



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

STUDHOLME CREEK CULVERT REPLACEMENT

SITE NO. 39W-132/C

HIGHWAY 11 – STATION 20+617

STUDHOLME TOWNSHIP, DISTRICT OF NEW LISKEARD, ONTARIO

ASSIGNMENT NO. 5015-E-0009

GWP 5213-05-00

WP 5224-13-01

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PML Ref.: 16TF013A
Index No.: 166FIR and 167FDR
GEOCRES No.: 42F-56
December 12, 2018



PART A - FOUNDATION INVESTIGATION REPORT

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PART A - FOUNDATION INVESTIGATION REPORT

Studholme Creek Culvert Replacement
Site No. 39W-132/C
Highway 11 – Station 20+617
Studholme Township, District of New Liskeard, Ontario
Assignment No. 5015-E-0009, GWP 5213-05-00, WP 5224-13-01

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-132/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 Studholme Creek and Highway 11 (Sta. 20+617). Studholme Creek culvert, County Site Number 39W-132/C, is located 1.1 km west of the intersection of Highway 11 and Highway 663, 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 north to south, almost perpendicular to Highway 11. Studholme Creek flows from Studholme Lake, meanders downstream and discharges into Kabinakagami River, approximately 1.5 km 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 3.5 m high above the creek bed.



Based on the General Arrangement (GA) drawing and information provided by GHD on April 27, 2018, the existing structure is a 22.7 m long twin-cell timber culvert, each cell with an opening size of 2.1 m in span and 1.4 m high, and a fill height of 2.0 m above the deck. This culvert was constructed in 1942 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 on the soffit, and light weathering and minor to moderate checks and splits of cells on the east and west barrels. Signs of deterioration include moderate corrosion of bolts and connections, and one missing timber member at the north side of the culvert. Further, narrow crack was observed along the centerline of the roadway.

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

3. FIELD INVESTIGATION PROCEDURES

The field work for the foundation investigation involved advancing four (4) boreholes. The boreholes were drilled to depths ranging from 11.0 m to 12.4 m below the existing ground surface (El. 245.6 to El. 244.1), and were terminated in competent soils.

The staff of PML visited the site on August 10, 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 16-132-01, 16-132-02, 16-132-03 and 16-132-04 were drilled between August 11 and 20, 2016. The boreholes were advanced using a CME 55 track-mounted drilling rig equipped with 200 mm diameter hollow stem augers.

Boreholes 16-132-01 and 16-132-02 were drilled on the gravel shoulders of Highway 11. Boreholes 16-132-03 and 16-132-04 were drilled at the outlet and inlet of the culvert, respectively. The borehole locations are shown on the attached Drawing 132/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. In addition, in-situ vane shear test was carried out using N-size (MTO) vane to measure the undrained shear strength of clayey soils.

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 El. 243.3 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 our laboratory for detailed visual examination, and index tests.



4. LABORATORY TEST PROCEDURES

4.1 Soil Testing

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 (36)
- Grain size distribution analysis (10)
- Atterberg limit analysis (8)
- Specific gravity of soil (1)
- One-dimensional consolidation test (1)
- Unconsolidated undrained test (1)

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 specific gravity (LS-705) and hydrometer test (LS-702). Unconsolidated undrained (ASTM D 2850) and one-dimensional consolidation (ASTM D 2435) tests on thin-walled tube (Shelby tube) sample were performed in accordance with ASTM test procedures. The results of the grain size distribution analyses are presented in Figures 132-GS-1 to 132-GS-4. The results of the Atterberg Limit tests are represented in Figures 132-PC-1 and 132-PC-2. Consolidation test results are presented on Figure 132-C-1. All of the test results are summarized on the attached Record of Borehole Logs in Appendix B.

4.2 Chemical Analysis

One soil sample from the clayey 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 corrosivity effects. Test results are presented in Table 5.2.8.



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 sub-surface conditions in the area of the culvert site consist of glaciolacustrine 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 132/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 granular base ranging in thickness from 300 mm to 800 mm below the Highway 11 shoulders. The granular base on the highway shoulders is immediately underlain by 3.0 m to 3.6 m of sand fill with varying proportions of gravel and silt. A 1.8 m to 2.2 m thick layer of organic silt (alluvium) was encountered immediately below the ground surface near the culvert outlet and inlet. The organic silt (alluvium) layer, and sandy fill layer are immediately underlain by 3.1 m to 4.9 m thick soft to firm clayey silt deposit. The clayey silt deposit in boreholes (Boreholes 16-132-01 and 16-132-04) located on the west side of the culvert is immediately underlain by 1.4 m thick sandy deposit. The clayey silt deposit and sand deposit are followed by very dense silt with varying proportions of gravel, sand and clay (till). This till deposit extends to the maximum depth of investigation of 12.4 m below the grade of highway shoulders. For classification purposes, the soil encountered at this site can be divided into six distinct zones:

- a) Sand and Gravel (Granular Base)
- b) Sand, Some Gravel, Trace Silt (Fill)



- c) Organic Silt (Alluvium)
- d) Clayey Silt, Trace Sand
- e) Sand
- f) Silt, With Sand, Some Clay, Trace Gravel (Till)

5.2.1 Sand and Gravel (Granular Base)

The granular base was encountered in Boreholes 16-132-01 and 16-132-02, immediately below the ground surface of the highway shoulder. The thickness of this granular base varies from 300 mm to 800 mm. The asphalt pavement on Highway 11 was not sampled. For details, refer to the pavement design report.

5.2.2 Sand, Some Gravel, Trace Silt (Fill)

The sand fill with varying proportions of gravel and silt was encountered in Boreholes 16-132-01 and 16-132-02, immediately below the granular base on the highway shoulders. The thickness of this sandy fill layer varies from 3.0 m to 3.6 m and extends to a maximum depth of 4.4 m (El. 241.2) below the existing grade. The fill below El. 241.8 in Borehole 16-132-02 is mixed with wood pieces. The SPT N-values in this fill layer range widely from as low as 2 blows to 31 blows, indicating a very loose to dense state of compaction.

The moisture content of this fill material varies from 2.1% to 11%, with an average value of 4.3%. The results of the grain size distribution analysis performed on a representative sample of the sand fill are shown on Figure 132-GS-1. The test results revealed that this fill layer consists of 13% gravel, 80% sand, and 7% passing 75 µm sieve (silt and clay).

5.2.3 Organic Silt (Alluvium)

A 1.8 m to 2.2 m thick layer of organic silt (alluvium) was encountered immediately below the ground surface in Boreholes 16-132-03 and 16-132-04 located near the outlet and inlet, respectively. The SPT N-values in this deposit range from 2 blows to 4 blows, indicating a soft consistency. The moisture content of this deposit varies widely from as low as 15.8% to as high as 263.0% depending on the organic contents.



5.2.4 Clayey Silt, Trace Sand

The organic silt (alluvium) deposit in Boreholes 16-132-03 and 16-132-04, and the sandy fill layer in Boreholes 16-132-01 and 16-132-02 are immediately underlain by this clayey silt deposit, which extends to a maximum depth of 7.1 m (El. 237.1) below the ground surface, near the culvert inlet. The SPT N-values in this layer range from none (penetration under the weight of the hammer and rods) to 2 blows, indicating a very soft consistency. However, the in-situ vane shear test results range from 16 kPa to 59 kPa, indicating soft to firm consistency.

The moisture content samples tested from this layer varies from 22.1% to 56.1%, with an average value of 33.2%. The results of the grain size distribution analysis performed on four (4) representative samples from this deposit are provided on Figure 132-GS-2. The test results indicate that this deposit, with the exception of Sample SS 9 from Borehole 16-132-04, consists of 0% to 1% gravel, 3% to 9% sand, 57% to 69% silt and 27% to 38% clay. However, Sample SS9 from Borehole 16-132-04 indicated higher gravel (10%) and sand (24%) contents compared to other samples from this layer. Atterberg limits tests performed on four (4) representative samples from this deposit are provided on Figure 132-PC-1. The test results indicate liquid limit values ranging from 27 to 34, plastic limit values ranging from 14 to 17, and plasticity index values calculated range from 13 to 17. Based on the results of Atterberg limit tests, the soil may be classified as clayey silt of low plasticity (CL) in the Unified Soil Classification System (USCS).

Unconsolidated undrained (UU) and one-dimensional consolidation tests were performed on a thin-walled tube (Shelby tube) sample obtained at a depth of 3.3 m below the ground surface. Unconsolidated undrained test was conducted with a confining (cell) pressure of 50 kPa and the test result indicated an undrained shear strength (C_u) value of 15.2 kPa. The result of the consolidation test conducted to determine the compressibility characteristics of the clayey silt is given on Figure 132-C-1, in Appendix B. The test result indicated a pre-consolidation pressure of 45 kPa compared to the effective overburden pressure of about 40 kPa. The computed initial void ratio (e_o) was 1.45 and the compression index (C_c) was 0.45.



5.2.5 Sand

The clayey silt deposit in Boreholes 16-132-01 and 16-132-04 is underlain by 1.4 m thick sand deposit at a depth of about 7.1 m to 7.2 m and extends to El. 236.9 to El. 235.7. The SPT values vary from as low as 3 blows/300 mm to refusal (50 blows/130 mm). The moisture content was determined from both samples and was found to be 10% and 9.8%. Grain size analysis was performed on one of the two samples retrieved from this deposit and the results are presented on Figure 132-GS-3. This sandy deposit consists of 1% gravel, 97% sand and 2% silt.

5.2.6 Silt, with Sand, Some Clay, Trace Gravel (Till)

The clayey silt and sandy deposits are underlain by a silt deposit with varying proportions of sand and gravel (till). This till deposit extends to the maximum termination depth of 12.4 m below the grade of highway shoulder and to El. 231.9. The SPT N-values in this this till deposit, with the exception of Sample SS 8 in Borehole 16-132-02, range from 68 blows to over 100 blows (refusal), indicating a very dense state of compaction.

The moisture content of samples tested from this till deposit varies from 7.8% to 19.9%, with an average value of 12.0%. The results of the grain size distribution analysis performed on four (4) representative samples from the till deposit are provided on Figure 132-GS-4. The test results indicate that this till deposit consists of 4% to 15% gravel, 14% to 32% sand, 47% to 66% silt and 10% to 14% clay. Atterberg limits tests performed on four (4) representative samples from this deposit are provided on Figure 132-PC-2. The test results indicate liquid limit values ranging from 16 to 23, plastic limit ranging from 12 to 15, and plasticity index computed range from 3 to 10. Based on the results of Atterberg limit tests, the soil may be classified as silts of low plasticity (ML) in the Unified Soil Classification System (USCS).

5.2.7 Groundwater

The groundwater level during drilling was observed between 1.5 m and 4.0 m (El. 243.2 and El. 240.1) below the ground surface.

The water level in the creek was observed at approximately El. 243.2 during the fieldwork for the investigation.



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

5.2.8 Chemical Analysis

A summary of the chemical test results provided by AGAT Laboratories are presented in Table 5.2.8 below. The detail test results provided by AGAT Laboratories are also presented in Appendix B.

Table 5.2.8 Soil Chemical Analysis Results

BOREHOLE	SAMPLE	DEPTH / ELEVATION (m)	SOIL TYPE	SULPHATE (µg/g)	CHLORIDE (µg/g)	pH	RESISTIVITY (Ohm-cm)
16-132-02	SS-7	6.9 – 7.3 / 238.7 – 238.3	Clayey Silt to Silt	44	16	8.14	5520



6. CLOSURE

Mr. F. Portela and 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. N. 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.

A handwritten signature in black ink, reading 'Natasha Leong-Sem', is positioned above the nameplate for Natasha Leong-Sem.

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NL/MK/CN:nl-nk



APPENDIX A

Site Photographs



Photograph A1: Looking east on Highway 11 eastbound lane shoulder. Borehole 16-132-01 was drilled on the eastbound lane shoulder (July 26, 2016).



Photograph A2: Looking east on Highway 11 westbound lane shoulder. Borehole 16-132-02 was drilled on the westbound lane shoulder (July 26, 2016).



Photograph A3: Looking southwest from Studholme Creek culvert inlet. Borehole 16-132-03 was drilled southeast from the end of the culvert inlet (August 26, 2016).



Photograph A4: Looking east from the Studholme Creek culvert outlet. Borehole 16-132-04 was drilled northwest from the end of the culvert outlet. (August 26, 2016).



APPENDIX B

Borehole Location Plan and Soil Strata at Structure Drawing 132/C-1

Explanation of Terms Used in Report

Record of Borehole Sheets

Results of Grain Size Distribution Analyses – Figures 132-GS-1 to 132-GS-4

Results of Atterberg Limit Tests – Figures 132-PC-1 and 132-PC-2

Results of Consolidation Tests – Figure 132-C-1

Results of Chemical Tests Provided by AGAT Laboratories

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 16-132-01

1 of 1

METRIC

G.W.P. 5213-05-00 LOCATION Co-ords: 5 511 966.8 N ; 294 571.7 E ORIGINATED BY F.P.
DIST New Leaskerd BOREHOLE TYPE Hollow Stem Augers and Wash Borings COMPILED BY N.L.
DATUM Geodetic HWY 11 DATE August 19, 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									
								20 40 60 80 100									
								20 40 60 80 100									
245.5	Ground Surface																
0.0	Sand and gravel																
245.2	(GRANULAR BASE)																
0.3	Sand some gravel, trace silt																
	Compact Brown Wet to loose																
	(FILL)																
			1	SS	13											13 80 (7)	
			2	SS	5												
242.2			3A	SS													
3.3	Clayey silt, trace sand organics to a depth of 3.7 m		3B	SS	4										263		
	Soft Grey Wet		4	SS	WH											0 9 64 27	
			5	TW	PH												
				FV													
			6	SS	WH												
			7	SS	WH												
238.3																	
7.2	Sand																
	Very loose Grey Wet		8	SS	3												
236.9																	
8.6	Silt, with sand some clay, trace gravel																
	Very dense Grey Wet		9	SS	103/28cm											4 32 51 13	
	(TILL)																
			10	SS	100/15cm												
233.1			11	SS	50/5cm												
12.4	End of borehole																
	* 2016 08 19																
	▽ Water level observed during drilling																
	WH denotes penetration due to weight of rods and hammer																
	PH Pushed hydraulically																

RECORD OF BOREHOLE No 16-132-02

1 of 1

METRIC

G.W.P. 5213-05-00 LOCATION Co-ords: 5 511 975.8 N ; 294 589.4 E ORIGINATED BY F.P.
DIST New Leaskerd BOREHOLE TYPE Hollow Stem Augers and Wash Borings COMPILED BY N.L.
DATUM Geodetic HWY 11 DATE August 19, 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									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
							WATER CONTENT (%)										
245.6	Ground Surface							20	40	60	80	100					
0.0	Sand and gravel						245										
	(GRANULAR BASE)																
244.8	Sand, some gravel																
0.8	Dense to compact Brown/ grey Wet		1	SS	31								○				
	(FILL)					▽*											
			2	SS	11								○				
	Silty sand, wood pieces		3	SS	2									○			
241.2	Clayey silt, trace sand						241							○			
4.4	Soft Grey Wet		4	SS	1									○			
			5	SS	WH		240							○			0 3 69 28
			6	TW	PH												
				FV			239			1							
			7	TW	PH												
				FV													
238.1	Silt, with sand some clay, trace gravel		8	SS	6		238			3				○			
7.5	Loose to very dense Grey Wet to moist						237										
	(TILL)		9	SS	50/10cm		236										
							235							○ H			9 14 66 14
			10	SS	52/8cm		234										
233.3	End of borehole		11	SS	50/10cm												
12.3																	
	* 2016 08 19																
	▽ Water level observed during drilling																
	WH denotes penetration due to weight of rods and hammer																
	PH Pushed hydraulically																

RECORD OF BOREHOLE No 16-132-03

1 of 1

METRIC

G.W.P. 5213-05-00 LOCATION Co-ords: 5 511 959.1 N ; 294 582.2 E ORIGINATED BY K.D.
DIST New Leaskerd BOREHOLE TYPE C.F.H.S.A., NW Casing and Wash Boring COMPILED BY N.L.
DATUM Geodetic HWY 11 DATE August 11, 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											
								○ UNCONFINED + FIELD VANE											
								● QUICK TRIAXIAL × LAB VANE											
					WATER CONTENT (%)														
					20 40 60 80 100					20 40 60									
244.1	Ground Surface						244												
0.0	Organic silt wood pieces, rootlets		1	SS	4														
	Soft Brown/ Moist																		
	black to wet																		
	(ALLUVIUM)		2	SS	2		243									109			
242.3			3	SS	2														
1.8	Clayey silt, trace sand						242												
	Soft Grey Moist																		
			4	SS	1														
	Sand seam						241												
			5	SS	1		240												
			6	TW	PH		239												
				FV			238												
237.4																			
6.7	Silt, with sand some clay, some gravel		7	SS	100/20cm		237												
	Very dense Grey Moist																		
			8	SS	100/18cm		236												
	(TILL)																		
			9	SS	68		235												
							234												
233.1			10	SS	100/25cm														
11.0	End of borehole																		

RECORD OF BOREHOLE No 16-132-04

1 of 1

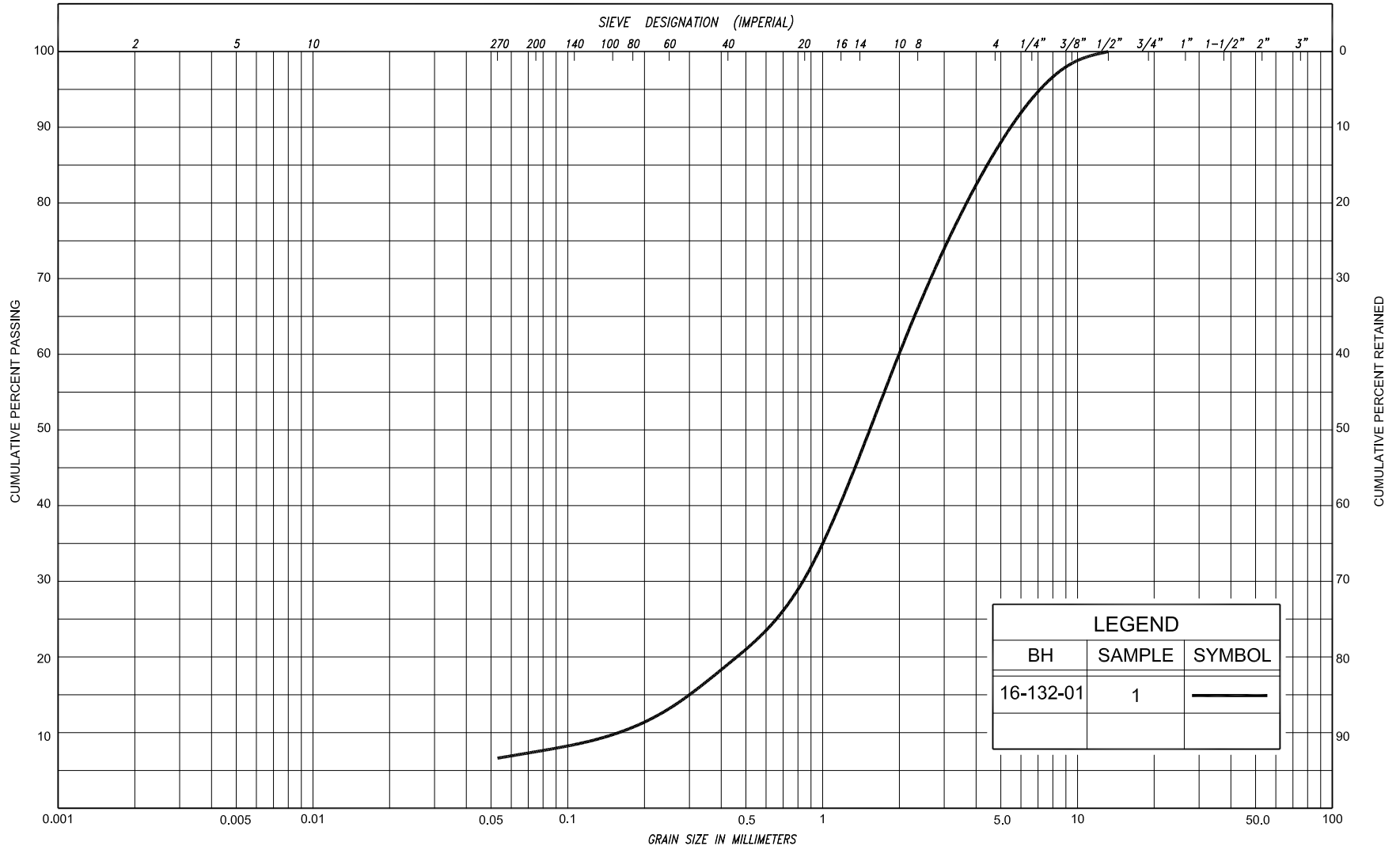
METRIC

G.W.P.	5213-05-00	LOCATION	Co-ords: 5 511 982.0 N ; 294 570.8 E	ORIGINATED BY	F.P.
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DIST New Leaskerd BOREHOLE TYPE Hollow Stem Augers and Wash Borings COMPILED BY N.L.

DATUM Geodetic HWY 11 DATE August 20, 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/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											
○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)												
244.2	Ground Surface																
0.0	Organic silt																
	Soft Dark brown Moist to wet		1	SS	4												
			2	SS	4												
	(ALLUVIUM)																
			3	SS	2										128		
242.0																	
2.2	Clayey silt trace sand, trace gravel		4	SS	WH												
	Soft Grey Wet to moist																
			5	TW	PH												
				FV													
			6	SS	2												
			7	SS	WH												
			8	SS	WH												
	with sand		9	SS	WH												
237.1																	
7.1	Sand																
	Very dense Grey Wet		10	SS	50/13cm												
235.7																	
8.5	Silt, with sand, some clay, trace gravel																
	Very dense Grey Moist		11	SS	81												
	(TILL)																
			12	SS	50/8cm												
	cobbles																
231.9			13	SS	100/13cm												
12.3	End of borehole																
	* 2016 08 19																
	▽ Water level observed during drilling																
	WH Denotes penetration due to weight of rods and hammer																
	PH Pushed hydraulically																



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

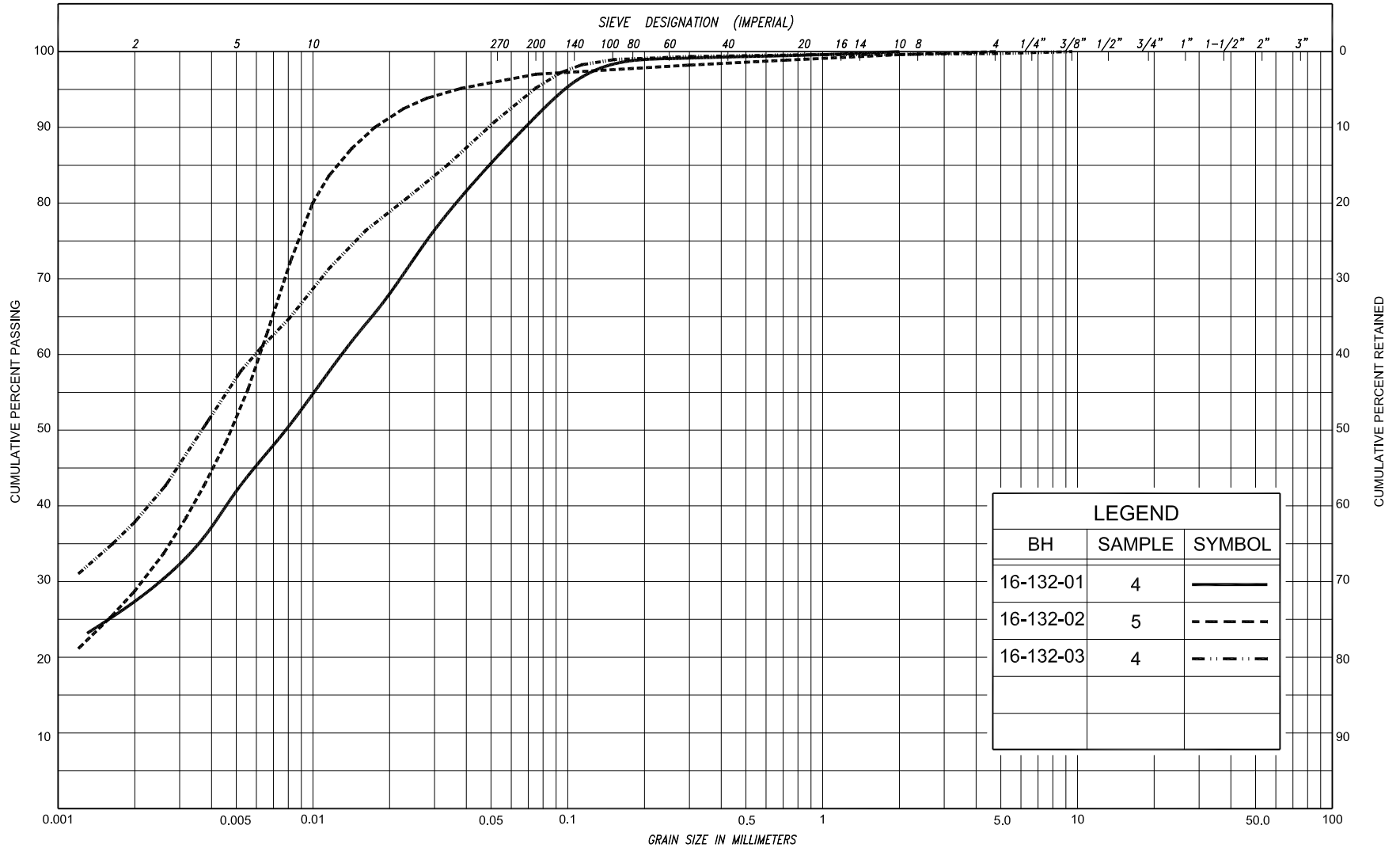


GRAIN SIZE DISTRIBUTION SAND, some gravel, trace silt (FILL)

FIG No. 132-GS-1

HWY 11

G.W.P. 5213-05-00



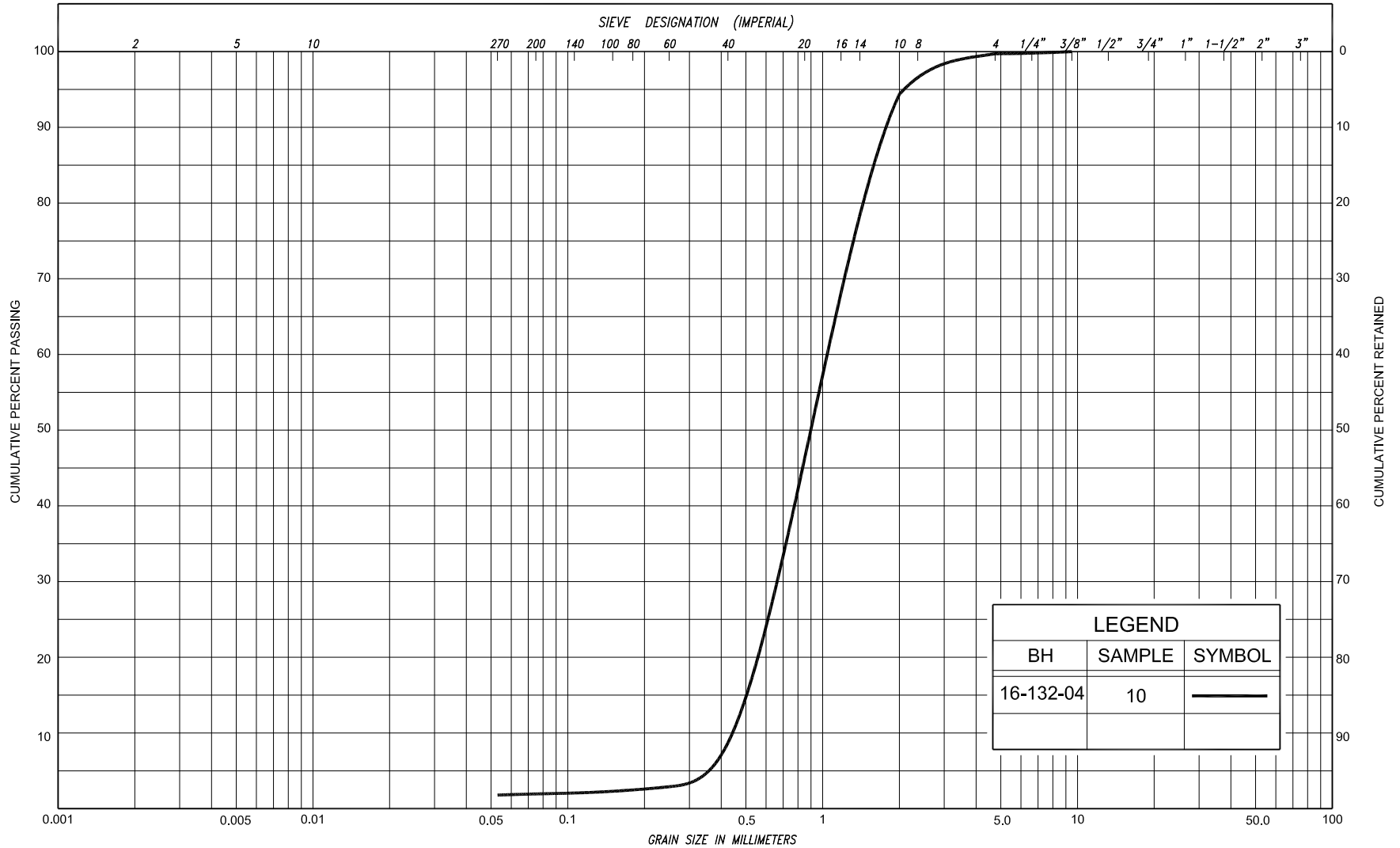
SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL		COBBLES	UNIFIED				
				SAND						GRAVEL		COBBLES	M.I.T.			
CLAY	FINE		MEDIUM	COARSE	FINE		MEDIUM	COARSE								
	SILT				SAND											
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL						U.S. BUREAU		
				SAND												



GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand

FIG No. 132-GS-2
 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														
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL					U.S. BUREAU
				SAND											

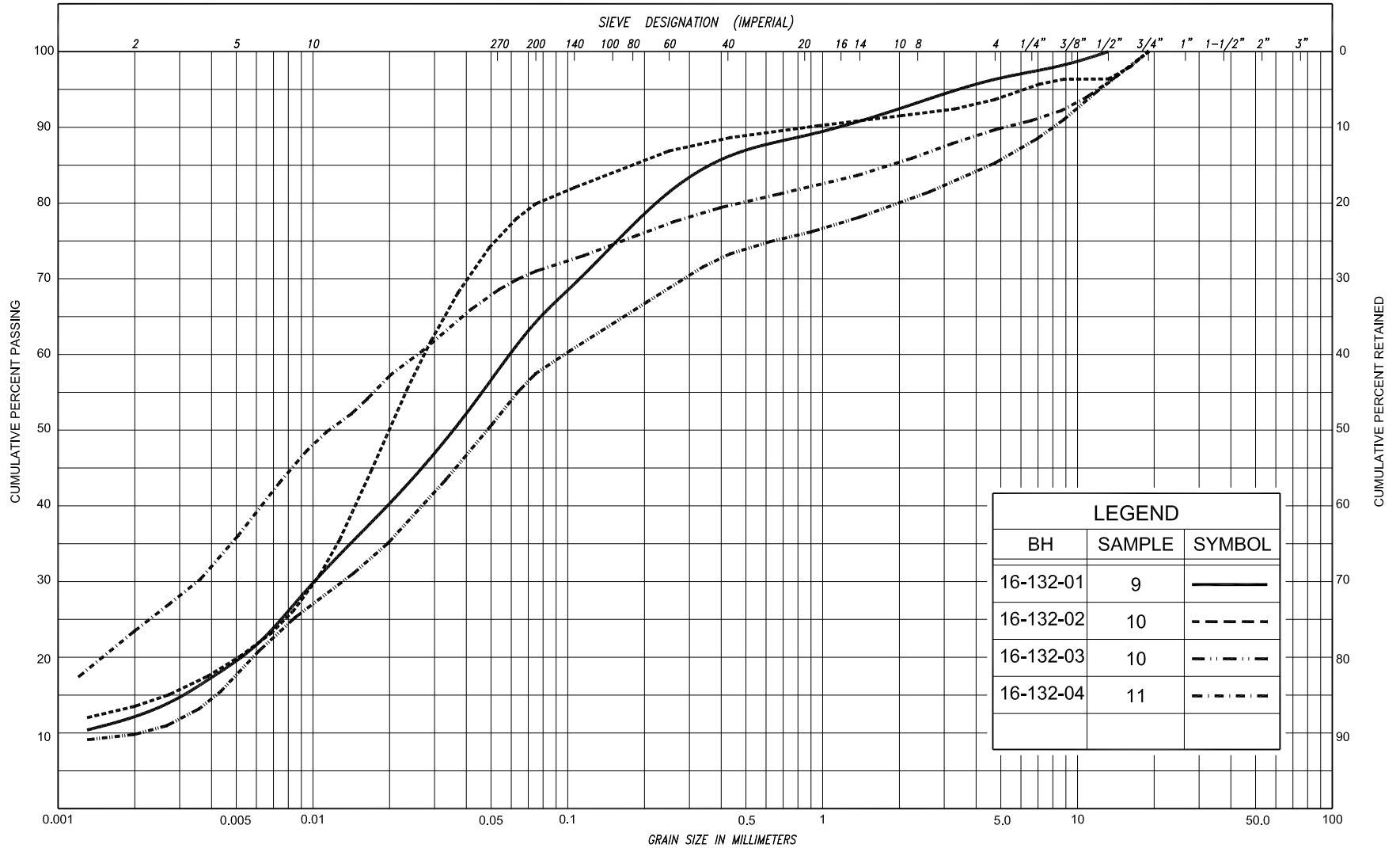


GRAIN SIZE DISTRIBUTION SAND

FIG No. 132-GS-3

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															
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL						U.S. BUREAU
					SAND											



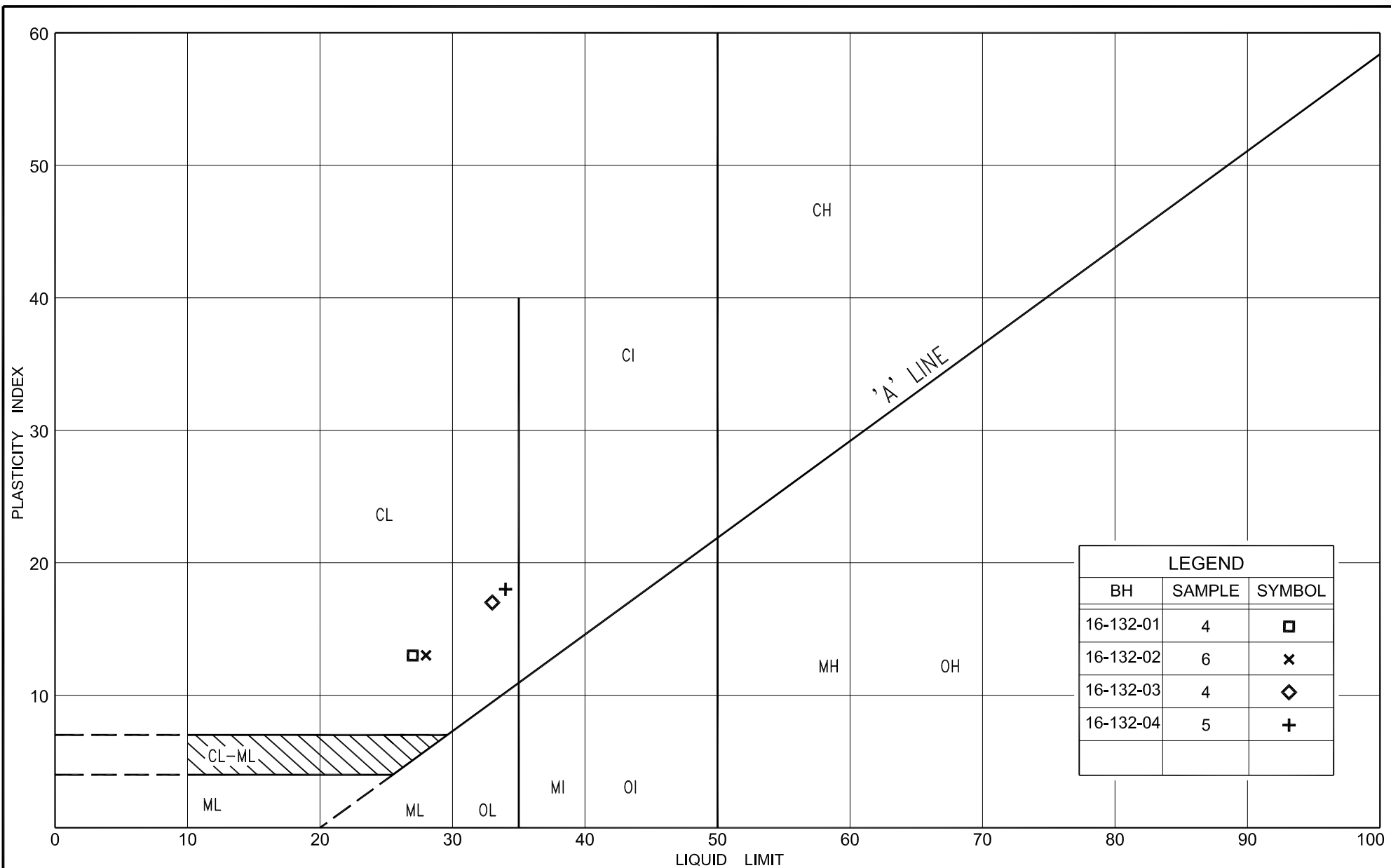
GRAIN SIZE DISTRIBUTION

SILT, with sand, some clay, trace gravel
(TILL)

FIG No. 132-GS-4

HWY 11

G.W.P. 5213-05-00

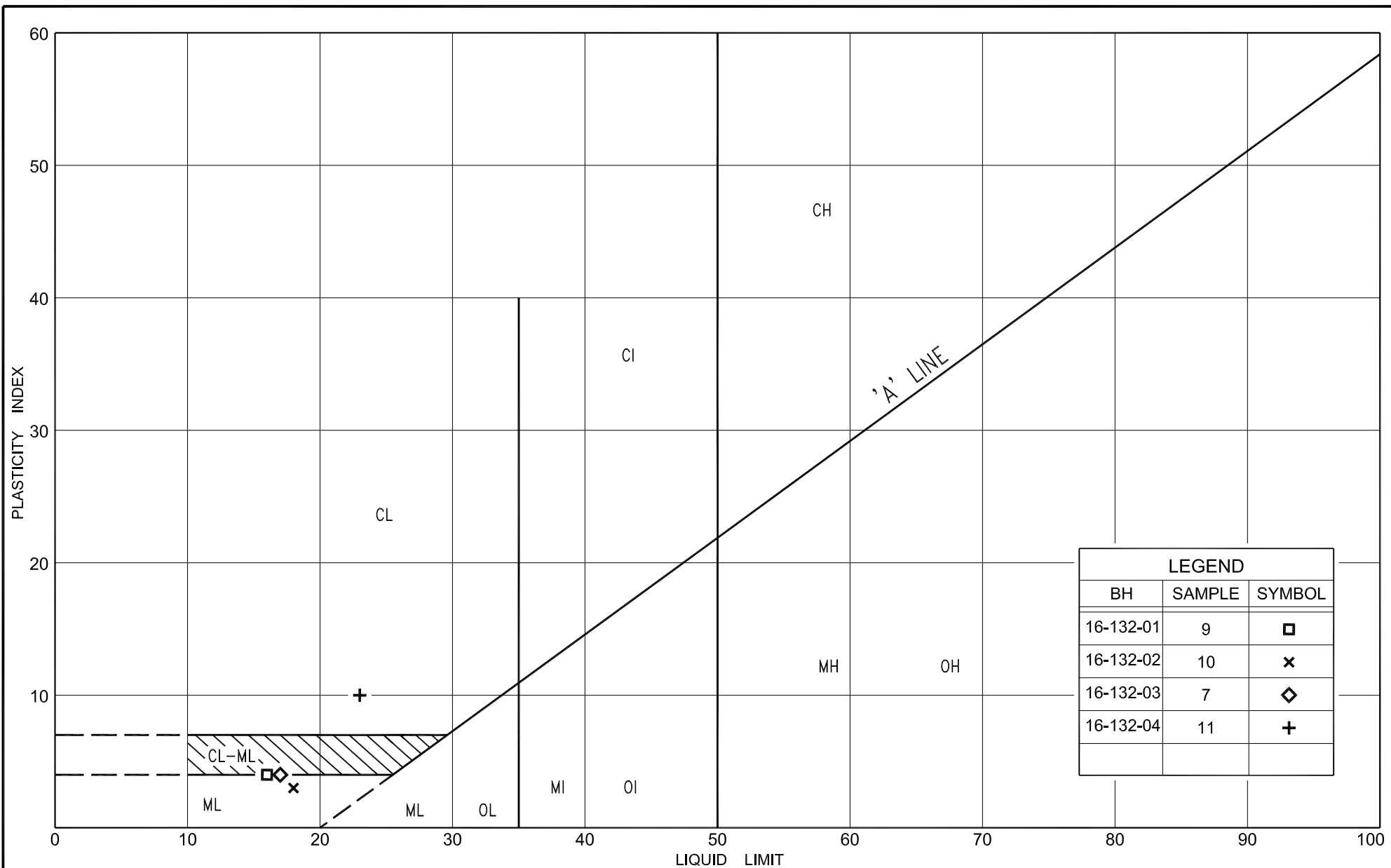


PLASTICITY CHART CLAYEY SILT, trace sand (CL)

FIG No. 132-PC-1

HWY 11

G.W.P. 5213-05-00



PLASTICITY CHART

SILT, with sand, some clay, trace gravel (ML)

FIG No. 132-PC-2

HWY 11

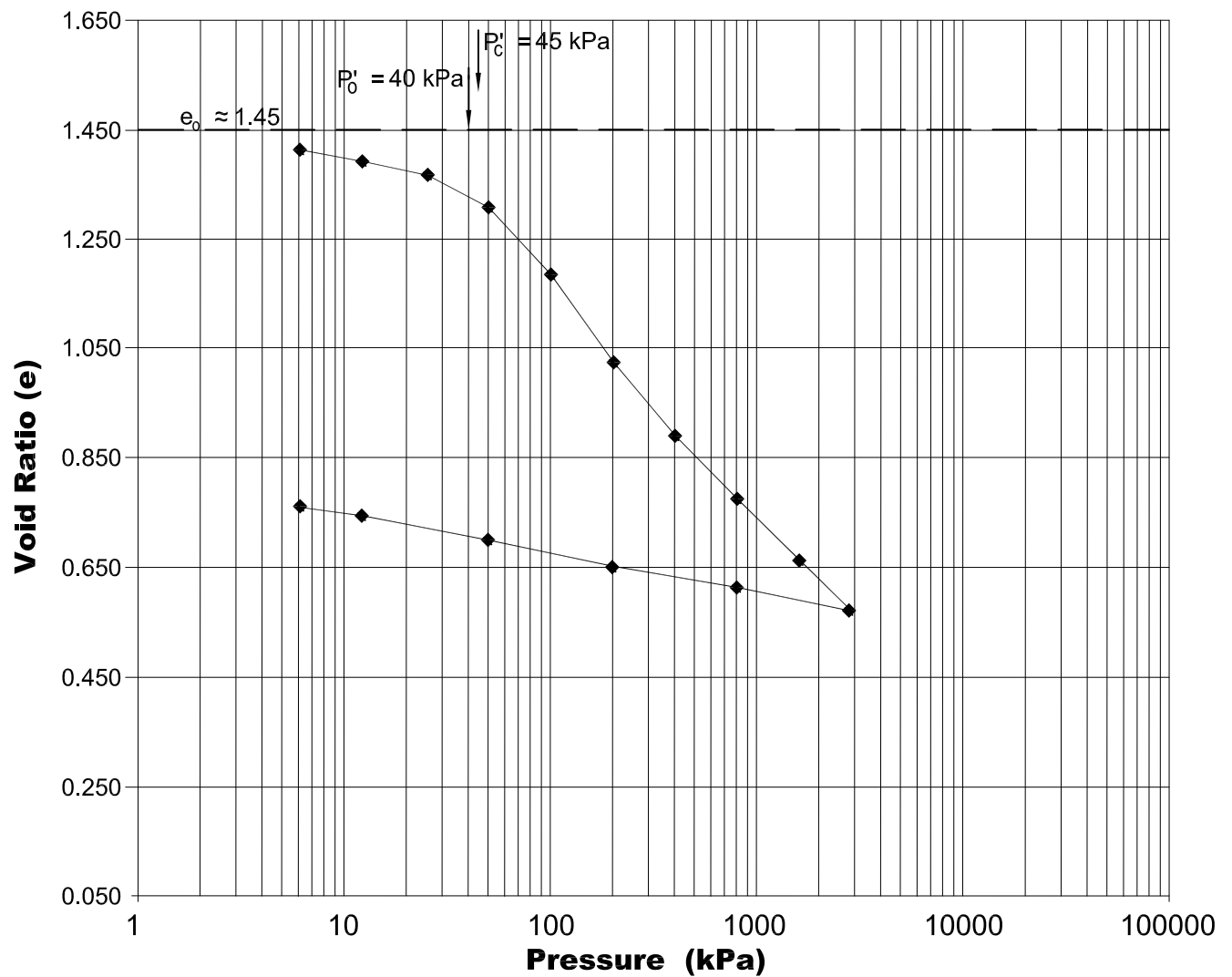
G.W.P. 5213-05-00

Laboratory Consolidation Test Results

Highway 11
Replacement/Rehabilitation of Sixteen Structures
New Liskeard, Ontario

Borehole 16-132-4, Sample 5, Depth 3.1 to 3.5 m

Void Ratio versus Log of Pressure



SOIL TYPE: CLAYEY SILT, Trace Sand

$e_0 \approx 1.45$

$C_c = 0.45$

$\gamma = 17.5 \text{ kN/m}^3$

$P'_0 = 40 \text{ kPa}$

$P'_c = 45 \text{ kPa}$

$W_L = 34$

$W_P = 17$

$PI = 17$

FIGURE No: 132-C-1

HIGHWAY: 11

DISTRICT NEW LISKEARD

G.W.P. 5213-05-00



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 16T137399

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

ATTENTION TO: Lul Yimam

SAMPLING SITE:

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2016-09-14

DATE REPORTED: 2016-09-22

		SAMPLE DESCRIPTION:		16-126-1 SS7	16-127-1 SS4	16-128-1 SS3	16-132-2 SS7
		SAMPLE TYPE:		Soil	Soil	Soil	Soil
		DATE SAMPLED:		8/21/2016	8/21/2016	8/23/2016	8/19/2016
Parameter	Unit	G / S	RDL	7843395	7843416	7843418	7843419
Chloride (2:1)	µg/g	2	5	27	15	16	
Sulphate (2:1)	µg/g	2	81	61	30	44	
pH (2:1)	pH Units	NA	7.65	7.81	7.92	8.14	
Electrical Conductivity (2:1)	mS/cm	0.005	0.189	0.251	0.194	0.181	
Resistivity (2:1)	ohm.cm	1	5290	3980	5150	5520	
Redox Potential (2:1)	mV	5	296	288	284	271	

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

7843395-7843419 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:

Elizabeth Potokowska

Quality Assurance

CLIENT NAME: PETO MACCALLUM LIMITED

PROJECT: 16TF013A

SAMPLING SITE:

AGAT WORK ORDER: 16T137399

ATTENTION TO: Lui Yimam

SAMPLED BY:

Soil Analysis

RPT Date: Sep 22, 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

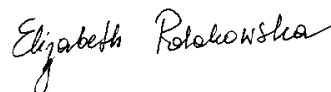
Corrosivity Package

Chloride (2:1)	7843395	7843395	5	5	NA	< 2	94%	80%	120%	101%	80%	120%	105%	70%	130%
Sulphate (2:1)	7843395	7843395	81	81	0.0%	< 2	97%	80%	120%	95%	80%	120%	100%	70%	130%
pH (2:1)	7843395		7.65	7.64	0.1%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7843395	7843395	0.189	0.189	0.0%	< 0.005	99%	90%	110%	NA			NA		
Redox Potential (2:1)	7843395	7843395	296	297	0.3%	< 5	102%	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: 16T137399

PROJECT: 16TF013A

ATTENTION TO: Lul Yimam

SAMPLING SITE:

SAMPLED BY:

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

STUDHOLME CREEK CULVERT REPLACEMENT

SITE NO. 39W-132/C

HIGHWAY 11 – STATION 20+617

STUDHOLME TOWNSHIP, DISTRICT OF NEW LISKEARD, ONTARIO

ASSIGNMENT NO. 5015-E-0009

GWP 5213-05-00

WP 5224-13-01

PETO MacCALLUM LTD.
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TORONTO, ONTARIO
M6A 1V5
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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.: 167FDR
GEOCRES No.: 42F-56
December 12, 2018



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Appendix C – Evaluation of the Field Virgin Compression Curve – Figure 132-C-2

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

PART B — FOUNDATION DESIGN REPORT

Studholme Creek Culvert Replacement
Site No. 39W-132/C
Highway 11 – Station 20+617
Studholme Township, District of New Liskeard, Ontario
Assignment No. 5015-E-0009
GWP 5213-05-00
WP 5224-13-01

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 replacement of Studholme Creek culvert, located at the crossing of Highway 11 and Studholme 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.

A precast concrete box culvert was initially proposed by GHD as the replacement structure to the existing culvert at the crossing of Studholme Creek and Highway 11. Based on the GA drawing provided by GHD on January 19, 2018, a draft FIDR dated February 06, 2018 was submitted to MTO for their review and comments. MTO provided their review comments on a Memorandum dated April 23, 2018 and assigned a Geocres Number (MTO Geocres No. 42F-56) for the report. As outlined in this report, the proposed design was revised after the design liaison between GHD and PML and consultation with MTO.



8.2 Existing Culvert

The culvert to be replaced is located at the crossing of Studholme Creek and Highway 11. The existing structure 39W-132/C is a 22.7 m long twin-cell timber culvert, each cell with an opening size of 2.1 m in span and 1.4 m in rise, and supports approximately 2.0 m high fill above the deck.

This culvert was constructed in 1942 and there is no record of rehabilitation. Based on the GA drawing provided by GHD, dated January 2018, the invert of the existing culvert at the inlet and outlet is located at approximate elevation of El. 242.5. 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 on the soffit, and light weathering and minor to moderate checks and splits of cells on the east and west barrels. Signs of deterioration include moderate corrosion of bolts and connections, and one missing timber member at the north side of the culvert. Further, a narrow crack was observed along the centerline of the roadway.

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 each cell of the existing culvert at the founding level may not exceed 125 kN to 140 kN per meter length of the culvert.

8.3 Proposed Culvert

8.3.1 Background

The replacement structure initially proposed was a 30 m long precast concrete box culvert, with an opening size of 4.8 m in span, 1.8 m in rise and wall thicknesses of 290 mm to 320 mm. The information provided to PML did not include provision for headwalls or wing walls for the proposed replacement culvert. The proposed invert of the box culvert slopes from about El. 242.0 at the inlet to El. 241.9 at the outlet. Based on the proposed invert levels, the founding level of the bedding for the replacement culvert was expected to be at about El. 241.3. The proposal was to construct the replacement culvert along the same vertical and horizontal alignment and grade of the road at the culvert location was to be maintained at the existing elevation of El. 245.6. This resulted in a proposed fill height of 2.5 m, including the pavement structure, above the box culvert.



GHD specified that the proposed culvert including the fill needs to be designed for a minimum factored load at ULS of 120 kPa at the subgrade level and the culvert is expected to impose a minimum load of 69 kPa at Serviceability Limit State (SLS).

The total and differential settlements associated with the precast concrete box culvert placed at the proposed invert level were found to exceed the tolerable limit. The option of placing the proposed precast concrete box culvert on approximately 4.0 m high replacement fill consisting of Granular B Type II was also evaluated and found to be costly. PML submitted a technical memo, dated August 2, 2018 to GHD advising them to replace the existing structure with a corrugated steel plate arch (CSPA) culvert with a hydraulic size similar to that of the proposed precast concrete box. After the design liaison between GHD and PML and consultation with MTO, a revised GA drawing was provided by GHD on November 14, 2018.

8.3.2 Additional Culvert Option

Based on the revised GA drawing, provided on December 6, 2018, the proposed replacement structure will consist of a 30 m long, 5 mm thick corrugated pipe arch (CSPA) culvert, with an opening size of 3.73 m in span, 2.29 m in rise, placed on 600 mm thick bedding consisting of Granular A. The proposed invert elevation of the culvert at the south end (outlet) will be approximately at El. 241.89 and at (inlet), it will be at El. 241.99. Based on the proposed invert levels and the thickness of bedding, the founding level of the bedding for the CSP culvert is expected to be at about El. 241.3. It is proposed to construct the replacement culvert along the same vertical and horizontal alignments, and grade of the road at the culvert location will be maintained at the existing elevation of El. 245.6. This will result in a proposed fill height of 1.4 m, including the pavement structure, above the crown of the culvert.

The GA drawing also indicates that the CSP culvert will be fitted with sheet pile cut-off walls at the inlet and outlet, extending to a depth of 1.2 m below the invert level. The cut-off walls will extend to a distance of 1.0 m on both sides of the culvert.



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

8.4 Structure Foundation

In summary, the subsoil conditions in the boreholes include unpaved shoulders of Highway 11 ranging in thickness from 300 mm to 800 mm. The granular base on the highway shoulders is immediately underlain by 3.0 m to 3.6 m of sandy fill. Organic silt layer (alluvium) ranging in thickness from 1.8 m to 2.2 m was encountered immediately below the ground surface in boreholes located near the culvert outlet and inlet. The organic silt (alluvium) layer and sandy fill layer are immediately underlain by 3.1 m to 4.9 m thick soft to firm clayey silt layer. The clayey silt layer in boreholes (Boreholes 16-132-01 and 16-132-04) located on the west side of the culvert is underlain by 1.4 m thick sand deposit. The clayey silt layer and sand deposit are underlain by very dense silt with varying proportions of gravel, sand and clay (till), which extends to the maximum borehole termination depth of 12.4 m below the grade of highway shoulders. The groundwater level was observed between El. 243.2 and El. 240.1 during the fieldwork.

The thickness of the soft to firm clayey silt deposit below the proposed bedding level of El. 241.3 varies from 3.9 m to 4.2 m, with an average thickness of approximately 4.0 m. The in-situ vane shear values of the clayey silt range from 16 kPa to 59 kPa, with an average undrained shear strength (C_u) of 36 kPa. The consolidation test indicated that the clayey silt deposit is normally consolidated with a pre-consolidation pressure of 45 kPa compared to an effective over burden pressure of 40 kPa. The laboratory consolidation test, in effect is a re-loading of the thin-wall tube sample and the compression index (C_c) obtained by this test is somewhat less than that of the "field virgin compression index (C_{cc})". The graphical procedure developed by Schmertmann (1955) was used to estimate the field virgin compression index and resulted in a C_{cc} value of 0.54. The graphical construction to evaluate the field virgin compression curve is shown on Figure 132-C-2 in Appendix C. The initial void ratio (e_o) was observed to be 1.45 and the field virgin compression ratio $C_{cc}/(1+e_o)$ computed for this sample falls at 0.22.



The feasibility of the following four 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,
- Replacement with an open footing concrete culvert, and
- Replacement with a Corrugated Structural Plate Arch (CSPA) Culvert.

A comparison of the technical advantages and disadvantages for the replacement culvert are presented in Table 8.4. Considering the subsoil conditions, the recommendations for the replacement culvert are provided below and the preferred option is identified in Section 8.4.7.



Table 8.4 Comparison of Alternate Culvert Options

Option 1a and 1b: Precast Concrete Box Culvert Placed on Clayey Silt Subgrade	Option 1c: Precast Concrete Box Culvert on Granular B Type II Replacement Fill	Option 2: Cast In-Place Concrete Box Culvert	Option 3: Three-Sided Precast Open Culvert	Option 4: CSP Arch 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	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	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	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 5. Ease of construction and installation in wet conditions is possible	Advantages: 1. Load imposed by CSP is significantly less than precast concrete box structures 2. Magnitude of differential settlements is significantly lower than precast concrete box structures 3. CSP is flexible enough to withstand differential settlement without damage to the joints 4. Ease of construction and less costly than other options 5. Limited excavation, dewatering and replacement with granular backfill
Disadvantages: 1. Excessive total and differential settlements 2. Natural stream bed will not remain intact 3. Cause sediment accumulation in the upstream of the channel 4. Possibility for degradation of subgrade	Disadvantages: 1. Natural stream bed will not remain intact 2. Cause sediment accumulation in the upstream of the channel	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 6.1 m high water	Disadvantages: 1. Subsoil conditions at shallow depths are not favourable to support the culvert on strip footings 2. Probability of uneven or differential settlements is high 3. Limited ability to withstand differential settlements	Disadvantages: 1. Require protection against floatation during installation 2. Bedding requires shaping to the culvert geometry 3. Concerns for adverse drainage impacts elsewhere and maintenance of natural stream pattern
Cost of Construction: Total Cost: \$15,500/m	Cost of Construction: Total Cost: \$17,500/m	Cost of Construction: Total Cost: \$18,500/m	Cost of Construction: Total Cost: \$18,000/m	Cost of Construction: Total Cost: \$8,000/m
Technically Not Feasible; Not Recommended	Recommended but Costly	Technically Feasible but Not Recommended	Technically Feasible but Not Recommended	Recommended



8.4.1 Option 1a: Precast Concrete Box Culvert Placed at El. 241.0

Based on the information provided by GHD, it is assumed that the bedding for the precast concrete box culvert will be placed at about El. 241.0. In case the culvert is placed at the proposed subgrade level of El. 241.0, there will be about 2.7 m to 3.9 m thick, soft to firm clayey silt layer underneath the base of culvert, which will result in significant differential settlements along the length of the culvert. The magnitude of differential settlements expected from the variation in thickness of clayey layer under the imposed load of 69 kPa indicated by GHD will be significantly higher than that of the tolerable limit of 100 mm generally assumed for a precast concrete box culvert.

Specifically, the 2.7 m to 3.9 m thick soft to firm clayey silt below the proposed founding level of the culvert under an imposed load of 69 kPa at SLS is expected to undergo a total settlement ranging from 200 mm to 385 mm and the associated differential settlement may be expected to be in the order of 185 mm to 280 mm. The total and differential settlements are in excess of tolerable settlement limits for a precast concrete box culverts and the joints may be severely damaged, which will lead to deterioration of the culvert. Therefore, the option of placing the replacement culvert on native soils at El. 241.0 is not feasible.

8.4.2 Option 1b: Precast Concrete Box Culvert on Granular B Type II Replacement Fill

Alternatively, the clayey silt deposit may be partially excavated to El. 239.0 and replaced with Granular B Type II up to the proposed founding level of EL. 241.0. This option will result in soft to firm clayey silt layer with thickness varying from as low as 0.7 m to 1.9 m underneath the culvert. The variation in thickness of clay layer underneath the culvert will result in significant magnitude of differential settlements along the length of the culvert.

A total settlement as low as 50 mm near the outlet to about 175 mm near the inlet may be expected under a SLS load of 69 kPa and the associated differential settlements may be expected to be in the order of 125 mm along the length of the culvert. Therefore, this option is also not feasible and the clay layer down to El. 237.0 need to be removed and replaced with Granular B Type II to minimise or eliminate the post construction settlements.



8.4.3 Option 1c: Remove Clayey Silt Layer to EL. 237.0 and Replace with Granular B Type II

The total and differential settlements indicated are in excess of the tolerable limit for precast concrete box culverts. Therefore, it is recommended that the clayey silt deposit down to El. 237.0 be removed and replaced with Granular B Type II up to the proposed founding level of El. 241.0. The precast concrete box culvert placed on 4.0 m thick replacement fill consisting of Granular B Type II may be designed assuming a geotechnical resistance of 300 kPa at ULS and 175 kPa at SLS. The total settlement induced under the SLS load of 175 kPa may be expected to be in the range of 25 mm to 40 mm and the associated differential settlement may be in the range of 20 mm to 30 mm.

It is recommended that the clayey silt encountered down to El. 237.0 be removed and replaced with Granular B Type II up to the proposed founding level of El. 241.0. The sub-excavation of clayey silt should extend to a distance of at least 1.0 m from the external face of the culvert invert and sloped at 3H:1V to the bottom of excavation, i.e., El 237.0. If the construction is carried out under water, the replacement fill should consist of Granular B Type II containing particle sizes no finer than 75 µm. However, Granular B Type II meeting the requirements of OPSS 1010 may be used if the construction is carried out in dry conditions.

The replacement fill should be placed in layers not exceeding 200 mm in thickness before compaction and compacted in accordance with OPSS 501. Granular bedding can be placed below the water level if the material is sufficiently self-compacting or by overbuilding above the water level by 1.0 m and then compacting and trimming to the bedding level.

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 Code (CHBDC 2014), cut-off walls at both ends of the culvert should be provided. Cut-off walls should 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 should meet the requirements of clauses 1.9.5.6 and 1.9.11.6.5 of CHBDC 2014, to protect against scour or undermining.



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

The soft to firm clayey silt encountered below the proposed founding level extends to more than 4.0 m (El. 237.1). The subsoil conditions at this site are not favorable or capable of providing adequate geotechnical resistance for supporting cast-in place reinforced concrete box culvert at the proposed invert level. Considering the depth of clayey silt below the invert, it is not cost effective or practical to excavate and replace with lean concrete to support the culvert. In addition, construction under 6.1 m of ground water will impose greater difficulties for construction in dry conditions. In view of the subsoil conditions, deep foundation such as piles will be required if option of using cast-in-place reinforced concrete box culvert is considered. For these reasons, this option is not preferred.

8.4.5 Option 3: Three Sided Open Precast Concrete Culvert on Strip Footings

Same as in Option 2, the soft to firm clayey silt encountered below the proposed founding level extends to more than 4.0 m (El. 237.1). Subsoil condition at this site is not favorable or capable of providing adequate geotechnical resistance for supporting precast concrete culvert on strip footings at the proposed invert level. Considering the depth of clayey silt below the invert, it is not cost effective or practical to excavate and replace with lean concrete to support the culvert. In addition, construction under 6.1 m of ground water will impose greater difficulties for construction in dry conditions. In view of the subsoil conditions, deep foundation such as piles will be required if option of supporting precast concrete culvert on strip footings is considered. For these reasons, this option is not preferred.

8.4.6 Option 4: Corrugated Structural Plate Arch (CSPA) Culvert

Based on the revised GA drawing dated May, 2018, the existing culvert would be replaced with a 3.73 m x 2.29 m, CSP arch culvert along the existing horizontal and vertical alignments. It is understood that there will be no grade raise.

The height of fill above the culvert, including the pavement structure will be approximately 1.4 m above the crown. Based on the information provided by GHD, the expected load imposed by the proposed CSP culvert at the subgrade level of El. 241.3 is not expected to exceed 40 kPa at SLS and 70 kPa at ULS. In case the culvert is placed at the proposed subgrade level of El. 241.3, there will be about 3.0 m to 4.2 m thick, soft to firm clayey silt layer underneath the base of CSP culvert, which will result in total settlements in the range of 160 mm to 230 mm along the length of the



culvert. The magnitude of differential settlements expected from the variation in thickness of clayey layer under the imposed load of 40 kPa will be in the range of 115 mm to 165 mm. The CSPA culvert placed at the proposed invert elevation of El. 241.9 may be designed assuming a factored geotechnical resistance of 70 kPa at ULS and 40 kPa at SLS.

In order to counteract the effects of differential settlements and to avoid ponding of water inside the culvert, it may be designed with an approximately 100 mm to 125 mm camber, sloping down from inlet to outlet. However, the magnitude of camber may be designed in consultation with the Regional Geotechnical Section, which may be able to provide guidance based on local experience.

The installation of pipe culvert (CSP) shall be in accordance with OPSS 421.07.12.04 and the bedding material for the CSPA shall be Granular A meeting the OPSS 421.07.11. The bedding embedment and backfill shall be as specified for Type 4 Soil on OPSD 802.020.

The dimensions of cut-off walls should be in accordance with OPSD 812.010 to prevent washout of granular bedding. In accordance with OPSD 812.010, a CSPA culvert with a size of 3.73 m x 2.29 m requires minimum of 6.17 m wide and 2.28 m deep cut-off wall. Further, the design of cut-off wall should meet the requirements of clauses 1.9.5.6 and 1.9.11.6.5 of CHBDC 2014, to protect against scour or undermining.

8.4.7 Recommended Option for Culvert Replacement

In view of the construction difficulties and cost associated with the use of a precast concrete box culvert for replacement, from the Foundations standpoint, PML recommends that the existing culvert be replaced with a CSP arch culvert (Option 4).

Option 1a and 1b are not technically feasible. Options 1c, 2, and 3 are technically feasible but not cost effective. Considering the construction difficulties and cost of dewatering 6.1 m high groundwater, Options 2 and 3 are not recommended.

8.4.8 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 assumed 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' Type II 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	OPSS GRANULAR A AND GRANULAR B TYPE II
Angle of Internal Friction, degrees	35°
Unit Weight, kN/m ³	22.5
Coefficient of Active Earth Pressure (K_a)	0.27
Coefficient of Earth Pressure at Rest (K_o)	0.43
Coefficient of Passive Earth Pressure (K_p)	3.69

Backfill shall be placed simultaneously behind both sides of the culvert, maintaining the height of backfill approximately the same. Bedding material shall be placed on each side of the pipe and shall be



completed simultaneously. At no time shall the levels on each side differ by more than the 200 mm uncompacted layer.

8.5 Approach Embankment

The height of the existing approach fill is approximately 3.5 m above the creek bed. PML understands that there will be no widening of embankment or increase in the profile grade of the road and it will be maintained at El. 245.6. Based on the performance of existing embankments, 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 (Granular A or Granular B), preferably Granular B Type II below water level. 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 Town of Clavet, City of Hearst, Ontario (National Building Code of Canada, 2015). The soil at this site for seismic design purposes is classified as Type E in accordance with Clause 4.4.3.2, CHBDC 2014.



10.1 Cover and Backfill

In the case of CSP culvert, backfill should meet the requirements specified in OPSS 421.07.11, and placed according to the procedures described in OPSS 401. It should 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 culvert should be completed simultaneously and at no time, the levels on each side of the culvert exceed more than 200 mm uncompacted layer. It is recommended to place a geotextile layer over the founding soil prior to placing granular bedding material to serve as a protection and to distribute the load evenly.

Frost taper and protection shall be in accordance with OPSD 803.031.

11. CONSTRUCTION CONSIDERATIONS

11.1 Staged Construction

The construction of culvert replacement is expected to be carried out in three 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.

A slope of 2H:1V should be maintained for excavation through existing fill if a staging scheme is considered for detouring the traffic during the removal of existing culvert and installation of replacement culvert.

Temporary roadway protection should 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
245.5	241.2	Sandy Fill	28	18	0
241.2	238.1	Clayey Silt	0	17.5	25
238.1	231.9	Silt (Till)	32	20	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 should 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 clayey silt deposit. For OHSA classification purposes, the fill materials and soft to firm clayey silt deposit should be classified as Type 4 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. 243.2 to El. 240.1 and the excavation to place the bedding for CSP culvert may have to be carried out under a maximum of 1.9 m high water level, depending on the time of construction. The groundwater level should be lowered to a minimum of 0.5 m below the proposed founding levels to allow for construction in the dry and to place bedding materials.

Since groundwater levels are subject to seasonal fluctuations and precipitation patterns, higher dewatering gradients may be required.

The creek may have to be temporarily diverted and a cofferdam may be required due to the relatively pervious nature of the sandy fill material. 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 creek, the culvert replacement may have to be constructed under the prevailing water level. If the construction is carried out under water, the backfill material should consist of Granular B Type II containing particle sizes not finer than 75 μm .

13. TEMPORARY WORKS

The contractor shall be responsible for the selection, performance and detail 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 D.



14. SOIL CORROSION

One sample from the clayey 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 5.2.9 of Part A of this report. The sulphate concentration of 44 µg/g (0.0044%) reported in Table 5.2.9 for the clayey 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 16 ppm or 0.0016% (16 µg/g) reported in Table 5.2.9 is significantly 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 relatively 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 5520 ohm-cm reported is significantly higher than 2000 and suggests a moderately or non-corrosive environment at this site for steel elements. However, pH value of 8.14 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

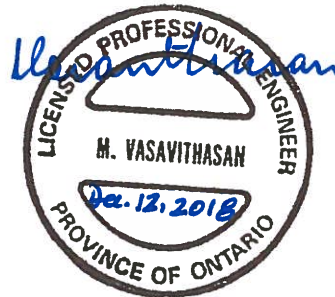
This Foundation Investigation and Design Report was prepared by Ms. N. Leong-Sem, B.Eng., EIT., Geotechnical Services, and reviewed by M. Vasavithasan, MSc.Eng., P.Eng. Senior Engineer, Geotechnical Services. Mr. C.M.P. Nascimento, P.Eng., Principal Consultant, conducted an independent review of the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

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in black ink, appearing to read 'Natasha Leong-Sem', is positioned above the name and title of the signatory.

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/MV/CN:nl-nk



APPENDIX C

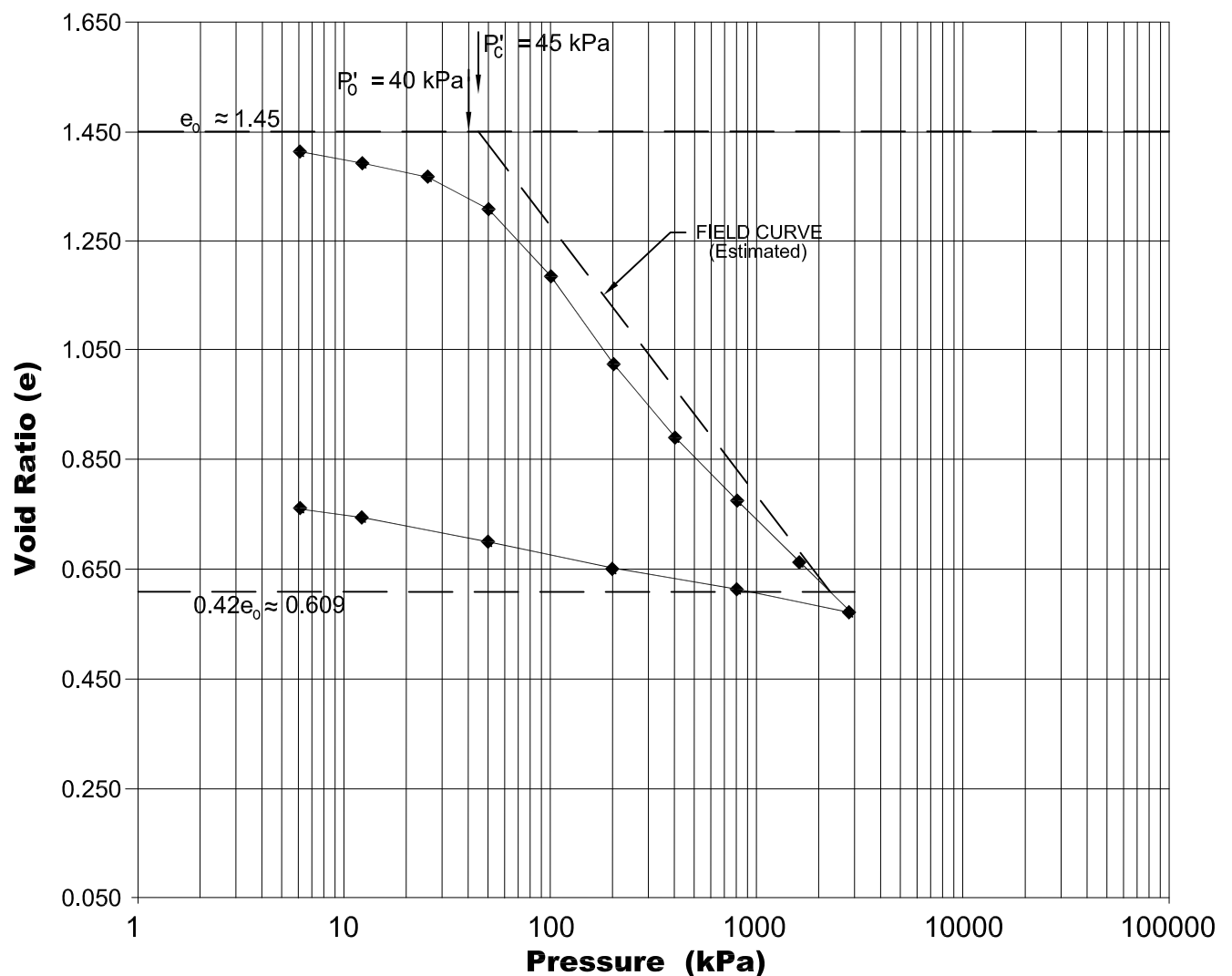
Evaluation of the Field Virgin Compression Curve – Figure 132-C-2

Laboratory Consolidation Test Results

Highway 11
Replacement/Rehabilitation of Sixteen Structures
New Liskeard, Ontario

Borehole 16-132-4, Sample 5, Depth 3.1 to 3.5 m

Void Ratio versus Log of Pressure



SOIL TYPE: CLAYEY SILT, Trace Sand

$e_0 \approx 1.45$

$C_c = 0.45$

$\gamma = 17.5 \text{ kN/m}^3$

$P'_0 = 40 \text{ kPa}$

$P'_c = 45 \text{ kPa}$

$W_L = 34$

$W_P = 17$

$PI = 17$

FIGURE No: 132-C-2

HIGHWAY: 11

DISTRICT NEW LISKEARD

G.W.P. 5213-05-00



APPENDIX D

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
NSSP FOUND003	Dewatering Structure Excavations – Amendment to OPSS 902
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 Required



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.