



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

HIGHWAY 400

HEADWALL AT THE INLET AND OUTLET OF CULVERT 96, STA. 23+665

AND HEADWALL AT THE INLET AT CULVERT 107, STA. 26+100

RETAINER ASSIGNMENT – TASK NO. 2013-E-0039-010

WP 2184-10-00

**TOWN OF INNISFIL AND CITY OF BARRIE, SIMCOE COUNTY,
ONTARIO**

PREPARED FOR MINISTRY OF TRANSPORTATION OF ONTARIO

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PML Ref.: 15TF020-5
Index No.: 039FIR and 040FDR
GEOCRES No.: 31D-660
June 30, 2016



PART A - FOUNDATION INVESTIGATION REPORT

for

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PART A
FOUNDATION INVESTIGATION REPORT

For
Highway 400 Upgrading – Culverts Headwalls
At Sta. 23+665 and Sta. 26+100
Retainer Assignment – Task No. 2013-E-0039-010, WP2184-10-00
Town of Innisfil and City of Barrie, Simcoe County, Ontario

1. INTRODUCTION

This report presents the factual findings obtained from the geotechnical investigation carried out at the inlet and outlet of Culvert 96, and at the inlet of Culvert 107 located on Highway 400 at Sta. 23+665 and Sta. 26+100, respectively.

The field work was carried out on April 14, 15 and 20, 2016. The purpose of the investigation was to explore the subsurface conditions at both sites to provide anticipated subsurface conditions influencing the design of headwalls at the culvert locations to accommodate widening of Highway 400.

Peto MacCallum Ltd. (PML) carried out the investigation and prepared this report for the Ministry of Transportation of Ontario (MTO) as part of the Retainer Assignment task No. 2013-E-0039-010.

The assignment includes preparation of five (5) geotechnical investigation reports for the following locations:

PML REF. No.	FIR AND FIDR DESCRIPTION
15TF020-1	Highway 400 Upgrading - Median Sewers Northern Part from Maplevue Drive to Essa Road
15TF020-2	Highway 400 Upgrading - Lateral Sewers Northern Part from Maplevue Drive to Essa Road
15TF020-3	Highway 400 Upgrading - Median Sewers Southern Part from Innisfil Beach Road to Maplevue Drive
15TF020-4	Highway 400 Upgrading - Lateral Sewers Southern Part from Innisfil Beach Road to Maplevue Drive
15TF020-5	Highway 400 Upgrading - Headwalls at Culvert 96 and Culvert 107



The scope of project involves providing subsurface information for the detail design of headwalls at two culverts located on Highway 400 between Innisfil Beach Road and Essa Road.

2. SITE DESCRIPTION

The topography of the project area is generally flat to gently undulating, except for the highway embankments. Several commercial developments are also located north of Maplevue Drive along Highway 400 and residential area are located on the north side of Essa Road. The site is generally lined by farmland and heavily wooded area along Highway 400.

Culvert 96:

The Culvert 96 is located approximately 1.6 km south of Maplevue Drive at Sta. 23+665. The existing culvert is a 52.13 m long, open type with an opening size of 1.5 m wide and 0.9 m high. The drainage through this culvert is from the west side to east side of Highway 400.

Culvert 107:

The Culvert 107 is located approximately 800 m north of Maplevue Drive at Sta. 26+100. The existing culvert is a 1.5 m wide, 0.9 m high and 60.44 m long open type structure. This culvert serves to drain water from the west side to east side of Highway 400.

3. FIELD INVESTIGATION PROCEDURES

The investigation included advancing two (2) boreholes numbered 96-1 and 96-2 at the location of Culvert 96, and one borehole (No. 107-1) at the inlet of Culvert 107. Boreholes at Culvert 96 were advanced to depths of 11.1 and 11.3 m and the borehole at Culvert 107 was advanced to a maximum depth of 5.0 m. The depth of borehole at the location of Culvert 107 was limited to 5.0 m due to presence of weak soil that was not capable of supporting the drill rig to advance the borehole deeper. Location of boreholes and soil stratigraphic sections are shown on the attached Drawing Nos. 400WM – C1 and C2. A Key Plan of the project site is provided on Drawing 400WM-A.



The underground services at the borehole locations were cleared by the respective utility companies and then the locations were established in the field by portable GPS device. Boreholes were strategically located to provide a minimum safe distance from the existing sewer pipes. PML carried out the survey of the borehole locations and elevations and provided the co-ordinates of locations in MTM NAD 83 northings and eastings. All elevations reported in this report are referred to Geodetic and expressed in metres.

The boreholes were located at the toe of the embankment close to the existing culvert inlet and outlet. Boreholes were advanced using continuous flight solid stem augers, powered by a track-mounted Geoprobe drill rig. The drill rig used for drilling was owned and operated by Tri-Phase of Mississauga, Ontario. Tri-Phase is a specialist drilling contractor, was working under the full-time supervision of a member of PML's engineering staff.

Representative soil samples were recovered from the boreholes at 0.75 m intervals using a conventional 51 mm O.D split spoon sampler in accordance with the Standard Penetration Test (SPT) procedure. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

The groundwater conditions at the borehole locations were observed during drilling by visual examination of the soil samples, sampler and drill rods as the samples were retrieved. In addition, water level measurements were taken in open boreholes. Upon completion of drilling, the boreholes were backfilled with bentonite/cement grout in accordance with the MTO guidelines and MOE Regulation 903 for borehole abandonment procedures.

The recovered soil samples were returned to our laboratory for detailed visual examination, and index tests.



4. LABORATORY TEST PROCEDURES

Laboratory tests on representative SPT samples recovered during the field work were carried out by the laboratory owned by PML, located in Toronto. The laboratory testing program included the following:

- Natural moisture content determinations (26)
- Grain size distribution analyses (7)
- Atterberg Limits Tests (3)

The laboratory tests to determine the index properties were performed in accordance with the MTO test procedures, which follow American Society for Testing Materials (ASTM) test procedures, with the exception of hydrometer test (LS-702). The results of the grain size distribution analyses and Atterberg limits tests are presented in Figures C96-GS-1 to C96-GS-3 and C96-PC-1, and Figures C107-GS-1 and C107-PC-1 for Culvert 96 and 107, respectively. All of the test results are summarized on the attached Record of Borehole sheets.

5. SITE GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Site Geology

The project site is located within the Simcoe Lowlands Physiographic Region of Southern Ontario. The physiographic region of Simcoe Lowlands is bordered by Georgian Bay and Lake Simcoe. This region falls into two major divisions separated by the uplands of Simcoe County. The plains to the west of Simcoe County are draining into Nottawasaga Bay by way of the Nottawasaga River and this area is called "Nottawasaga Basin". The low lying area to the east of Simcoe County is referred to as the "Lake Simcoe" basin.

The Nottawasaga basin and Lake Simcoe basin are connected at Barrie by a flat-floored valley. Both of these low lands and transverse valleys were flooded by Lake Algonquin and are bordered by shore cliffs, beaches and boulder terraces. Thus these basins are floored by sand, silt and clay.



The surficial soils of these sections of the Simcoe lowlands consist primarily of sand although silt, clay or peat may be found in low-lying areas.

5.2 Subsurface Conditions

The subsurface conditions described below is split into two parts, the first part presents the subsurface conditions at the location of Culvert 96, where boreholes were advanced at the inlet and outlet. The second part provides information on the subsoil conditions at the inlet of the Culvert 107.

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are shown on the attached Record of Borehole Sheets. The borehole locations and stratigraphic profile sections are shown on Drawings 400WM-C1 and 400WM-C2. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary. Description of the soil strata encountered are summarised below.

5.2.1 Culvert 96:

In general, the subsoil conditions at the inlet and outlet of the culvert consist of 1.5 m to 2.2 m sand to silty sand fill, followed by 1.4 m to 1.5 m silty sand to sandy silt (native material). The silty sand to sandy silt layer is underlain by stiff to very stiff low plastic silt to clayey silt deposit, which extends to the maximum depth of investigation of 11.3 m (El. 267.5). . For classification purposes, the soils encountered at this site can be divided into three distinct zones.

- a) Sand to Silty Sand, Trace Gravel, Trace Clay (Fill)
- b) Silty Sand to Sandy Silt, Trace Gravel, Trace Clay
- c) Silt to Clayey Silt, Trace Sand



5.2.1.1 Sand to Silty Sand, Trace Gravel, Trace Clay (Fill)

The surficial sand to silty sand fill layer was encountered in both boreholes immediately below a thin layer (0 to 200 mm) of topsoil. This fill layer ranges in thickness from 1.5 m at the outlet to 2.2 m at the inlet of the culvert, and extends to a maximum depth of 2.2 m (El. 276.9) below the existing grade. The SPT values in this fill layer varies widely ranging from as low as 3 blows/300 mm to 15 blows/300 mm, indicating very loose to compact state of compaction.

The moisture content of this fill material varies from 18% to as high as 32%. The results of the grain size distribution analyses of two representative samples from this fill layer are shown on Figure C96-GS-1. The test results reveal that the sand to silty sand fill consists of 3% and 5% gravel, 49% and 76% sand, 12% and 45% silt and 3% and 7% clay.

5.2.1.2 Silty Sand to Sandy Silt, Trace Gravel, Trace Clay

The embankment fill is underlain by this silty sand to sandy silt deposit at a depth of 1.7 m (El. 276.9) and 2.2 m (El. 277.1) in BH96-2 and BH96-1, respectively. This silty sand to sandy silt deposit extends to a depth of 3.2 m (El. 275.4) in 96-2 and 3.6 m (El. 275.7) in 96-1.

In general, SPT values in this deposit range from 17 blows/300 mm to 22 blows/300 mm, indicating compact state of compaction.

Moisture content of this deposit varies from 17% to 21%. The sand and silt contents of this deposit vary widely. The results of the sieve analysis test performed on two representative samples from this deposit are provided on Figure C96-GS-2. The test results indicate that the silty sand to sandy silt deposit consists of 2% to 28% gravel, 36% to 59% sand, 11% to 56% silt and 2% to 6% clay.

5.2.1.3 Silt to Clayey Silt, Trace Sand

The silty sand to sandy silt layer is immediately underlain by this silt to clayey deposit. This clayey silt deposit extends to the maximum depth of investigation of 11.1 m (El.267.5) in BH96-2 and 11.3 m (El. 268.0) in BH96-1. The SPT values in this deposit range from 14 blows/300 mm



to 65 blows/300 mm, indicating very stiff to hard consistency. Occasional cobble layers were encountered in BH96-2, which is reflected by the high SPT values.

The moisture content of recovered samples tested varied from 11% to 23% with an average value of 21%. The results of the sieve analysis test performed on two representative samples from this deposit are provided on Figure C96-GS-3. The test results indicate that this deposit consists of 0% gravel, 1% to 2% sand, 83% to 84% silt and 14% to 16% clay. Atterberg limit test was performed on two samples and the results are provided on Figure C96-PC-1. Based on the Atterberg limit values ($LL = 20$ and $LL = 24$), the soil may be classified as silts of low plasticity (CL - ML) in the Unified Soil Classification System (USCS).

5.2.1.4 Groundwater

The groundwater was observed in both boreholes during and upon completion of drilling. The groundwater levels in BH96-1 and BH96-2 were measured at depths of 0.6 m (El. 278.0) and 2.1 m (El. 277.2), respectively below the existing ground surface.

The groundwater level may fluctuate due to the influence of precipitation and seasonal changes.

5.2.2 Culvert 107:

In general, the subsoil conditions at the inlet of the culvert consist of 100 mm of topsoil, followed by 700 mm of sand fill, which is underlined by 900 mm of native silty sand to sandy silt deposit. This is underlain by clayey silt deposits, which extends to the maximum depth of investigation of 5.0 m (288.3). For classification purposes, the soils encountered at this site can be divided into four distinct zones.

- a) Topsoil
- b) Sand, Trace Gravel (Fill)
- c) Silty Sand to Sandy Silt, Occasional Gravel, Trace Organics
- d) Clayey Silt, Trace Sand



5.2.2.1 Topsoil

A 100 mm thick surficial topsoil was observed in borehole BH107-1, which extends to elevation 293.2.

5.2.2.2 Sand, Trace Gravel (Fill)

The top soil is immediately followed by 700 mm thick sandy fill, which extends to El. 292.5. . The fill material consisted of sand with less than 10% of gravel. SPT value of 15 blows/300 mm in this layer indicate a compact state of denseness.

5.2.2.3 Silty Sand to Sandy Silt, Occasional Gravel, Trace Organics

The granular fill layer is underlined by 1.1 m thick silty sand to sandy silt (native). The silty sand sandy silt deposit extended to a depth of 1.7 m (El. 291.6). Occasional gravelly layer within this deposit is reflected by the high "N" value of 115 blows/300 mm. The SPT values in this layer vary from 25 blows/300 mm to 115 blows/300 mm, indicating compact to very dense state of compaction. The moisture content of two samples from this deposit varies from 17% to 19%.

5.2.2.4 Clayey Silt, Trace Sand

The silty sand to sandy silt is immediately underlain by this clayey silt deposit. This clayey silt deposit extends from 1.7 m (El. 291.6) to the maximum depth of investigation of 5.0 m (El. 288.3). The SPT values in this deposit were 23 blows/300 mm and 69 blows/300 mm, indicating very stiff to hard consistency.

The moisture content of two samples tested varied from 15% to 21%. The results of the sieve analysis test performed on a representative sample from this deposit is provided on Figure C107-GS-1. The test results indicate that this deposit consists of 0% gravel, 6% sand, 53% silt and 41% clay. Atterberg limit test was performed on a representative sample and the results are provided on Figure C107-PC-1. Based on the Atterberg limit values (LL = 30 and PL = 17), the soil may be classified as clay of low plasticity (CL) in the Unified Soil Classification System (USCS).



5.2.2.1 Groundwater

The groundwater was observed in the borehole during and upon completion of drilling. The groundwater level was measured at a depth of 0.8 m (El. 292.5) below the existing ground surface.

The groundwater level may fluctuate due to the influence of precipitation and seasonal changes.



6. CLOSURE

Mr. D. Woodcock and Mr. S. Aziz carried out the field investigation for this study under the supervision of Mr. M. Khorsand, BSc, E.I.T., and Mr. C. M. P. Nascimento, P. Eng., Project Manager. Tri-Phase Drilling Inc. supplied the drill rig for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

This report was prepared by Mr. M. Khorsand, BSc, E.I.T., and reviewed by Mr. M. Vasavithasan, M.Sc.Eng., P.Eng. Senior Engineer, Geotechnical Services. Mr. C. M. P. Nascimento, P. Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A blue ink signature of Mansoor Khorsand, written in a cursive style.

Mansoor Khorsand, BSc, EIT
Project Supervisor, Geotechnical Services

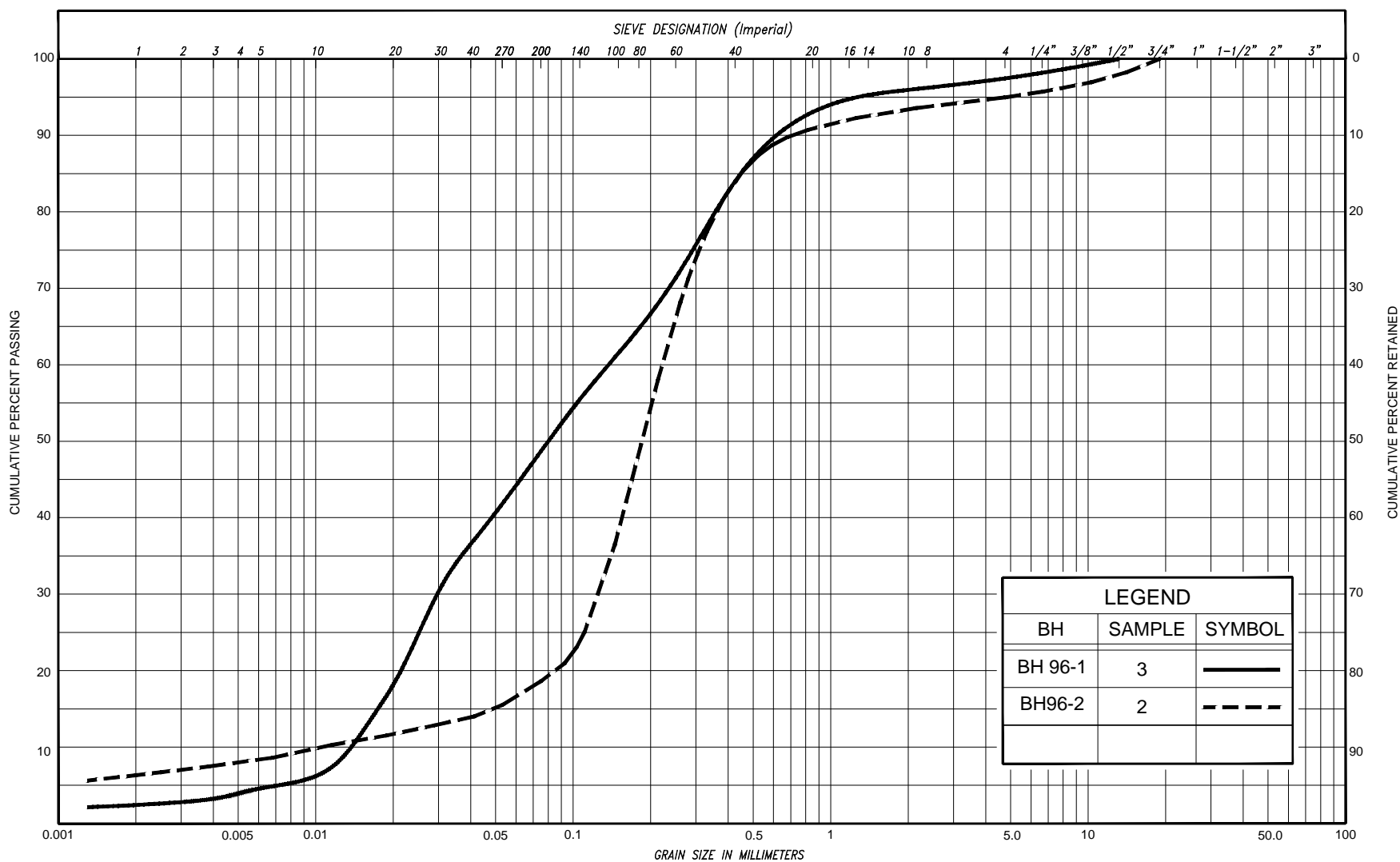


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Project Manager and
MTO Designated Principal Contact

MKH/MV/CN:jk



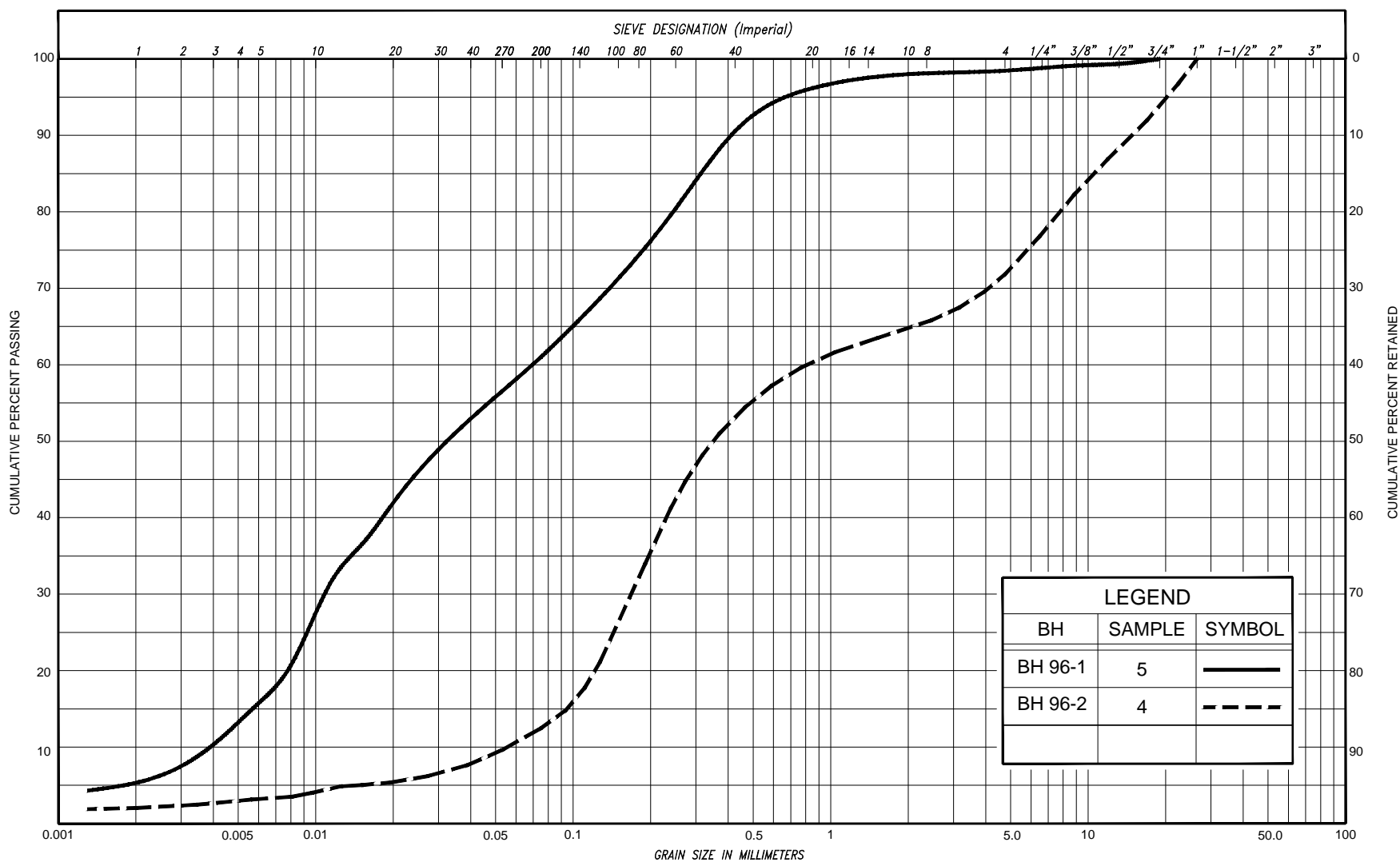
SILT & CLAY					FINE		MEDIUM		COARSE		GRAVEL			COBBLES	UNIFIED		
CLAY	FINE		MEDIUM		COARSE		SAND										
							FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.
CLAY			SILT			V. FINE		FINE		MED.		COARSE		GRAVEL			U.S. BUREAU



GRAIN SIZE DISTRIBUTION

SAND to SILTY SAND, trace clay, trace gravel (FILL)

FIG No.	C96-GS-1
HWY:	400
W.P. No.	2184-10-00



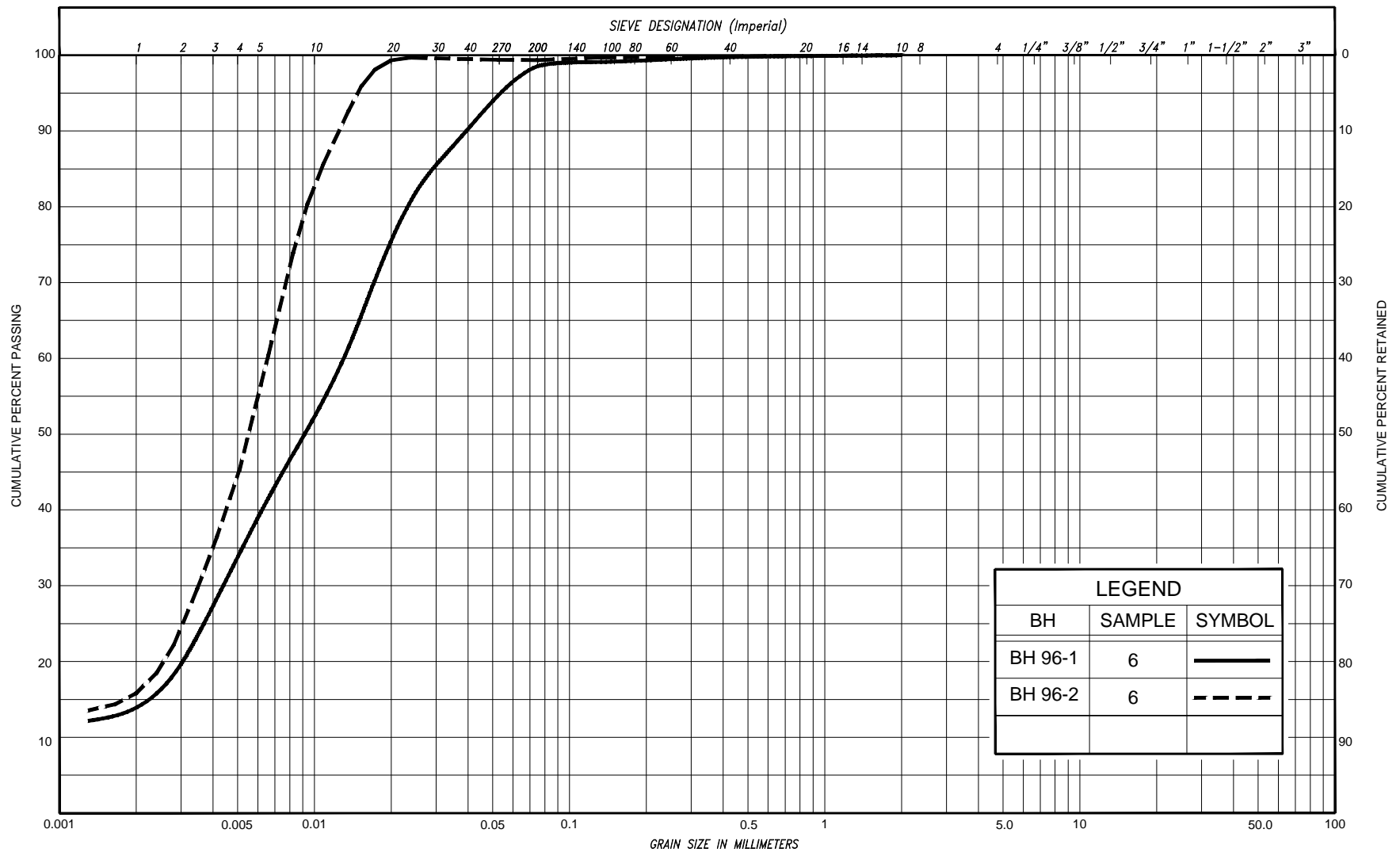
SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL		COBBLES	UNIFIED		
				SAND											
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL	COBBLES	M.I.T.
			SILT						SAND						
CLAY		SILT			V. FINE		FINE		MED.		COARSE		GRAVEL		U.S. BUREAU



GRAIN SIZE DISTRIBUTION

SILTY SAND to SANDY SILT, trace gravel, trace clay

FIG No.	C96-GS-2
HWY:	400
W.P. No.	2184-10-00



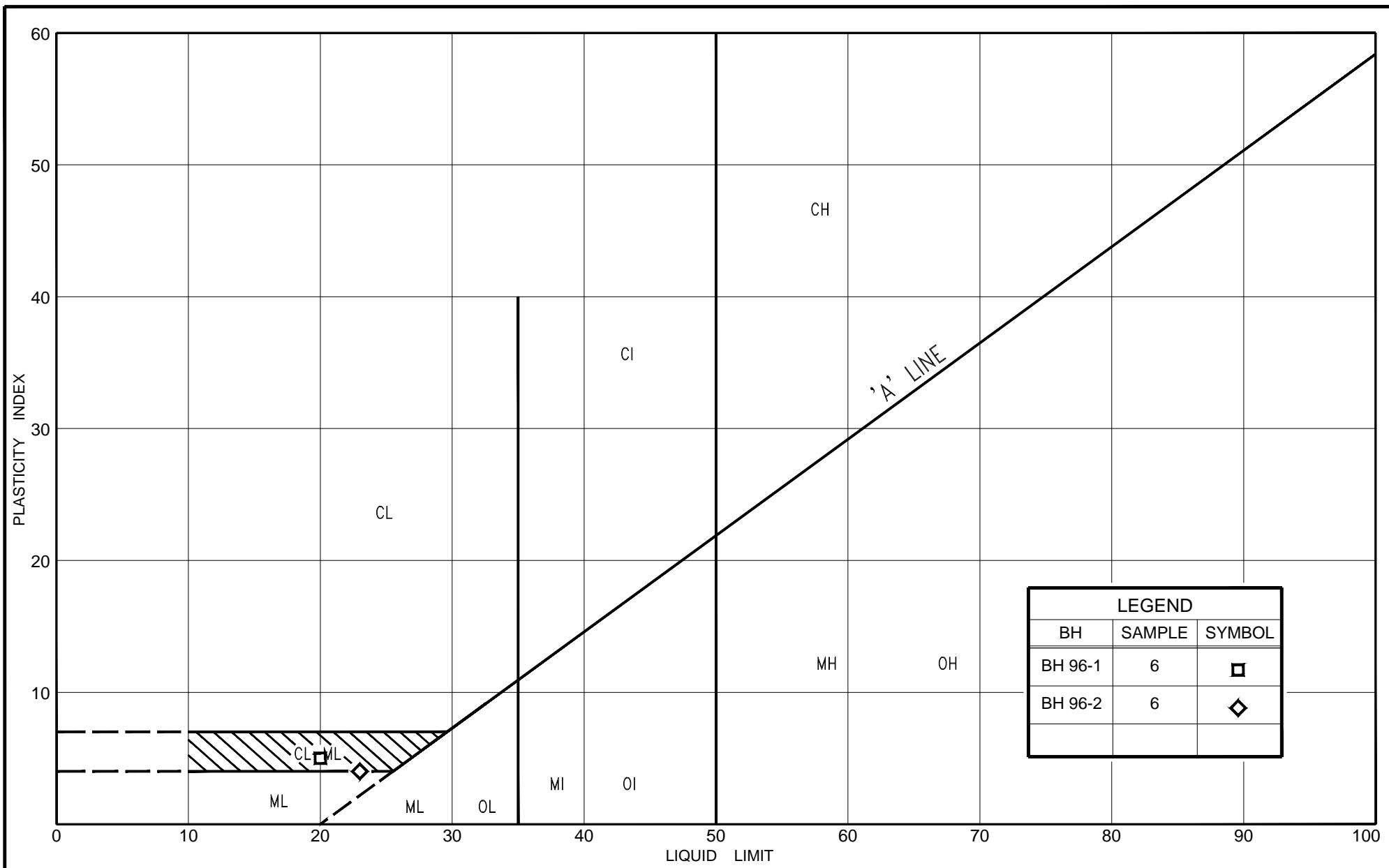
SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL				COBBLES	UNIFIED	
CLAY	FINE	MEDIUM		COARSE	FINE		MEDIUM		COARSE	GRAVEL				COBBLES	M.I.T.	
	SILT				FINE		SAND		COARSE		GRAVEL				COBBLES	M.I.T.
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL						COBBLES	U.S. BUREAU



GRAIN SIZE DISTRIBUTION

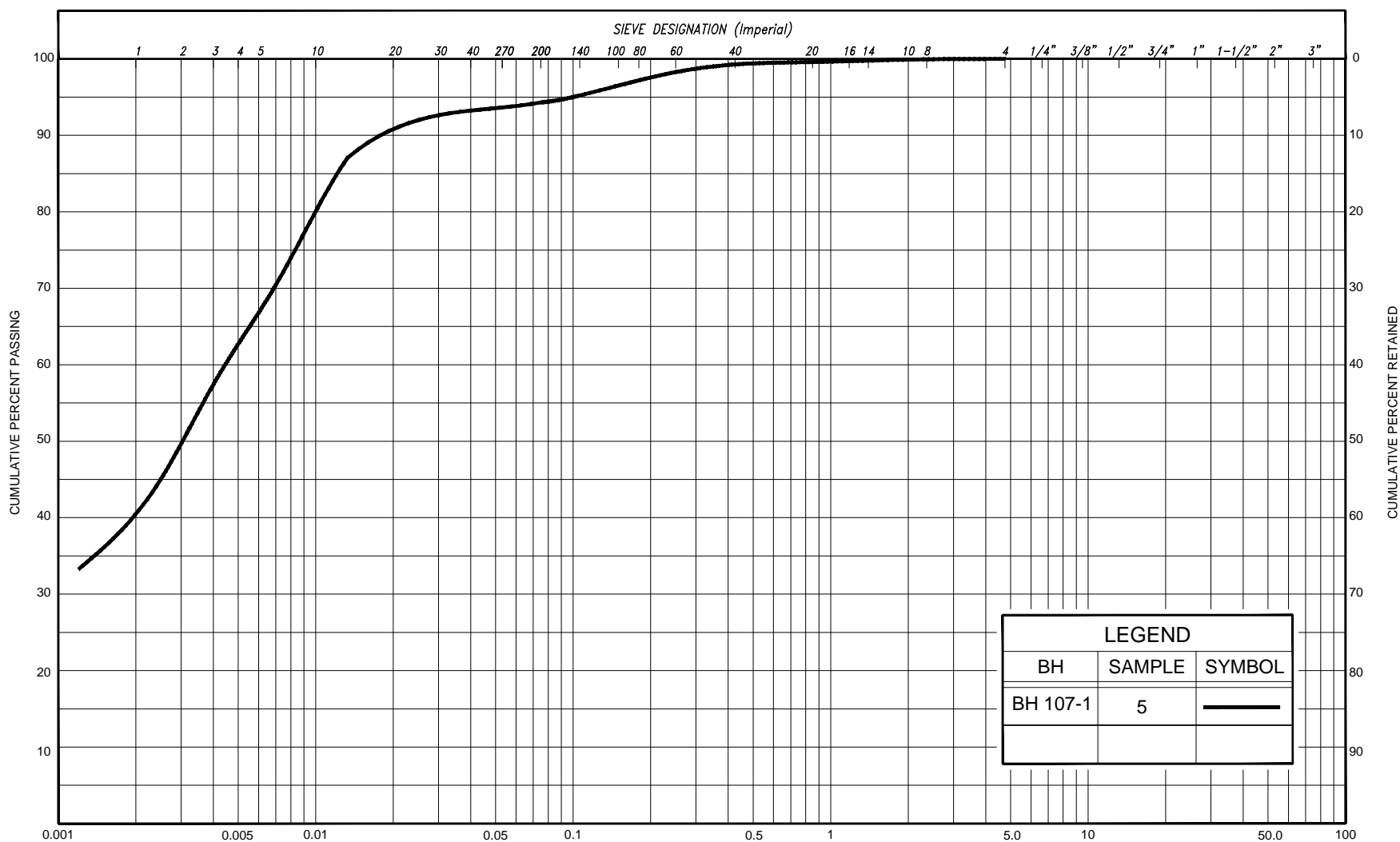
SILT to CLAYEY SILT, trace sand

FIG No.	C96-GS-3
HWY:	400
W.P. No.	2184-10-00



PLASTICITY CHART
SILT to CLAYEY SILT, trace sand (CL-ML)

FIG No. C96-PC-1
HWY: 400
W.P. No. 2184-10-00



LEGEND		
BH	SAMPLE	SYMBOL
BH 107-1	5	—

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



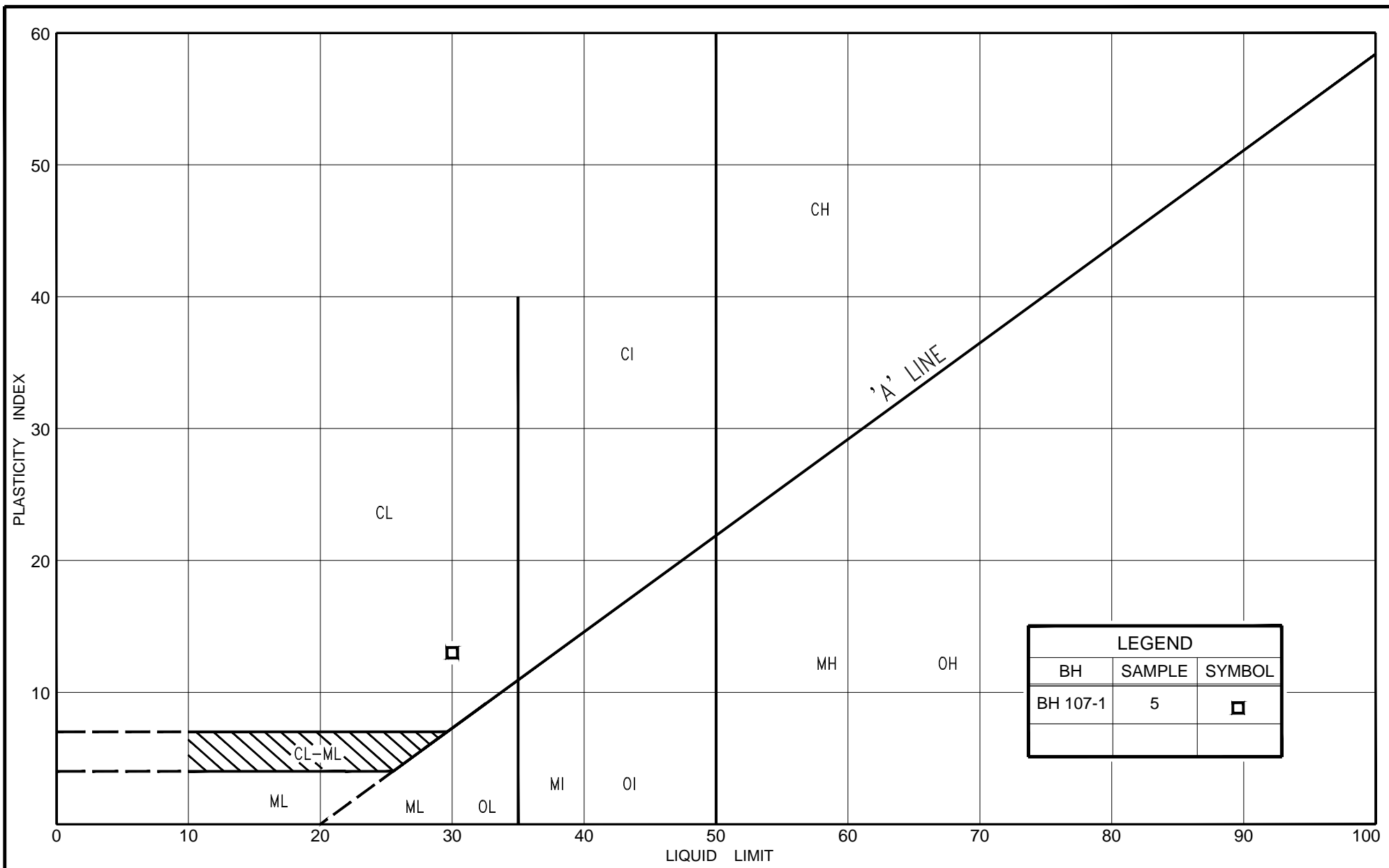
GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand

FIG No. C107-GS-1

HWY: 400

W.P. No. 2184-10-00



PLASTICITY CHART

CLAYEY SILT, trace sand

FIG No.	C107-PC-1
HWY:	400
W.P. No.	2184-10-00

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{v0}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No 96-1

1 of 1

METRIC

W.P. 2184-10-00 LOCATION Co-ords: 4 909 033.3 N; 290 175.8 E ORIGINATED BY S.A.
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.
DATUM Geodetic DATE April 14, 2016 CHECKED BY _____

SOIL PROFILE					SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa												
						20 40 60 80 100												
						20 40 60 80 100												
279.3	Ground Surface																	
0.0	Sandy silt organics, rootets		1	SS	3													
	Very loose Dark Moist to compact brown/black																	
	(FILL)		2	SS	13												5 76 12 7	
277.6	Silty sand		3	SS	15												First water strike at 1.7m	
1.7	Compact Grey Wet																	
			4	SS	22												28 59 11 2	
			5	SS	20													
275.7	Clayey silt trace sand, trace gravel																	
3.6	Stiff to Grey Wet very stiff																	
			6	SS	14												0 1 83 16	
	clayey seams		7	SS	17													
			8	SS	25													
269.9	sand seams		9	SS	22													
9.4	Clayey silt trace sand, trace gravel																	
	Hard Grey Moist (TILL)																	
			10	SS	30													
268.0	End of borehole																	
11.3																		
	* 2016 04 14																	
	▽ Water level observed during drilling																	
	▼ Water level measured after drilling																	
	Upon completion of augering, free water at 2.1m cave-in at 6.4m																	

RECORD OF BOREHOLE No 96-2

1 of 1

METRIC

W.P. 2184-10-00 LOCATION Co-ords: 4 909 023.1 N; 290 241.6 E ORIGINATED BY D.W.
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.Kh.
DATUM Geodetic DATE April 15, 2016 CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										○		
								● QUICK TRIAXIAL × LAB VANE												
278.6	Ground Surface						20	40	60	80	100	20	40	60						
278.4	Topsoil																			
0.2	Sandy silt		1	SS	9															
	Loose to compact Dark brown to brown Wet		2	SS	13															
	Sand, trace gravel																			
	Compact Grey to brown Wet		3	SS	17															
	silty sand, trace gravel		4	SS	18															
	(FILL)																			
275.4	Clayey silt		5	SS	27															
3.2	Very stiff Grey Moist to wet																			
			6	SS	20															
			7	SS	24															
271.2	Clayey silt, trace sand																			
	Very stiff Grey to hard		8	SS	60															
	clayey silt to silty clay		9	SS	24															
267.5	(TILL)																			
			10	SS	66															
11.1	End of borehole																			

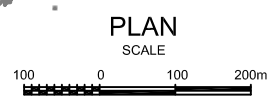
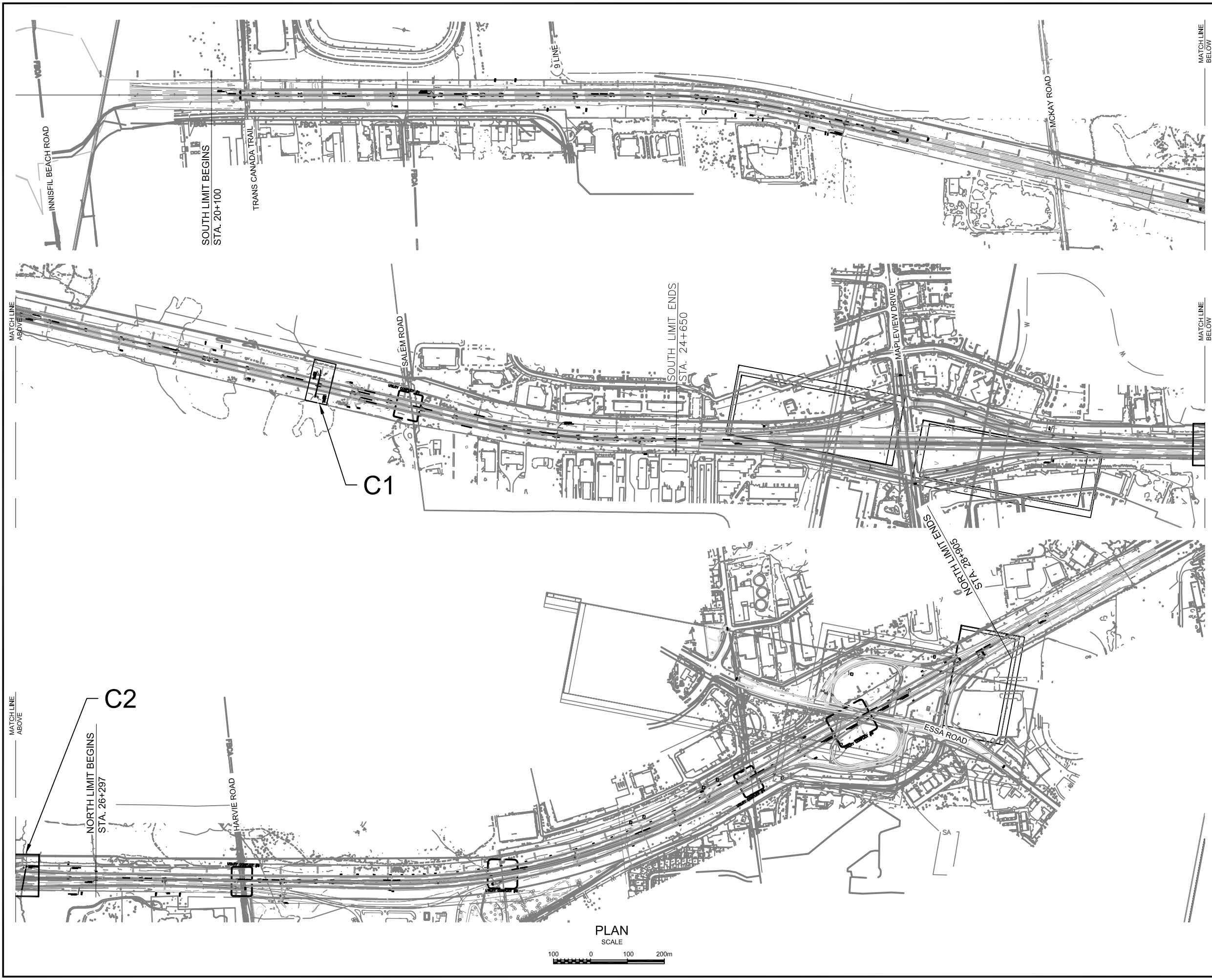
RECORD OF BOREHOLE No 107-1

1 of 1

METRIC

W.P. 2184-10-00 LOCATION Co-ords: 4 911 425.2 N; 289 896.5 E ORIGINATED BY D.W.
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY M.Kh.
DATUM Geodetic DATE _____ CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
293.3	Ground Surface						20	40	60	80	100	20	40	60						
293.2	Topsoil																			
0.1	Sand, trace gravel		1	SS	15															
292.5	Compact Brown Wet																			
0.8	Silty sand trace organics		2	SS	25															
	Compact Brown Wet																			
	with gravel																			
291.3			3	SS	115															
2.0	Sandy silt																			
	Compact Grey Moist		4	SS	9															
	(TILL)																			
290.3																				
3.0	Sandy silt, trace clay sand seams		5	SS	23															
	Compact Grey Moist																			
	sand layer																			
	brown/grey		6	SS	69															
288.3																				
5.0	End of borehole																			

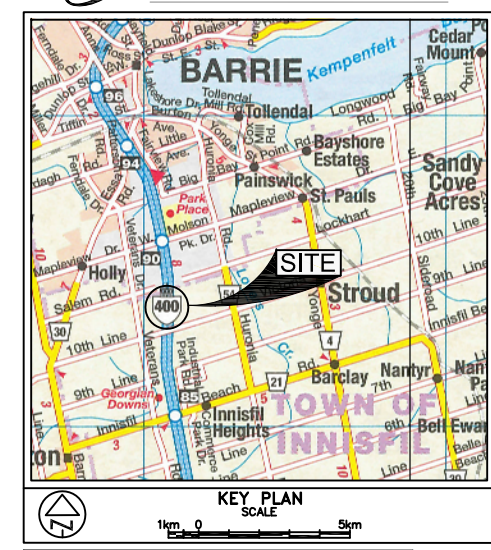


TASK No 2013-E-0039-010
WP No 2184-10-00

HIGHWAY 400 SEWER REPLACEMENT

KEY PLAN

SHEET



LEGEND

C2

 Culvert Site

BH No	BOREHOLE LOCATION PLAN
96-1	Refer to Sheet No. 400WM-C1
96-2	Refer to Sheet No. 400WM-C1
107-1	Refer to Sheet No. 400WM-C2

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. 31D-660

HWY No	400	DIST	CENTRAL
SUBM'D	NA	CHECKED	M.K.H.
DRAWN	NL	CHECKED	MV
DATE	JUNE 27, 2016	APPROVED	MV
SITE		DWG	400WM-A



LEGEND

Borehole Location

Blows/0.3m (Std. Pen Test, 475 J / blow)

Piezometer

WL observed during drilling (April 2016)

Existing Sewer

Replacement/New Sewer

FILL

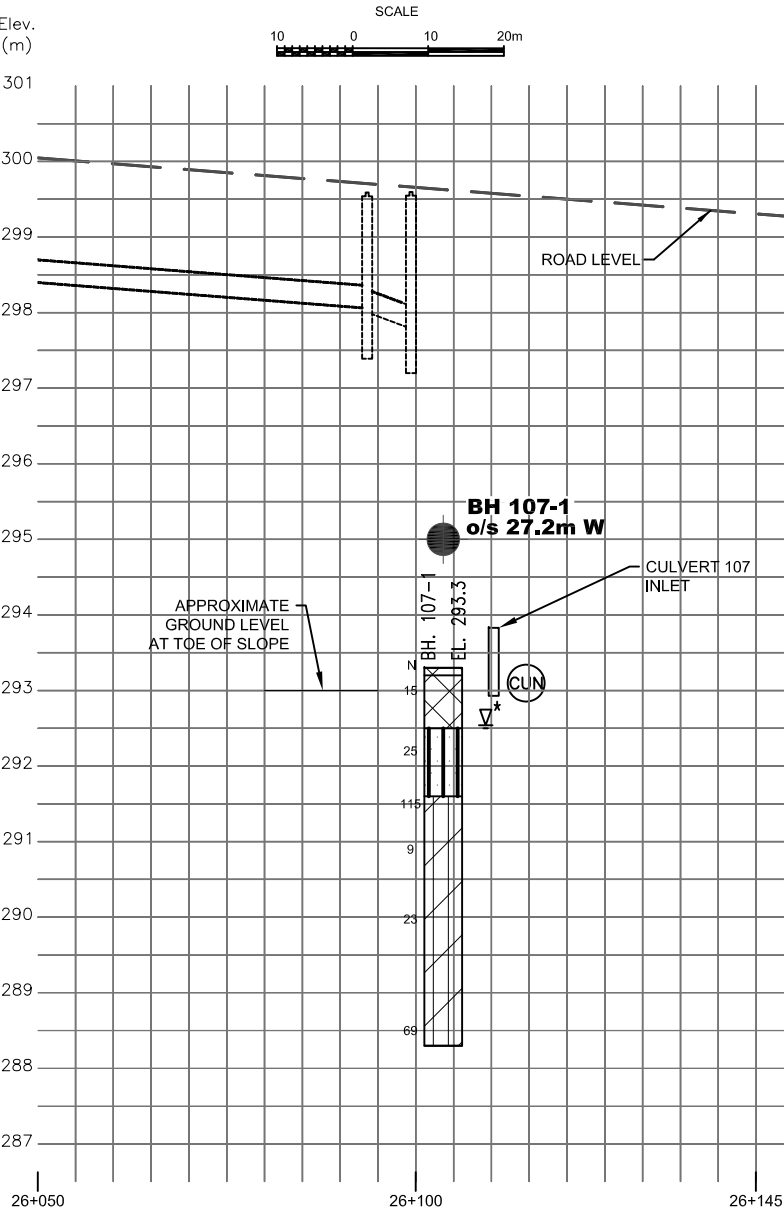
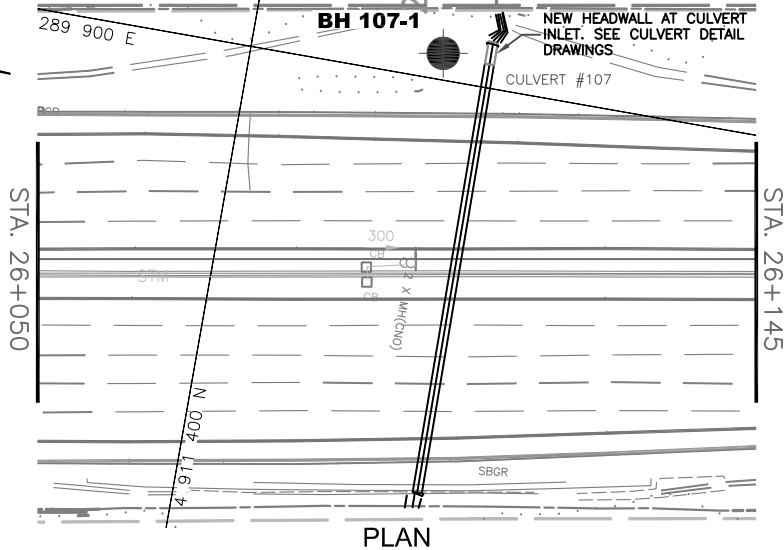
SILTY SAND TO SANDY SILT

CLAYEY SILT

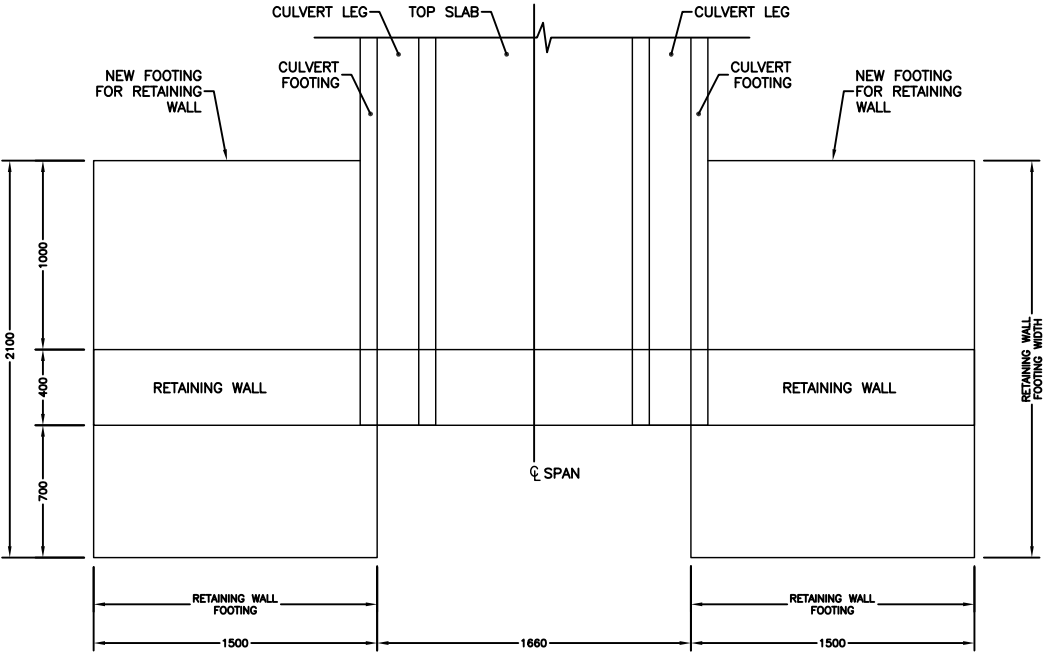
BH No	ELEVATION	CO-ORDINATES	
		NORTHINGS	EASTINGS
107-1	293.3	4 911 425.2	289 896.5

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

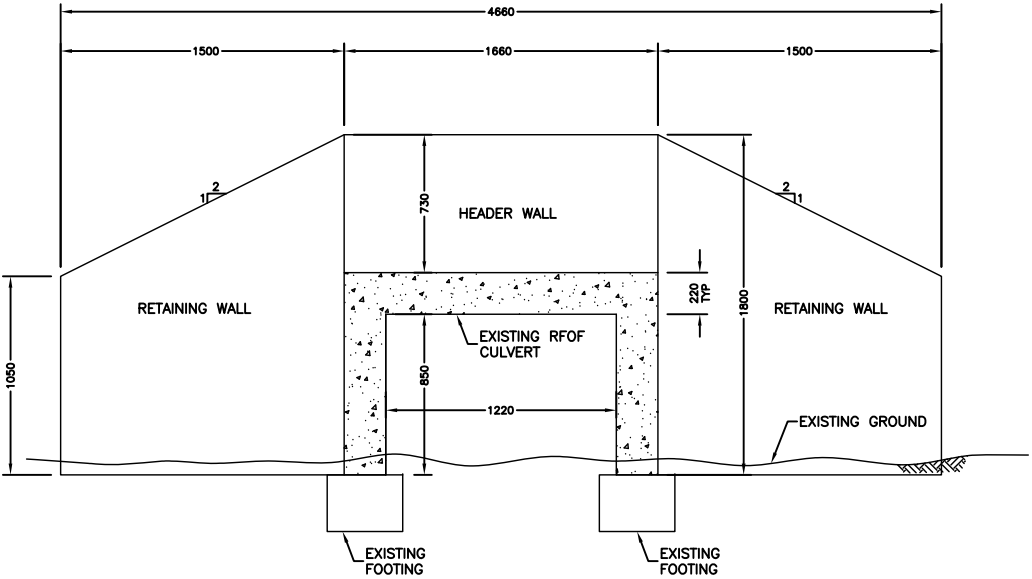
REVISIONS		
DATE	BY	DESCRIPTION
Geocres No. 31D-660		
HWY No	400	DIST CENTRAL
SUBM'D	NA	CHECKED M.K.H. DATE JUNE 27, 2016 SITE
DRAWN	NL	CHECKED MV APPROVED MV DWG 400WM-C2



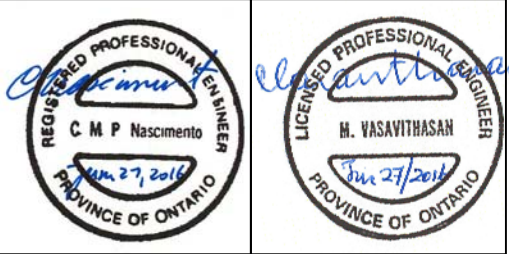
PROFILE AT TOE OF SLOPE



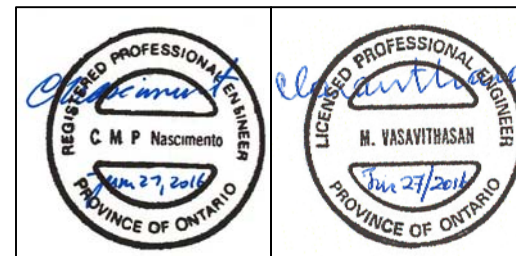
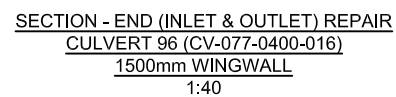
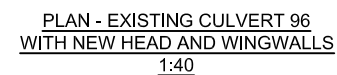
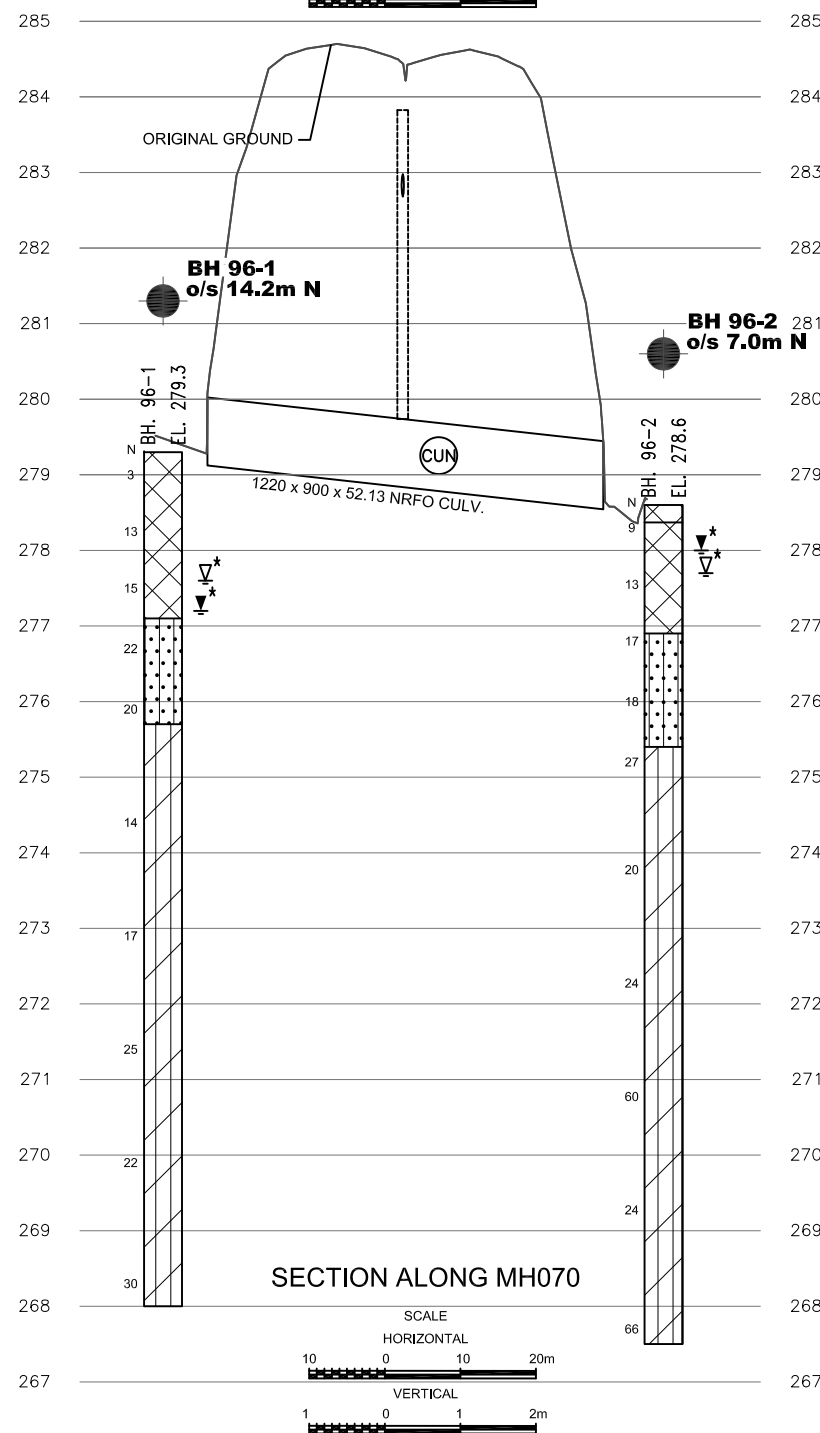
PLAN - EXISTING CULVERT 107
WITH NEW HEAD AND WINGWALLS
1:40



SECTION - END (INLET) REPAIR
CULVERT 107 (CV-077-0400-021)
1500mm WINGWALL
1:40



REF MTO Drawings; 09.NEWCONS-For FDN.dwg, 10.PROFILES.dwg & 96-107 CULVERT DETAILS.dwg; dated January 13, 2016, January 12, 2016, & February 10, 2016 respectively.



BH No	ELEVATION	CO—ORDINATES	
		NORTHINGS	EASTINGS
96—1	279.3	4 909 033.3	290 175.8
96—2	278.6	4 909 023.1	290 241.6

HWY No 400				DIST	CENTRAL
SUBM'D	NA	CHECKED	M.Kh	DATE	JUNE 27, 2016
DRAWN	NL	CHECKED	MV	APPROVED	MV
				DWG	400WM-C1

REF MTO Drawings; 09.NEWCONS-For FDN.dwg, 10.PROFILES.dwg & 96-107 CULVERT DETAILS.dwg; dated January 13, 2016, January 12, 2016, & February 10, 2016 respectively.



PART B - FOUNDATION DESIGN REPORT

for

HIGHWAY 400

HEADWALL AT THE INLET AND OUTLET OF CULVERT 96, STA. 23+665

AND HEADWALL AT THE INLET AT CULVERT 107, STA. 26+100

RETAINER ASSIGNMENT – TASK NO. 2013-E-0039-010

WP 2184-10-00

**TOWN OF INNISFIL AND CITY OF BARRIE, SIMCOE COUNTY,
ONTARIO**

PREPARED FOR MINISTRY OF TRANSPORTATION OF ONTARIO

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1 cc: MTO, Pavements and Foundations Section
+ 1 digital copy (pdf)
1 cc: PML Toronto

PML Ref.: 15TF020-5
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GEOCRES No.: 61D-660
June 30, 2016



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List of Standard Specifications Relevant to Report

PART B
FOUNDATION DESIGN REPORT

For
Highway 400 Upgrading – Culvert Headwalls
At Sta. 23+665 and Sta. 26+100
Retainer Assignment – Task No. 2013-E-0039-010, WP2184-10-00
Town of Innisfil and City of Barrie, Simcoe County, Ontario

6. INTRODUCTION

This report provides recommendations for the design and construction of the proposed headwalls for Culvert 96 and Culvert 107 located at Sta. 23+665 and Sta. 26+100, respectively. The comments made on the construction issues are intended to highlight those aspects that could have impact or affect the detail design and construction of the proposed headwalls.

This Foundation Design Report is for the sole purpose of the Ministry of Transportation and shall not be used for any other purposes or by any other parties including the contractor who will be carrying out the construction. The recommendations are provided based on the contract drawings provided to PML. Refer to the associated contract drawings for design requirements.

Where comments are made on construction, they are provided solely to identify aspects that could affect the design of the project. Contractors should make their own assessment of the factual information provided in Part A - Foundation Investigation portion of this report, for their decisions related to construction including, but not limited to, equipment selection, proposed construction methods and scheduling.

7. GEOTECHNICAL DISCUSSIONS AND RECOMMENDATIONS

7.1 Existing Culverts

Based on the detail drawings of the culverts provided, the existing Culvert 96 located at Sta. 23+665 is an open type concrete structure supported on spread footings. The drawings also indicate that the culvert consists of 1.22 m clear span and 0.9 m rise with 52.13 m long and 1.94 m wide deck. The drainage ditch slopes from about El. 279.1 at the inlet to approximate elevation of El. 278.5 at the outlet. However, founding level and width of the footings of the culvert are not available. The



plan and profiles of Highway 400 provided in the 60% Design Package indicate that the embankment at this location is approximately 4.5 m to 5.0 m high.

There is no rip-rap on either side of the drainage ditch, i.e., inlet or outlet, to protect against the scour or erosion. However, no major erosion or undermining of the drainage ditch was observed and the existing embankment appears to be in good condition.

The existing Culvert 107 located at Sta. 26+100 is also an open type concrete structure supported on spread footings. The drawings indicate that the culvert consists of 1.22 m clear span and 0.85 m rise with 60.44 m long and 1.66 m wide deck. The drainage ditch slopes from about El. 293.0 at the inlet to approximate elevation of El. 292.8 at the outlet. Similar to Culvert 96, the founding level or width of the footings are not available. The plan and profiles of Highway 400 provided in the 60% Design Package indicate that the embankment at this location is approximately 6.0 m high.

There is no rip-rap on either side of the drainage ditch at this culvert location to protect against the scour or erosion. However, no major erosion or undermining of the drainage ditch was observed and the existing embankment appears to be in good condition

7.2 Proposed Head and Wing Walls

7.2.1 Culvert 96

Based on the drawings provided to PML, we understand that 680 mm high above the existing culvert and 1.94 m long Headwalls flanked by Wingwalls extending to a distance of 1.5 m from the external face of the culvert are proposed to be constructed at the inlet and outlet to accommodate - of Highway 400 rehabilitation works. The Wingwalls are expected to be located along the same alignment (180°) as the headwall and sloped at 2H:1V at the top to retain about 1.8 m to 1.05 m high embankment fill.



7.2.2 Culvert 107

We understand that 730 mm high and 1.66 m long headwall above the existing culvert, flanked by Wingwalls extending to a distance of 1.5 m from the external face of the culvert is proposed to be constructed only at the inlet to accommodate - of Highway 400 rehabilitation works. The Wingwalls are expected to be located along the same alignment (180°) as the headwall, parallel to the roadway and sloped at 2H:1V at the top to retain about 1.8 m to 1.05 m high embankment fill.

7.3 Foundations for Head and Wing Walls

7.3.1 Culvert 96

The subsoil conditions at this culvert location consist of 1.5 m to 2.2 m sand to silty sand fill, followed by 1.4 m to 1.5 m thick silty sand to sandy silt (native material). The silty sand to sandy silt layer is underlain by stiff to very stiff low plastic silt to clayey silt deposit with occasional cobbles. This silt to clayey silt deposit extends to the maximum depth of investigation of 11.3 m (El. 267.5). The groundwater level was observed at about elevation El. 278.0 at the inlet and at El. 277.2 at the outlet.

There is no foundation investigation and design report or as constructed drawing is available for the existing culvert to establish the founding levels of the spread footings on which the culvert is supported. In order to prevent overloading of existing footings, the footings for the proposed head walls should be placed at the same elevation as the foundations of the culverts. In the absence of any information on the existing footings, the founding elevations for the proposed head and wing walls recommended are based on the findings from the geotechnical investigation conducted.

The head and wing walls can be either cast-in-place concrete retaining structure placed below El. 277.0 at the inlet and El. 276.8 at the outlet or a gabion wall placed on a competent subgrade at least 500 mm below the elevation of the drainage ditch bed.

Considering the subsoil conditions at the inlet and outlet of the culvert, gabion walls and/or cast-in-place concrete wall are recommended to retain the soil behind the head and wing walls.



However, gabion wall will be less expensive and easier to construct. Further, installation of gabion for wing walls will not require deep excavation or dewatering scheme compared to cast-in-place-concrete wall.

In case a gabion wall is adopted, it shall be constructed in accordance with OPSS 512. The fines from the fill material may migrate through the gabion walls, especially when the drainage ditch is flooded. This may lead to erosion, bulging of the gabion walls or failure of embankment. In order to prevent loss of fines, a properly designed filter or geotextile shall be placed behind the gabion wall.

Considering the order of load expected at the foundation level including the load imposed by the fill and the subsoil conditions at this site, a strip footing is recommended for the cast-in-place concrete wall. A strip footing of 1.0 m wide placed at a depth of 1.7 ± 0.2 m below the proposed finished grade may be designed assuming the geotechnical resistances recommended below.

The geotechnical resistance values at Ultimate Limit State (ULS) and Serviceability Limit State (SLS) provided below shall be used for the design of 1.0 m wide strip footings. The geotechnical resistance at ULS provided is based on a factor of 0.5 as recommended in the Canadian Highway Bridge Design Code (CHBDC 2014). Estimated total settlement for the geotechnical resistance at SLS recommended will be in the range of 20 to 25 mm. Most of the settlement is expected to take place immediately and continuing settlement will be minimal to cause any differential settlement.

Factored Geotechnical Bearing Resistance at ULS	=	350 kPa
Geotechnical Bearing Resistance at SLS	=	175 kPa

The founding depth and corresponding elevations at the inlet and outlet of the culvert are provided below. The footings shall be placed at or below the depth recommended and the designer shall use the data from the borehole closest to the inlet or outlet.

LOCATION	BOREHOLE NO.	DEPTH (m)	ELEVATION (m)
Inlet	BH96-1	2.2	277.0
Outlet	BH96-2	1.7	276.8



7.3.2 Culvert 107

The subsoil conditions at the inlet of the culvert consist of 100 mm of surficial topsoil, followed by 700 mm of sand fill, which is underlined by 900 mm of native silty sand to sandy silt deposit. This is underlain by clayey silt deposits, which extends to the maximum depth of investigation of 5.0 m (El. 288.3). The groundwater level was observed at about elevation El. 292.5 at this site. Similar to Culvert 96, there is no information available on the foundation of the existing culvert and the recommendations provided are based on the findings from the geotechnical investigations conducted by PML.

The proposed head and wing walls at the inlet can be either a gabion wall placed on a competent ground at least 500 mm below the drainage ditch bed or a cast-in-place concrete wall placed below El. 291.5. The subgrade material at the founding level recommended consists of very stiff to hard clayey silt and the following geotechnical resistance values at Ultimate Limit State (ULS) and Serviceability Limit State (SLS) are recommended for the design of 1.0 m wide strip footings placed at or below El. 291.5. The estimated total settlement for the geotechnical resistance at SLS recommended is not expected to exceed 20 mm and the associated differential settlement will be minimal to cause any difference to the proposed structures.

Factored Geotechnical Bearing Resistance at ULS	=	350 kPa
Geotechnical Bearing Resistance at SLS	=	200 kPa

In general, the depth of existing culverts foundation are unknown. Therefore, confirmation of the founding level of the existing culvert foundation will be required. Care should be taken not to excavate deeper than the existing foundation level of the culvert, as not to undermine the existing foundation. Once the foundation elevation of the existing culvert is determined, the founding level for the wing walls need to be adjusted to match the existing footings. The foundation of wing walls should not be founded deeper or higher than the footings of existing culvert.



7.3.3 Protection of Subgrade

The subsoil conditions at the founding level of both culvert locations should be prepared in accordance with OPSS 206. The subgrade is susceptible to disturbance from construction traffic and any ponded water. In order to limit the degradation of the founding soil, it is recommended that a concrete working slab (lean concrete) be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. This requirement should be addressed by a note on the structural drawings.

7.3.4 Excavation

Groundwater levels higher than those encountered during the investigation should be anticipated due to seasonal variations, depending on the time of construction. The excavation for the construction of concrete headwalls should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO regulations.

Based on the record of boreholes, the excavations for the will be advanced through existing granular fill material to the native sandy to silty deposit and clayey silt layer. For OHSA classification purposes, the fill materials should be classified as Type 3 soils, including silts below the water level. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

Trench and slopes of excavation should be continually inspected, particularly following periods of heavy rainfall, spring thaw, and when the trench has been left open for any extended period of time. Any cobbles or boulders exposed on the faces of excavation slope must be removed.

Occasional cobble layers encountered within the fill as well as in the native materials may hamper the installation of shoring system or progress of excavation.



7.3.5 Earth Pressures

The temporary support system should be designed by a Professional Engineer in accordance with OPSS 539 (Temporary Protection Systems) performance level 2 and OPSS 404 (Construction Specification for Support Systems). The temporary protection system should be designed to meet the Performance Level 2 specified in OPSS 539. The design of protection system should consider the maximum water level that may be expected during the construction.

The lateral earth pressure on the supporting structure is strongly dependent on the permissible lateral deformation. The pressure distribution for the sandy material encountered in the project area remains close to a triangular distribution. The lateral earth pressure for the design of temporary protection system shall be calculated assuming the soil parameters recommended below:

$$P_h = K_o \cdot \gamma \cdot h + K_o \cdot q$$

Where:

- P_h = horizontal pressure at depth h (kN/m²)
- γ = unit weight of soil as shown in Table 8.1.1.1
- h = depth of excavation below ground surface (m)
- q = surcharge load at ground surface (kPa)
- K_o = coefficient of lateral earth pressure at rest for a horizontal ground surface condition as shown in Table 8.1.1.1

Table 8.1.1.1 – Lateral Earth Pressure Parameters

Parameter	Existing Fill Material (*)	Native Soils
Angle of Internal Friction, degrees (°)	30	32
Unit Weight (kN/m ³)	21.0	20
Active Earth Pressure Coefficient (K_a)	0.33	0.30
At-Rest Earth Pressure Coefficient (K_o)	0.50	0.47
Passive Earth Pressure Coefficient (K_p)	3.0	3.25

(*) Assumes cohesionless fill materials similar to those encountered in the boreholes.

The submerged unit weight of the soil shall be assumed below the groundwater table. The supporting system should be designed to resist the hydrostatic pressure in addition to the earth pressure.



Longitudinal drains and weep holes shall be installed to provide positive drainage for the granular backfill. Other aspects of the granular backfill requirements with respects to sub-drains and frost taper shall be in accordance with OPSD 3101.150 (Walls, Abutment, and Backfill) and OPSD 3190.100 (Walls, Retaining and Abutment Wall Drain).

7.3.6 Frost Depth

The foundation frost depth for structure foundations at this site is 1.5 m, according to OPSD 3090.101.

7.3.7 Sliding and Base Friction

The following parameters shall be used for calculation of sliding resistance of base for both concrete retaining wall and gabion wall..

Table 7.2.1 – Sliding Parameter

Parameter	Very Stiff Silt to Clayey Silt	Compact Silty Sand to Sandy Silt
Friction Angle, degrees	0	30
Cohesion, kPa	100	0
Unit Weight, kN/m ³	20.0	20.0

An unfactored friction angle of 26 degrees shall be assumed at the interface of footing and founding material or subgrade for the calculation of sliding resistance.. The designer shall use appropriate factors on the angle of internal friction and cohesion values provided on the table to check the sliding resistance.. Foundation keys or dowels may be specified if adequate resistance from the subgrade cannot be mobilised.

7.3.8 Seismic Considerations

The soil at this site for seismic design purposes is classified as Type D. For the both culvert site the PGA_{ref} should be used as 0.044 in accordance to CHBDC 2014.



7.3.9 Backfill, Drainage Control and Erosion Control

The backfill behind the cast-in-place retaining walls should consist of suitable free draining granular materials such as Granular A, Granular B Type I or Type II and the backfill geometry shall be according to OPSD 3121.150. The backfill shall be placed and compacted to at least 95% of the standard Proctor maximum dry density determined in accordance with MTO LS-706.

Backfilling adjacent to retaining structures should be carried out in conformance with OPSS 501 and SP105S10. Operation of compaction equipment adjacent to retaining structures should be restricted to limit the compaction pressure noted in clause 6.9.3 of the CHBDC. Refer to SP 105S10 for additional information with regards to compaction of fill material adjacent to a structure.

A subdrain system (SP 405F03) and weep holes (OPSD-3190.100) should be installed to minimize the build-up of hydrostatic pressure behind the cast-in-place concrete walls. The subdrains should be surrounded by a properly designed granular filter or non-woven Class II geotextile with a Filtration Opening Size (FOS) of 75 – 100 μm as specified in OPSS 1860 to prevent migration of fines into the drainage system. The drainage pipes should be installed on a positive grade and lead to frost-free outlets.

The slope of earth embankment shall not be steeper than 2H:1V. The earth slopes should be protected against surface erosion by sodding and suitable vegetation. Refer to OPSS 571 or 572 for time constraints and the type of seed and mulch required. The benching for the widening shall be in accordance with OPSD 208.01.

7.3.10 Dewatering

Groundwater was observed in both boreholes at the location of Culvert 96. The depth of water level ranged from 0.6 to 2.1 m (El. 278.0 to 277.2). The groundwater at the inlet of Culvert 107 was observed approximately 0.8 m (El. 292.5) below the existing ground level.

If any groundwater or surface run-off is encountered during the excavation, a sump and pump method supplemented with perimeter drains should be adequate to control the water.



It should be noted that dewatering during construction would be challenging due to the nature of the subsoil conditions. In order to maintain a dry condition during construction, the groundwater should be lowered to at least 500 mm below the bottom of the excavation.

8. CLOSURE

This Foundation Investigation and Design Report was prepared by Mr. M. Khorsand, EIT and was reviewed by Mark Vasavithasan, M.Sc.Eng., P.Eng., Senior Engineer, Geotechnical Services. Mr. C. Nascimento, P.Eng., Principal Designate MTO Contact conducted an independent review of the report.

Sincerely

Peto MacCallum Ltd.

A handwritten signature in blue ink, appearing to read "Mansoor", is written over a faint, larger signature.

Mansoor Khorsand, BSc. EIT.
Project Supervisor, Geotechnical Services



Mark Vasavithasan, M.Sc.Eng., P.Eng.
Senior Engineer, Geotechnical Services



Carlos M. P. Nascimento, P.Eng
Principal Consultant
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MK/MV/CN:jk



LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

DOCUMENT	TITLE
OPSS.PROV 1010	Material Specification for Aggregates - Base, Subbase, Select Subgrade, And Backfill Material
OPSS 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS 404	Construction Specification for Support Systems
OPSS 415	Construction Specification for Pipeline installation by Tunnelling
OPSS 416	Construction Specification for Pipeline and Utility Installation by Jacking and Boring
OPSS 450	Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling
OPSS 501	Construction Specification for Compacting
OPSS 512	Construction Specification for Installation of Gabions□
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 539	Construction Specification for Temporary Protection Systems
OPSD 3090.101	Ontario Provincial Standard Drawing. Foundation. Frost Penetration Depths
OPSD 802.010	Flexible Pipe, Embedment and Backfill, Earth Excavation
OPSD 802.030	Rigid Pipe Bedding, Cover, and Backfill, Type 1 or 2 Soil - Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover, and Backfill, Type 3 Soil - Earth Excavation