Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT
for
RETAINING WALLS
HIGHWAY 401 AT BROCK STREET
W.O. 09-20009, WP 2123-10-00
WHITBY, ONTARIO

PETO MacCALLUM LTD.
165 CARTWRIGHT AVENUE
TORONTO, ONTARIO
M6A 1V5
Phone: (416) 785-5110
Fax: (416) 785-5120
Email: toronto@petomaccallum.com

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PML Ref.: 10TF008A-RW
Index No.: 079FIR and 080FDR
GEOCRES No.: 30M15-319
December 13, 2017

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FOUNDATION INVESTIGATION REPORT

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for
Retaining Walls
Highway 401 at Brock Street
W.O. 09-20009, WP 2123-10-00
Whitby, Ontario

1. INTRODUCTION

This report summarises the results of a foundation investigation carried out for construction of retaining walls associated with a widening of Highway 401 at the Brock Street interchange in Whitby, Ontario. The investigation was conducted for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

Highway 401 crosses under Brock Street at approximate Station 13+858, Highway 401 chainage (ref. General Arrangement drawing 'Highway 401 / Brock Street Underpass' prepared by AECOM in September 2014).

The project involves construction of two retaining walls west and east of Brock Street to the south of Highway 401. The first retaining wall (RW1) is envisaged to be located along the W-E/W ramp and the second retaining wall (RW2) just north of the GO transit and CN railways some 200 m south of Highway 401 and east of Brock Street.

The report provides subsurface information pertaining to the proposed retaining walls.

All elevations in this report are expressed in meters.

2. SITE DESCRIPTION AND GEOLOGY

The site is situated at the Highway 401 and Brock Street interchange in the Town of Whitby, Ontario. Highway 401 is oriented in the west-east direction at the site.

The study area is located in the physiographic region known as the Iroquois Plain (“Physiography of Southern Ontario” by Chapman and Putnam and Map 1050A of Lindsay-Peterborough Area, for Ontario, published by the Geological Survey of Canada). In general, the plain is a mosaic of lacustrine sandy and clayey deposits with till plains and drumlins. Small drainage courses and creeks currently drain the area southerly towards Lake Ontario.

The topography at the site is irregular in detail, with soils underlain by bedrock of the Whitby Formation that typically comprises grey and black shale according to the Aggregate Resources Inventory of the Town of Whitby published by the Ontario Geological Survey, Paper 41. The bedrock in the vicinity of the site is less than 15 m deep.

3. INVESTIGATION PROCEDURES

The fieldwork for this study was carried out during the period of February 28 to March 2, 2017 and comprised seven boreholes advanced to depths of 7.1 to 10.0 m. The previous borehole SRW-4 is relevant for retaining wall RW1, with its subsurface data used in preparation of this report. The borehole locations are indicated on Drawings RW1-1 and RW2-1 in Appendix FIR-A.

The locations of the boreholes were established in the field by Peto MacCallum Ltd. The coordinates of and ground surface elevations at the boreholes were provided by Callon-Dietz Inc.

The boreholes were advanced using continuous flight solid stem augers, powered by truck-mounted D-50 and track-mounted CME-55 drill rigs, supplied and operated by a specialist drilling contractor, working under the full-time supervision of a member of our engineering staff.

Representative soil samples were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests (SPT) were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

Groundwater conditions at the borehole locations were assessed during drilling by visual examination of soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in an open borehole. Piezometers were installed in boreholes RW1-1, RW1-2, RW2-1 and RW2-3, with two sets of readings taken. Upon completion of drilling and piezometer readings, the boreholes were backfilled with bentonitecement grout where required in accordance with the MTO guidelines and MOE Regulation 903 for borehole abandonment procedures.

Soils were identified in the field in accordance with the MTO Soil Classification procedures. Recovered soil samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determination. Atterberg limits testing (8) and grain size distribution analyses (16) were conducted on selected soil samples. The laboratory test results are presented in Appendix FIR-B and on the corresponding logs.

4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, boundary elevations, standard penetration test data and groundwater observations. The results of laboratory Atterberg limits testing, grain size distribution analyses and natural moisture content determination are also shown on the Record of Borehole sheets.

The borehole locations are shown on Drawings RW1-1 and RW2-1. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

The strata encountered are summarised below.

4.1 Retaining Wall RW1

The subsurface stratigraphy revealed in the boreholes drilled at the site of retaining wall RW1 generally comprised topsoil over fill underlain by sand and/or clayey silt till mantling weathered shale. Cobbles were encountered in one borehole. The piezometric water level was at depths of 3.4 to 4.9 m (elevation 83.9 to 84.1) in boreholes RW1-1 and RW1-2.

4.1.1 Topsoil

Surficial topsoil was present in boreholes RW1-1 to RW1-3. The silty topsoil was 200 to 300 mm thick and penetrated at elevation 87.3 to 88.5.

4.1.2 Fill

Present surficially in borehole SRW-4 or directly beneath the topsoil at depths of 0.2 to 0.3 m (elevation 87.3 to 88.5) in boreholes RW1-1 to RW1-3 was fill consisting of clayey silt with interbedded sandy units. The fill was firm to hard in consistency (compact to dense within sandy layers) and 7 to 26% in moisture content. The fill had a thickness of 2.3 to 4.3 m and was penetrated at depths of 2.3 to 4.5 m (elevation 82.6 to 85.8). It is noteworthy that cobbles were encountered in the clayey silt fill in borehole RW1-2.

The results of grain size distribution analysis conducted on a sample of the sand fill are presented in Figure RW1-GS-1.

4.1.3 Sand

Overlain by the fill at a depth of 2.3 m (elevation 82.6) in borehole SRW-4 was a layer of cohesionless sand. This layer was compact in relative density (SPT-‘N’ values of 16 and 26) and had a moisture content of 14 to 15%. The sand was 2.2 m thick and penetrated at 4.5 m depth (elevation 80.4).

The results of grain size distribution analysis performed on a sample of the sand are presented in Figure RW1-GS-2.

4.1.4 Clayey Silt Till

Underlying the fill at depths of 3.0 to 4.5 m (elevation 83.0 to 85.8) in boreholes RW1-1 to RW1-3 was a cohesive deposit of clayey silt till. Containing a layer of silt in borehole RW1-2, this deposit was 2.6 to 6.8 m in thickness and very stiff to hard in consistency, its moisture content varying between 7 and 20%. The clayey silt till extended to probable bedrock inferred at depths of 7.1 to 9.8 m (elevation 79.0 to 81.0).

The results of Atterberg limits testing and grain size distribution analyses conducted on 4 cohesive samples of the deposit are presented in respective Figures RW1-PC-1 and RW1-GS-3. The liquid and plastic limits of the clayey silt till ranged from 15 to 23 and from 10 to 14 respectively, with a plasticity index of 4 to 9.

4.1.5 Silt

Non-plastic silt was revealed within the clayey silt till at a depth of 6.4 m (elevation 82.4) in borehole RW1-2. This unit was 1.1 m thick and dense to very dense. The silt was penetrated at 7.5 m depth (elevation 81.3).

The results of grain size distribution analysis performed on the silt sample are presented in Figure RW1-GS-4.

4.1.6 Bedrock

Weathered shale was encountered at a depth of 7.5 m (elevation 77.4) in borehole SRW-4 and inferred at depths of 7.1 to 9.8 m (elevation 79.0 to 81.0) in boreholes RW1-1 to RW1-3.

4.1.7 Groundwater

In the process of augering, water was detected at depths of 2.3 to 6.4 m (elevation 82.3 to 83.2) in boreholes RW1-1 to RW1-3 and SRW-4. Upon completion of drilling, groundwater was at a depth of 3.0 m (elevation 81.9) in borehole SRW-4 and not observed in the remaining boreholes.

Two piezometers were installed in boreholes RW1-1 and RW1-2. Two sets of piezometer readings subsequently taken showed water levels to be at the following depths / elevations:

Table 4.1.7 – Water Levels in Piezometers (RW1)

BOREHOLE NO.	MARCH 20, 2017		APRIL 16, 2017	
	DEPTH, m	ELEVATION	DEPTH, m	ELEVATION
RW1-1	3.6	83.9	3.4	84.1
RW1-2	5.1	83.7	4.9	83.9

The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.2 Retaining Wall RW2

The subsurface stratigraphy revealed in the boreholes drilled at the site of retaining wall RW2 comprised topsoil over clayey silt / clay overlying clayey silt till underlain by sand mantling weathered shale. The piezometric water level was at depths of 0.4 to 0.7 m (elevation 81.4 to 82.6) in boreholes RW2-1 and RW2-3.

4.2.1 Topsoil

Surficial topsoil was present in boreholes RW2-1 to RW2-4. The silty topsoil was 200 to 300 mm thick and penetrated at elevation 81.4 to 83.0.

4.2.2 Clayey Silt / Clay

Directly beneath the topsoil at depths of 0.2 to 0.3 m (elevation 81.4 to 83.0) in all the boreholes was clayey silt / clay. This unit was firm to very stiff in consistency and 15 to 46% in moisture content. The clayey silt / clay had a thickness of 1.0 to 2.3 m and was penetrated at depths of 1.3 to 2.5 m (elevation 79.1 to 82.0).

The results of Atterberg limits testing and grain size distribution analyses performed on 2 samples of the unit are presented in respective Figures RW2-PC-1 and RW2-GS-1. The liquid and plastic limits of the clay were 55 and 20 respectively, thus giving a plasticity index of 35.

4.2.3 Clayey Silt Till

Overlain by the clayey silt / clay at depths of 1.3 to 2.5 m (elevation 79.1 to 82.0) in boreholes RW2-1 to RW2-4 was a cohesive deposit of clayey silt till. This deposit was 1.8 to 3.1 m in thickness and firm to very stiff in consistency, its moisture content varying between 12 and 31%. The clayey silt till was penetrated at depths of 3.1 to 5.6 m (elevation 76.0 to 80.2).

The results of Atterberg limits testing and grain size distribution analyses conducted on 3 samples of the deposit are presented in respective Figures RW2-PC-2 and RW2-GS-2. The clayey silt till had a liquid limit of 20 and 21, a plastic limit of 11, its plasticity index being 9 to 10.

4.2.4 Sand

Underlying the clayey silt till at depths of 3.1 to 5.6 m (elevation 76.0 to 80.2) in all the boreholes was cohesionless sand. This stratum was compact to very dense (SPT-‘N’ values of 17 to over 87) and had a moisture content of 5 to 12%. The sand was 3.9 to 5.8 m thick and penetrated at depths of 9.5 to 9.6 m (elevation 72.0 to 72.8) in boreholes RW2-2 to RW2-4. The stratum was not penetrated upon termination of drilling at 10.0 m depth (elevation 73.3) in borehole RW2-1.

The results of grain size distribution analyses performed on 4 samples of the sand are presented in Figure RW2-GS-3.

4.2.5 Bedrock

Weathered shale was encountered at depths of 9.5 to 9.6 m (elevation 72.0 to 72.8) in boreholes RW2-2 to RW2-4.

4.2.6 Groundwater

In the process of augering, water was detected at depths of 1.5 to 3.8 m (elevation 78.0 to 80.2) in boreholes RW2-1 to RW2-4. Upon completion of drilling, groundwater was measured at depths of 0.6 to 2.7 m (elevation 80.6 to 81.6) in boreholes RW2-1, RW2-2, RW2-4 and a depth of 7.3 m (elevation 74.5) in borehole RW2-3.

Two piezometers were installed in boreholes RW2-1 and RW2-3. Two sets of piezometer readings subsequently taken showed water levels to be at the following depths / elevations:

Table 4.2.6 – Water Levels in Piezometers (RW2)

BOREHOLE NO.	MARCH 20, 2017		APRIL 16, 2017	
	DEPTH, m	ELEVATION	DEPTH, m	ELEVATION
RW2-1	0.8	82.5	0.7	82.6
RW2-3	0.4	81.4	0.4	81.4

The piezometric water level was 2.4 to 5.2 m above the top of the sand stratum. It appears that artesian conditions are in existence at the site of retaining wall RW2.

The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

5. CLOSURE

The field work was carried out under the supervision of Mr. S. Aziz, Technician, and Mr. M. Vaccaro, B.Eng, E.I.T., under the coordination of Ms. N. Leong-Sem, B.Eng, and direction of Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer. The equipment was supplied by Tri-Phase Group.

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer

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

GD/CN:nk

APPENDIX FIR-A

Explanation of Terms Used in Report

Record of Borehole Sheets

Drawings RW1-1 and RW2-1 – Borehole Locations

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/0.3 m)	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:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL
e	1,%	VOID RATIO

n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX $= w_L - w_P$
I_L	1	LIQUIDITY INDEX $= \frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX $= \frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT

e_{max}	1,%	VOID RATIO IN LOOSEST STATE
e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

RECORD OF BOREHOLE SHEETS
FOR RETAINING WALL RW1

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No SRW-4

METRIC

TASK No. 09-20009 LOCATION Co-ord: 4 858 603.8 N; 350 019.5 E ORIGINATED BY S.A.

DIST Durham **HWY** 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.K.

DATUM Geodetic DATE May 02, 2014 CHECKED BY C.N.

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
84.9	Ground Surface							
0.0	Clayey silt, rootlets organics. Firm, Dark brown, Moist	1	SS	4			○	
	Sand, with gravel some silt, trace clay. Dense, Brown, Moist	2	SS	47		84	○	22 57 17 4
	Clayey silt shale fragments. Stiff, Brown, Moist (FILL)	3	SS	14		83	○	
82.6 / 2.3	Sand, with silt trace clay. Compact, Grey, Wet	4	SS	26	▽ (82.6)		○	0 70 27 3
		5	SS	16	▼ (82.0)	82 / 81	○	
80.4 / 4.5	Clayey silt trace sand, trace gravel. Hard, Grey, Moist (TILL)	6	SS	50/10cm		80	○	
		7	SS	84/28cm		79 / 78	○	
77.4 / 7.5	Weathered shale	8	SS	70/10cm				
77.2 / 7.7	End of borehole. Samples 6 to 8: Sampler bouncing							

* 2014 05 02

▽ Water level observed during drilling

▼ Water level measured after drilling

Column headings not used: STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

5 Numbers refer to Sensitivity

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

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No RW1-1

METRIC

TASK No. 2009-E-0038 LOCATION Coords: 4 858 595.4 N ; 350 054.8 E ORIGINATED BY S.A.

DIST Durham **HWY** 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 01, 2017 CHECKED BY C.N.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	Water content (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
87.5	Ground Surface						
87.3	Topsoil						
0.2	Clayey silt, sand inclusions, organic inclusions. Firm to very stiff, Dark brown/grey, Moist	1	SS	3	87	o	
		2	SS	15		o	
		3	SS	23	86	o	
	Silty sand layered, wet sand seams, organic inclusions. Compact to dense, Brown/grey, Moist	4	SS	32	85	o	
	Clayey silt, trace gravel (FILL)	5	SS	31	84	o	
83.0					83		
4.5	Clayey silt with sand, some gravel. Very stiff, Grey, Moist. sand layers. Hard, Wet to moist (TILL)	6	SS	28	82	o ├┤	11 22 49 18
		7	SS	54	81		
80.4		8	SS	50/5cm			
7.1	End of borehole. Refusal on probable bedrock						

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; STRAT PLOT; GROUND WATER CONDITIONS.

* 2017 03 01

▽ Water level observed during drilling

▼ Water level measured in Monitoring Well

Water Level Readings:

Date	Depth (m)	Elev.
Mar.20/'17	3.6	83.9
Apr.16/'17	3.4	84.1

Monitoring Well Legend:

- Flush cover and concrete
- Bentonite seal
- Filter sand
- Screen

5 Numbers refer to Sensitivity

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

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No RW1-2

METRIC

TASK No. 2009-E-0038 LOCATION Coords: 4 858 590.8 N ; 350 101.9 E ORIGINATED BY S.A.

DIST Durham **HWY** 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 02, 2017 CHECKED BY C.N.

ELEV / DEPTH (m)	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
88.8	Ground Surface						
88.5 / 0.0–0.3	Topsoil	1	SS	7			
	Clayey silt, rootlets, organic inclusions, cobbles; Firm to very stiff, Brown/dark brown, Moist	2	SS	24		88	
	Gravelly sand; Compact to dense	3	SS	35		87	
85.8 / 3.0	Clayey silt, sand seams; Very stiff to hard, Dark brown/grey, Moist (FILL)	4	SS	48		86	
	Clayey silt, sandy, trace gravel; Very stiff to hard, Brown/grey, Moist (TILL)	5	SS	30		85	8 48 32 12
		6	SS	42	Water level measured in monitoring well	84	
82.4 / 6.4						83	
	Silt, some sand, trace clay, trace gravel; Dense to very dense, Grey, Wet	7	SS	43	Water level observed during drilling	82	1 12 81 6
81.3 / 7.5	Clayey silt, sandy, trace to some gravel; Hard, Brown/grey, Moist (TILL); wet sand seams	8	SS	77		81	10 37 42 11
						80	
79.0 / 9.8	End of borehole; Refusal on probable bedrock	9	SS	92/20cm		79	

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

* 2017 03 02

▽ Water level observed during drilling

▼ Water level measured in Monitoring Well

Water Level Readings:

Date	Depth (m)	Elev.
Mar.20/'17	5.1	83.7
Apr.16/'17	4.9	83.9

Monitoring Well Legend:

- Flush cover and concrete
- Bentonite seal
- Filter sand
- Screen

5 Numbers refer to Sensitivity; 20 / 15 –○– 5 / 10 (%) STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No RW1-3

METRIC

TASK No. 2009-E-0038 LOCATION Coords: 4 858 545.0 N ; 350 115.3 E ORIGINATED BY S.A.

DIST Durham **HWY** 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 01, 2017 CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
88.7	Ground Surface						
0.0 / 88.4	Topsoil	1	SS	4			
0.3	Clayey silt, sand and gravel inclusions, rootlets. Firm, Dark brown, Moist	2	SS	6			
	Silty clay, brick debris, rootlets, organic inclusions. Stiff, Dark brown/brown, Moist	3	SS	17			
	Clayey silt, trace gravel. Very stiff, Dark brown/grey, Moist (FILL)	4	SS	23			
		5	SS	23			
84.2 / 4.5	Clayey silt with sand, trace gravel. Very stiff, Brown/grey, Moist	6	SS	24			1 23 62 14
	wet sand seams				▽		
	Hard, Grey (TILL)	7	SS	72/28cm			
81.0 / 7.7	End of borehole. Refusal on probable bedrock	8	SS	50/8cm			

NOTE:
Another borehole 2 m to the west was augered to refusal at 7.6m depth

* 2017 03 01

▽ Water level observed during drilling

Elevation scale: 88, 87, 86, 85, 84, 83, 82, 81

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

5 Numbers refer to Sensitivity

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

RECORD OF BOREHOLE SHEETS
FOR RETAINING WALL RW2

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No RW2-1

METRIC

TASK No. 2009-E-0038 LOCATION Coords: 4 858 413.0 N ; 350 323.1 E ORIGINATED BY Mi.V.

DIST Durham **HWY** 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE February 28, 2017 CHECKED BY C.N.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
83.3	Ground Surface					
0.0 83.0	Topsoil					
0.3	Clayey silt trace to some sand; Very stiff to stiff; Brown/grey; Moist	1	SS	21	83	
		2	SS	11		
82.0 1.3	Clayey silt with sand to sandy some to trace gravel; Stiff to very stiff; Brown/grey; Moist (TILL)	3	SS	13	82	10 29 39 22
		4	SS	19	81	
		5	SS	21		4 33 37 26
80.2 3.1	Sand, with gravel some silt, trace clay; Compact to dense; Dark grey; Wet				80, 79	
		6	SS	32	78	25 54 17 4
	shale fragments	7	SS	17	77	
	gravelly, trace silt; Dense to very dense; Grey				76	
		8	SS	50	75, 74	37 52 9 2
73.3		9	SS	87/25cm		
10.0	End of borehole					

* 2017 02 28

Water level observed during drilling

Water level measured after drilling

Water level measured in Monitoring Well

Water Level Readings:

Date	Depth (m)	Elev.
Mar.20/'17	0.8	82.5
Apr.16/'17	0.7	82.6

Monitoring Well Legend:

- Flush cover and concrete
- Bentonite seal
- Filter sand
- Screen

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

Numbers refer to Sensitivity 5

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

Ontario

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Foundation Design

RECORD OF BOREHOLE No RW2-2

METRIC

TASK No. 2009-E-0038 LOCATION Coords: 4 858 408.0 N ; 350 351.9 E ORIGINATED BY Mi.V.

DIST Durham **HWY** 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 01, 2017 CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS
82.4	Ground Surface					
82.2 / 0.2	Topsoil					
	Clayey silt to clay, trace sand. Firm to stiff, Mottled brown/grey, Moist	1	SS	7		
		2	SS	9	▼ (approx. 81.6)	
		3	SS	14		
80.5 / 1.9	Clayey silt, some sand, trace gravel. Very stiff, Brown/grey, Moist (TILL)	4	SS	28		
		5	SS	18		
78.6 / 3.8	Sand, some gravel, trace to some silt. Dense to very dense, Dark grey, Wet				▽ (approx. 78.6)	
		6	SS	35		
		7	SS	53		
		8	SS	73		
72.8 / 9.6	Weathered shale	9	SS	50/13cm		
72.7 / 9.7	End of borehole					

Natural moisture content (approx. from plot): Sample 1 ≈ 20%; Sample 2 ≈ 33%; Sample 3 ≈ 28%; Sample 4 ≈ 20%; Sample 5 ≈ 18%; Sample 6 ≈ 14%; Sample 7 ≈ 17%; Sample 8 ≈ 15%.

Elevation scale: 82, 81, 80, 79, 78, 77, 76, 75, 74, 73

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

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

* 2017 03 01

▽ Water level observed during drilling

▼ Water level measured after drilling

5 Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No RW2-3

METRIC

TASK No. 2009-E-0038 LOCATION Coords: 4 858 402.9 N ; 350 377.2 E ORIGINATED BY Mi.V.

DIST Durham **HWY** 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 02, 2017 CHECKED BY C.N.

Soil Profile

ELEV / DEPTH	DESCRIPTION
81.8	Ground Surface
0.0 / 81.5	Topsoil
0.3	Clayey silt to clay trace sand Firm to very stiff, Brown, Moist
79.3 / 2.5	Clayey silt with sand, trace gravel Stiff to firm, Grey, Moist (TILL)
76.2 / 5.6	Sand, with silt some gravel, trace clay Dense to very dense, Dark grey, Moist
72.3 / 9.5	
72.1 / 9.7	Weathered shale
	End of borehole

Samples

NUMBER	TYPE	"N" VALUES	Water content (%)	GR	SA	SI	CL
1	SS	6					
2	SS	11					
3	SS	21					
4	SS	24		0	3	28	69
5	SS	7					
6	SS	4		6	29	37	28
7	SS	78/28cm		17	46	30	7
8	SS	50/13cm					
9	SS	50/10cm					

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (81, 80, 79, 78, 77, 76, 75, 74, 73); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

* 2017 03 02

▽ Water level observed during drilling

▼ Water level measured after drilling

Water level measured in Monitoring Well

Water Level Readings:

Date	Depth (m)	Elev.
Mar.20/'17	0.4	81.4
Apr.16/'17	0.4	81.4

Monitoring Well Legend:

- Flush cover and concrete
- Bentonite seal
- Filter sand
- Screen

5 Numbers refer to Sensitivity 20 15 5 10 (%) STRAIN AT FAILURE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No RW2-4

METRIC

TASK No. 2009-E-0038 LOCATION Coords: 4 858 400.5 N ; 350 394.6 E ORIGINATED BY Mi.V.

DIST Durham **HWY** 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.

DATUM Geodetic DATE March 01, 2017 CHECKED BY C.N.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
81.6	Ground Surface					
81.4 / 0.2	Topsoil					
	Clayey silt to clay, some to trace sand. Firm to very stiff, Brown/grey, Moist	1	SS	4	Water level measured after drilling (approx. El. 81.1)	
		2	SS	5	Water level observed during drilling (approx. El. 80.2)	
		3	SS	16		
		4	SS	16		0 2 27 71
79.1 / 2.5	Clayey silt, some sand, trace gravel. Firm, Brown/grey, Wet to moist (TILL)	5	SS	6		
		6	SS	2		
76.0 / 5.6	Sand, with silt with gravel, trace clay. Dense to very dense, Dark grey, Moist to wet	7	SS	39		21 53 23 3
		8	SS	75		
72.0 / 9.6	Weathered shale	9	SS	50/8cm		
71.9 / 9.7	End of borehole					

* 2017 03 01

▽ Water level observed during drilling

▼ Water level measured after drilling

Chart columns: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³. ELEVATION SCALE 81 to 72.

Numbers refer to Sensitivity

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

CONT No	
W.O. No	09–20009
WP No	2123–10–00

HIGHWAY 401 / BROCK STREET
RAMP W–EW RETAINING WALL (RW1)
GEOGRAPHIC TOWNSHIP OF WHITBY
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

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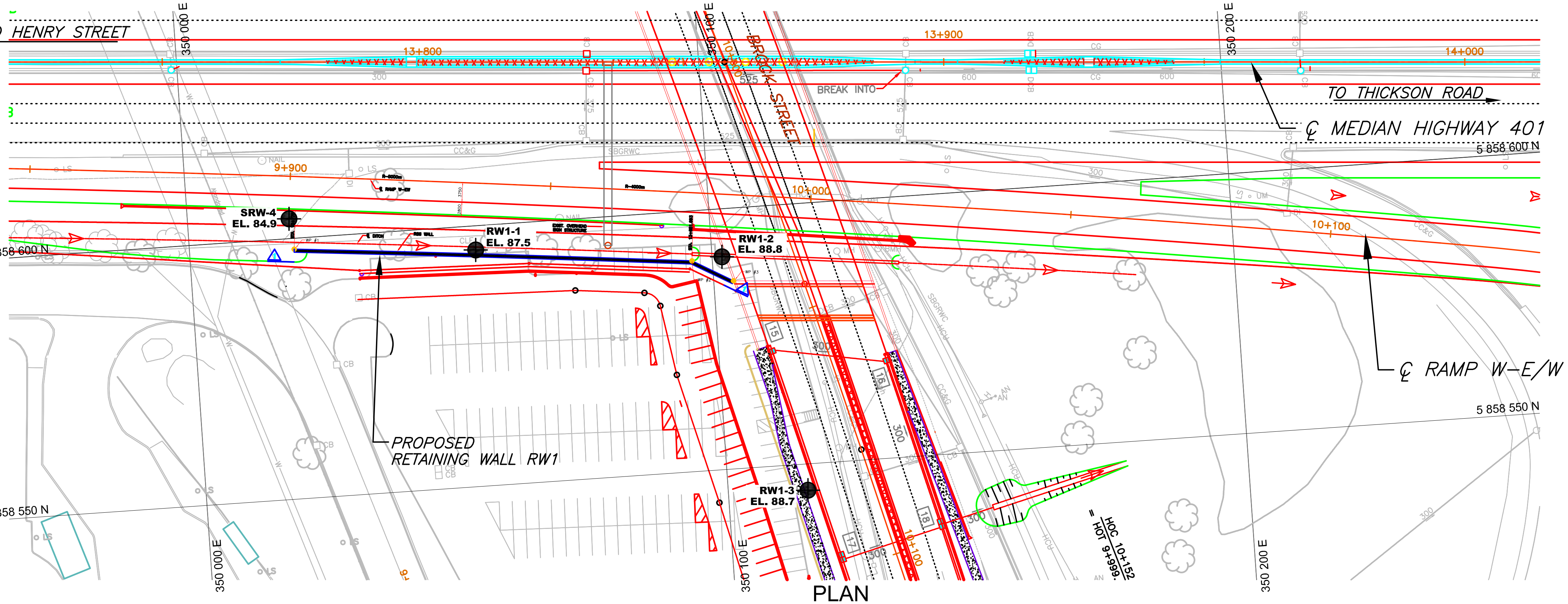
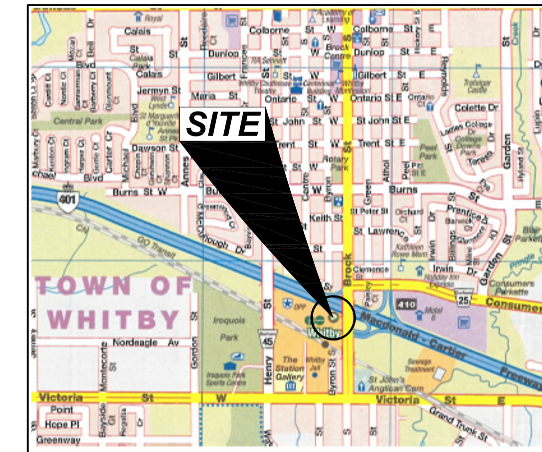
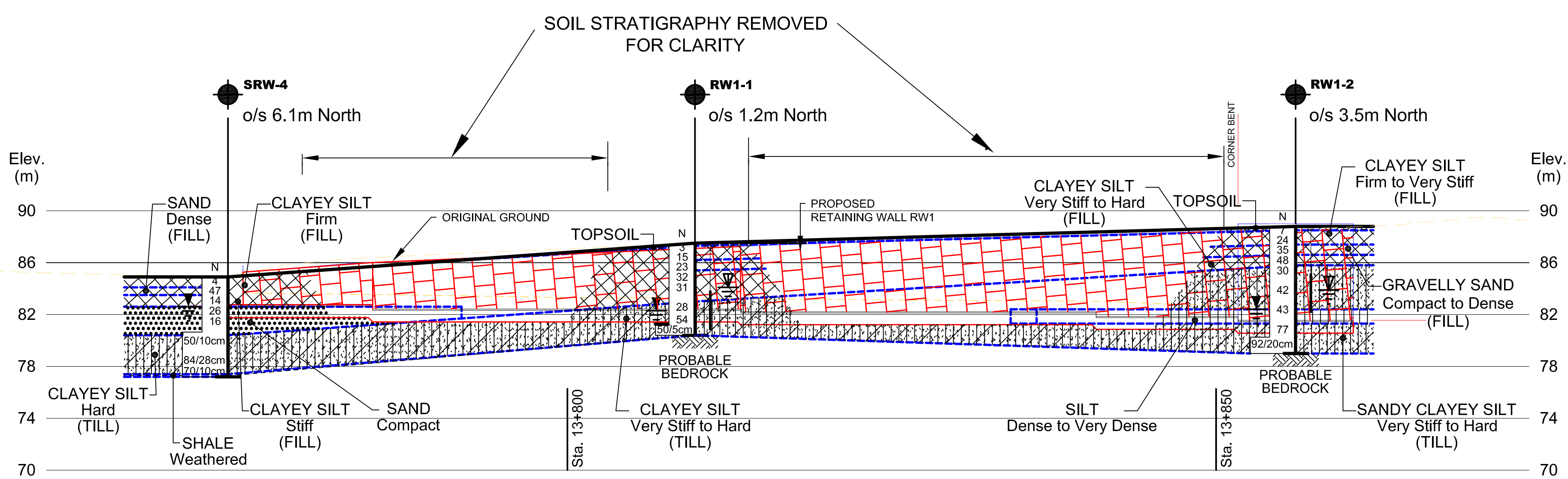


PLAN
SCALE 10 0 10 20m



KEY PLAN
SCALE 250m 0 500m 1.0km



PROFILE
SCALE 5 0 5 10m

LEGEND

Symbol	Description
	Borehole
	Borehole and Cone
N	Blows/0.3m (Std. Pen Test, 475 J/blow)
CONE	Blows/0.3m (60 Cone, 475 J/blow)
	WL at time of investigation March & April 2017
WH	Penetration due to weight of hammer
	Head ARTESIAN WATER Encountered
	PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
RW1-1	87.5	4 858 595.4	350 054.8
RW1-2	88.8	4 858 590.8	350 101.9
RW1-3	88.7	4 858 545.0	350 115.3
SRW-4	84.9	4 858 603.8	350 019.5

– NOTE –

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

NOTES:

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

Reference AECOM Drawing:
60154317-BROCK_RW_W_EW-GA.dwg dated July 2017

REVISIONS

DATE	BY	DESCRIPTION

Geocres No. 30M15-319

HWY No 401			DIST Central
SUBM'D NA	CHECKED GD	DATE DEC. 13, 2017	SITE
DRAWN NA	CHECKED GD	APPROVED CN	DWG RW1-1

CONT No	
W.O. No 09–20009	
W.P. No 2123–10–00	
HIGHWAY 401 / BROCK STREET E–W SERVICE ROAD RETAINING WALL (RW2) GEOGRAPHIC TOWNSHIP OF WHITBY BOREHOLE LOCATIONS AND SOIL STRATA	SHEET

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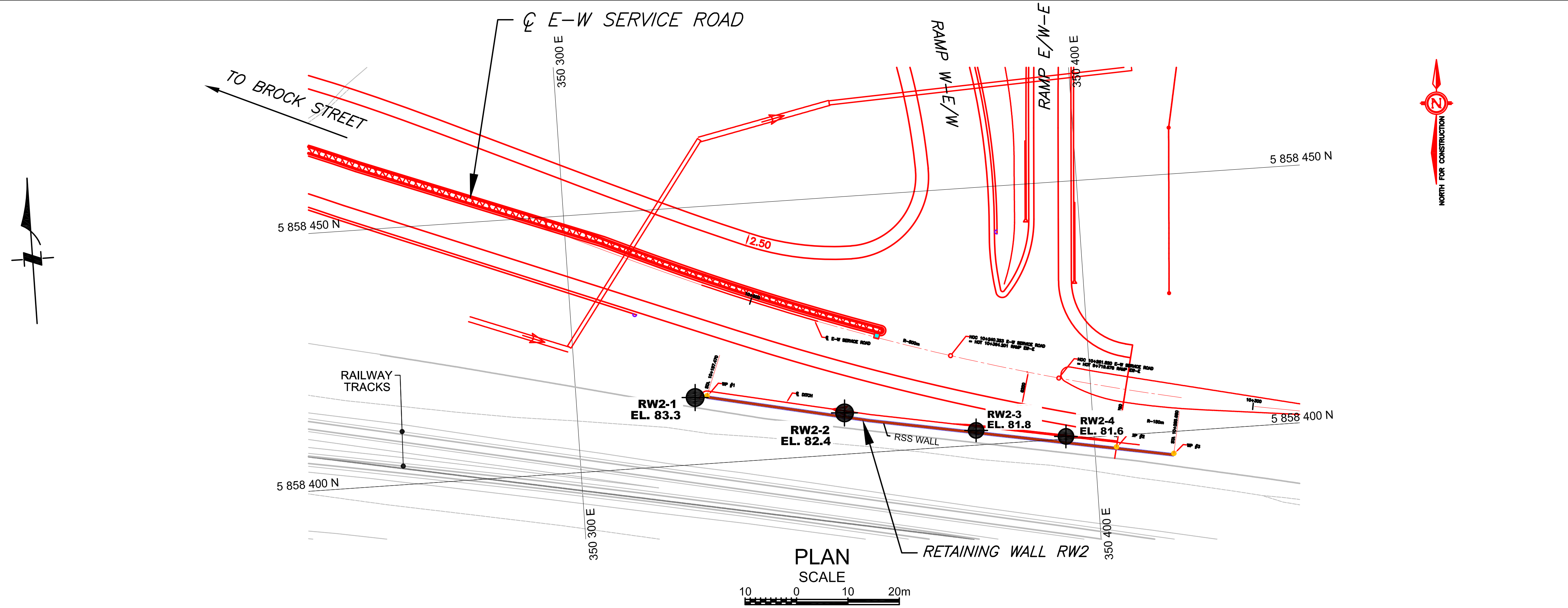
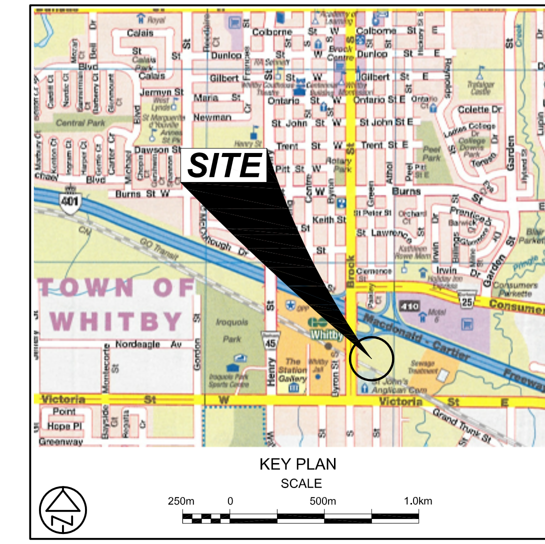
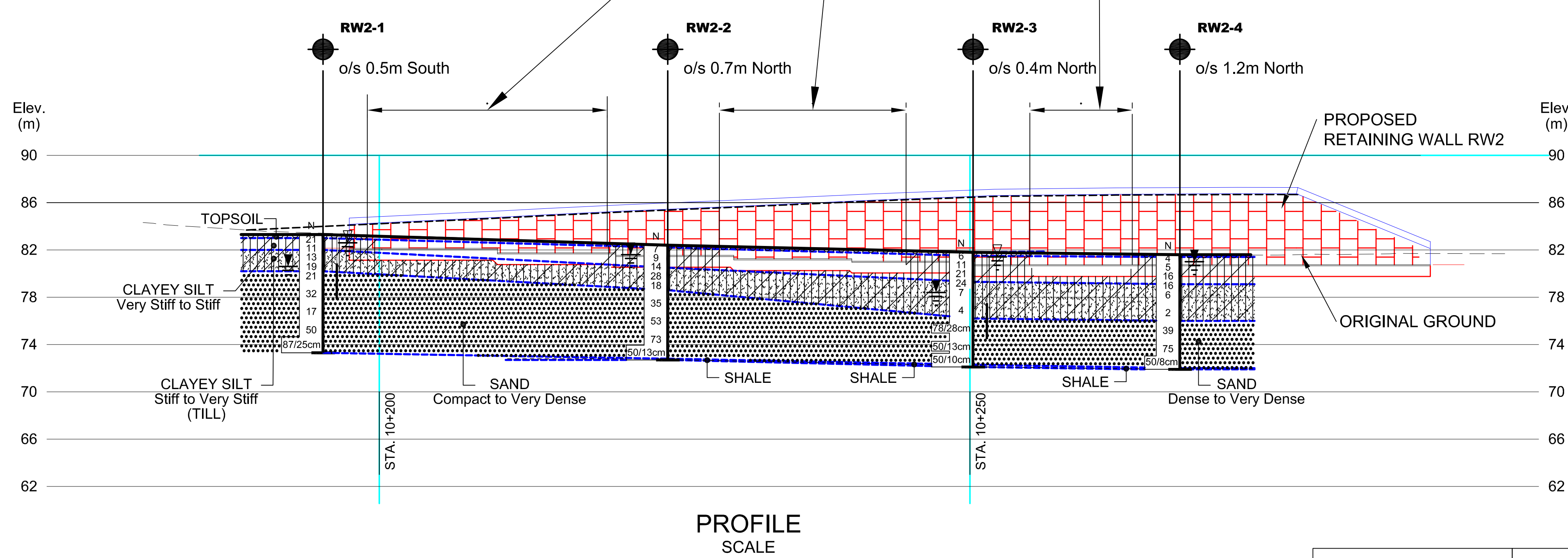






LEGEND

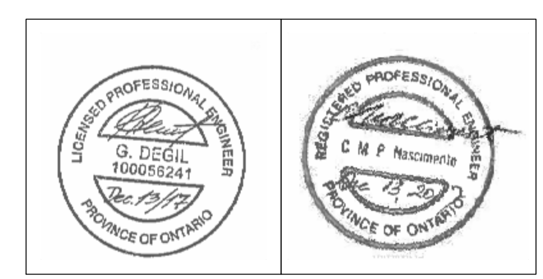
- Borehole
- Borehole and Cone
- N — Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE — Blows/0.3m (60 Cone, 475 J/blow)
- WL at time of investigation Feb. to April 2017
- WL in Monitoring Well
- WH — Penetration due to weight of hammer
- Head ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
RW2-1	83.3	4 858 413.0	350 323.1
RW2-2	82.4	4 858 408.0	350 351.9
RW2-3	81.8	4 858 402.9	350 377.2
RW2-4	81.6	4 858 400.5	350 394.6

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

NOTES:

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



Reference AECOM Drawing:
60154317-Brock_RW_E-W_Service RD-GA dated July. 2017

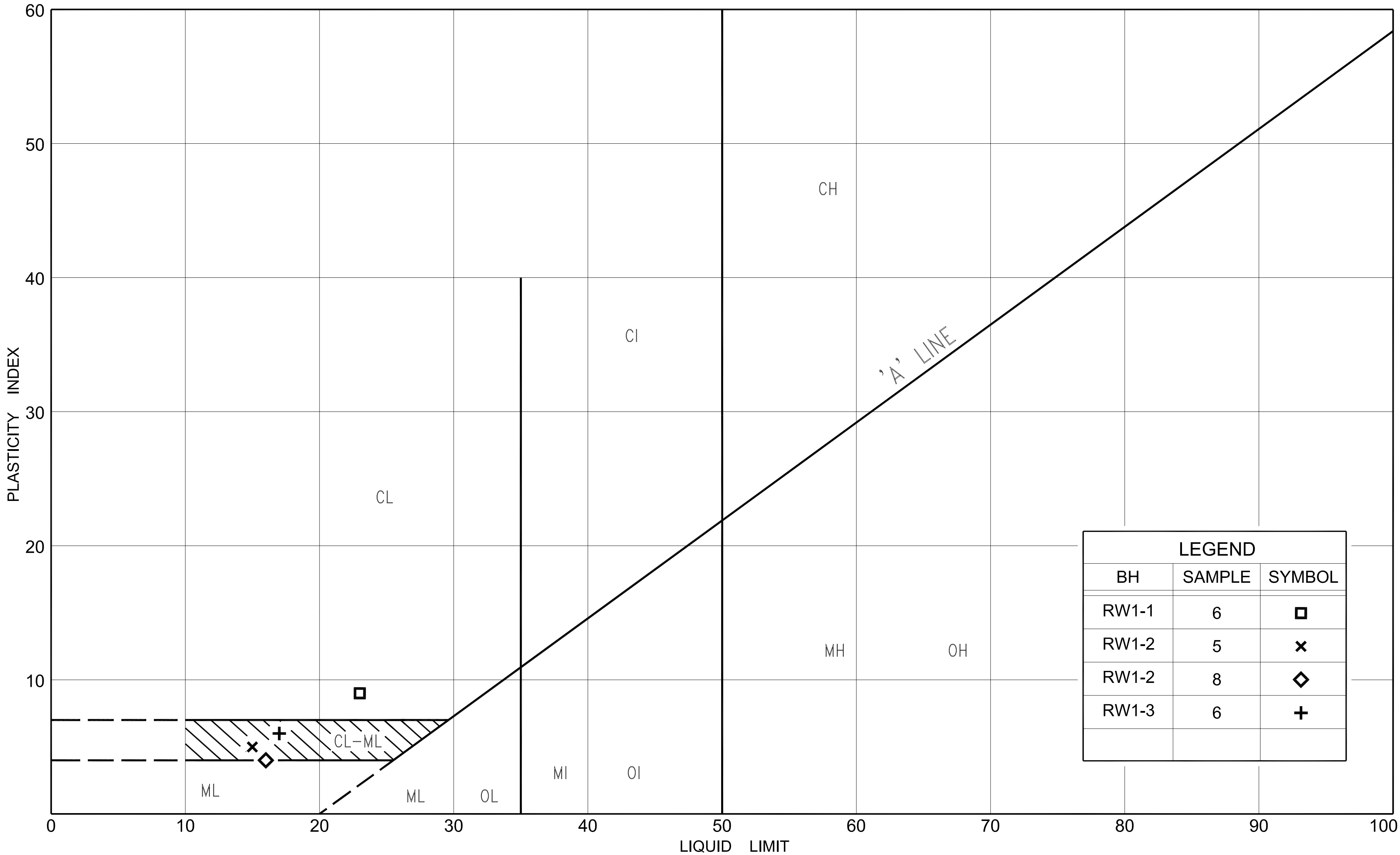
REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 30M15-319

HWY No 401			DIST Central
SUBM'D NA	CHECKED GD	DATE DEC. 13, 2017	SITE
DRAWN NA	CHECKED GD	APPROVED CN	DWG RW2-1

APPENDIX FIR-B

Plasticity Charts and Results of Grain Size Distribution Analyses

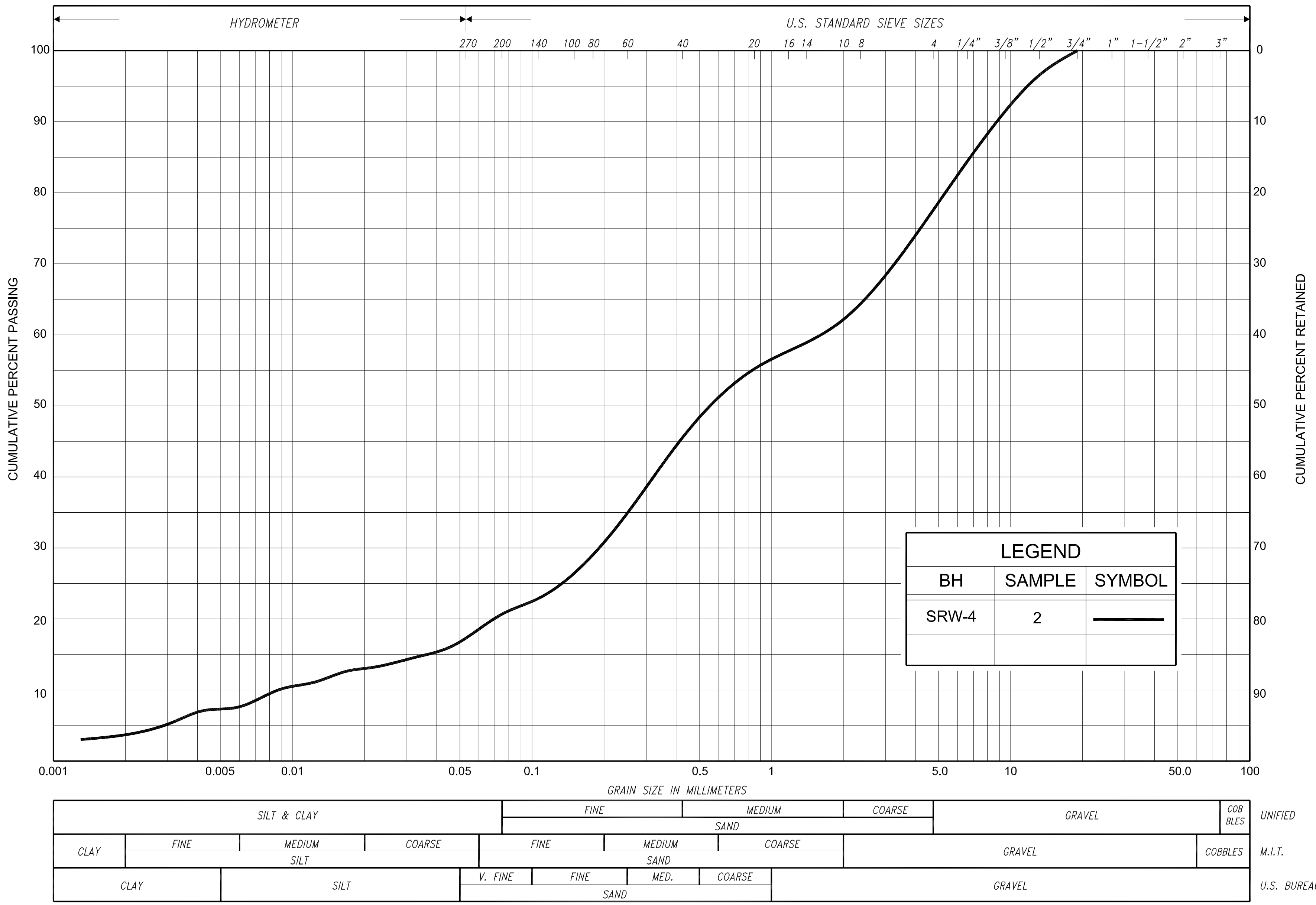


PLASTICITY CHART

CLAYEY SILT, with sand to sandy, trace to some gravel (CL to CL-ML)
(TILL)

FIG No.	RW1-PC-1
HWY	401
W.O.	09-20009

Ontario

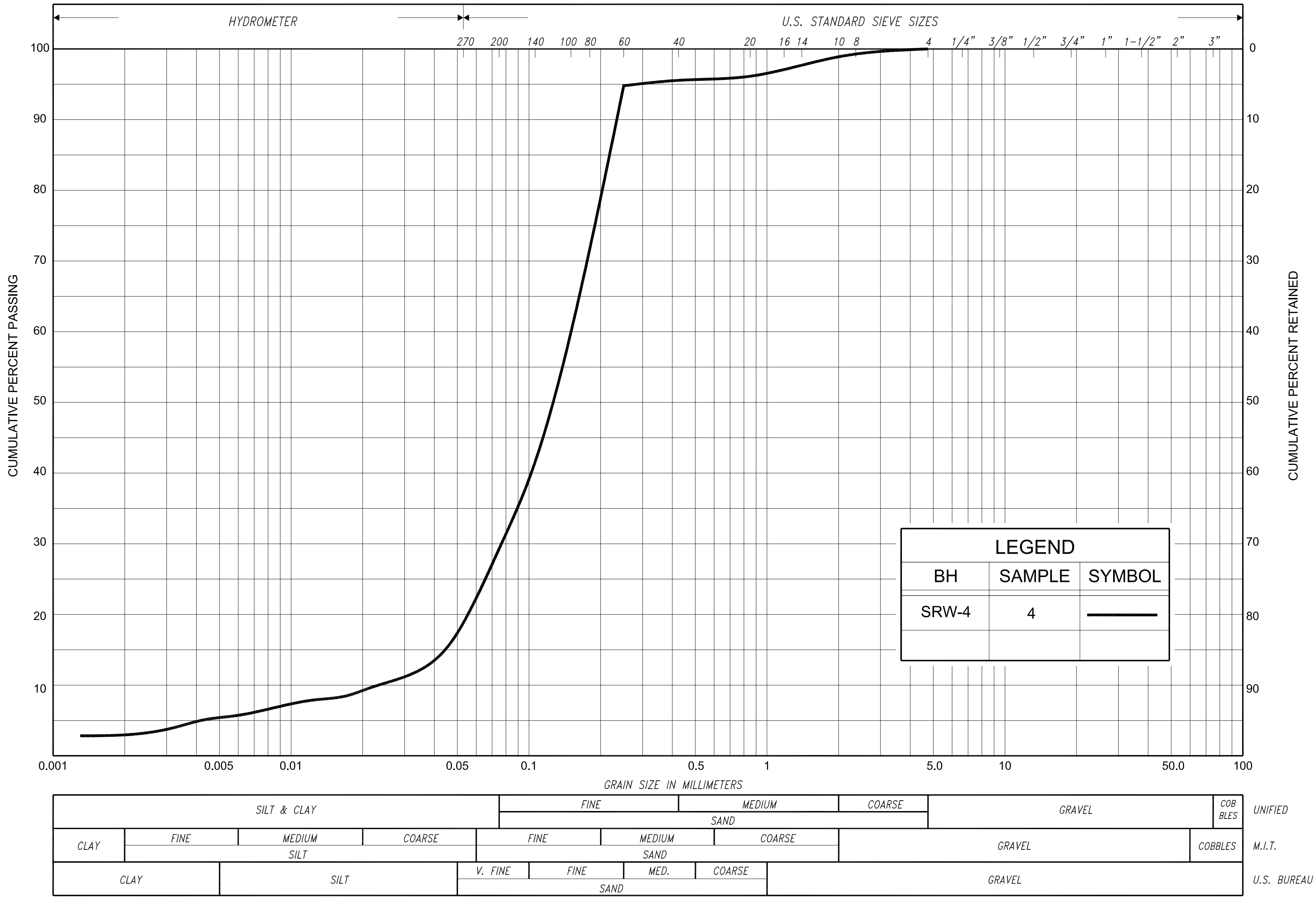


Ontario

GRAIN SIZE DISTRIBUTION

SAND, with gravel, some silt, trace clay
(FILL)

FIG No.	RW1-GS-1
HWY	401
W.O.	09-20009

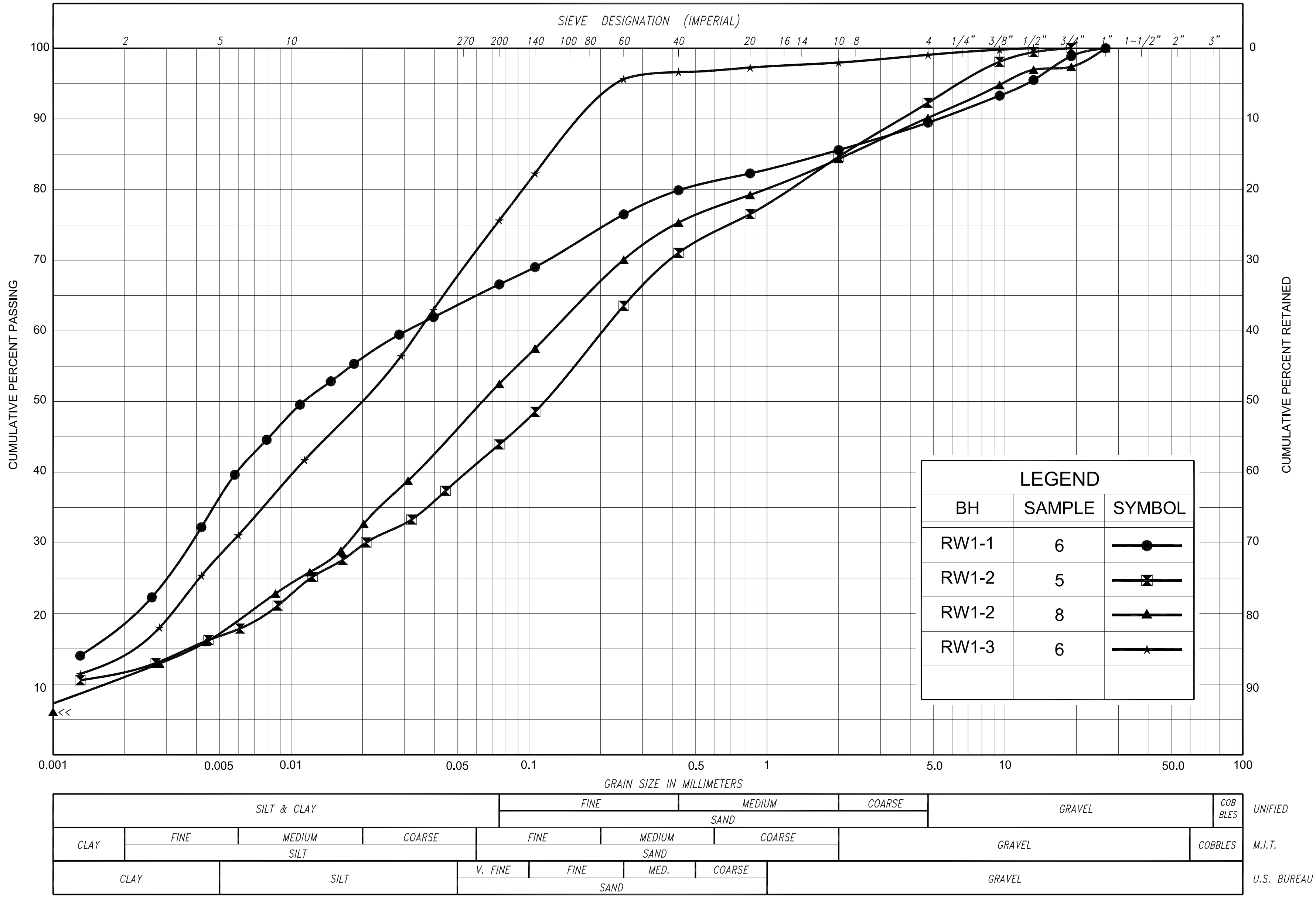


Ontario

GRAIN SIZE DISTRIBUTION

SAND, with silt, trace clay

FIG No.	RW1-GS-2
HWY	401
W.O.	09-20009

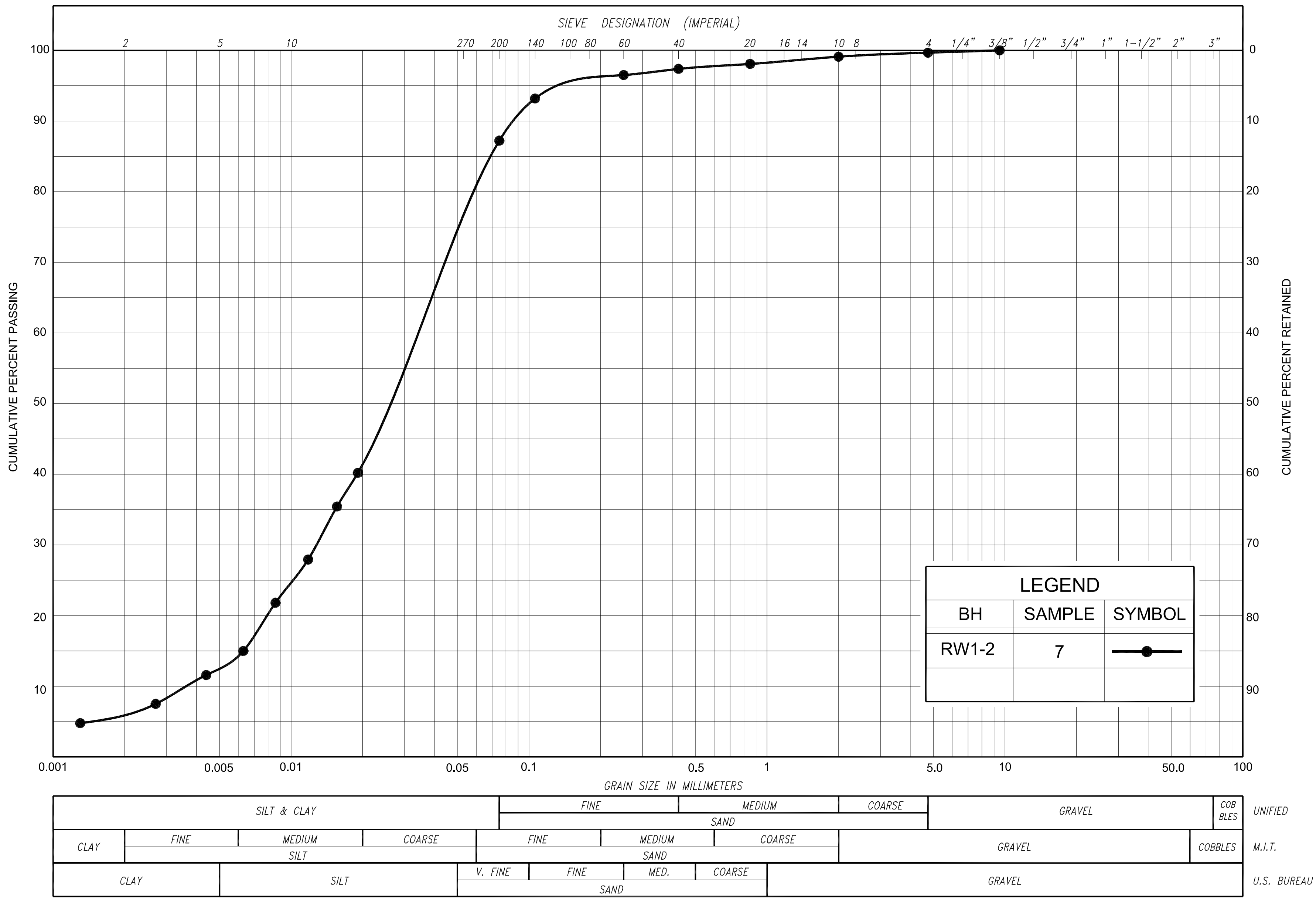


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, with sand to sandy, trace to some gravel (CL to CL-ML)
(TILL)

FIG No.	RW1-GS-3
HWY	401
W.O.	09-20009

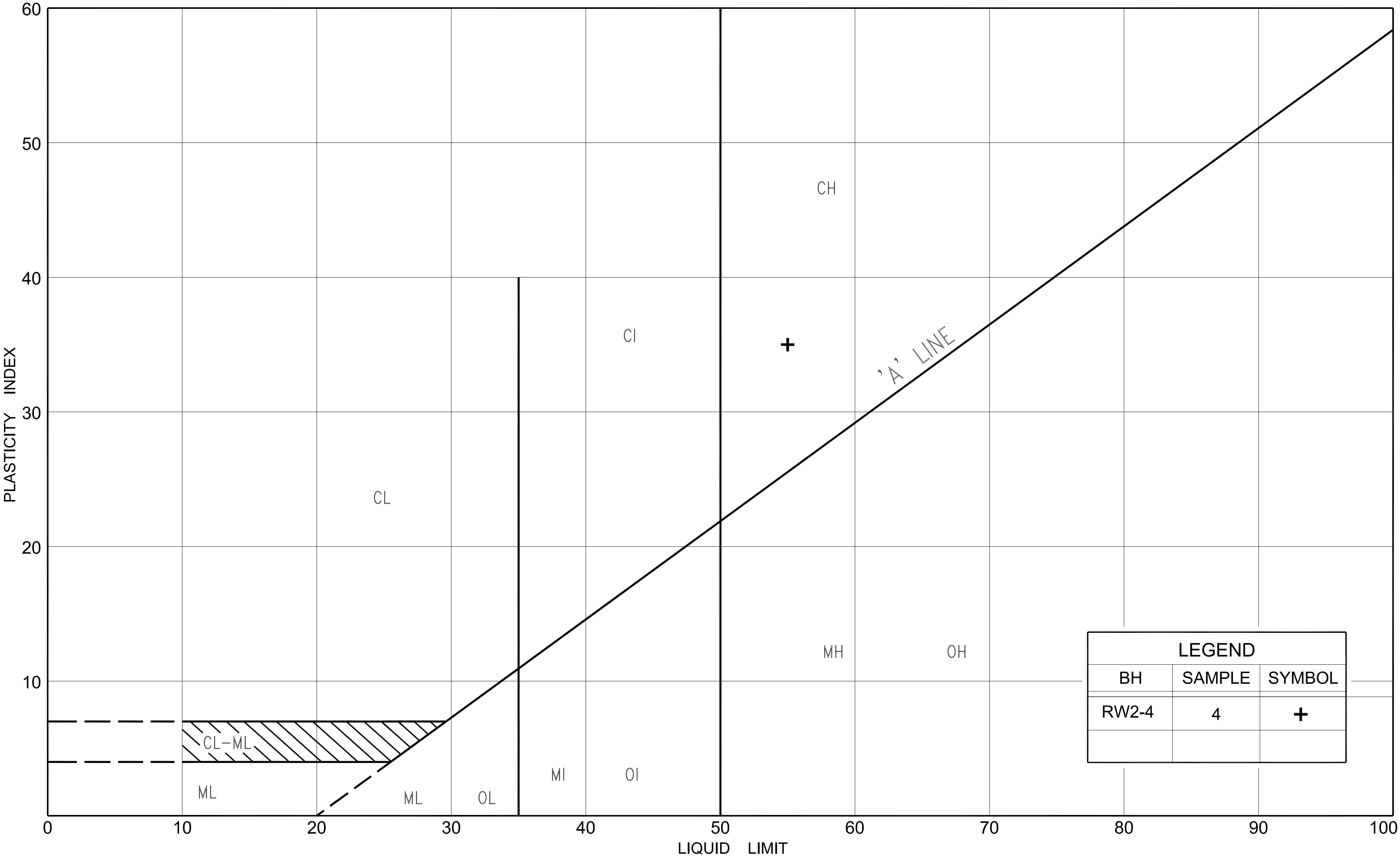


Ontario

GRAIN SIZE DISTRIBUTION

SILT, some sand, trace clay, trace gravel

FIG No.	RW1-GS-4
HWY	401
W.O.	09-20009



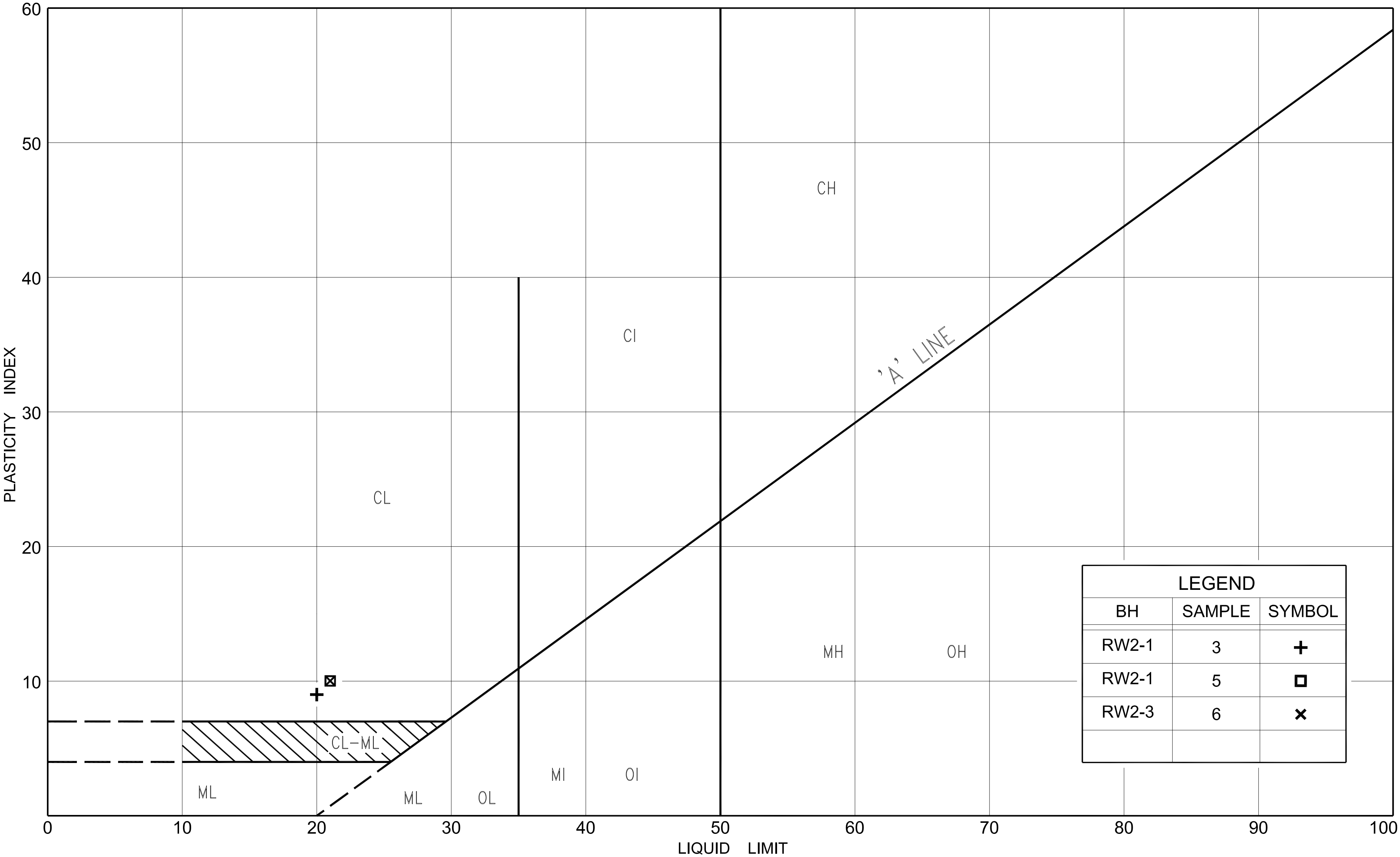
LEGEND		
BH	SAMPLE	SYMBOL
RW2-4	4	+

Ontario

PLASTICITY CHART

CLAY, trace sand (CH)

FIG No.	RW2-PC-1
HWY	401
W.O.	09-20009



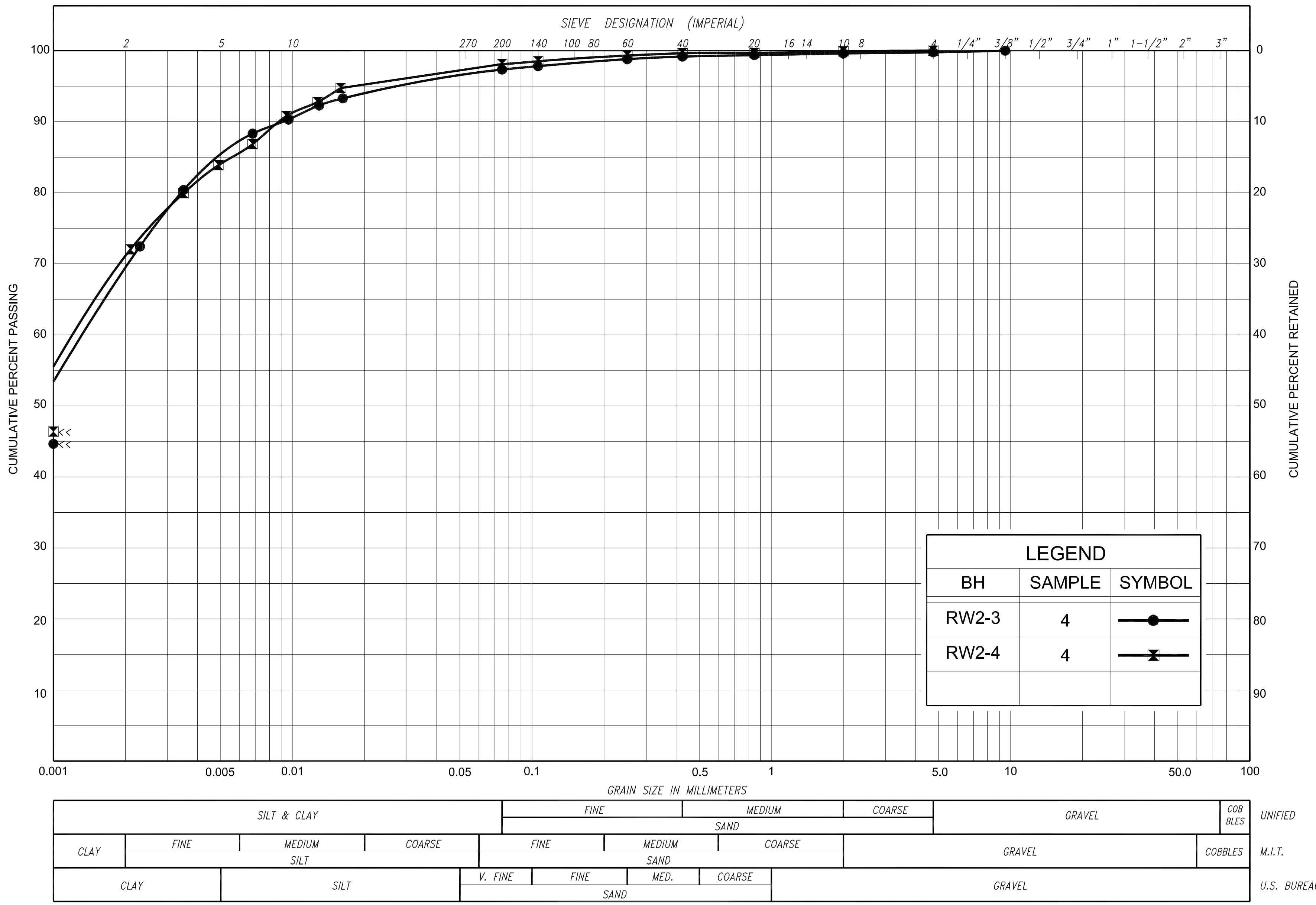
LEGEND		
BH	SAMPLE	SYMBOL
RW2-1	3	+
RW2-1	5	◻
RW2-3	6	×

Ontario

PLASTICITY CHART

CLAYEY SILT, with sand to sandy, trace to some gravel (CL)
(TILL)

FIG No.	RW2-PC-2
HWY	401
W.O.	09-20009

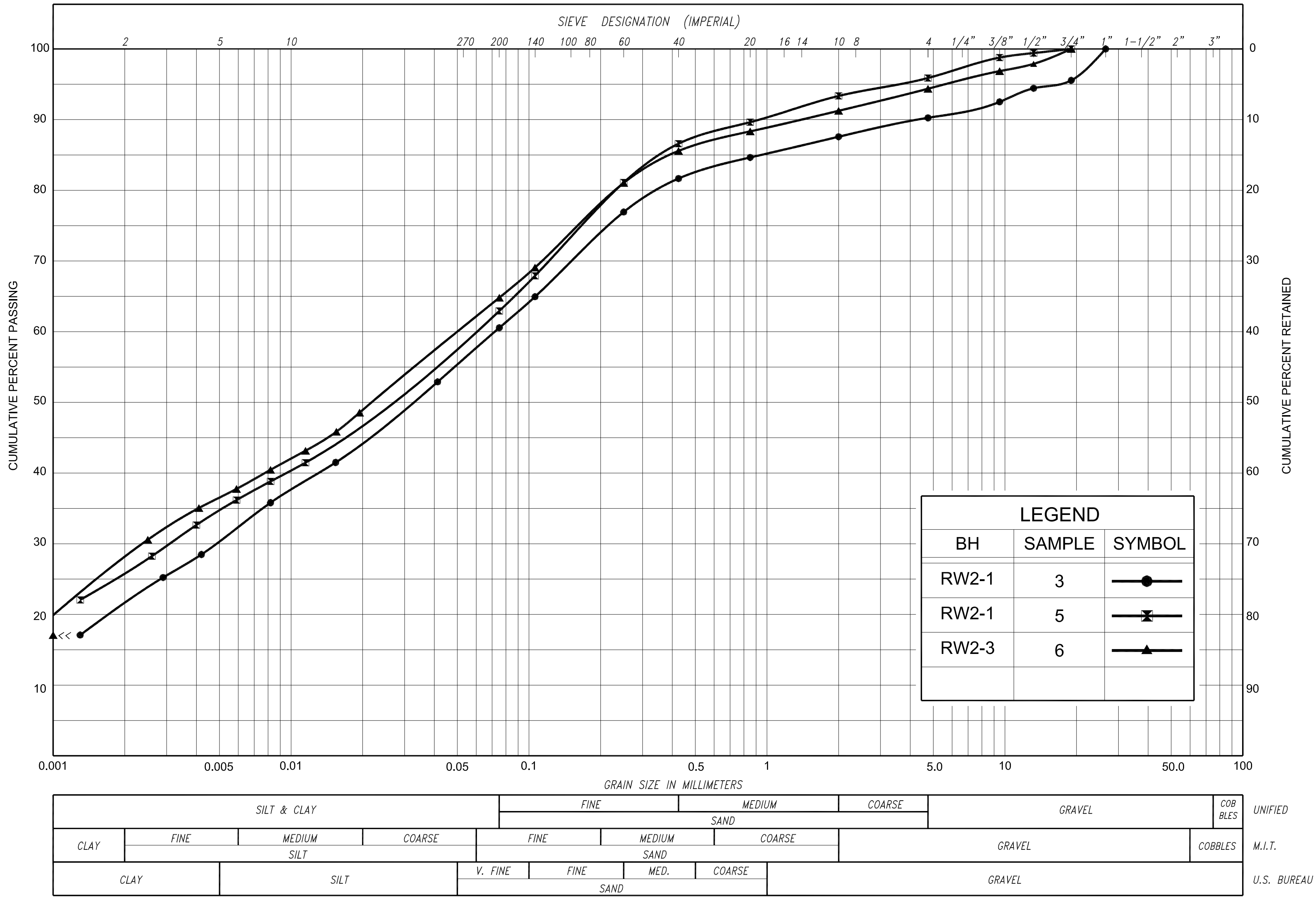


Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand (CH)

FIG No.	RW2-GS-1
HWY	401
W.O.	09-20009

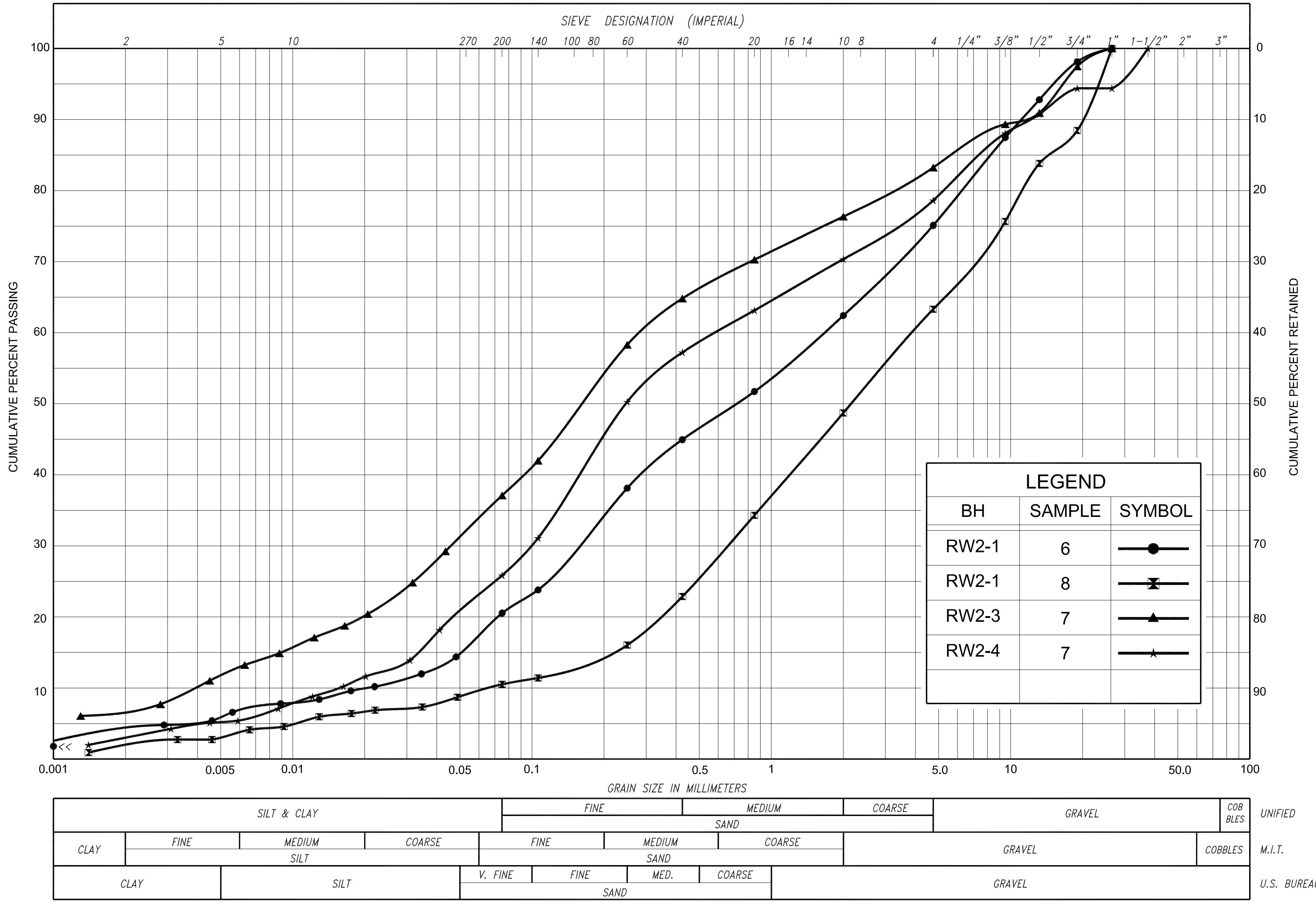


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, with sand to sandy, trace to some gravel (CL)
(TILL)

FIG No.	RW2-GS-2
HWY	401
W.O.	09-20009



Ontario

GRAIN SIZE DISTRIBUTION

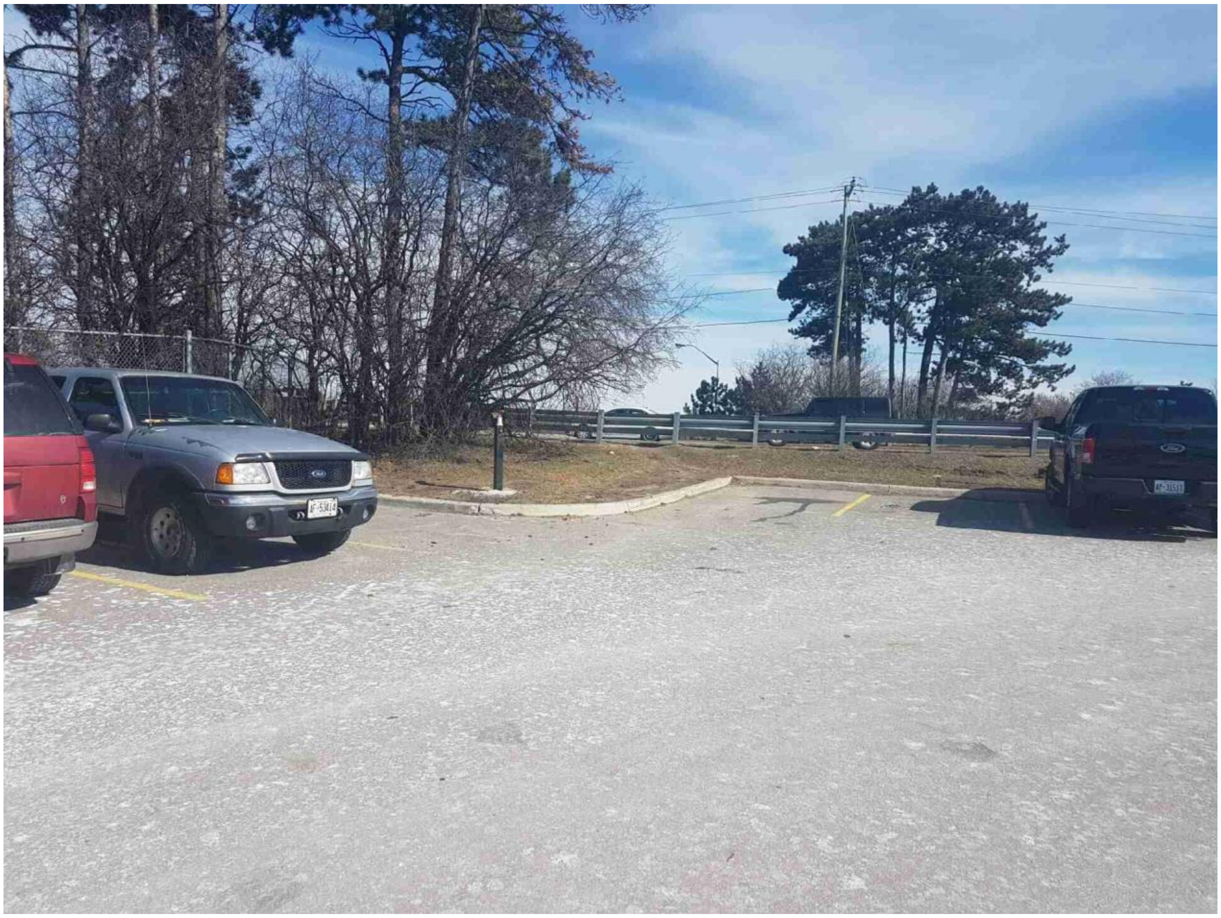
SAND, some gravel to gravelly, trace to with silt, trace clay

FIG No.	RW2-GS-3
HWY	401
W.O.	09-20009

APPENDIX FIR-C

Site Photographs

Photograph 1: Drilling at the location of borehole RW1-1 (March 1, 2017).



Photograph 2: Piezometer installed in borehole RW1-2 (March 2, 2017).

Photograph 3: Location of borehole RW1-3 (March 1, 2017).

Photograph 4: Drilling for retaining wall RW2 (March 2, 2017).

Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN REPORT
for
RETAINING WALLS
HIGHWAY 401 AT BROCK STREET
W.O. 09-20009, WP 2123-10-00
WHITBY, ONTARIO

PETO MacCALLUM LTD.
165 CARTWRIGHT AVENUE
TORONTO, ONTARIO
M6A 1V5
Phone: (416) 785-5110
Fax: (416) 785-5120
Email: toronto@petomaccallum.com

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FOUNDATION DESIGN REPORT

FOUNDATION DESIGN REPORT
for
Retaining Walls
Highway 401 at Brock Street
W.O. 09-20009, WP 2123-10-00
Whitby, Ontario

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6. INTRODUCTION

6.1 General

This report provides foundation engineering recommendations regarding design and comments for construction of retaining walls associated with a widening of Highway 401 at the Brock Street interchange in Whitby, Ontario. The report has been prepared for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

Highway 401 crosses under Brock Street at approximate Station 13+858, Highway 401 chainage (ref. General Arrangement drawing 'Highway 401 / Brock Street Underpass' prepared by AECOM in September 2014).

The project involves construction of two retaining walls west and east of Brock Street to the south of Highway 401. Use of a retained soil system (RSS) is planned for both retaining walls.

Retaining wall RW1 will be 85.5 m long and located along the W-E/W ramp. The founding level is proposed to be at elevation 81.5 to 82.6 (ref. General Arrangement Drawing 1 'Brock Street. Ramp W-EW Retaining Wall' prepared by AECOM in July 2017).

Retaining wall RW2 will be 91.5 m long and situated just north of the GO transit and CN railways some 200 m south of Highway 401 and east of Brock Street. The founding level is specified to range from elevation 80.7 to 82.1 (ref. General Arrangement Drawing 2 'Brock Street. E-W Service Road Retaining Wall' prepared by AECOM in July 2017).

All elevations in this report are expressed in metres.

6.2 Retaining Walls RW1 and RW2

The road grade on Highway 401 along the proposed location of retaining wall RW1 is near elevation 84.0. The ground surface at the wall varies between elevation 84.9 and 88.8. It is expected that excavation for construction of retaining wall RW1 will extend to depths of up to 7 m to reach the proposed founding level at elevation 81.5 to 82.6.

The subsurface stratigraphy revealed in boreholes RW1-1 to RW1-3 and SRW-4 drilled at the site of retaining wall RW1 generally comprised topsoil over fill extending to elevation 82.6 to 85.8 and underlain by compact sand and/or very stiff to hard clayey silt till mantling weathered shale. Cobbles were encountered in one borehole. The piezometric water level was at depths of 3.4 to 4.9 m (elevation 83.9 to 84.1).

Retaining wall RW2 is located along the GO transit railway at the intersection of the Highway 401 W-E/W and E/W-E ramps with E-W Service Road. The wall will retain 2 to 4 m of new fill to be placed at the intersection. The founding level of retaining wall RW2 is envisaged to be at shallow depths due to the artesian conditions present at the site.

The subsurface stratigraphy revealed in boreholes RW2-1 to RW2-4 drilled for retaining wall RW2 comprised topsoil over firm to very stiff clayey silt / clay overlying firm to very stiff clayey silt till underlain by compact to very dense sand mantling weathered shale. The piezometric water level was at depths of 0.4 to 0.7 m (elevation 81.4 to 82.6).

It is considered that construction of retaining walls RW1 and RW2 is feasible at the site.

6.3 Retaining Wall Alternatives

A retained soil system (RSS) wall and a conventional cast-in-place reinforced concrete wall bearing on spread footings may be employed for retaining walls RW1 and RW2 at the site. It is noted that RSS walls may include reinforcement using geogrid or metal strips to be specified by a proprietary RSS system designer.

A retaining scheme using caissons is not recommended due to the presence of cohesionless sandy soils and high groundwater levels at this site.

The following table provides a summary of the advantages, disadvantages, risks / consequences and relative costs for two retaining wall alternatives:

Table 6.3 – Comparison of Retaining Wall Alternatives

ALTERNATIVE	ADVANTAGES	DISADVANTAGES	RISKS / CONSEQUENCES	RELATIVE COST
RSS Wall	Fast and efficient design and construction Less depth of excavation required for frost protection of footings	Shorter service life than CIP walls	Contracting protocol for RSS would permit any type of RSS wall that meets the performance and appearance requirements	Less expensive than cast-in-place reinforced concrete walls on spread footings
Cast-in-Place Reinforced Concrete Wall on Spread Footings	Longer service life than RSS walls Superior appearance	Requires site specific design Requires deeper excavations to construct footings	Increased risk of dewatering issues and destabilisation of retained soil due to deeper excavation requirements for foundations	More expensive than RSS walls

Taking into account the presence of competent soils at shallow depths and high groundwater levels at the site, it is considered that the most appropriate option for both retaining walls is an RSS wall. The founding levels are specified to be at elevation 81.5 to 82.6 for retaining wall RW1 and elevation 80.7 to 82.1 for retaining wall RW2.

7. FOUNDATIONS

7.1 General

A retaining scheme by means of an RSS wall is considered to be the preferred option for retaining walls RW1 and RW2. The walls should be founded on the native soils or on compacted granular materials in compliance with the requirements of the RSS design.

7.2 Frost Protection

The foundation frost penetration depth for structure foundations at this site is 1.2 m according to OPSD 3090.101. All spread footings for cast-in-place concrete wall foundations subject to frost action should therefore be provided with 1.2 m of earth cover or equivalent thermal insulation.

The thickness of levelling pads for RSS walls is designed by the proprietary RSS system and only partial frost protection is generally provided.

7.3 Seismic Design

The reference Peak Ground Acceleration (PGA_{ref}) is 0.075 for the Town of Whitby, Ontario (National Building Code of Canada, 2015). The soil at the project site for seismic design purposes is classified as Type C in accordance with clause 4.4.3.2 of the CHBDC, 2014.

Based on the SPT data, seismic-induced liquefaction of the foundation soils is not anticipated under the earthquake design.

7.4 RSS Walls

A retained soil system (RSS) can be used for retaining walls RW1 and RW2 at the Highway 401 and Brock Street interchange. The RSS walls may be constructed utilising a series of steps in founding level to meet site grading and construction requirements.

High performance, high appearance rated RSS walls will be required. The design, supply and construction of the RSS wall should conform to SP 599S22 and SP 599S23.

The founding material of the RSS walls is expected to be variable and includes native sand, silt, clayey soils and/or granular fill. It is recommended that the subgrade soils along retaining wall RW1 be replaced with a 500 mm thick Granular A pad for uniformity of support.

As outlined in section 6.2 of this report, the piezometric water level at RW2 was at elevation 81.4 to 82.6, which likely reflects artesian conditions in the sand layer encountered at elevation 79.3 to 80.2, below a clayey silt layer. Consequently, it is recommended that excavation at the RW2 site, if required, be kept to a level at or above elevation 81.5 to 82.5 to avoid potential basal heave issues. Placement of additional fill may be needed above the founding levels to achieve the required minimum founding depth of 0.8 m for the RSS wall foundation. An NSSP to advise the RSS wall designer about the potential groundwater issues is included in the report.

The recommended geotechnical bearing resistance at ultimate limit states (ULS) and serviceability limit states (SLS) for a RSS wall constructed on the native sand, silt, clayey soils is as follows:

Table 7.4.1 – Geotechnical Bearing Resistance for RSS Walls

WALL No.	PROPOSED FOUNDING ELEVATION (m)	REFERENCE BOREHOLES	FOUNDING CONDITIONS	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	FACTORED GEOTECHNICAL RESISTANCE AT SLS (kPa)
RW1	81.5 – 82.6	RW1-1 to RW1-3, SRW-4	Very stiff to hard clayey silt till / Compact sand / Dense to very dense silt	375	250
RW2	80.7 – 82.1	RW2-1 to RW2-4	Firm to stiff clayey silt / clay	150	100

The geotechnical parameters employed to design the RSS will be dependent upon the type of backfill required for internal stability of the proprietary system as well as the soil contiguous to the RSS system that will govern global stability, overturning and/or sliding of the base. The design parameters for granular fill and the native sand / clayey soils are as follows:

Table 7.4.2 – Geotechnical Parameters for RSS walls

PARAMETERS	GRANULAR A / GRANULAR B TYPE II	FIRM TO HARD CLAYEY SOILS	SAND / SILT
Friction Angle, degrees	35	0	32
Cohesion, kPa	0	50 – 150	0
Unit Weight, kN/m^3	22.8	19.5	20.0

The horizontal force at the base of the RSS will be resisted by the friction along the interface between the granular backfill and the founding soil. Resistance to lateral forces / sliding should be calculated in accordance with clause 6.12 of the CHBDC, 2014. An unfactored friction coefficient of 0.6 is considered to be appropriate.

It is considered that the global stability of the RSS walls designed and constructed as recommended in this report, would satisfy a recommended safety factor of at least 1.3 that is adequate for retaining walls on embankments not supporting bridge structures. The assessment takes into account the relatively low retained soil height and the presence of competent founding soils at the site. The global stability of the final design of the proprietary system should be checked using the geotechnical parameters noted in Table 7.4.2.

The RSS supplier should be responsible for specifying the type of backfill material employed, taking into consideration the engineering properties of the proprietary product, the design life of the structure, the pull-out resistance required, drainage requirements and the estimated settlements.

The MTO guidelines for RSS wall design should be followed. The supplier of the RSS should also be responsible for the detail design of the structure (backfill, reinforcement, internal stability) in conformance to SP 599S22 and SP 599S23 and provide drawings to show pertinent information such as location, length, height, elevations, performance level, appearance, etc.

7.5 Structural Fill Pad

Since the requirements for the levelling pad should conform to the accepted proprietary design of the RSS, the following recommendations apply only if the structural designer determines that structural fill pads are necessary to raise the foundations for the walls.

The structural fill pad should comprise Granular A material placed in maximum 200 mm thick lifts compacted to 100% of the ASTM D698 (standard Proctor) maximum dry density. The following geotechnical bearing resistance should be used for the design depending on the thickness of a structural fill pad:

Table 7.5.1 – Geotechnical Bearing Resistance for RSS Walls Founded on Structural Fill

STRUCTURAL FILL PAD THICKNESS (m)	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	FACTORED GEOTECHNICAL RESISTANCE AT SLS (kPa)
Minimum 2.0	400	250
Minimum 3.0	900	350

The granular fill should extend horizontally a minimum 1.0 m from the edge of the structure to be supported. The granular fill pad should be widening with depth at an inclination of 1 horizontal to 1 vertical (1H:1V). The depth of a granular pad underneath the levelling pad varies according to the subsurface conditions at each retaining wall.

The following parameters should be used for sliding resistance of retaining wall foundations on a structural fill pad in accordance with clause 6.12 of the CHBDC, 2014:

Table 7.5.2 – Geotechnical Parameters for Structural Fill Pad

PARAMETER	GRANULAR A / GRANULAR B TYPE II	GRANULAR B TYPE I
Friction Angle, degrees	35	32
Cohesion, kPa	0	0
Unit Weight, kN/m^3	22.8	21.2

The structural designer should apply appropriate factors to the values of friction angle and cohesion for the sliding resistance check.

The fill should be placed and compacted in accordance with OPSS.PROV 501.

7.6 Cast-in-Place Reinforced Concrete Wall

Retaining walls RW1 and RW2 may be constructed as a cast-in-place reinforced concrete wall bearing on spread footings. The geotechnical resistance values recommended in Section 7.4 for the RSS foundations placed on native soils are considered to be appropriate for cast-in-place concrete walls. The varying founding level for the concrete walls should allow for a foundation frost penetration depth of 1.2 m.

It is noted that the excavation at the RW2 location should be limited to elevation 81.5 or above as recommended in section 7.4. Reference is made to the attached NSSP for "potential groundwater concerns at RW2."

8. LATERAL EARTH PRESSURE

The retaining wall should be designed to resist the unbalanced lateral earth pressure imposed by the backfill adjacent to the wall. The lateral earth and water pressure, p (kPa) may be computed using the equivalent fluid pressure diagrams presented in Section 6.9 of the CHBDC or employing the following equation:

$$p = K(\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + Cp + Cs$$

where K = coefficient of lateral earth pressure (dimensionless)

γ = unit weight of free-draining granular material above design water level, kN/m^3

γ' = unit weight of submerged backfill material below design water level, kN/m^3

= $\gamma - \gamma_w$

γ_w = unit weight of water

= 9.8 kN/m^3

h_1 = depth below final grade, m, above design water level

h_2 = depth below design water level, m

q = surcharge load, kPa, if present

Cp= compaction pressure, kPa (refer to clause 6.12.3 of CHBDC)

Cs = earth pressure induced by seismic events, kPa (refer to clause 4.6.5 of CHBDC)

where Ø = angle of internal friction of retained soil (35º for Granular B Type II)

δ = angle of friction between the soil and wall (23.5º for Granular B Type II)

Free-draining granular material should be used as backfill behind the wall. The following parameters are recommended for design:

Table 8 – Geotechnical Parameters for Granular Backfill

PARAMETERS	GRANULAR A / GRANULAR B TYPE II
Internal Friction Angle, Ø (degrees)	35
Unit weight, γ (kN/m^3)	22.8
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

The coefficient of earth pressure at-rest should be used for design of rigid and unyielding walls, the active earth pressure coefficient for unrestrained structures. The earth pressure coefficients should be reviewed if the slope of the backfill exceeds 10º to the horizontal. Alternatively, the material above the top of the wall could be treated as a surcharge load (q in the preceding equation).

The magnitude of the passive resistance is dependent on the actual lateral movement of the structure toward the retained soil. We refer to Figure C6.16 of the CHBDC for this computation. The backfill should be considered as medium dense sand for the project.

9. CONSTRUCTION CONSIDERATIONS

9.1 Excavation

Excavation for construction of retaining wall RW1 is expected to extend through the fill and native soils to depths of up to 7 m below existing grade.

The fill, compact sand and firm to hard clayey soils at the site are classified as Type 3 soils according to Occupational Health and Safety Act (Ontario Regulation 213/91) criteria. Temporary cut slopes in earth over the full depth of excavation should therefore be inclined at an angle of 45° to the horizontal.

The earth fill slopes and other exposed earth surfaces should be protected against surface erosion by sodding and suitable vegetation. Refer to OPSS 803 and OPSS.PROV 804 for time constraints and the type of seed and mulch required.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

9.2 Roadway Protection System

Depending on the depth of excavation for construction of retaining wall RW1, a roadway protection system may be necessary along Highway 401 / Brock Street. The roadway protection system is required where excavation geometry is steeper than 1H:1V.

The roadway protection system should be designed according to OPSS.PROV 539. It is recommended that a minimum performance level 2 be implemented to prevent excessive lateral movement of the adjacent embankment during construction.

The contractor should be responsible for the selection, detailed design and performance of the roadway protection scheme. OPSS.PROV 539 also calls for monitoring of the roadway protection system by the contractor to check the horizontal and vertical displacements of the roadway surface during construction.

9.3 Groundwater Control

The piezometric water level was at depths of 3.4 to 4.9 m (elevation 83.9 to 84.1) at the site of retaining wall RW1. Taking into account that the groundwater level is up to 2.4 m above the proposed founding level at elevation 81.5 to 82.6, it is anticipated that conventional sump pumping techniques will not be sufficient to control seepage of groundwater into the excavation and more positive groundwater control measures will be necessary. For long-term drainage, an additional weeping tile along the rear of the excavation should be provided at the level of the base of excavation. Also refer to section 10 of the report for further drainage recommendations.

For retaining wall RW2, the piezometric water level was at depths of 0.4 to 0.7 m (elevation 81.4 to 82.6). If excavation does not extend below the groundwater level more than 0.6 m, it is considered that seepage from soil fissures or surface water run-off that enters the excavation for construction of retaining wall RW2 may be readily handled by sump pumping techniques. It is noteworthy that any excavation extending into the sand encountered at depths of 3.1 to 5.6 m (elevation 76.0 to 80.2) is likely to require more positive groundwater control measures such as a well-point system, sheet piling or equivalent.

The groundwater level should be maintained a minimum of 0.5 m below the base of excavation. It is worth noting that groundwater levels at both sites are subject to seasonal fluctuations and precipitation patterns. Reference is made to NSP FOUND 003 “Dewatering Structure Excavation” for further recommendation to handle dewatering at this site.

10. BACKFILL AND DRAINAGE CONTROL

The drainage behind the RSS wall should be designed by the RSS supplier.

The backfill behind the cast-in-place concrete retaining wall should consist of suitable free draining granular materials such as Granular A or Granular B Type II conforming to the requirements of OPSS.PROV 1010. The backfill geometry should be in accordance with OPSD 3121.150.

Backfilling adjacent to retaining walls should be carried out in conformance to OPSS.PROV 501. Operation of compaction equipment at the retaining structures should be restricted to limit the compaction pressure noted in clause 6.12.3 of the CHBDC. Refer to OPSS.PROV 501 for additional information in this regard.

All backfilling and compaction operations should be supervised on a full-time basis by geotechnical personnel to examine and approve backfill materials, evaluate placement operations and verify that the specified degree of compaction is achieved uniformly throughout the fill.

A subdrain system (OPSS 405) and weep holes (OPSD 3190.100) should be installed to minimise the build-up of hydrostatic pressure behind the cast-in-place concrete retaining walls. The subdrain tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-100 μm according to OPSS 1860) to prevent migration of fines into the system. The drainage pipes should be installed on a positive grade.

The upper 600 mm of backfill against the wall should consist of relatively impermeable local clayey material to mitigate stormwater infiltration.

11. CLOSURE

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer

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

GD/CN:nk

APPENDIX FDR-A

List of Standard Specifications Referenced in Report

NSSP - Groundwater Concerns at RW2

NSP - Dewatering Structure Excavations

TABLE 1

LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE
OPSS 405	Construction Specification for Pipe Subdrains
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification For Temporary Protection Systems
OPSS 803	Construction Specification for Sodding
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 1860	Material Specification for Geotextiles
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
SP 599S22	Requirements for The Design, Supply and Construction of Retaining Soil Systems (RSS)
SP 599S23	Requirements for Materials, Quality Control and Quality Assurance Testing and Acceptance Criteria for Precast Concrete Facing Elements Including Panels
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario
OPSD 3121.150	Walls Retaining, Backfill Minimum Granular Requirement
OPSD 3190.100	Walls Retaining and Abutment Wall Drain

NSSP – GROUNDWATER CONCERNS AT RW2

Groundwater levels at the site of retaining wall RW2 were found to be under artesian pressure. The RSS designer and contractor are advised to limit any excavation at this site to elevation 81.5 to 82.5 or above to minimize the risk of basal heave in the excavation.

<u>DEWATERING STRUCTURE EXCAVATIONS</u> - Item No.

Special Provision

Amendment to OPSS 902, November 2010

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517 Dewatering
OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a [* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of [** Designer Fill-In, See Notes to Designer] metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website https://www.ontario.ca/environment-and-energy/map-well-records or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

The Quality Verification Engineer shall witness the following Interim Inspections of the work:

a) Dewatering of excavation for structure.

b) Completion of excavation for foundation.

c) Excavation for backfill and frost tapers.

d) Backfilling.

A copy of the written permission to proceed shall be submitted to the Contract Administrator prior to commencement of the successive operation.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

NOTES TO DESIGNER:

<u>Designer Fill-Ins</u>

* Fill in the design storm return period according to MTO Drainage Design Standard TW-1.

** Fill in the preconstruction survey distance as recommended by the foundation engineer.

WARRANT: Include with this standard tender item <u>**only**</u> on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.