FOUNDATION INVESTIGATION AND DESIGN REPORT

Overhead Sign Supports
Highway 401/Dorchester Road Underpass Replacement and Interchange Improvements
MTO DB 2022-3009, GWP 3053-11-03

Submitted to:

Dillon Consulting Limited

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Submitted by:

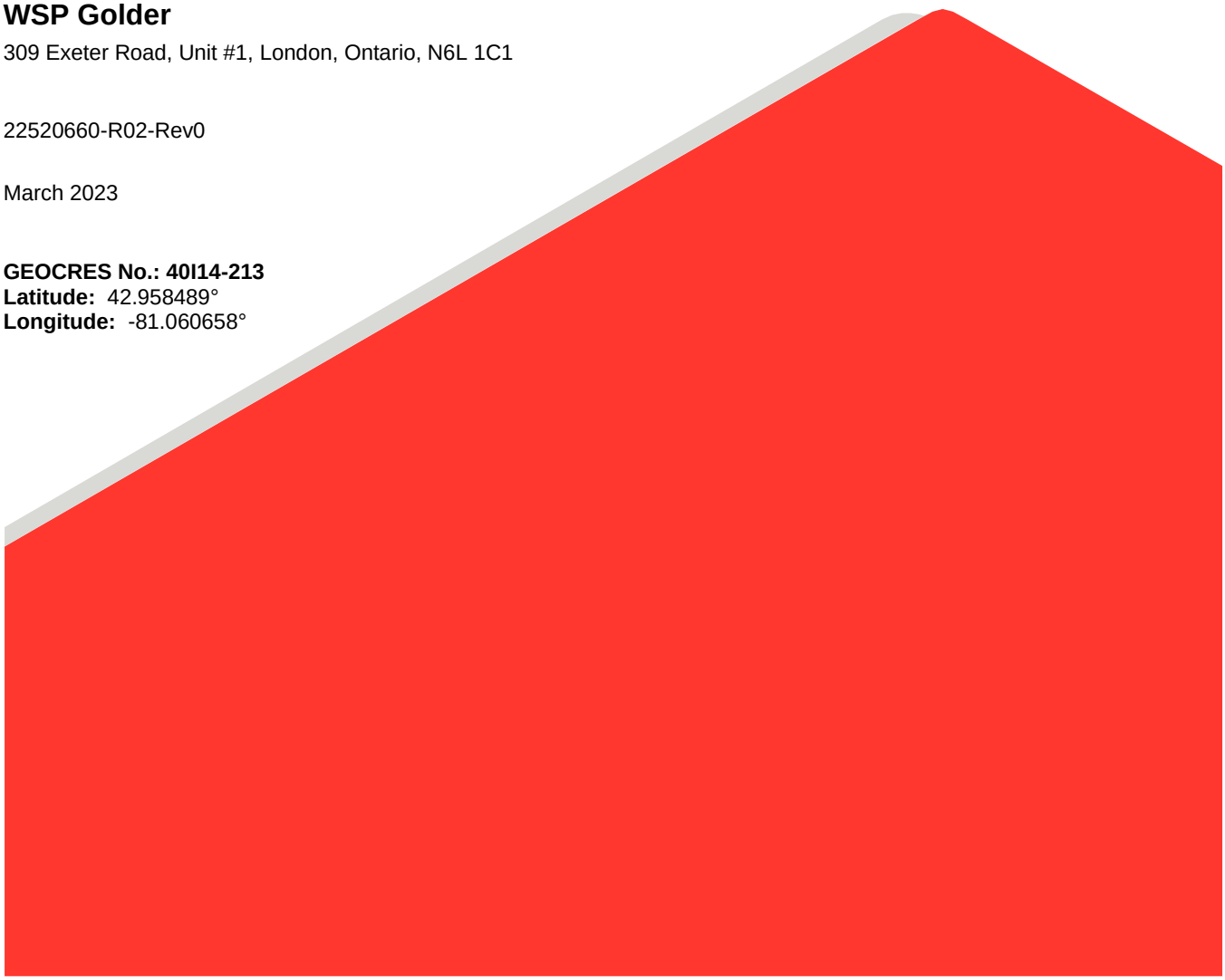
WSP Golder

309 Exeter Road, Unit #1, London, Ontario, N6L 1C1

22520660-R02-Rev0

March 2023

GEOCRES No.: 40I14-213
Latitude: 42.958489°
Longitude: -81.060658°



Distribution List

1 E-Copy - MTO West Region

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PART A

FOUNDATION INVESTIGATION REPORT

OVERHEAD SIGN SUPPORTS
HIGHWAY 401/DORCHESTER ROAD UNDERPASS REPLACEMENT
AND INTERCHANGE IMPROVEMENTS
MTO DB 2022-3009, GWP 3053-11-00

1.0 INTRODUCTION

WSP Golder (formerly Golder Associates Ltd., now a member of WSP Canada Inc.) has been retained by Dillon Consulting Limited (Dillon) on behalf of Green Infrastructure Partners (GIP) to provide detailed foundation engineering services as part of Ministry of Transportation Ontario (MTO) Contract DB 2022-3009 for the Highway 401/Dorchester Road underpass replacement and associated interchange improvements.

This report addresses four new overhead sign (OHS) supports associated with the interchange improvements, as follows:

Location	MTO Structure No.
Highway 401 EBL, Station 12+310	19X-0748/S0
Highway 401 EBL, Station 13+310	19X-0749/S0
Highway 401 WBL, Station 14+235	19X-0750/S0
Highway 401 WBL, Station 15+235	19X-0751/S0

2.0 SITE DESCRIPTION

2.1 General

The Highway 401/Dorchester Road underpass and interchange is located south of the Village of Dorchester in the Municipality of Thames Centre, Ontario. The structure is located about 3.7 kilometres east and west of Westchester Bourne and Elgin Road, respectively. The location of the project is shown on the Key Plan on Drawing 1. For the purposes of this report, Highway 401 and Dorchester Road are taken to be oriented in an east-west and a north-south direction, respectively.

This section of Highway 401 is currently a six-lane divided highway, surrounded by relatively flat-lying agricultural and commercial lands. The highway and surrounding grade are as follows in the vicinity of the proposed OHS:

- Highway 401 was constructed near original ground surface west of Dorchester Road, at approximately Elevation 283 m at Station 12+310 and on an approximately 2.5 m high embankment with grade at about Elevation 285.5 m at Station 13+310.
- The Highway 401 grade has been constructed in a partial cut at and immediately east of the Dorchester Road underpass, with grade at approximately Elevation 279 m compared to the surrounding original ground surface at approximately Elevation 282 m to 286 m.
- East of Dorchester Road, the Highway 401 grade declines toward the Dorchester Swamp, a Class 1 Provincially Significant Wetland located east of approximately Station 14+275, with a drainage feature and culvert crossing Highway 401 at approximately Station 14+300. The Highway 401 grade is at approximately Elevation 265 m at Station 14+235, and Elevation 263 m at Station 15+235, relative to the Dorchester Swamp grade of approximately Elevation 261 m to 262 m.

2.2 Site Geology

This project lies within the physiographic region known as the Westminster Moraine. The physiographic mapping indicates that the Dorchester Road underpass is located on a till moraine.[1] Geological mapping indicates that the surficial material consists of Port Stanley silty clay and clayey silt till which is, in places, covered by thin patches of lacustrine silt.[2]

The rock formation in the area of the site is described as medium brown, microcrystalline limestone of the Dundee Formation which belongs to the Hamilton Group of Middle Devonian Age.[3] The bedrock surface is estimated to be at about Elevation 229 m, on the order of 50 m below Highway 401 grade at the project site.

3.0 INVESTIGATION PROCEDURES

3.1 2013 Investigation (Golder Associates Ltd., MTO GEOCRES No. 40I14-182)

Golder Associates Ltd. (Golder) carried out a preliminary foundation investigation for the speed change lanes east of Dorchester Road in March 2013, the results of which are provided in the following report:

- **MTO GEOCRES No. 40I14-182:** "Preliminary Foundation Investigation and Design Report, Middlesex Road 32 (Dorchester Road) E-N/S and N/S-W Ramps, Highway 401 Interchange Improvements/Structural Replacements, GWP 3053-11-00, Assignment No. 2 (3011-E-0047)", dated November 2018.

Borehole BH-412 from this 2013 investigation is located near the OHS that is proposed to be located at Station 14+235. The borehole record and the related geotechnical laboratory testing data are included in Appendix A. The approximate location of the borehole is shown on Drawing 1. The table below summarizes the borehole location coordinates (MTM NAD83, Zone 11 northing and easting coordinates as well as latitude and longitude coordinates), ground surface elevation at the borehole location and borehole depth.

Borehole No.	Location					Ground Surface Elevation (m)	Borehole Depth (m)
	Approximate Station	Northing (m)	Easting (m)	Latitude (°)	Longitude (°)		
BH-412	14+237	4,758,765.1	422,682.5	42.959565	-81.055129	264.4	5.0

The investigation was carried out using truck-mounted drilling equipment supplied and operated by a specialist drilling contractor using hollow stem augers. Samples of the overburden were obtained at 0.75 m intervals of depth using 50 mm outside diameter split-spoon sampling equipment in accordance with ASTM D 1586. The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. Larger particle sizes including cobbles and boulders are known to be present in the glacial till materials. The results of the SPT testing as presented on the borehole

[1] Chapman, L.J. and Putnam, D.F., 1984: The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey, Special Volume 2.

[2] Dreimanis, A., 1963: Pleistocene Geology of the St. Thomas Area (East Half), Southern Ontario. Ontario Department of Mines, Preliminary Geological Map P.606, scale 1:50,000.

[3] Sanford, B.V., 1969: Geology, Toronto-Windsor Area, Ontario. Geological Survey of Canada, Map 1263A, scale 1:250,000.

record in Appendix A and discussed subsequently in this report have not been factored to account for the use of an automatic hammer.

The groundwater conditions in the borehole were observed throughout the drilling operations; Borehole BH-412 was dry on completion of drilling. The borehole was backfilled in accordance with MTO procedures and Ontario Regulation 903 (as amended).

3.2 2019 Investigation (Peto MacCallum Ltd., GEOCRES No. 40I14-191)

Peto MacCallum Ltd. (PML) completed a borehole investigation in the vicinity of three of the OHS sites in October 2019, the results of which are provided in the following report:

- **MTO GEOCRES No. 40I14-191:** "Foundation Investigation Report for Dorchester Road Overhead Signs, Highway 401 Station 12+385 to Station 15+153, London, Ontario, assignment No. 3016-E-0009", dated January 2020.

The records of three boreholes and the related geotechnical laboratory testing data from that report are attached in Appendix B and the approximate locations of the boreholes are shown on Drawing 1. The table below summarizes the borehole location coordinates (referenced to MTM NAD83, Zone 11 coordinates as well as latitude and longitude), ground surface elevations at the borehole locations and borehole depths.

Borehole No.	Location					Ground Surface Elevation (m)	Borehole Depth (m)
	Approximate Station	Northing (m)	Easting (m)	Latitude (°)	Longitude (°)		
25E	12+385	4,758,303.3	420,888.6	42.955684	-81.077206	281.8	9.8
26E	13+385	4,758,526.7	421,863.3	42.957546	-81.065217	284.9	9.8
14W	15+153	4,758,971.5	423,574.4	42.961284	-81.044157	262.7	9.8

According to the above-referenced report, the boreholes were advanced using continuous flight hollow stem augers, with soil samples obtained at 0.75 m and 1.5 m intervals of depth using a split-spoon sampler driven by an automatic hammer. Groundwater conditions were observed within the open boreholes, and the boreholes were backfilled in accordance with MTO guidelines and Ontario Regulation 903 (as amended).

4.0 SUBSURFACE CONDITIONS

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and laboratory testing carried out on selected samples, are provided on the borehole records in Appendices A and B. The stratigraphic boundaries shown on the borehole records are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary beyond the borehole locations.

4.1 Soil Conditions

The boreholes drilled near the proposed OHS generally encountered the existing pavement structures and fill materials overlying an extensive deposit of clayey silt to silty clay which has been interpreted to be glacial till;

localized surficial deposits of sand are present atop the till at some locations. The following table summarizes the subsurface conditions in the vicinity of each of the proposed OHS; reference should be made to the applicable borehole record in Appendices A and B for further details.

Proposed OHS	Borehole No.	Depth (m)	Elevation (m)	Soil Description and SPT N Values (blows/0.3 m)
19X-0748/S0 12+310 EBL	25E	0.0 to 1.2	281.8 to 280.6	Dense gravelly sand fill (pavement structure) – SPT N = 30-41
		1.2 to 9.8	280.6 to 272.0	Stiff to very stiff clayey silt – SPT N = 13-22
19X-0749/S0 13+310 EBL	26E	0.0 to 0.8	284.9 to 284.1	Compact gravelly sand fill (pavement structure) – SPT N = 14
		0.8 to 3.4	284.1 to 281.5	Stiff clayey silt fill – SPT N = 8-11
		3.4 to 9.8	281.5 to 275.1	Stiff to very stiff clayey silt – SPT N = 9-16
19X-0750/S0 14+235 WBL	BH-412	0.0 – 1.4	264.4 – 263.0	210 mm asphalt over very dense sand and gravel fill (pavement structure) – SPT N = 52
		1.4 – 5.0	263.0 – 259.4	Very stiff to hard clayey silt to silty clay till – SPT N = 25-42
19X-0751/S0 15+235 WBL	14W	0.0 to 0.8	262.7 to 261.9	300 mm asphalt over compact sand and gravel fill (pavement structure) – SPT N = 22
		0.8 to 3.0	261.9 to 258.9	Loose to compact sand – SPT N = 8 -16
		3.0 to 9.8	258.9 to 252.9	Compact to dense sand – SPT N = 11-40

4.2 Groundwater Conditions

It is noted that the groundwater levels/conditions encountered in the boreholes during and shortly after drilling and recorded on the borehole records may not be representative of static groundwater levels. Groundwater levels and seepage conditions in the area will fluctuate seasonally and in response to precipitation.

Boreholes 25E, 26E and BH-412, all located west of the Dorchester Swamp, were dry on completion of drilling, although wet cohesive soils were observed at about 5.5 m depth (Elevation 279.6 m) in Borehole 26E. Based on other borehole information in the area, it is estimated that the groundwater level associated with the clayey silt deposit is at a depth of approximately 3 m to 5 m; perched groundwater may be present at the base of granular fills atop the cohesive soil.

Borehole 14W which was drilled through the highway in the Dorchester Swamp area, was advanced using a head of water to control disturbance in the encountered non-cohesive soils. Hence, the groundwater level was not measured in this area, but it is estimated that the groundwater level may be close to the natural ground surface in the swamp particularly during wet periods of the year.

5.0 CLOSURE

This Foundation Investigation Report was prepared and peer reviewed by Michael Beadle, P. Eng., Senior Principal and Lisa Coyne, P. Eng., Fellow and MTO Designated Principal Foundations Contact with WSP Golder.

WSP Golder

Michael E. Beadle, P.Eng.
Senior Principal

Lisa Coyne, P.Eng.
Fellow, MTO Designated Foundations Contact

MEB/LCC/cr

https://golderassociates.sharepoint.com/sites/160773/project files/6 deliverables/r02-fidr ohs/db 2022-3009 22520660-r02-rev0 final fidr dorchester up_2023-03-16.docx

FOUNDATION DESIGN REPORT

OVERHEAD SIGN SUPPORTS
HIGHWAY 401/DORCHESTER ROAD UNDERPASS REPLACEMENT AND INTERCHANGE IMPROVEMENTS
MTO DB 2022-3009, GWP 3053-11-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides recommendations on the foundation aspects for design of the overhead sign (OHS) support foundations. The recommendations are based on our interpretation of the factual information obtained during the previous investigations completed by Golder and PML and provided by MTO as part of the RFP. This Foundation Investigation and Design Report, with the interpretation and recommendations, is intended for the use of the design engineers. 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 factual information provided as it may affect equipment section, proposed construction methods and scheduling.

6.2 Overhead Sign Foundations

Support of the overhead signs, understood to be ground mounted and median mounted tri-chord static sign supports, are typically designed with a “standard” drilled shaft (caisson) foundation design in accordance with the requirements in MTO’s Sign Support Manual (2019). The minimum design parameters/values specified in the Sign Support Manual (2019) for caissons are applicable to the design of the foundation, as follows:

- **Case 1 (“Sand”):** Non-cohesive soil with an effective friction angle of 28° surrounding the upper two-thirds of the caisson below the frost depth, and an effective friction angle of 30° surrounding the lower one-third of the caisson below the design frost depth.
- **Case 2 (“Soft Clay”):** Cohesive soil with an undrained shear strength of 25 kPa surrounding the upper two-thirds of the caisson below the frost depth, and an undrained shear strength of 50 kPa surrounding the lower one-third portion of the caisson below the design frost depth.

The soil conditions at all proposed OHS locations meet and exceed these criteria and, therefore, the standard design is applicable. The Sign Support Manual includes a standard caisson foundation design for ground mounted and median mounted tri-chord static signs (Section 4 and Standard Drawings SS118-3, SS118-4 and SS118-5). As shown on the depth to frost penetration isopleths for Southern Ontario OPSD 3090.101 (Foundation Frost Penetration Depths), the estimated depth of frost penetration for this project area is approximately 1.2 m. Overhead sign foundations should be constructed in accordance with OPSS 915.

6.3 Construction Considerations

Non-cohesive soils, such as granular fill associated with the pavement structure, seams or layers within the cohesive deposits, and the sand deposit encountered in the borehole near the proposed OHS at Station 15+235, are expected to run or flow into unsupported caisson holes. Therefore, use of temporary liners or drilling fluids is recommended to support the sides of the caisson holes during augering and placement of reinforcement steel.

Given the fine-grained cohesive nature of the soil conditions at the proposed OHS sites west of the Dorchester Swamp, groundwater is unlikely to fill the drilled holes to a degree that would prevent adequate placement of concrete. However, given that some groundwater seepage may occur near the boundary of any surface fill materials and the underlying cohesive soil or through relatively thin sand or silt seams, provision should be made for appropriate concrete placement methods such as tremie placement. For the proposed OHS at Station 15+235, high groundwater conditions are anticipated and tremie placement is expected to be required.

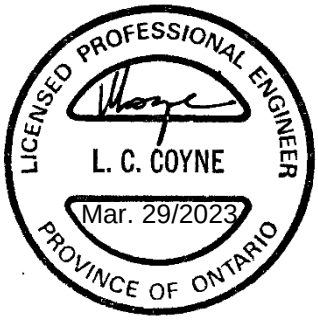
While not explicitly encountered in the boreholes near the proposed OHS locations, cobbles and boulders should be expected in the soils in this project area and the contractor should be prepared to address their presence, if required.

The final grade surrounding the sign support should be shaped to promote drainage of surface water away from the sign foundation.

7.0 CLOSURE

This Foundation Design Report was prepared and peer reviewed by Michael Beadle, P. Eng., Senior Principal and Lisa Coyne, P. Eng., Fellow and MTO Designated Foundations Contact with WSP Golder.

WSP Golder



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Senior Principal

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Fellow, MTO Designated Foundations Contact

MEB/LCC/cr

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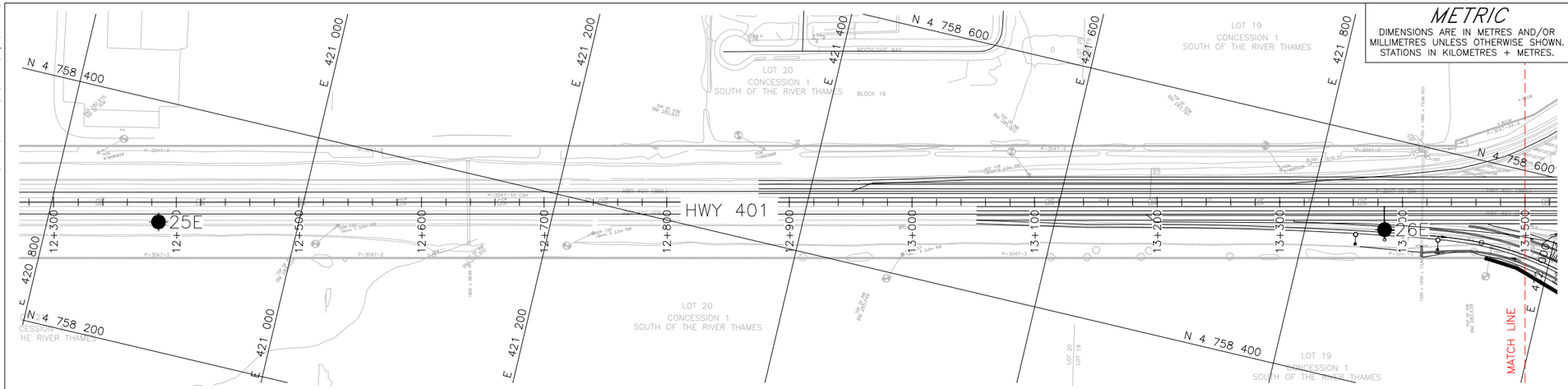
MINISTRY OF TRANSPORTATION, ONTARIO



METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

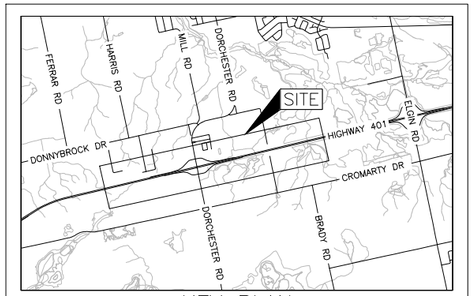
CONT No. 2022-3009
WP No. 3053-11-03

HIGHWAY 401
DORCHESTER ROAD INTERCHANGE – OHS

BOREHOLE LOCATIONS

SHEET

wsp



KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- Borehole – GEOCRES No. 40I14-191
- Borehole – GEOCRES No. 40I14-182

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
14W	262.7	4758971.5	423574.4
25E	281.8	4758303.3	420888.6
26E	284.9	4758526.7	421863.3
BH-412	264.4	4758765.1	422682.5

HORIZONTAL SCALE
10 0 10 20 m

M.E. BEADLE
LICENSED PROFESSIONAL ENGINEER
Mar. 27, 2023
PROVINCE OF ONTARIO

L.C. COYNE
LICENSED PROFESSIONAL ENGINEER
Mar. 27, 2023
PROVINCE OF ONTARIO

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

REFERENCE

Base plans and GA provided in digital format by Dillon, drawing file nos. "x3035 – Base.dwg" and "3053-09-GA.dwg", received January 23, 2023. Ground surface provided in digital format by Dillon, drawing file no. "2022-3009 – Alignments.dwg", received January 25, 2023.

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 40I14-213

HWY. 401	PROJECT NO. 22520660		DIST. .
SUBM'D. LCC	CHKD. LCC	DATE: 03/27/2023	SITE: .
DRAWN: SA	CHKD. MEB	APPD. LCC	DWG. 1

PLOT DATE: March 27, 2023
FILENAME: S:\Clients\MTO\Hwy_401_At_Dorchester\Wp_PROJ\22520660\45_PROD\0002_Overhead_Sign_Replacements\22520660-0002-BE-0001.dwg

APPENDIX A

2013 Investigation - GEOCRES No. 40I14-182

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation
w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)
A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Compactness Condition	N Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency

	c_u, s_u kPa	c_u, s_u psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-412

1 OF 1

METRIC

PROJECT 12-1132-0076-2001A
W.P. 3053-11-00
DIST HWY 401
DATUM GEODETIC

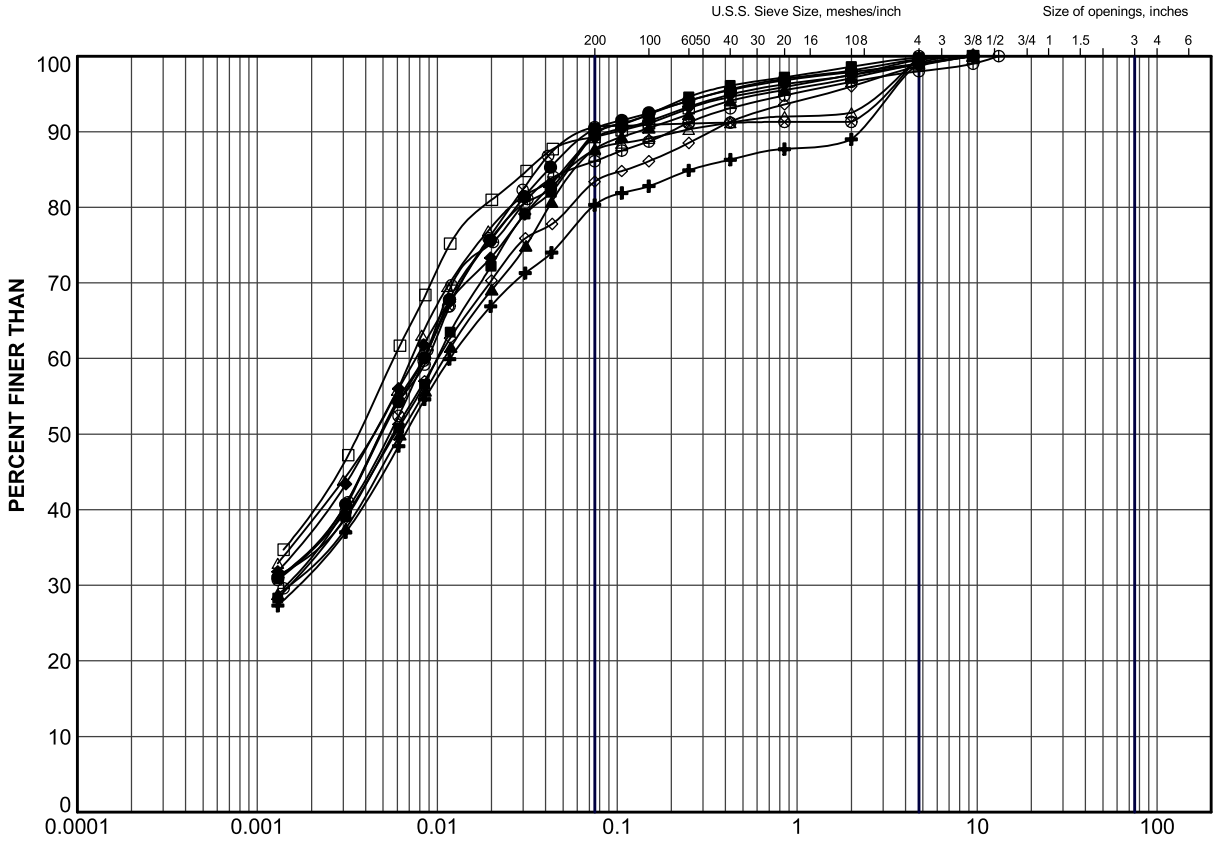
LOCATION N 4758765.1 , E 422682.5
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
DATE June 5, 2017

ORIGINATED BY MR
COMPILED BY ZJB/LMK
CHECKED BY LW

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
264.42	GROUND SURFACE										
0.00	ASPHALT										
0.21	FILL, sand and gravel, some silt Very dense Brown		1	SS	52		264		○		
263.05											
1.37	SILTY CLAY TILL, some sand Very stiff to hard Brown		2	SS	27		263				
			3	SS	42		262		○——42		0 14 44 42
			4	SS	36						
260.76							261				
3.66	CLAYEY SILT TILL, some sand Very stiff Brown turning grey at about elev. 259.7m		5	SS	26				○——		0 10 54 36
							260				
259.39			6	SS	25						
5.03	END OF BOREHOLE Borehole dry during drilling on June 5, 2017										

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-405	6	272.8
■	BH-405	10	269.7
▲	BH-406	4	271.1
✚	BH-407	3	272.3
◆	BH-408	4	267.4
◇	BH-409	6	262.7
○	BH-410	5	263.1
△	BH-411	1	264.4
⊗	BH-412	5	260.4
⊕	BH-421	3	263.4
□	BH-422	8	257.4

PROJECT

DORCHESTER ROAD RAMPS
HIGHWAY 401 INTERCHANGE IMPROVEMENTS
GWP 3053-11-00

TITLE

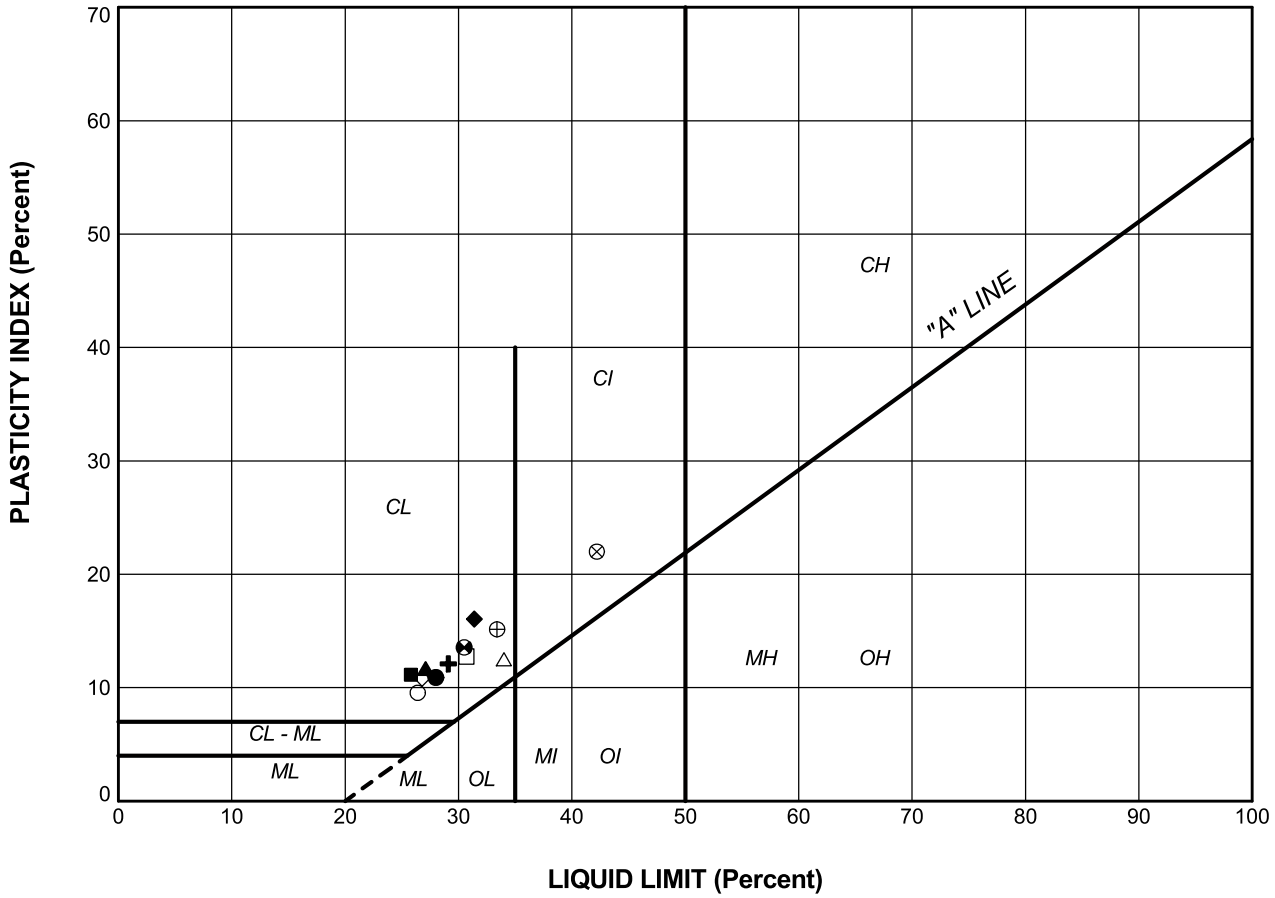
GRAIN SIZE DISTRIBUTION

CLAYEY SILT TILL

Golder Associates

PROJECT No. 12-1132-0076			FILE No. 1211320076-2001A-F010A10
			SCALE N/A / REV.
DRAWN	LMK	Mar 08/18	
CHECK			FIGURE A-10

LDN_MTO_GSD-15 GLDR_LDN.GDT 24/01/18 14:30



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH-405	6	28.0	17.1	10.9
■	BH-405	10	25.8	14.7	11.2
▲	BH-406	4	27.1	15.4	11.7
✚	BH-407	3	29.1	17.0	12.1
◆	BH-408	4	31.4	15.4	16.1
◇	BH-409	6	26.8	16.0	10.8
○	BH-410	5	26.4	16.9	9.6
△	BH-411	4	34.0	21.5	12.5
⊗	BH-412	3	42.2	20.2	22.0
⊕	BH-412	5	33.4	18.3	15.2
□	BH-421	3	30.7	18.0	12.8
◓	BH-422	8	30.5	17.0	13.6

PROJECT
DORCHESTER ROAD RAMPS
HIGHWAY 401 INTERCHANGE IMPROVEMENTS
GWP 3053-11-00

TITLE
PLASTICITY CHART
(GLACIAL TILL)

Golder Associates

PROJECT No.	12-1132-0076	FILE No. 12-1132-0076-2001A-F010A13
		SCALE N/A REV.
DRAWN	ZJR	Mar 08/18
CHECK		

FIGURE A-13

LDN_MTO_PI GLDR_LDN.GDT 26/02/18 12:06

APPENDIX B

2019 Investigation - GEOCRES No. 40I14-191

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:

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 No 14W

1 OF 1 **METRIC**

G.W.P. 3016-E-0009 LOCATION Coords: 4 758 971.5 N; 423 574.4 E ORIGINATED BY M.M.

DIST West Region HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.

DATUM Geodetic DATE 2019.10.07 LATITUDE 42.961284 LONGITUDE -81.044157 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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
262.7	Ground										
0.0	300 mm Asphalt\ over SAND and GRAVEL, some silt Compact, Brown, Moist (PAVEMENT STUCTURE)		1	SS	22		262	○	○		
261.9											
0.8	SAND, trace silt, trace gravel Loose to compact, moist, brown		2	SS	16				○		
			3	SS	8		261		○		
			4	SS	9		260		○		3 91 6 0
			5	SS	15				○		
			6	SS	40		259		○		
			7	SS	17		258		○		
			8	SS	11				○		0 94 5 1
			9	SS	20		257		○		
							256				
			10	SS	19		255		○		
	some gravel						254				
			11	SS	20				○		19 71 8 2
252.9							253				
9.8	End of borehole										

NOTES:
1. Groundwater was charged with drilling water at a depth of 3.8 m (El. 258.9) below the existing ground surface, thus groundwater level could not be established during or upon completion of drilling.
2. Borehole caved-in at a depth of 7.5 m (El. 255.2) below the existing ground surface, upon extraction of hollow stem augers.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 25E

1 OF 1 **METRIC**

G.W.P. 3016-E-0009 LOCATION Coords: 4 758 303.3 N; 420 888.6 E ORIGINATED BY M.M.

DIST West Region HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.

DATUM Geodetic DATE 2019.10.07 LATITUDE 42.955684 LONGITUDE -81.077206 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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
281.8	Ground										
0.0	gravelly SAND, trace silt, trace clay Dense, Grey, Moist (PAVEMENT FILL)		1	SS	41		281	○	○		
280.6			2	SS	30				○		
1.2	CLAYEY SILT, some sand, trace gravel Stiff to very stiff, Brown to grey, Moist		3	SS	13		280				10 12 47 31
			4	SS	19		279		○		
			5	SS	17				○		
			6	SS	14		278				2 15 55 28
			7	SS	14		277		○		
			8	SS	16				○		
			9	SS	17		276		○		
							275				
			10	SS	18		274				2 13 54 31
							273				
272.0			11	SS	22				○		
9.8	End of borehole						272				

NOTES:
1. Groundwater was not encountered during or upon completion of drilling.
2. No cave-in was noted upon extraction of hollow stem augers.

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 26E

1 OF 1 **METRIC**

G.W.P. 3016-E-0009 LOCATION Coords: 4 758 526.7 N; 421 863.3 E ORIGINATED BY M.M.

DIST West Region HWY 401 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.

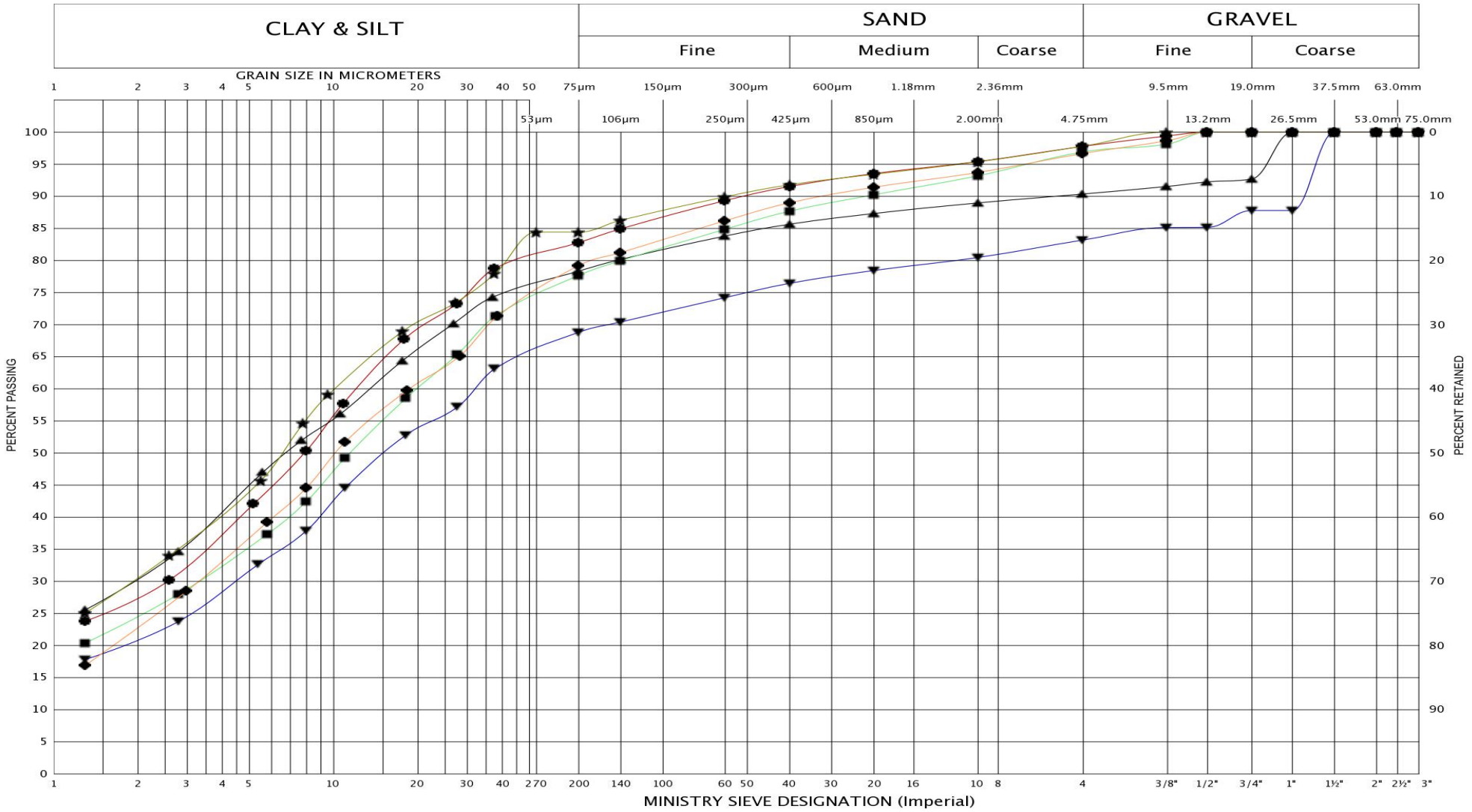
DATUM Geodetic DATE 2019.10.07 LATITUDE 42.957546 LONGITUDE -81.065217 CHECKED BY N.R.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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
284.9	Ground										
0.0	gravelly SAND, trace silt, trace clay Compact, Brown, Moist (PAVEMENT FILL)		1	SS	14				○		
284.1							284				
0.8	CLAYEY SILT, some sand, trace gravel Stiff, Grey, Moist (FILL)		2	SS	8				○		
			3	SS	11		283		○		
			4	SS	8				○		
281.5							282				
3.4	CLAYEY SILT, some sand, trace gravel Stiff, Grey, Moist		5	SS	9				⊖		3 17 57 23
			6	SS	10		281		○		
			7	SS	10				○		
			8	SS	10	▽	280		⊖		3 19 53 25
			9	SS	13		279		○		
							278				
			10	SS	16		277		○		
							276				
275.1			11	SS	15				⊖ ○		17 14 48 21
9.8	End of borehole ▽ Groundwater observed during drilling NOTES: 1. Groundwater was not encountered upon completion of drilling. 2. No cave-in was noted upon extraction of hollow stem augers.										

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO 19KF028A-DORCHESTER ROAD.GPJ ONTARIO MTO.GDT 1/8/20

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	25E	25E	25E	26E	26E	26E
	SAMPLE	3	6	10	5	8	11
	SYMBOL	▲	●	✱	◆	■	▼

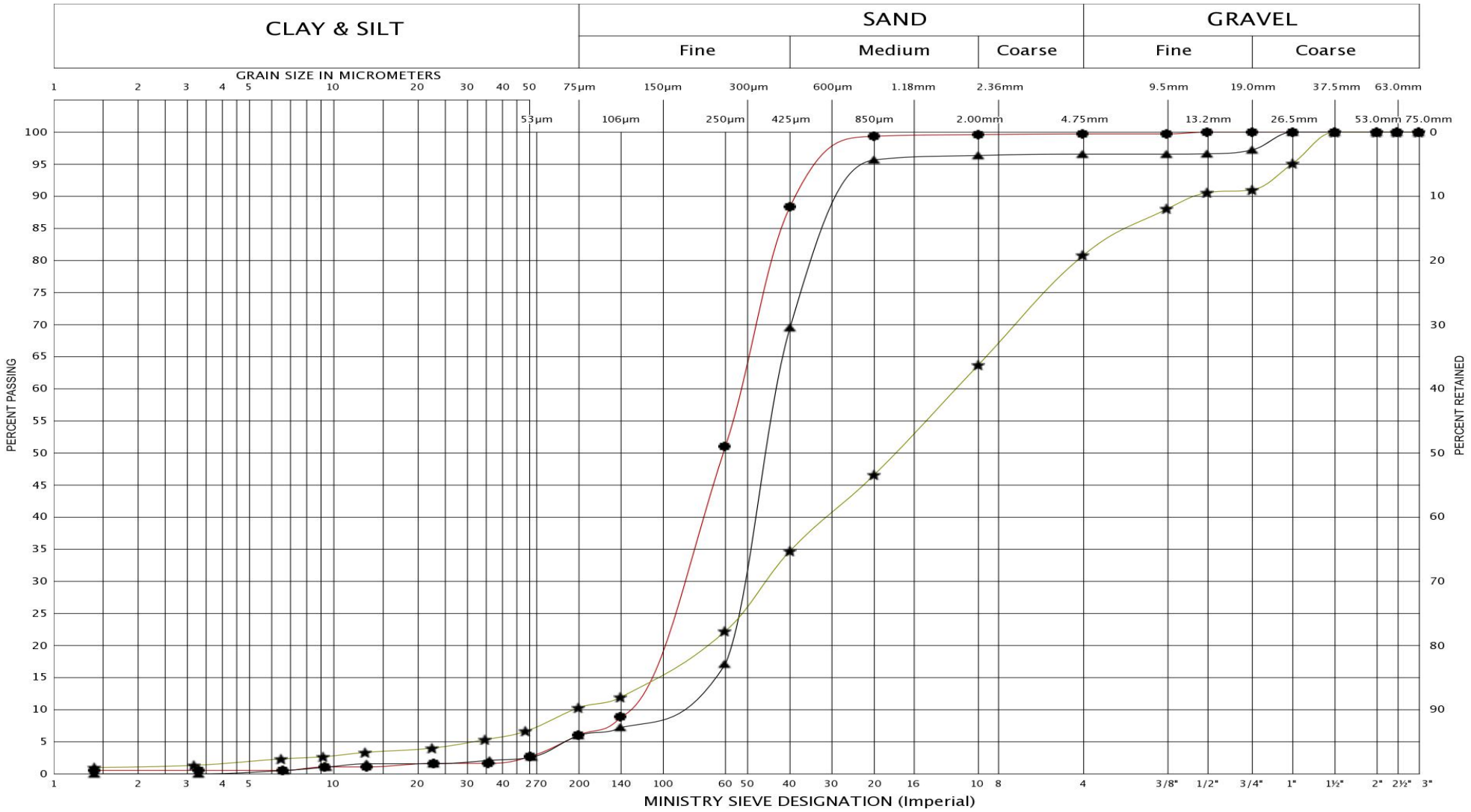
Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, some sand, trace/some gravel

FIG No.:	GS-OHS-1
HWY :	401
GWP	3016-E-2009

UNIFIED SOIL CLASSIFICATION SYSTEM



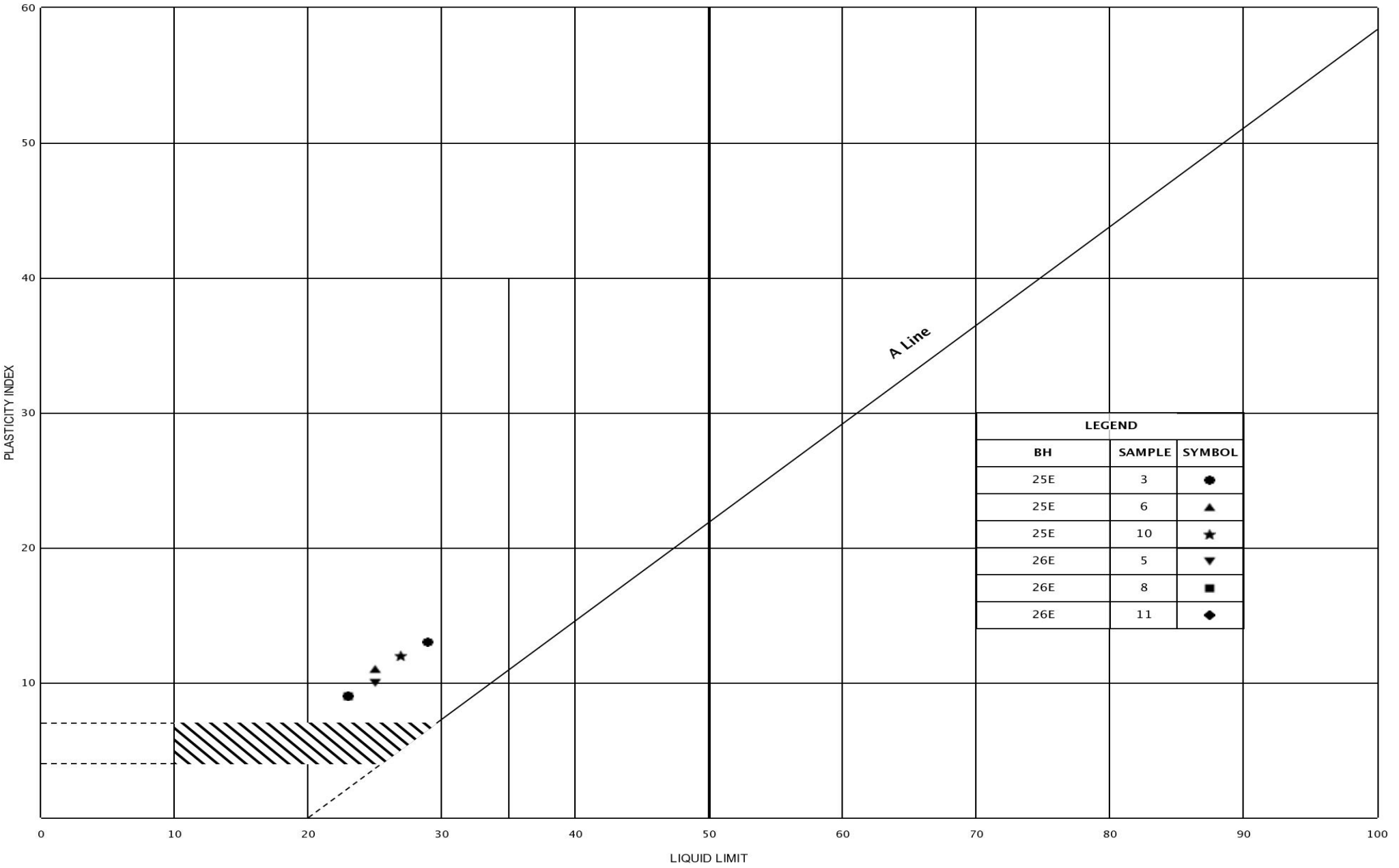
LEGEND	BH	14W	14W	14W
	SAMPLE	4	8	11
	SYMBOL	▲	●	★

Ontario

GRAIN SIZE DISTRIBUTION

SAND, trace silt, trace/some gravel

FIG No.:	GS-OHS-2
HWY :	401
GWP	3016-E-2009



Ontario

PLASTICITY CHART

CLAYEY SILT, some sand, trace/some gravel

FIG No.:	PC-OHS-1
HWY.:	401
GWP	3016-E-2009

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