



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

**HIGHWAY 427 EXPANSION – MCGILLIVRAY ROAD REALIGNMENT
EAST ROBINSON CREEK CULVERT
CITY OF VAUGHAN, ONTARIO
ASSIGNMENT NO. 2014-E-0056
WORK ORDER #32
LATITUDE AND LONGITUDE: 43.810071,-79.653889**

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PML Ref.: 15TF013F
Index No.: 068FIR and 069FDR
GEOCRES No.: 30M13-230
November 20, 2019



PART A - FOUNDATION INVESTIGATION REPORT

for

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PART A - FOUNDATION INVESTIGATION REPORT
Highway 427 Expansion - McGillivray Road Realignment
East Robinson Creek Culvert
City of Vaughan, Ontario
Assignment No. 2014-E-0056, Work Order #32

1. INTRODUCTION

The Ministry of Transportation Ontario (MTO) has retained AECOM Canada Ltd. (AECOM) as the Prime Consultant, to provide Owner's Engineer services for the Highway 427 Expansion Project. AECOM retained Peto MacCallum Ltd. (PML) on behalf of MTO to provide geotechnical engineering services for the assignment.

The geotechnical investigation work reported herein is part of Assignment No. 2014-E-0056, Work Order #32 (WO #32). This WO #32 involves the realignment of the southern section of the two-lane McGillivray Road approximately 520 m to the east of its present intersection with Rutherford Road.

The Terms of Reference and Scope of Work for the Foundation Engineering services are outlined in the MTO WO No. 32 under Assignment No. 2014-E-0056, issued on August 5, 2016 and the PML revised proposal, dated August 15, 2016.

This report summarizes the results of the foundation investigation carried out for the design of the new culvert located at the crossing of East Robinson Creek and the proposed realigned McGillivray Road (Sta. 9+795.1), located in Kleinburg, City of Vaughan, Ontario.

The initially proposed orientation of the culvert was revised after the completion of the initial investigations and submission of the pre-draft foundation investigation report, dated February 27, 2019. The location of the culvert was revised by shifting 5.0 m easterly in relation to the initially proposed alignment, to accommodate the creek flow pattern and to minimise grading on the approaches. The changes to the proposed structure and its orientation were communicated to PML by e-mail, dated March 13, 2019. The revision of the culvert orientation required an additional borehole, designated Borehole BH-7 in the northeast corner of the revised location. Fieldwork investigation for the additional Borehole BH-7 was conducted on October 16, 2019.



In addition, based on the updated General Arrangement (GA) drawing, dated November, 2019, berm walls will be constructed at the inlet and outlet of the culvert. Fieldwork investigation for the berm walls included two additional boreholes RW-1Alt and RW-1A, which were drilled on October 16, 2019 and two test pit holes, which were advanced on November 1, 2019.

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

2. SITE DESCRIPTION

The location of proposed culvert is approximately 520 m east of the existing McGillivray Road intersection and 180 m north of Rutherford Road. McGillivray Road and Rutherford Road are slightly elevated from the natural topography, and accommodate two (2) and four (4) lanes of vehicular traffic, respectively. The site is generally a flat area, with the exception of the roadway embankments. East Robinson creek flows from north to south, almost perpendicular to Rutherford Road. The proposed culvert site is located within farmlands and is surrounded by long grass and forestation with mature trees and shrubs.

3. FIELD INVESTIGATION PROCEDURES

The fieldwork for the culvert foundation investigation involved advancing seven (7) boreholes. Two (2) boreholes RW-1 and RW-1A were also drilled for the new berm wall. The boreholes were drilled to depths ranging from 9.6 m to 11.3 m below the existing ground surface (El. 176.5 to El. 174.8), and were terminated in competent soils. The boreholes 7 and RW-1 were supplemented by two (2) test pit holes, TP-7 and TP-RW-1, which were investigated by hand augers to 1.5 m below the existing ground surface (El. 184.7 to El. 183.3)

The staff of PML visited the site with terrestrial representatives of AECOM on August 22, 2018 to mark out the borehole locations and access routes for tree clearing services.

Tree clearing was carried out between November 26 and 29, 2018. The equipment used for tree clearing was owned and operated by Ecogreen Tree Services and Landscape Construction (Ecogreen) of Vaughan, Ontario. Ecogreen is a licensed specialist tree services contractor and worked under the full time supervision of a PML field supervisor and AECOM ecologist field supervisor.



PML staff visited the site with terrestrial representatives of AECOM on September 18, 2019 to confirm the location of borehole BH-7. The permission to enter (PTE) permit to access BH-7 location through the adjacent private property was received on October 15, 2019. 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, PML carried out the survey of the borehole locations as drilled and elevations using a Sokkia SHC5000 Differential GPS system, equipped with a GCX3 (Network RTK rover) GNSS Receiver. The vertical and horizontal accuracy of this equipment are within 0.1 m and 0.5 m, respectively. All elevations reported in this report are referred to in MTM NAD 83 Northing and Easting (MTM Zone – ON10) Geodetic datum and expressed in meters.

The equipment used for drilling was owned and operated by Landshark Drilling Inc. (Landshark), of Brantford, Ontario. Landshark is a specialist drilling contractor and worked under the full time supervision of a PML field supervisor. Boreholes numbered BH-1 to BH-6 were drilled between January 7 and 22, 2019. The boreholes were advanced using a CME 55 track-mounted drilling rig equipped with 200 mm diameter hollow stem augers. Boreholes BH-7, RW-1 and RW-1A were drilled on October 15, 2019, and advanced using a D-50 Turbo track-mounted drilling rig equipped with 200 mm diameter hollow stem augers. The two test holes, TP-7 and TP-RW-1, were investigated manually with hand augers to a depth of 1.5 m on November 1, 2019.

Boreholes BH-1, BH-3 to BH-6 were drilled on the west side of East Robinson Creek. Boreholes BH-2, BH-7, RW-1 and RW-1A were drilled on the east side of East Robinson Creek. Boreholes BH-1 and BH-4 were drilled at the inlet and outlet of the culvert, respectively. The borehole locations are shown on the attached Drawing 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. SPT were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. Chunk samples from the hand augers were grabbed from the two test holes at three different depths.



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 upon completion of drilling. Monitoring well, consisting of 50 mm outside diameter rigid PVC pipe, was installed near the inlet and outlet of the proposed culvert. Refer to Record of Borehole Sheet in Appendix A for details of monitoring well installation. Water levels were measured using a Solinst flat tape water level reader.

The water level in the creek was observed at approximate elevation of El. 186.0 during the fieldwork.

Upon completion of drilling, the boreholes were backfilled with bentonite/cement grout in accordance with the MTO guidelines and O.Reg. 903 for borehole abandonment procedures. The annular space between the borehole wall and the pipe installed for monitoring well was backfilled above the filter pack to ground surface using bentonite pellets.

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 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 (88)
- Grain size distribution analysis (26)
- Atterberg limit tests (26)

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 on Figures GS-1A, GS-1B, GS-1C, GS-2, and GS-3. The results of the Atterberg Limit tests are presented on Figures PC-1A, PC-1B, PC-1C, PC-2, and PC-3. All of the test results are summarized on the attached Record of Borehole Logs provided in Appendix A.



5. SITE GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Site Geology

In general, the project area is located within the Peel Plain physiographic region, which is dominated by a mixture of clays, sands, and silt deposits of fluvial and lacustrine origin, as outlined in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984).

The Quaternary Geology map published by the Ontario Ministry of Northern Development and Mines (MNDM), indicates that the surface conditions in the area of the culvert site consist of Halton Till deposits; predominantly silt to silty clay matrix. Based on the Bedrock Geology map (MRD126-REV1, 2011) published by the MNDM, the culvert site lies within the Georgian Bay rock formations. The project area consists mainly of Upper Ordovician shale, limestone, dolostone, and siltstone.

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 Drawings C-1 and C-2, respectively. 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 200 mm to 300 mm organics immediately below the ground surface, underlain by stiff to very stiff clayey silt, with the exception of two boreholes advanced on the west side of the proposed culvert location. The organics in these two boreholes is immediately followed by 1.1 m to 1.9 m thick, soft to firm silty clay. The clayey silt layer encountered extends to the maximum termination depth of 11.3 m (El. 174.8) below the existing ground surface, with the exception of two of the boreholes advanced near the southwest side of the culvert outlet. In these two boreholes, the clayey silt layer is immediately underlain by very dense silt to the termination depth of 9.6 m (El. 176.5). For classification purposes, the soils encountered at this site can be divided into two (2) distinct zones:

- a) Clayey Silt, Trace Sand, Trace Gravel
- b) Silt, Trace Sand



5.2.1 Clayey Silt, Trace Sand, Trace Gravel

A surficial layer of organics, approximately 200 mm to 300 mm in thickness, was encountered above the clayey silt layer in all of the investigated boreholes and two test holes.

This clayey silt deposit extends to depths of 8.6 m and 7.6 m in boreholes BH-4 and BH-6 (El. 177.5 and El. 178.6), respectively. It was not fully penetrated in boreholes BH-1 to BH-3, BH-5, BH-7, RW-1 and RW-1A and in the two test holes, TP-7 and TP-RW-1, to establish the thickness of this deposit. Generally, the SPT N-values in this deposit to about El. 184.5 varies from 3 blows to 7 blows, indicating soft to firm consistency, with the exception of one SPT N-value of 12 in borehole RW-1A indicating stiff consistency. The clayey silt deposit below El. 184.5 was generally found to be stiff to hard consistency with SPT N-values ranging from 6 blows to more than 100 blows with the exception one SPT N-value of 5 in borehole BH-7.

The moisture content of samples tested from the clayey silt deposit varies from 9.1% to 26.7%. However, the moisture content of four of the samples containing organics were found to be between 27.4% and 37.0%. The results of the sieve analysis test performed on 23 representative samples from this deposit are provided on Figures GS-1A, GS-1B, and GS-1C. The test results indicate that this deposit consists of none to 9% gravel, 1% to 31% sand, 53% to 77% silt, and 14% to 34% clay sized particles. Atterberg limits were performed on the same 23 representative samples and the results are provided on Figures PC-1A, PC-1B, and PC-1C. The test results indicate liquid limit values of 18 to 32, plastic limit values of 13 to 19, and corresponding plasticity index values of 5 to 14. Based on the test results, the soil may be classified as clay of low plasticity (CL) in the Unified Soil Classification System (USCS), i.e., clayey silt.

The sieve analysis test results of two samples from the silty clay (CI) layer are provided on Figure GS-2. The test results indicate that this layer consists of none to 2% gravel, 11% to 16% sand, 47 to 57% clay. The Atterberg limit test results are presented on Figure PC-2 and the results indicate liquid values of 36 and 43, plastic limit values of 19 and 20, and plasticity index values of 17 and 23.



5.2.2 Silt, Trace Sand

The clayey silt deposit in boreholes BH-4 and BH-6 is underlain by very dense silt to termination depth of 9.6 m below the existing ground surface. The SPT N-Values in this deposit vary from 30 blows to 100 blows, indicating a dense to very dense state of compaction.

The moisture content of samples tested from the silt deposit varies from 14.1% to 15.2%, with an average value of 14.5%. The results of the sieve analysis test performed on one (1) representative sample from this deposit are provided on Figure GS-3. The test results indicate that this deposit consists of 0% gravel, 2% sand, 84% silt, and 14% clay-sized particles. The Atterberg limit test results are presented on Figure PC-3 and the results indicate liquid value of 22, plastic limit value of 16, and plasticity index value of 6. Based on the Atterberg limit test results, the soil may be classified as silt of low plasticity (CL-ML) in the USCS.

5.2.3 Groundwater

Groundwater was not encountered during drilling in any of the boreholes. Groundwater level measured upon completion of drilling in the boreholes are summarized in Table 5.2.3.

Table 5.2.3: Groundwater Level Readings

BOREHOLE NO.	GROUND SURFACE ELEVATION (m)	GROUNDWATER LEVELS UPON COMPLETION OF DRILLING		DATE OF READING
		DEPTH (m)	ELEVATION (m)	
BH-1	186.9	Not Encountered	--	Jan. 09, 2019
BH-2	186.1	Not Encountered	--	Jan. 11, 2019
BH-3	186.6	Not Encountered	--	Jan. 09, 2019
BH-4	186.1	Not Encountered	--	Jan. 10, 2019
BH-5	186.2	Not Encountered	--	Jan. 09, 2019
BH-6	186.2	4.6	181.6	Jan. 10, 2019
BH-7	186.1	9.1	177.0	Oct. 16, 2019
RW-1	186.6	9.1	177.5	
RW-1A	185.8	4.0	181.8	



Groundwater monitoring wells consisting of 50 mm diameter PVC pipe were installed in boreholes BH-6 and BH-7. Additional water level measurement readings from the monitoring wells installed in boreholes BH-6 and BH-7 are shown on the Record of Borehole sheets provided in Appendix A.

The water level in the creek was observed at approximately elevation of El. 186.0 during the fieldwork in October, 2019.

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 A.



6. CLOSURE

Mr. M. Mohamed carried out the field investigations under the supervision of Mr. N. Rahman, P.Eng., Project Engineer, and Ms. N. Leong-Sem, EIT. Landshark Drilling Ltd. of Brantford, Ontario supplied the drilling equipment for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.

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

Yours very truly,

Peto MacCallum Ltd.



Nazibur Rahman, P.Eng.
Project Engineer, Geotechnical Services



Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

NL/NR/MV/CN:nl-nk



APPENDIX A

Borehole Locations Plan and Soil Strata Drawings C-1 and C-2

Explanation of Terms Used in Report

Record of Borehole Sheets

Results of Grain Size Distribution Analyses – Figures GS-1A/B/C, GS-2, and GS-3

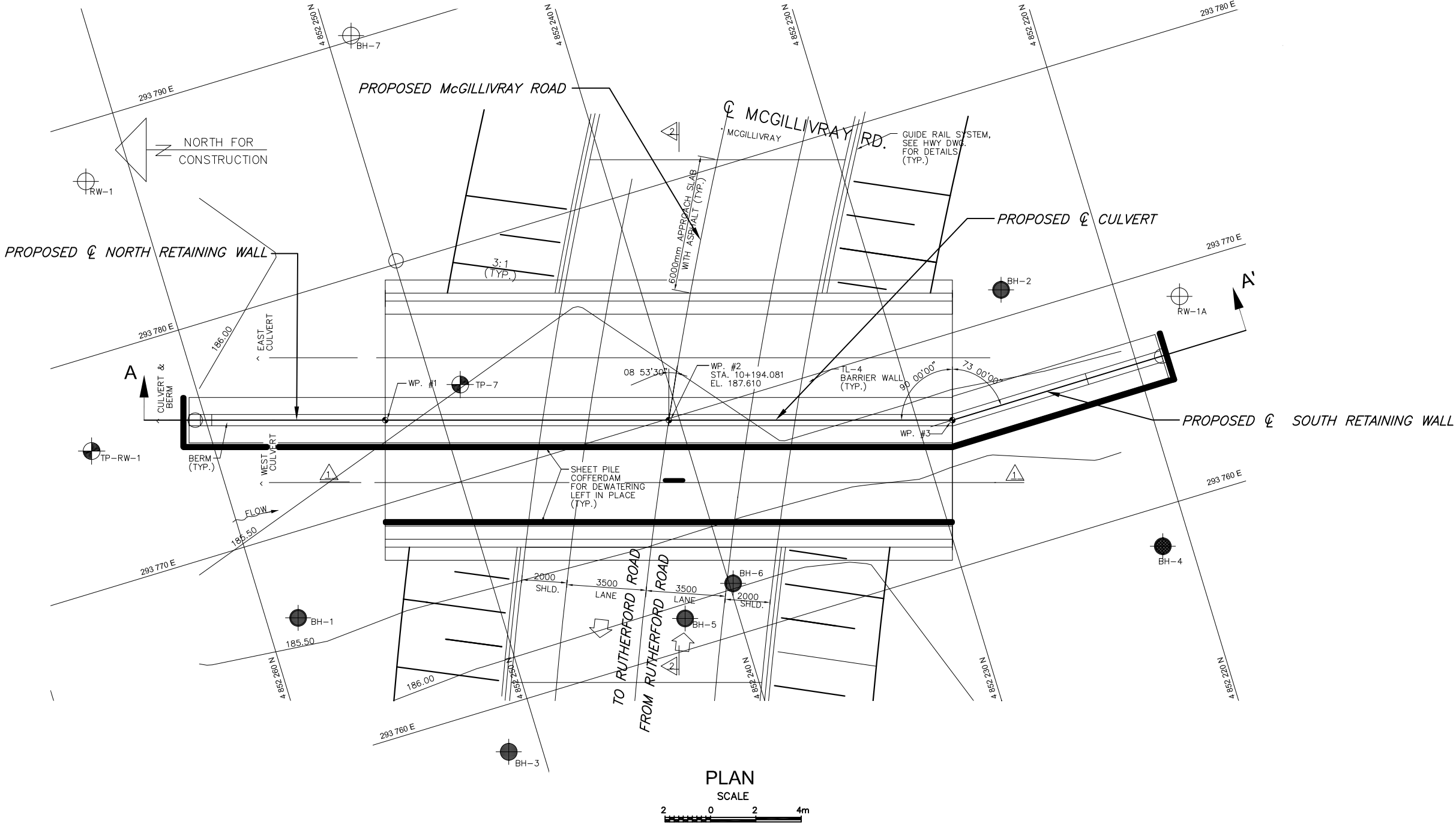
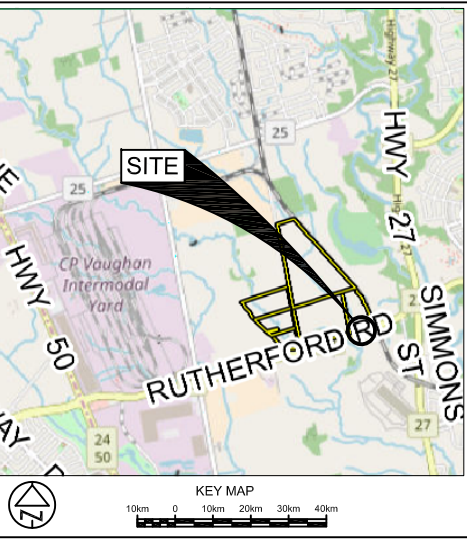
Results of Atterberg Limit Tests – Figures PC-1A/B/C, PC-2, and PC-3

CONT No 2019-2028
GWP No 2087-16-00
WP No



HIGHWAY 427 EXPANSION
EAST ROBINSON CREEK CULVERT
BOREHOLE PLAN

SHEET

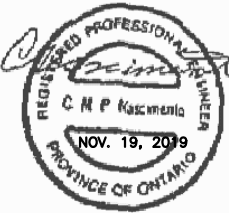
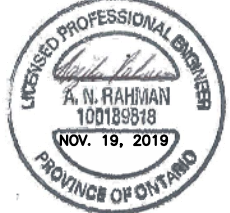


- NOTES:
- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
 - DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.
 - REFER TO DRAWING C-2 FOR PROFILE ALONG A-A'.

LEGEND			
	Borehole Location (Previous Investigation - January 2019)		
	Borehole Location (Current Investigation - October 2019)		
	Test Pit / Hand Auger Location		

BH No	ELEVATION	NORTHINGS	EASTINGS
PREVIOUS INVESTIGATION - JANUARY 2019			
BH-1	186.9	4 852 258.6	293 766.3
BH-2	186.1	4 852 224.8	293 771.2
BH-3	186.6	4 852 251.4	293 758.0
BH-4	186.1	4 852 221.2	293 758.3
BH-5	186.2	4 852 242.3	293 761.4
BH-6	186.2	4 852 239.8	293 762.2
CURRENT INVESTIGATION - OCTOBER 2019			
BH-7	186.1	4 852 249.4	293 793.3
RW-1	186.6	4 852 265.4	293 787.8
RW-1A	185.8	4 852 223.3	293 768.7
TP-7	184.8	4 852 248.8	293 774.1
TP-RW-1	186.2	4 852 265.2	293 776.0

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



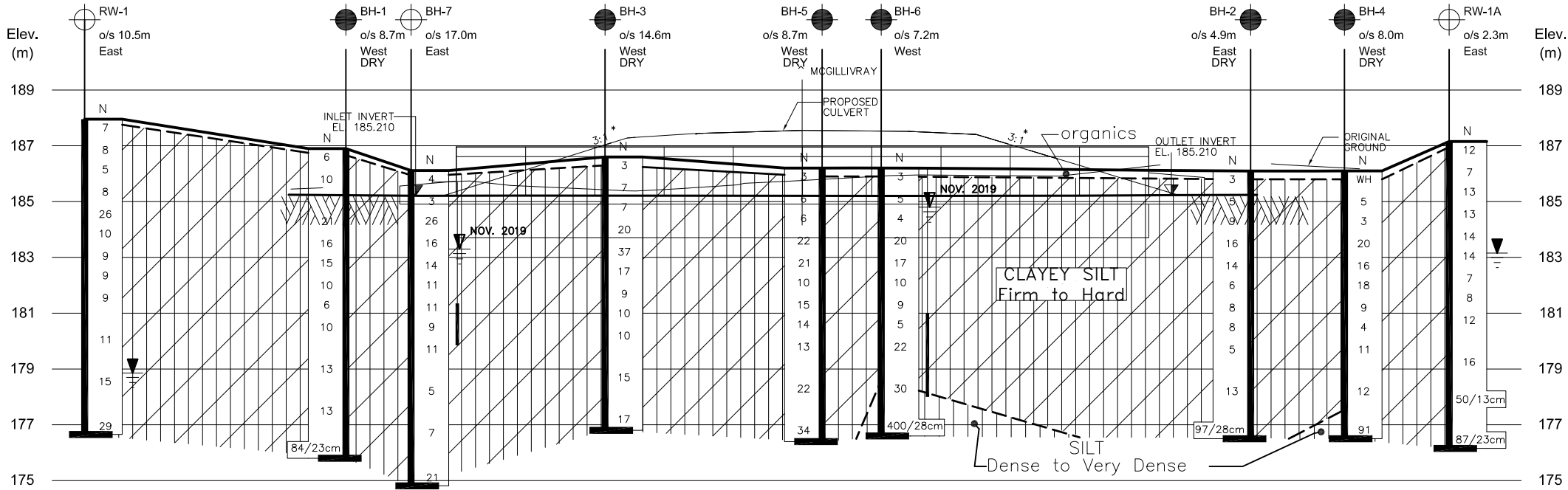
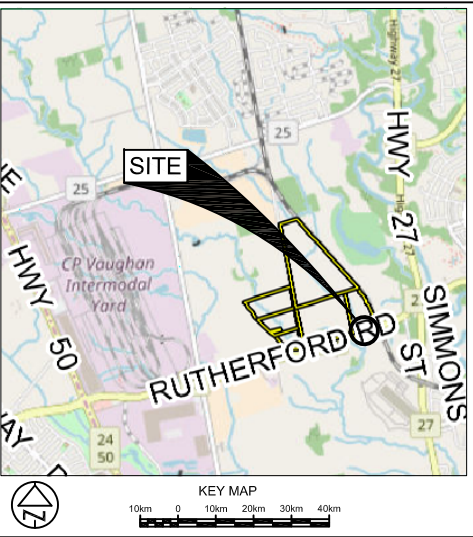
REF AECOM Drawing: 01_Realignment of McGillivray Rd._GA - Rotate Culvert.dwg, dated November 2019

REVISIONS			
DATE	BY	DESCRIPTION	
Geocres No. 30M13-230			
HWY No	427	DIST Central	
SUBM'D NL	CHECKED NR	DATE NOV. 19, 2019	SITE
DRAWN NL	CHECKED CN	APPROVED CN	DWG C-1

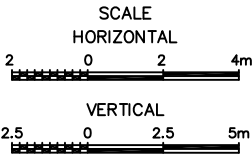
CONT No 2019-2028
GWP No 2087-16-00
WP No

HIGHWAY 427 EXPANSION
EAST ROBINSON CREEK CULVERT
SOIL STRATATIGRAPHY

SHEET



PROFILE ALONG A-A'



LEGEND

- BOREHOLE LOCATION (PREVIOUS INVESTIGATION - JANUARY 2019)
- BOREHOLE LOCATION (CURRENT INVESTIGATION - OCTOBER 2019)
- TEST PIT / HAND AUGER LOCATION
- N BLOWS / 0.3 m (STANDARD PENETRATION TEST, 475 J/BLOW)
- DRY WATER LEVEL NOT ENCOUNTERED UPON COMPLETION OF DRILLING
- NOV. 2019 WATER LEVEL IN PIEZOMETER
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
PREVIOUS INVESTIGATION - JANUARY 2019			
BH-1	186.9	4 852 258.6	293 766.3
BH-2	186.1	4 852 224.8	293 771.2
BH-3	186.6	4 852 251.4	293 758.0
BH-4	186.1	4 852 221.2	293 758.3
BH-5	186.2	4 852 242.3	293 761.4
BH-6	186.2	4 852 239.8	293 762.2
CURRENT INVESTIGATION - OCTOBER 2019			
BH-7	186.1	4 852 249.4	293 793.3
RW-1	186.6	4 852 265.4	293 787.8
RW-1A	185.8	4 852 223.3	293 768.7
TP-7	184.8	4 852 248.8	293 774.1
TP-RW-1	186.2	4 852 265.2	293 776.0

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 30M13-230			
HWY No 427	CHECKED NR	DATE NOV 19, 2019	DIST Central
SUBM'D NL	CHECKED MV	APPROVED CN	SITE
DRAWN NL			DWG C-2

- NOTES:
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 - DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.
 - REFER TO DRAWING C-1 FOR BOREHOLE LOCATION PLAN.



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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No BH-1

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 258.6 N; 293758.3 E ORIGINATED BY M.M.
DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
DATUM Geodetic DATE 2019.01.09 LATITUDE 43.81021 LONGITUDE -79.637144 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
186.9 0.0	Ground CLAYEY SILT, trace sand, trace gravel Stiff to very stiff, Brown to grey, Moist organics		1	SS	6		186							
			2	SS	10		185							
			3	SS	7		184							
			4	SS	21		183							
			5	SS	16		182							
			6	SS	15		181							
			7	SS	10		180							
			8	SS	6		179							
			9	SS	10		178							
			10	SS	13		177							
			11	SS	13		176							
			12	SS	84/23cm									
175.8 11.1	End of borehole													
	NOTES: 1. Groundwater was not encountered during or upon completion of drilling. 2. Borehole caved-in at a depth of 10.1 m below the ground surface.													

ONTARIO MTO 15TF013F.GPJ ONTARIO MTO.GDT 20-11-19

RECORD OF BOREHOLE No BH-2

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 224.8 N; 293 771.2 E ORIGINATED BY M.M.
DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
DATUM Geodetic DATE 2019.01.11 LATITUDE 43.809905 LONGITUDE -79.637082 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
186.1 0.0	Ground						186													
							185													
							184													
							183													
							182													
							181													
							180													
							179													
							178													
							177													
176.5 9.6	End of borehole																			
NOTES: 1. Groundwater was not encountered during or upon completion of drilling. 2. Borehole caved-in at a depth of 8.3 m below the ground surface.																				

ONTARIO MTO 15TF013F.GPJ ONTARIO MTO.GDT 20-11-19

RECORD OF BOREHOLE No BH-3

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 251.4 N; 293 758.0 E ORIGINATED BY M.M.
 DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
 DATUM Geodetic DATE 2019.01.09 LATITUDE 43.810145 LONGITUDE -79.637247 CHECKED BY C.N.

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 (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL	×					LAB VANE							
186.6 0.0	Ground <div>organics</div>																							
	SILTY CLAY, some sand, trace gravel Firm, Brown, Moist		1	SS	3													2	16	47	35			
			2	SS	7																			
	CLAYEY SILT, trace/some sand, trace gravel Stiff to very stiff, Brown to grey, Moist		3	SS	7																			
			4	SS	20													9	11	53	27			
			5	SS	37																			
			6	SS	17																			
			7	SS	9																			
			8	SS	10													1	7	65	27			
			9	SS	10																			
			10	SS	15																			
			11	SS	17																			
176.8 9.8	End of borehole																							
NOTES: 1. Groundwater was not encountered during or upon completion of drilling. 2. No cave-in was noted in the borehole upon extraction of hollow stem augers.																								

ONTARIO MTO 15TF013F.GPJ ONTARIO MTO.GDT 20-11-19

RECORD OF BOREHOLE No BH-4

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 221.2 N; 293 758.3 E ORIGINATED BY M.M.
 DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
 DATUM Geodetic DATE 2019.01.10 LATITUDE 43.809874 LONGITUDE -79.637242 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				W _p W W _L WATER CONTENT (%)				
186.1 0.0	Ground <div>CLAYEY SILT, trace sand, trace gravel Firm to very stiff, Brown to grey, Moist to wet</div> <div>organics</div>		1	SS	WH		186								0 11 62 27	
			2	SS	5		185									
			3	SS	3		184									
			4	SS	20		183									
			5	SS	16		182									
			6	SS	18		181									
			7	SS	9		180									
			8	SS	4		179									
			9	SS	11		178									
			10	SS	12		177									
177.5 8.6	SILT, trace sand Very dense, Grey, Moist		11	SS	91										0 2 84 14	
176.5 9.6	End of borehole															
NOTES: 1. Groundwater was not encountered during or upon completion of drilling. 2. No cave-in was noted in the borehole upon extraction of hollow stem augers.																

ONTARIO MTO 15TF013F.GPJ ONTARIO MTO.GDT 20-11-19

RECORD OF BOREHOLE No BH-5

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 242.3 N; 293 761.4 E ORIGINATED BY M.M.
DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
DATUM Geodetic DATE 2019.01.09 LATITUDE 43.810063 LONGITUDE -79.637205 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
186.2 0.0	Ground CLAYEY SILT, trace sand, trace gravel Stiff to very stiff, Brown to grey, Moist to wet organics		1	SS	3		186							
			2	SS	6		185							
			3	SS	6		184							
			4	SS	22		183							1 9 58 32
			5	SS	21		182							1 9 63 27
			6	SS	10		181							
			7	SS	15		180							1 12 62 25
			8	SS	14		179							
			9	SS	13		178							
			10	SS	22		177							
176.4 9.8	End of borehole hard		11	SS	34									
NOTES: 1. Groundwater was not encountered during or upon completion of drilling. 2. No cave-in was noted in the borehole upon extraction of hollow stem augers.														

ONTARIO MTO 15TF013F.GPJ ONTARIO MTO.GDT 20-11-19

RECORD OF BOREHOLE No BH-6

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 239.8 N; 293 758.3 E ORIGINATED BY M.M.
 DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
 DATUM Geodetic DATE 2019.01.10 LATITUDE 43.810041 LONGITUDE -79.637194 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W _p	W	W _L			WATER CONTENT (%)									
186.2 0.0	Ground SILTY CLAY, trace sand Firm, Brown, Moist		1	SS	3		20	40	60	80	100														
			2	SS	5																				
			3	SS	4																				
	CLAYEY SILT, trace sand, trace gravel Firm to very stiff, Brown to grey, Moist to wet		4	SS	20																				
			5	SS	17																				
			6	SS	10																				
			7	SS	9																				
			8	SS	5																				
			9	SS	22																				
178.6 7.6	SILT, trace sand, Very dense, Grey, Moist		10	SS	30																				
			11	SS	400/28cm																				
176.6 9.6	End of borehole																								
<div><div><div><div></div><div></div><div></div></div><div>Groundwater observed during drilling</div></div><div><div><div></div><div></div><div></div></div><div>Groundwater measured in monitoring well</div></div><div><div>Monitoring Well Readings:</div><table><thead><tr><th>Date</th><th>Depth (m)</th><th>Elev.</th></tr></thead><tbody><tr><td>Feb.12/19</td><td>1.40</td><td>184.8</td></tr><tr><td>Nov.19/19</td><td>1.50</td><td>184.7</td></tr></tbody></table></div><div><div>Monitoring Well Legend:</div><div><div><div></div><div></div><div></div></div><div>PVC Pipe Stick-up</div></div><div><div><div></div><div></div><div></div></div><div>Bentonite Seal</div></div><div><div><div></div><div></div><div></div></div><div>Filter Sand</div></div><div><div><div></div><div></div><div></div></div><div>Screen</div></div></div></div> <div><div>NOTES:</div><div><div>1.</div><div>Groundwater was not encountered upon completion of drilling.</div></div><div><div>2.</div><div>No cave-in was noted in the borehole upon extraction of hollow stem augers.</div></div></div>																	Date	Depth (m)	Elev.	Feb.12/19	1.40	184.8	Nov.19/19	1.50	184.7
Date	Depth (m)	Elev.																							
Feb.12/19	1.40	184.8																							
Nov.19/19	1.50	184.7																							

ONTARIO MTO 15TF013F.GPJ ONTARIO MTO.GDT 20-11-19

RECORD OF BOREHOLE No BH-7

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 249.4 N; 293 793.3 E ORIGINATED BY M.M.
 DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
 DATUM Geodetic DATE 2019.10.16 LATITUDE 43.810127 LONGITUDE -79.636809 CHECKED BY C.N.

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
186.1 0.0	Ground CLAYEY SILT, trace/some sand, trace gravel Soft, Brown/grey, Moist 														

RECORD OF BOREHOLE No RW-1

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 265.4 N; 293 787.8 E ORIGINATED BY M.M.
 DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
 DATUM Geodetic DATE 2019.10.16 LATITUDE 43.810271 LONGITUDE -79.636877 CHECKED BY N.R.

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 (%)										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa																			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE																			
186.6 0.0	Ground <div>CLAYEY SILT, trace/some sand, trace gravel Firm to very stiff, Brown/Grey</div> <div>organics</div>		1	SS	7		186										0 15 64 21										
			2	SS	8		185											5 12 56 27									
			3	SS	5		184												1 12 63 24								
			4	SS	8		183																				
			5	SS	26		182																				
			6	SS	10		181																				
			7	SS	9		180																				
			8	SS	9		179																				
			9	SS	9		178																				
			10	SS	11		177																				
			11	SS	15		176																				
			12	SS	29																						
175.3 11.3	End of borehole																										
	Groundwater measured upon completion of drilling																										
	NOTE: Borehole caved-in at a depth of 7.6 m (El. 179.0) below the existing ground surface, upon extraction of hollow stem augers.																										

ONTARIO MTO 15TF013F.GPJ ONTARIO MTO.GDT 20-11-19

RECORD OF BOREHOLE No RW-1A

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 223.3 N; 293 768.7 E ORIGINATED BY M.M.
 DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
 DATUM Geodetic DATE 2019.10.16 LATITUDE 43.809892 LONGITUDE -79.637114 CHECKED BY N.R.


SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
185.8 0.0	Ground							20	40	60	80	100	20	40	60					
	CLAYEY SILT, trace/some sand, trace organics gravel		1	SS	12									○						
	Firm to stiff, Brown/grey, Moist		2	SS	7									○						
			3	SS	13									○						
			4	SS	13									○						
			5	SS	14									○						
			6	SS	14									○						
			7	SS	7									○						
			8	SS	8									○						
			9	SS	12									○						
			10	SS	16									○						
			11	SS	50/13cm									○						
			12	SS	87/23cm									○						
174.8 11.0																				
		</																		

RECORD OF TEST HOLE No TP-7

1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 248.8 N; 293 774.1 E ORIGINATED BY F.M.
 DIST Central HWY 427 BOREHOLE TYPE Manual Hand Augers COMPILED BY N.L.
 DATUM Geodetic DATE 2019.11.01 LATITUDE 43.810122 LONGITUDE -79.637048 CHECKED BY N.R.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			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					W _p	W	W _L		
184.8 0.0	Ground CLAYEY SILT, trace sand, trace gravel Grey, Wet		1	CS		184											
			2	CS													
183.3 1.5	End of test pit		3	CS													

RECORD OF TEST HOLE No TP-RW-1

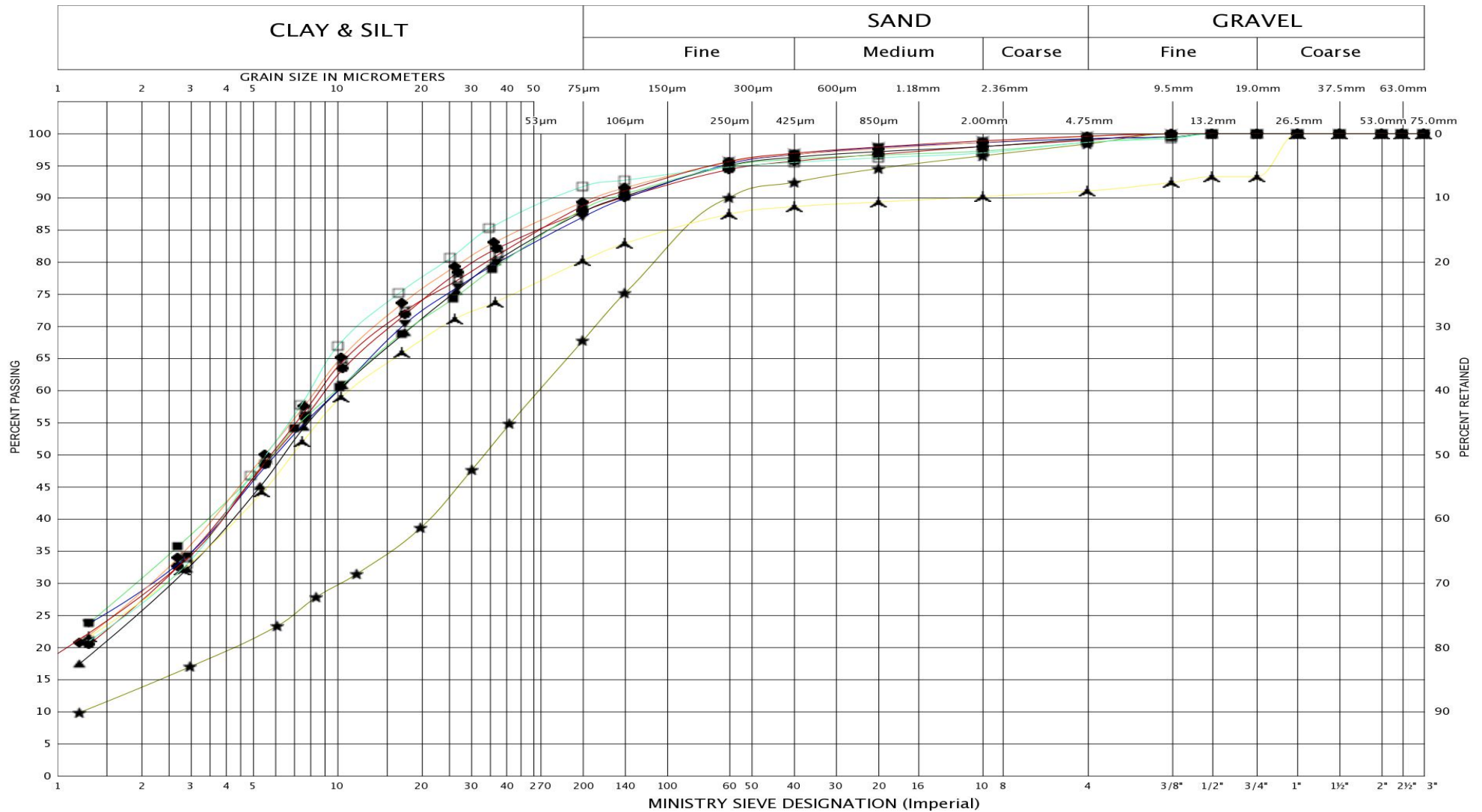
1 OF 1

METRIC

G.W.P. #32 LOCATION Coords: 4 852 265.2 N; 293 776.0 E ORIGINATED BY F.M.
 DIST Central HWY 427 BOREHOLE TYPE Manual Hand Augers COMPILED BY N.L.
 DATUM Geodetic DATE 2019.11.01 LATITUDE 43.810269 LONGITUDE -79.637024 CHECKED BY N.R.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
186.2 0.0	Ground		1	CS			186							
	CLAYEY SILT, trace sand, trace gravel		2	CS			185							
	Grey, Wet		3	CS										
184.7 1.5	End of test pit													

UNIFIED SOIL CLASSIFICATION SYSTEM



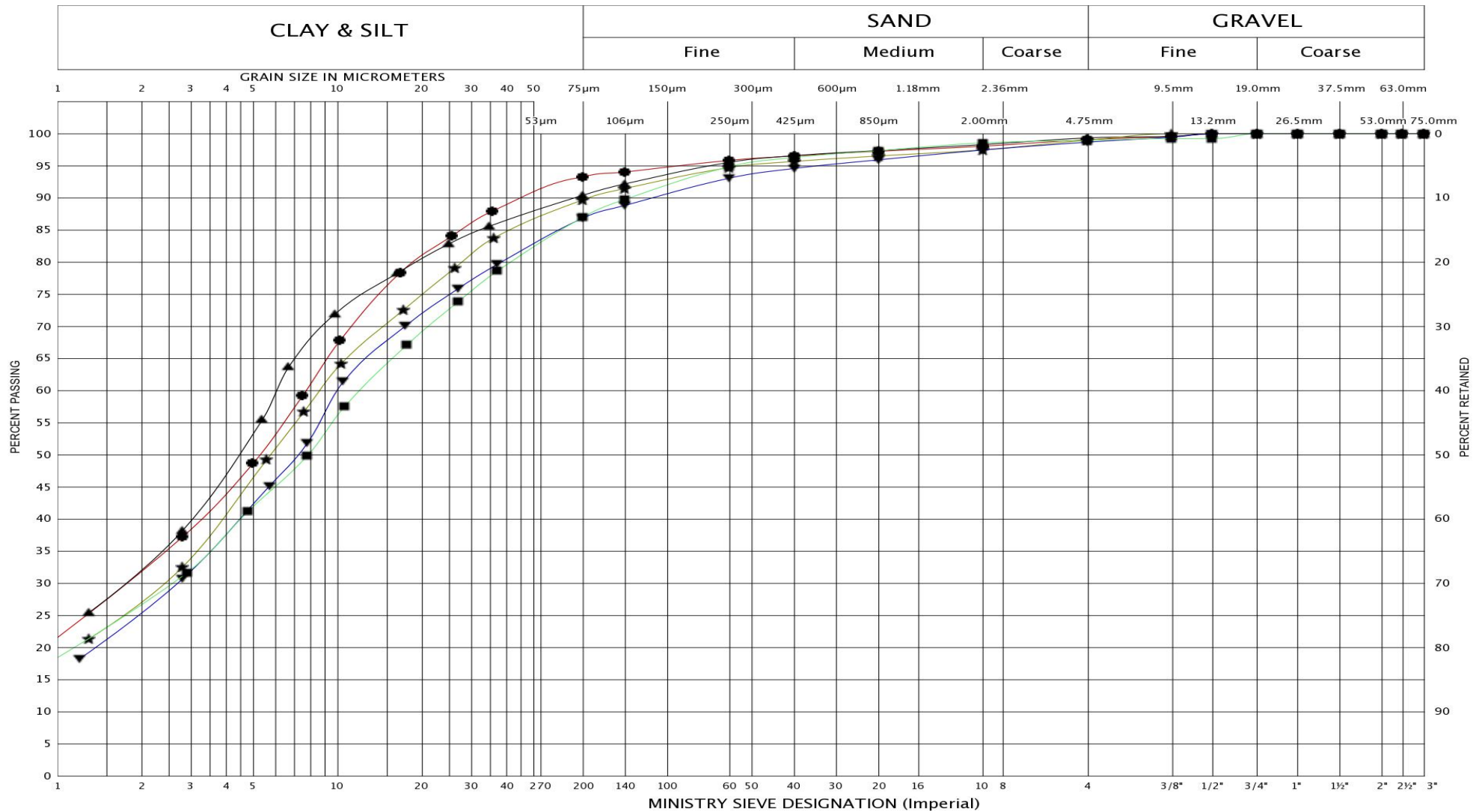
LEGEND	BH	BH-1	BH-1	BH-1	BH-2	BH-2	BH-2	BH-3	BH-3	BH-4
SAMPLE	4	6	10	3	4	6	4	7	5	
SYMBOL	●	▲	★	▼	◆	■	▲	□	⊠	



GRAIN SIZE DISTRIBUTION
CLAYEY SILT, trace sand, trace gravel

FIG No.: GS-1A
HWY : 427
WO #32

UNIFIED SOIL CLASSIFICATION SYSTEM



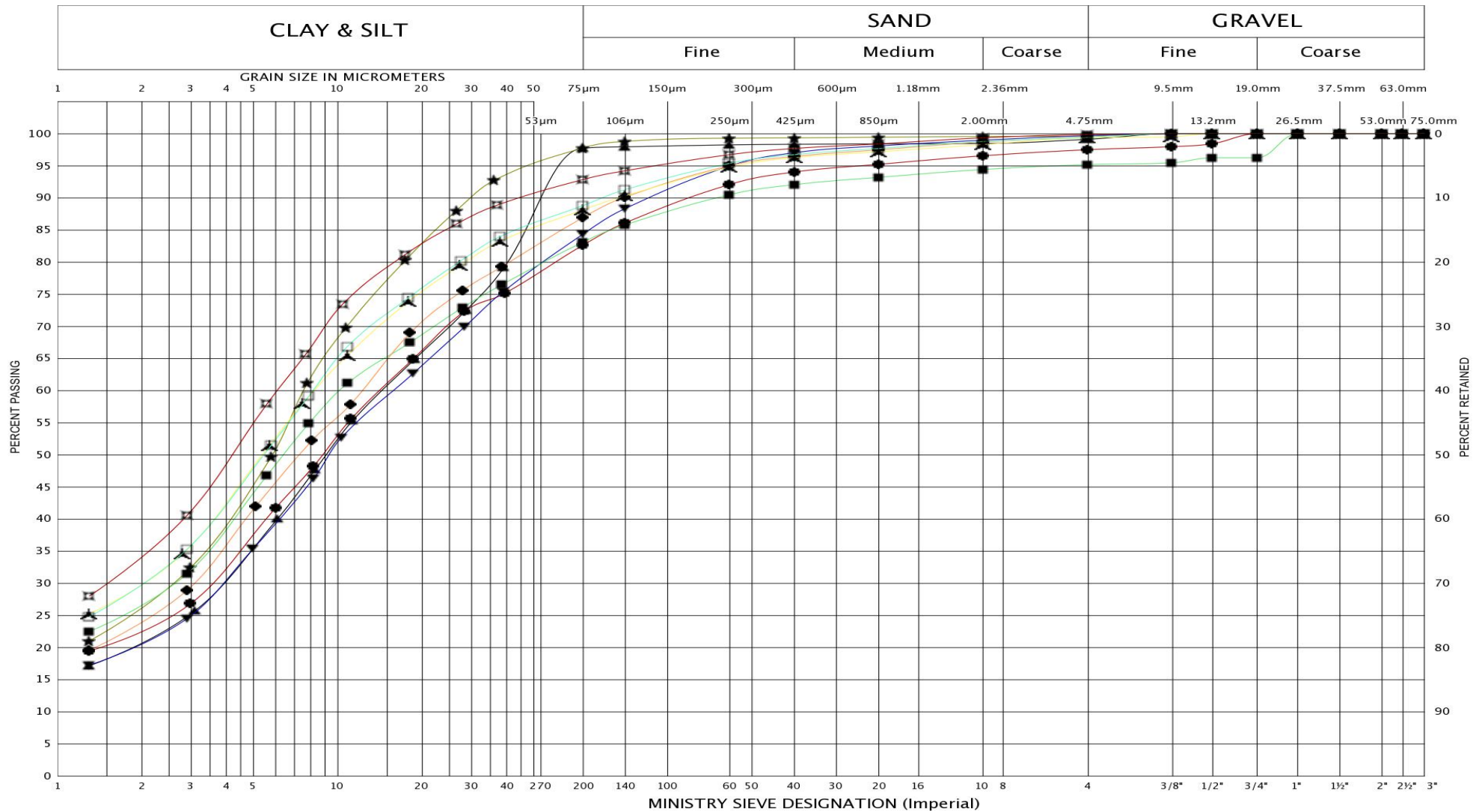
LEGEND	BH	BH-4	BH-5	BH-5	BH-5	BH-6
	SAMPLE	8	5	6	9	4
	SYMBOL	●	▲	★	▼	■



GRAIN SIZE DISTRIBUTION
CLAYEY SILT, trace sand, trace gravel

FIG No.: GS-1B
HWY : 427
WO #32

UNIFIED SOIL CLASSIFICATION SYSTEM



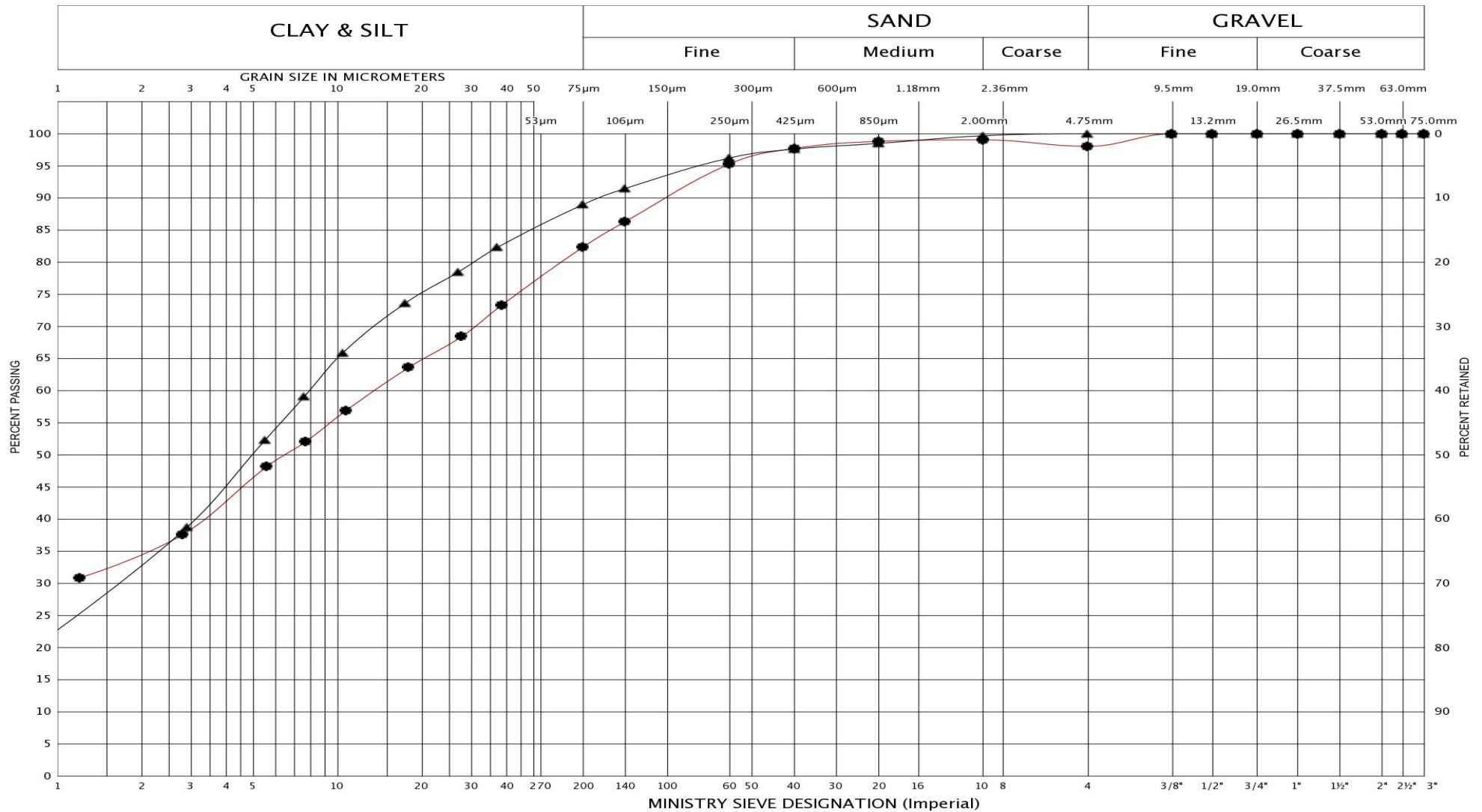
LEGEND	BH	RW-1A	RW-1	RW-1A	RW-1	RW-1A	RW-1	BH-7	BH-7	BH-7
	SAMPLE	4	5	6	7	8	9	6	8	10
	SYMBOL	▲	▼	□	■	⊠	◆	●	▲	★



GRAIN SIZE DISTRIBUTION
CLAYEY SILT, trace/some sand, trace gravel

FIG No.: GS-1C
HWY : 427
WO #32

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	BH-3	BH-6
	SAMPLE	2	3
	SYMBOL	●	▲



GRAIN SIZE DISTRIBUTION

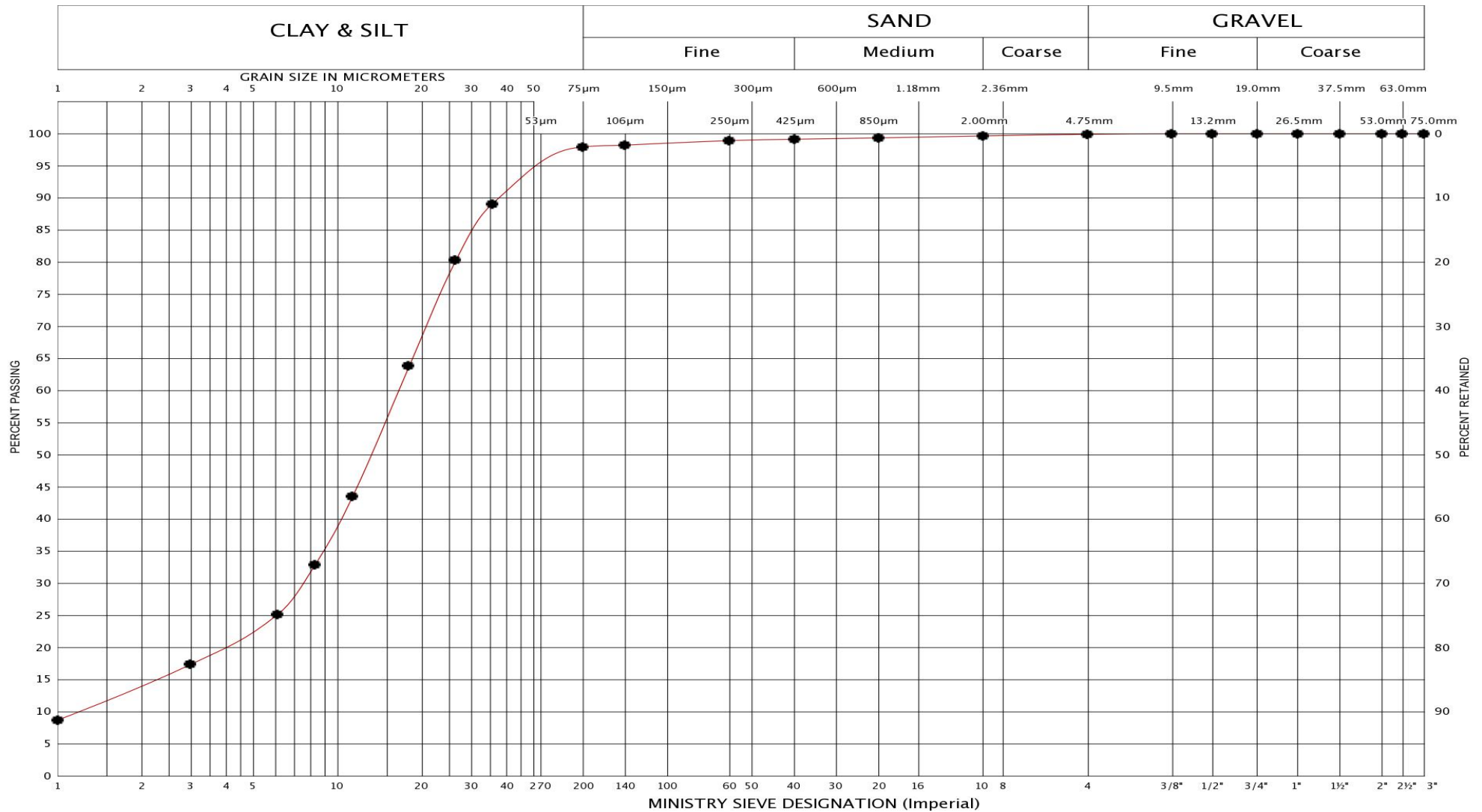
SILTY CLAY, trace/some sand

FIG No.: GS-2

HWY : 427

WO #32

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	BH-4
	SAMPLE	11
	SYMBOL	•



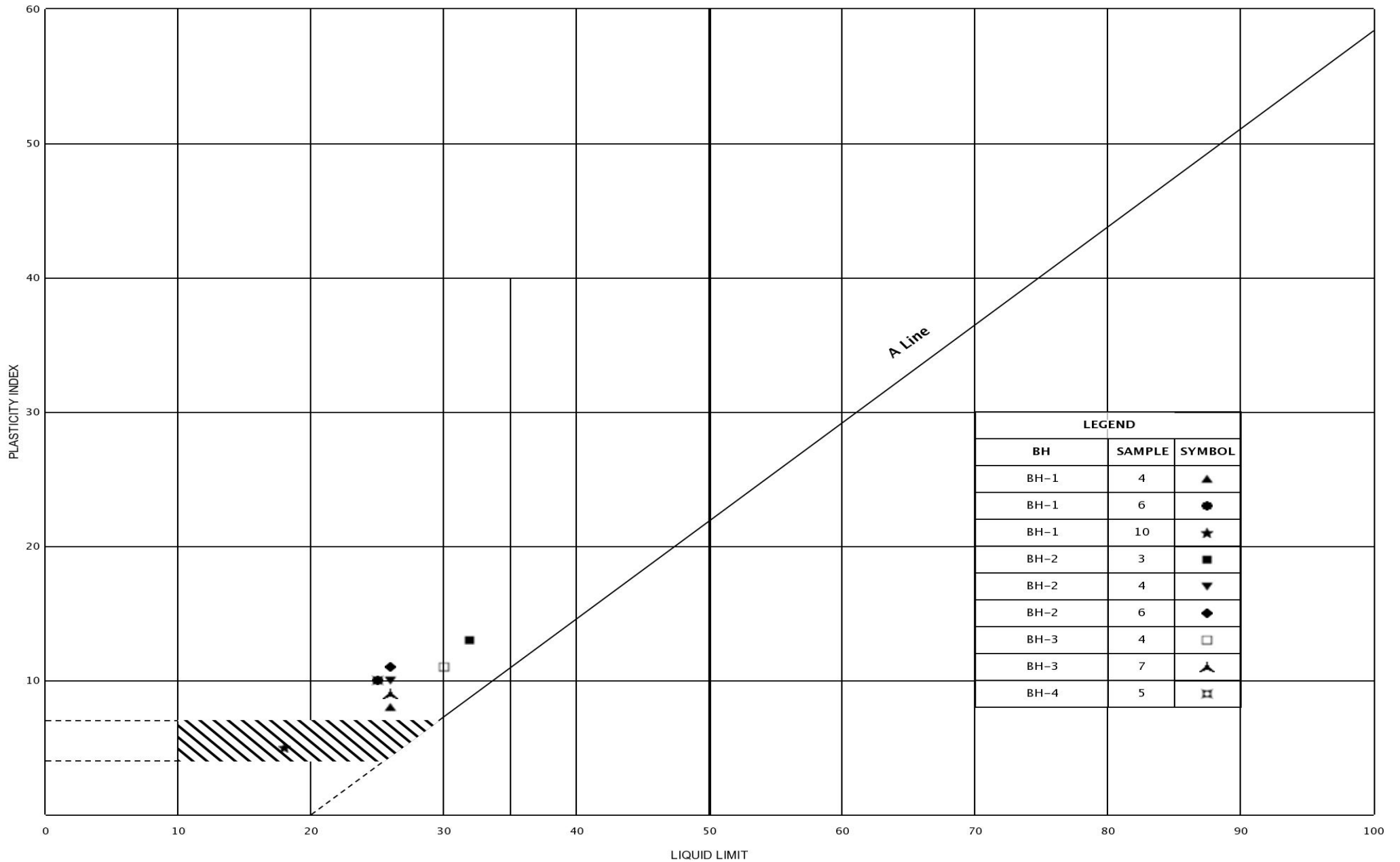
GRAIN SIZE DISTRIBUTION

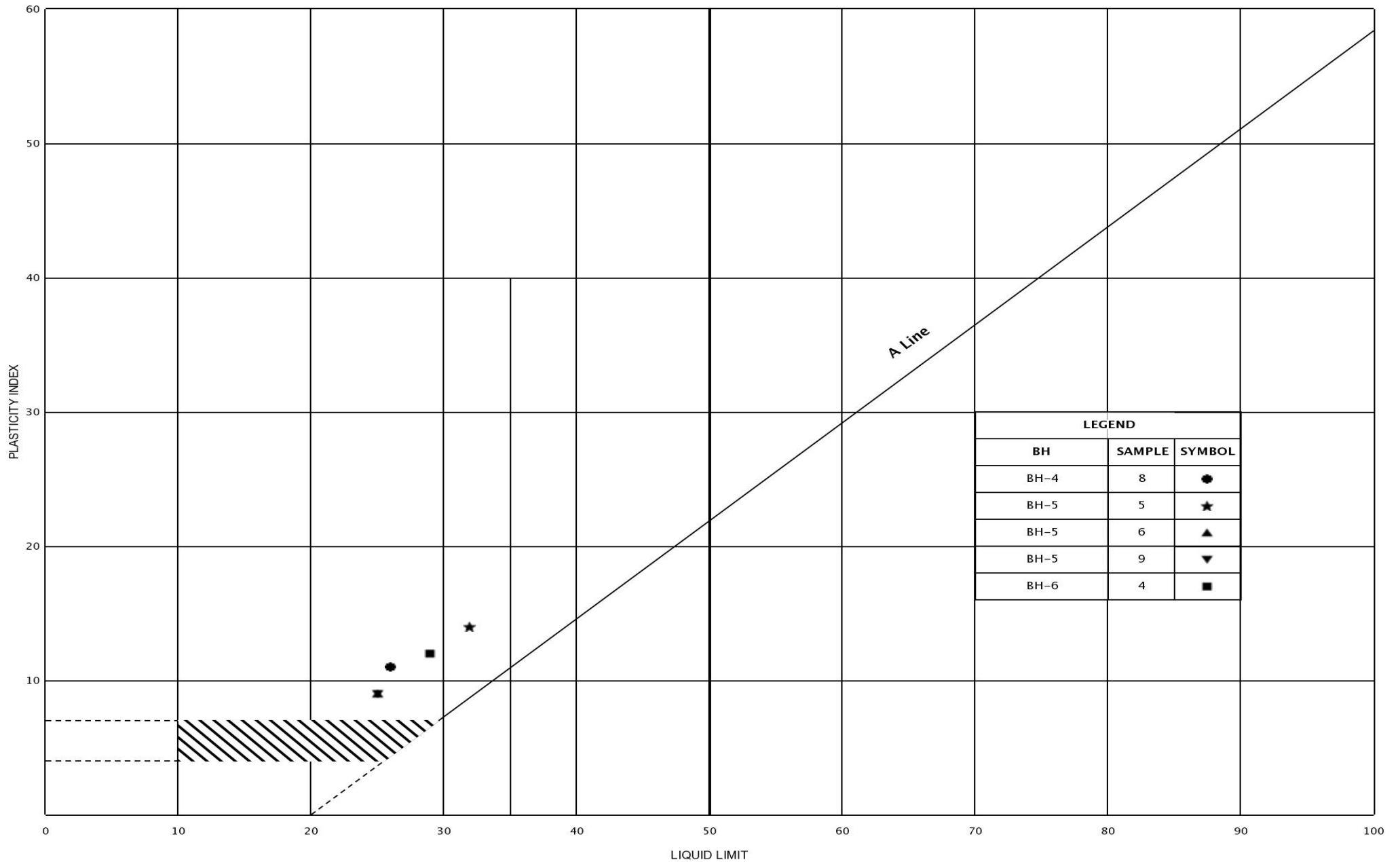
SILT, trace sand

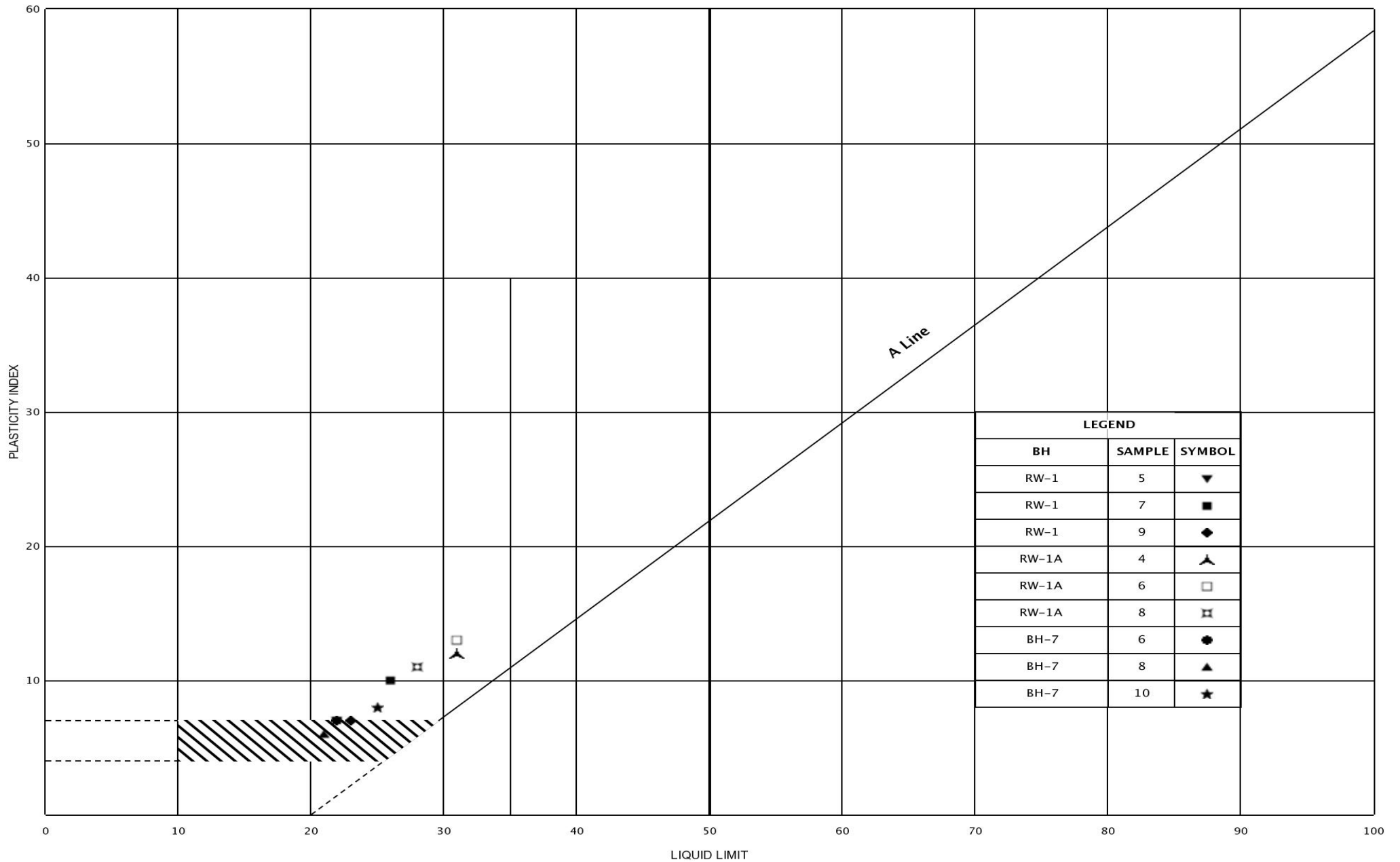
FIG No.: GS-3

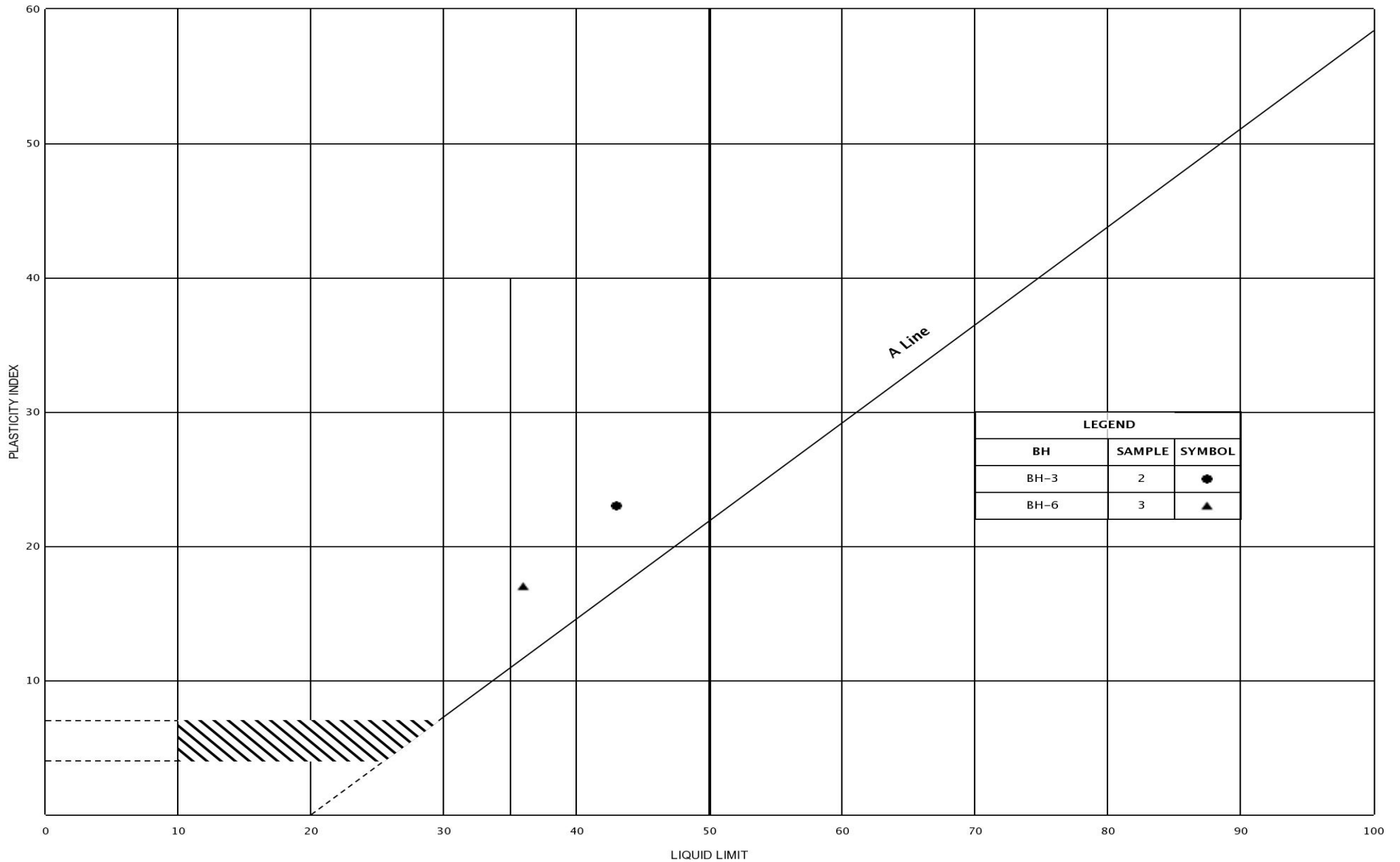
HWY : 427

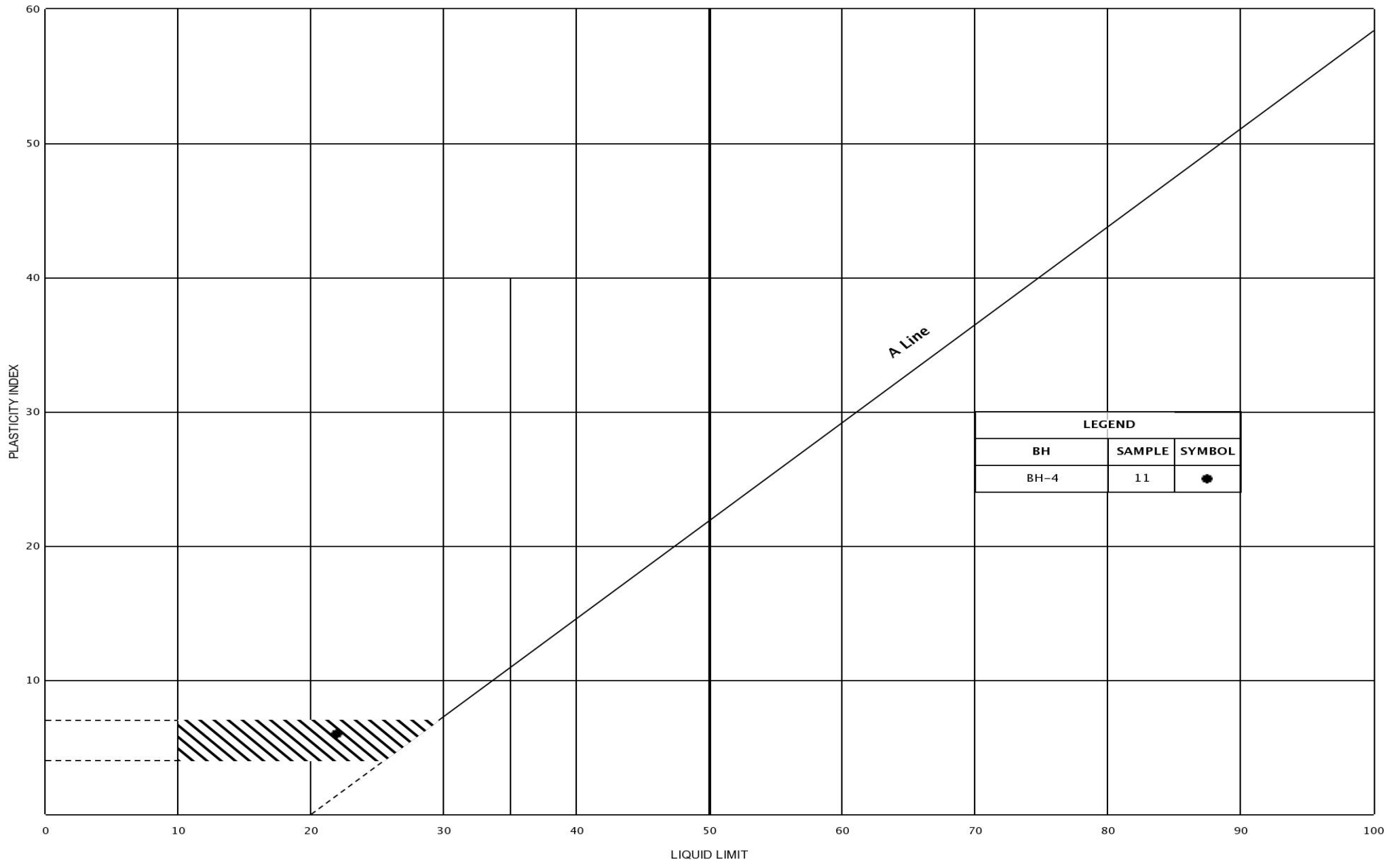
WO #32













PART B – FOUNDATION DESIGN REPORT

for

**HIGHWAY 427 EXPANSION – MCGILLIVRAY ROAD REALIGNMENT
EAST ROBINSON CREEK CULVERT
CITY OF VAUGHAN, ONTARIO
ASSIGNMENT NO. 2014-E-0056
WORK ORDER #32
LATITUDE AND LONGITUDE: 43.810071,-79.653889**

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November 20, 2019



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PART B - FOUNDATION DESIGN REPORT

Highway 427 Expansion - McGillivray Road Realignment
East Robinson Creek Culvert
City of Vaughan, Ontario
Assignment No. 2014-E-0056, Work Order #32

7. INTRODUCTION

This foundation investigation and design report with the interpretation and recommendations are intended for the use of AECOM on behalf of MTO, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. 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 recommendations for foundation design 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 new culvert at the crossing of McGillivray Road and the East Robinson creek in the City of Vaughan, York Region.

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

8.2 Proposed Culvert

The GA drawing, dated November 2019, and the information provided by AECOM on March 13, 2019, indicates that the proposed structure will be a 25 m long open type cast-in-place (CIP) concrete culvert with twin-cell, each with an opening size of 5.0 m in span and approximately 1.5 m in rise from the invert levels. The twin-cell culvert will consist of a 350 mm thick roof slab supported by 350 mm thick outside walls and a 500 mm thick wall in the middle. An asphalt and waterproofing system with a combined thickness of 90 mm will be added to the floor slab for a total roof thickness of 440 mm.



The GA drawing indicates that the inverts (creek bed) of the culvert at the west and east inlets are proposed to be at about El. 185.3 and El. 185.4, respectively. The inverts (creek bed) of the culvert at the west and east outlets are proposed to be at about El. 185.1 and El. 185.3, respectively. The strip footing for the open type culvert is proposed to be located at a depth of 1.5 m below the creek bed at about El. 183.7.

Based on the GA drawing, the alignment of proposed culverts will be on a skew of approximately 8.5 degrees to the new center line alignment of McGillivray Road. The structural arrangement of the culvert includes 6.0 m long approach slabs on both sides of the culvert. Berm walls will be constructed at the two ends of the proposed culvert.

The existing ground surface in the vicinity of the culvert alignments varies from approximately Elevations 184.8 m to 186.9 m.

Based on the information provided on March 13, 2019, the middle wall of the CIP open type concrete culvert is expected to impose a load of 460 kN/m at Ultimate Limit State (ULS) and 310 kN/m at Serviceability Limit State (SLS) at the founding level of the strip footing. The side walls are expected to impose a load of 310 kN/m at ULS and 200 kN/m at SLS. The combined loadings of middle wall and side walls indicated above may result in an imposed load of approximately 65 kPa at SLS and 100 kPa at ULS, if a CIP concrete box culvert is opted.

8.3 Structure Foundation

In summary, the subsoil conditions consist of 200 mm to 300 mm organics immediately below the ground surface, underlain by soft to firm silty clay to clayey silt to about El. 184.5. Below about El. 184.5, the subsoil consists of stiff to hard clayey silt. The clayey silt layer near the southwest side of the culvert outlet is immediately underlain by very dense silt at about El. 178.6 to El. 177.5, which extends to the termination depth of 9.6 m (El. 176.5), below the existing ground surface. The groundwater level was observed only in one borehole at El. 181.6 during drilling. Groundwater was encountered at El. 181.8 to El. 177.0 in three boreholes upon completion of drilling. The water level in the East Robinson Creek was observed at approximately El. 186.0 during the fieldwork in October 2019.



As per Clause 6.5.1 of CHBDC 2014, the consequence classification should be determined by the Regulatory Authority (MTO). However, in the absence of any information, consequence level was assumed as “Typical” with a consequence factor of 1.0.

The feasibility of the following two options is discussed for the design of proposed new culvert:

- Open type footing Cast-In Place (CIP) concrete culvert, and
- CIP concrete box culvert.

Considering the subsoil conditions, the recommendations for the new culvert are provided below in the order of preference. A comparison of the technical advantages and disadvantages for the new culvert are presented in Table 8.3.

Table 8.3: Comparison of Alternate Culvert Options

Option 1: Three-Sided CIP Open Type Culvert	Option 2: CIP Concrete Box Culvert
Advantages: <ol style="list-style-type: none"> 1. Generally allows for natural streambed to remain intact 2. Less accumulation of sediments in the upstream of channel 3. Adequate geotechnical resistance is available at the founding level 4. Reduced environmental impact on East Robinson Creek 	Advantages: <ol style="list-style-type: none"> 1. Adequate geotechnical resistance is available at the founding level 2. Culvert may be placed at a shallower depth than open type 3. Reduces uneven settlement 4. Reduces water leakage and deterioration of culvert 5. Ability withstand differential settlements
Disadvantages: <ol style="list-style-type: none"> 1. Probability of uneven or differential settlements is high 2. Limited ability to withstand differential settlements 	Disadvantages: <ol style="list-style-type: none"> 1. Natural stream bed will not remain intact 2. Cause sediment accumulation in the upstream of the channel 3. Possibility for degradation of subgrade 4. Environmental impacts on East Robinson Creek 5. Significant area of excavation
Recommended	Environmentally not preferred But Recommended



8.3.1 Option 1: Three Sided Open Type CIP Concrete Culvert on Strip Footing

Based on the information provided by AECOM, it is assumed that the footing for three sided CIP concrete culvert will be placed at about El. 183.7. The subsoil conditions below elevation of about El. 184.0 are capable of supporting the culvert placed on strip footings.

The clayey silt deposit at the invert level is not susceptible to scour and capable of providing adequate geotechnical resistance to support the culvert on strip footings. The strip footings placed at or below El. 183.7 may be designed assuming factored geotechnical resistances of 250 kPa at ULS and 170 kPa at SLS. A total settlement of 15 mm to 20 mm may be expected under the recommended factored geotechnical resistance of 170 kPa with a footing width of 1.5 m to 2.0 m.

The clayey silt layer at the subgrade 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 100 mm thick concrete working slab (lean concrete) be placed on the subgrade within four hours after preparation, inspection, and approval of the foundation subgrade.

8.3.2 Option 2: CIP Concrete Box Culvert

In case a CIP concrete box culvert is considered, it may be placed at a subgrade level no higher than El. 184.5. The twin cell CIP concrete box culvert may be designed assuming a factored geotechnical resistance of 175 kPa at ULS and 120 kPa at SLS. A total settlement of 15 to 20 mm under the geotechnical resistance at SLS may be expected.

In order to limit the degradation of the founding soil, it is recommended 100 mm thick concrete working slab (lean concrete) be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade.

In view of the environmental sensitivity of the project area, this option is not preferred.

8.3.3 Recommended Option for New Culvert

From a geotechnical perspective and based on the subsurface conditions, three-sided open type precast concrete culvert placed at about El. 183.7 is the preferred option for the new culvert.

Option 2 is technically feasible. However, considering the environmental impact that would be imposed on East Robinson Creek, this option is not preferred.



9. 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 both 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 9.0: Recommended Geotechnical Parameters

GEOTECHNICAL PARAMETER	GRANULAR A or GRANULAR B TYPE II	GRANULAR B TYPE I
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.

10. BERM WALLS

Based on the GA drawing, dated November 2019, a berm wall, consisting of a low-rise CIP concrete earth retaining wall, is proposed at each end of the culvert. The north berm wall is proposed to be approximately 8.7 m in length and the south berm wall is proposed to be approximately 9.7 m in length.

Based on the Berm Wall Details drawings dated November 2019, provided by AECOM on November 4, 2019, the south berm wall will be at a skew of approximately 17 degrees to the center line of the culvert alignment. The proposed footings for the berm walls will be 2.0 m wide and 0.6 m high, and will be placed at the same founding elevation as the proposed culvert, El. 183.7. The wall height above the footing will vary approximately from 0.8 m to 1.9 m and the wall thickness will be maintained at 500 mm.

The berm wall foundations may be designed assuming a factored geotechnical resistance of 175 kPa at ULS and 120 kPa at SLS. A total settlement of 15 to 20 mm under the geotechnical resistance at SLS may be expected.

For design purposes, active earth pressure coefficient presented in Section 9.0 of this report should be considered for lateral resistance. A weeping tile system and weeping holes should be incorporated behind the berm walls to avoid excess build-up of hydrostatic pressures, as outlined in Section 14 of this report.

The sliding resistance of footings against lateral loads between the concrete footing and subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC (2014). The sliding resistance for cast in place concrete footings constructed on concrete working slabs and on top of very stiff clayey silt are as follows:

- Cast-In-Place footing on concrete working slab: = 0.6
- Cast-In-Place concrete working slab on very stiff clayey silt: = 0.6



The ground surface around the berm walls, including the surface behind the top of the wall, should be protected from potential erosion caused by the peak flows and overtopping of the creek. It is recommended to place rock protection or a concrete revetment on the ground in accordance with OPSS.PROV 511. The rock protection material should conform to OPSS.PROV 1004. PML understands from the discussions with AECOM that the proposed realignment of McGillivray Road is located within the flood plain and the road is not designed for overtopping of East Robinson Creek.

11. APPROACH EMBANKMENTS

The existing ground surface in the vicinity of the culvert alignments varies from approximately Elevations 186.1 m to 186.9 m. The proposed grade of McGillivray Road along the centerline varies from El. 186.7 to El. 186.8. The height of embankment fill required above the culverts to the proposed grade of re-aligned McGillivray Road at approximately Station 9+795.1 is not expected to exceed 0.6 m, including the pavement structure, above the culvert. Based on the GA drawing, the height of the proposed embankment above the existing ground level is not expected to exceed about 1.5 m. Considering the subsoil conditions at this site, no major instability problems are anticipated for the embankments constructed with 2H:1V side slope or flatter. Any spongy or soft area observed within the base of the embankment should be removed before placing the fill.

Riprap 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 the 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.

12. FOUNDATION FROST DEPTH

In accordance with OPSD 3090.100, a minimum of 1.2 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.



13. SEISMIC CONSIDERATIONS

The reference Peak Ground Acceleration (PGA) for the project site is 0.096 based on the longitude and latitude coordinates of the proposed structure (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. The 2015 National Building Code Seismic Hazard Calculation sheet is included in Appendix B.

14. COVER AND BACKFILL

Backfilling adjacent to abutment and retaining structures should be carried out in conformance with OPSS 902. The minimum requirement of granular backfill material behind abutment should be in accordance with OPSD 3101.150 and for retaining walls should be in accordance with OPSD 3121.150. The granular material should be in accordance OPSS.PROV 1010.

A weeping tile system (OPSD 3190.100) and/or weep holes should be installed to minimize the build-up of hydrostatic pressure behind the wall. The weeping tiles should be surrounded by a properly designed granular filter or geotextile to prevent migration of fines into the system. The drainage pipe should be installed on a positive grade.

15. EXCAVATION

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, amended by SP 105S09 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 the new culvert will be advanced through native silty clay to clayey silt deposit. All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO Regulations for Construction Projects. According to Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, the very stiff cohesive soil is considered as Type 2 soil. The stiff cohesive soil is considered as Type 3 soil. Soils below groundwater table and soils showing persistent seepages are considered



having the characteristics of a Type 4 soil. The open cut procedure will be governed by soils with the highest soil type number.

16. GROUNDWATER CONTROL

The groundwater level was measured at El. 184.8, and the excavation to the founding level will have to be carried out under approximately 1.6 m high water level. A temporary dewatering system may be required to construct the strip footing for the culvert in the dry condition. The groundwater level should be lowered to a minimum of 0.5 m below the proposed founding level of the strip footings to allow for construction in the dry and to place the footings.

In case Option 2 is opted, 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 the lean concrete.

For construction in the dry, the creek may have to be temporarily diverted and a cofferdam may be required. 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 infiltration is anticipated, a more positive dewatering scheme is required to lower the water level a minimum of 0.5 m below the base of excavation. Such a dewatering scheme may require the construction of a dewatering system incorporating an appropriately designed sheet pile or prefabricated trench box cofferdam.

17. TEMPORARY WORKS

The contractor shall be responsible for the selection, performance, and detailed design of the temporary shoring and/or dewatering system. The dewatering system should be designed to conform to the requirement of OPSS.PROV 517, amended by SP 517F01, in addition to the NSSP provided in Appendix B.

In accordance with SP 517F01, the dewatering system should be designed by a designer with a minimum 5 years of experience in the field. A preconstruction survey is not required due to the relatively large distances to critical private properties.



18. CLOSURE

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

Yours very truly,

Peto MacCallum Ltd.



Nazibur Rahman, P.Eng.
Project Engineer, Geotechnical Services



Carlos M.P. Nascimento, P.Eng.
Project Manager and
MTO Designated Principal Contact

NL/NR/MV/CN:nl-nk



APPENDIX B

2015 National Building Code Seismic Hazard Calculation

List of Standard Specifications Relevant to Report

Non-Standard Special Provisions (NSSP)

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Site: 43.810N 79.654W

User File Reference: East Robinson Creek Culvert

2019-11-15 15:49 UT

Requested by: Peto MacCallum Ltd.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.138	0.077	0.045	0.011
Sa (0.1)	0.175	0.103	0.062	0.017
Sa (0.2)	0.154	0.093	0.059	0.019
Sa (0.3)	0.121	0.075	0.049	0.017
Sa (0.5)	0.091	0.058	0.038	0.013
Sa (1.0)	0.051	0.033	0.022	0.006
Sa (2.0)	0.026	0.016	0.010	0.003
Sa (5.0)	0.006	0.004	0.002	0.001
Sa (10.0)	0.003	0.002	0.001	0.000
PGA (g)	0.096	0.056	0.034	0.010
PGV (m/s)	0.073	0.044	0.028	0.008

Notes: Spectral ($S_a(T)$, where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information



Natural Resources
Canada

Ressources naturelles
Canada

Canada



LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

DOCUMENT	TITLE
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Temporary Protection Systems
OPSS 902	Excavation and Backfilling of Structures
OPSS.PROV 1004	Material Specification for Aggregates - Miscellaneous
OPSS.PROV 1010	Material Specification For Aggregates - Base, Subbase, Select Subgrade, And Backfill Material
SP 105S09	Amendment to OPSS 539, November 2014
SP 517F01	Amendment to OPSS 517, November 2016
OPSD 810.010	General Rip-Rap Layout Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration depths for Southern Ontario
OPSD 3190.100	Walls, Retaining And Abutment, Wall Drain
OPSD 3101.150	Walls, Abutment, Backfill, Minimum Granular Requirement
OPSD 3121.150	Walls, Retaining, 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 the creek bed in-the-dry, whichever is applicable.

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.