



**FOUNDATION INVESTIGATION AND DESIGN REPORT
for
MCGILLVRAY CREEK TRIBUTARY CULVERT
MAIN STREET EXTENSION STATION 11+125
SITE NO. 44-507
TOWNSHIP OF SOUTH HIMSWORTH
NORTH BAY AREA, ONTARIO
G.W.P. 323-00-00**

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PML Ref.: 10TF013A-C3
Index No.: 321FIR and 322FDR
GEOCRES No.: 31L-162
December 12, 2012



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FOUNDATION INVESTIGATION REPORT

for
McGillvray Creek Tributary Culvert
Main Street Extension Station 11+125
Site No. 44-507
Township of South Himsworth
North Bay Area, Ontario
GWP 323-00-00

1. INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the proposed culvert at the Main Street Extension for the Tributary to McGillvray Creek. The culvert is part of the new interchange at the south entrance to Powassan project which extends from 5.7 km south of the Highway 534 to northerly 5.0 km. The study was carried out by Peto MacCallum Ltd. (PML) for AECOM Canada Ltd (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

The culvert is at approximate Station 11+125, Main Street Extension chainage, in the Township of South Himsworth (ref. General Arrangement Drawing 'Main Street Extension Box Culvert' prepared by AECOM dated December 2010).

The purpose of this report was to summarize the subsurface stratigraphy encountered in the foundation investigation at the proposed culvert.

2. SITE DESCRIPTION AND GEOLOGY

The contemplated new culvert will be located on the proposed Main Street Extension about 50 m south of the existing Chiswick Line and about 150 m east of the existing Highway 11 northbound lanes in the Municipality of Powassan. The site is about 34 km south of the City of North Bay in the Geographic Township of South Himsworth.

Land use in the vicinity of the site includes the existing Chiswick Line and farming land. The local topography of the culvert site is generally flat and sloping to the west. The Tributary Creek flows approximately in an east to west direction at the proposed Main Street Extension. The ground cover includes grasses and bushes near the creek area and stands of trees elsewhere.



The project site is located within the physiographic region known as the Number 11 Strip. The soil cover at the project site is from sandy glaciolacustrine plain deposits which overlies Precambrian age monzonitic (granitic) rock formation.

3. INVESTIGATION PROCEDURES

The subsurface investigation was carried out during the period of December 21 to 23, 2011. A total of three boreholes (CM-1 to CM-3) were drilled to 3.1 to 5.4 m at the locations shown on Drawing M-1, appended. The culvert location was not accessible from the south at the time of the fieldwork. Consequently, the boreholes were drilled approximately 4 to 10 m away from the culvert location. Although the results of the investigation are considered representative, allowances should be made for variations in subsurface stratigraphy.

The culvert control points were staked in the field by exp Geomatics according to the GA Drawing dated December 2010 prepared by AECOM. The positions of the boreholes relative to the structure control points were selected by PML allowing for drill rig accessibility and underground utilities. The ground surface elevations at the borehole locations were established by PML using the ground surface elevations at the control points. All elevations in this report are expressed in metres.

The boreholes were advanced using continuous flight hollow stem augers through the soil cover with a track-mounted D-120 drill rig, supplied and operated by a specialist drilling contractor, working under the full-time supervision of a PML field supervisor. Borehole CM-1 extended 0.9 m into probable bedrock to 3.5 m depth using NQ diamond rock coring equipment supplemented by wash boring techniques.

Soil samples were recovered from the boreholes at regular 0.75 and 1.5 m intervals of depth using the standard penetration test method. Standard penetration tests were conducted to assess the strength characteristics of the substrata. Soils were identified in accordance with the MTO soil classification manual procedures.



The groundwater conditions in the boreholes were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, where encountered, by measuring the groundwater level in the open holes.

The boreholes were backfilled with a bentonite/cement mixture where required in accordance with the MTO guideline and MOE Reg. 903 for borehole abandonment.

The recovered soil samples were returned to our laboratory in Toronto for detailed visual examination, laboratory testing and classification. The laboratory testing program included the following tests:

- Natural moisture content determinations (10)
- Grain size distribution analyses (3)

The laboratory grain size distribution charts are presented in Figures CM-GS-1 to CM-GS-3. All of the test results are summarized on the Record of Borehole sheets.

4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole Sheets for details of the subsurface conditions including soil classifications, bedrock description, inferred stratigraphy, standard penetration test results and groundwater observations. The results of laboratory particle size distributions and moisture content determinations are also shown on the Record of Borehole Sheets.

The borehole locations, stratigraphic profile and cross-sections prepared from the borehole data are shown on Drawing M-1. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

Three boreholes (CM-1 to CM-3) were drilled along the alignment of this culvert to depths ranging from 3.1 to 5.4 m. The subsurface stratigraphy revealed in the boreholes generally comprised a topsoil underlain by cohesionless deposits of silt / sand and silt over sand. A 400 mm thick organic silt was encountered in one borehole below the topsoil. Cobbles and boulders were encountered within the



sand deposit. Granite bedrock was contacted/inferred at 2.6 to 5.4 m (elevation 253.8 to 256.8). Groundwater was observed in two boreholes.

4.1 Topsoil

A 300 mm thick topsoil layer was encountered surficially in all of the boreholes extending to 0.3 m (elevation 258.9 to 259.1).

4.2 Organic Silt

Below topsoil in borehole CM-3, a 400 mm thick organic silt layer (alluvium) was encountered at 0.3 m (elevation 258.9) extending to 0.7 m (elevation 258.5). Composite N value of 4 was obtained indicating loose relative density. One moisture content determination was 26%.

Organic soils (alluvium) should be anticipated within the areas to be excavated to found the culvert within the McGillvray Creek Tributary.

4.3 Silt / Sand and Silt

A cohesionless silt deposit containing clayey silt layers was encountered at 0.3 m (elevation 259.0 and 259.1) in boreholes CM-1 and CM-2. The unit was 1.1 and 1.9 m thick extending to a sand deposit at 1.4 and 2.2 m (elevation 257.2 and 257.9). N values ranged from 3 to 12 indicating very loose to compact relative density. A low N value of 3 may be affected by hydraulic disturbance during drilling.

Below the organic silt in borehole CM-3, a cohesionless sand and silt stratum containing organics was encountered at 0.7 m (elevation 258.5). The unit was 2.3 m thick extending to 3.0 m (elevation 256.2). N values ranged from 2 to 8 indicating very loose to loose relative density. A low N value of 2 may have been affected by hydraulic disturbance during drilling.

The results of grain size distribution analyses for silt / sand and silt samples are included in Figures CM-GS-1 and CM-GS-2. The moisture content determinations ranged from 19 to 23%, locally 33 to 49%, the higher values due to the presence of clayey silt layers and organics.



4.4 Sand

A cohesionless sand deposit was encountered below the silt / sand and silt at 1.4 to 3.0 m (elevation 256.2 to 257.9) in all of the boreholes. The unit was 0.4 to 2.4 m thick extending to the underlying probable bedrock at 2.6 to 5.4 m (elevation 253.8 to 256.8). N values ranged from 1 to 33 and 15 for 8 cm sampler penetration. The stratum was found to have a very loose to compact relative density. A low N value of 1 may have been affected by hydraulic disturbance during drilling.

The results of grain size distribution analysis for a sand sample are included in Figure CM-GS-3. The moisture content determinations ranged from 13 to 33%.

4.5 Probable Bedrock

Probable granite bedrock was contacted in borehole CM-1 at 2.6 m (elevation 256.8), where a 0.9 m long core was recovered. The recovery and RQD of the recovered sample were 100%. The core does not prove bedrock and may have been taken from a boulder in view of the core length less than 3 m long. The probable bedrock was inferred by auger refusal in boreholes CM-2 and CM-3 at 3.1 and 5.4 m (elevation 256.2 and 253.8), respectively.

The probable bedrock surface has a maximum relief of 2.4 m between the locations of the boreholes and slopes at angles of 2° to 4° in the east to west direction. Variations in bedrock depth and inclination should be anticipated at the designed culvert footprint.

4.6 Groundwater

Groundwater was encountered in boreholes CM-2 and CM-3. During augering, groundwater was observed at 1.4 and 1.5 m (elevation 257.8). Upon completion of drilling, groundwater was measured at 1.5 m (elevation 257.8) in borehole CM-2. Borehole CM-1 was charged with drilling water for rock coring. At the time of the investigation, the water level in the Tributary Creek was at about elevation 258.0 and was at about elevation 259.0 in January 2011. The groundwater level is subject to seasonal fluctuations and rainfall patterns.



5. CLOSURE

Mr. F. Portela carried out the field investigation for this study under the supervision of Mrs. N.S. Balakumaran, P. Eng., and Mr. C. M. P. Nascimento, P. Eng., Project Manager. Walker Drilling Ltd. supplied the drill rig for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

This Foundation Investigation Report was prepared by Mrs. N. S. Balakumaran, P. Eng., and reviewed by Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact. Mr. C. M. P. Nascimento, P. Eng., Project Manager conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.



Nesam S. Balakumaran, P.Eng.
Project Engineer

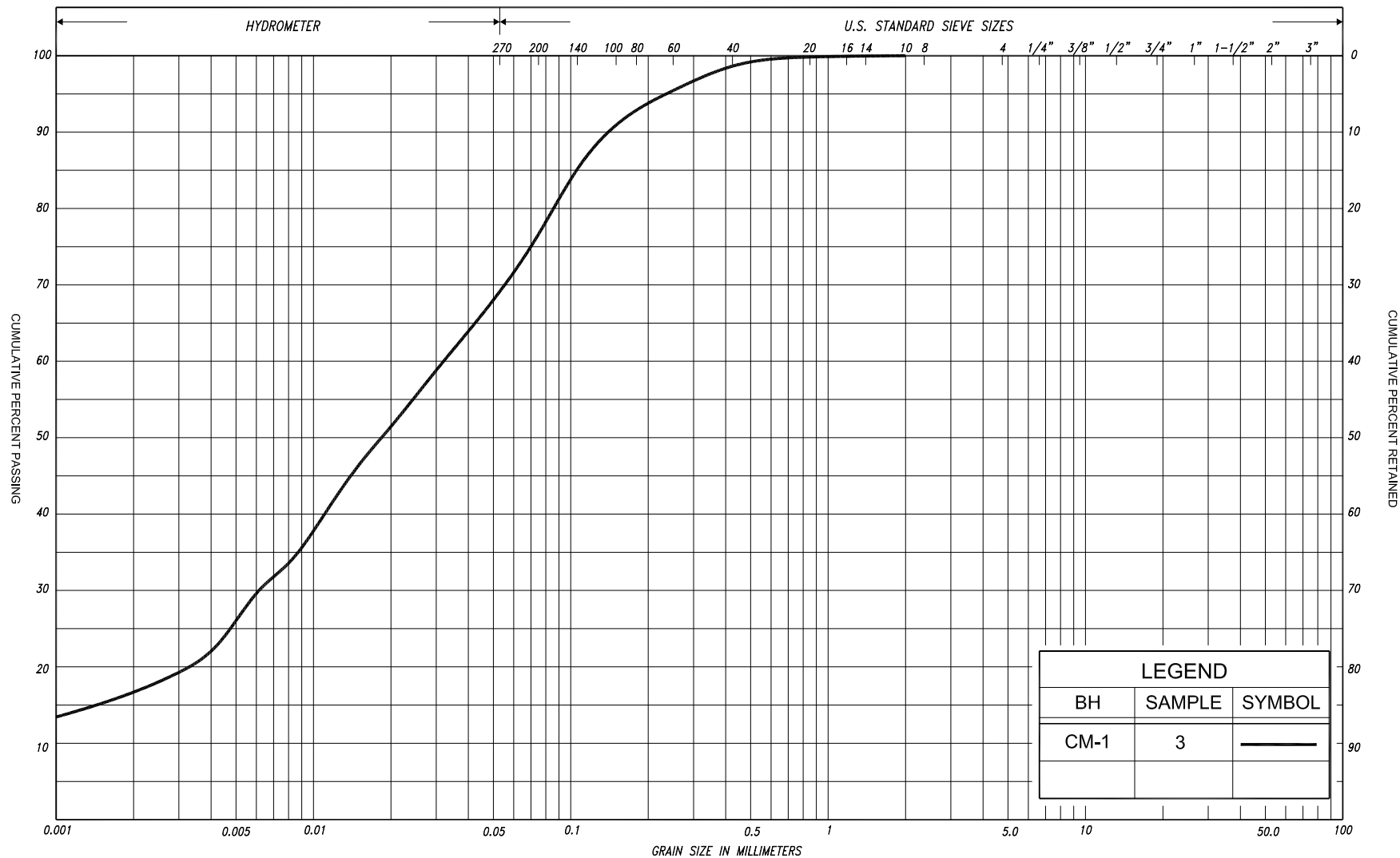


Carlos M.P. Nascimento, P.Eng.
Project Manager



Brian R. Gray, MEng, P.Eng.
MTO Designated Principal Contact

NB/CN/BRG:nb-mi-nk



SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED		
					SAND											
CLAY	FINE		MEDIUM		COARSE	FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.
	SILT											GRAVEL			COBBLES	U.S. BUREAU
CLAY		SILT		V. FINE	FINE	MED.	COARSE									
				SAND												



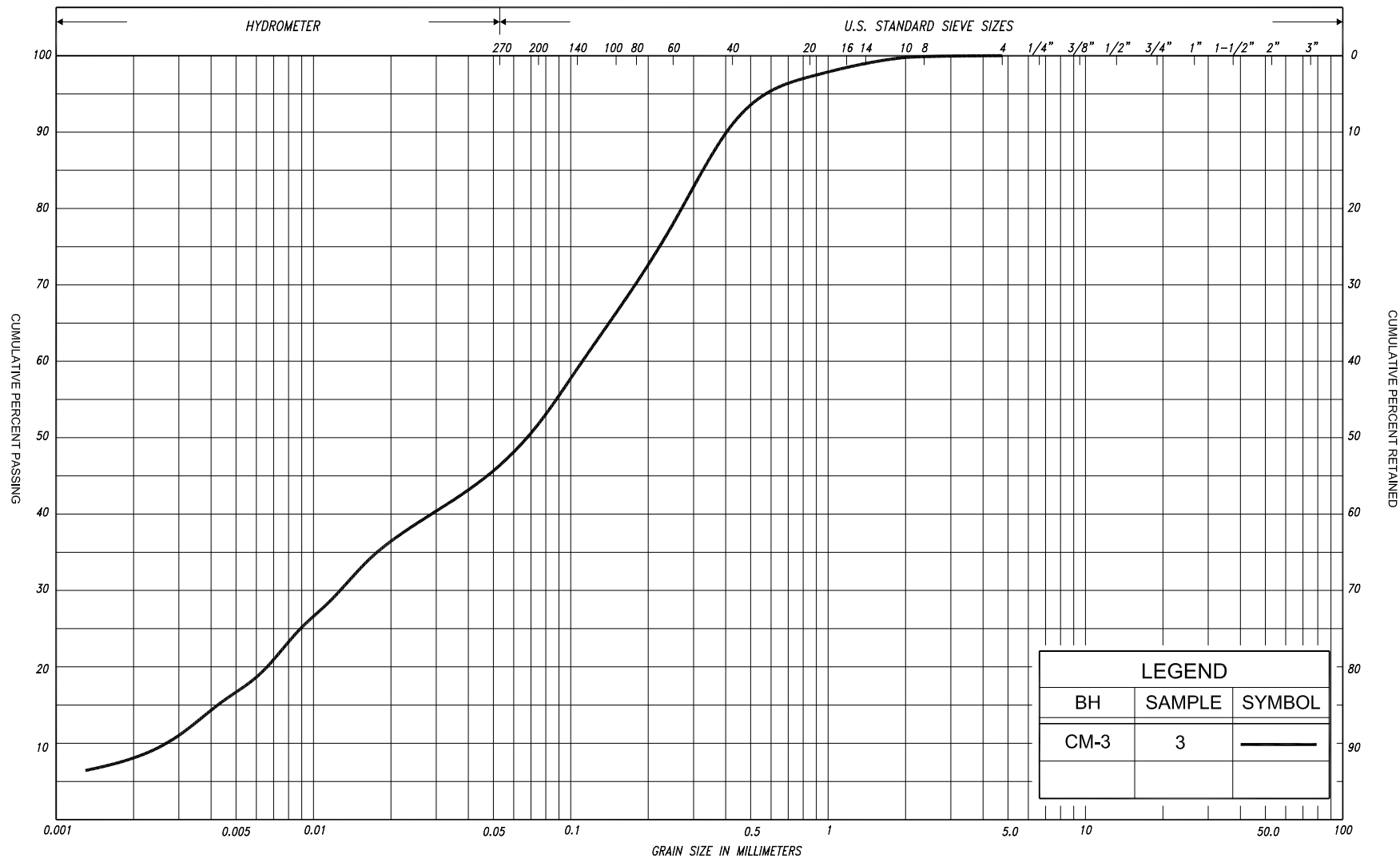
GRAIN SIZE DISTRIBUTION

SILT, with sand, some clay

FIG No. CM-GS-1

HWY: 11

G.W.P. No. 323-00-00



SILT & CLAY				FINE SAND			MEDIUM SAND		COARSE SAND	GRAVEL			COBBLES	UNIFIED
CLAY	FINE SILT			MEDIUM SILT			COARSE SILT			GRAVEL			COBBLES	M.I.T.
	CLAY			SILT			V. FINE	FINE	MED.	COARSE	GRAVEL			U.S. BUREAU



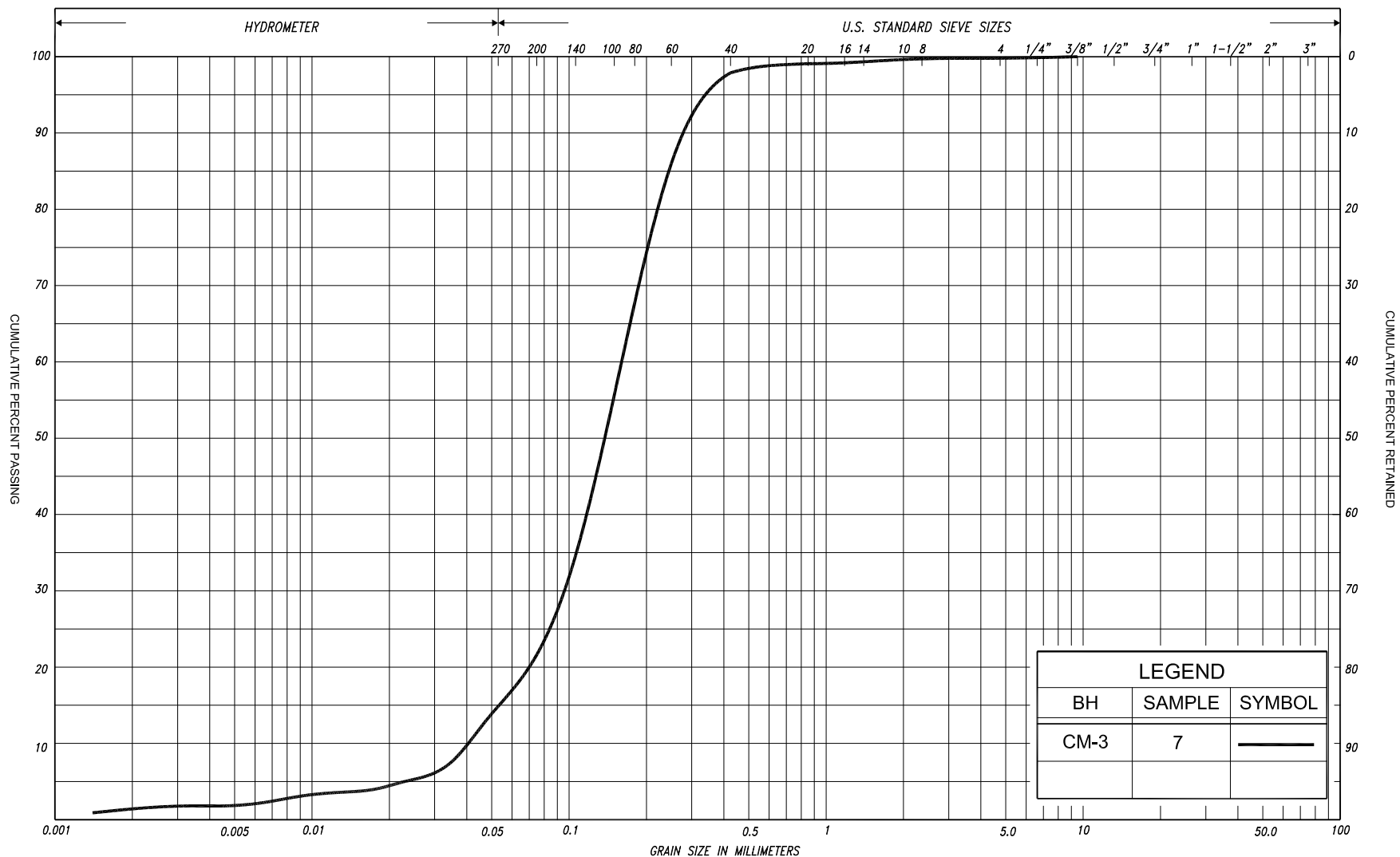
GRAIN SIZE DISTRIBUTION

SAND and Silt, trace clay

FIG No. CM-GS-2

HWY: 11

G.W.P. No. 323-00-00



SILT & CLAY					FINE		MEDIUM		COARSE		GRAVEL			COBBLES	UNIFIED		
					SAND												
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.
	SILT																
CLAY			SILT			V. FINE	FINE	MED.	COARSE		GRAVEL					U.S. BUREAU	
					SAND												



GRAIN SIZE DISTRIBUTION

SAND, some silt, trace clay

FIG No. CM-GS-3

HWY: 11

G.W.P. No. 323-00-00

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m 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: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm 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 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SILTY)	AND (AND SILT)

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

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

N (BLOWS/0.3m)	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, 100mm+ IN LENGTH EXPRESSED AS A PERCENT 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

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE
F V	FIELD VANE		

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL











ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	e_{max}	1, %	VOID RATIO IN LOOSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	e_{min}	1, %	VOID RATIO IN DENSEST STATE
ρ_w	kg/m ³	DENSITY OF WATER	S_r	%	DEGREE OF SATURATION	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
γ_w	kN/m ³	UNIT WEIGHT OF WATER	w_L	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_p	%	PLASTIC LIMIT	D_n	mm	n PERCENT - DIAMETER
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_s	%	SHRINKAGE LIMIT	C_u	1	UNIFORMITY COEFFICIENT
ρ_d	kg/m ³	DENSITY OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	m ³ /s	RATE OF DISCHARGE
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL	WTP		WETTER THAN PLASTIC LIMIT	j	kN/m ³	SEEPAGE FORCE
e	1, %	VOID RATIO						

RECORD OF BOREHOLE No CM-1

1 of 1

METRIC

G.W.P. 323-00-00 **LOCATION** Co-ords: 5 103 064.6 N ; 316 266.0 E **ORIGINATED BY** F.P.
DIST North Bay **HWY** 11 **BOREHOLE TYPE** C.F.H.S.A. and NQ Diamond Coring **COMPILED BY** N.S.B.
DATUM Geodetic **DATE** December 22, 2011 **CHECKED BY** B.R.G.

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 (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
259.4	Ground Surface						20	40	60	80	100									
0.0 259.1	Topsoil		1	SS	8		259										0 24 59 17			
0.3	Silt, trace clay clayey silt layers																			
	Loose to Brown Moist compact		2	SS	12															
	with sand, some clay																			
	Very loose		3	SS	3		258													
257.2																				
2.2	Sand, trace gravel cobbles and boulders		4	SS	15/8cm	257														
256.8																				
2.6	Compact Brown Wet Granite bedrock		5	RC NQ	REC 100%											RQD 100%				
255.9						256														
3.5	End of borehole																			
	Sample 4: Sampler bouncing																			

RECORD OF BOREHOLE No CM-2

1 of 1

METRIC

G.W.P.	<u>323-00-00</u>	LOCATION	<u>Co-ords: 5 103 069.9 N ; 316 285.9 E</u>	ORIGINATED BY	<u>F.P.</u>
DIST	<u>North Bay</u>	HWY	<u>11</u>	BOREHOLE TYPE	<u>Continuous Flight Hollow Stem Augers</u>
DATUM	<u>Geodetic</u>	DATE	<u>December 23, 2011</u>	CHECKED BY	<u>B.R.G.</u>

[illegible]

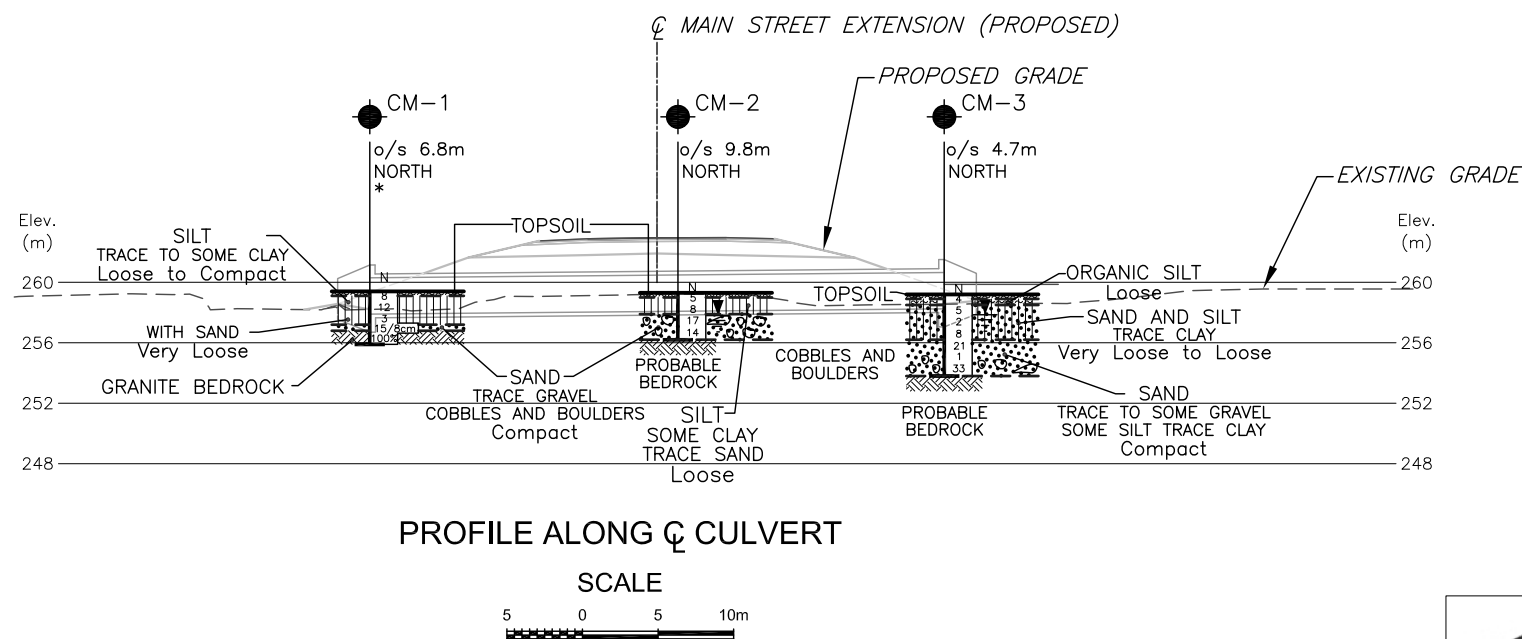
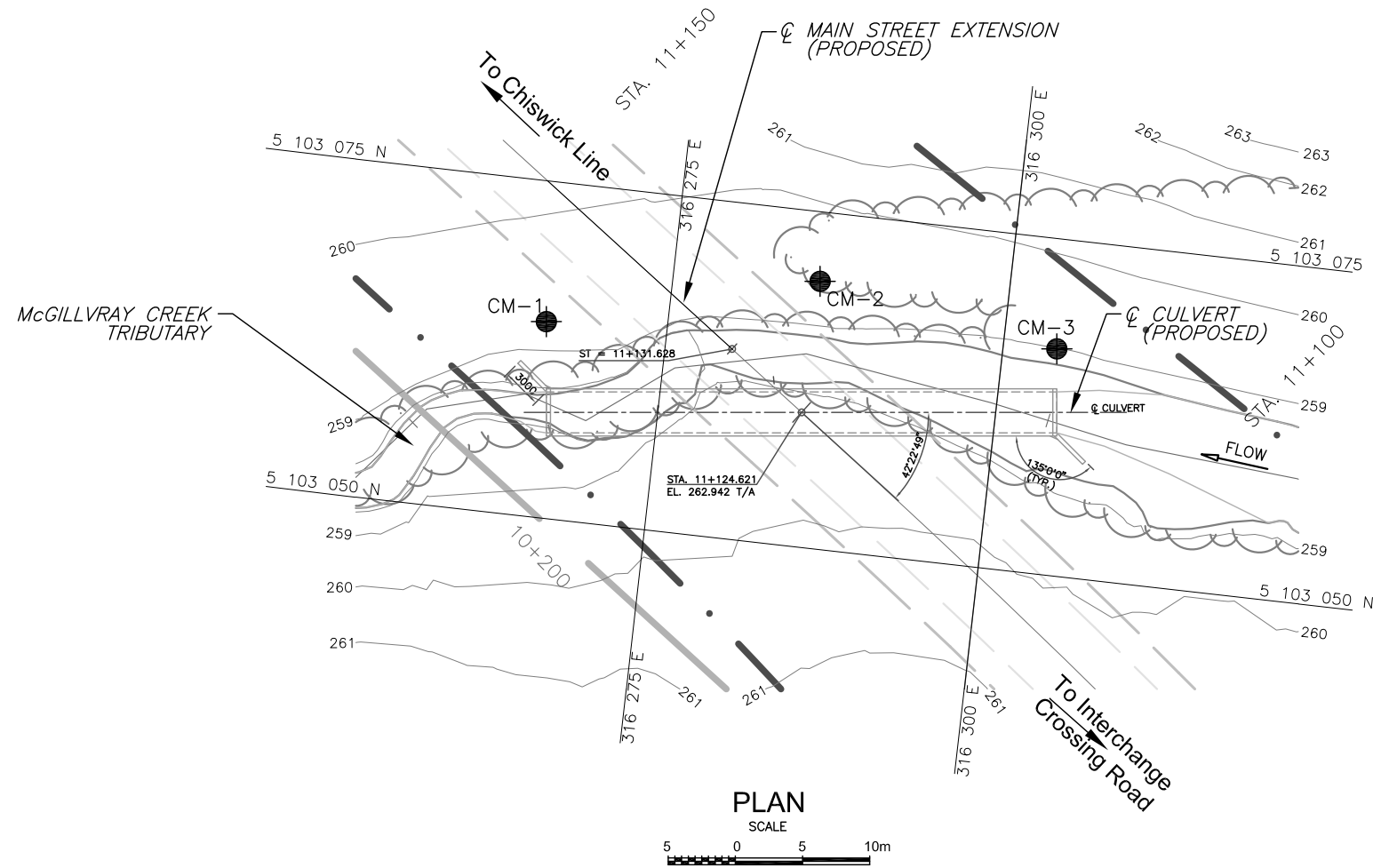
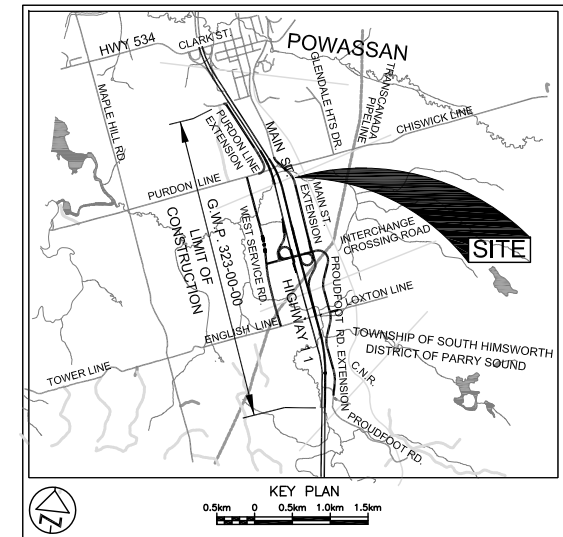
RECORD OF BOREHOLE No CM-3








1 of 1

METRIC

G.W.P.	<u>323-00-00</u>	LOCATION	<u>Co-ords: 5 103 066.8 N ; 316 304.0 E</u>	ORIGINATED BY	<u>F.P.</u>
DIST	<u>North Bay</u>	HWY	<u>11</u>	BOREHOLE TYPE	<u>Continuous Flight Hollow Stem Augers</u>
DATUM	<u>Geodetic</u>	DATE	<u>December 21, 2011</u>	COMPILED BY	<u>N.S.B.</u>
				CHECKED BY	<u>B.R.G.</u>

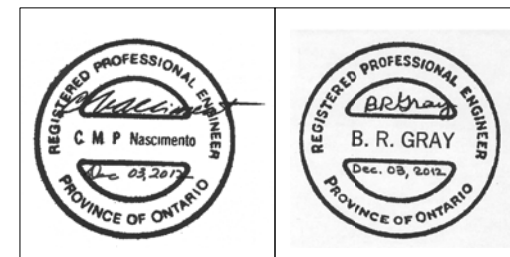
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LEGEND			
	Borehole		
	Auger Probe		
N	Blows/0.3m (Std. Pen Test, 475 J/blow)		
CONE	Blows/0.3m (60 Cone, 475 J/blow)		
	WL at time of investigation Dec. 2011		
*	Water level not established		
	Head		
	ARTESIAN WATER		
	Encountered		
	PIEZOMETER		
BH No	ELEVATION	NORTHINGS	EASTINGS
CM-1	259.4	5 103 064.6	316 266.0
CM-2	259.3	5 103 069.9	316 285.9
CM-3	259.2	5 103 066.8	316 304.0

NOTES:

- SOUTH SIDE OF CREEK WAS NOT ACCESSIBLE AT THE TIME OF THE FIELD WORK. ALLOWANCE SHOULD BE MADE FOR VARIATIONS IN SUBSURFACE STRATIGRAPHY.
- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



Ref AECOM Drawing:
60157537 McGillivray_Creek_Trib_Main St_Culvert-11+124_1_GA.dwg
dated Dec., 2010

— NOTE —
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 31L-162

HWY No 11	CHECKED NSB	DATE DEC. 03, 2012	DIST North Bay
SUBM'D NA	CHECKED BRG	APPROVED CN	SITE 44-507
DRAWN NA	CHECKED BRG	APPROVED CN	DWG M-1



**FOUNDATION DESIGN REPORT
for
MCGILLVRAY CREEK TRIBUTARY CULVERT
MAIN STREET EXTENSION STATION 11+125
SITE NO. 44-507
TOWNSHIP OF SOUTH HIMSWORTH
NORTH BAY AREA, ONTARIO
G.W.P. 323-00-00**

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Table 1 – List of Standard Specifications Referenced in Report

FOUNDATION DESIGN REPORT
for
McGillvray Creek Tributary Culvert
Main Street Extension Station 11+125
Site No. 44-507
Township of South Himsworth
North Bay Area, Ontario
GWP 323-00-00

1. INTRODUCTION

The installation of the proposed Main Street Extension culvert for the Tributary to the McGillvray Creek is planned as part of the new interchange at the south entrance to Powassan project that extends from 5.7 km south of the Highway 534 to northerly 5.0 km. This report was prepared for AECOM Canada Ltd (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

This foundation design report provides foundation engineering comments and recommendations for the proposed culvert design and construction.

According to the preliminary General Arrangement drawing dated December 2010, the Tributary to the McGillvray Creek culvert will be located at Sta. 11+125 (Main Street Extension chainage) in the Township of South Himsworth. The proposed culvert will be a cast-in-place 3.0 × 2.4 m concrete box culvert with a total length of 38 m. This proposed culvert is proposed at a skew angle of 42.4° towards the north at the Main Street Extension centreline. The proposed road grade is at elevation 262.9 at the culvert location which is about 3.9 m above existing grade.

In summary, the subsurface stratigraphy revealed in the boreholes generally comprised a 0.3 to 0.7 m thick topsoil and/or organic silt unit overlying 1.1 to 2.3 m thick cohesionless silt / sand and silt deposits and 0.4 to 2.4 m thick cohesionless sand mantling probable bedrock. Cobbles and boulders were encountered within sand deposit. The probable granite bedrock was contacted / inferred at 2.6 to 5.4 m depths (elevation 253.8 to 256.8). The groundwater level measured during the field investigation was at 1.4 and 1.5 m depths (elevation 257.8).



From a foundation perspective, the construction of the proposed cast-in-place culvert is feasible at the culvert location. However, the sandy soils encountered below the proposed subgrade level contained cobbles and boulders that should be removed from the subgrade level.

It is understood that a cast-in-place concrete box culvert will be installed at the proposed culvert location. Therefore, the recommendations for precast culvert and a discussion of the advantages and disadvantages of the two culvert options are not included in this report.

It is noted that the boreholes were drilled approximately 4 to 10 m away from intended borehole locations due to drill rig accessibility and underground utilities. An allowance should be made for any variations in soil stratigraphy and inferred bedrock levels.

The foundation frost penetration depth at the site is 1.9 m according to OPSD 3090.100.

The "red flag" issues outlined in the preceding paragraphs and the recommended methods of overcoming these issues noted in the following sections of the report are intended to alert and aid the designer and the contractor. It is noted that no responsibility or liability is assumed by the consultants or the MTO for alerting the contractor to all critical issues. The requirement to deliver acceptable construction quality remains the responsibility of the contractor.

A list of the standard specifications referenced in this report is compiled in Table 1. All elevations in this report are expressed in metres.

2. FOUNDATIONS

The invert levels of the proposed box culvert are specified to be near elevation 258.3 at the east end (inlet) and elevation 257.9 at the west end (outlet). The subgrade level for a concrete box culvert is interpreted to be about 0.6 m below the proposed invert levels at elevation 257.7 and 257.3 allowing for the thickness of concrete base of the culvert and for the bedding and levelling courses. The proposed road grade at the proposed culvert will be at about elevation 262.9.



In summary, the subgrade soils revealed in the boreholes below the anticipated culvert subgrade level (elevation 257.3) comprised of 3.6 m loose to compact sand and silt / sand over probable bedrock (borehole CM-3) at the east end of culvert. In the middle section, 1.1 m thick compact sand trace gravel containing cobbles and boulders (borehole CM-2) was encountered over the probable bedrock. At the west end of culvert, 0.5 m thick compact silt / sand (borehole CM-1) was present over the bedrock. It is noted that cobbles and boulders were encountered within the sand deposit.

Groundwater was contacted in two boreholes at elevation 257.8 at the time of the field investigation in December 2011. The stabilized groundwater level is expected to be consistent with the water in the Tributary Creek, near elevation 258.0, about 0.7 m above the inferred subgrade level.

It is estimated that about 0.3 to 0.7 m thick topsoil and/or organic soils and 1.1 and 1.8 m thick cohesionless silty / sandy soils excavation will be required to achieve the anticipated culvert subgrade level at the inlet and outlet locations (boreholes CM-3 and CM-1). In addition, about 1.7 m thick silt / sand is to be excavated to achieve subgrade level in the middle section.

The Granular A / Granular II bedding materials and the underlying cohesionless soils that are in the zone of influence below the design subgrade level are considered capable of adequately supporting the stress imposed by the concrete box culvert.

The culvert bedding should be 300 mm thick and comprise Granular A or Granular B Type II with a maximum particle size of 37.5 mm.

The estimated maximum total settlement of the culvert at the east end (inlet) is some 25 mm with 10 and 5 mm at the centreline and west end (outlet). It is estimated that the resulting differential post-construction settlement between the east end and centreline of the culvert will be in the order of 15 mm and between the centreline and west end of the culvert will be approximately 5 mm should the culvert be constructed concurrently with the new embankment construction.



The estimated magnitude of differential settlements under the culvert of 5 to 15 mm is considered tolerable for the proposed cast-in-place concrete culvert. Construction joints, if required, could be added at the design engineer's discretion to accommodate for the maximum estimated 15 mm of differential settlement.

It is considered that a cast-in-place culvert can typically tolerate a maximum of 25 mm of settlement, after which, cracking may appear within the culvert. Consideration should be given by the design engineer, to introduce joints in the culvert to accommodate the anticipated 15 to 20 mm differential settlements.

The recommended factored geotechnical bearing resistances at ultimate limit states (ULS) and the geotechnical reaction at serviceability limit states (SLS) for the 3.0 m wide concrete box culvert constructed on the native cohesionless soils below the granular bedding layer are as follows:

CULVERT SECTION	SUBGRADE SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL REACTION AT SLS (kPa)
Entire Length	Typically compact Cohesionless Sand and Silt / Sand	250	150

The geotechnical reaction at SLS normally allows for a 25 mm compression of the founding medium. In addition, the cohesionless soil settlements under the proposed culvert discussed previously in this section should be considered. A foundation embedment depth of 2.0 m and groundwater at about the level of the culvert invert were assumed for computation of the geotechnical resistance.



2.2 General Comments

2.2.1 Subgrade Preparation

Preparation of the subgrade for construction of the culverts should be performed and monitored in accordance with OPSS 902. All the cobbles and boulders should be removed from the subgrade level. A site review should be conducted by qualified geotechnical personnel during preparation of the subgrade and compaction of the granular fill.

For the box culvert, it is recommended to provide a 300 mm thick granular bedding below the culvert. The bedding material should comprise Granular A, satisfying the specifications within OPSS 1010, compacted to 100% of the ASTM D-698 (standard Proctor) maximum dry density in conformance to OPSS 501 (Method A).

The geometry of the subgrade preparation, cover backfill and frost taper treatment for the box culverts should be carried out in accordance with OPSS 422 and MTO SP 109S31.

Topsoil/ organic silt and any other deleterious soils revealed during the subgrade preparation should be excavated and cobbles and boulders also be removed prior to placement of the granular base below the box culvert, and the materials replaced with compacted Granular A or Granular B Type II. Granular B Type II should be preferred for construction under wet conditions. In addition, any boulders encountered immediately below the subgrade level should be removed to avoid point loads.

The probable bedrock level may be higher than those in the 3 boreholes put down at the site and bedrock excavation will be required to accommodate the full granular bedding thickness above the bedrock to avoid point loads under the culvert. An allowance for possible rock excavation should be carried in the contract.

Wet cohesionless silty / sandy soils are anticipated at the subgrade final excavation level elevation 257.3. Site conditions may be unfavourable due to 0.5 m higher water level above the



subgrade final excavation level and the existing pervious wet sandy/silty soils. Groundwater control will be required for construction of the proposed culvert as outlined in Section 5.4 of this report.

To facilitate the construction under the anticipated wet conditions, the approved subgrade should be immediately covered with a layer of biaxial geogrid (25 by 35 mm maximum aperture / 1.2 to 2.0 kN/m minimum peak tensile strength). Granular B Type II should be used to backfill over the geogrid where required to bring the grade up to the bottom of the granular bedding. To obtain adequate compaction of the granular material under wet conditions, the granular bedding may be placed to a level about 300 mm above the design grade to be above the estimated groundwater level and be compacted from the surface. The grade should then be lowered to the design level of the bedding by carefully excavating the excess bedding material. Under the anticipated wet conditions the levelling course may not be required. It is recommended to provide the minimum 300 mm thickness of granular bedding above the geogrid.

2.2.2 Modulus of Subgrade Reaction

The estimated value of the modulus of subgrade reaction for a box culvert constructed on various compacted base materials over the native soils is as follows.

SOIL TYPE	MODULUS OF SUBGRADE REACTION (MN/m ³)
Granular A or Granular B Type II	45
Compact sandy soils	10

2.2.3 Sliding Resistance

The following parameters should be used to compute sliding resistance of cast-in-place box culvert or cast-in-place headwall and wingwall foundations.



SOIL TYPE	FOUNDATION FRICTION ANGLE (DEGREES)	COHESION (kPa)	UNIT WEIGHT (kN/m ³)
Granular A or Granular B Type II	35	0	22.8
Sandy Soils	30	0	20.0

The structural designer should use a factor of 0.8 for the above values of friction angle and cohesion when performing the sliding resistance check.

2.2.4 Seismic Site Coefficient

The seismic site coefficient for the conditions at the proposed Main Street Extension culvert site is 1.0 –Type I soil profile as per clause 4.4.6 of the CHBDC.

3. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with OPSD 3121.150, OPSS 422 and MTO SP 422S01. The requirements for frost tapers are provided in the Pavement Design Report.

Backfill should be brought up simultaneously on each side of the culvert and operation of heavy equipment within 0.5 times the height of the culvert (each side) should be restricted to minimize the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction. Refer to OPSS 501 for additional comments.

The proposed culvert must be designed to support the stress imposed by the overlying fill as well as to resist the unbalanced lateral earth pressure and compaction pressure exerted by the backfill adjacent to the culvert walls.



The lateral earth and water pressure, p (kPa), should be computed using the equivalent fluid pressures presented in Section 6.9 of the Canadian Highway Bridge Design Code (CHBDC) or employing the following equation assuming a triangular pressure distribution.

$$p = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p + C_s$$

where p = lateral earth pressure (kPa)
 K = lateral earth pressure coefficient
 γ = unit weight of backfill material above design water level (kN/m³)
 γ' = unit weight of submerged backfill material below design water level (kN/m³)
 $= \gamma - \gamma_w$
 γ_w = unit weight of water
 $= 9.8 \text{ kN/m}^3$
 h_1 = depth below final grade (m), above design water level
 h_2 = depth below design water level (m)
 q = any surcharge load (kPa)
 C_p = compaction pressure (refer to clause 6.9.3 of CHBDC)
 C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)
 where ϕ = angle of internal friction of retained soil (35° for Granular A or B Type II)
 δ = angle of friction between soil and wall (23.5° for Granular A or B Type II)

The seismic site coefficient for the conditions at this site was provided in Section 2.2.4.

The following parameters are recommended for design:

PARAMETER	GRANULAR A OR GRANULAR B TYPE II	EXCAVATED NATIVE SOIL (*)
Angle of Internal Friction, degrees	35	30
Unit Weight, kN/m ³	22.8	20.0
Coefficient of Active Earth Pressure (K_a)	0.27	0.33
Coefficient of Earth Pressure At Rest (K_o)	0.43	0.50
Coefficient of Passive Earth Pressure (K_p)	3.69	3.00

(*) Assumes that excavated native soils used for backfill are inorganic cohesionless soils.

The design should consider both the maximum water level in the stream and the stabilized groundwater level condition. The maximum stream water level will be dictated by flood flow conditions and should be defined by the project hydrological engineer.



The coefficient of earth pressure at rest should be employed to design rigid and unyielding walls.

4. HEADWALLS AND WINGWALLS

The previous recommendations and geotechnical parameters for culvert foundations and backfill should be utilized for the design of the foundations for headwalls and wingwalls. The wall founding levels should match those of the culvert where the walls are designed integral with the culvert structure. For walls designed separately from the culvert structure, the founding levels should be established to provide 1.9 m of earth cover for adequate frost protection.

The design of the walls should be checked for sliding resistance using the geotechnical parameters provided previously in Section 2 for cast-in-place concrete foundations.

A weeping tile system and/or weep holes should be installed to minimise the build-up of hydrostatic pressure behind the headwalls and wingwalls. The weeping tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150 μ m according to OPSS 1860) placed to prevent migration of fines into the system.

5. CONSTRUCTION CONSIDERATIONS

5.1 Excavation

Excavation to the anticipated founding level of the proposed Main Street Extension culvert is expected to extend through the topsoil / organic silt into the native deposits of cohesionless silty / sandy soils. Subject to adequate groundwater control, excavation of the soils should be feasible using conventional equipment. All excavations should be conducted in accordance with OPSS 902.

The native silty/sandy soils above the water table are classified as Type 3 soils necessitating temporary cut slopes to be inclined at 1H:1V. Below the water table, cut slopes should be shaped



at 3H:1V or flatter. Where composite soil types exist, the excavation slopes should be cut to the requirements of the soil type with the highest number that is present in the slope according to OHSA.

5.2 Groundwater Control

The stabilized groundwater level is expected to be consistent with the water level in the Tributary Creek, near elevation 258.0 about 0.7 m above the inferred subgrade level. If construction under wet condition as outlined in Section 2.2.1 is not implemented, it will be necessary to implement measures to temporarily lower groundwater table and to permit construction of cast-in-place culvert, headwalls and wingwalls. The groundwater level should be lowered to a minimum of 0.5 m below the proposed founding levels.

It is considered that a dewatering system involving dam and pumping techniques will not be sufficient due to pervious subgrade soils. Consequently, cofferdams will likely be required for the installation of the culvert for construction in the dry. The contractor is responsible for the selection, performance and detailed design of the dewatering system. Any seepage water that enters in the excavation from the excavation slope may be handled by sump and pumping techniques.

From the Foundations standpoint the requirement for a permit to take water (PTTW) will depend on the water tightness of the contractor's selected type of dewatering system. The PTTW requirement will also depend on the groundwater levels at the time of construction since these are subject to seasonal fluctuations and precipitation patterns. A PTTW may be required to address other engineering facets, such as those of Hydrology engineering.

It should be noted that a water level at elevation 259.0 was measured in January 2011, and the construction should be scheduled during summer months to reduce the requirements for groundwater control. The flow of surface water should be diverted away from the excavations.



6. EROSION CONTROL

The protective measures noted in the OPSD 800 series to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls etc.) are considered to be appropriate. The backfill should comprise OPSS Granular A or Granular B Type II. The cut-off walls should extend laterally to protect the granular backfill material and to a depth at least equal to the fluctuation of the water level at the culvert location to prevent flow below the culvert that could erode the granular base/bedding material. The requirements of CHBDC clauses 1.9.5.6 and 1.9.11.6.5 should be applied.

Inlet and outlet protection in accordance with OPSS 511 and 1004 and OPSD 810.010 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert foundation. The actual design requirements concerning the length and width of aprons at the inlet/outlet of the culvert as well as the rip-rap size, apron thickness, height of erosion protection on the embankment slope and type of material (clay seals at the inlet, drainage and/or filter blankets at the outlet) will be dictated by stream hydraulics, stream configuration, the water level in the stream and should be established by a hydraulic engineer. A non-woven Class II geotextile with an FOS of 75-150 μm according to OPSS 1860 should be placed below the rip-rap to minimize the potential for erosion of fine particles from below the treatment.

Any newly constructed embankment slopes and retained soils behind the headwalls and wingwalls should be covered with topsoil or suitable excess earth material and seeded in accordance with OPSS 802 and 804, as soon after grading as possible to prevent erosion. Where slopes are inclined at 2.5H:1V or steeper, the permanent slopes should be protected with erosion control blankets. Also, sod (as per OPSS 803) may be placed instead of erosion control blankets. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor.

SOIL TYPE	K FACTOR
Sand	0.2
Silt	0.3



7. CLOSURE

This Foundation Design Report was prepared by Mrs. N. S. Balakumaran, P. Eng., and reviewed by Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact. Mr. C. M. P. Nascimento, P. Eng., Project Manager conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.



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TABLE 1
LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS 802	Construction Specification for Topsoil
OPSS 803	Construction Specification for Sodding
OPSS 804	Construction Specification for Seed and Cover
OPSS 902	Excavation and Backfilling of Structures
OPSS1010	Material Specification for Aggregates, Base, Subbase, Select Subgrade and Backfill Material
OPSS 1860	Material Specification for Geotextiles
SP 422S01	Construction Specification for Precast Concrete Box Culvert
SP 109S31	Substitution of Precast Concrete Box Culverts for Cast-In-Place Concrete Box Culverts
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Depth for Northern Ontario
OPSD 3121.150	Minimum Granular Backfill Requirements - Walls Retaining