



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

MUNICIPAL DRAIN NO. 6 CULVERT EXTENSION

SITE NO. 35-506C

REHABILITATION OF HIGHWAY 23

G.W.P. 58-00-00

PALMERSTON TO HARRISTON

TOWN OF MINTO, ONTARIO

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PML Ref.: 04KF132C
Index No.: 052FIR and 053FDR
Geocres No.: 40P15-33
October 11, 2005



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FOUNDATION INVESTIGATION REPORT

for

Municipal Drain No. 6 Culvert Extension

Site No. 35-506C

Rehabilitation of Highway 23

G.W.P. 58-00-00

Palmerston to Harriston

Town of Minto, Ontario

1. INTRODUCTION

Rehabilitation of the approximate 9 km long section of Highway 23 that extends from Palmerston northerly to the Harriston west limits in the town of Minto, Ontario is planned. This report was prepared for Stantec Consulting Ltd. on behalf of the Ministry of Transportation of Ontario.

Rehabilitation of Highway 23 will involve the extension of a culvert where Municipal Drain No. 6 crosses the highway at approximate Station 16+373, Highway 23 chainage. The culvert designated as C-10 is a concrete rigid frame box structure with a size of 3.04 m wide by 1.83 m high and 39.6 m long. Extension of the culvert by some 5 m at the west end is envisaged.

This report provides a summary of the factual information obtained during the field investigation conducted at the location of the proposed culvert extension.

2. SITE DESCRIPTION AND GEOLOGY

Highway 23 within the project limits is primarily situated in a rural setting with rolling terrain containing streams and swampy areas. Land use along the study corridor is mainly agricultural with some forested/swamp areas and residential development.

The project area lies in the physiographic region known as the Teeswater Drumlin Field characterized by a complex of low, broad hills with gentle slopes. The principal soil along the study corridor is represented by the Harriston Loam, a medium textured sandy silt to silt till with good drainage. Some of the low lying areas between drumlins are swampy with poor drainage (L.J.Chapman & D.F.Putnam, *The Physiography of Southern Ontario*, 3rd Edition, Ontario Research Foundation, 1984).



The frost penetration depth for design purposes as outlined in the Pavement Design and Rehabilitation Manual is 1.6 m. The average annual freezing index in the area is in the order of 800 degree-days Celsius.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out on May 17, 2005 and comprised two boreholes advanced to depths of 7.7 and 10.8 m below existing grade. The approximate locations of the boreholes put down at the west end of the proposed culvert extension and on the west shoulder of the highway along with a stratigraphic cross-section are shown on Drawing 1, appended.

The borehole numbers are provided with prefix code C10 to reflect the specific MTO culvert number for ease of reference.

The borehole layout was established in accordance with the requirements noted in the Request for Proposal. Peto MacCallum Ltd. selected the borehole locations in the field. The ground surface elevations at the boreholes were provided by the surveying company AGM.

The boreholes were advanced using continuous flight hollow stem augers, powered by a track-mounted CME-55 Bombardier drill rig, supplied and operated by a specialist drilling contractor working under the full-time supervision of a member of our engineering staff.

Representative samples of the soil were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

Soils were identified visually in the field in accordance with the MTO Soil Classification procedures. The groundwater conditions at the borehole locations were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open boreholes. All the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO guidelines for borehole abandonment procedures.



The recovered samples were returned to our laboratory for detailed visual examination and classification. The laboratory testing program consisting of moisture content determinations as well as four grain size distribution analyses was carried out on selected samples. The results of the laboratory grain size distribution analyses are presented in Figures GS-1 to GS-4.

4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, boundary elevations, standard penetration test data, groundwater observations and moisture content determinations. The results of laboratory grain size distribution analyses conducted on selected samples are also shown on the borehole logs.

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

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised a surficial topsoil or the embankment fill made up of sand and gravel underlain by cohesionless silty/sandy/gravelly soils. Cobbles were encountered below elevation 374.7 in one borehole. Groundwater was measured in both boreholes at depths of 1.2 and 3.5 m (elevation 379.0 and 380.1). The strata encountered are summarized below.

4.1 Fill

The sand and gravel fill with silt that makes up the highway embankment is present surficially in borehole C10-2 put down on the west shoulder of the highway. The fill has a thickness of 3.8 m and was penetrated at elevation 379.8.



4.2 Topsoil

Surficial topsoil is present in borehole C10-1 advanced near the west end of the proposed culvert extension. Represented by medium organic sandy silt, the topsoil has a thickness of 1.1 m, a moisture content of 44% and was penetrated at elevation 379.1.

4.3 Silty Sand

Underlying the topsoil or sand and gravel fill is a cohesionless silty sand trace clay trace gravel. This unit is 0.7 and 1.4 m thick in boreholes C10-1 and C10-2 respectively. The silty sand is compact (N-values of 14 to 17), with the moisture content varying between 10 and 15%. The unit was penetrated at depths of 1.8 and 5.2 m (elevation 378.4).

The results of a grain size distribution analysis performed on this material are presented in Figure GS-1.

4.4 Gravel

Directly beneath the silty sand in both boreholes is a layer of gravel with sand and trace to some silt. The thickness of this deposit was 1.9 m in borehole C10-1 and 1.5 m in borehole C10-2. The gravel is in a compact to very dense condition (N-values of 26 to 51) and has a moisture content of 7 to 9%. The deposit was penetrated at depths of 3.7 and 6.7 m (elevation 376.5 and 376.9) in boreholes C10-1 and C10-2 respectively.

The results of a grain size distribution analysis conducted on a representative sample of this material are presented in Figure GS-2.



4.5 Sandy Silt Till

Cohesionless sandy silt till is present below the gravel at 3.7 m depth (elevation 376.5) in borehole C10-1. This unit is 2.7 m thick and very dense (50 to 97 blows of hammer per 50 to 250 mm penetration). The moisture content of the sandy silt till ranges from 8 to 11%. The unit was penetrated at a depth of 6.4 m (elevation 373.8).

The results of a grain size distribution analysis performed on this material are presented in Figure GS-3.

4.6 Sand and Gravel Till

Underlying the sandy silt till in borehole C10-1 and gravel in borehole C10-2 is a deposit of sand and gravel till. This deposit has a minimum thickness of 1.3 m in the former borehole and 4.1 m in the latter. The sand and gravel till is dense (N-value of 37) in the upper 1 m thick portion in borehole C10-2 and very dense elsewhere (up to 50 blows of hammer per 25 mm penetration). The moisture content of the unit varies between 9 and 13%. Augering was terminated within the deposit at depths of 7.7 and 10.8 m (elevation 372.5 and 372.8) in boreholes C10-1 and C10-2 respectively.

Cobbles were encountered within the sand and gravel till below a depth of 8.9 m (elevation 374.7) in borehole C10-2. The results of a grain size distribution analysis conducted on a representative sample of this material are presented in Figure GS-4.

4.7 Groundwater

Groundwater was observed in both boreholes in the course of the field work. Upon completion of drilling, groundwater was measured at depths of 1.2 and 3.5 m (elevation 379.0 and 380.1) in boreholes C10-1 and C10-2 respectively. The roadside ditches at the inlet and outlet of the culvert were dry at the time of the investigation. The observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.



5. CLOSURE

The field work was carried out under the supervision of Mr. M. Rapsey and direction of Mr. P. Cullen, P.Eng., Project Engineer. The equipment was supplied by Marathon Drilling Co. Ltd.

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Senior Foundation Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in red ink, appearing to read "Grigory O. Degil", is positioned above the name and title of the first engineer.

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer



A handwritten signature in red ink, appearing to read "Carlos M.P. Nascimento", is positioned above the name and title of the second engineer.

Carlos M.P. Nascimento, P.Eng.
Senior Foundation Engineer

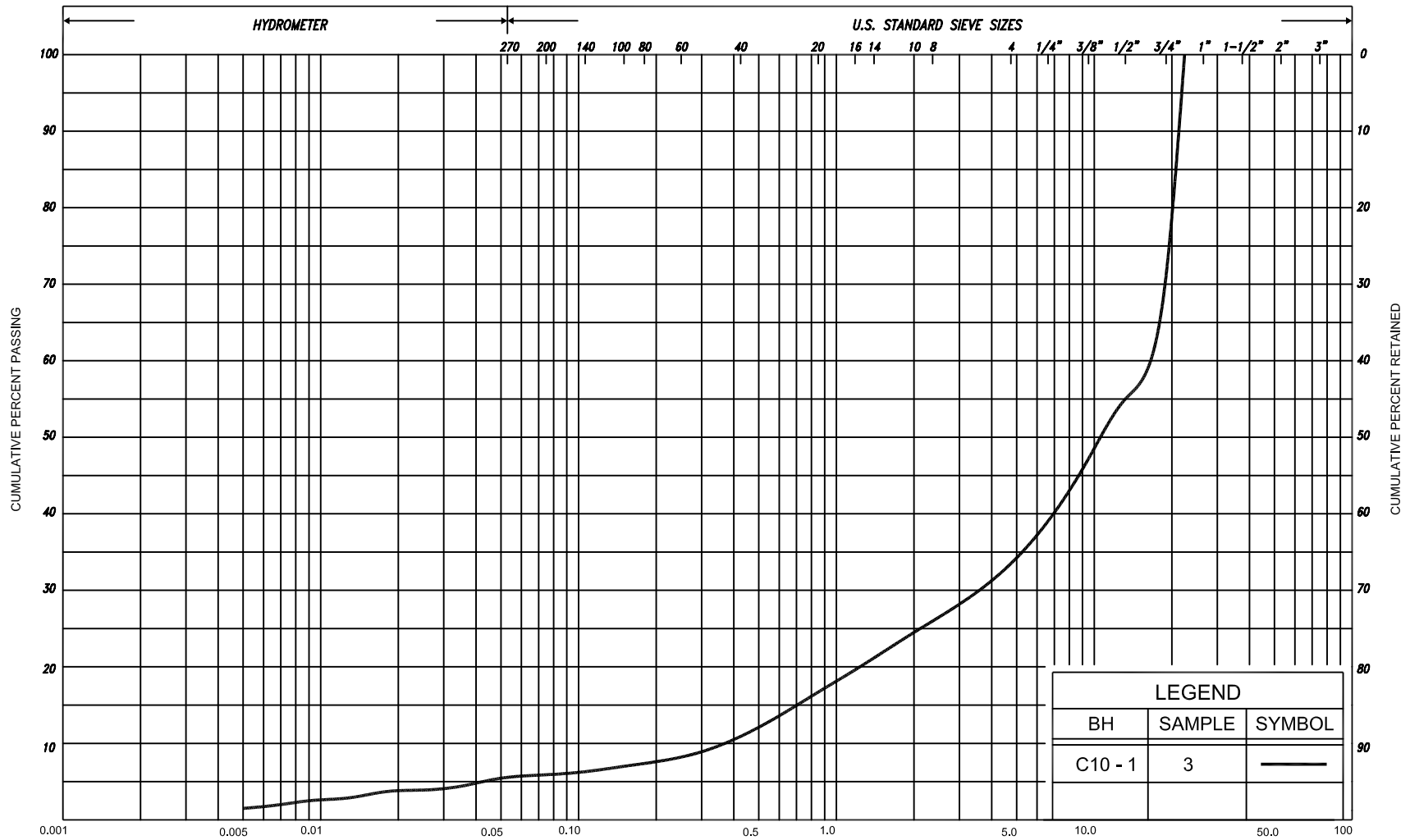


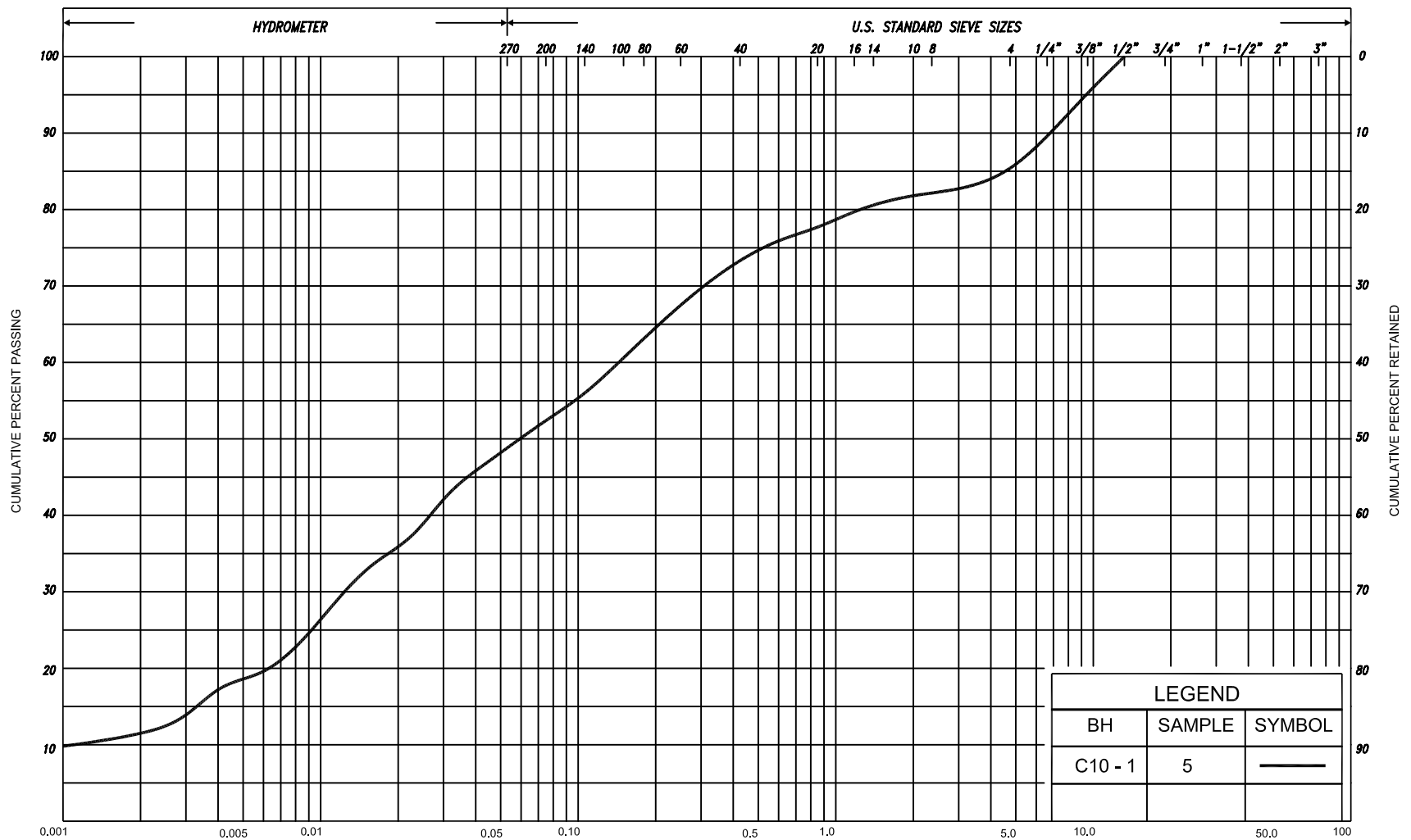
A handwritten signature in blue ink, appearing to read "Brian R. Gray", is positioned above the name and title of the third engineer.

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

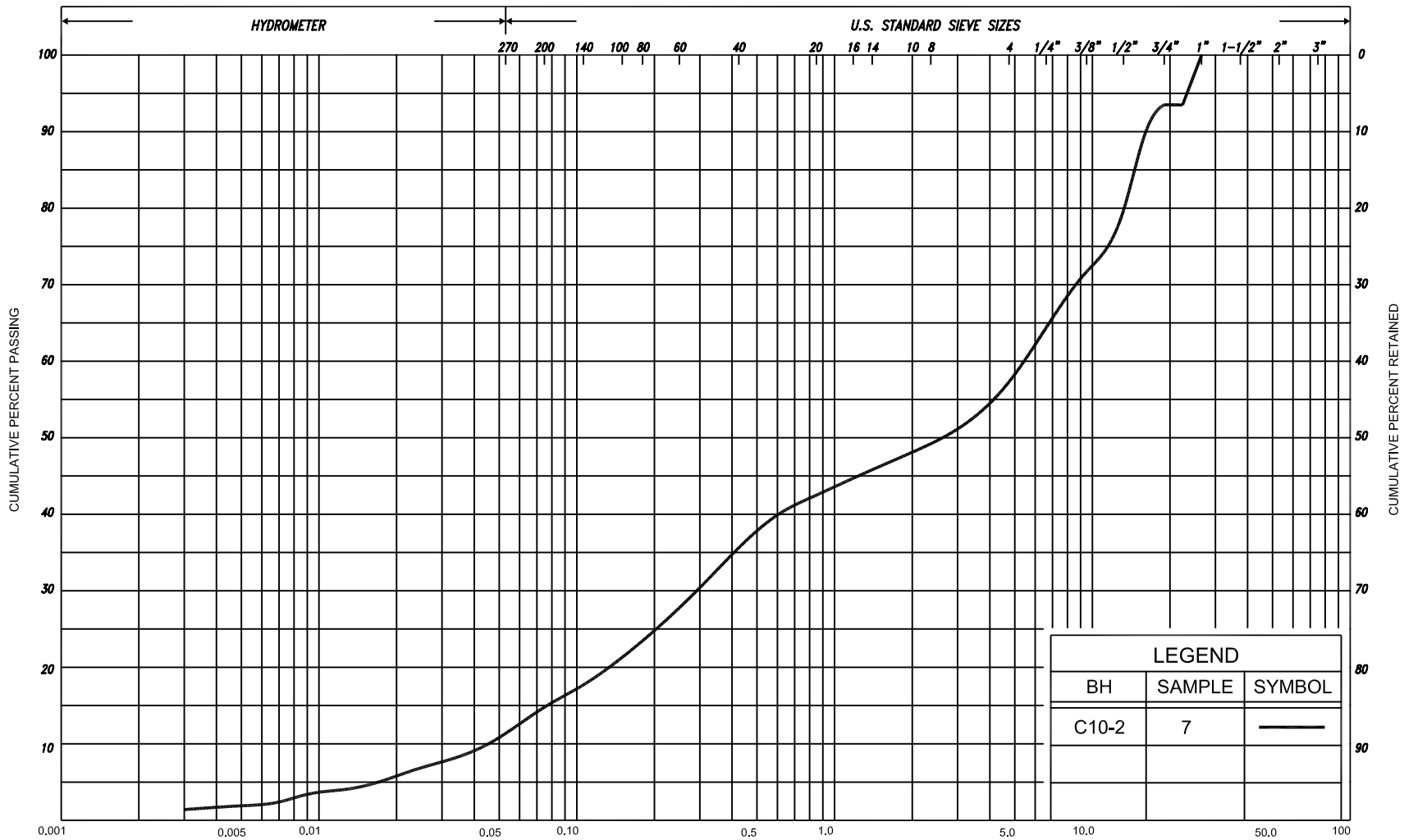


GD/CN/BRG:mm-mi





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



LEGEND		
BH	SAMPLE	SYMBOL
C10-2	7	—

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

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.

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 (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	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_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

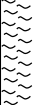













ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	e_{\max}	1, %	VOID RATIO IN LOOSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	e_{\min}	1, %	VOID RATIO IN DENSEST STATE
ρ_w	kg/m^3	DENSITY OF WATER	S_r	%	DEGREE OF SATURATION	I_D	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
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	WTPL		WETTER THAN PLASTIC LIMIT	j	kN/m^2	SEEPAGE FORCE
e	1, %	VOID RATIO						

RECORD OF BOREHOLE No C10-1

1 of 1

METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 861 860 N; 193 804 E ORIGINATED BY MR
DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD
DATUM Geodetic DATE May 17, 2005 CHECKED BY _____

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							
	Ground Surface																	
	Topsoil						380											
	Silty sand, trace to some gravel		1	SS	14		379											
	Compact Brown Damp to wet		2	SS	30		378											
	Gravel, with sand, trace silt						378											
	Compact Brown Wet to dense		3	SS	26		377											
			4	SS	37		377											
	Sandy silt, some gravel, some clay		5	SS	50/ 15cm		376											
	Very dense Grey Damp (TILL)		6	SS	50/5cm		376											
						375												
			7	SS	97/ 25cm	374												
	Sand and gravel, some silt					373												
	Very dense Brown Wet (TILL)		8	SS	50/3cm													
	End of borehole																	
	<div>* 2005 17 05</div> <div> Water level measured after drilling</div>																	























RECORD OF BOREHOLE No C10-2

1 of 1

METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 861 884 N; 193 812 E
DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers ORIGINATED BY MR
DATUM Geodetic DATE May 17, 2005 COMPILED BY GD
CHECKED BY

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									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
					WATER CONTENT (%)												
383.6	Ground Surface						20	40	60	80	100	20	40	60			
0.0	Sand and gravel, with silt Brown Damp (FILL)																
			1	SS	36												
																	
			2	SS	53/ 15cm												
379.8																	
3.8	Silty sand, trace clay, trace gravel Compact Grey Wet																
			3	SS	17							○				1 60 36 3	
378.4												○					
5.2	Gravel, with sand, some silt Very dense Brown Wet to dense		4	SS	51												
																	
			5	SS	45							○					
376.9																	
6.7	Sand and gravel, some silt, trace clay Dense to Brown Wet very dense (TILL)		6	SS	37							○					
												○				43 42 14 1	
			7	SS	72							○					
			8	SS	50/ 10cm							○					
	cobbles		9	SS	50/ 8cm							○					
																	
																	
372.8			10	SS	50/ 10cm												
10.8	End of borehole																



FOUNDATION DESIGN REPORT

for

MUNICIPAL DRAIN NO. 6 CULVERT EXTENSION

SITE NO. 35-506C

REHABILITATION OF HIGHWAY 23

G.W.P. 58-00-00

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Table 1 - List of Standard Specifications Referenced in Report

FOUNDATION DESIGN REPORT
for
Municipal Drain No. 6 Culvert Extension
Site No. 35-506C
Rehabilitation of Highway 23
G.W.P. 58-00-00
Palmerston to Harriston
Town of Minto, Ontario

1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the proposed extension of one culvert while rehabilitating the approximately 9 km long section of Highway 23 that extends from Palmerston northerly to the Harriston west limits in the Town of Minto, Ontario. This report was prepared for Stantec Consulting Ltd. on behalf of the Ministry of Transportation of Ontario (MTO).

Rehabilitation of Highway 23 will involve extension of a culvert where Municipal Drain No. 6 crosses the highway at approximate Station 16+373, Highway 23 chainage. The culvert designated as C-10 is a concrete rigid frame box structure with a size of 3.04 m wide by 1.83 m high and 39.6 m long. Extension of the culvert by some 5 m at the west end is envisaged.

This report pertains to the design and construction of the proposed culvert extension and associated bedding/backfill zones. A list of the standard specifications referenced in this report is compiled in Table 1.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised a surficial topsoil or the embankment fill made up of sand and gravel underlain by cohesionless silty/sandy/gravelly soils. The groundwater level measured during the field investigation conducted in May 2005 varied between elevations 379.0 and 380.1.

2. FOUNDATIONS

The invert of the existing culvert is indicated to be near elevation 378.5 (ref.: Plate 180-89/15-0 of 'Highway 23 Reconstruction. Culvert Recommendations' drawings provided by Stantec Consulting Ltd.). Since the native soils at the invert level consist of a gravel layer, it is considered



that bedding is not needed. In case of employing a precast concrete structure, a 75 mm thick levelling course is required. Therefore, the design founding subgrade level of the culvert extension is envisaged to be near elevation 378.2.

The subgrade material below the invert level revealed in both boreholes comprised a compact to very dense gravel deposit. The highest groundwater level at the time of the field investigation was measured within the embankment fill at elevation 380.1, some 2 m above the subgrade level of the culvert. West of the existing culvert outlet, the groundwater was at elevation 379.0, about 0.7 m above the inferred founding level.

Based on the road grade (elevation 383.7) and ground surface elevation at the toe of slope (elevation 380.2), the embankment fill height at the existing culvert location is assessed to be 3.5 m.

It is considered that the compact to very dense gravel exposed in the boreholes at and below the design subgrade is capable of supporting the stress imposed by the embankment and culvert foundations.

The culvert foundations constructed on the compact to very dense gravel deposit should be designed using the following geotechnical resistance at ultimate and serviceability limit states (ULS and SLS) for the 3 m span box culvert:

Factored Geotechnical Resistance at ULS	=	400 kPa
Geotechnical Resistance at SLS	=	200 kPa

The resistance at SLS allows for 25 mm of settlement of the founding medium. The total and differential settlements along the culvert extension length are expected to be negligible in view of the relatively low net bearing pressures under the culvert extension foundations. Therefore, provision for camber is not considered necessary for the culvert extension.

The topsoil revealed above the subgrade and any other deleterious soils encountered below the subgrade level should be excavated prior to placement of the granular levelling course, if required, below the culvert and replaced with engineered fill.



Preparation of the subgrade for construction of the culvert extension should be performed and monitored in accordance with OPSS 902 and SP 902S01. This should include site review by qualified geotechnical personnel during preparation of the subgrade as well as during placement and compaction of the engineered fill, if required.

Fill placed under the culvert to accommodate any variation in the level of the native surface and/or replace any deleterious soils extending below the design founding level should comprise Granular A material compacted to at least 95% of the target density with conformance to OPSS 501 and SP 105S10. The limit of the granular fill zone should extend sideways a minimum 0.3 m beyond the culvert base and down to the subgrade at 45° to the horizontal and be established by a site specific survey.

Subgrade preparation, cover backfill and frost taper treatment for the culvert should be carried out in accordance with OPSD 803.010 and OPSS 422.

A frost penetration depth of 1.6 m should be employed.

It is noted that the depth of excavation will be 2 m beyond the toe of the existing embankment and up to about 5.5 m within the existing embankment fill.

In addition, the excavation will be approximately 2 m below the groundwater level encountered within the embankment fill, about 0.7 m below grade beyond the culvert outlet and extend into the existing embankment. A positive groundwater control system will be needed and bracing required to support the cut slopes. Further comments in this regard are provided in subsequent sections of this report.

3. CULVERT BACKFILL

Backfill adjacent to the culvert should be placed in accordance with the Ontario Provincial Standard specifications and drawings (OPSD 803.010, OPSD 3504.000 and OPSS 422).

Backfill should be brought up simultaneously on each side of the culvert extension and operation of heavy equipment within 0.5 times the height of the culvert (each side) restricted to minimise the



potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction. Refer to OPSD 808.010 for additional requirements for operation of heavy equipment near the culvert.

The culvert extension 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 imposed 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), CAN/CSA-S6-00, March 2001, or employing the following equation assuming a triangular pressure distribution:

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

where p = lateral earth pressure (kPa)

K = lateral earth pressure coefficient

γ = unit weight of backfill material above design water level (kN/m^3)

γ' = unit weight of submerged backfill material below design water level (kN/m^3)
 $= \gamma - \gamma_w$

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)

The following parameters are recommended for design:

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



The design should consider both the maximum water level in the stream and the stabilised groundwater level condition. The groundwater level measured at the culvert location varied between elevations 379.0 and 380.1. The maximum stream water level will be dictated by flood flow conditions and should be defined by the project hydraulic engineer.

The coefficient of earth pressure at rest should be employed to design rigid and unyielding walls. The horizontal force imposed on the walls of the box culvert will be resisted by the slabs.

A weeping tile system and/or weep holes should be installed at the wing walls to minimise the build-up of hydrostatic pressure behind the wall. The weeping tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150 μm according to OPSS 1860) placed to prevent migration of fines into the system. The drainage pipe should be placed on a positive grade and lead to a frost free outlet.

4. EXCAVATION AND GROUNDWATER CONTROL

The groundwater level measured in the boreholes at the time of the field investigation was about 1 to 2 m above the anticipated levels of excavation. Since the gravel and sandy soils at the site are relatively pervious, conventional sump pumping techniques to control groundwater inflow are unlikely to be sufficient and wells or well points may be required prior to excavation to provide a stable excavation base.

The dewatering system should be installed by a specialist dewatering contractor. The design of the dewatering system should be left to the Contractor's discretion so that the system meets a performance specification to maintain and control the groundwater at least 0.6 m below the excavation base.

Excavation to the anticipated founding level of the culvert is expected to extend about 2 m below the highest groundwater level through the fill, topsoil, silty sand and gravel. Subject to adequate groundwater control, excavation of the soil should be feasible using conventional equipment. According to Occupational Health and Safety Act criteria, the in situ materials are classified as Type 3 soils necessitating temporary cut slopes to be inclined at 1H:1V (horizontal to vertical). Below the groundwater table, the materials are classified as Type 4 soils requiring 3H:1V slopes.



It is anticipated that a suitable roadway protection scheme following SP 539501 will be required to support the walls of the excavation and adjacent traffic lanes during construction. Several protection scheme alternatives such as sheet piling, sheeting supported by rakers or bracing, cantilever soldier piles and lagging may be considered. The schemes should be designed for performance level 2 provided that groundwater control is in place. Otherwise, a performance level 1 system such as soldier piles and lagging with anchored tiebacks is recommended to prevent movement of the existing embankment. The contractor is responsible for preparing a detailed design for the road protection scheme.

It will be necessary to implement measures to control water flow in the stream. Conventional procedures such as draining and/or diversion of the stream should be sufficient. Observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

It is recommended that the work be carried out during the dry summer months to minimise the amount of groundwater inflow to be handled and the volume of surface water, if any, to be diverted from the construction area.

All construction work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

5. EMBANKMENT FILL

The embankment height at the culvert extension location does not exceed 4 m.

The anticipated subgrade for the embankment comprises compact silty sand and typically dense gravel. Topsoil was encountered in the borehole drilled beyond the toe of the existing embankment. The topsoil and other excessively loose, soft, organic or otherwise deleterious materials encountered in the ditch beyond the culvert outlet within the limits of the embankment fill should be subexcavated prior to fill placement.

The embankment side slopes should be inclined no steeper than 2H:1V. A vegetation cover or other measures should be established to control surface runoff and minimise erosion of the embankment slopes.



It is considered that the subgrade soil is capable of supporting the embankment. Settlement of the embankment material is assessed to be in the order of 25 mm. The settlement is expected to occur as the fill is placed and be essentially complete within one month following fill placement.

6. EROSION CONTROL

The protective measures noted in the OPSD 800 series (particularly OPSD 803.030 and 803.020 for open and box culverts) to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls) are considered to be appropriate. The backfill should comprise OPSS Granular A or Granular B Type II. The cut-off walls should extend 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 bedding material as well as extend laterally to protect the granular material. The requirements of CHBDC clauses 1.10.5.6 and 1.10.11.6.5 should be applied.

Outlet protection in accordance with OPSS 511 and 1004 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert and/or embankment foundation. The actual design requirements (length and width of the aprons at the outlet of the culvert as well as the rock size, apron thickness and height of erosion protection on the embankment slope) 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 μ m, according to OPSS 1860, should be placed below the rip-rap to minimise the potential for erosion of fine particles from below the treatment.

All newly constructed embankment slopes and retained soils behind the wing walls (if provided) should be covered with topsoil and seeded (as per OPSS 570 and 572) 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 571) shall be placed where it currently exists with a view to aesthetics. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor:

<u>SOIL TYPE</u>	<u>K FACTOR</u>
Gravel	0.1
Silty Sand	0.2



7. CLOSURE

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Senior Foundation Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

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GD/CN/BRG:mm-mi



TABLE 1
LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

TITLE	DOCUMENT	DATE
Construction Specification for Precast Reinforced Concrete Box Culverts and Box Culverts in Open Cut	OPSS 422	April 2004
Construction Specification for Compacting	OPSS 501	February 1996
Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting	OPSS 511	November 2004
Construction Specification for Topsoil	OPSS 570	August 1990
Construction Specification for Sodding	OPSS 571	November 2001
Construction Specification for Seed and Cover	OPSS 572	November 2003
Excavation and Backfilling of Structures	OPSS 902	December 1983
Material Specification for Aggregates - Miscellaneous	OPSS 1004	November 2004
Material Specification for Geotextiles	OPSS 1860	November 2004
Construction Specification for Compaction	SP 105S10	November 2004
Construction Specification for Protection Schemes	SP 539S01	April 2004
Excavation and Backfilling of Structures	SP 902S01	September 2003
Backfill and Cover for Concrete Culverts	OPSD 803.010	November 1999
Frost Treatment - Pipe Culverts Frost Penetration Line Below Bedding Grade	OPSD 803.030	September 15, 1996
Pipe Protection against Heavy Construction Equipment	OPSD 808.010	September 15, 1996
Minimum Granular Backfill Requirements - Retaining Walls	OPSD 3504.000	April 1999