Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT
for
STRUCTURAL CULVERT AT STATION 20+612
SITE NO. 35-454/C
HIGHWAY 6 IMPROVEMENTS
FROM ARTHUR (WELLS STREET) TO SOUTH OF MOUNT FOREST
AGREEMENT NUMBER 3005-E-0036
GWP NO. 342-97-00
TOWNSHIP OF ARTHUR, ONTARIO

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PML Ref.: 05KF104C
Index No.: 143FIR and 144FDR
Geocres No.: 40P15-38
December 29, 2006

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FOUNDATION INVESTIGATION REPORT
for
Structural Culvert at Station 20+612
Site No. 35-454/C
Highway 6 Improvements
From Arthur (Wells Street)
to South of Mount Forest
Agreement Number 3005-E-0036
G.W.P. 342-97-00
Township of Arthur, Ontario

1. INTRODUCTION

Planned under this project is the rehabilitation and widening of Highway 6 from Arthur (Wells Street) to south of Mount Forest in the Township of Arthur, Ontario for an approximately 21.2 km long section. Included in the scope of work is the replacement of the structural culvert located at Station 20+612. This report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

The structural culvert (Site No. 35-454/C) is located 0.8 km south of Arthur Road 7, at about Station 20+612. This report summarizes the site conditions obtained during the foundation investigation carried out at the structural culvert site.

2. SITE DESCRIPTION

The structural culvert is a rigid frame open footing concrete culvert. The structure is about 29.0 m long, has a span of 3.69 m and a height of 1.22 m. Surface water flows from east to west through the culvert.

The local land use is mainly agricultural with farms and residences in relative proximity of the highway. The ground cover comprises crops and grasses.

The Highway 6 pavement surface dips gradually about 6.0 m from the south towards the culvert location and rises to the north about 6.5 m. The highway was constructed over an earth embankment about 3.0 to 4.0 m high in the vicinity of the culvert.

The site is located within the physiographic region known as the Dundalk Till Plain characterised by a gently undulating glacial till plain. The typical surficial soil is a shallow medium textured sandy silt which overlays cohesive glacial tills. Some of the low lying areas are swampy with poor drainage (L. J. Chapman and D. J. Putnam, the Physiography of Southern Ontario, 3rd Edition, Ontario Research Foundation, 1984).

The bedrock underlying the culvert site is of the Salina Formation and mainly composed of dolostone, shale, gypsum and salt. The estimated bedrock level is at about 40 m depth.

The frost penetration depth for the area of the culvert is 1.6 m.

3. INVESTIGATION PROCEDURES

The field work was carried out on May 30 and June 20, 2006 and comprised a total of three sampled boreholes, denoted C12-1, C12-2 and C12-3 which were advanced to depths of 6.7 and 11.3 m.

The borehole layout at the culvert was established by Peto MacCallum Ltd.(PML) in accordance with the requirements noted in the Request for Proposal. The ground surface elevations of the boreholes were determined by MRC and referred to a geodetic benchmark. All elevations in this report are expressed in meters.

The boreholes were advanced using continuous flight solid stem augers through the soil cover with truck and track-mounted CME-75 drill rigs, supplied and operated by a specialist drilling contractor, working under the full-time supervision of a member of our engineering staff.

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 boreholes. All of the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO guideline for borehole abandonment.

The recovered soil samples were returned to our laboratory for detailed visual examination and classification. The laboratory testing program consisted of 20 natural moisture content determinations, grain size distribution analyses of 6 selected soil samples and determination of Atterberg plasticity limits on 2 samples. The laboratory grain size determinations are reported on Figures C12-GS-1 to C12-GS-3 and the plasticity limits tests on plasticity chart C12-PC-1. All of the test results are shown 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 soil stratigraphy, natural moisture content determinations, results of grain size analyses, plasticity limits and groundwater observations. Stratigraphic profiles prepared from the borehole data are presented on Drawing C12-1.

The stratigraphy revealed in the boreholes generally comprised the Highway 6 gravel shoulder pavement and embankment fill overlying discontinuous deposits of silty clay, gravelly sand/sandy gravel/sand overlying clayey silt till/silty clay till with interbedded silt till. Cobbles and boulders should be anticipated within till soils although these particles were not found in the boreholes. The strata encountered are described below.

4.1. Pavement

The pavement fill encountered on Highway 6 comprised of the sand and gravel of the granular material of the Highway 6 shoulder. The estimated thickness of the shoulder pavement was 600 mm at the culvert location. The granular material was in a compact condition with one N value of 10 blows for 300 mm penetration of the sampler. The water content determination was about 18%.

4.2. Fill

The embankment fill of Highway 6 was encountered below the pavement granular materials in borehole C12-1 drilled on the shoulder of the roadway. The fill comprised compact sand with silt some gravel mixed and layered with clayey silt and silty clay, cobbles, organics and topsoil. The fill extended to a depth of 5.8 m below the road shoulder surface, elevation 446.4. N values in the embankment fill ranged from 10 to 28 blows.

The particle size distribution charts of two samples of the embankment fill are shown on Figure C12-GS-1. Water content determinations ranged from 8 to 10%.

4.3 Topsoil

Layers of topsoil 500 and 600 mm thick were found at the surface of boreholes C12-3 and C12-2, respectively drilled on the east and west sides of the highway embankment. The topsoil was penetrated at elevations 447.4 and 448.1.

4.4 Silty Clay

A localized layer of cohesive firm silty clay was encountered below the topsoil in borehole C12-2. The silty clay extended to 1.4 m depth, elevation 447.3. The single N value obtained on the unit was 6 blows. The water content determination was 24%.

4.5 Gravelly Sand and Sand

A layer of typically compact cohesionless gravelly sand trace silt was encountered below the fill in borehole C12-1 and extended to 7.2 m depth, elevation 445.0. The unit was encountered below the silty clay in borehole C12-2 and topsoil in borehole C12-3 and extended to a depth of 2.2 m, elevations 446.5 and 445.7. A localized layer of compact cohesionless sand trace gravel trace silt was found below the gravelly sand between 2.2 and 2.9 m depths, elevation 446.5 and 445.8 in borehole C12-2. N values in these sandy materials ranged from 5 to 26, with typical values of 20 to 26 blows.

The grain size distribution charts of two gravelly sand samples are presented on Figures C12-GS-2. The natural water content of the materials was about 9 and 17%.

4.6 Clayey Silt Till/Silty Clay Till

A deposit of glacial till comprising cohesive very stiff clayey silt till to silty clay till was encountered below the cohesionless gravelly sand and sand deposits in the three boreholes. This unit extended to elevation 442.0 to 440.9 at the 6.7 and 11.3 m termination depths of the boreholes. Locally, in boreholes C12-2 and C12-3 the unit was interbedded with silt till (described on the following section). N values in the clayey silt till/silty clay till ranged from 15 to 23 blows. Penetrometer tests on the samples ranged from 125 to 213 kPa.

The grain size distribution charts of two samples of the clayey silt till/silty clay till are shown on Figure C12-GS-3, attached. The results of the Atterberg tests are shown on Figure C12-PC-1. The liquid limit of the material varied from 31 to 35, the plastic limit from 16 to 17 and the computed plasticity indexes from 15 to 18. Natural moisture content determinations ranged from 11 to 22%.

4.7 Sandy Silt Till

A cohesionless compact glacial till consisting of silt trace sand, trace clay, trace gravel was interbedded within the clayey silt till/silty clay till in boreholes C12-2 and C12-3. The soil occurred from depths of 4.8 m (elevations 443.1 and 443.9) to depths of 5.9 to 6.0 m (elevations 441.9 and 442.8). N values in the deposit were 18 and 23 blows. The natural water content of 2 samples of the material was 18 and 20%.

4.8 Groundwater

The three boreholes encountered groundwater during and upon completion of drilling. During drilling, groundwater strikes were noted at depths ranging from 1.5 to 4.5 m, elevations 446.4 to 447.7. Upon completion of the drilling, the groundwater stabilized in the open boreholes at 2.0 to 5.5 m depths, elevations 445.2 to 446.7. At the time of the fieldwork the water flowing in the culvert was about 0.1 m deep, at about elevation 447.9.

The groundwater levels at this site are subjected to fluctuations due to seasonal rainfall patterns.

5. <u>CLOSURE</u>

The subsurface investigation was carried out under the supervision of Mr. F. Portela and direction of Mr. C. M. P. Nascimento, P. Eng., Senior Project Engineer. Geo-Environmental Drilling Inc. supplied the drilling equipment. This report was prepared by Mr. C. M.P. Nascimento, P. Eng. and reviewed by Mr. Brian R. Gray, MEng, P. Eng, MTO Designated Contact and Project Manager.

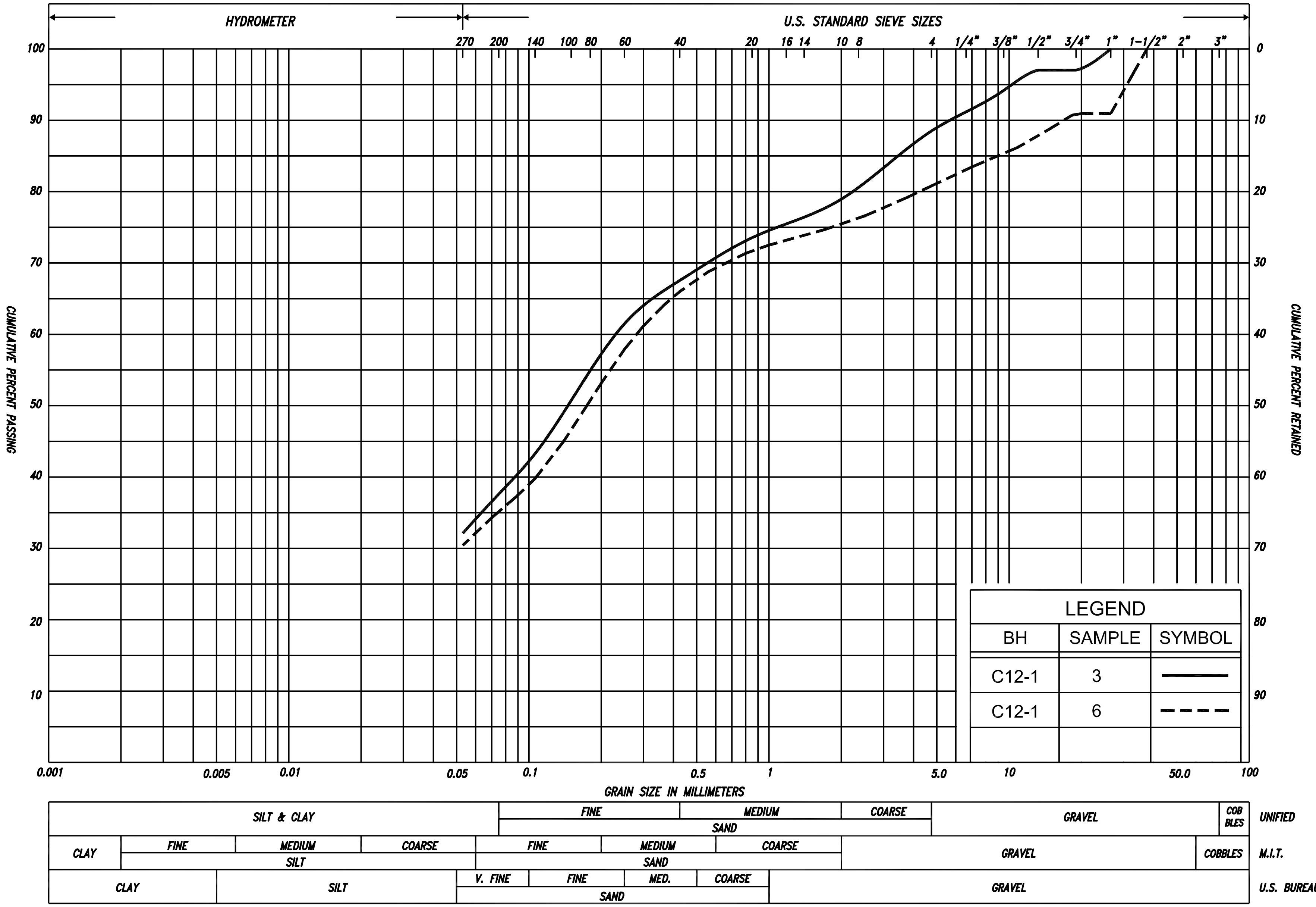
Sincerely,

Peto MacCallum Ltd.

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

Brian R. Gray, MEng, P. Eng,
MTO Designated Contact and Project Manager

CN-cn:lr-mi



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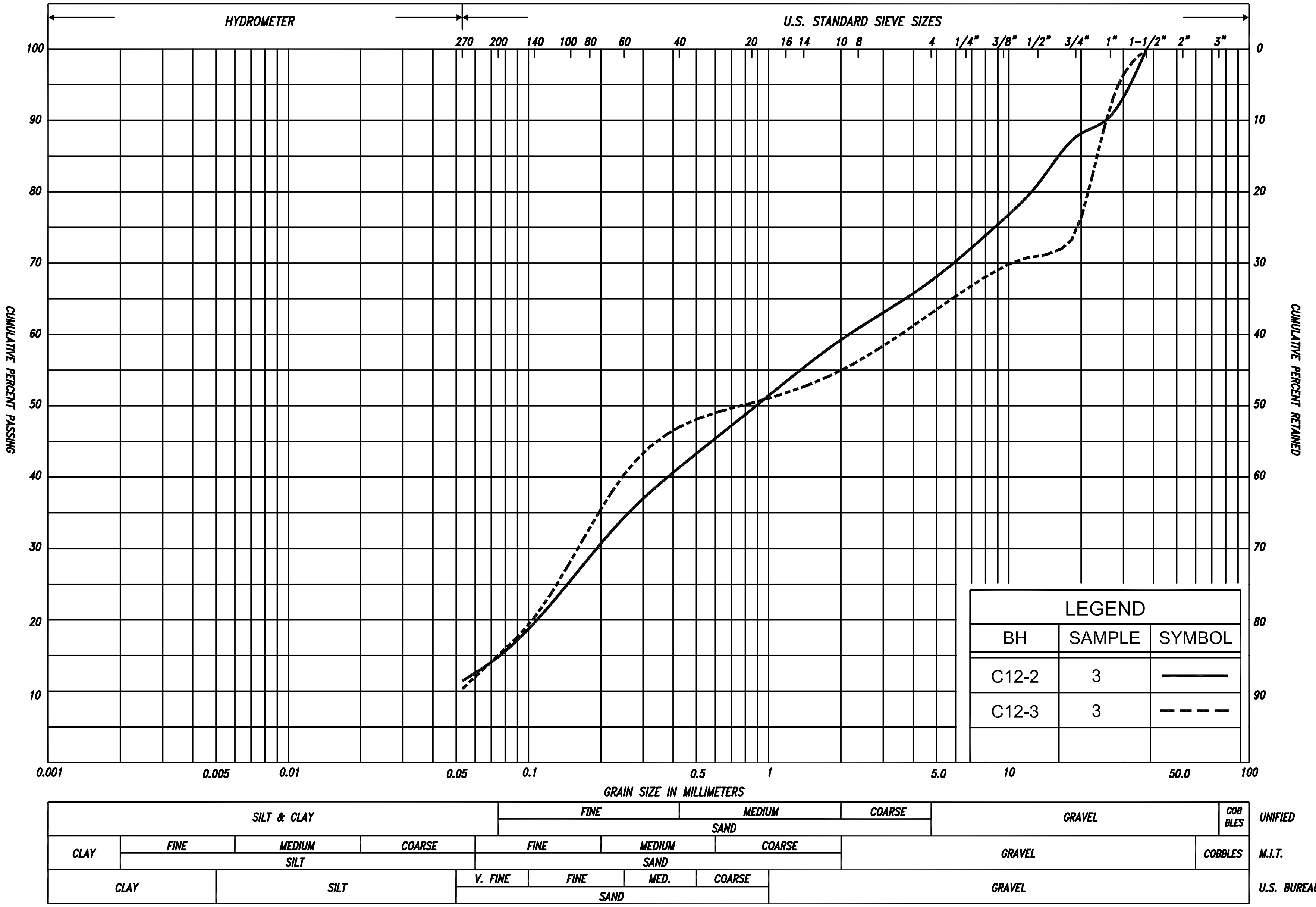
GRAIN SIZE DISTRIBUTION
SAND with silt some gravel, trace clay
(FILL)

FIG No.	C12-GS-1
PROJECT:	HWY 6 REPLACEMENT OF CULVERT AT STA. 20+612
G.W.P. No.	342-97-00



LEGEND

BH	SAMPLE	SYMBOL
C12-2	3	——— (solid)
C12-3	3	- - - - (dashed)

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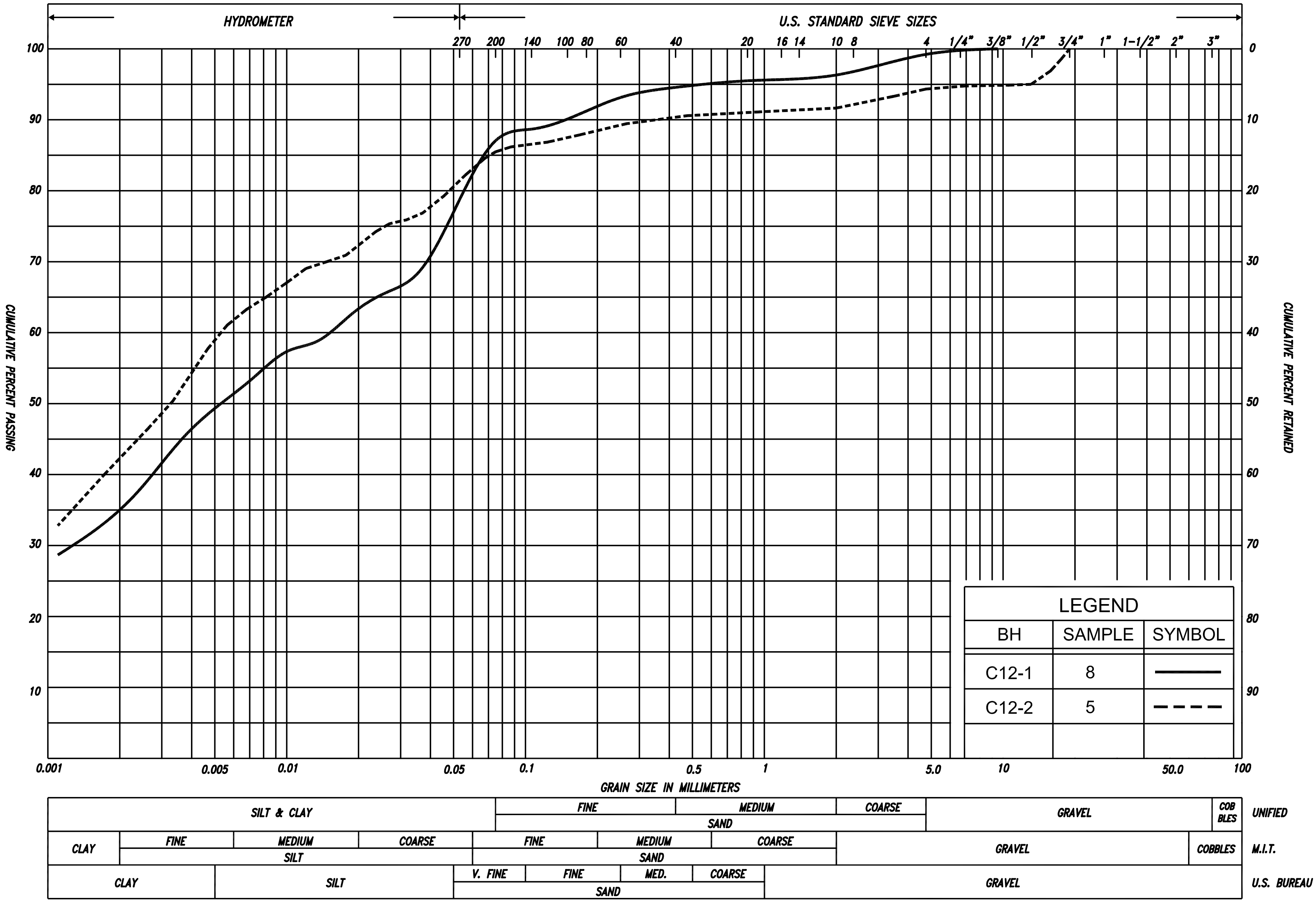
Ontario

GRAIN SIZE DISTRIBUTION
GRAVELLY SAND, trace silt

FIG No. C12-GS-2

PROJECT: HWY 6 REPLACEMENT OF CULVERT AT STA. 20+612

G.W.P. No. 342-97-00



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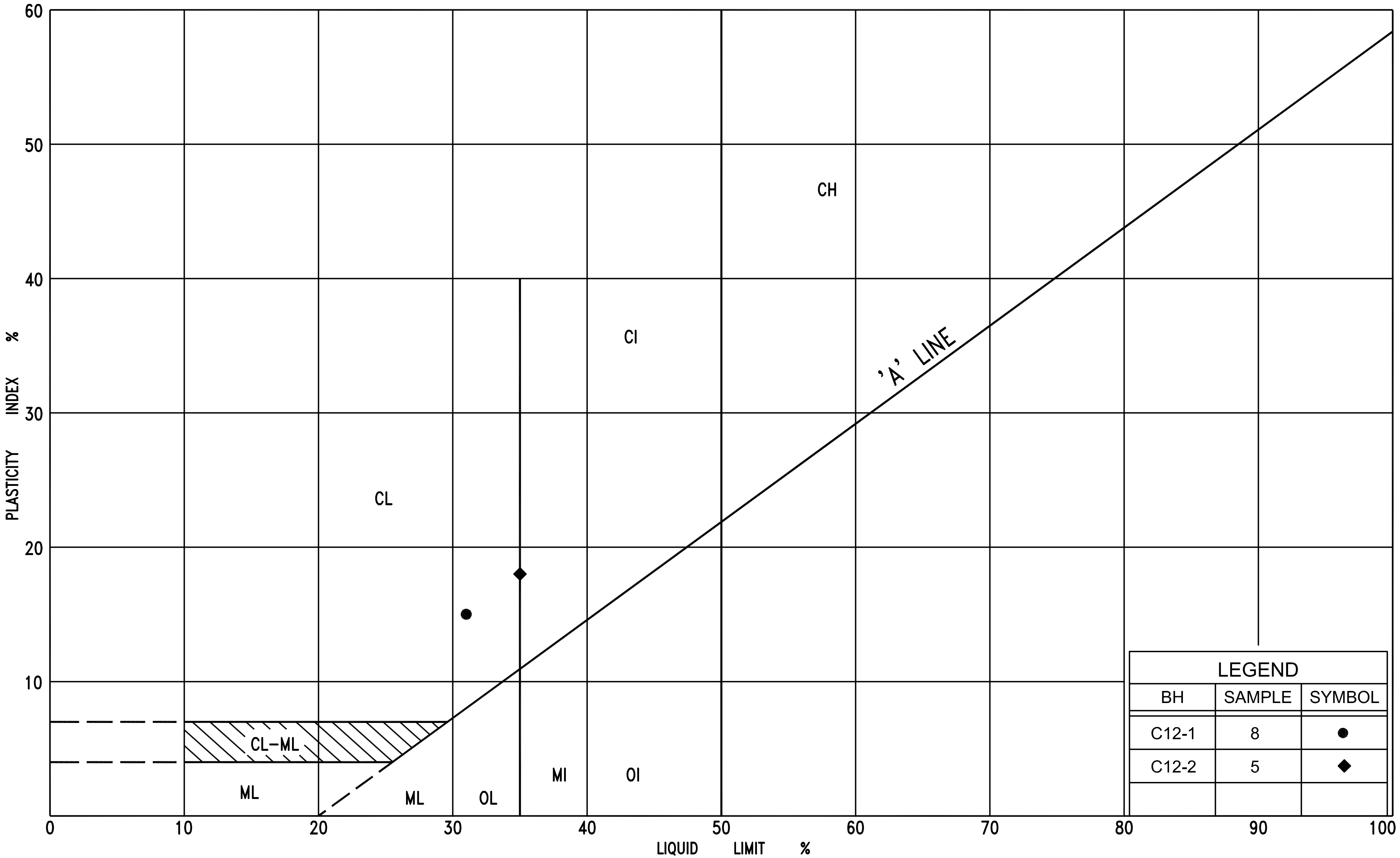
GRAIN SIZE DISTRIBUTION
CLAYEY SILT to SILTY CLAY some sand, trace gravel
(TILL)

FIG No.	C12-GS-3
PROJECT:	HWY 6 REPLACEMENT OF CULVERT AT STA. 20+612
G.W.P. No.	342-97-00



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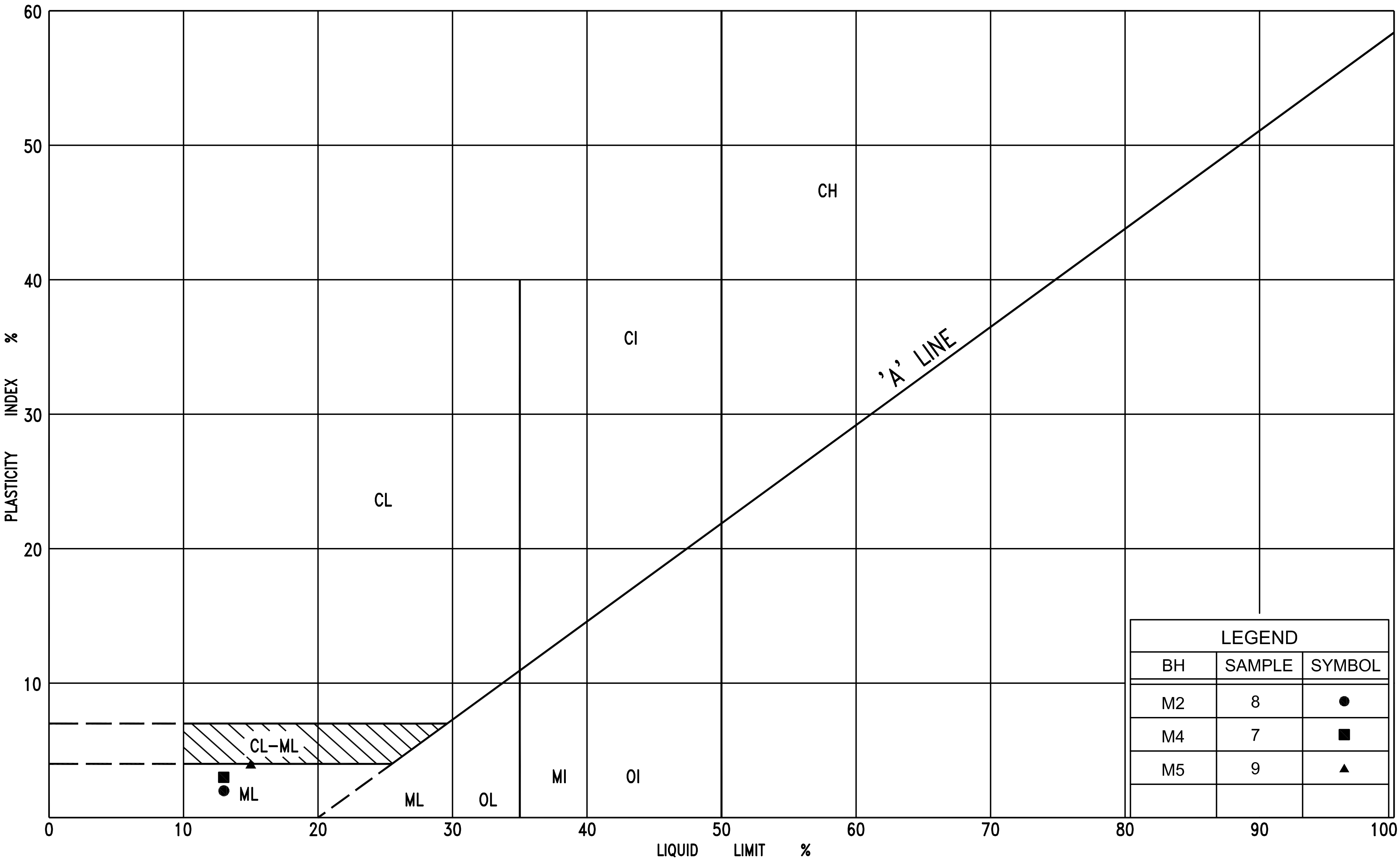
PLASTICITY CHART

CLAYEY SILT to SILTY CLAY trace to some sand, trace gravel (TILL)

FIG No.	C12-PC-1
PROJECT:	HWY 6 REPLACEMENT OF CULVERT AT STA. 20+612
G.W.P. No.	342-97-00



LEGEND

BH	SAMPLE	SYMBOL
M2	8	●
M4	7	■
M5	9	▲

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PLASTICITY CHART
SANDY SILT, trace to some gravel trace to some clay (TILL) - ML

FIG No.	C12-PC - 2
PROJECT:	FOUR MILE CREEK BRIDGE REPLACEMENT
G.W.P. No.	342-97-00

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.

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
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

Ministry of Transportation Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C12-1

METRIC

G.W.P. 342-97-00 | LOCATION Co-ords. 4 862 059 N; 214 567 E Hwy 6-Sta. 20+616, o/s 5.5m Lt. | ORIGINATED BY F.P.

DIST Owen Sound HWY 6 | BOREHOLE TYPE Continuous Flight Solid Stem Augers | COMPILED BY G.D.

DATUM Geodetic | DATE May 30, 2006 | CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	PENETROMETER (kPa)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
452.2	Ground Surface						
0.0	Sand and gravel, Brown (PAVEMENT FILL)	1	SS	10			
451.6 / 0.6	Sand with silt, some gravel, trace clay, silty clay layers; Compact, Brown, Moist	2	SS	28			
	organic inclusions, Dark grey	3	SS	11			13 50 (37)
	clayey silt layers, Brown	4	SS	11			
		5	SS	13			
	Grey (FILL)	6	SS	10	▽* (approx. 447.7); ▼* (approx. 446.8)		19 46 (35)
446.4 / 5.8	Gravelly sand; Compact, Grey, Wet	7	SS	20			
445.0 / 7.2	Clayey silt to Silty clay, some sand, trace gravel; Very stiff, Grey, Moist (TILL)	8	SS	23		137	1 12 52 35
		9	SS	21		187	
442.2 / 10.0	Silty clay, trace sand, trace gravel; Very stiff, Grey, Wet (TILL)	10	SS	21		137	
440.9 / 11.3	End of borehole						

Elevation scale: 452, 451, 450, 449, 448, 447, 446, 445, 444, 443, 442, 441

Dynamic cone penetration resistance plot / Shear strength kPa (20, 40, 60, 80, 100): ○ Unconfined, ● Quick triaxial, + Field vane, × Lab vane

Water content (%) 20 40 60 — plastic limit w_P, natural moisture content w, liquid limit w_L. Unit weight γ kN/m³

* 2006 05 30

▽ Water level observed during drilling

▼ Water level measured after drilling

■ Penetrometer test

+7, ×5 : Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No C12-2

METRIC

G.W.P. 342-97-00
LOCATION Co-ords. 4 862 052 N; 214 557 E Hwy 6-Sta. 20+618, o/s 17.0m Lt.
ORIGINATED BY F.P.
DIST Owen Sound HWY 6
BOREHOLE TYPE Continuous Flight Solid Stem Augers
COMPILED BY F.P.
DATUM Geodetic
DATE July 20, 2006
CHECKED BY C.N.

ELEV / DEPTH (m)	DESCRIPTION	Sample NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	Shear strength (kPa)	Natural moisture content (approx. %)	REMARKS GR SA SI CL
448.7	Ground Surface							
448.7 / 0.0	Topsoil	1	SS	6			~35	
448.1 / 0.6	Silty clay, trace sand, with gravel. Firm, Brown, Wet	2	SS	6			~30	
447.3 / 1.4	Gravelly sand, trace silt. Compact, Brown, Moist	3	SS	21	▼* ▽*		~10	33 52 (15)
446.5 / 2.2	Sand, trace gravel, trace silt. Compact, Brown, Wet	4	SS	22			~16	
445.8 / 2.9	Clayey silt to Silty clay, trace sand, trace gravel. Very stiff, Grey, Moist (TILL)	5	SS	18		213 (penetrometer)	~15 (Wp ~16, WL ~34)	6 8 43 43
443.9 / 4.8	Silt, trace sand, trace clay. Compact, Grey, Moist (TILL)	6	SS	23			~17	
442.8 / 5.9	Silty clay, trace sand, trace gravel. Very stiff, Grey, Wet (TILL)	7	SS	15		125	~23	
442.0 / 6.7	End of borehole							

* 2006 07 20

▽ Water level observed during drilling

▼ Water level measured after drilling

■ Penetrometer test

Elevation scale: 448, 447, 446, 445, 444, 443, 442

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
REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

Ministry of Transportation Ontario

Peto MacCallum Ltd.

Foundation Design

RECORD OF BOREHOLE No C12-3

METRIC

G.W.P. 342-97-00
LOCATION Co-ords. 4 862 070 N; 214 586 E Hwy 6-Sta. 20+610, o/s 16.0m Rt.
ORIGINATED BY F.P.

DIST Owen Sound HWY 6
BOREHOLE TYPE Continuous Flight Solid Stem Augers
COMPILED BY F.P.

DATUM Geodetic
DATE July 20, 2006
CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
447.9	Ground Surface												
0.0	Topsoil	1	SS	9									
447.4 / 0.5	Gravelly sand, trace silt. Loose to compact, Grey, Wet	2	SS	5		447							
					∇* (observed)								
		3	SS	26		446		o		37	48	(15)	
445.7 / 2.2	Clayey silt to Silty clay, trace sand, trace gravel. Very stiff, Grey, Moist (TILL)	4	SS	22	▼* (measured)	445		o					
		5	SS	16		444		o					
443.1 / 4.8	Silt, trace sand, trace clay, trace gravel. Compact, Grey, Moist (TILL)	6	SS	18		443		o					
441.9 / 6.0	Silty clay, trace sand, trace gravel. Very stiff, Grey, Wet (TILL)	7	SS	18		442	137 ■	o					
441.2 / 6.7	End of borehole												

* 2006 07 20

∇ Water level observed during drilling

▼ Water level measured after drilling

■ Penetrometer test

Dynamic cone penetration resistance plot: 20 40 60 80 100. Shear strength: O Unconfined, + Field vane, ● Quick triaxial, × Lab vane. Plastic limit w_P, natural moisture content w, liquid limit w_L. Water content (%) 20 40 60.

+7, ×5: Numbers refer to Sensitivity

20 / 15 — 5 / 10 (%) STRAIN AT FAILURE

CONT No
GWP No 342-97-00

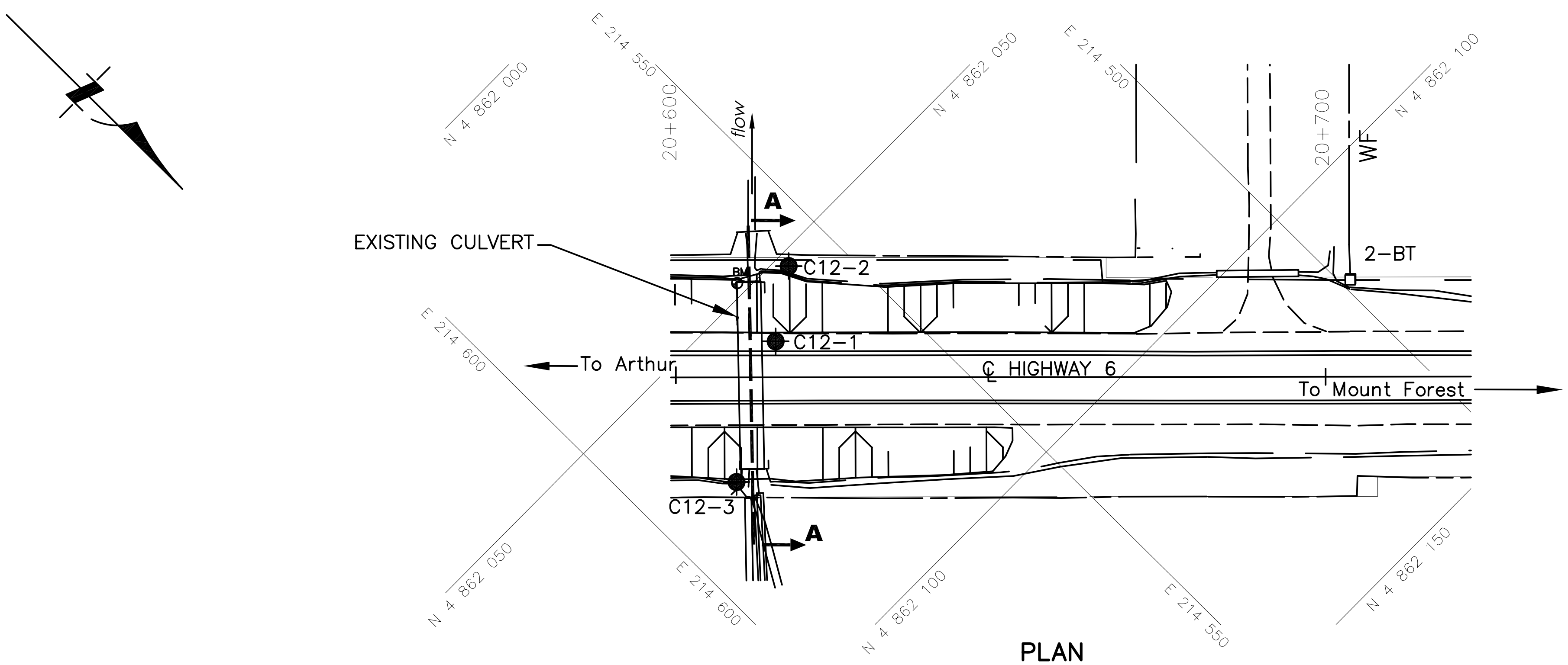
SHEET

HIGHWAY 6
CULVERT AT STA. 20+612
BOREHOLE LOCATIONS AND SOIL SECTION

Peto MacCallum Ltd.
CONSULTING ENGINEERS

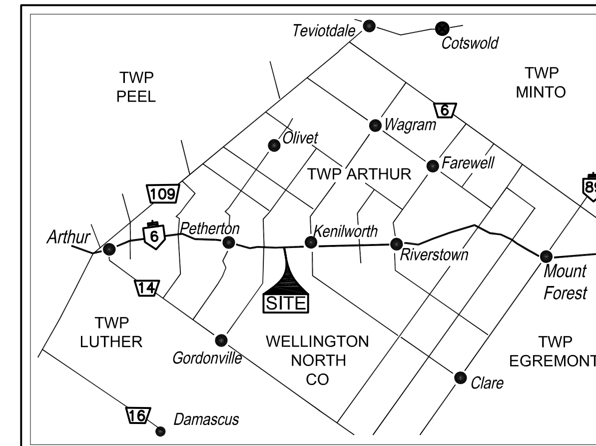
METRIC

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



PLAN

SCALE
10 0 10 20m

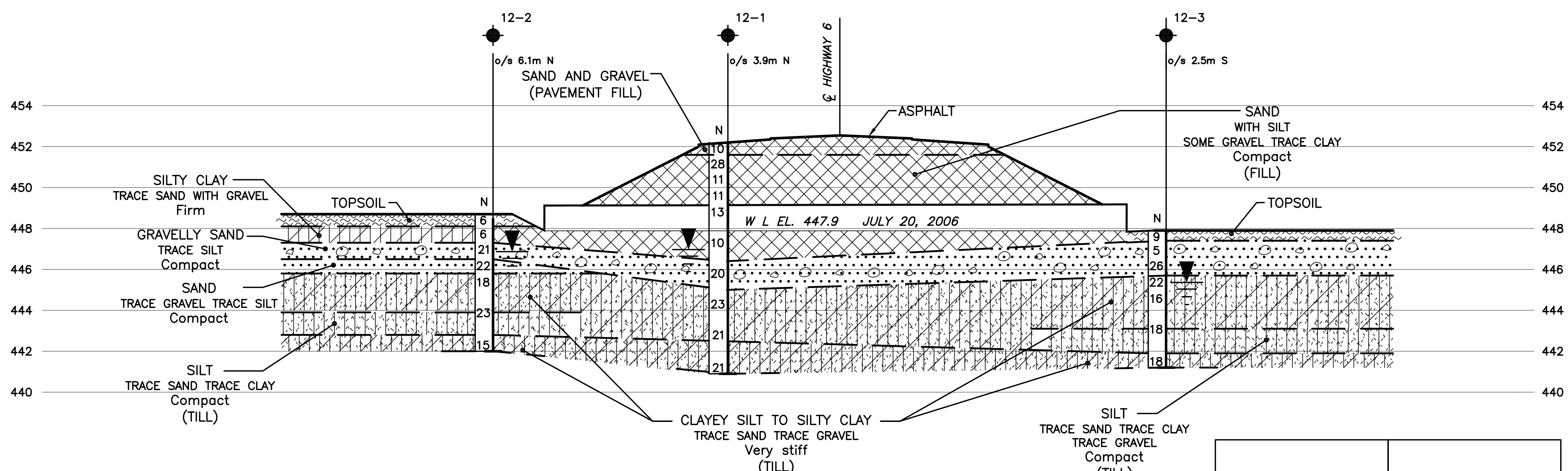


KEY PLAN
SCALE
2 0 4 8km

LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & Cone
- N — Blows/0.3m (Std. Pen Test, 475 J / blow)
- CONE — Blows/0.3m (60 Cone, 475 J / blow)
- W L at the time of investigation May, July 2006
- Head ARTESIAN WATER Encountered

BH No	ELEVATION	CO-ORDINATES NORTH	EAST
C12-1	452.2	4 862 059	214 567
C12-2	448.7	4 862 052	214 557
C12-3	447.9	4 862 070	214 586



SECTION A-A

SCALE
2.5 0 2.5 5m

– 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: 40P15-38

HIGHWAY 6			DIST Owen Sound
SUBM'D FP	CHECKED CN	DATE DEC. 20, 2006	SITE 35-454/C
DRAWN NA	CHECKED CN	APPROVED BRG	DWG C12-1

NOTE: THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY.
SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

REF. No. 156-6-21-0.dwg; January 2006

FOUNDATION DESIGN REPORT
for
STRUCTURAL CULVERT AT STATION 20+612
SITE NO. 35-454/C
IMPROVEMENT OF HIGHWAY 6
FROM ARTHUR (WELLS STREET) TO SOUTH OF MOUNT FOREST
AGREEMENT NUMBER 3005-E-0036
GWP NO. 342-97-00
TOWNSHIP OF ARTHUR, ONTARIO

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Distribution:
5 cc: McCormick Rankin Corporation for distribution to MTO, Project Manager + one digital copy (PDF format)
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2 cc: McCormick Rankin Corporation + one digital copy (PDF format)
1 cc: PML Kitchener
1 cc: PML Toronto

PML Ref.: 05KF104C
Index No.: 144FDR
Geocres No.: 40P15-38
December 29, 2006

TABLE OF CONTENTS

FOUNDATION DESIGN REPORT
for
Structural Culvert at Station 20+612
Site No. 35-454/C
Highway 6 Improvements
From Arthur (Wells Street)
to South of Mount Forest
Agreement Number 3005-E-0036
G.W.P. 342-97-00
Township of Arthur, Ontario

1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the proposed replacement of the structural culvert located at Station 20+612 as part of the rehabilitation of an approximately 21.2 km long section of Highway 6 between Arthur and Mount Forest. This report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

This structural culvert is designated as Site No. 35-454/C and is located about 8 km north of the Arthur north limits (Wells Street) on Highway 6. The Culvert is an approximately 29.0 m long rigid frame open footing concrete structure, with 3.69 by 1.22 m opening size. A road grade raise of about 0.3 to 0.4 m is proposed at the culvert location.

This report pertains to design and construction of the proposed culvert replacement and associated backfill zones.

The stratigraphy revealed in the boreholes generally comprised the Highway 6 gravel shoulder pavement and embankment fill overlying a discontinuous deposit of firm silty clay and continuous, compact gravelly sand/sand overlying very stiff clayey silt till/silty clay till with interbedded compact silt till. Cobbles and boulders should be anticipated within till soils although these particles were not found in the boreholes.

The three boreholes encountered perched water during drilling within the gravelly sand deposits and at the base of the embankment fill at depths ranging from 1.5 to 4.5 m, elevations 446.4 to 447.7. The groundwater stabilized in the open boreholes at 2.0 to 5.5 m depths, elevations 445.2 to 446.7. At the time of the fieldwork the water flowing in the culvert was about 0.1 m deep.

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The site conditions indicate that the design of the proposed replacement culvert as an open footing structure or a precast or cast-in place concrete box culvert is feasible. A discussion of alternatives is presented in this report. Care should be taken with subgrade preparation and erosion protection as outlined in this report.

It is understood that one of the alternatives for the construction and traffic staging at this site consists of limiting traffic to one lane for the duration of the replacement culvert construction. In this scenario, temporary road protection will be required along the centreline of the highway as a minimum. In view of the existing cohesionless sandy fill embankment and gravelly sand founding subgrade it is anticipated that the road protection will need to comprise of sheetpiling equipped with driving shoes in view of potential boulders in the till soils. Where groundwater control is required it should be designed to prevent affecting existing water wells in the vicinity of the site. If the traffic staging comprises the temporary closure of the Highway 6 and diverting traffic for the duration of the construction, it is anticipated that the excavation will be feasible by open cut and the groundwater will be controllable with sump pumping.

We also note that the alignment of the replacement culvert may be changed from the existing alignment. Consequently the new footings (in the open footing option) will not be located over the existing footing founding subgrade.

It is noted that no responsibility or liability is assumed by the consultants for alerting the contractor 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. FOUNDATIONS

2.1 General

The invert of the existing open footing culvert is inferred to be near elevation 447.8. The existing subgrade founding level of the spread footings is inferred to be at elevation 446.2 based on the footing depth of 1.6 m required for adequate frost protection.

The subgrade material that was revealed in the boreholes just below the founding level comprises compact gravelly sand. The groundwater level at the time of the field investigation was at elevations 445.2 to 446.7, some 0.5 m above and 1.0 m below the inferred subgrade level of the existing footings. Perched water was at elevations 446.4 to 447.7, about 0.2 to 1.5 m above the existing founding levels.

Based on ground surface elevations at the borehole locations and the road grade (elevation 452.2), the embankment fill at the location of the culvert is assessed to be about 4 m high.

The replacement culvert may consist of an open footing culvert founded at or below the 1.6 m frost protection level, elevation 446.2 that is the inferred level of the existing culvert foundations.

A precast or cast-in-place concrete box culvert is also considered a feasible replacement. The base of the new box culvert may be placed about 0.4 m below the design invert level at about elevation 447.4. At this level the subgrade is variable comprising fill, loose gravelly sand and firm clay that will require replacement. Alternatively, the culvert may be founded at deeper levels and the design invert level of the crossing established on fill placed inside the culvert.

The excavation of disturbed subgrade caused by the removal of the existing footings and any unsuitable fill on loose/soft native soils potentially present between and beyond the footing should be restored using engineered fill, mass concrete or unshrinkable fill. A discussion of the advantages and disadvantages of the three foundation alternatives outlined above is presented in Section 7 of this report.

Preparation of the subgrade for construction of the culvert 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 granular fill or, if required, mass concrete fill.

The topsoil and other deleterious soils revealed at and below the subgrade and soil disturbed by the removal of the existing footings should be excavated. Any grade differences found under the foundations of the open footing culvert should be made up with mass concrete fill.

The geometry of the 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 for the design.

2.2 Open Footing Culvert Replacement

For the open footing culvert design, the new footings should be founded at elevation 446.2 to provide 1.6 m of frost protection. Construction of the foundations for the culvert replacement on spread footings bearing on the compact gravelly sand found in the boreholes within the zone of influence of the new foundations is considered to be feasible.

The culvert foundations should be constructed on the compact gravelly sand and consider an assumed groundwater table at about elevation 446.7. The foundations should be designed using the following geotechnical resistances at ultimate and serviceability limit states (ULS and SLS) for the minimum 0.5 m wide footing:

Factored Geotechnical Resistance at ULS	=	400 kPa
Geotechnical Resistance at SLS	=	150 kPa

The resistance at SLS allows for 25 mm settlement of the founding medium. Total and differential settlements along the culvert are expected to be negligible in view of the relatively low net bearing pressure exerted by the culvert foundations. Therefore, provision for camber is not considered necessary for the replacement culvert.

2.3 Box Culvert Replacement

As indicated previously, the base of the replacement box culvert may be placed at about elevation 447.4 that is about 1.2 m above the level of the existing footing subgrade. At this level, the subgrade comprises of fill (borehole C12-1) or loose to compact gravelly sand.

Alternately, the box culvert base could be established at a lower elevation, down to about elevation 446.2, if required to allow placement of fill inside the culvert (for environmental purposes) or to minimize the placement of engineered fill, concrete or unshrinkable fill. These levels should allow for the estimated thickness of the culvert base slab and granular bedding.

The box culvert founded at the levels indicated will be placed on existing compact gravelly sand, or on fill placed and compacted to raise the founding grade levels to the base of the culvert. Groundwater was assumed at about elevation 446.7, about 0.5 m above the lowest recommended founding level. The following geotechnical resistances at ultimate and serviceability limit states (ULS and SLS) should be used for design.

Factored Geotechnical Resistance at ULS	=	600 kPa
Geotechnical Resistance at SLS	=	200 kPa

For the box culvert replacement option the existing footings, fill and any organic or loose/soft materials present between and outside of the footings should be removed to allow placement of engineered fill, unshrinkable fill or mass concrete to make up the grade below the culvert bedding.

Engineered 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 laterally outward 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.

The geometry of the subgrade preparation, cover backfill and frost taper treatment for the culvert should be carried out in accordance with OPSD 803.010 and OPSS 422. The bedding material for a precast box culvert should comprise a minimum 150 mm thick layer of Granular A.

Since the estimated thickness of engineered fill is less than 1.0 m, the box culvert foundation on the engineered fill at this site should be designed using the recommended geotechnical resistances in this section of the report.

Settlement considerations for the box culvert replacement are the same as those provided previously in the report for the open footing type culvert.

It is noted that the depth of excavation for the new foundations will be about 3 m beyond the toe of the existing embankment and through the existing embankment fill. Where the excavation extends into the existing embankment and construction staging requires traffic diversion into a single lane or where the designer/contractor chooses to limit the width of the excavation, road protection will require bracing to support the cut slopes. Refer to Section 5 of this report for further comments.

It is anticipated that conventional sump pumping techniques will be sufficient to control seepage of groundwater into the excavation. Further comments in this regard are provided in subsequent Section 5 of this report.

3. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with OPSD 803.010, OPSD 3121.150 and OPSS 422. The compaction of earth backfill against the culvert should follow the OPSS 501 and SP 105S10.

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.

The replacement 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), 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 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	21.0
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

* Assumes that excavated materials used for backfill are inorganic mainly cohesionless soils

The design should consider both the maximum water level in the stream and the stabilised groundwater levels. The groundwater level measured during the field investigation was variable at the culvert location, from 1.1 to 2.6 m below the invert level of the existing culvert. The highest 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.

4. HEADWALLS AND WING WALLS

If headwalls and wing walls are utilised, 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 respective culverts.

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

PARAMETER	GRANULAR A OR GRANULAR B TYPE II	SILTY CLAY	GRAVELLY SAND
Friction Angle, degrees	35	0	32
Cohesion, kPa	0	50	0
Unit Weight, kN/m^3	22.8	20.0	21.0

A weeping tile system and/or weep holes should be installed 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.

5. EXCAVATION AND GROUNDWATER CONTROL

Excavation to the anticipated founding level of the replacement culvert is expected to extend through the topsoil and/or fill, localized deposit of firm silty clay (borehole C12-2) and into the native loose to compact gravelly sand. Provision for excavation of cobbles and boulders at the site should be made. Subject to adequate groundwater control, excavation of the soils should be feasible using conventional equipment. According to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, the in situ materials are typically classified as Type 3 soils necessitating an inclination of temporary cut slopes at 1H:1V (horizontal to vertical). The need to excavate flatter side slopes below the groundwater table or if excessively soft/wet materials or concentrated seepage zones are encountered locally during construction should be considered. The full depth of the existing fill soils which may extend to the founding level of the existing footings should be supported.

Should construction and traffic staging requires traffic adjacent to the excavations it is anticipated that a suitable roadway protection scheme following SP 105S19 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 or anchored soldier piles and lagging may be considered. It is noted however that soldier pile and lagging schemes are not considered adequate where the excavation will be carried out through the sand with gravel fill or native gravelly sand material in particular under the water table. The schemes should be designed for performance level 2 provided that groundwater control is in place.

Otherwise, a performance level 1a system is recommended to prevent movement of the existing embankment. The contractor is responsible for the selection, preparation and performance of a detailed design for the road protection scheme.

The highest regional groundwater level observed in the boreholes at the time of the field investigation (elevation 446.9) was up to 0.7 m above the anticipated deepest level of excavation (elevation 446.2). Cognisant of the permeability characteristics of the gravelly sand and the relatively low hydraulic head, it is anticipated that pumping from sumps or wells installed within the gravelly sand will be sufficient to control seepage of groundwater into the excavation. Where groundwater control is required it should be designed to prevent affecting existing water wells. The contract documents should clearly state that the design and implementation of groundwater control of the excavations is the contractor's responsibility.

It will be necessary to implement measures to control water flow in the stream. Conventional procedures such as dam and pump and/or temporary diversion of the stream should be sufficient. Observed stream and 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 and with local/MTO regulations.

6. EROSION CONTROL

The protective measures noted in the OPSD 800 series 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 materials. Where required for the box culvert options, 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 granular base/bedding material as well as extend laterally to protect the granular backfill material. The cut-off walls should also protect the existing sand and gravel fill and new engineered fill which would be required to install a replacement box culvert. The requirements of CHBDC clauses 1.10.5.6 and 1.10.11.6.5 should be applied.

Inlet and outlet protection in accordance with OPSS 511, OPSS 1004 and OPSD 810.010 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 inlet/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 µm, 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 headwalls and 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:

SOIL TYPE	**K FACTOR**
Silty Clay	0.5
Gravelly Sand	0.1

7. DISCUSSION OF FOUNDATION ALTERNATIVES

7.1 Advantages and Disadvantages of Foundation Alternatives

The following table summarizes the advantages and disadvantages and inferred risks/consequences of each of the foundation alternatives for the replacement culvert at the Station 20+612.

ADVANTAGES AND DISADVANTAGES – CULVERT AT STA. 20+612

OPEN FOOTING		BOX CULVERT WITH BASE SET LOWER THAN ELEV. 447.4		BOX CULVERT WITH BASE SET AT ELEV. 447.4	
ADVANTAGES	**DISADVANTAGES**	**ADVANTAGES**	**DISADVANTAGES**	**ADVANTAGES**	**DISADVANTAGES**
Design matches existing configuration. Cut-off walls not required between footings. Design incorporates full frost protection.	Erosion control of soil between the footings is required. Relatively high user cost due to longer construction schedule than precast culvert construction.	Precast concrete box culvert alternative is feasible. Concrete base provides erosion protection. Depth of fill under subgrade is shallower than for box culvert at Elev. 447.4. Precast box culvert option expedites construction, minimizing user costs.	Requires fill placement inside culvert to make up grade to design invert level. Only partial frost protection is incorporated - frost tapers required.	Precast concrete box culvert alternative is feasible. Concrete base provides erosion protection at invert level. Precast box culvert option expedites construction, minimizing user costs.	Subgrade level needs to be adjusted using engineered fill. Cut-off walls should extend below engineered fill level (minimum). Requires deeper fill under the subgrade and adequate site conditions (ground water control) for engineered fill construction. Only partial frost protection is incorporated - frost tapers required.

Notes: Culvert base and invert elevations are inferred for the purpose of this report.

The precast concrete box culvert option founded below elevation 447.4 is considered to be less costly at this site, since the construction will be expedited without the forming and the setting time required for cast-in-place concrete construction and the depth of engineered fill, concrete or unshrinkable fill to be placed below the granular bedding of the culvert will be minimized. However, it is expected that the construction of cut-off walls will offset some of the cost advantages of box culvert construction.

7.2 Preferred Foundation Option Considerations

From the foundation perspective, either of the three foundation schemes is feasible, however the box culverts provide a more effective erosion protection. The box culvert constructed at the level lower than about elevation 447.4 is considered the preferred option in view of the estimated lower cost of construction and user cost. The optimum founding level will depend on other considerations, such as the commercially available culvert sizes.

It is noted that the selected foundation alternative also depends on other considerations, such as potential fish habitat protection, which are being evaluated separately by MRC.

8. CLOSURE

This report was prepared by Mr. C.M.P. Nascimento, P.Eng., Senior Project Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

REGISTERED PROFESSIONAL ENGINEER
C M P Nascimento
PROVINCE OF ONTARIO

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MTO Designated Contact and Project Manager

CN:lr-mi

TABLE 1

LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE	DATE
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Culverts in Open Cut	April 2004
OPSS 501	Construction Specification for Compacting	November 2005
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting	November 2004
OPSS 570	Construction Specification for Topsoil	August 1990
OPSS 571	Construction Specification for Sodding	November 2001
OPSS 572	Construction Specification for Seed and Cover	November 2003
OPSS 902	Excavation and Backfilling of Structures	November 2002
OPSS 1004	Material Specification for Aggregates – Miscellaneous	November 2005
OPSS 1860	Material Specification for Geotextiles	November 2004
SP 105S10	Construction Specification for Compaction	November 2004
SP 105S19	Construction Specification for Protection Systems	March 2005
SP 902S01	Excavation and Backfilling of Structures	September 2003
OPSD 803.010	Backfill and Cover for Concrete Culverts	November 1999
OPSD 810.010	Rip-Rap Treatment for Culvert Outlets	November 2001
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls	November 2005