvert subgrade should include removal of any organic soils or other unsuitable materials remaining after excavation to the subgrade level. In the event that subexcavation is required, the width of the subexcavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The subexcavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted in accordance with OPSS.PROV 501.

The culvert should be designed to resist external loadings including lateral earth pressures, hydrostatic pressure, the weight of embankment fill, traffic loadings and surcharge due to construction equipment.

Foundation design for wing walls, if required, are discussed further in the report.

3.2 Corrugated Steel Arch or Open Footing Concrete Culvert

The preliminary General Arrangement drawing for a steel arch option indicates a 6.6 m wide by 2.9 m high arch with a streambed level of Elev. 332.8 at the inlet and Elev. 332.6 at the outlet of the culvert. A 600 mm thick layer of river stone will be placed on the streambed.

Strip footings supporting a steel arch or open footing concrete culvert should be founded on the firm to stiff silty clay at or below Elev. 331.0. The footings should extend below any existing embankment fill and surficial organic materials, where encountered. A factored geotechnical resistance at the Ultimate Limit State (ULS) of 200 kPa and a geotechnical reaction at Serviceability Limit State (SLS) of 150 kPa are recommended for design of 1.5 to 2.5 m wide footings constructed on the silty clay at this level.

The resistance values may be increased to 285 kPa at factored ULS and 200 kPa at SLS by subexcavating to a depth of 1.5 m below the design founding level and placing a minimum 1.5 m thick layer of granular engineered fill below the wall base. The granular fill should comprise OPSS Granular B Type II material compacted in accordance with OPSS.PROV 501. The width of the subexcavation should be defined by a line extending outward and downward at 1H:1V starting 0.3 m beyond the outside edge of the proposed wall.

The resistance values provided are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance between precast concrete and the underlying soil should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for firm to stiff silty clay or 0.5 for granular fill.

All organic soil and excessively loose/soft material should be removed from the footing subgrade. The founding surface should be protected from softening during construction by placement of a 75 mm mud slab on the prepared bearing surface as soon as practical following inspection and approval.

Scour and erosion protection must be provided for the footings.

3.3 Corrugated Steel Pipe (CSP) Culvert

The preliminary General Arrangement drawing for a CSP option (September 2016) indicates twin 3600 mm diameter pipes with obvert levels near Elev. 331.5 and a cover of 1.5 m. River stone will be placed in the culvert up to the streambed level.

Based on the borehole information, the subgrade at the level of the culvert base will consist of native firm to stiff silty clay. The firm to stiff clay subgrade is considered suitable for support of the replacement culvert.

In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements should be provided on the approved subgrade under the base of the CSP, as per OPSS 421 and OPSD 802.014. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

Preparation of the culvert subgrade should include removal of any organic soils or other unsuitable materials remaining after excavation to the subgrade level. In the event that subexcavation is required, the width of the subexcavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The subexcavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted in accordance with OPSS.PROV 501.

The culvert should be designed to resist external loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

3.4 Frost Cover

The design depth of frost penetration at this site is 2.3 m. The base of all footings, if employed, must be provided with a minimum of 2.3 m of earth cover as protection against frost action. The frost cover requirement does not apply to the base of a box culvert or CSP. Frost treatment should be as per OPSD 803.010 for a box culvert, and as per OPSD 803.031 for a CSP. A frost taper is not required where the excavation backfill consists of non-frost susceptible granular material similar to the existing sand embankment fill.

4 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Culvert backfill should consist of granular material conforming to OPSS.PROV 1010 Granular A, Granular B Type II or Granular B Type III specifications. Granular backfill should be placed to the extents shown in OPSD 803.010. Backfilling to the culvert should be in accordance with OPSS 401 for a CSP or OPSS 902 for a box culvert.

Backfill should be placed and compacted in accordance with OPSS.PROV 501. The backfill must be placed in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation should be within 400 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction equipment to be used adjacent to culverts should be restricted in accordance with OPSS.PROV 501.

Lateral earth pressures acting on the culvert walls may be assumed to be distributed triangularly and to be governed by the characteristics of the abutment backfill and the underlying soils. 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 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 retaining walls are dependent on the material used as backfill. Recommended values of the earth pressure coefficients are shown in Table 4.1.

Table 4.1 – Earth Pressure Coefficients, K

Wall Condition	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ; \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Existing Sand Fill $\phi = 32^\circ; \gamma = 21.2 \text{ kN/m}^3$	
	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	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

In accordance with Clause 6.12.3 of the CHBDC 2014, 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.

5 SEISMIC CONSIDERATIONS

Based on the undrained shear strength of the silty clay, Site Class D (stiff soil) should be assumed to evaluate the seismic site response, as per Table 4.1, Clause 4.4.3.2 of the CHBDC 2014.

The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.038 as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, 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 5.1 may be used:

Table 5.1 – Earth Pressure Coefficients for Earthquake Loading

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

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

** After Woods

The firm to stiff silty clay underlying this site is not considered to be prone to liquefaction. In view of the soil conditions and the estimated peak ground acceleration, liquefaction is not a concern.

6 WINGWALLS

It is understood that gabion walls will be constructed at the four quadrants of the replacement culvert. The gabion walls will have a height of 3.3 to 4.0 m, a base width of 2.0 to 2.5 m, and extend laterally 6.0 to 9.0 from the culvert.

Based on the borehole data, it is recommended that the gabion walls be founded on the native firm to stiff silty clay at Elev. 332.0 or lower. A factored geotechnical resistance at the Ultimate Limit State (ULS) of 150 kPa and a geotechnical reaction at Serviceability Limit State (SLS) of 90 kPa are recommended for design of a 2.5 m wide gabion wall constructed at this level. The SLS reaction value may be increased to 105 kPa provided the granular bedding layer is increased to a minimum thickness of 600 mm.

It is estimated that gabion walls designed using the above SLS values will induce foundation settlement in the order of 25 mm. Approximately half of the estimated settlement is expected to occur over a 6-month period following completion of the fill placement and the remaining settlement will take place in approximately 2 to 3 years after construction. The culverts and gabion walls must be designed to accommodate the estimated settlement.

The Factored Geotechnical Resistance at ULS and Geotechnical Reaction at SLS were estimated adopting geotechnical resistance factors of 0.5 and 0.8 for ultimate and serviceability limit states, respectively for a “typical” degree of the site understanding, as per CHBDC 2014.

The resistance values provided are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design should be reduced in accordance with the CHBDC 2014 Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for firm to stiff silty clay. Sliding resistance between the gabions and the underlying granular material should be calculated assuming an ultimate coefficient of friction of 0.5.

Preparation of the wall subgrade should be carried out as per the culvert subgrade. In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements should be provided on the approved subgrade prior to construction of the wing walls. The bedding material should be placed in the dry as soon as practical following subgrade inspection and approval. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

7 EMBANKMENT RESTORATION

The existing highway embankment is up to 4 m in height at the culvert locations, and the embankment slopes appear to be performing satisfactorily. Provided that the embankment is reconstructed at the same slope inclination as the existing embankment, but not steeper than 2H:1V, the restored embankment slope should remain stable.

The preliminary GA indicates that up to 1.0 m of new fill will be placed behind the gabion walls at the northwest and southeast quadrants to balance the lateral earth pressures acting on the sides of the culvert inlet/outlet. It is estimated that the gabion walls and additional fill will induce foundation settlement in the order of 25 to 30 mm. Approximately half of the estimated settlement is expected to occur over a 6-month period following completion of the fill placement and the remaining settlement will take place in approximately 2 to 3 years after construction. The culverts and the gabion walls must be designed to accommodate the estimated settlement.

Embankment restoration should be carried out in accordance with OPSS.PROV 206. In general, surface vegetation, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from within the embankment footprint prior to placement of fill.

8 EROSION CONTROL

Erosion protection must be provided along any soil surfaces that may be in contact with the stream flow. In general, this will involve placement of rock protection at the culvert inlet and outlet areas to prevent erosion and undermining of the culvert base or footings.

A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

For a concrete box culvert, a concrete cut-off wall should be used to minimize the potential for erosion or piping around the culvert.

A clay seal may be used to minimize the potential for erosion near the inlet area. Where applicable, the clay seal should extend to the order of 0.3 m above the high water level and laterally for the width of the granular backfill material, and have a minimum thickness of 0.5m. The material requirements should be in accordance with OPSS 1205. A geosynthetic liner may be used as a clay seal.

9 EXCAVATION AND GROUNDWATER CONTROL

Excavation for culvert replacement will be carried out through the existing embankment fill and into the native silty clay extending below the water level.

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the native silty clay and the embankment fill above the water level at this site are classified as Type 3 soils. Cohesionless fill and any soft/loose alluvial materials below the water level are classified as Type 4 soils.

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

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out at or below the creek water level, and diversion of creek flow will be required. The underlying clay subgrade is relatively impermeable, however seepage should be anticipated from the embankment fill and any seams or sandy zones in the clay. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps within the enclosure will be required to maintain dry excavations during the course of staged construction.

The design of the shoring and 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. Unwatering must remain operational and effective until the culvert is installed and backfilled. Suggested wording for an NSSP in this regards is included in Appendix C.

Roadway protection will be required during construction staging. Roadway protection should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2. The design of roadway protection is the responsibility of the Contractor and all shoring should be designed by a Professional Engineer experienced in such designs.

10 CONSTRUCTION CONCERNS

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

- A suitable dewatering/unwatering system must be employed to enable construction in the dry and prevent sloughing and instability of the excavation walls.
- The thickness and depth to the base of the existing fill and any soft streambed deposits may vary at locations away from the boreholes.
- Cobbles are present within the embankment fill. These materials may interfere with excavation or installation of roadway protection systems. The Contractor must be prepared to remove or otherwise penetrate these obstructions.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e, as a pad for crane support). Site conditions may limit the type of equipment suitable for use. The design and safety of any temporary works is the responsibility of the Contractor.

Due to the culvert skew, staged construction for culvert replacement will require temporary widening of the approximate 4 m high roadway embankment. Placement of the temporary embankment fill beyond the existing embankment footprint is expected to result in up to 70 mm of foundation settlement during construction. Given the magnitude of the estimated settlement, the pavement over

the widened roadway platform should be routinely inspected and padded as necessary to maintain traffic during the construction period.

11 CLOSURE

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

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Appendix A

Record of Borehole Sheets and Borehole Location Plan

Geocres No. 52C-34

EXPLANATION OF TERMS USED IN REPORT

SPT 'N' VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE OF THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51 mm O.D. SPLIT BARREL SAMPLES TO PENETRATE 0.3 m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5 kg, FALLING FREELY A DISTANCE OF 0.76 m. FOR PENETRATION OF LESS THAN 0.3 m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST (DCPT): CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51 mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3 m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS

TEXTURAL CLASSIFICATION OF SOILS

BOULDERS	COBBLES	GRAVEL	SAND	SILT	CLAY
GREATER THAN 200 mm	75 TO 200 mm	4.75 TO 75 mm	0.075 TO 4.75 mm	0.002 TO 0.075 mm	LESS THAN 0.002 mm

COARSE GRAIN SOIL DESCRIPTION (50% GREATER THAN 0.075 mm)

TERMINOLOGY	TRACE OR OCCASIONAL	SOME	WITH	ADJECTIVE (e.g. SILTY OR SANDY)	AND (e.g. SAND AND SILT)
	LESS THAN 10%	10 TO 20%	20 TO 30%	30 TO 40%	40 TO 60%

CONSISTENCY*: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (C_u) AND SPT 'N' VALUES AS FOLLOWS

C_u (kPa)	0 – 12	12 – 25	25 – 50	50 - 100	100 - 200	> 200
N (BLOWS / 0.3 m)	<2	2 - 4	4 - 8	8 - 15	15 - 30	>30
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS ON DENSENESS AS INDICATED BY SPT 'N' VALUES AS FOLLOWS

N (BLOWS / 0.3 m)	0 – 5	5 – 10	10 – 30	30 – 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100 mm+ IN LENGTH EXPRESSED AS A PERCENTAGE OF THE LENGTH OF THE CORING RUN.

THE **ROCK QUALITY DESIGNATION (R.Q.D)** FOR MODIFIED RECOVERY IS:

R.Q.D (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

LEGEND OF RECORDS FOR BOREHOLES: SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

SS	SPLIT SPOON SAMPLE	WS	WASH SAMPLE
TW	THIN WALL SHELBY TUBE SAMPLE	AS	AUGER (GRAB) SAMPLE
PH	SAMPLER ADVANCED BY HYDRAULIC PRESSURE	TP	THIN WALL PISTON SAMPLE
WH	SAMPLER ADVANCED BY SELF STATIC WEIGHT	PM	SAMPLER ADVANCED BY MANUAL PRESSURE
SC	SOIL CORE	RC	ROCK CORE
	WATER LEVEL	$SENSITIVITY = \frac{UNDISTURBED\ SHEAR\ STRENGTH}{REMOLDED\ SHEAR\ STRENGTH}$	

*HIERARCHY OF SOIL STRENGTH PREDICTION: **1)** LABORATORY TRIAXIAL TESTING. **2)** FIELD INSITU VANE TESTING. **3)** LABORATORY VANE TESTING. **4)** SPT VALUES. **5)** POCKET PENETROMETER.

RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. 6013-E-0023 LOCATION Westover Creek Culvert: STA. 20+501 - 4.0 m LT ORIGINATED BY JF
 DIST HWY 11 BOREHOLE TYPE Hollow Stem Auger COMPILED BY ML
 DATUM LOCAL DATE 2014 05 02 CHECKED BY DB

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			20 40 60 80 100	50 100 150 200 250	20 40 60						
101.5	GROUND SURFACE															
101.4	ASPHALT - 75 mm		AS1	AS												Water level at 3.5 m on completion
100.7	FILL - SAND & CRUSHED GRAVEL - trace silt, brown															
0.8	FILL - SAND - some gravel and silt, brown, dense to very dense		SS2	SS	28											
			SS3	SS	50+											
			SS4	SS	100+											
			SS5	SS	100+											
	- COBBLES															
97.7																
3.8	CLAY - Silty, trace sand and gravel, grey, firm to stiff		SS6	SS	10											
			SS7	SS	9											
			SS8	SS	5											
			SS9	SS	5											
			SS10	SS	5											
91.8			SS11	SS	6											
9.7	End of Borehole at 9.7 m															

ON_MOT-HIGH VANES GS-TB-018738 - WESTOVER CREEK CULVERT.GPJ DST_MIN.GDT 6/11/14

+ ³, X ³: Numbers refer to Sensitivity ○ ³% STRAIN AT FAILURE

ENCLOSURE 1

RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. 6013-E-0023 LOCATION Westover Creek Culvert: STA. 20+480 - 4.0 m RT ORIGINATED BY JF
DIST HWY 11 BOREHOLE TYPE Hollow Stem Auger COMPILED BY ML
DATUM LOCAL DATE 2014 05 02 CHECKED BY DB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20	40	60	80		
101.4	GROUND SURFACE												
101.3	ASPHALT - 75 mm		AS1	AS									
100.7	FILL - SAND & CRUSHED GRAVEL - trace silt, brown												
0.8	FILL - SAND - with silt, some gravel, brown, dense to very dense		SS2	SS	29								
			SS3	SS	29								
			SS4	SS	27								
			SS5	SS	100+								
97.6	- COBBLES												
3.8	CLAY - Silty, some sand and gravel, trace organics, grey, firm to stiff		SS6	SS	7								
			SS7	SS	5								
			SS8	SS	6								
			SS9	SS	5								
			SS10	SS	5								
			SS11	SS	7								
91.7	End of Borehole at 9.7 m												
9.7													

ON_MOT-HIGH VANES GS-TB-018738 - WESTOVER CREEK CULVERT.GPJ DST_MIN.GDT 6/11/14

+ ³, X ³: Numbers refer to Sensitivity ○ ³% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. 6013-E-0023 LOCATION Westover Creek Culvert: STA. 20+475 - 17.5 m RT ORIGINATED BY JF
 DIST HWY 11 BOREHOLE TYPE Hollow Stem Auger COMPILED BY ML
 DATUM LOCAL DATE 2014 05 02 CHECKED BY DB

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
97.4	GROUND SURFACE							20 40 60 80 100						GR SA SI CL
97.2	TOPSOIL							50 100 150 200 250						
0.2	CLAY - Sandy, some gravel, grey, very stiff - COBBLES		AS1	AS			97							15 59 (26)
							96							CPT 964 kPa CPT 1378 kPa
			AS2	AS										
95.4	CLAY - Silty, some sand, trace gravel and silt, grey, very stiff						95							CPT 1102 kPa CPT 1205 kPa
2.0			AS3	AS										
94.3	End of Borehole at 3.1 m													
3.1														

ON_MOT-HIGH VANES GS-TB-018738 - WESTOVER CREEK CULVERT.GPJ DST_MIN.GDT 6/11/14

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

ENCLOSURE 3

RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

W.P. 6013-E-0023 LOCATION Westover Creek Culvert: STA. 20+505 - 13.5 m LT ORIGINATED BY JF
 DIST HWY 11 BOREHOLE TYPE Hollow Stem Auger COMPILED BY ML
 DATUM LOCAL DATE 2014 05 02 CHECKED BY DB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL LIMIT 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		WATER CONTENT (%)				
98.1	GROUND SURFACE							20 40 60 80 100						
97.9 0.2	TOPSOIL CLAY - Sandy, some gravel and organics, trace silt, grey, very stiff - COBBLES						98	50 100 150 200 250	○ UNCONFINED + FIELD VANE		W _P W W _L			
							97		□ QUICK TRIAXIAL × LAB VANE					
96.1 2.0	CLAY - Silty, some sand and gravel, grey, very stiff						96							
95.1 3.0	End of Borehole at 3.0 m													

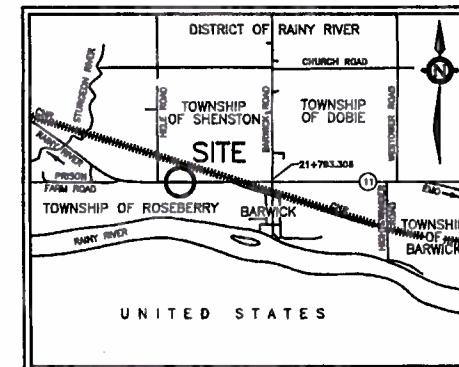
ON_MOT-HIGH VANES GS-TB-018738 - WESTOVER CREEK CULVERT.GPJ DST_MIN.GDT 6/11/14

+ ³, × ³: Numbers refer to Sensitivity ○ ³% STRAIN AT FAILURE

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METERS

CONT No 6013-E-0023
WP No 6944-10-01
SITE No 45-137/C
GEOCRES No 52C-34

WESTOVER CREEK
CULVERT REPLACEMENT HWY 11
STA 20+400 TO STA 20+600
Survey 00-00 Revised



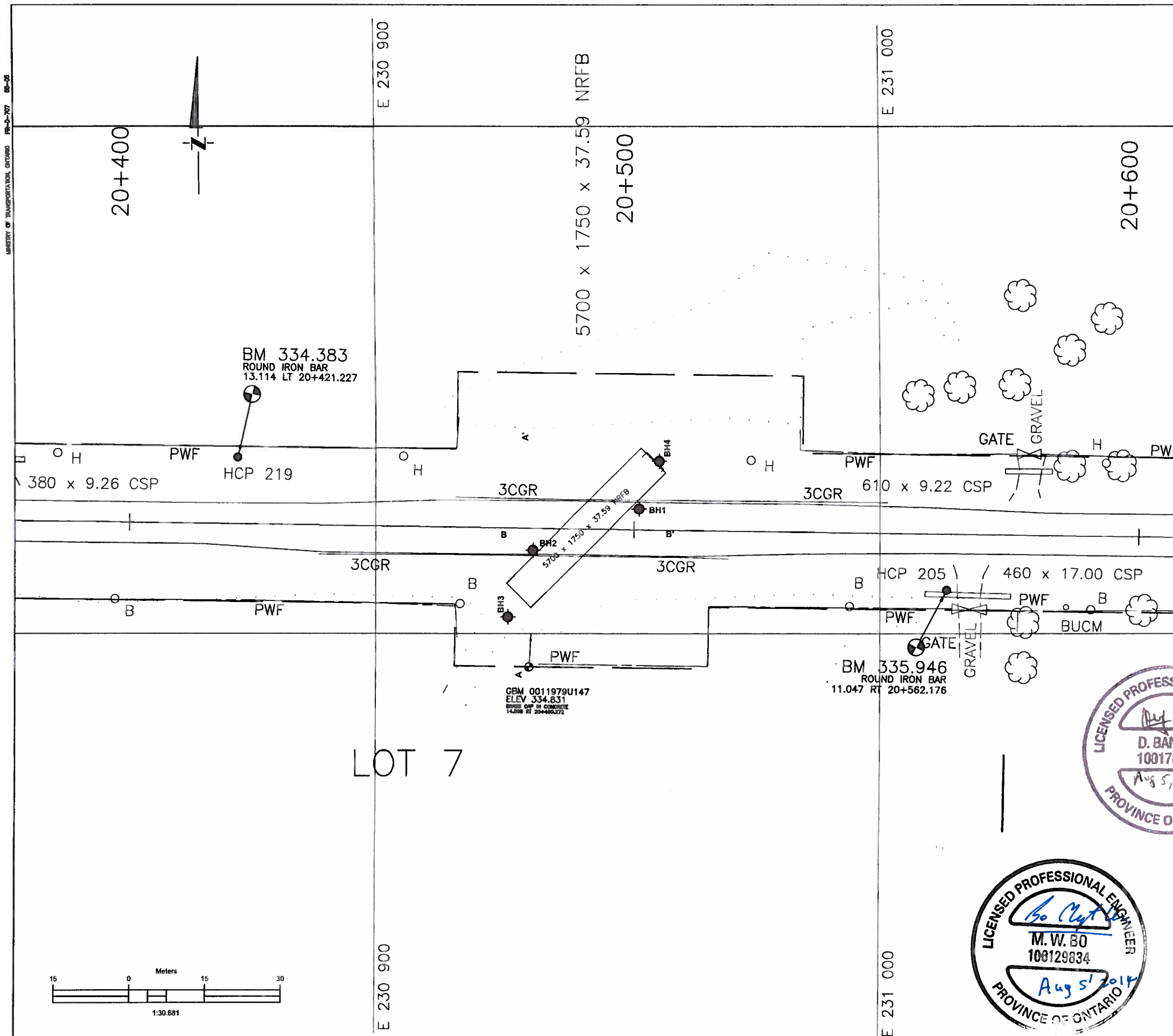
KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

LEGEND					
	Borehole		Borehole with DCPT		Pavement Hole
	Rock Probe		Blows/0.3m (Std. Pen Test, 475 J/Blow)		Water level at time of investigation
	Fill		Organics		Topsoil
	Till		Bedrock		Sand
	Silt		Clay		Sand & Gravel
	Boulders				

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.
Borehole coordinate system reference: UTM NAD83 Zone 17T

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DRAWING 1



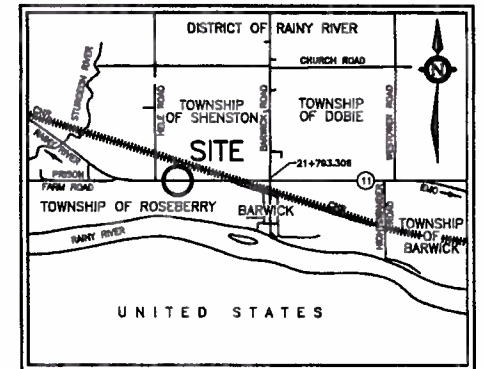
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METERS

CONT No 6013-E-0023
WP No 6944-10-01
SITE No 45-137/C
GEOCRES No 52C-34



WESTOVER CREEK
CULVERT REPLACEMENT HWY 11
STA 20+400 TO STA 20+600
Survey 00-00 Revised

SHEET



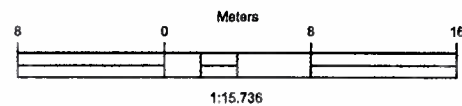
KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

LEGEND					
◆	Borehole	◆	Borehole with DCPT	◆	
⊕	Pavement Hole	●	Rock Probe	'N'	Blows/0.3m (Std. Pen Test, 475 J/Blow)
▽	Water level at time of investigation.				
▨	Fill	▨	Sand	▨	Silt
▨	Organics	▨	Topsoil	▨	Clay
▨	Bedrock	▨	Sand & Gravel	▨	Boulders
No.	Elevation	Northing	Easting	Station	Offset
BH1	101.481	5300524	230952	20+501	4.0 m LT
BH2	101.414	5300516	230951	20+480	4.0 m RT
BH3	97.378	5300503	230926	20+475	17.5 m RT
BH4	98.089	5300533	230956	20+505	13.3 m LT

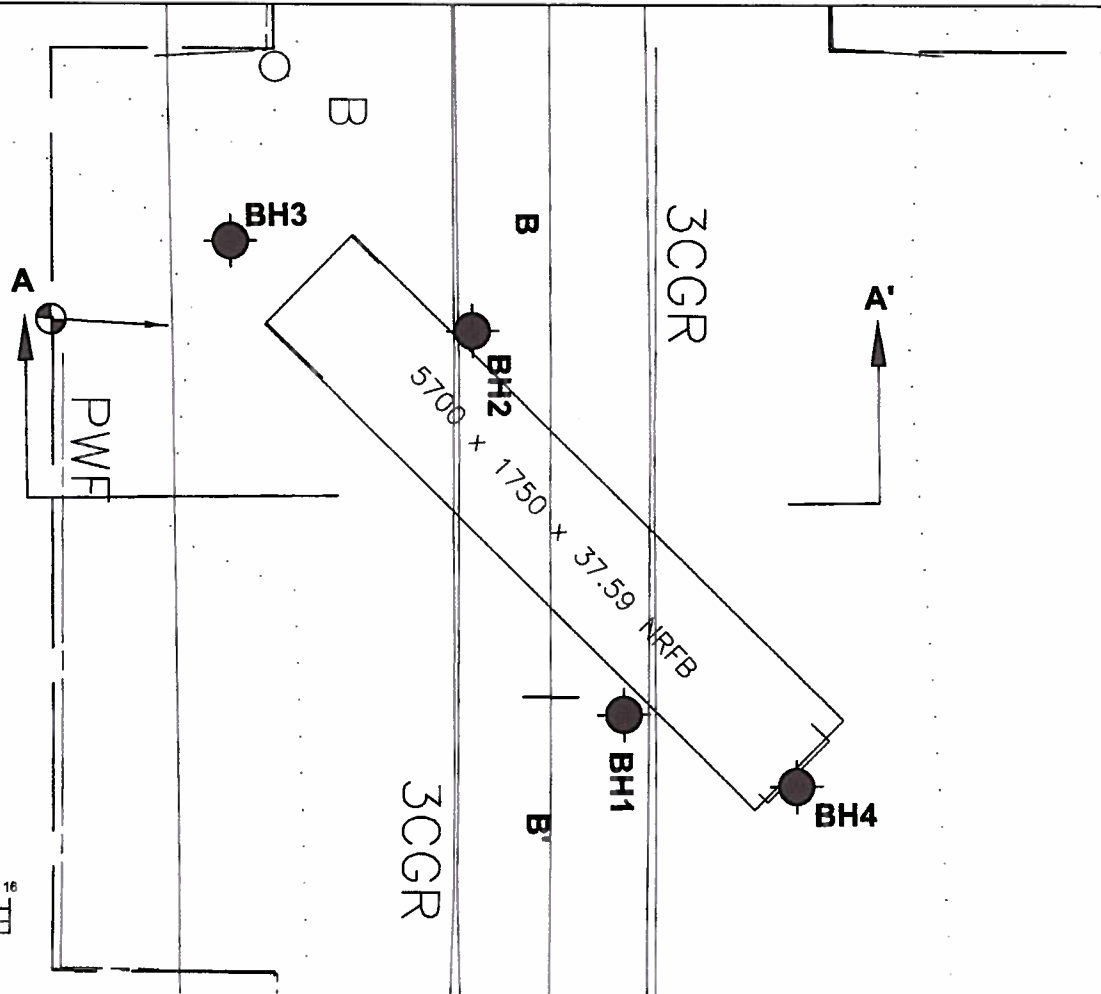
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DRAWING 2



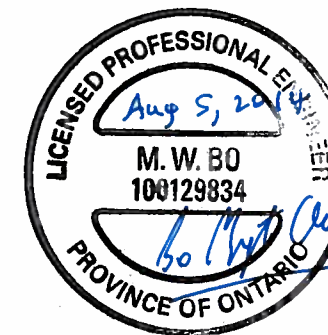
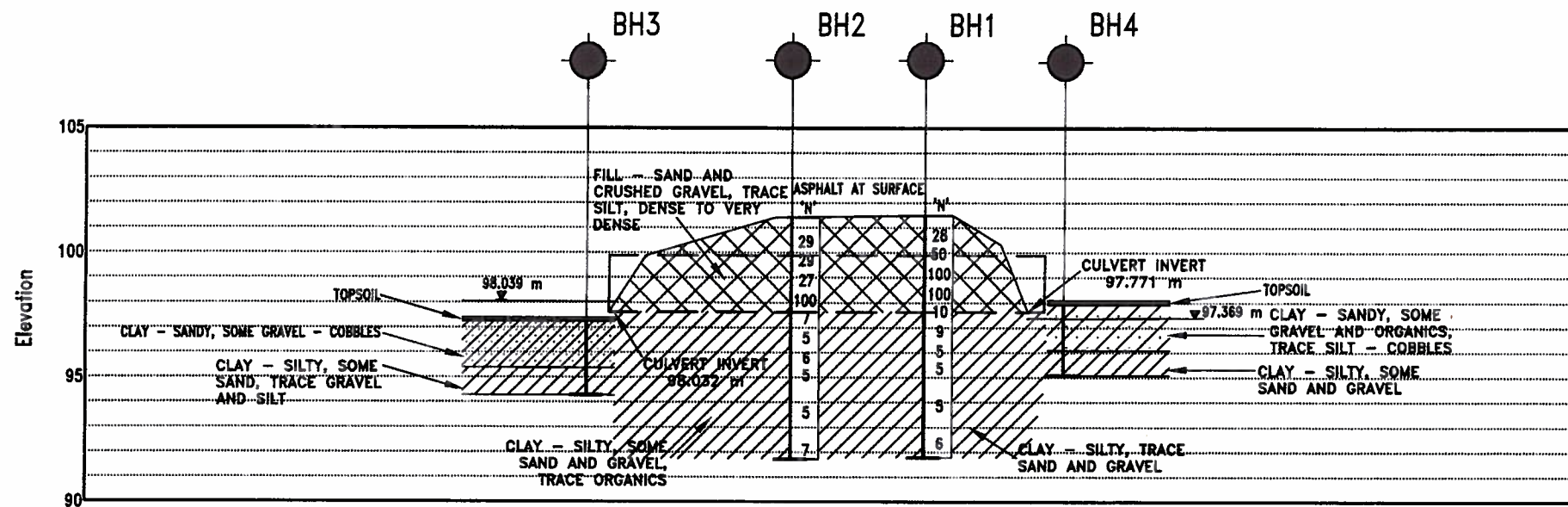
GBM 0011979U147
ELEV 334.831
BRASS CAP IN CONCRETE
14.538 RT 20+480.272



5700 x 175

2

PROFILE ALONG SECTION A-A'



JLGR

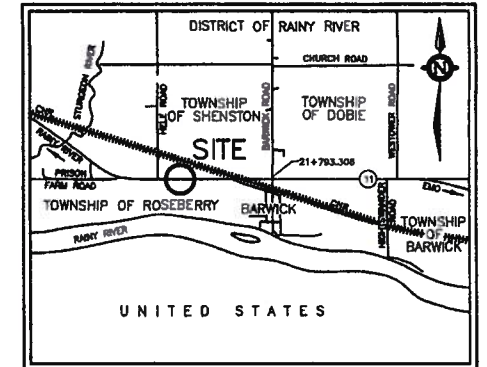
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETERS + METERS

CONT No 6013-E-0023
WP No 6944-10-01
SITE No 45-137/C
GEOCRE No 52C-34



WESTOVER CREEK
CULVERT REPLACEMENT HWY 11
STA 20+400 TO STA 20+600
Survey 00-00 Revised

SHEET



KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

B

BH2

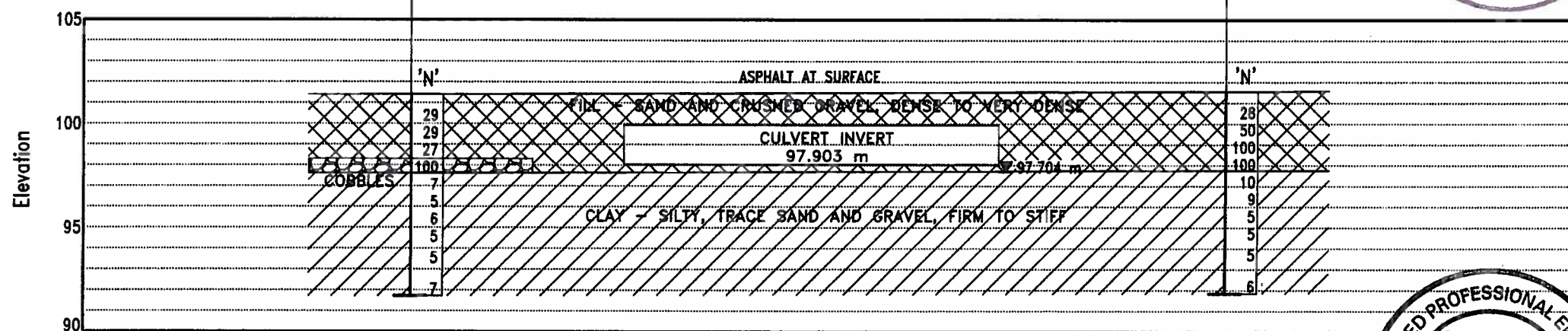
BH1

B'

BH2

PROFILE ALONG SECTION B-B'

BH1



LEGEND					
◆	Borehole				
◆	Borehole with DCPT				
◆	Pavement Hole				
●	Rock Probe				
'N'	Blows/0.3m (Std. Pen Test, 475 J/Blow)				
▽	Water level at time of investigation.				
▨	Fill	▨	Sand		
▨	Organics	▨	Silt		
▨	Topsoil	▨	Clay		
▨	Till	▨	Sand & Gravel		
▨	Bedrock	▨	Boulders		
No.	Elevation	Northing	Easting	Station	Offset
BH1	101.481	5390524	230952	20+501	4.0 m LT
BH2	101.414	5390518	230931	20+480	4.0 m RT
BH3	97.379	5390503	230928	20+475	17.5 m RT
BH4	98.089	5390533	230956	20+505	13.5 m LT

NOTE:
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Appendix B

Comparison of Foundation Alternatives

COMPARISON OF CULVERT TYPE / FOUNDATION ALTERNATIVES

Concrete Box Culvert	Open Footing Concrete Culvert	Corrugated Steel Arch Culvert	Corrugated Steel Pipe Culvert
<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively rapid installation and shorter construction time. ii. Less disturbance to subgrade soils if precast units are used. iii. Loading is spread over a larger width, hence lesser geotechnical resistance is required. iv. Typically least costly culvert type. v. Can tolerate some differential settlement. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Excavation to place bedding material will extend below water level. ii. Maintenance of water flow may be an issue and require a sacrificial culvert. iii. Potential impact on fisheries. <p>RECOMMENDED</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Potentially less disturbance of creek channel. ii. Conventional construction. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires deeper excavation for strip footing construction. ii. Potentially more difficult unwatering requirements. iii. Possible inadequate geotechnical resistance available in native soils. iv. Cannot tolerate differential settlement. <p>FEASIBLE</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively rapid installation if precast units are used. ii. May be more cost effective than cast-in-place culverts. iii. Less disturbance of creek channel. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires deeper excavation for strip footing construction. ii. Potentially more difficult unwatering requirements. iii. Possible inadequate geotechnical resistance available in native soils. iv. Cannot tolerate differential settlement. <p>FEASIBLE</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively rapid installation. ii. Ease of construction. iii. Geotechnical resistance is not a concern. iv. Can tolerate differential settlement. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Steel pipe may have a shorter service life than concrete alternatives. ii. Multiple pipes may be required to accommodate hydraulic demands. <p>RECOMMENDED</p>

Appendix C

List of OPSSs and OPSDs and Suggested Wording for NSSP

1. List of OPSS and OPSD Documents Relevant to this Project

- OPSS 206
- OPSS 422
- OPSS.PROV 501
- OPSS.PROV 539
- OPSD 803.010
- OPSS 804
- OPSS 902
- OPSS.PROV 1010
- OPSS 1205

2. Suggested Wording for NSSP on Dewatering

Dewatering shall be provided by the Contractor during structure excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the creek and groundwater level may lead to instability and sloughing of the cohesionless embankment fill and upper firm silty clay with sand seams. The dewatering system must remain operational and effective until the culvert is installed and backfilled.