



May 11, 2017

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

**BAYFIELD STREET UNDERPASS, SITE NO. 30-172
HIGHWAY 400 WIDENING
FROM 1 KM SOUTH OF HIGHWAY 89 TO JUNCTION OF HIGHWAY 11
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 06-20016**

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GEOCRES Number: 31D-673

Report Number: 14-1111-0002-11

Distribution:

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REPORT





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PART A

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
BAYFIELD STREET UNDERPASS – SITE NO. 30-172
HIGHWAY 400 WIDENING
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (now AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the replacement of the Bayfield Street Underpass in Barrie, Ontario. The proposed work is part of the preliminary and design-build ready design associated with the Highway 400 widening from 1 km south of Highway 89 to the junction of Highway 11 in Simcoe County, Ontario.

This report addresses the proposed replacement of the Bayfield Street Underpass (MTO Structure Site No. 30-172) and the associated approach embankments only.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated July 2013. Golder's scope of work for foundation engineering services associated with the Bayfield Street Underpass replacement is contained in Section 5.8 of URS Canada's (now AECOM's) Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated January 20, 2014.

2.0 SITE DESCRIPTION

The Bayfield Street Underpass, which is part of the Highway 400-Bayfield Street Interchange, is located approximately 2.3 km north of Dunlop Street (Simcoe Road 90, formerly Highway 90) and 5 km south of Highway 11 in Barrie, Ontario, as shown in the Key Plan on Drawing 1.

Highway 400 at Bayfield Street is constructed in an approximately 6.5 m to 7.5 m deep cut at the west and east abutments, respectively, with the existing Highway 400 grade at between about Elevations 266.1 m and 266.8 m. The existing Bayfield Street grade is near the original ground surface and is at about Elevation 273.5 m. The existing structure is a one-span bridge founded on spread footings, with a span length and width of approximately 34 m and 27 m, respectively.

3.0 INVESTIGATION PROCEDURES

3.1 Previous Borehole Investigation

Two boreholes were advanced at the Bayfield Street Underpass structure as part of a geotechnical investigation in 1979 for the widening of the Bayfield Street Underpass (MTO, 1980)¹. Boreholes 1 and 2 were advanced from the Highway 400 grade on the outside shoulders of the northbound and southbound lanes. The boreholes were advanced to depths of 7.5 m and 8.1 m below ground surface. The record of boreholes and associated laboratory test results are provided in Appendix A and the borehole locations are shown on Drawing 1.

Borehole 1 was advanced using an 82 mm inner diameter (I.D.) hollow stem auger and Borehole 2 was advanced using 102 mm solid stem auger. Soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m,

¹ Ministry of Transportation, Ontario. 1980. Preliminary Foundation Investigation Report Bayfield Street (Highway 26) Underpass Structure Site 30 172, Highway Widening from 1 km south of Highway 89 to Highway 11, G.W.P. 30 95 00, Agreement o. 3005 A 000074, GEOCREs No. 31D 268, prepared by Ministry of Transportation, Ontario.



FOUNDATION REPORT - HIGHWAY 400 BAYFIELD STREET

using a 50 mm outer diameter split-spoon sampler driven by a manual hammer in accordance with the Standard Penetration Test (SPT) procedure². The water level in the open boreholes was observed on completion of drilling.

The borehole locations in MTM NAD83 (Zone 10) northing and easting coordinates, ground surface elevations referenced to Geodetic datum and drilled depths are summarized below.

Borehole Number	Location (MTM NAD83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
1	4,917,669	288,980	266.1	7.5
2	4,917,695	288,964	266.4	8.1

3.2 Current Borehole Investigation

The field work at the site of the Bayfield Street Underpass was carried out on March 20, 2016 during which time one borehole was advanced to supplement the existing subsurface information from the 1979 investigation. The Record of Borehole sheet is presented in Appendix B. The location of this borehole is shown in plan on Drawing 1.

The borehole investigation was carried out using a Diedrich D-120 truck-mounted drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The borehole was advanced through the overburden using 108 mm I.D. hollow stem augers. Soil samples were generally obtained at intervals of depth about 0.75 m and 1.5 m, using a 50 mm outside diameter split-spoon sampler driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586)². The borehole was advanced to a depth of 15.6 m, penetrating into at least 3 m into a “refusal” stratum, defined as material for which the SPT ‘N’-values exceed 100 blows per 0.3 m of penetration.

The groundwater conditions and water level in the open borehole was observed during and immediately following the completion of drilling operations. The borehole was backfilled upon completion of drilling in accordance with Ontario Regulation 903 (as amended), and the pavement was reinstated using cold patch asphalt.

The field work was observed by a member of Golder’s engineering staff who located the borehole, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the borehole and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to Golder’s Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, grain size distribution and Atterberg limits) was carried out on selected soil samples. The results of the laboratory testing are included in Appendix B.

The as-drilled borehole location was measured relative to existing on-site features shown on the Digital Terrain Model (TDM) for the site, and the ground surface elevations were interpolated from the topographic data provided by AECOM. The borehole location provided on the Record of Borehole and shown in plan on Drawing 1 are given using MTM NAD83 (Zone 10) northing and easting coordinates, and the ground surface elevation is referenced to Geodetic datum. The borehole location, ground surface elevation and drilled depth are summarized below.

² ASTM D1586

Standard Test Method for Standard Penetration Test (SPT) and Split Barrel Sampling of Soils



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Borehole Number	Location (MTM NAD83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
BF1-1	4,917,706.1	289,002.2	266.8	15.6

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in *The Physiography of Southern Ontario*³, the section of Highway 400 from 6 km south of Highway 89 to the junction of Highway 11 traverses, generally in a south–north direction, the following physiographic regions: the Peterborough Drumlin Field; the Simcoe Lowlands; and the Simcoe Uplands. Along Highway 400, the Peterborough Drumlin Field is present from the southern limit of the project site to south of Line 13 of the Township of Bradford West Gwillimbury, as well as between about 1 km north of Highway 89 to about Essa Road. The Simcoe Lowlands covers the area from south of Line 13 to approximately 1 km north of Highway 89 and from about Essa Road to just north of Anne Street. The Simcoe Uplands extends from just north of Anne Street to beyond the northern limit of this project site.

The surficial soils in the western portion of the Peterborough Drumlin Field consist primarily of sandy till deposits and sand to sand and gravel deposits. Deposits of silt, clay or peat may also be found in the low-lying areas between drumlins and eskers.

Along Highway 400, the Simcoe Lowlands include: the Holland River valley; the lowlands of the Lake Simcoe basin to the east; the lowlands of the Nottawasaga basin to the west, which includes Innisfil Creek and the Nottawasaga River to the south and west of the project limits, respectively. The Lake Simcoe and Nottawasaga basins are connected by a flat floored valley through Barrie which extends from the shores of Kempenfelt Bay west generally along Dunlop Street (formerly Highway 90). The Simcoe Lowlands are generally characterized by deep deposits of deltaic or lacustrine silts, sands and clays associated with glacial Lake Algonquin.

The Simcoe Uplands, which encompasses the Bayfield Street site, consist of till plains and ancient shorelines. The till deposits range from clayey to silty and generally become more sandy and containing more boulders in the north. The low-lying areas of this region may also contain shallow deposits of sand and gravel associated with former glacial lake shorelines.

4.2 Subsurface Conditions

The Record of Borehole sheets and laboratory testing results from the 1979 and 2016 investigations are presented in Appendices A and B, respectively. The interpreted stratigraphic profile and cross-sections are shown on Drawings 1 and 2.

The results of the in situ field tests (i.e. SPT 'N'-values) carried out during the 2016 investigation as presented on the Record of Borehole sheets and in Section 4.2 are uncorrected. According to the Canadian Foundation

³ Chapman, L. J. and Putnam, D. F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey. Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000. Ontario Ministry of Natural Resources.



Engineering Manual (CFEM, 2006)⁴, the energy delivered to the drill rod varies with the hammer release system, hammer type, anvil and operator characteristics. It should be noted that different hammer release systems were used during the 1979 and 2016 investigations (i.e. manual vs automatic) and as such SPT 'N'-values measured during the 1979 investigation may be higher than the 'N'-values measured during the current investigation within the same deposit.

The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile and cross-sections are inferred from observations of drilling progress and non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the site consist of a layer of a sand and gravel fill underlain by a glacial till deposit generally comprised of clayey silt, silt and sand, and silty sand which extends to the termination of the boreholes.

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Asphalt and Sand and Gravel Fill

A 0.3 m to 0.5 m thick layer of asphalt was encountered between Elevation 266.1 m and 266.8 m in the three boreholes advanced on site. A 0.6 m thick deposit of sand and gravel fill was encountered at Elevation 266.3 m below the asphalt in Borehole BF1-1.

The SPT 'N'-value measured across the interface between the asphalt and granular fill and within the granular fill is 50 blows and 21 blows per 0.3 m of penetration, respectively, generally indicating a compact relative density.

The natural water content measured on a sample of the fill deposit is about 4 per cent.

4.2.2 Clayey Silt to Silt with Sand to Silty Sand to Sand Till

A glacial till deposit comprised of clayey silt, to silt with sand, silt and sand, and silty sand was encountered below the asphalt in Boreholes 1 and 2, and below the fill in Borehole BF1-1. A 1.5 m thick interlayer of sand till was encountered within the silt and sand to silty sand till deposit in Borehole BF1-1 at Elevation 253.7 m. The presence of cobbles was inferred within the till deposit in Boreholes 1 and 2 between Elevations 266.1 m and 258.3 m from the 1979 investigation and from auger grinding at depths between 3.1 m and 3.7 m (Elevations 263.7 m and 263.1 m), and at a depth of 5.2 m (Elevation 261.6 m) in Borehole BF1-1. All boreholes were terminated within the till deposit after penetrating it for between 7.2 m and 14.5 m.

The SPT 'N'-values measured within the till deposit range from 13 blows to 128 blows per 0.3 m of penetration and up to 100 blows per 0.13 m of penetration, suggesting/indicating a stiff to hard consistency and a compact to very dense relative density.

⁴ Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.



The natural water content measured on samples of the clayey silt to silt with sand till deposit ranges from about 7 per cent to 9 per cent. The natural water content measured on samples of the silty sand to sand till deposit ranges from about 4 per cent to 9 per cent.

The envelope created from the results of grain size distribution tests completed on seven samples of the clayey silt to silt with sand till from Boreholes 1 and 2 are shown on Figure 1 in Appendix A. The results of the grain size distribution tests completed on four samples from the silt and sand to silty sand to sand till in Borehole BF1-1 are presented on Figure B1 in Appendix B.

Atterberg limits tests carried out on two samples of the fines component of the silty sand till deposit measured liquid limits of about 12 per cent and 15 per cent, plastic limits of about 10 per cent and 11 per cent and plastic indices between about 1 per cent and 5 per cent. An Atterberg limits test carried out on a sample of the fines component of the silty sand till deposit indicate that the sample is non-plastic. The Atterberg limits results indicate that the fines component of the till deposit is comprised of non-plastic silt to a silt of slight plasticity.

4.3 Groundwater Conditions

In general the soil samples retrieved in the boreholes were moist. All boreholes were dry upon completion of drilling. The water level was noted on the borehole records as “not observed” in Boreholes 1 and 2, but qualified as “dry” in the text of the report from the 1979 investigation.

The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and periods of precipitation.

5.0 CLOSURE

This report was prepared by Mr. Martin Legroulx, B.A.Sc. and Ms. Madison Kennedy, B.A.Sc., members of the geotechnical engineering group, and was reviewed by Mr. Christopher Ng, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with Golder and Designated MTO Foundations Contact, conducted an independent quality control review of this report.



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Report Signature Page

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FOUNDATION REPORT - HIGHWAY 400 BAYFIELD STREET

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Canadian Foundation Engineering Manual. 2006. Fourth Edition, Canadian Geotechnical Society: Richmond, British Columbia.

Chapman, L. J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

Ministry of Transportation, Ontario. 1980. *Preliminary Foundation Investigation Report Bayfield Street (Highway 26) Underpass Structure Site 30-172, Highway Widening from 1 km south of Highway 89 to Highway 11, G.W.P. 30-95-00, Agreement o. 3005-A-000074*, GEOCRE No. 31D-268, prepared by Ministry of Transportation, Ontario.

Ministry of Transportation, Ontario. 2002. *Foundation Investigation Report Hwy. #26/27 (Bayfield Street) Underpass Widening, Hwy. 400 District #5, Owen Sound, W.P. 28-78-02, Site: 30-172*, GEOCRE No. 31D-479, prepared by Golder Associates Ltd.

ASTM International:

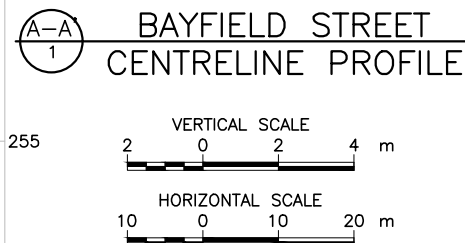
ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Ontario Water Resources Act:

Ontario Regulation 903 Wells (as amended)



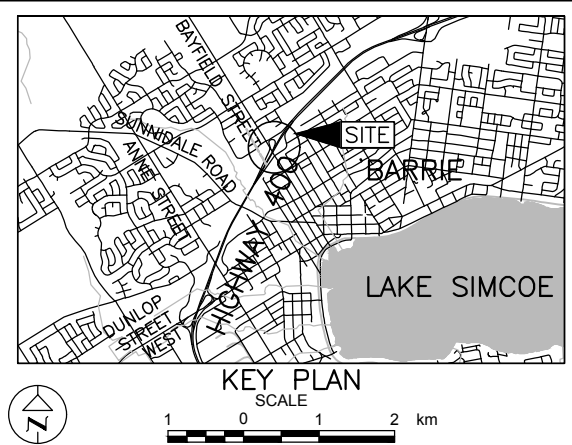
DRAWINGS





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



SHEET



- | LEGEND | |
|---|--|
|  | Borehole - Current Investigation |
|  | Borehole - Previous Investigation
(Geocres No. 31D-268) |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow) |

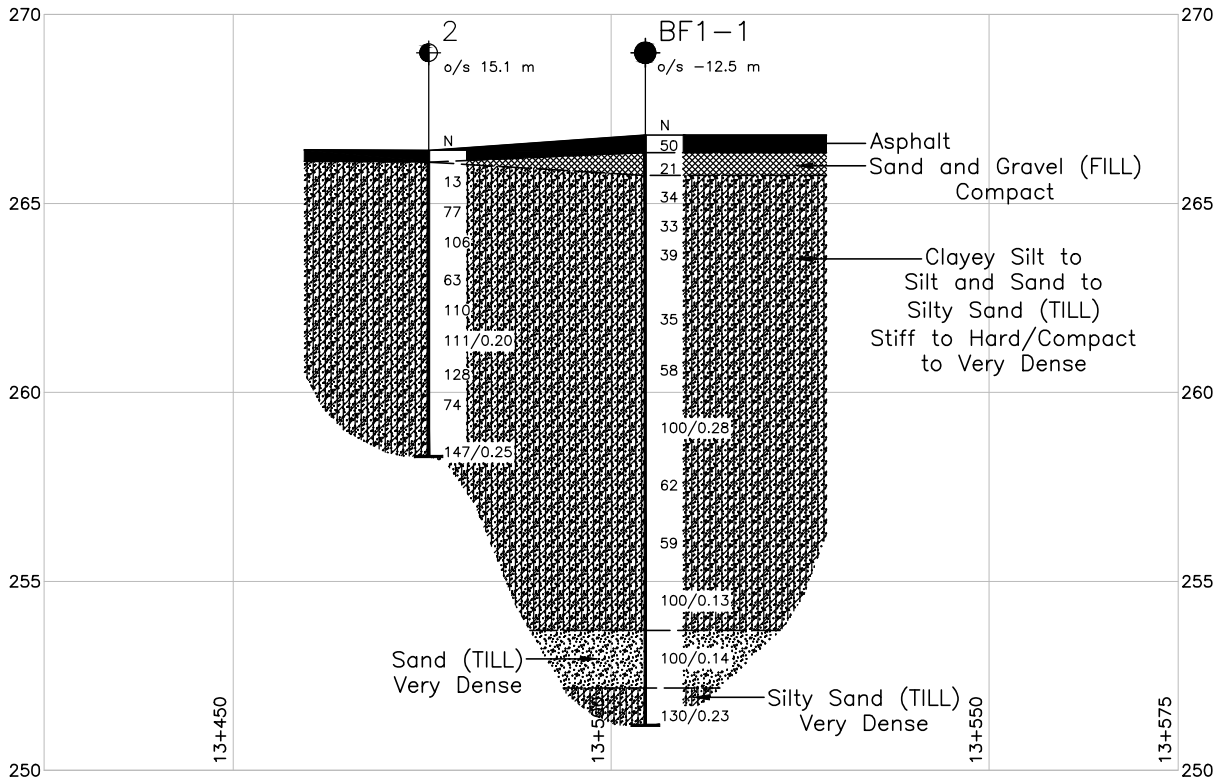
BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
1	266.1	4917669.0	288980.0
2	266.4	4917695.0	288964.0
BF1-1	266.8	4917706.1	289002.2

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.

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

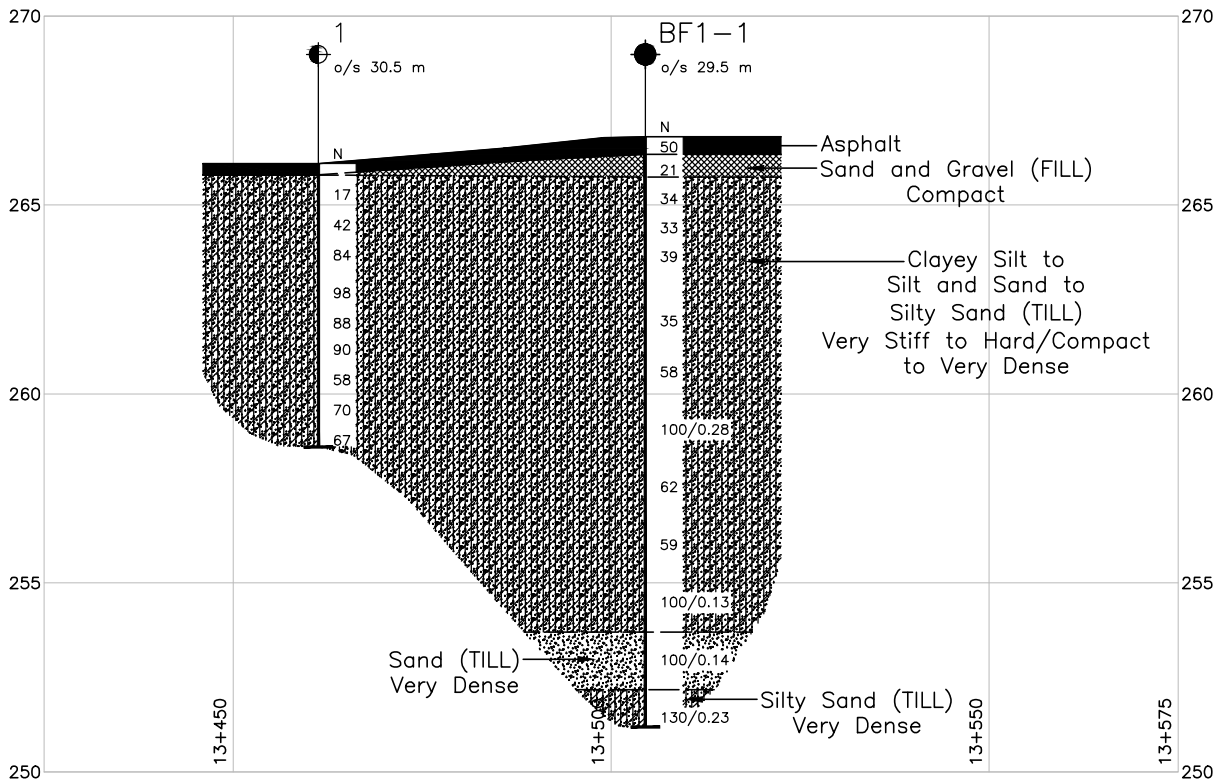
General arrangement, designs, base plans, profile and surface data provided in digital format by AECOM, drawing file nos. "Bayfield Rd_30-172_GA.dwg", received October 3, 2016, "X-Base_All.dwg", received January 27, 2016, "X-Design_4th Line_Interim.dwg", received June 22, 2015, and "X-Surfaces.dwg", received April 14, 2015.

NO.	DATE	BY	REVISION		
Geocres No. 31D-673					
HWY. 400		PROJECT NO. 14-1111-0002			DIST. .
SUBM'D. MCK	CHKD. MCK	DATE: 5/11/2017			SITE: 30-172
DRAWN: MR/DD	CHKD. CN	APPD. JMAG			DWG. 1



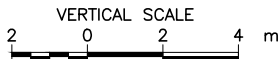
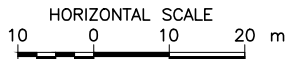
B-B
1

PIER CROSS-SECTION



C-C
1

EAST ABUTMENT CROSS-SECTION

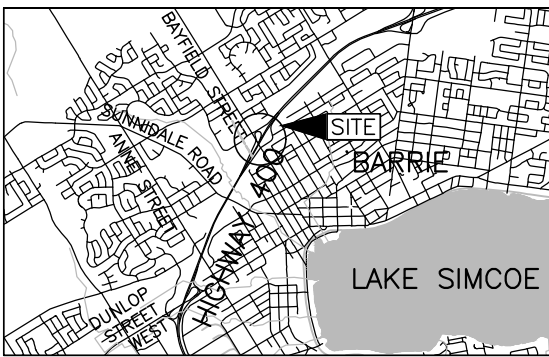


METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WO No. 06-20016

BAYFIELD STREET UNDERPASS
HIGHWAY 400 WIDENING
SOIL STRATA

SHEET



KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- Borehole - Current Investigation
- ⊕ Borehole - Previous Investigation (Geocres No. 31D-268)
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
1	266.1	4917669.0	288980.0
2	266.4	4917695.0	288964.0
BF1-1	266.8	4917706.1	289002.2

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.

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

REFERENCE

General arrangement, designs, base plans, profile and surface data provided in digital format by AECOM, drawing file nos. "Bayfield Rd_30-172_GA.dwg", received October 3, 2016, "X-Base_All.dwg", received January 27, 2016, "X-Design_4th Line_Interim.dwg", received June 22, 2015, and "X-Surfaces.dwg", received April 14, 2015.



NO.	DATE	BY	REVISION
Geocres No. 31D-673			
HWY. 400		PROJECT NO. 14-1111-0002	
SUBM'D. MCK	CHKD. MCK	DATE: 5/11/2017	SITE: 30-172
DRAWN: MR/DD	CHKD. CN	APPD. JMAC	DWG. 2



APPENDIX A

**Record of Boreholes and Laboratory Test Results – 1979
Investigation (GEOCRES No. 31D-268)**

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 1/4 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.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

MECHANICAL PROPERTIES OF SOIL

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

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

PHYSICAL PROPERTIES OF SOIL

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



RECORD OF BOREHOLE No 1

METRIC

7

W P 28-78-02 LOCATION Sta. 10+446.3 o/s 13.4 m Lt. of Hwy. 26 & 27 ORIGINATED BY PRK
 DIST 5 HWY 400 BOREHOLE TYPE Hollow Stem Auger 82 mm I.D. COMPILED BY PRK
 DATUM Geodetic DATE 1979.06.06 CHECKED BY AS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100		
266.1	Ground Level													
0.0	Asphalt Pavement					*	266							GR SA SI CL
0.3	Very Stiff		1	SS	17									6 63 21 10
			2	SS	42		264							
	Clayey Silt to Silt With Sand Trace of Gravel Occasional Cobbles Hard (Glacial Till)		3	SS	84									9 58 23 10
			4	SS	98									
			5	SS	88		262							
			6	SS	90									
			7	SS	58									4 59 25 12
			8	SS	70		260							
258.6			9	SS	67									5 59 25 11
7.5	End of Borehole * Water Level Not Observed at Completion of Augering													

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 2

METRIC

8

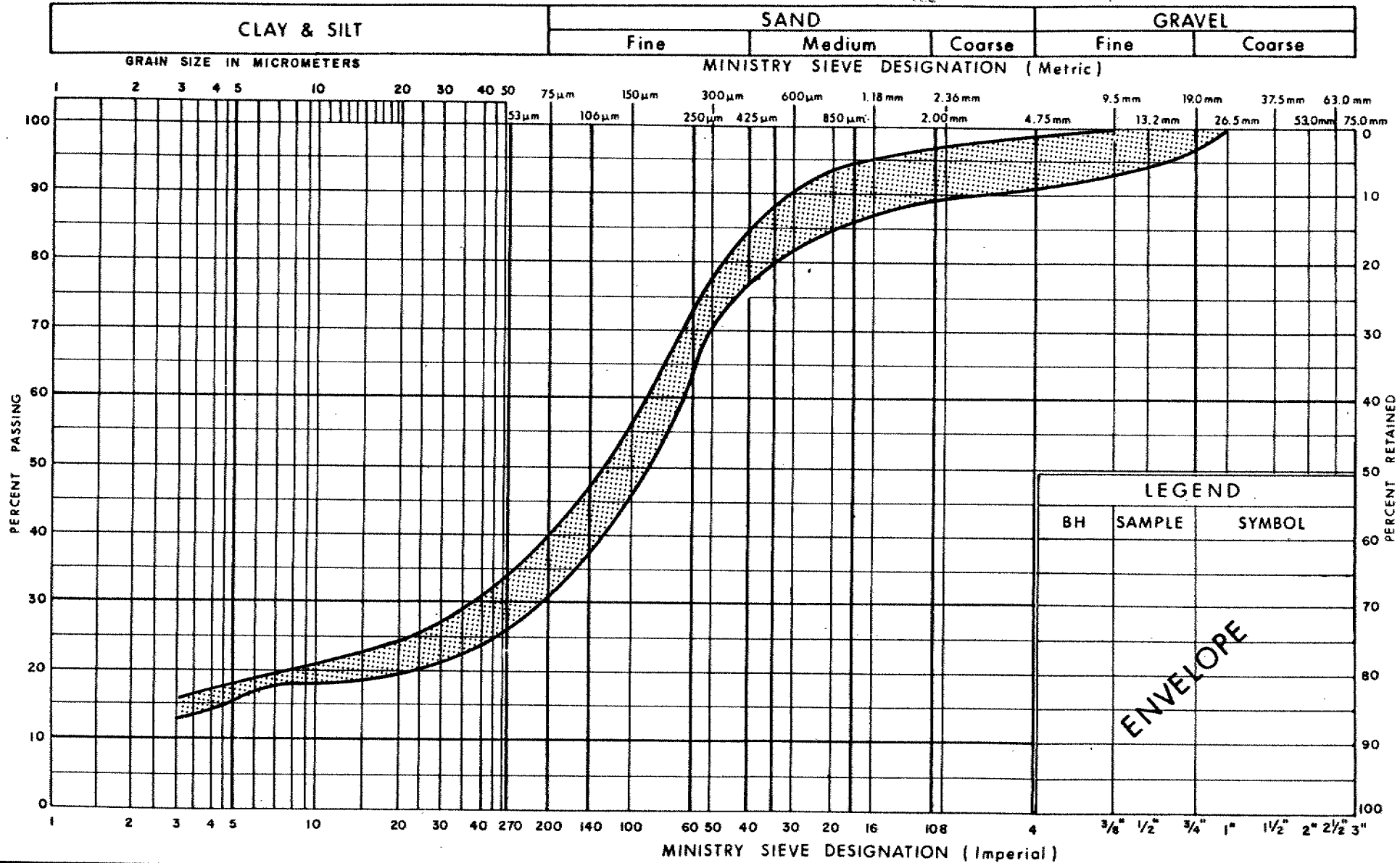
W P 28-78-02 LOCATION Sta. 10+477.1 o/s 12.5 m Lt. of Hwy. 26 & 27 ORIGINATED BY PRK
DIST 5 HWY 400 BOREHOLE TYPE Solid Stem Auger, Cone Test COMPILED BY PRK
DATUM Geodetic DATE 1979 06 07 CHECKED BY RS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40					
266.4	Ground Level													
0.0	Asphalt Pavement													
0.3	Stiff Clayey Silt to Silt With Sand Traces of Gravel Occasional Cobbles Hard (Glacial Till)		1	SS	13									
			2	SS	77									8 55 26 11
			3	SS	106									2 59 27 12
			4	SS	63									
			5	SS	110									
			6	SS	111/	0.20 m								3 62 23 12
			7	SS	128									
			8	SS	74									
258.3	End of Borehole Water Level Not * Observed at Completion of Augering		9	SS	147/	0.25 m								

+3, x5: Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

Ministry of
Transportation and
Communications

GRAIN SIZE DISTRIBUTION CLAYEY SILT TO SILT

WITH SAND, TRACES OF GRAVEL, OCC COBBLES (GLACIAL TILL)

FIG No 1

W P 28 - 78 - 02



APPENDIX B

Record of Boreholes and Laboratory Test Results – Golder 2016 Investigation



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
ν	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

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

(a) Index Properties (continued)

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)

(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 = $\tan \delta$
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
2

$\tau = c' + \sigma' \tan \phi'$
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, 60° 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 cm² 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 Soils

Density Index	N
Relative Density	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	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



PROJECT 14-1111-0002		RECORD OF BOREHOLE No BF1-1		SHEET 1 OF 2		METRIC	
W.O. 06-20016		LOCATION N 4917706.1; E 289002.2 MTM ZONE				ORIGINATED BY MPL	
DIST Central HWY 400		BOREHOLE TYPE Diedrich D-120 108 mm I.D. Hollow Stem Auger (Auto Hammer)				COMPILED BY MCK	
DATUM Geodetic		DATE March 20, 2016				CHECKED BY MCK	


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+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

○ 3% STRAIN AT FAILURE

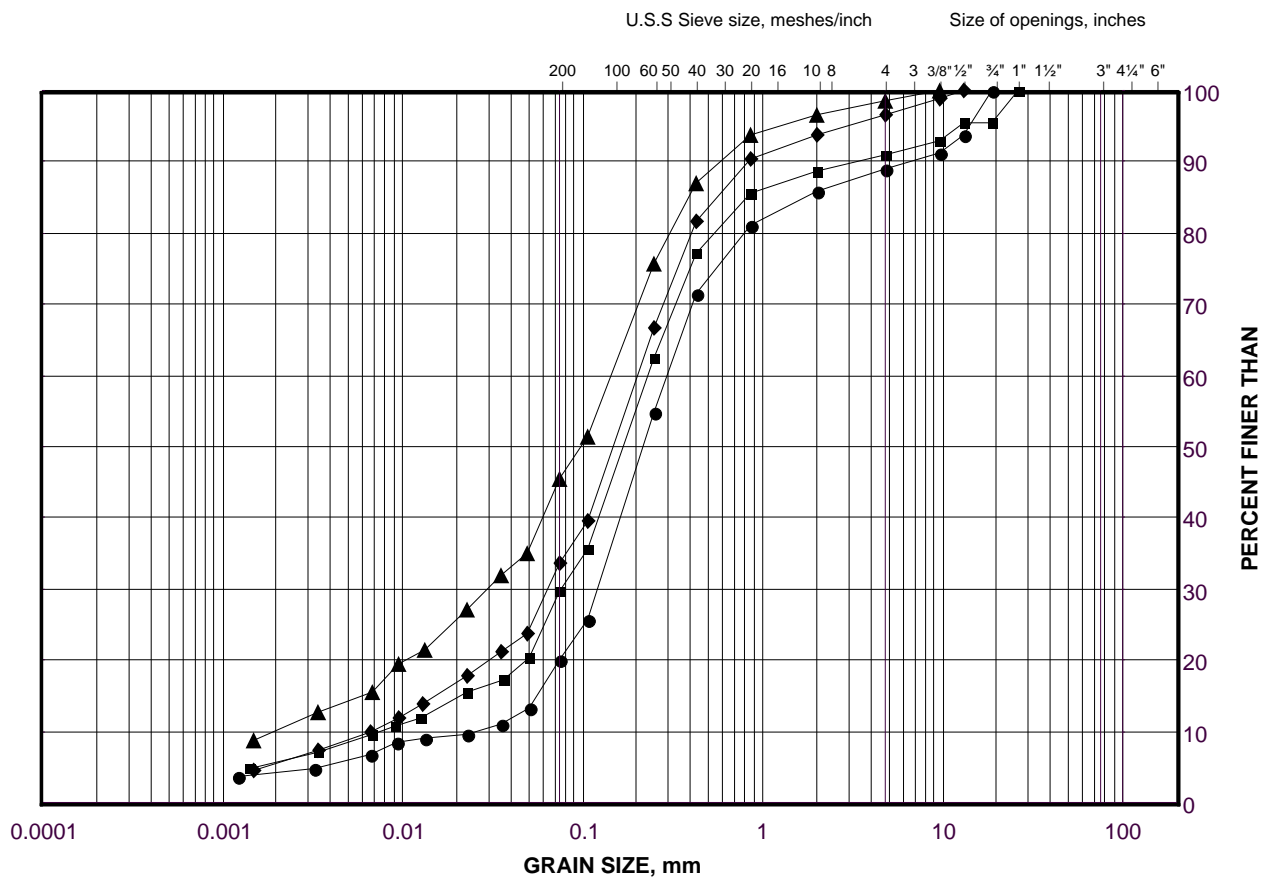
PROJECT <u>14-1111-0002</u>		RECORD OF BOREHOLE No BF1-1		SHEET 2 OF 2		METRIC	
W.O. <u>06-20016</u>		LOCATION <u>N 4917706.1; E 289002.2 MTM ZONE</u>		ORIGINATED BY <u>MPL</u>			
DIST <u>Central</u> HWY <u>400</u>		BOREHOLE TYPE <u>Diedrich D-120 108 mm I.D. Hollow Stem Auger (Auto Hammer)</u>		COMPILED BY <u>MCK</u>			
DATUM <u>Geodetic</u>		DATE <u>March 20, 2016</u>		CHECKED BY <u>MCK</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						W _p	W	W _L		GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED							WATER CONTENT (%)					
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100									
251.2 15.6	Silty SAND, some gravel (TILL) Very dense Brown Moist END OF BOREHOLE NOTE: 1. Borehole dry upon completion of drilling.		13	SS	130/0.23									○					NP		

GTA-MTO 001 S:\CLIENTS\MTOWHY_400_BARRIER02_DATA\GINT\1411110002_LAT_LONG.GPJ GAL-GTA.GDT 06/04/17

Silt and Sand to Silty Sand to Sand (Till)

FIGURE B1



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

LEGEND

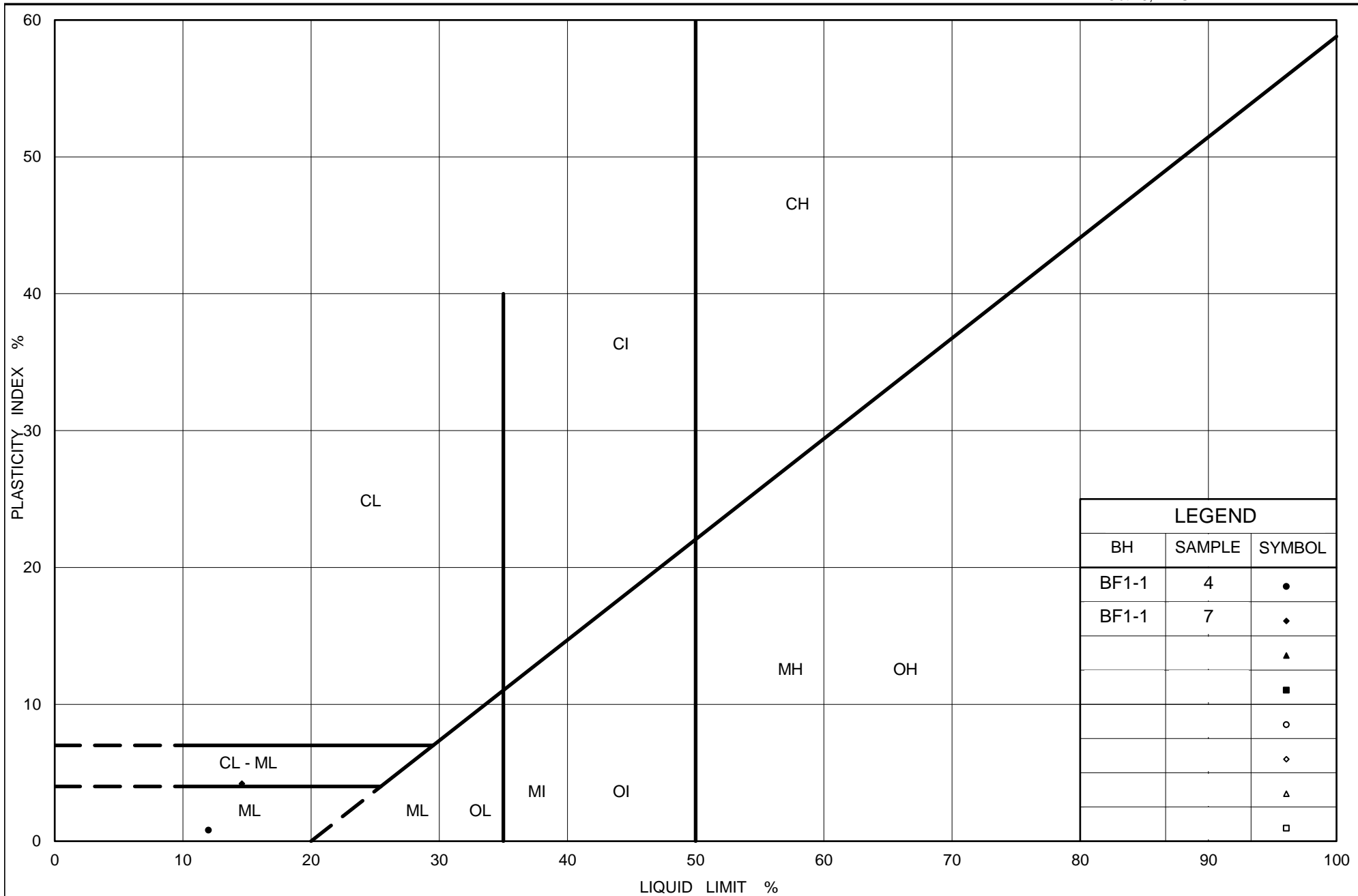
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BF1-1	12	253.0
■	BF1-1	2B	265.6
◆	BF1-1	4	264.2
▲	BF1-1	7	260.4

Project Number: 14-1111-0002

Checked By: CN

Golder Associates

Date: 14-Dec-16



Ministry of Transportation

Ontario

PLASTICITY CHART

Silty Sand (TILL)

Figure No. B2

Project No. 14-1111-0002

Checked By: CN

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