FOUNDATION INVESTIGATION AND DESIGN REPORT
for
TWIN CELL CULVERT (SITE NO. 8-610/C)
HIGHWAY 26, STA. 17+617
THORNBURY
G.W.P. 43-00-00
DISTRICT OF LONDON, ONTARIO

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PML Ref.: 11KF065A-C3
Index No. 110FIR and 111FDR
GEOCRES No. 41A-226
December 3, 2012

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for
Twin Cell Culvert (Site No. 8-610/C)
Highway 26, Sta. 17+617
Thornbury
G.W.P. 43-00-00
District of London, Ontario

1. INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the new twin cell culvert replacement on Highway 26 near Thornbury. This isolated work unit is part of the rehabilitation of Highway 6, from Springmount to Hepworth. This work was carried out by Peto MacCallum Ltd. (PML) for McCormick Rankin (MRC), a member of MMM Group Ltd. (MMM), on behalf of the Ministry of Transportation of Ontario (MTO).

The purpose of this report is to summarize the subsurface stratigraphy and groundwater conditions encountered in the boreholes advanced during the foundation investigation at the new culvert site.

2. SITE DESCRIPTION AND GEOLOGY

The new twin culverts will replace the existing twin culverts located under the Highway 26 eastbound and westbound lanes, about 80 m west of the intersection of Highway 26 and Lakeshore Road in Thornbury, Ontario. The existing twin culverts are 1.7 m by 1.9 m CSP type pipe structures and convey the flow from the unnamed Watercourse WC-3.

Land use in the vicinity of the site includes the existing Highway 26 transportation corridor and vacant areas vegetated with grass, brush and scattered trees. The topography of the site is generally level. Site photographs of the culvert location are included in the Appendix A.

The geology in the vicinity of the site consists of three to four till strata over bedrock consisting of Ordovician Shale which is anticipated at about 23 m depth based on Drift Thickness Series Map of the Collingwood – Nottasawaga Area (Preliminary Map P.925).

3. INVESTIGATION PROCEDURES

The subsurface investigation was carried out on December 6, 12 and 13, 2011. Three boreholes, CT3-1 to CT3-3 were drilled to 9.6 to 12.3 m, elevation 170.0 to 171.9, as shown on Drawing TWC-1, appended.

The boreholes were advanced with a truck-mounted CME 55 drill rig using continuous flight hollow stem augers. The equipment was supplied and operated by a specialist drilling contractor, working under the full-time supervision of a PML field supervisor. Since wet sand was contacted in the boreholes, a dynamic cone test was conducted near boreholes CT3-1 and CT3-2 to verify the SPT N values. Results of the dynamic cone test are shown on the borehole logs.

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 co-ordinates and ground elevations at the borehole locations were provided by MMM. The borehole locations are indicated on Drawing TWC-1. All elevations in this report are in metres.

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 (30)
- Grain size distribution analyses (8)
- Atterberg Limits (1)

The laboratory grain size distribution charts are presented in Figures CT3-GS-1 to CT3-GS-6. The plasticity chart is presented in Figure CT3-PC-1. 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, inferred stratigraphy, standard penetration test results as well as groundwater observations. The results of laboratory particle size distributions, Atterberg Limits test and moisture content determinations are also shown on the Record of Borehole Sheets. The approximate borehole locations are presented on the foundation Drawing TWC-1.

Three boreholes (CT3-1 to CT3-3) were drilled along the alignment of this culvert to depths of 9.6 to 12.3 m, elevation 170.0 to 171.9. The subsurface stratigraphy revealed in the boreholes generally comprised of surficial topsoil or local fill underlain by silt and sand mixtures in varying proportions. The boreholes were terminated within the silty sand/sandy silt till stratum. Groundwater was observed in all the boreholes at the time of drilling; however it was only observed in boreholes CT3-1, and CT3-2 on completion of drilling.

4.1.1 Topsoil

A 200 and 300 mm thick layer of topsoil was contacted in boreholes CT3-1 and CT3-3, respectively.

4.1.2 Sand and Gravel Fill

A surficial fill stratum was contacted in borehole CT3-2 to 2.2 m, elevation 180.4 drilled off the shoulder of the highway. The fill consisted of compact sand and gravel. SPT N values in the fill ranged from 14 to 18.

4.1.3 Sand and Gravel

Below the fill in Borehole CT3-2, a localized 0.8 m thick sand and gravel stratum was contacted from 2.2 m, elevation 180.4 to 3.0 m, elevation 179.6. SPT N value in the sand and gravel stratum was 12 indicating a compact relative density.

The results of grain size distribution analysis for a sample from this stratum are included in Figure CT3-GS-2. The moisture content of the sample was 7%.

4.1.4 Silty Sand/Silt with Sand/Silt

Cohesionless deposits of varying gradations were encountered in the three boreholes.

Below the surficial topsoil in borehole CT3-3, a 2.2 m thick silty sand stratum was contacted to 2.5 m, elevation 179.0. SPT N values in the silty sand stratum ranged from 13 to 50 blows without penetration. The SPT N value of 50 blows without penetration is likely due to the presence of cobbles in this stratum.

Below the surficial topsoil layer in borehole CT3-1, a 1.4 m thick stratum of silt with sand was contacted to 1.6 m, elevation 179.5. SPT N values in this unit ranged from 6 to 9 indicating a loose relative density.

The results of grain size distribution analysis for a sample from this stratum are included in Figure CT3-GS-1. The moisture content of the sample was 32%, indicating a wet condition.

Below the sand and gravel in borehole CT3-2, a 0.7 m thick silt stratum with some sand was contacted from 3.0 m, elevation 179.6 to 3.7 m, elevation 178.9. The single SPT N value in the silt was 25 indicating a compact relative density.

Below the silt with sand layer in borehole CT3-1, a 4.4 m thick silt stratum was contacted from 1.6 m, elevation 179.5 to 6.0 m, elevation 175.1. SPT N values in this stratum ranged from 2 to 24 indicating a very loose to compact relative density. A localized very loose to loose layer of silt with SPT N values of 2 and 4 was contacted from elevation 175.4 to 176.6. This loose layer was confirmed by the dynamic cone test conducted adjacent to the borehole.

The results of grain size distribution analysis for two samples from the silt stratum are included in Figure CT3-GS-3. The moisture content of the sample from borehole CT3-2 was 11% while the moisture content of the sample from borehole CT3-1 was 23%.

4.1.5 Clayey Silt

Below the silt stratum in borehole CT3-2, a 1.8 m thick soft clayey silt stratum was contacted from 3.7 m, elevation 178.9 to 5.5 m, elevation 177.1. SPT N values in the silt stratum were 3 and 13. Cobbles were contacted from elevation 175.8 to 176.5 within the clayey silt. The SPT N value of 13 was likely elevated due to presence of cobbles.

The results of the grain size distribution analysis for the clayey silt sample are included in Figure CT3-GS-4. The Atterberg liquid and plastic limits were 24 and 17 respectively, with a plasticity index of 7. A plasticity chart of the clayey silt sample is presented in Figure CT3-PC-1.

4.1.6 Sandy Silt Till /Silt and Sand Till /Silty Sand Till

A cohesionless till deposit consisting of varying amounts of silt and sand was contacted in all three boreholes to the borehole termination depths of 9.6 to 12.3 m, elevation 170.0 to 171.9 as described in detail below.

Below the silt in borehole CT3-1, a 5.1 m thick sandy silt till stratum was contacted from 6.0 m, elevation 175.1 to the borehole termination depth of 11.1 m, elevation 170.0. SPT N values in this stratum ranged from 7 to 64 indicating a loose to very dense relative density.

The results of the grain size distribution analysis for the sandy silt till sample are included in Figure CT3-GS-5. The moisture content of the recovered sample was 11%.

Underlying the clayey silt stratum in borehole CT3-2, a 6.8 m thick, a sandy silt stratum was contacted from 5.5 m, elevation 177.1 to the borehole termination depth of 12.3 m, elevation 170.3. SPT N values in this stratum ranged from 18 to 50 blows per 80 mm, indicating a compact to very dense relative density. Shale fragments were contacted below 10.5 m, elevation 172.1. A sand and gravel layer was contacted below 11.9 m, elevation 170.7 in this stratum.

Below the silty sand stratum in borehole CT3-3, a 2.1 m thick silt and sand till stratum was contacted from 2.5 m, elevation 179.0 to 4.6 m depth, elevation 176.9. SPT N values in this stratum ranged from 9 to 65 indicating a loose to very dense relative density.

The results of the grain size distribution analysis for two samples recovered from this stratum are included in Figure CT3-GS-6. Moisture contents of the samples were 7 and 8%.

Below the silt and sand till stratum, a 5.0 m thick silty sand till stratum was contacted from 4.6 m, elevation 176.9 to the borehole termination depth of 9.6 m, elevation 171.9 in borehole CT3-3. SPT N values in this stratum ranged from 25 to 92 blows indicating a compact to very dense relative density. Shale fragments were observed in this stratum below 7.6 m, elevation 173.9 and sandy silt seams were observed below 9.1 m, elevation 172.4.

4.1.7 Groundwater

During augering, groundwater was observed at 0.9 to 3.6 m, elevation 179.0 to 180.6 in all the boreholes. Ground water was observed at 1.2 and 6.4 m, elevation 179.9 and 176.2, respectively in boreholes CT3-1 and CT3-2, on completion of drilling. Groundwater was not observed in boreholes CT3-3 on completion of drilling. The groundwater level is subject to seasonal fluctuation and rainfall patterns.

5. MISCELLANEOUS

Mr Alan Lo carried out the field investigation for this study under the supervision of Mrs. N .S. Balakumaran, P. Eng. Aardvaark 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.

6. CLOSURE

This Foundation Investigation Report was prepared by Mr. H. Gharegrat, 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 carried out an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

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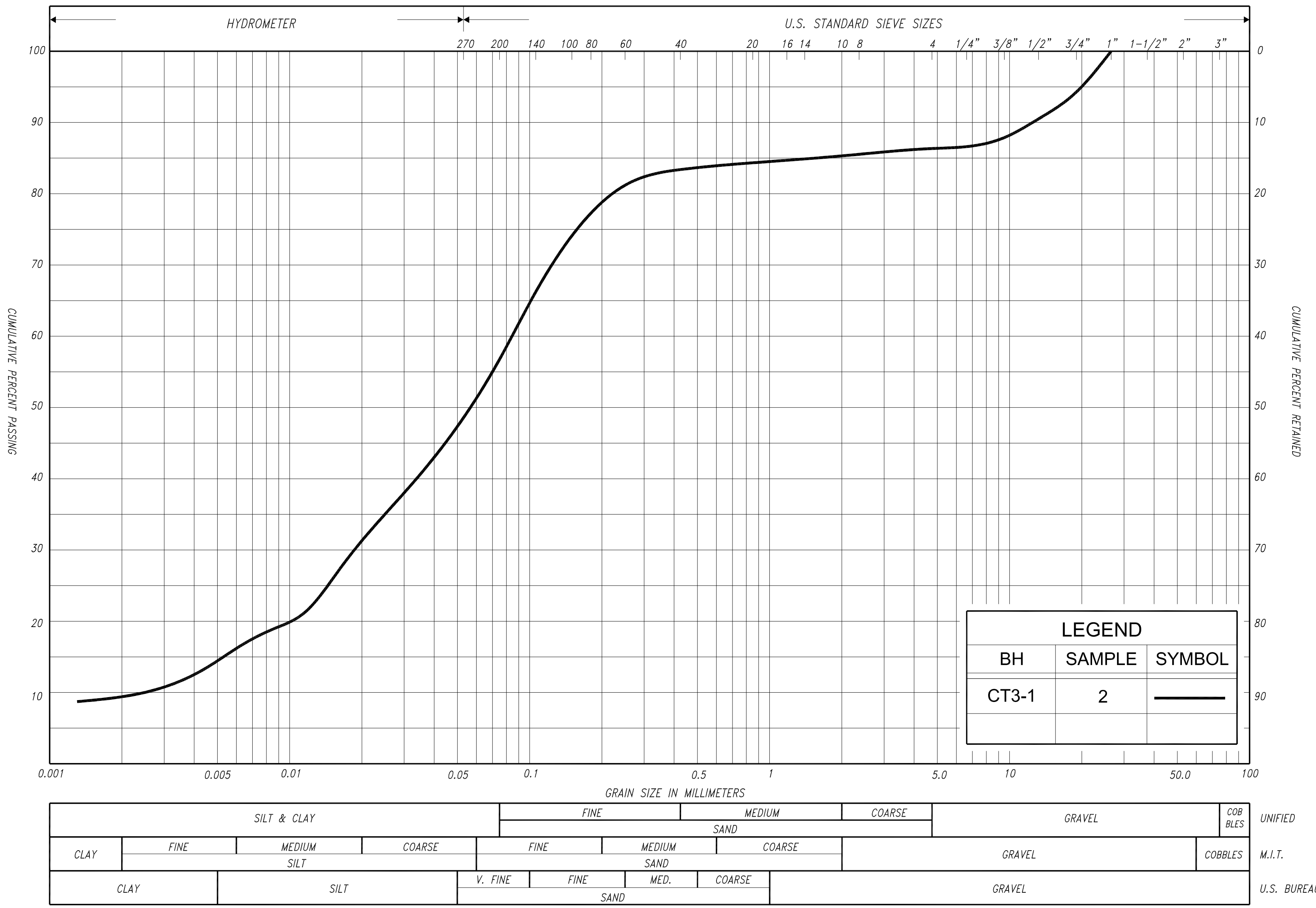
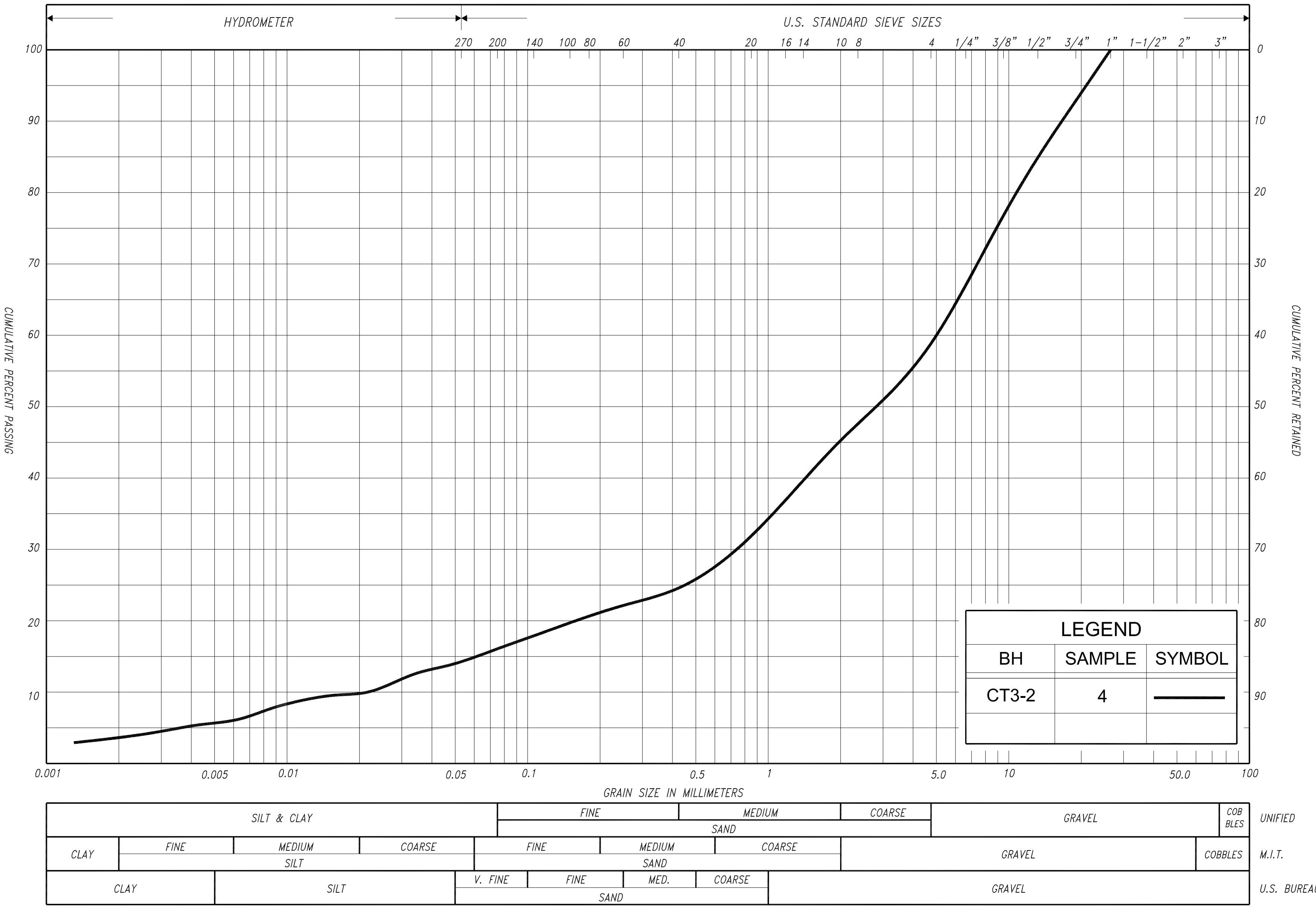


GRAIN SIZE DISTRIBUTION

SILT, with sand, some gravel, trace clay

FIG No.	CT3-GS-1
HWY:	26
G.W.P. No.	43-00-00

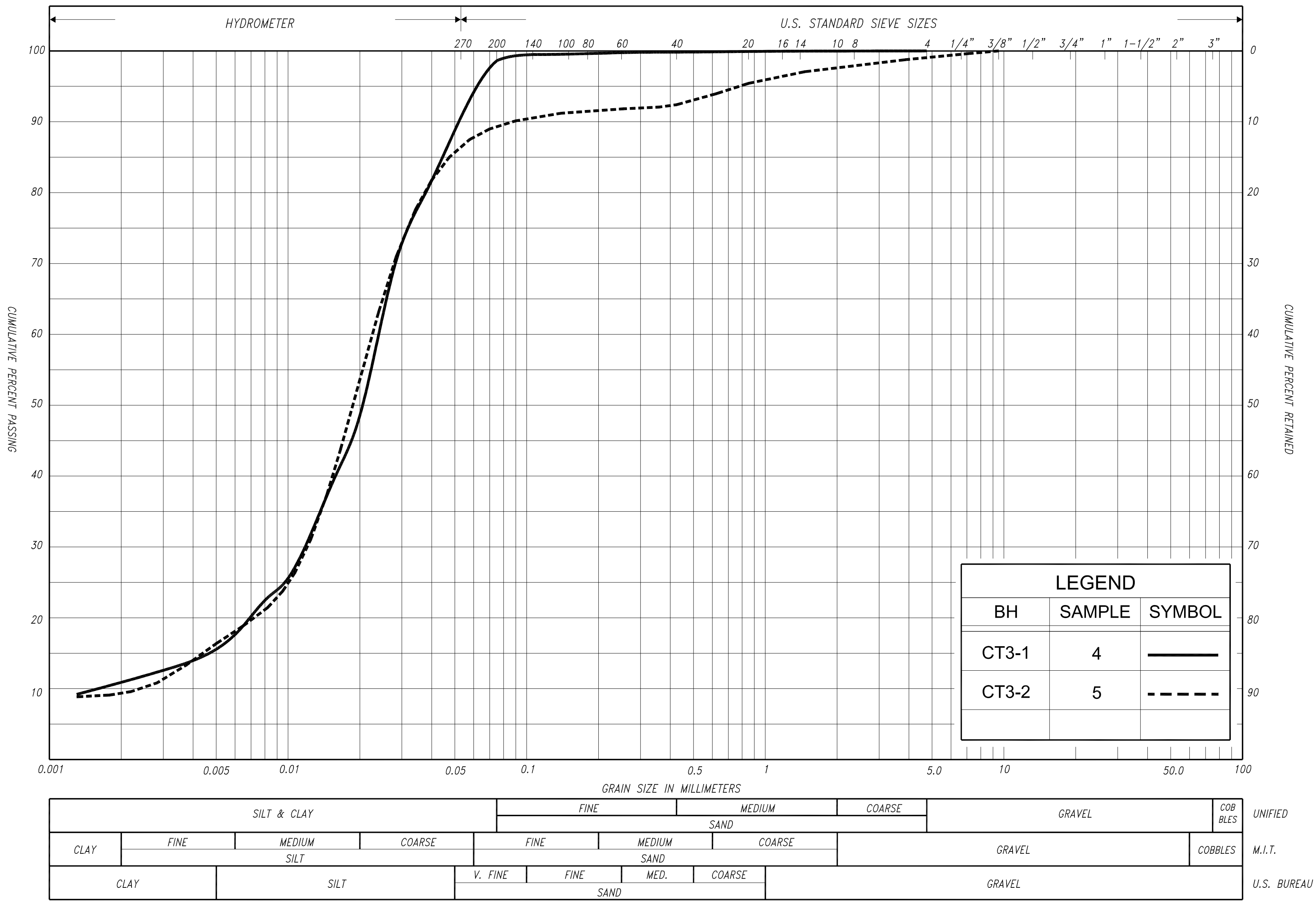


Ontario

GRAIN SIZE DISTRIBUTION

SAND AND GRAVEL, some silt, trace clay

FIG No.	CT3-GS-2
HWY:	26
G.W.P. No.	43-00-00



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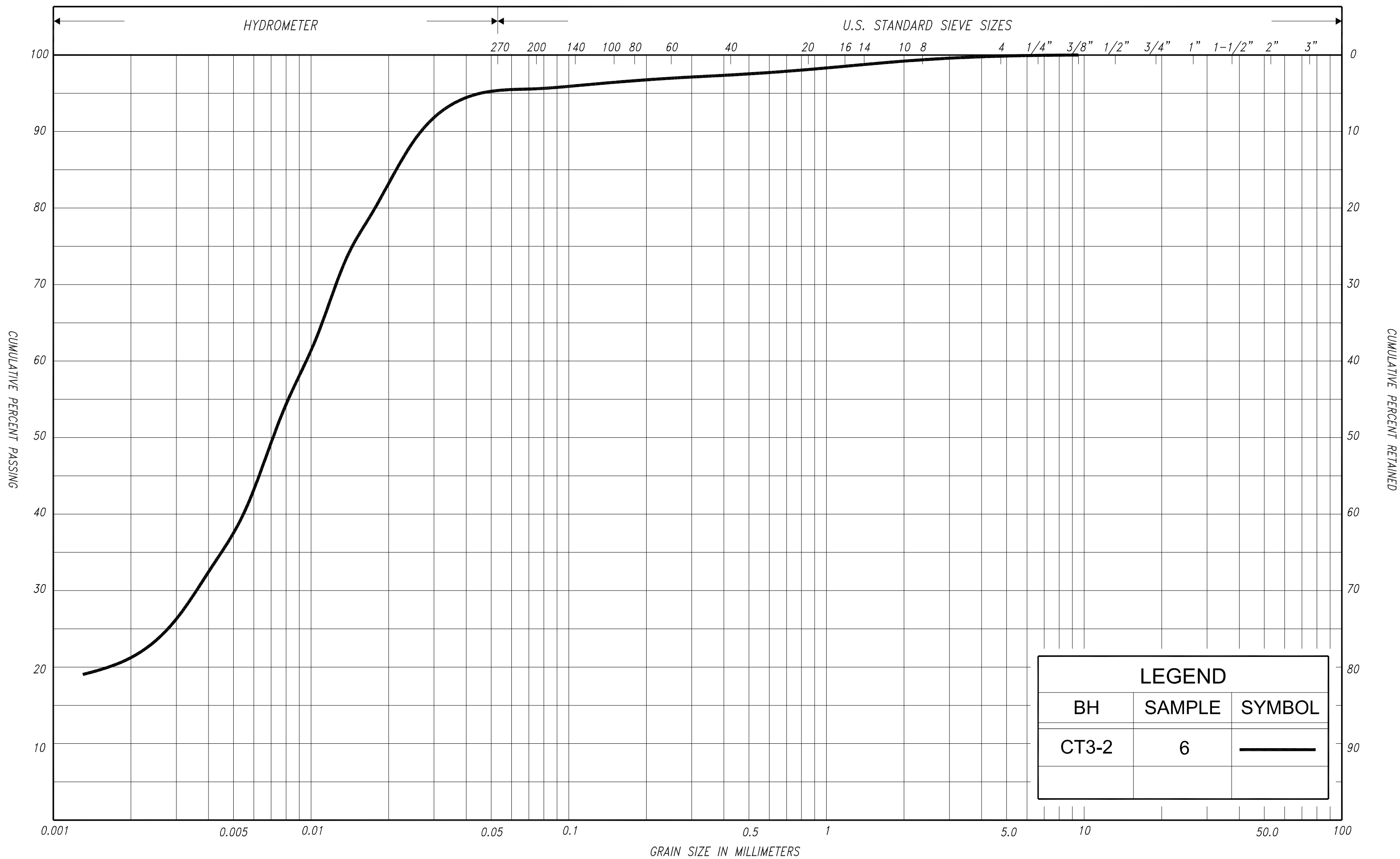
GRAIN SIZE DISTRIBUTION

SILT, some to trace clay, trace to some sand, trace gravel

FIG No.	CT3-GS-3
HWY:	26
G.W.P. No.	43-00-00



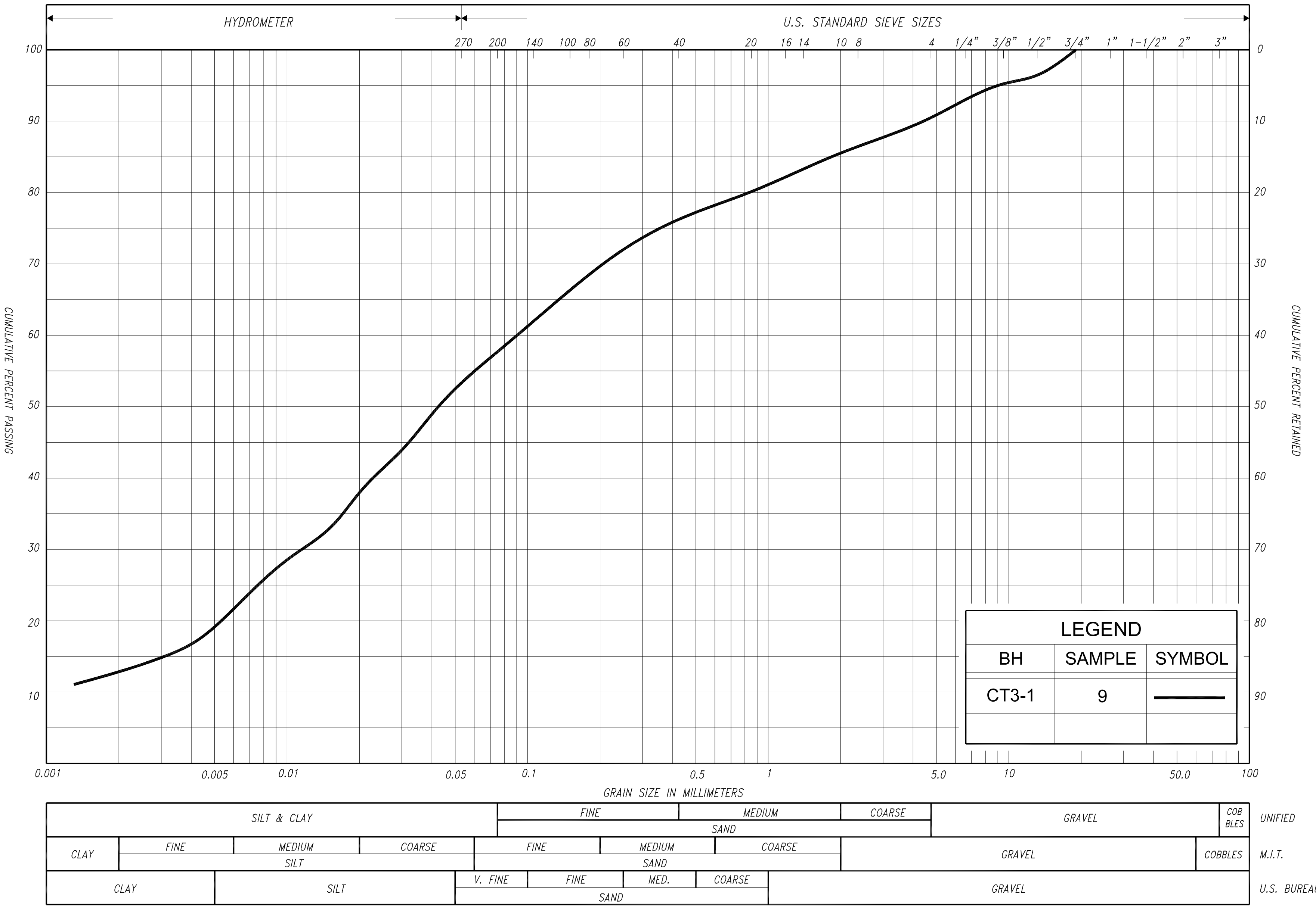
SILT & CLAY			SAND: FINE	SAND: MEDIUM	SAND: COARSE	GRAVEL	COBBLES	UNIFIED
CLAY	SILT: FINE	SILT: MEDIUM	SILT: COARSE	SAND: FINE	SAND: MEDIUM	SAND: COARSE	GRAVEL	COBBLES	M.I.T.
CLAY	SILT	SAND: V. FINE	SAND: FINE	SAND: MED.	SAND: COARSE	GRAVEL		U.S. BUREAU

Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand (CL)

FIG No.	CT3-GS-4
HWY:	26
G.W.P. No.	43-00-00

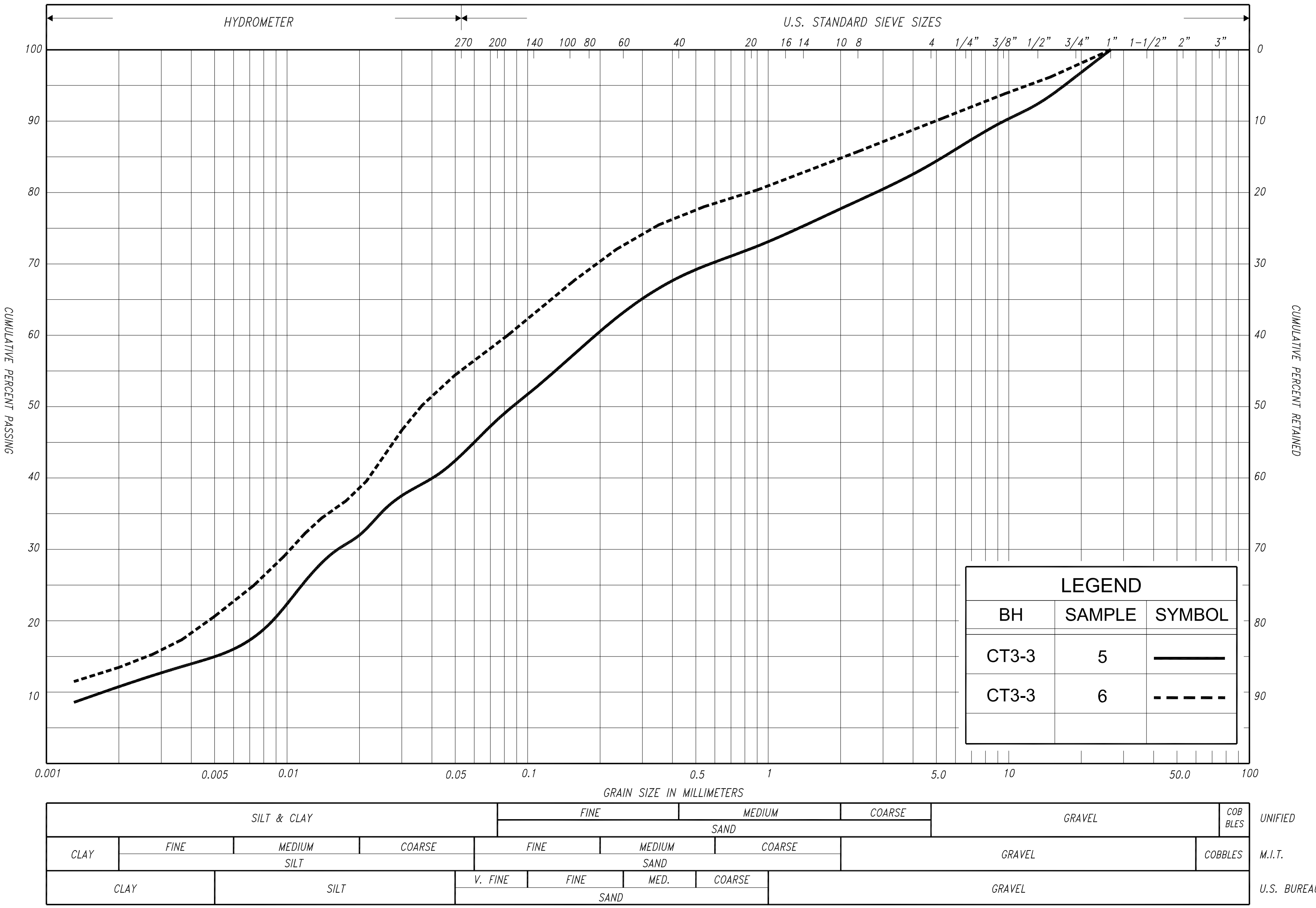


GRAIN SIZE DISTRIBUTION

SILT, with sand, some clay, some gravel

FIG No.	CT3-GS-5
HWY:	26
G.W.P. No.	43-00-00

Ontario

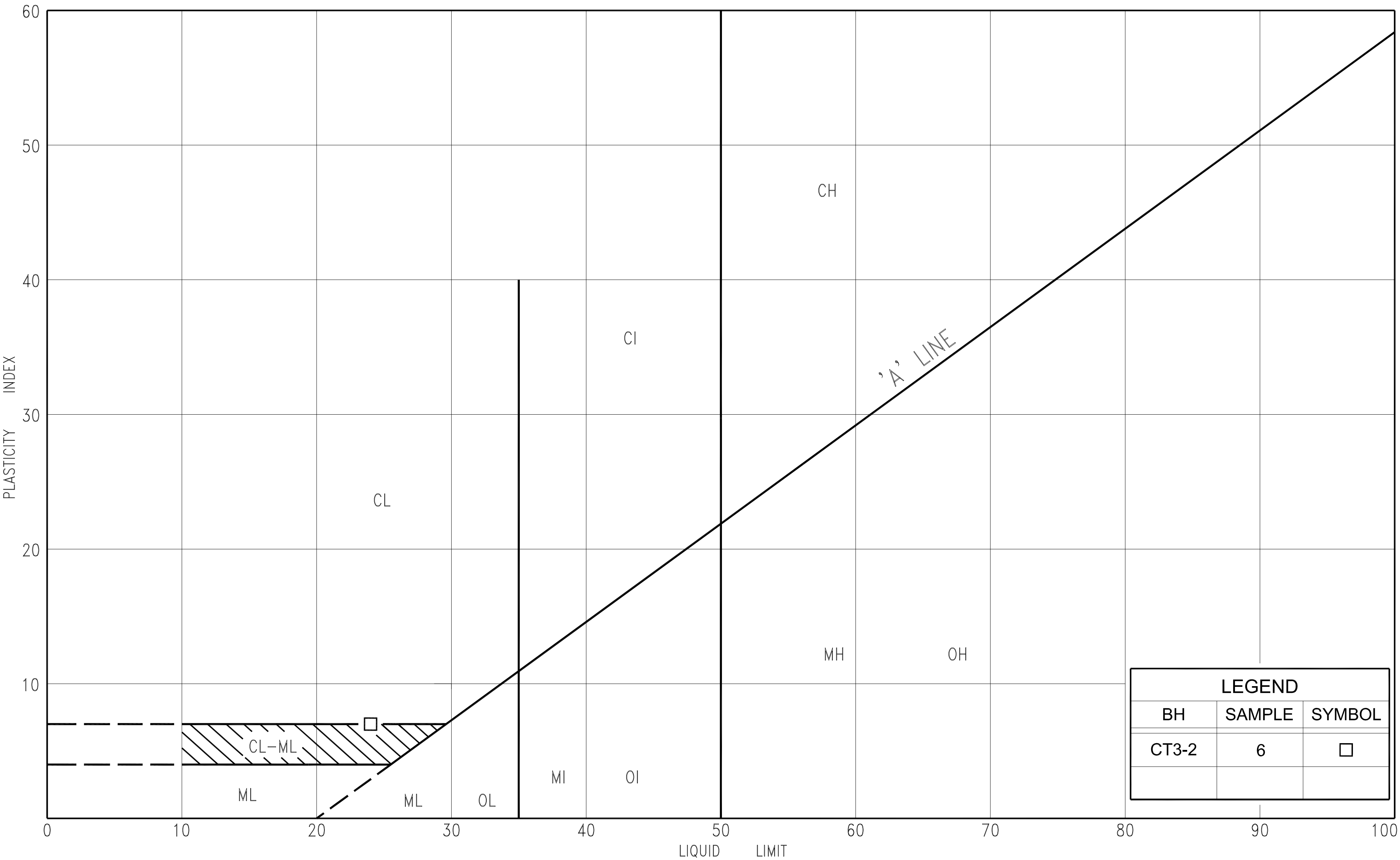


Ontario

GRAIN SIZE DISTRIBUTION

SILT AND SAND, some clay, trace to some gravel
(TILL)

FIG No.	CT3-GS-6
HWY:	26
G.W.P. No.	43-00-00



LEGEND		
BH	SAMPLE	SYMBOL
CT3-2	6	□

Ontario

PLASTICITY CHART

CLAYEY SILT, trace sand (CL)

FIG No.	CT3-PC-1
HWY:	26
G.W.P. No.	43-00-00

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/0.3 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, 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:

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
r_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
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL
e	1,%	VOID RATIO

n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX $= w_L - w_P$
I_L	1	LIQUIDITY INDEX $= \frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX $= \frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT

e_{max}	1,%	VOID RATIO IN LOOSEST STATE
e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_u	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

Ontario

Peto MacCallum Ltd.
CONSULTING ENGINEERS
Foundation Design

RECORD OF BOREHOLE No CT3-1

METRIC

G.W.P. 43-00-00 **LOCATION** Co-ords: 4 934 794.0 N ; 230 981.0 E **ORIGINATED BY** A.L.

DIST London **HWY** 6 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** H.G.

DATUM Geodetic **DATE** December 06, 2011 **CHECKED BY** B.R.G.

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
181.1	Ground Surface				
0.0	Topsoil				
180.9 / 0.2	Silt with sand, some gravel, trace clay, rootlets, oxodized partings. Loose, Brown, Moist to wet	1	SS	6	
		2	SS	9	15 28 48 9
179.5 / 1.6	Silt, some clay, trace sand. Compact to very loose, Grey, Wet	3	SS	11	
		4	SS	10	0 1 88 11
		5	SS	4**	
		6	SS	2**	
		7	SS	24	
	cobbles				
175.1 / 6.0	Sandy silt, some clay, some gravel. Loose to very dense, Grey, Moist (TILL)	8	SS	7	
		9	SS	19	10 32 45 13
		10	SS	64	
	sand and gravel layer	11	SS	51	
170.0 / 11.1	End of borehole				

GROUND WATER CONDITIONS: ▽* (water level observed during drilling) at approx. El. 179.7; ▼* (water level measured after drilling) at approx. El. 180.0

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 70/23cm at approx. El. 174.1 (bouncing on probable boulder)

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%)

UNIT WEIGHT γ kN/m³

* 2011 12 06 & 11

▽ Water level observed during drilling

▼ Water level measured after drilling

NOTE: Dynamic cone was carried-out 1.5m east of borehole CT3-1

** Low 'N' values due to hydraulic disturbance

5 × Numbers refer to Sensitivity

20 / 15 –○– 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CT3-2

METRIC

Ontario — Peto MacCallum Ltd. Consulting Engineers — Foundation Design

G.W.P. 43-00-00 **LOCATION** Co-ords: 4 934 789.0 N ; 230 949.8 E **ORIGINATED BY** A.L.

DIST London **HWY** 6 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** H.G.

DATUM Geodetic **DATE** December 06 and 12, 2011 **CHECKED BY** B.R.G.

Soil Profile

ELEV / DEPTH	DESCRIPTION
182.6	Ground Surface
0.0	Sand and gravel; Compact, Brown, Moist; trace silt (FILL)
180.4 / 2.2	Sand and gravel, trace silt, trace clay; Compact, Brown, Moist
179.6 / 3.0	Silt, some sand, trace clay, trace gravel; Compact, Grey, Moist to wet
178.9 / 3.7	Clayey silt, trace sand; Soft, Grey, Moist; cobbles; sand and gravel layer
177.1 / 5.5	Sandy silt, trace clay, trace gravel; Compact to very dense, Grey, Moist (TILL); shale fragments; sand and gravel layer
170.3 / 12.3	End of borehole

Samples

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	15	
2	SS	14	
3	SS	18	
4	SS	12	41 43 12 4
5	SS	25	1 10 80 9
6	SS	3**	0 4 74 22
7	SS	13	
8	SS	18	
9	SS	31	
10	SS	34	
11	SS	51	
12	SS	80	
13	SS	50/8cm	

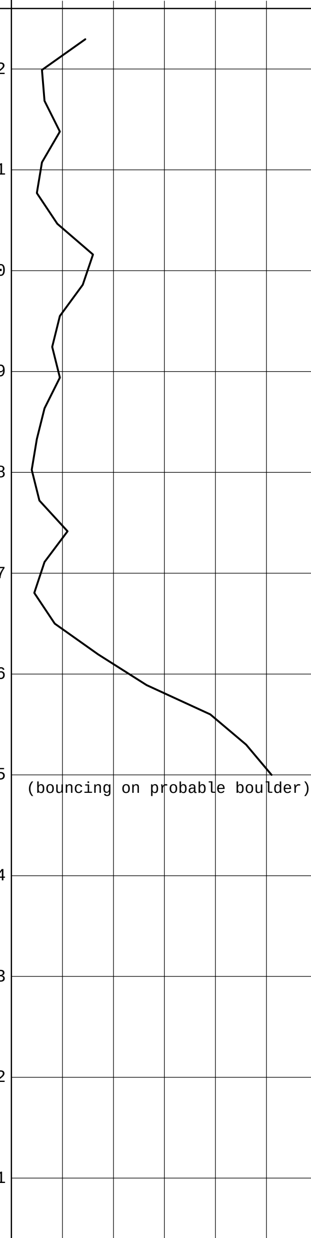
Elevation scale: 182, 181, 180, 179, 178, 177, 176, 175, 174, 173, 172, 171

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³



** Low 'N' value due to hydralic disturbance

Samples 11 and 13: Sampler bouncing

* 2011 12 06 & 12

▽ Water level observed during drilling

▼ Water level measured after drilling

NOTE: Dynamic cone was carried-out 1.5m east of borehole CT3-2

5 × Numbers refer to Sensitivity; 20 / 15 – 5 / 10 (%) STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No CT3-3

METRIC

G.W.P. 43-00-00 | LOCATION Co-ords: 4 934 758.7 N ; 230 967.5 E | ORIGINATED BY A.L.

DIST London | HWY 6 | BOREHOLE TYPE Continuous Flight Hollow Stem Augers | COMPILED BY H.G.

DATUM Geodetic | DATE December 12 and 13, 2011 | CHECKED BY B.R.G.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
181.5	Ground Surface										
0.0 / 181.2	Topsoil										
0.3	Silty sand, trace gravel cobbles, rootlets; Loose to compact; Dark grey; Wet	1	SS	4		181	~48				
		2	SS	50/0cm	∇*						
		3	SS	13		180	~20				
179.0 / 2.5	Silt and sand, some clay trace to some gravel cobbles and boulders; Loose to very dense; Grey; Moist (TILL)	4	SS	9		179					
		5	SS	31		178	~7	16	36	37	11
		6	SS	65			~7	10	31	46	13
176.9 / 4.6	Silty sand trace clay, trace gravel; Compact to very dense; Grey; Wet (TILL)	7	SS	25		177	~12				
		8	SS	28		176	~19				
		9	SS	27		175	~19				
	shale fragments	10	SS	80		174	~11				
	sandy silt seams					173					
171.9 / 9.6		11	SS	92		172	~11				
	End of borehole										
	Sample 2: Sampler bouncing										

* 2011 12 12

∇ Water level observed during drilling

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L. UNIT WEIGHT γ kN/m³. REMARKS & GRAIN SIZE DISTRIBUTION (%).

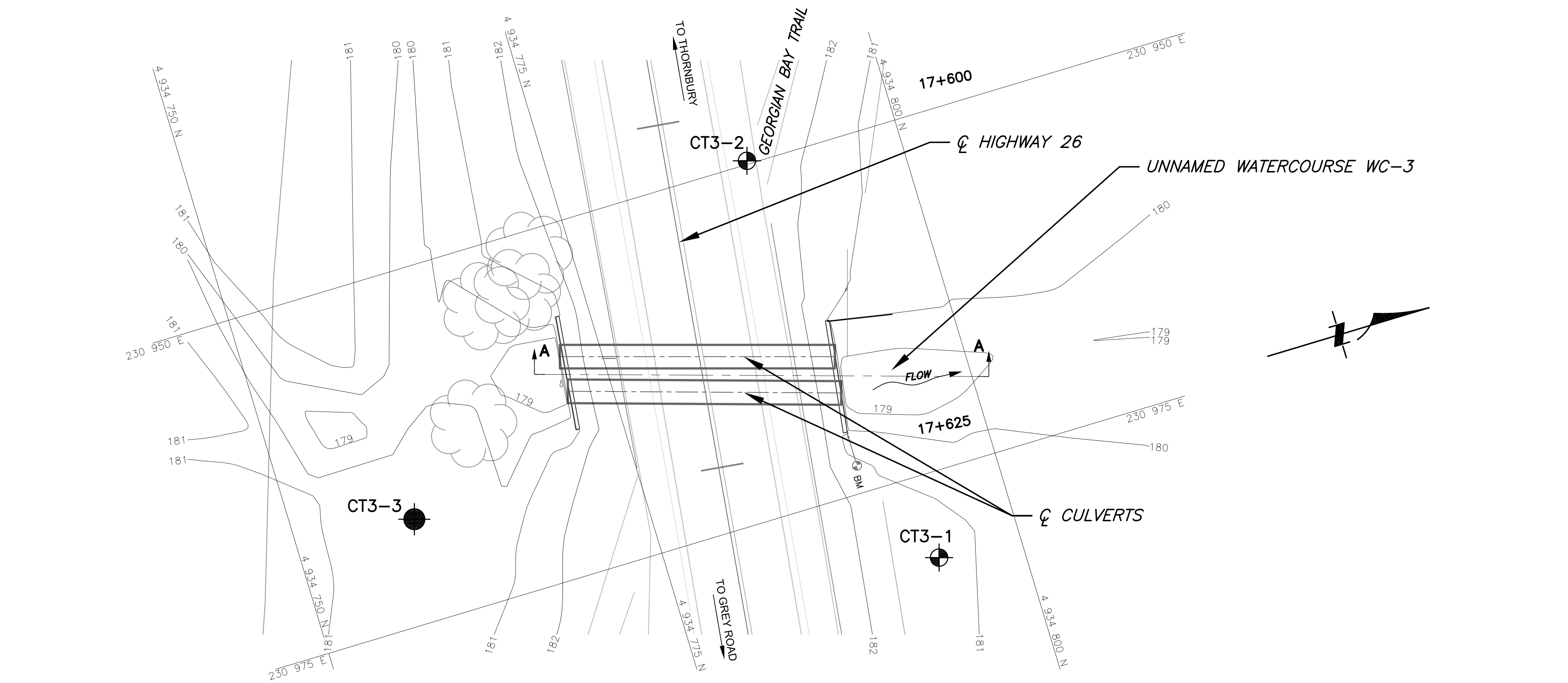
7, 5 × : Numbers refer to Sensitivity — 20 / 15 —○— 5 / 10 (%) STRAIN AT FAILURE

CONT No
GWP No 43-00-00

TWIN CELL CULVERT REPLACEMENT
HIGHWAY 26 – THORNBURY
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS

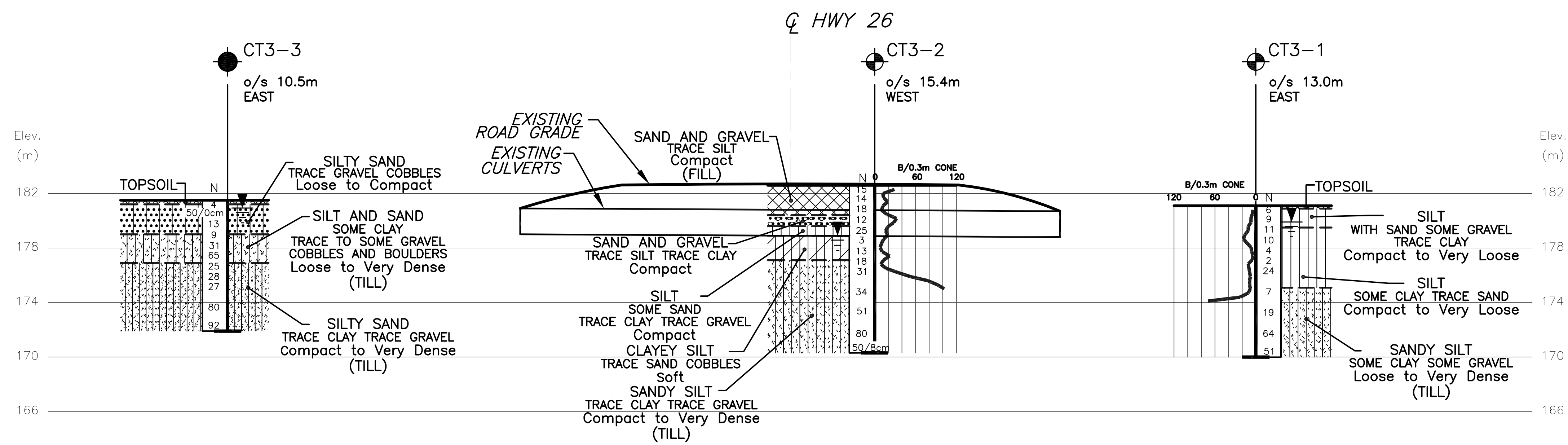


PLAN

SCALE

5 0 5 10m

KEY PLAN
NOT TO SCALE



PROFILE A-A THROUGH ℄ CULVERTS

SCALE

HORIZONTAL
2.5 0 2.5 5

VERTICAL
5 0 5 10

LEGEND

- Borehole
- Borehole & Cone
- 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
CT3-1	181.1	4 934 794.0	230 981.0
CT3-2	182.6	4 934 789.0	230 949.8
CT3-3	181.5	4 934 758.7	230 967.5

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

NOTES:

1. GENERAL ARRANGEMENT DRAWING WAS NOT AVAILABLE AT THE TIME OF DRAFT REPORT. COORDINATES AND ELEVATIONS WERE ESTIMATED FROM THE REFERENCE DRAWING.
2. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
3. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
4. DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.

REF MRC Drawing: DTM_THORNBURY.dwg dated July 2012

REVISIONS DATE	BY	DESCRIPTION

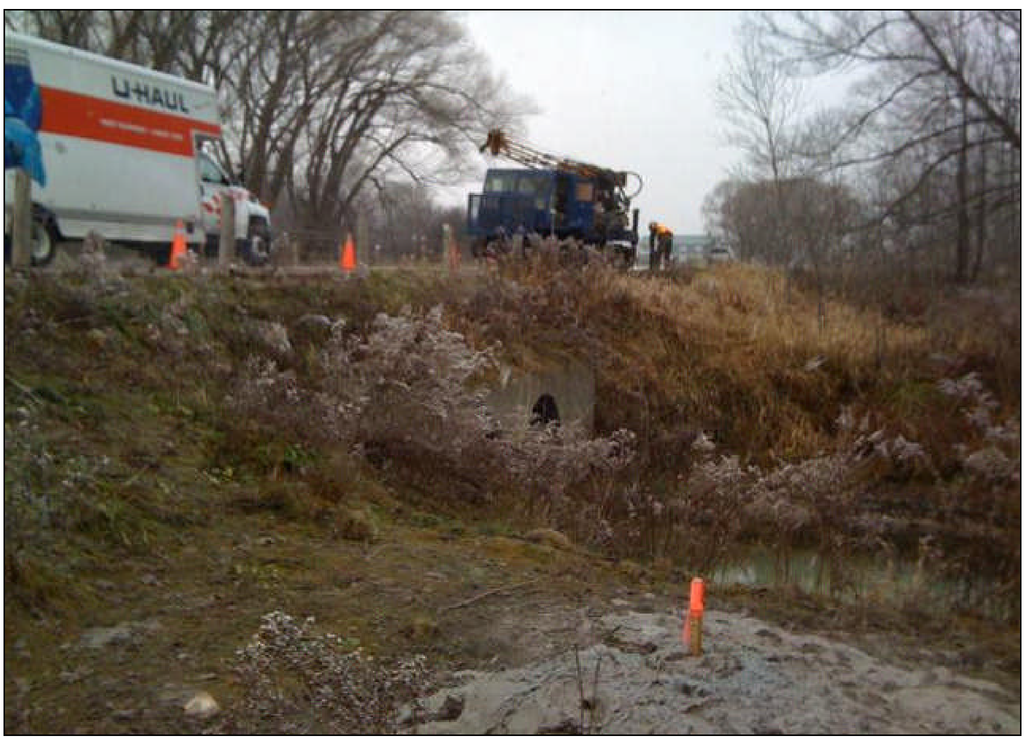
Geocres No. 41A-226

HWY No 26			DIST London
SUBM'D NA	CHECKED HG	DATE DEC. 03, 2012	SITE 8-610/C
DRAWN NA	CHECKED GD	APPROVED BRG	DWG TWC-1

APPENDIX A

Site Photographs

Photograph 1: Looking west along Highway 26 towards the culvert. Drill rig is on borehole CT3-2. (December 6, 2011)



Photograph 2: Looking southwest towards culvert from borehole CT3-1. (December 6, 2011)

Photograph 3: Looking west along Highway 26. Drill rig is on CT3-3. (December 12, 2011)

FOUNDATION DESIGN REPORT
for
TWIN CELL CULVERT (SITE NO. 8-610/C)
HIGHWAY 26, STA. 17+617
THORNBURY
G.W.P. 43-00-00
DISTRICT OF LONDON, ONTARIO

PETO MacCALLUM LTD.
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Distribution:
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PML Ref.: 11KF065A-C3
Index No. 111FDR
GEOCRES No. 41A-226
December 3, 2012

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Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN REPORT
for
Twin Cell Culvert (Site No. 8-610/C)
Highway 26, Sta. 17+617
Thornbury
G.W.P. 43-00-00
District of London, Ontario

1. INTRODUCTION

The installation of a new twin cell culvert at Station 17+617 on Highway 26 replacing the existing culvert is planned. This isolated work unit is part of the rehabilitation of Highway 6 project, from Springmount to Hepworth. This report was prepared for McCormick Rankin (MRC), a member of MMM Group Ltd.(MMM), on behalf of the Ministry of Transportation of Ontario (MTO).

This report provides foundation engineering comments and recommendations for design and construction of the new twin cell culvert at Station 17+617 and temporary roadway protection which will be required for the staged construction of the culvert.

A General Arrangement (GA) drawing was not available at the time of this report. An undated and untitled surveying base plan provided by MMM was used to obtain the existing site conditions. Based on the provided drawing the existing culvert consists of a twin 1.7 m by 1.9 m oval corrugated steel pipe (CSP) culvert with a base near elevation 179.0. Recommendations to construct the culverts as open footing type culverts and as closed box culverts are provided. Invert levels for the new culverts were not available and it is assumed that the new culverts will be founded at the same elevation as the existing twin cell culverts. It was also assumed that a temporary roadway protection system will be installed along the centreline of Highway 26 to maintain traffic during construction staging.

In summary, the subsurface stratigraphy revealed in the boreholes generally comprised a surficial topsoil and local fill underlain by mainly cohesionless deposits consisting of silt and sand in varying proportions. Ground water was observed at 1.2 and 6.4 m, elevation 179.9 and 176.2, in boreholes CT3-1 and CT3-2, respectively on completion of drilling. Groundwater was not observed in borehole CT3-3 on completion of drilling, but was observed at 0.9 m, elevation 180.6 during drilling.

The foundation frost penetration depth at the site is 1.4 m according to OPSD 3090.101.

Since a GA drawing was not available for this project, it was assumed that the existing twin cell culvert will likely be replaced with a precast concrete twin cell box culvert with similar dimensions as those of the existing culverts and with the invert at the same elevation 179.0

The alternative open footing type culverts would need to be founded approximately 1.0 m lower than the box culvert subgrade alternative for foundation frost protection, this alternative would need a cast-in-place concrete construction below the groundwater table which would require extensive groundwater control measures due to the relatively pervious local soil conditions. Therefore, recommendations for a cast-in-place concrete culvert and further discussion of the advantages and disadvantages of culvert options are not included in this report. These recommendations should be reviewed and revised as necessary when the GA drawing for the culvert replacement is prepared.

When removing the existing culvert, care should be taken not to disturb the founding subgrade to minimize the preparation needed for placing the new culvert.

It is noted that no responsibility or liability is assumed by the consultants and MTO for alerting the contractors, and to “red-flag” 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. TWIN CELL CULVERT (NEW)

2.1 Foundations

The invert level of the new box culvert is assumed near elevation 179.0, the same as at the base of the existing culvert. The subgrade is assumed at elevation 178.5 allowing for the concrete base and bedding thickness. The proposed road grade level at the new culvert will be about elevation 182.4, thus about 1.2 to 1.4 m of road fill cover is assumed above the culvert.

The subgrade soils revealed in the boreholes at the culvert invert level (elevation 179.0) and at the culvert open footing subgrade level (elevation 178.5) was found to be variable and comprised compact silt at the outlet borehole CT3-1, compact silt/“soft” clayey silt under the embankment at borehole CT3-2 and loose to dense silt and sand in the inlet borehole CT3-3. The SPT N value in the clayey silt at elevation 178.9 was likely impacted by hydraulic disturbance and is not considered representative of the clay strength.

Based on the encountered subsurface condition, the proposed precast concrete box culvert can be adequately founded on the local native soils.

The recommended factored geotechnical bearing resistance at ultimate limit states (ULS) and geotechnical reaction at serviceability limit states (SLS) for a precast concrete box culverts constructed on the cohesionless deposits are as follows:

CULVERT SECTION	SUBGRADE SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL REACTION AT SLS (kPa)
Entire Length	Compact silt Compact silt/clayey silt Loose to dense silt and sand	300	150

The geotechnical reaction at SLS normally allows for 25 mm compression of the founding medium. Since the new culvert site has been preloaded by the existing embankment negligible settlements are anticipated under the proposed culvert and the uniform recommended resistance and reaction values may be used for design.

2.2 General Comments

2.2.1 Subgrade Preparation

Preparation of the subgrade for construction of the culvert should be performed and monitored in accordance with OPSS 902. A site review should be conducted by qualified geotechnical personnel during preparation of the subgrade and compaction of the granular fill.

Deleterious or disturbed soils revealed during the preparation at or below the footing subgrade should be excavated and replaced with compacted Granular A or Granular B Type II. Granular B Type II should be preferred for construction under wet conditions.

For the precast concrete box culvert being considered, a 300 mm thick granular bedding (OPSS Granular A) is recommended below the culvert. The backfill and bedding material should be compacted to 95% 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 (if applicable) and frost taper treatment for the precast culvert should be carried out in accordance with MTOD 803.021, OPSS 422 and MTO SP 422S01.

2.2.2 Modulus of Subgrade Reaction

The estimated value of the modulus of subgrade reaction for a box culvert constructed on the undisturbed subgrade native soils is as follows:

SOIL TYPE	MODULUS OF SUBGRADE REACTION, MN/m^3
Native compact silt, clayey silt, loose to dense silt and sand	20

2.2.3 Sliding Resistance

The following parameters should be used to compute sliding resistance of a precast box culvert and cast-in-place footings, including headwalls and wingwalls if applicable. The friction angles have been reduced by a factor of 0.67 for precast box culvert foundations to account for the smooth concrete base.

SOIL TYPE	FOUNDATION FRICTION ANGLE, DEGREES		COHESION, kPa	UNIT WEIGHT, kN/m^3
	CAST-IN-PLACE	PRECAST		
Granular A or Granular B Type II	35	23	0	22.8
Loose to compact silt	25	17	0	18.0
Firm clayey silt	15	10	50	19.0

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

2.2.4 Seismic Site Coefficient

The boreholes were terminated at depths of 9.6 to 12.3 m, within native soil, hence a determination of seismic site coefficient was based on available geological information which indicates that bedrock exists at about 23.0 m depth in the vicinity of the site. Hence, the seismic site coefficient for the conditions at the subject 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. Requirement for frost taper is 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 minimise the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction. Refer to MTO OPSS 501 for additional comments.

The new 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/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 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 Ø = angle of internal friction of retained soil (35º for Granular A or B Type II)
δ = angle of friction between soil and wall (23.5º 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 estimating the earth pressure for granular backfill:

PARAMETER	GRANULAR A OR GRANULAR B (Type II)
Angle of Internal Friction, degrees	35
Unit Weight, kN/m^3	22.8
Coefficient of Active Earth Pressure (K_a)	0.27
Coefficient of Earth Pressure At Rest (K_o)	0.43
Coefficient of Passive Earth Pressure (K_p)	3.69

The design should consider both the maximum water level in the stream and the stabilised 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

For headwalls and wingwalls design, the previous recommendations and geotechnical parameters for culvert foundations and backfill should be utilized for the design of the foundations. 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 with 1.4 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 2.2.3 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 walls. 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 drainage system.

5. CONSTRUCTION CONSIDERATIONS

5.1 Staged Construction

Staged construction will be required to install the new culvert and to remove the existing culvert while maintaining traffic on Highway 26. A staged construction drawing was not available at the time of this Report. In general, based on our experience, three construction stages are identified for culvert replacement and are as follows:

- Stage 1: Install roadway protection system.
- Stage 2: Removal of east half of existing culvert. Installation of east half (outlet) of new culvert and backfill.
- Stage 3: Removal of the west half of existing culvert. Installation of west half (inlet) of new culvert followed by the removal of the roadway protection system, if required.

5.2 Roadway Protection

It is anticipated that a suitable roadway protection scheme following OPSS 539 will be necessary to support the walls of the anticipated about 4.0 m deep excavation and adjacent traffic lanes during staged construction.

A roadway protection system designed for performance level 2 according to OPSS 539 is recommended to prevent excessive lateral and/or vertical movement of the existing embankment during construction. The contractor is responsible for the selection, performance and detailed design of the roadway protection scheme. The contractor should monitor the movement of the roadway protection system. To meet the performance Level 2, the maximum lateral displacement is limited to 25 mm with a maximum allowable angular distortion of 1:200.

In case excessive movement is experienced in the roadway protection system, a monitoring system should be implemented to check the horizontal and vertical displacements of the roadway surface during construction. A maximum of 12 mm of settlement should be allowed on the travelled highway section to be used as required.

Alternative roadway protection schemes such as sheet piling or anchored soldier piles and lagging were considered. Typically, sheet piling can be used to reduce loss of native soils below the water table. Soldier piles and lagging are generally considered suitable for applications above groundwater table in cohesionless soils.

The following table presents an overview assessment of the advantages and disadvantages, including relative costs and risk/consequences of the roadway protection system alternatives from the foundation perspectives at the subject site.

ALTERNATIVES	ADVANTAGES	DISADVANTAGES
Sheet piles	• Sheet piles will be interlocked therefore loss of native soils will be negligible • Suitable for high water table • Suitable to drive for varying bedrock profile, if required • Faster construction than soldier piles and lagging • Low risk of soil loss	• Higher cost than for soldier piles • May require soil anchors/rakers for lateral support • Larger construction equipment is required than for soldier piles • Not suitable if boulders are present within the soil
Soldier piles and lagging	• Lower cost than for sheet piles • Smaller construction equipment is required than for sheet piles	• Excessive settlement may occur due to loss of cohesionless soils/ fill materials with high water table • Slower construction than sheet piles • Unsuitable with high water table • High risk of soil loss

Based on the above table and considering the groundwater is at or below the assumed founding elevation of the culvert, an anchored or braced soldier pile and lagging system is considered feasible at the site. The presence of debris in the fill and cobbles and boulders in the native soils must be considered during installation of soldier piles.

5.3 Excavation

Excavation to the anticipated founding level of the new culvert is expected to extend through the topsoil, silt with sand, sand and gravel and silty sand. 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.

According to OHSA criteria, the loose silty sand and silt with sand the compact sand and gravel fill and silty sand are considered as Type 3 soils. Accordingly, temporary cut slopes over the full depth of excavation inclined at 1 horizontal to 1 vertical should be provided assuming adequate groundwater control measures are in place.

5.4 Groundwater Control

Ground water was observed at 1.2 and 6.4 m, elevation 179.9 and 176.2 in boreholes CT3-1 and CT3-2, respectively, on completion of drilling in December, 2011. The level in borehole CT3-1 is above the assumed founding subgrade level, elevation 178.5.

In view of the relatively pervious native soils the local groundwater will reflect the prevailing water level in the watercourse at the time of construction. The higher water level locally found during drilling, up to elevation 180.6, indicates the presence of water level fluctuations in the creek. The culvert replacement should be planned and carried out for the drier time of the year to facilitate the Roadway Protection and culvert installation.

It is anticipated that conventional procedures such as dam and pump will be sufficient to dewater the foundation excavation during low groundwater conditions however more complex measures such as cofferdaming will be required during wet construction periods. The contract should include a NSSP to warn the contractor about the need for groundwater control during excavation due to the relatively pervious soils and potential high fluctuations in groundwater levels.

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 rock 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) shall be placed, where slopes are steeper than 3H:1V or for aesthetic reasons. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor.

SOIL TYPE	K FACTOR
Sand and gravel	0.18
Silt with sand/Silty sand	0.5

7. CLOSURE

This Foundation Design Report was prepared by Mr. H. Gharegrat, 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 carried out an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

Harry Gharegrat, MS, P.Eng.
Senior Engineer

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

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

HG/BRG:hg-nk

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 539	Construction Specification for Temporary Protection Systems
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
OPSS 1004	Material Specification For Aggregates – Miscellaneous
OPSS 1860	Material Specification for Geotextiles
SP 422S01	Construction Specification for Precast Concrete Box Culvert
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depth for Southern Ontario
OPSD 3121.150	Minimum Granular Backfill Requirements - Walls Retaining
MTOD 803.021	Bedding and Backfill for Precast Concrete Box Culverts