



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

FORDE LAKE CULVERT REPLACEMENT

SITE NO. 39W-112/C

HIGHWAY 11 – STATION 13+003 – STUDHOLME TOWNSHIP

DISTRICT OF NEW LISKEARD, ONTARIO

ASSIGNMENT NO. 5015-E-0009

GWP 5213-05-00

WP 5213-05-01

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PML Ref.: 16TF013A
Index No.: 162FIR and 163FDR
GEOCRES No.: 42F-57
May 7, 2018



PART A - FOUNDATION INVESTIGATION REPORT

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PART A - FOUNDATION INVESTIGATION REPORT

Forde Lake Culvert Replacement
Site No. 39W-112/C
Highway 11 – Station 13+003
Studholme Township, District of New Liskeard, Ontario
Assignment No. 5015-E-0009, GWP 5213-05-00, WP 5213-05-01

1. INTRODUCTION

GHD Ltd. (GHD) has retained Peto MacCallum Ltd. (PML) on behalf of the Ministry of Transportation Ontario (MTO) to conduct the geotechnical investigation for the replacement or rehabilitation of 13 structures located on Highway 11 and three (3) structures located on Highway 583. This foundation investigation work is part of an assignment to prepare detail design for the replacement/rehabilitation of 15 culverts and Fraser River Bridge. This assignment involves five contracts assigned to be carried out under four different General Work Plans (GWPs). The foundation investigation for Structure 39W-112/C was conducted under GWP 5213-05-00.

This report summarizes the results of the foundation investigation carried out for the proposed replacement of the culvert located at the crossing of an Unnamed Creek and Highway 11 (Sta. 13+003). Forde Lake culvert, County Site Number 39W-112/C, is located 8.8 km west of the intersection of Highway 11 and Highway 663 (2.2 km west of Forde Creek) in Studholme Township, New Liskeard District, Ontario.

The purpose of the investigation was to explore the subsurface conditions expected to influence the design of the culvert replacement and to aid the designer in selecting the suitable type of replacement structure.

2. SITE DESCRIPTION

The roadway is slightly elevated from the natural topography, and accommodates two lanes of vehicular traffic. The site is generally a flat area, with the exception of the highway embankments. The creek flows from south to north, almost perpendicular to Highway 11. The unnamed creek flows from Forde Lake downstream through gradual slopes and discharges into Angelina Lake, which is located approximately 250 m downstream of the structure. The culvert site is surrounded by long grass and coniferous forestation with mature trees and shrubs. The approach embankment is approximately 4.0 m high above the creek bed.

Based on the General Arrangement (GA) drawing provided by GHD on April 27, 2018, the existing structure is a 22.7 m long twin-cell rectangular timber culvert, each cell with an opening size of



2.1 m in span and a fill height of 1.0 m above the deck. This culvert was constructed in 1956 and has no headwalls or wingwalls. The structure has no record of rehabilitation.

The Ontario Bridge Management System (OBMS) inspection report dated September 25, 2015, reveals that there were wet areas, light checking and splitting of cells. Signs of distress including shifting of the top timbers (bracings) and crushing of the bottom transvers timber between spans at the outlet were also noted. Further, buildup of sediments at the inlet and outlet, as well as debris at the inlet of the west barrel were also observed.

Refer to the photographs A1 to A4 provided in Appendix A, for general conditions of the.

3. FIELD INVESTIGATION PROCEDURES

The field work for the foundation investigation involved advancing four (4) boreholes. The boreholes were drilled to depths ranging from 11.3 m to 14.3 m below the existing ground surface (El. 244.6 to El. 243.0), and were terminated in competent soils.

The staff of PML visited the site on July 31, 2016 to mark out the borehole locations. The respective utility companies cleared the underground services at the borehole locations. Public and private utility authorities were informed and all of the utility clearance documents were obtained before the commencement of drilling work.

PML staff used a portable GPS device to establish the borehole locations in the field. Subsequently, Callon Dietz Inc. of London, Ontario, under contract to PML, carried out the survey of the borehole locations and elevations, and provided the co-ordinates for locations in MTM NAD 83 Northing and Easting (MTM Zone - ON10). PML used the survey data provided by Callon Dietz Inc. for the preparation of this report. All elevations reported in this report are referred to Geodetic datum and expressed in meters.

The equipment used for drilling was owned and operated by Landcore Drilling of Chelmsford, Ontario. Landcore Drilling is a specialist drilling contractor and worked under the full time supervision of a PML field supervisor. Boreholes numbered 16-112-01, 16-112-02, 16-112-03 and 16-112-04 were drilled between August 1 and 9, 2016. The boreholes were advanced using a CME 55 track-mounted drilling rig equipped with 200 mm diameter hollow stem augers.



Boreholes 16-112-01 and 16-112-02 were drilled on the gravel shoulders of Highway 11. Boreholes 16-112-03 and 16-112-04 were drilled at the inlet and outlet of the culvert, respectively. The borehole locations are shown on the attached Drawing 112/C-1.

Representative soil samples were recovered from the boreholes at 0.75 m intervals using a conventional 51 mm OD 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 the 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 the open boreholes. The water level in the creek was observed at approximate elevation of El. 254.8 during the fieldwork.

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 the PML laboratory for detailed visual examination, and index tests.

4. LABORATORY TEST PROCEDURES

Laboratory tests on representative Standard Penetration Test (SPT) samples recovered during the fieldwork were conducted by the laboratory owned by PML, located in Toronto. The laboratory testing program included the following:

- Natural moisture content determinations (40)
- Grain size distribution analysis (6)
- Atterberg limit tests (10)

All laboratory tests to determine the index properties were performed in accordance with the MTO test procedures, which follow the American Society for Testing Materials (ASTM) standards, with the exception of hydrometer tests (LS-702). The results of the grain size distribution analyses are presented in Figures 112-GS-1 and 112-GS-2. The results of the Atterberg Limit tests are



presented in Figures 112-PC-1 and 112-PC-2. All of the test results are summarized on the attached Record of Borehole Logs in Appendix B.

4.1 Chemical Analysis

One soil sample from the native silt layer was submitted to AGAT Laboratories in Mississauga, Ontario, for testing of chemical properties relevant to exposure of concrete elements to sulphate as well as potential soil corrosively effects. Test results are presented in Table 5.2.6.

5. SITE GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Site Geology

Based on the Bedrock Geology map (MRD126-REV1, 2011) published by the Ontario Ministry of Northern Development and Mines (MNDM), the culvert site lies within the Superior Province of the Precambrian rock formations. The project area consists mainly of Archean, Metasedimentary (Supercrustal) rocks (specifically, Paragneiss and Migmatite) and Muscovite-Bearing Granite rocks. The Quaternary Geology map published by the MNDM, indicates that the surface conditions in the vicinity of the culvert site consist of Glaciomarine deposits; silt and clay, minor sand basins and quiet water deposits.

5.2 Subsurface Conditions

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 Drawing 112/C-1. The boundaries between soil strata have been established at the borehole locations only. The boundaries of soil strata between and beyond the boreholes are assumed and may vary from location to location.

In general, the subsoil conditions consist of a pavement fill ranging in thickness from 500 mm to 570 mm below the Highway 11 shoulders. A 1.4 m thick layer of organics was encountered immediately below the ground surface near the culvert inlet and outlet. The pavement fill on the roadway is underlain by 1.7 m to 3.2 m gravelly sand fill. The gravelly sand fill on the highway shoulders and the organic layer near the culvert inlet and outlet are immediately underlain by silt with varying proportions sand and clay to the maximum depth of investigation of 14.3 m



(El. 243.0). For classification purposes, the soil encountered at this site can be divided into four distinct zones:

- a) Organics
- b) Pavement Fill
- c) Gravelly Sand, Some Silt (Fill)
- d) Clayey Silt to Silt, With sand, Trace Gravel

5.2.1 Organics

A layer of organics was encountered immediately below the ground surface near the culvert inlet and outlet, which extends to a depth of 1.4 m (El. 254.2) below the surface. The SPT N-values in this layer are 3 blows and 4 blows, indicating a soft consistency. The probable cause for high SPT N-values from 10 blows to 56 blows/200 mm at a depth of about 800 mm below the ground surface in Boreholes 16-112-03 and 16-112-04 was due to the presence of rootlets and wood pieces. Presence of wood was confirmed by recovering the samples with pieces of wood at the tip of the split spoon sampler.

5.2.2 Pavement Fill

A pavement fill layer, approximately 500 mm in thickness was encountered in both boreholes located on the shoulders of the roadway (BH 16-112-01 and BH 16-112-02). In Borehole 16-112-01, 80 mm of asphalt overlays the pavement fill, which extends to a maximum depth of 570 mm (El. 256.7).

5.2.3 Gravelly Sand, Some Silt (Fill)

The gravelly sand fill with varying proportions of gravel and sand was encountered in Boreholes 16-112-01 and 16-112-02, immediately below the 500 mm of pavement fill. This gravelly sand fill layer is approximately 1.7 m to 3.2 m thick and extends to a maximum depth of 3.8 m (El. 253.5) below the existing grade of the highway shoulder. The SPT N-values in this fill layer range between 8 blows and 15 blows, indicating a loose to compact state of compaction.

The moisture content of this fill material varies from 12.6% to 21.5%, with an average value of 16.4%. The results of the grain size distribution analysis performed on a representative sample of



the gravelly sand fill are shown on Figure 112-GS-1. The test results revealed that this fill layer consists of 37% gravel, 50% sand, 11% silt and 2% clay.

5.2.4 Clayey Silt to Silt, with Sand, Trace Gravel

The gravelly sand fill layer in Boreholes 16-112-01 and 16-112-02, and the organic layer in Boreholes 16-112-03 and 16-112-04 are immediately underlain by this clayey silt to silt layer, which extends to a maximum investigation depth of 14.3 m (El. 243.0) below the grade of the roadway. The SPT N-values to about El. 249.8 to 248.5 range from values as low as 2 blows to 15 blows, indicating a very loose to compact state of compactness. Below this depth (El. 249.8 to El. 248.5), the SPT N-values increase to a range of 10 blows to 50 blows, indicating a compact to dense state of compactness.

The moisture content of samples from this deposit range from 10.2% to 29.6%, with an average value of 16.1%. Atterberg limit tests were conducted on ten (10) of the samples retrieved from this deposit. The Atterberg limit tests performed on representative samples from this deposit are provided on Figures 112-PC-1 and 112-PC-2. Three (3) of the samples from Boreholes 16-112-01 and 16-112-04, within the top 1.8 m to 2.6 m indicated a slightly higher content of clay and classified as borderline between low plastic clay and silt. The liquid limits of these three samples vary between 20 and 23 and the corresponding plastic limits vary between 14 and 15, resulting in plasticity index values of 6 to 8. Based on the results of Atterberg limit tests, these three samples may be classified as clayey silt of low plasticity (CL-ML) in the Unified Soil Classification System (USCS). However, liquid limits of other seven (7) samples range between 15 and 17 and plastic limits range between 12 and 14, resulting in plasticity index of 1 to 4. Based on the results of Atterberg limit tests, these soil samples may be classified as inorganic silt of low plasticity (ML) in the Unified Soil Classification System (USCS).

The results of the grain size distribution analysis tests performed on five (5) representative samples from this clayey silt to silt deposit are provided on Figure 112-GS-2. The test results indicate that this deposit consists of 0% to 8% gravel, 12% to 30% sand, 51% to 75% silt and 10% to 16% clay.



5.2.5 Groundwater

The groundwater level during drilling was observed between 1.5 m and 2.6 m (El. 255.4 and El. 253.6) below the ground surface. Upon completion of drilling, the groundwater level was measured at a depth of 3.2 m to 4.6 m below the ground surface (El. 254.1 to El. 251.0).

The water level in the creek was observed at approximately elevation of El. 254.8 during the fieldwork.

Groundwater levels may fluctuate due to the influence of precipitation and seasonal change. The groundwater measurements were observed and measured prior to backfilling the boreholes. Groundwater levels are shown on the Borehole Logs in Appendix B.

5.2.6 Chemical Analysis

A summary of the chemical test results provided by AGAT Laboratories are presented in Table 5.2.6 below. The detail test results received from AGAT Laboratories are also provided in Appendix B.

Table 5.2.6 Soil Chemical Analysis Results

BOREHOLE NO.	SAMPLE	DEPTH / ELEVATION (m)	SOIL TYPE	SULPHATE (µg/g)	CHORIDE (µg/g)	pH	RESISTIVITY (Ohm-cm)
16-112-03	SS-4	4.6-5.2 / 251.0-250.4	Silt	43	159	8.07	2270



6. CLOSURE

Mr. K. Daly carried out the field investigations under the supervision of Mr. L. Yimam, P.Eng., Project Supervisor and Mr. C. M. P. Nascimento, P.Eng., Project Manager. LandCore Drilling Ltd. of Chelmsford, Ontario supplied the drilling equipment for the subsurface exploration. Surveying of borehole locations were carried out by Callon Dietz Incorporated of London, Ontario. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto. Chemical corrosivity tests were conducted by AGAT Laboratories, of Mississauga, Ontario.

This report was prepared by Ms. Natasha Leong-Sem, B.Eng., EIT, Geotechnical Services and reviewed by Mr. M. Vasavithasan, M.Sc. Eng., P.Eng., Senior Engineer, Geotechnical Services. Mr. C.M.P. Nascimento, P.Eng., Principal Consultant, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.

Natasha Leong-Sem, B.Eng., EIT
Geotechnical Services



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



Carlos M.P. Nascimento, P.Eng
Project Manager and
MTO Designated Principal Contact
NL/MK/CN:nl-nk



APPENDIX A

Site Photographs



Photograph A1: Looking west on Highway 11. Borehole 16-112-01 and 16-112-02 were drilled on the eastbound and westbound lane shoulder, respectively (July 26, 2016).



Photograph A2: Looking west from Forde Lake culvert inlet. Borehole 16-112-03 was drilled southeast from the end of the culvert inlet (August 26, 2016).



Photograph A3: Looking southeast from the Forde Lake culvert outlet. Borehole 16-112-04 was drilled northwest from the end of the culvert outlet (August 26, 2016).



Photograph A4: Looking north from the Forde Lake Culvert outlet. The unnamed creek discharges into Angelina Lake, captured in the background of the photograph (July 26, 2016).



APPENDIX B

Borehole Locations Plan and Soil Strata at Structure 39W-112/C

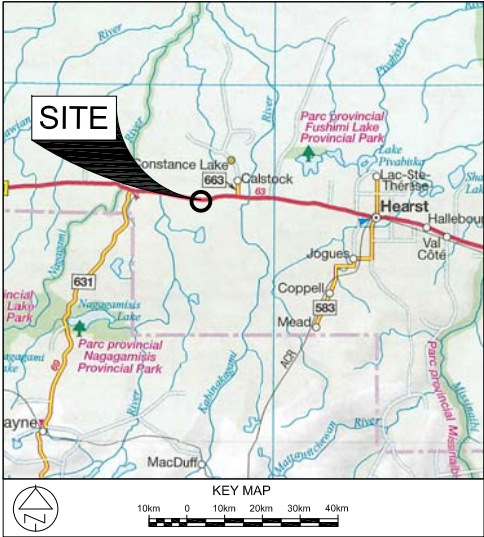
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Results of Chemical Tests Provided by AGAT Laboratories

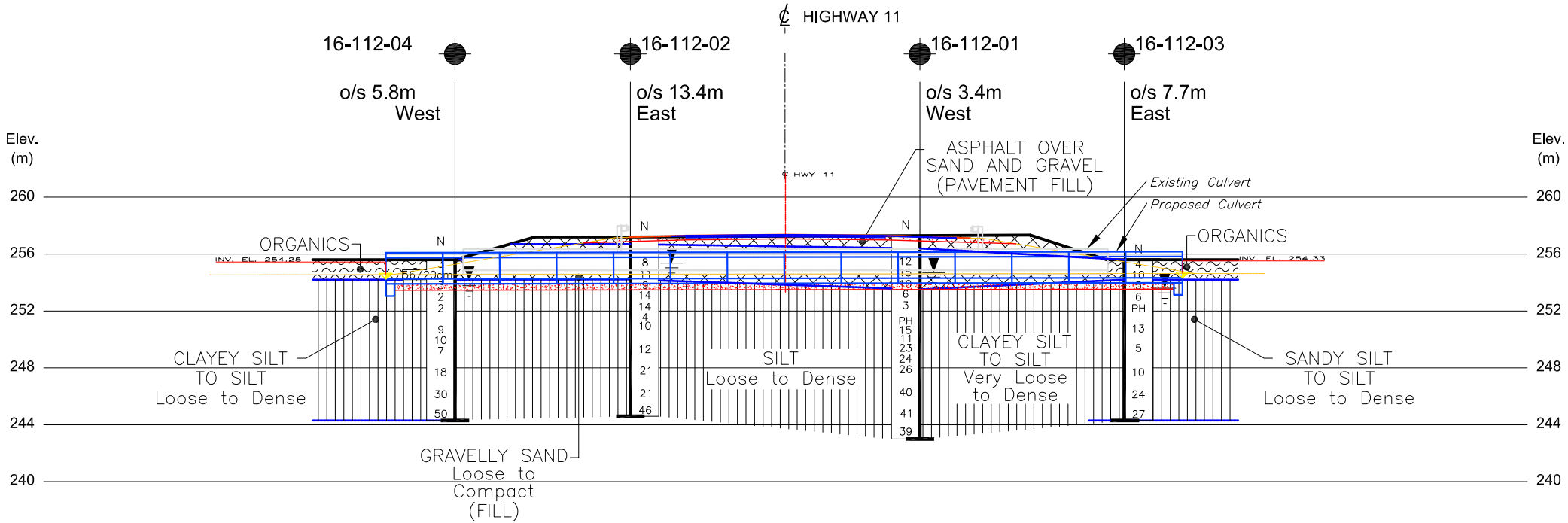
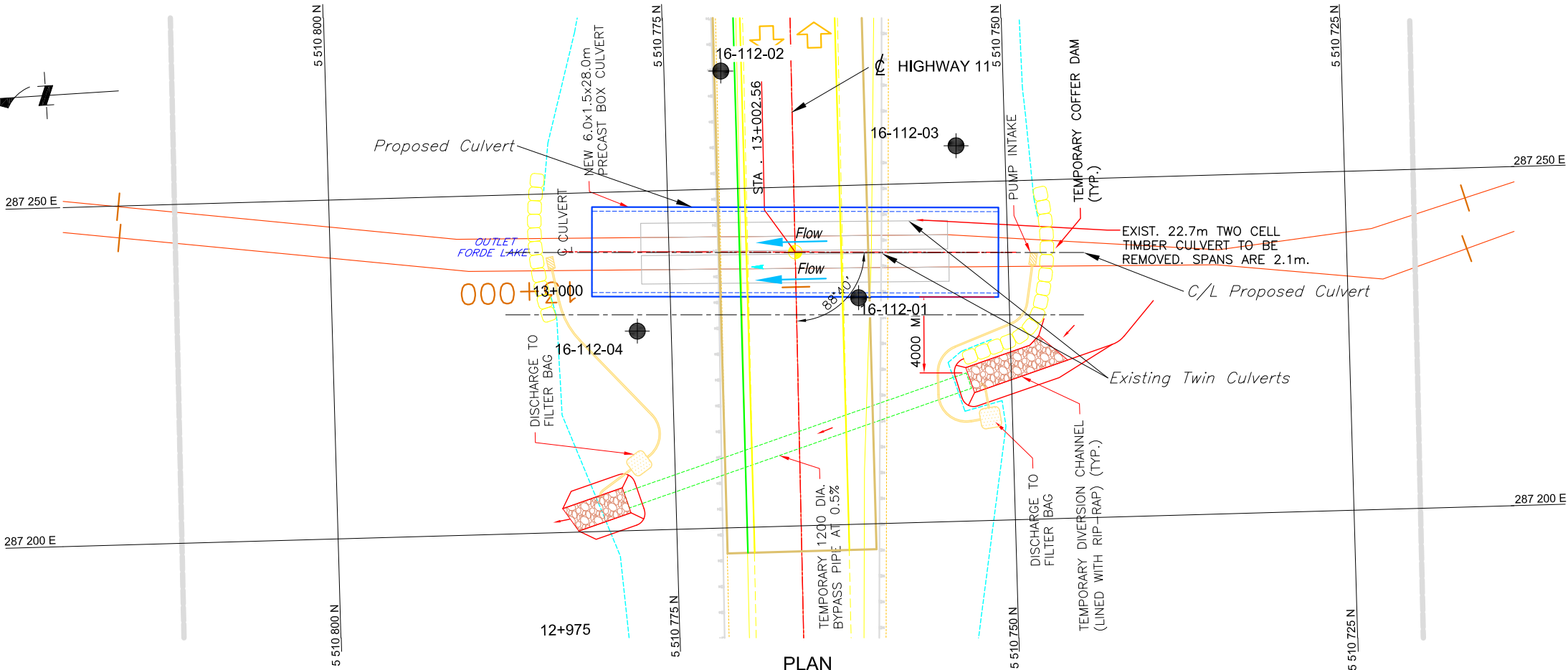


LEGEND			
	Borehole		
	Cone		
	Borehole and Cone		
N	Blows/0.3m (Std. Pen Test, 475 J/blow)		
CONE	Blows/0.3m (60 Cone, 475 J/blow)		
	WL at time of Investigation July 2016		
WH	Penetration due to weight of hammer and rod		
*	Water level not established		
	Head		
	ARTESIAN WATER		
	Encountered		
	PIEZOMETER		
BH No	ELEVATION	NORTHINGS	EASTINGS
16-112-01	257.3	5 510 761.1	287 241.7
16-112-02	257.2	5 510 770.8	287 258.7
16-112-03	255.6	5 510 753.6	287 252.7
16-112-04	255.6	5 510 777.5	287 239.7

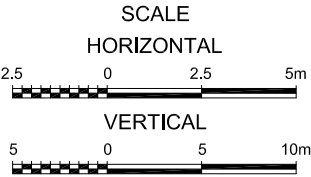
— NOTE —
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

DATE	BY	DESCRIPTION

Geocres No. 42F-57			
HWY No	11	CHECKED	NL
SUBM'D	NA	CHECKED	MY
DRAWN	NA	CHECKED	MY
DATE	MAY 7, 2018	APPROVED	CN
DIST	NEW LISKEARD	SITE	39W-112
DWG	112/C-1		



PROFILE ALONG C PROPOSED CULVERT



NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No 16-112-01

1 of 2

METRIC

G.W.P. 5213-05-00 LOCATION Co-ords: 5 510 761.1 N ; 287 241.7 E ORIGINATED BY K.D.
DIST New Leaskerd BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
DATUM Geodetic HWY 11 DATE August 09, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE						W _p	W	W _L
257.3	Ground Surface						20	40	60	80	100								
0.0	80 mm asphalt over sand and gravel						257												
256.7	(PAVEMENT FILL)																		
0.6	Gravelly sand, some silt																		
	Compact Brown Wet																		
			1	SS	12														
			2	SS	15														
	cobbles																		
	(FILL)		3	SS	10														
253.5	Clayey silt to silt with sand, trace gravel		4	SS	6														
3.8	Very loose Grey Wet to compact moist		5	SS	3														
			6	TW	PH														
			7	SS	15														
			8	SS	11														
			9	SS	23														
			10	SS	24														
			11	SS	26														

Cont'd

RECORD OF BOREHOLE No 16-112-01

2 of 2

METRIC

G.W.P.	5213-05-00	LOCATION	Co-ords: 5 510 761.1 N ; 287 241.7 E	ORIGINATED BY	K.D.
DIST	New Leaskerd	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers	COMPILED BY	N.L.
DATUM	Geodetic HWY 11	DATE	August 09, 2016	CHECKED BY	M.V.

[illegible]

RECORD OF BOREHOLE No 16-112-02



























1 of 1

METRIC

G.W.P.	5213-05-00	LOCATION	Co-ords: 5 510 770.8 N ; 287 258.7 E	ORIGINATED BY	K.D.
--------	------------	----------	--------------------------------------	---------------	------

DIST New Leaskerd BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.

DATUM Geodetic HWY 11 DATE August 09, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa										WATER CONTENT (%)		
							○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL						× LAB VANE		
257.2 0.0	Ground Surface 450 mm Sand and gravel					▽*	257												
256.7 0.5	(PAVEMENT FILL) Gravelly sand, some silt						256												
255.0 2.2	Loose Brown/ Moist grey (FILL)		1	SS	8		255												
	Silt with sand, trace gravel		2	SS	11		254												
	Loose to Grey Moist compact		3	SS	9		253												
			4	SS	14		252												
			5	SS	14		251												
			6	SS	4		250												
			7	SS	10		249												
			8	SS	12		248												
			9	SS	21		247												
	Compact to dense		10	SS	21	246													
						245													
																			
																			
																			
																			
																			
																			
																			
																			
																			
																			
																			
																			
																			

RECORD OF BOREHOLE No 16-112-03

1 of 1

METRIC

G.W.P.	5213-05-00	LOCATION	Co-ords: 5 510 753.6 N ; 287 252.7 E	ORIGINATED BY	K.D.
DIST	New Leaskerd	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers	COMPILED BY	N.L.
DATUM	Geodetic HWY 11	DATE	August 01, 2016	CHECKED BY	M.V.

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT
			NUMBER	TYPE	"N" VALUES
255.6	Ground Surface				
0.0	Organics		1	SS	4
	rootlets		2	SS	10
254.2					
1.4	Sandy silt to silt trace to some clay some sand		3	SS	5
	Loose to Grey Moist compact		4A	SS	6
			4B	SS	
			5	TW	PH
			FV		
			6	SS	13
			7	SS	5
	Compact to dense		8	SS	10
			9	SS	24
			10	SS	27
244.3	End of borehole				
11.3					
*	2016 08 10				
▽	Water level observed during drilling				
PH	Pushed hydraulically				

RECORD OF BOREHOLE No 16-112-04

1 of 1

METRIC

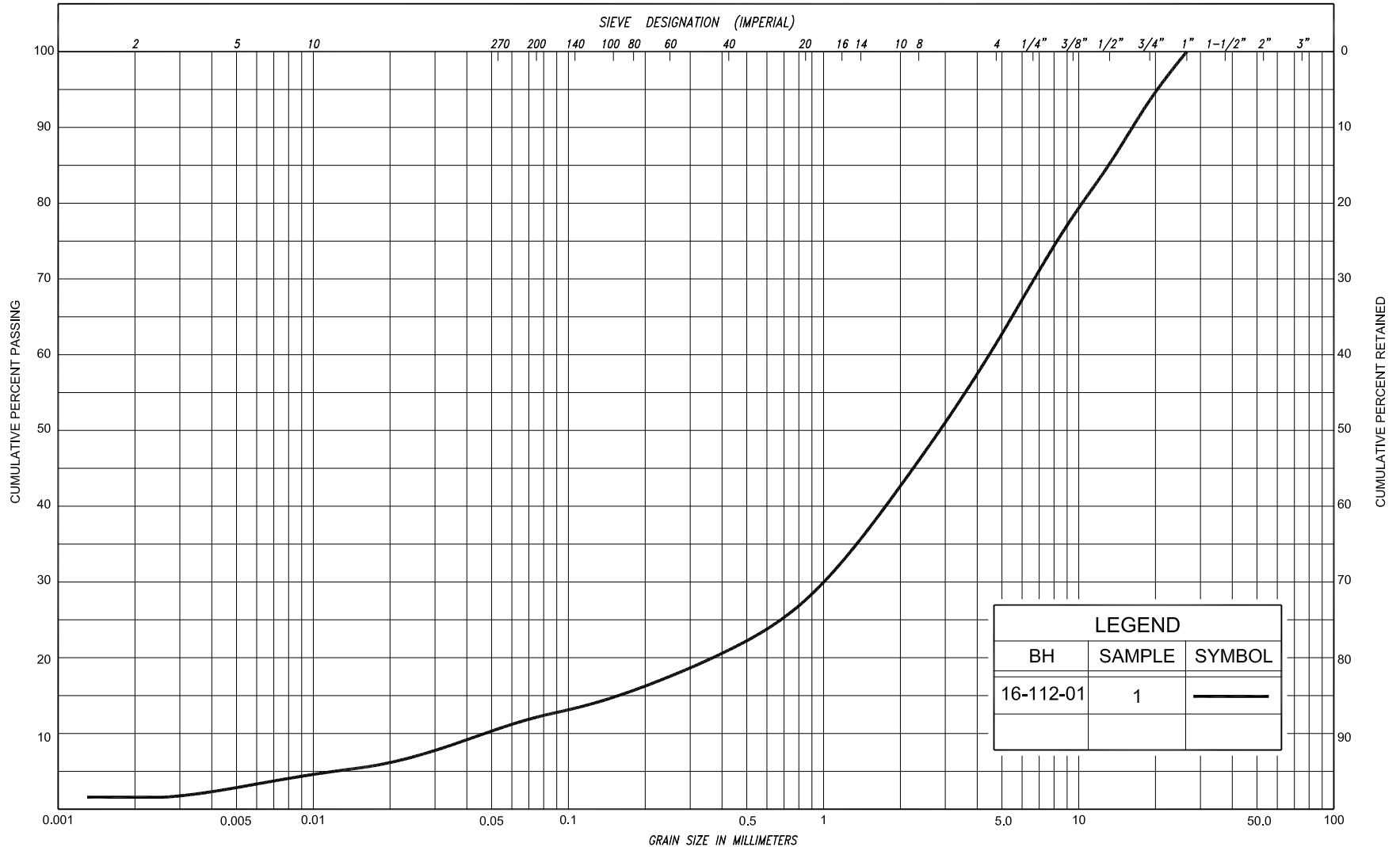
G.W.P. 5213-05-00 LOCATION Co-ords: 5 510 777.5 N ; 287 239.7 E ORIGINATED BY K.D.
DIST New Leaskerd BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
DATUM Geodetic HWY 11 DATE August 09, 2016 CHECKED BY M.V.

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 (%)
255.6	Ground Surface						20	40	60	80	100						
0.0	Organics		1	SS	3												
	rootlets																
			2	SS	56/20cm												
254.2																	
1.4	Clayey silt to silt some sand, some gravel		3	SS	3												
	Loose to compact Grey Moist to wet																
			4	SS	2												
			5	SS	2												
			6	SS	9												
			7	SS	10												
			8	SS	7												

* 2016 08 09

▽ Water level observed during drilling

▼ Water level measured after drilling



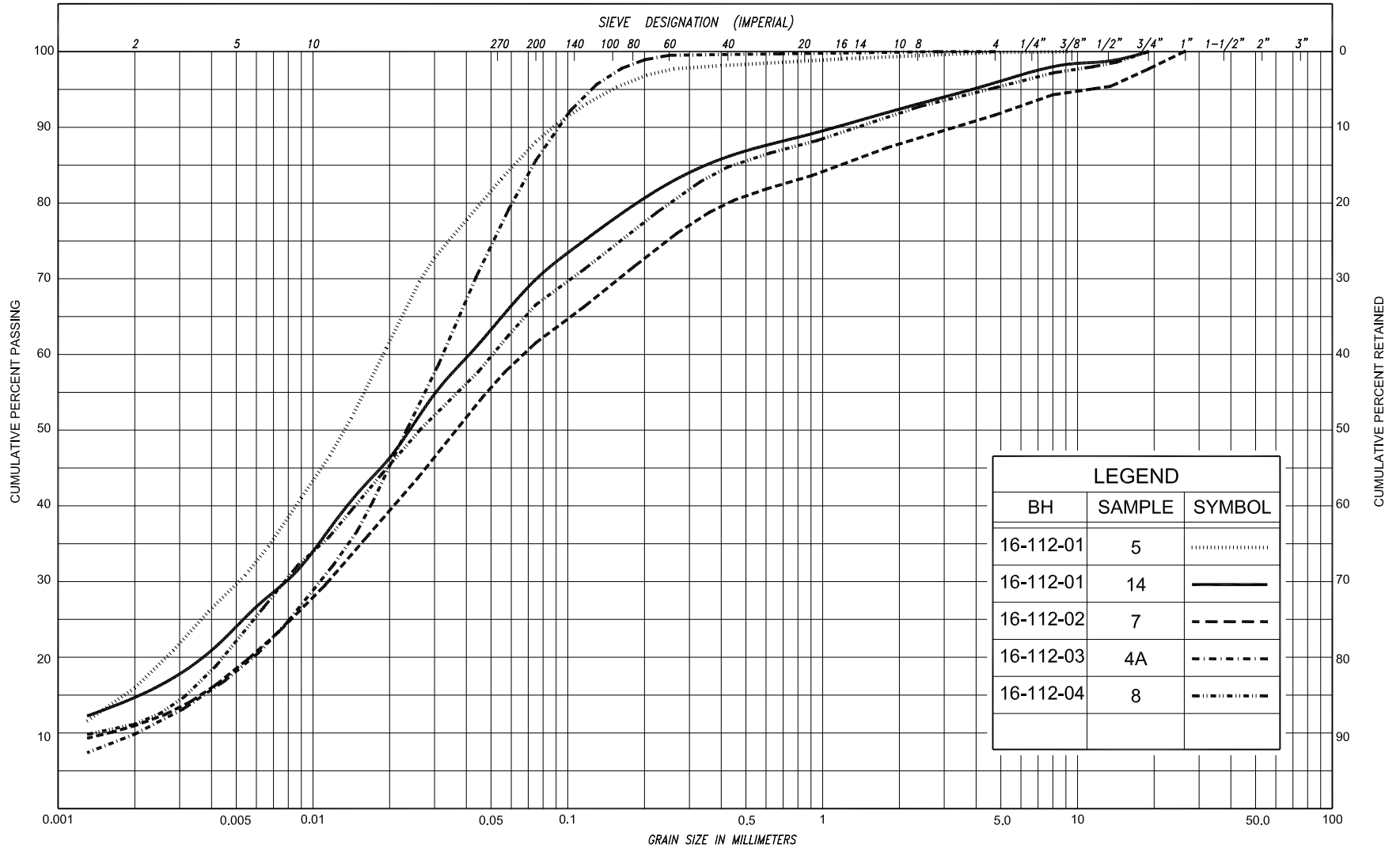
LEGEND		
BH	SAMPLE	SYMBOL
16-112-01	1	—

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



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

FIG No. 112-GS-1
HWY 11
G.W.P. 5213-05-00



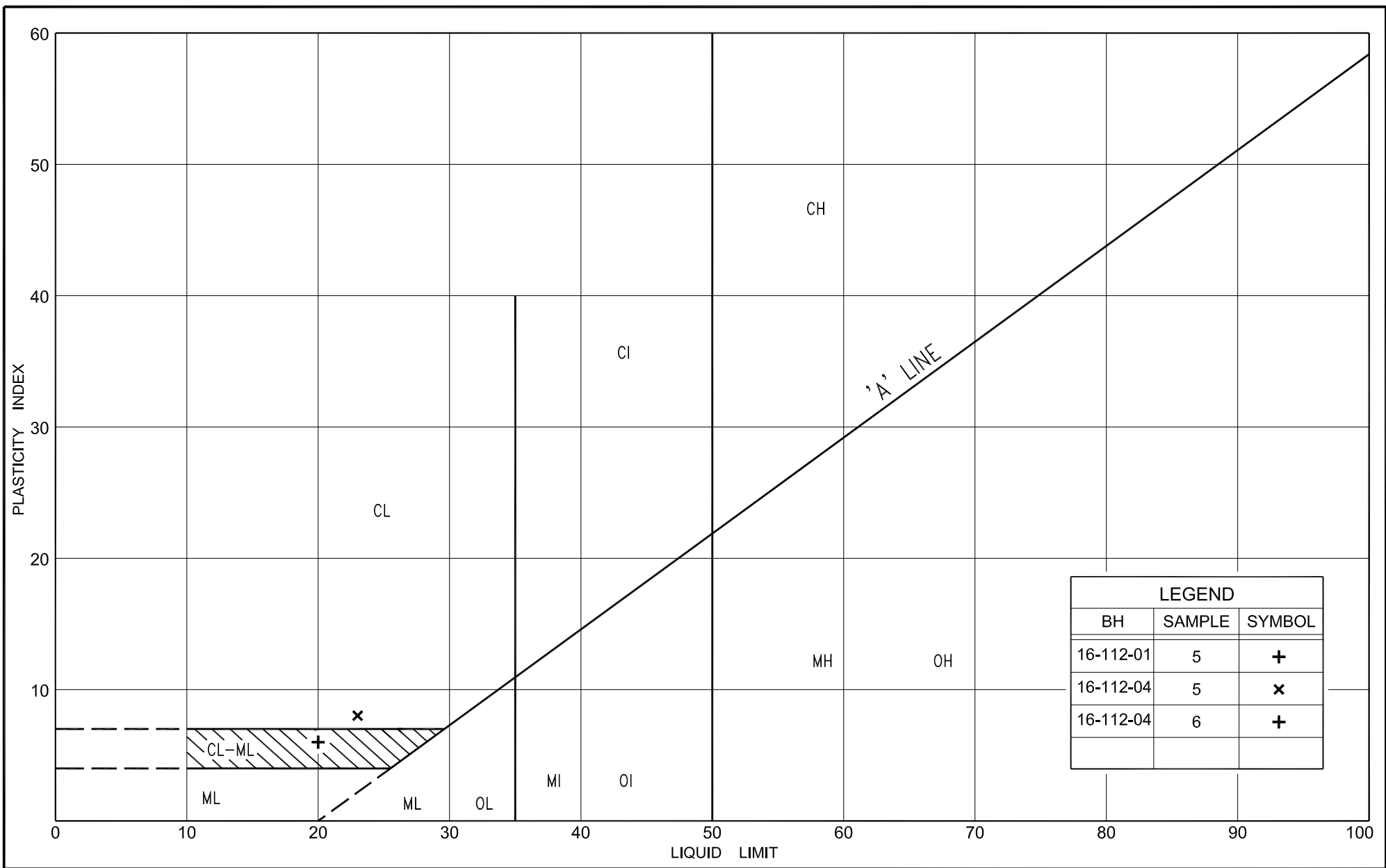
SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL		COBBLES	UNIFIED		
				SAND										
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE	GRAVEL	COBBLES	M.I.T.
	SILT				SAND									
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL					U.S. BUREAU
				SAND										



GRAIN SIZE DISTRIBUTION

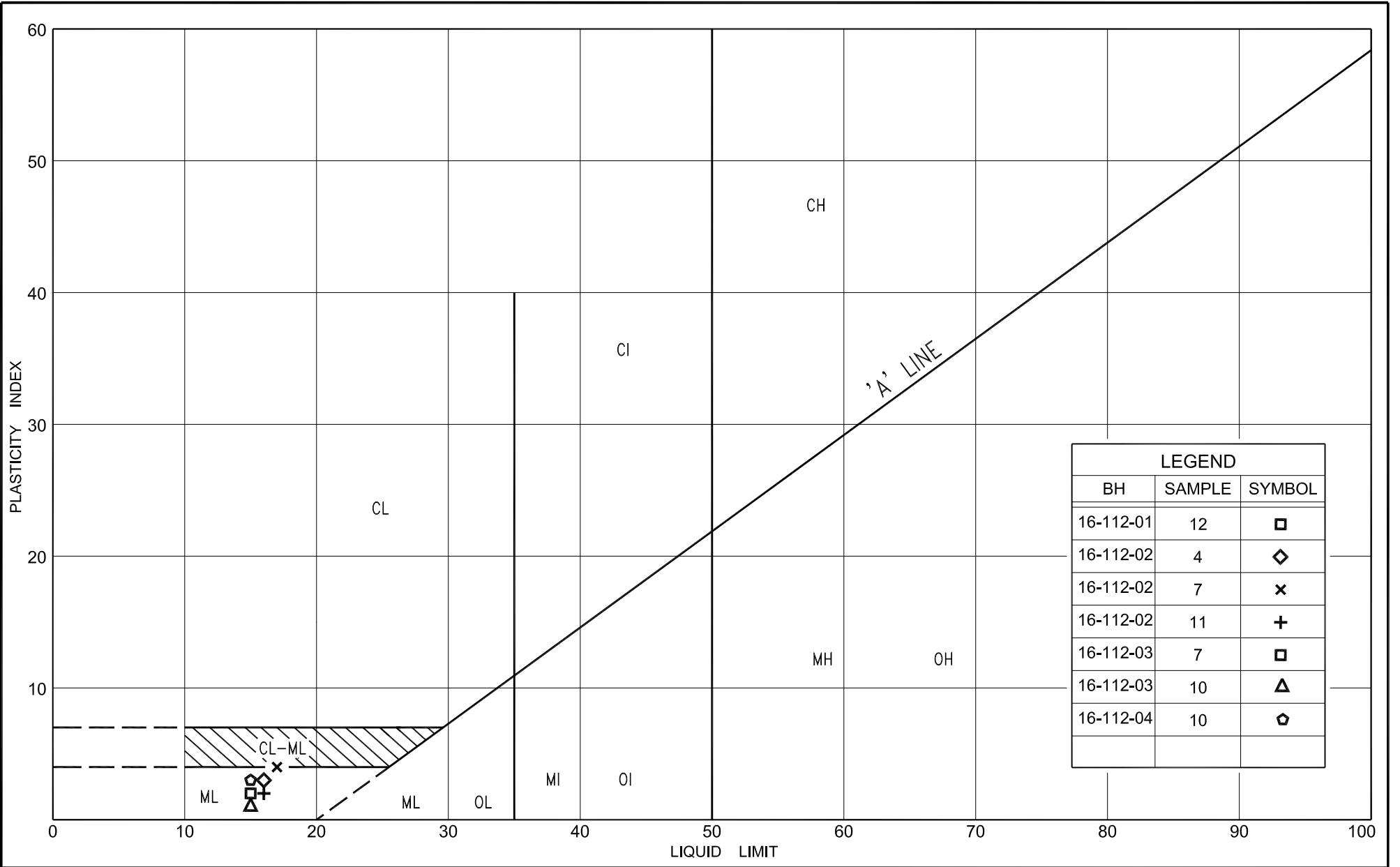
CLAYEY SILT TO SILT, trace to some clay, trace gravel

FIG No. 112-GS-2
 HWY 11
 G.W.P. 5213-05-00



PLASTICITY CHART
CLAYEY SILT (CL-ML)

FIG No. 112-PC-1
HWY 11
G.W.P. 5213-05-00



PLASTICITY CHART
SILT (ML)

FIG No.	112-PC-2
HWY	11
G.W.P.	5213-05-00



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 16T131831

PROJECT: 16TF013A

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: PETO MACCALLUM LIMITED

SAMPLING SITE:

ATTENTION TO: Lul Yimam

SAMPLED BY: Kyle Daly

Corrosivity Package

DATE RECEIVED: 2016-08-29

DATE REPORTED: 2016-09-07

				BH16-004-02	BH16-008-03	BH16-112-04	BH16-131-04	BH16-133-02
SAMPLE DESCRIPTION:				SS7	SS7	SS4A	SS4	SS3
SAMPLE TYPE:				Soil	Soil	Soil	Soil	Soil
DATE SAMPLED:				8/29/2016	8/29/2016	8/29/2016	8/29/2016	8/29/2016
Parameter	Unit	G / S	RDL	7813058	7813065	7813066	7813067	7813068
Chloride (2:1)	µg/g		2	16	7	159	44	559
Sulphate (2:1)	µg/g		2	62	47	43	3	14
pH (2:1)	pH Units		NA	8.44	8.56	8.07	8.61	8.37
Electrical Conductivity (2:1)	mS/cm		0.005	0.216	0.167	0.441	0.179	0.986
Resistivity (2:1)	ohm.cm		1	4630	5990	2270	5590	1010
Redox Potential (2:1)	mV		5	258	249	261	243	254

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

7813058-7813068 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

Certified By:

Amanjot Bhela

Quality Assurance

CLIENT NAME: PETO MACCALLUM LIMITED

PROJECT: 16TF013A

SAMPLING SITE:

AGAT WORK ORDER: 16T131831

ATTENTION TO: Lui Yimam

SAMPLED BY: Kyle Daly

Soil Analysis

RPT Date: Sep 07, 2016			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE		MATRIX SPIKE	
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper

Corrosivity Package

Chloride (2:1)	7813068	7813068	559	551	1.4%	< 2	91%	80%	120%	102%	80%	120%	104%	70%	130%
Sulphate (2:1)	7813068	7813068	14	14	0.0%	< 2	96%	80%	120%	102%	80%	120%	101%	70%	130%
pH (2:1)	7813068	7813068	8.37	8.29	1.0%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7813068	7813068	0.986	0.986	0.0%	< 0.005	100%	90%	110%	NA			NA		
Redox Potential (2:1)	7813068	7813068	254	254	0.0%	< 5	103%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By:





Method Summary

CLIENT NAME: PETO MACCALLUM LIMITED

AGAT WORK ORDER: 16T131831

PROJECT: 16TF013A

ATTENTION TO: Lui Yimam

SAMPLING SITE:

SAMPLED BY: Kyle Daly

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE



PART B – FOUNDATION DESIGN REPORT

for

FORDE LAKE CULVERT REPLACEMENT

SITE NO. 39W-112/C

HIGHWAY 11 – STATION 13+003 – STUDHOLME TOWNSHIP

DISTRICT OF NEW LISKEARD, ONTARIO

ASSIGNMENT NO. 5015-E-0009

GWP 5213-05-00

WP 5213-05-01

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Distribution:

3 cc: GHD for distribution to MTO
Project Manager + 1 digital copy (pdf)
1 cc: GHD for distribution to MTO
Foundations Section + 1 digital copy (pdf)
1 cc: GHD + 1 digital copy (pdf)
1 cc: PML Toronto
1 cc: PML Kitchener

PML Ref.: 16TF013A
Index No.: 163FDR
GEOCRES No.: 42F-57
May 7, 2018



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PART B - FOUNDATION DESIGN REPORT

Forde Lake Culvert Replacement
Site No. 39W-112/C
Highway 11 – Station 13+003
Studholme Township, District of New Liskeard, Ontario
Assignment No. 5015-E-0009, GWP 5213-05-00, WP 5213-05-01

7. INTRODUCTION

This foundation investigation and design report with the interpretation and recommendations are intended for the use of GHD Ltd. on behalf of the ministry of transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A of the report. Where comments are made on construction, they are provided only to highlight those aspects, which could affect the design of the project. Contractors must make their own interpretation of the factual information provided in Part A of the report, as it may affect equipment selection, proposed construction methods and scheduling.

8. PROJECT DESCRIPTION

8.1 General

This report provides foundation design recommendations based on interpretation of the geotechnical data presented in the factual report (Part A) to assist the design team in the selection of a suitable type of foundation for the Forde Lake culvert replacement at the crossing of Highway 11 and the unnamed creek in the Township of Studholme, District of New Liskeard.

The discussions and recommendations presented in this report are based on the information received by PML and the factual data obtained during the geotechnical investigation carried out by PML.

8.2 Existing Culvert

The proposed culvert to be replaced is located at the crossing of the unnamed creek and Highway 11. The existing structure 39W-112/C, is a 22.7 m long twin-cell rectangular timber culvert each with an opening size of 2.1 m in span, 1.2 m in rise, and a fill height of approximately 1.0 m above the deck. The culvert was constructed in 1956 with no record of rehabilitation. Based on the information provided by GHD, the invert of the existing culvert at the inlet and outlet is located at approximate elevation of El. 254.6 and El. 254.7, respectively. The embankment above the creek bed is approximately 4.0 m high.



The Ontario Bridge Management System (OBMS) inspection report dated September 25, 2015, reveals that there were wet areas, light checking and splitting of cells. Signs of distress including shifting of the top timbers (bracings) and crushing of the bottom transvers timber between spans at the outlet were also noted. Further, buildup of sediments at the inlet and outlet, as well as debris at the inlet of the west barrel were also observed.

The foundation details of the existing timber culvert are not available. However, considering the width of the culvert and the fill height above the deck, the load imposed by the exiting culvert at the founding level may not exceed 55 to 65 KN per meter length of the culvert.

8.3 Proposed Culvert

The GA drawing provided on April 27, 2018, and the information provided by GHD on January 19, 2018 indicates that the proposed replacement structure will be a 28 m long precast concrete box culvert, with an opening size of 6.0 m in span, 1.5 m in rise and wall thicknesses of 230 mm to 250 mm. The information provided to PML does not include provision for headwalls or wingwalls for the proposed replacement of the culvert. The proposed invert of the box culvert slopes from about El. 254.33 at the inlet to El. 254.25 at the outlet. The founding level of the subgrade is proposed to be approximately at El. 253.7, allowing for 300 mm thick concrete floor and approximately 300 mm of granular bedding. It is proposed to construct the replacement culvert along the same vertical and horizontal alignment and grade of the road at the culvert location will be maintained at the existing elevation of El. 257.3, which will result in a fill height including the pavement structure of 1.0 m above the box culvert.

It is understood that there is no local detour available to divert the traffic and the construction of the replacement culvert will be carried out in two stages by allowing the traffic to use one side of the highway with the aid of a temporary traffic signal. A properly designed temporary roadway protection along the centerline of the road will be required.

8.4 Structure Foundation

In summary, the subsurface stratigraphy at the proposed culvert generally consist of 500 mm to 570 mm of pavement fill in both boreholes located on the shoulder of the highway and 1.4 m layer of organics at the culvert inlet and outlet. The pavement fill is underlain by 1.7 m to 3.2 m of sandy fill. This fill layer and the organics layer encountered at the culvert inlet and outlet



are followed by a loose to dense silt deposit, which extends to the maximum termination depth of 14.3 m. However, the subsoil below the founding level of El. 253.7 may be classified as compact to dense silt. The groundwater level was observed between El. 255.4 and El. 253.6 during the fieldwork and was measured between El. 254.1 and El. 251.0 upon completion of drilling. The water level in the creek was observed at approximately El. 254.5 during the fieldwork.

The feasibility of the following three options are discussed for replacing the existing culvert along the same vertical and horizontal alignments:

- Replacement with a precast concrete box culvert,
- Replacement with a cast-in-place concrete box culvert, and
- Replacement with an open footing concrete culvert.

Considering the subsoil conditions, the recommendations for the replacement culvert are provided below in the order of preference. A comparison of the technical advantages and disadvantages for the replacement culvert are presented in Table 8.4.1.

8.4.1 Option 1: Precast Concrete Box Culvert

Based on the information provided by GHD, it is assumed that the precast concrete box culvert will be placed at about El. 253.7. The subsoil conditions below elevation El. 253.5 are capable of supporting the box culvert. It is recommended that the bedding for the culvert should be placed no higher than El. 253.5. The option of a precast concrete box culvert will require at least 75 mm of levelling course meeting the requirement of OPSS 422.07.08 and bedding material as specified in OPSS 422.05.13. The bedding for the replacement culvert should be placed in accordance with Section 422.07.07 of OPSS 422.

As required by Clauses 1.9.5.6 and 1.9.11.6.5 of Canadian Highway Bridge Design (CHBDC 2014), cut-off walls at both ends of the culvert shall be provided. Cut-off walls shall be in accordance with OPSD 812.010 or made of precast concrete with similar dimensions to prevent washout of granular bedding. The design of cut-off wall shall meet the requirements of clauses 1.9.5.6 and 1.9.11.6.5 of CHBDC 2014, to protect against scour or undermining.



Table 8.4.1 Comparison of Alternate Culvert Options

Option 1: Precast Concrete Box Culvert	Option 2: Cast In-Place Concrete Box Culvert	Option 3: Three-Sided Precast Open Culvert
Advantages: 1. High degree of quality and uniformity, design flexibility, superior strength and durability 2. Reduced weather dependency during installation 3. Reduced impact on traffic interruption 4. Ease of construction and installation in wet conditions is possible 5. The joints provide flexibility to accommodate differential settlement	Advantages: 1. Reduces uneven settlement 2. Reduces water leakage and deterioration of culvert 3. Ability to withstand differential settlements 4. Longer life span of the structure 5. Degradation of subgrade can be avoided by placing lean concrete	Advantages: 1. High degree of quality and uniformity, design flexibility, superior strength and durability 2. Generally allows for natural streambed to remain intact 3. Less accumulation of sediments in the upstream of channel 4. Reduced weather dependency during installation 6. Ease of construction and installation in wet conditions is possible 7. Adequate geotechnical resistance is available at the founding level
Disadvantages: 1. Natural stream bed will not remain intact 2. Cause sediment accumulation in the upstream of the channel 3. Possibility for degradation of subgrade	Disadvantages: 1. Natural stream bed will not remain intact 2. Cause sediments accumulation in the upstream of the channel 3. Weather dependent during construction 4. Major dewatering scheme is required to construct the floor slab under 1.0 m high water	Disadvantages: 1. Silty soil below the invert level is susceptible to scour 2. Probability of uneven or differential settlements is high 3. Limited ability to withstand differential settlements
Cost of Construction: Total Cost \$ 15,500/m	Cost of Construction: Total Cost \$ 16,500/m	Cost of Construction: Total Cost \$ 16,000/m
Recommended	Technically Feasible but Not Recommended	Technically Not Feasible; Not Recommended

For the design of the proposed twin cell precast concrete box culvert, a geotechnical resistance of 300 kPa at ULS and 200 kPa at SLS shall be utilized. A total settlement of 20 mm under the geotechnical resistance at SLS may be expected and majority of the settlements are expected to takeplace upon completion of construction.



The removal of the existing foundation may cause disturbance to the founding surface of the proposed culvert. In addition, the silt layer at the founding level will be susceptible to disturbance from construction traffic and any ponded water. In order to limit the degradation of the founding soil, it is recommended that the granular bedding be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade.

8.4.2 Option 2: Cast-in-Place Reinforced Concrete Box Culvert

The subsoil conditions below the proposed founding level of the culvert are capable of adequately supporting the cast-in-place concrete box culvert. However, the existing silty soil below the proposed founding surface will require a cut-off wall to prevent scour or washout. Further, construction under 2.0 m of ground water will impose greater difficulties for construction in dry conditions.

If this option is considered, a dewatering scheme shall be used to provide working platform for formwork and placing of concrete. In this case, the footing of box culvert may be placed at about El. 253.7 and designed assuming a geotechnical resistance of 300 kPa at ULS and 200 kPa at SLS. Same as in option 1, the total settlement is not expected to exceed 20 mm and the associated differential settlement will be within about 15 mm.

The removal of the existing foundation may cause disturbance to the founding surface of the proposed culvert. In addition, the silt layer at the founding level will be 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 100 mm thick concrete working slab (lean concrete) to be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. The dewatering to construct the cast-in-place culvert in dry condition may impose greater difficulties. In view of the construction difficulties, this option is not preferred.

8.4.3 Option 3: Three Sided Open Precast Concrete Culvert on Strip Footing

The subsoil conditions below the proposed founding level is capable of providing adequate geotechnical resistance to support the culvert on strip footings. However, compact to dense silty soil encountered below the proposed founding level of the replacement culvert is susceptible for scour. Section C1.9.11.1 of the Canadian Highway Bridge Design Code commentary (CHBDC 2014) suggests avoiding placing open footing on material that is susceptible to scour. Further,



construction under 2.0 m high water level will impose greater difficulties for construction in dry conditions.

In view of the subsoil conditions for potential scour and the difficulty to construct the culvert in dry condition, this option is not recommended.

8.4.4 Recommended Option for Culvert Replacement

From a geotechnical perspective and based on the subsurface conditions, precast concrete box culvert placed at about El. 253.7 is the preferred option for the replacement of the existing culvert.

Options 2 is technically feasible. Option 3 is technically not feasible. However, considering the construction difficulties, cost of dewatering 1.0 m high groundwater and technical reasons, these two options are not recommended.

8.4.5 Lateral Earth Pressure

Earth pressure for the concrete structure should be computed as per the Clause 6.12.2 (b) of Canadian Highway Bridge Design Code (CHBDC, 2014). Sufficient movement of the structure wall may not be permitted for all three options and “at rest” conditions may be assumed for the calculation of earth pressure. The earth pressure calculation should include maximum water level expected in the creek. The lateral earth and water pressure, p (kPa), may be computed using the equivalent fluid pressures presented in Section 6.12 of the CHBDC 2014 or employing the following equation assuming a triangular pressure distribution.



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

- Where, P = lateral earth pressure (kPa)
 K = lateral earth pressure coefficient
 γ = unit weight of backfill material above assumed water level (kN/m³)
 γ' = unit weight of submerged backfill ($\gamma - \gamma_w$) material below assumed water level (kN/m³)
 γ_w = unit weight of water (9.8 kN/m³)
 h_1 = depth below final grade (m), above assumed water level
 h_2 = depth below design water level (m)
 q = surcharge load (kPa)
 C_p = compaction pressure (refer to clause 6.12.3 of CHBDC 2014)
 C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.5 of CHBDC 2014)
- Where \emptyset = angle of internal friction of retained soil (35° for Granular A or 30° for Granular B Type II)
 δ = angle of friction between soil and wall (24° for Granular A or B Type II)

The seismic site coefficient for the conditions at this site is provided in Section 10 of this report. Granular 'A' or 'B' should be utilized as backfill material and should be carried out in accordance with the requirements specified in the OPSS 902. The following parameters are recommended for the granular backfill:

Table 8.4.5 Recommended Geotechnical Parameters

GEOTECHNICAL PARAMETER	GRANULAR 'A'	GRANULAR B TYPE II
Angle of Internal Friction, degrees	35°	30°
Unit Weight, kN/m ³	22.5	21.5
Coefficient of Active Earth Pressure (K_a)	0.27	0.33
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.5
Coefficient of Passive Earth Pressure (K_p)	3.69	3

Backfill shall be placed simultaneously behind both sides of the culvert, maintaining the height of backfill approximately the same. At no time should the difference in backfill elevation from one side to the other be greater than 500 mm.



8.5 Approach Embankment

The height of the existing approach fill is approximately 4.0 m above the creek bed. PML understands that there will be no increase in the profile grade of the road and it will be maintained at El. 257.3. No major instability problems are anticipated for the embankment constructed with 2H:1V side slope. Considering the high water level, the fill should consist of well compacted granular material, preferably Granular B Type II. Any spongy or soft area observed within the base of the embankment should be removed before placing the fill.

Rip-rap should be provided on both, the upstream and downstream sides of the creek to protect the toe of the embankments and to prevent erosion of creek bed in the proximity of the culvert. Rip-rap shall be in accordance with OPSD 810.010 and provided to a minimum height of 1.0 m above the high flood level expected in the creek.

9. FOUNDATION FROST DEPTH

In accordance with OPSD 3090.100, a minimum of 2.6 m earth cover is required to protect against the frost penetration in the area where the site is located.

Frost tapers within the granular backfill should be constructed in accordance with OPSD 3101.150. The frost penetration depth, f , is measured from the top of the grade to the bottom of the footing.

10. SEISMIC CONSIDERATIONS

The reference Peak Ground Acceleration (PGA) for the project site is 0.036 based on the City of Hearst, Ontario (National Building Code of Canada, 2015). The soil below the founding level at this site for seismic design purposes is classified as Type D in accordance with Clause 4.4.3.2, CHBDC 2014.



10.1 Cover and Backfill

Backfill materials shall meet the requirements of Group I, or Group II specified in OPSS 422.05.14, Table 1 and placed according to the procedures described in Section 422.07.11. It shall be placed in layers not exceeding 200 mm in thickness before compaction and compacted in accordance with OPSS 501. Backfill on each side of the box culvert shall be completed simultaneously and at no time, the levels on each side of the culvert exceeds more than 500 mm. Restrictions on compaction near the culvert shall be as specified in OPSS 902.07.06.02.

Cover material shall meet the requirements of OPSS 422.05.14 and placed in accordance with OPSS 422.07.12.

11. CONSTRUCTION CONSIDERATIONS

11.1 Staged Construction

The construction of the culvert replacement is expected to be carried out in two stages. The subsoil conditions encountered at this site is favourable for driving sheet piles to design and construct a shoring system to maintain traffic on Highway 11. A shoring system consisting of sheet pile wall with strutted excavation may be feasible.

Temporary roadway protection shall be designed to meet a Performance Level of 2 and constructed in accordance with OPSS 539 (Temporary Protection Systems). The following soil parameters are recommended for the design of the roadway protection system.

Table 11.1 Soil Parameters

ELEVATION		SOIL TYPE	SOIL PARAMETERS		
FROM	TO		FRICTION ANGLE (ϕ°)	UNIT WEIGHT (γ) kN/m ³	C _u , kN/m ²
256.7	254.8	Silty Sand to Sand Fill	30	20	0
255.0	248.5	Loose to Compact Silt	28	18	0
248.5	243.0	Compact to Dense Silt	30	19	0



11.2 Excavation

Staged construction with a roadway protection system will be required to remove the existing culvert and to install the new culvert while maintaining traffic on Highway 11. Surface water should be diverted away from open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects. The protection system for excavations should be in accordance with OPSS 539, Construction Specification for Temporary Protection Systems, and OPSS 902, Construction Specifications for Excavating and Backfilling–Structures. Excavated material shall not be stockpiled on top of the excavation.

Based on the record of boreholes, the excavations for the construction of replacement culvert will be advanced through existing granular fill material underlain by native silt deposit. For OHSA classification purposes, the fill materials and very loose to very dense silt deposit should be classified as Type 3 soils. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

12. GROUNDWATER CONTROL

The groundwater level was encountered between El. 251.0 and El. 255.4, and the excavation to the founding level will have to be carried out under 1.0 m high water level. The groundwater level should be lowered to a minimum of 0.5 m below the proposed founding level to allow for construction in the dry and to place bedding materials.

For construction in the dry, the creek may have to be temporarily diverted and a cofferdam may be required due to the relatively pervious nature of the subsoil. A cofferdam consisting of sheet piles may be feasible for excavation and dewatering at this site. Alternatively, cofferdam consisting of sand bags and clay puddle may be constructed by damming the upstream and downstream of the culvert. Dewatering may be carried out from the sumps located along the periphery of the cofferdam. If any environmental restrictions are imposed on placing clay puddle in the lake, the culvert replacement may have to be constructed under the prevailing water level. If the construction is carried out under water, the backfill material shall consist of Granular B Type II containing particle sizes not finer than 75 µm. However, Granular B Type II may be used if the construction is carried out in-the-dry, and the replacement fill should be placed in layers not



exceeding 200 mm in thickness before compaction and compacted in accordance with OPSS 501.

13. TEMPORARY WORKS

The contractor shall be responsible for the selection, performance and detailed design of the shoring and dewatering system including the cofferdam. The dewatering system should be designed to conform to the requirement of OPSS 517 (Construction Specification for Dewatering) in addition to the NSSP provided in Appendix C.

14. SOIL CORROSION

One sample from the silt layer was tested for soil corrosivity and potential exposure of concrete to sulphate attack. A summary of the chemical test results are provided in Table 5.2.6 of Part A of this report. The sulphate concentration of 43 µg/g (0.0043%) reported in Table 5.2.6 for the silt soil is far too low compared to the value of 0.1% suggested in Canadian Standard A23.1-14 to have any effect on buried concrete structures. Therefore, potential for sulphate attack will be mild or relatively low. The chloride content of 159 ppm or 0.0159% (159 µg/g) reported in Table 5.2.6 is marginally lower than the concentration value of 250 ppm (0.025%) that generally leads to corrosive environment for buried metals. Potential for corrosive environment at this site is low.

Electrical resistivity less than 2000 ohm-cm generally leads to highly corrosive environment for steel elements in contact with soil. The resistivity value of 2270 ohm-cm reported is slightly higher than 2000 and suggests a corrosive environment at this site for steel elements. However, pH value of 8.07 reported is slightly higher than the value of 5.5 that generally leads to corrosion.

Generally, no sulphate attack is expected from selected backfill materials. However, it may be advisable to test backfill material for corrosion potential if the material is imported from unknown sources.



15. CLOSURE

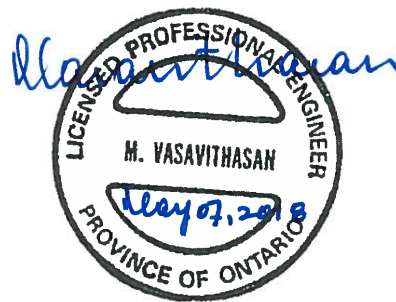
This Foundation Investigation and Design Report was prepared by Ms. Natasha Leong-Sem, B.Eng., EIT., Geotechnical Services, and reviewed by Mark Vasavithasan, MSc.Eng., P.Eng. Senior Engineer, Geotechnical Services. Mr. C.M.P. Nascimento, P.Eng., Principal Consultant, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in blue ink, reading 'Natasha Leong-Sem', is positioned above the name of the preparer.

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APPENDIX C

List of Standard Specifications Relevant to Report
Non-Standard Special Provisions (NSSP)



LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

DOCUMENT	TITLE
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 517	Construction Specification for Dewatering
OPSS 539	Temporary Protection Systems
OPSS 902	Excavation and Backfilling of Structures
OPSD 810.010	General Rip-Rap Layout Sewer and Culvert Outlets
OPSD 812.010	Cut Off Wall for Structural Plate Pipe Arch and Circular CSP
OPSD 3090.100	Foundation, Frost Penetration depths for Southern Ontario
OPSD 3101.150	Walls, Abutment, Backfill, Minimum Granular Requirement



NON-STANDARD SPECIAL PROVISIONS (NSSP)

NSSP 1 – Surface Water Control and Dewatering (Addition to OPSS 517 and NSSP FOUN0003)

The Contractor shall take necessary measures for diversion of surface water and drainage, and to lower the prevailing groundwater level to a minimum of 0.5 m below the base of the excavations to allow for construction work within the overburden or on the surface of bedrock in-the-dry, whichever is applicable.

The fill material encountered at this site is relatively pervious in nature. The Contractor shall be responsible for designing and implementing measures for surface water control and dewatering. The dewatering design and the implementation shall prevent unsafe conditions, such as sloughing, base heave, or boiling under unbalanced hydrostatic conditions. Contractor is also advised that damming of the creek and diversion of the flow by pumping through temporary conduits for staging of construction will likely be required at this site.