



November 28, 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

**HIGH FILL AREAS 1 TO 6
FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC) AND
ASSOCIATED MUNICIPAL ROADS, CITY OF HAMILTON
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2112-05-00**

Submitted to:

IBI Group
30 International Boulevard
Toronto, Ontario
M9W 5P3



REPORT

GEOCRES No.: 30M5-306

Report Number: 10-1184-0016

Distribution:

- 3 Copies – Ministry of Transportation, Ontario (Central Region)
- 1 Copy – Ministry of Transportation, Ontario (Foundations Section)
- 1 Copy – IBI Group, Toronto, Ontario
- 2 Copies – Golder Associates Ltd., Mississauga, Ontario





Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 INVESTIGATION PROCEDURES	2
3.1 Foundation Investigation.....	2
3.2 Stockpiled Material Investigation	4
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	5
4.1 Regional Geology	5
4.2 General Overview of Subsurface Conditions	5
4.3 Stockpiled Material	6
4.4 Highway 5: STA. 29+850 to STA. 29+960 (High Fill Area 1)	6
4.4.1 Asphalt.....	7
4.4.2 Topsoil	7
4.4.3 Fill	7
4.4.4 Clayey Silt Till	8
4.4.5 Refusal.....	8
4.4.6 Groundwater Conditions	8
4.5 Highway 5: STA. 30+040 to STA. 30+120 (High Fill Area 2)	9
4.5.1 Asphalt.....	9
4.5.2 Topsoil	9
4.5.3 Fill	9
4.5.4 Clayey Silt Till	10
4.5.5 Refusal.....	10
4.5.6 Groundwater Conditions	10
4.6 Ramp W-S: STA. 10+000 to STA. 10+140 (High Fill Area 3)	11
4.6.1 Asphalt.....	11
4.6.2 Fill	11
4.6.3 Clayey Silt Till	12
4.6.4 Refusal.....	12



FOUNDATION REPORT – HIGH FILL AREAS 1 TO 6, FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC), GWP 2112-05-00

4.6.5	Groundwater Conditions	12
4.7	Ramp E-S: STA. 10+000 to STA. 10+100 (High Fill Area 4)	13
4.7.1	Asphalt	13
4.7.2	Fill	13
4.7.3	Clayey Silt Till	14
4.7.4	Refusal	14
4.7.5	Groundwater Conditions	14
4.8	Ramp W-N: STA. 10+000 to STA. 10+100 (High Fill Area 5)	15
4.8.1	Asphalt	15
4.8.2	Fill	15
4.8.3	Clayey Silt Till	15
4.8.4	Refusal	16
4.8.5	Groundwater Conditions	16
4.9	Ramp E-N: STA. 10+000 to STA. 10+210 (High Fill Area 6)	16
4.9.1	Topsoil	17
4.9.2	Fill	17
4.9.3	Clayey Silt to Clayey Silt with Sand Till	17
4.9.4	Refusal	18
4.9.5	Groundwater Conditions	18
5.0	CLOSURE.....	19
PART B – FOUNDATION DESIGN REPORT		
6.0	DISCUSSION AND ENGINEERING RECOMMENDATIONS.....	20
6.1	General.....	20
6.2	High Fill Embankments.....	20
6.2.1	Embankment Fill Types and Benching Requirements.....	21
6.2.1.1	Stockpiled Material – Earth Fill	22
6.2.1.2	Escarpment Rock Cut – Rock Fill	23
6.3	Embankment Stability and Settlement	23
6.3.1	Static Global Stability	24
6.3.1.1	Methodology	24
6.3.1.2	Parameter Selection	24



FOUNDATION REPORT – HIGH FILL AREAS 1 TO 6, FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC), GWP 2112-05-00

6.3.1.3	Results of Analyses	26
6.3.2	Seismic Stability	26
6.3.2.1	Results of Analyses	26
6.3.3	Settlement.....	27
6.3.3.1	Methodology	27
6.3.3.2	Parameter Selection	27
6.3.3.3	Settlement Performance Requirements.....	28
6.3.3.4	Settlement of Foundation Soils.....	28
6.3.3.5	Settlement of New Embankment Fill.....	28
6.4	Subgrade Preparation and Embankment Construction.....	30
6.4.1	Subgrade Preparation	30
6.4.2	Embankment Construction.....	31
6.5	Design and Construction Considerations.....	32
6.5.1	Excavation	32
6.5.2	Obstructions (Cobbles and Boulders)	32
6.5.3	Control of Groundwater and Surface Water	32
6.5.4	Temporary Roadway Protection.....	33
7.0	CLOSURE.....	34

REFERENCES

LISTS OF ABBREVIATIONS AND SYMBOLS

TABLES

Table 1 – Summary of High Fill Embankments Foundation Recommendations

DRAWINGS

Drawing 1 – High Fill Areas 1 to 6 – Index Plan

Drawing 2 – Highway 5: STA. 29+850 to STA. 29+960 (High Fill Area 1), Borehole Locations and Soil Strata

Drawing 3 – Highway 5: STA. 30+040 to STA. 30+120 (High Fill Area 2), Borehole Locations and Soil Strata

Drawing 4 – Ramp W-S: STA. 10+000 to STA. 10+140 (High Fill Area 3), Borehole Locations and Soil Strata

Drawing 5 – Ramp E-S: STA. 10+000 to STA. 10+100 (High Fill Area 4), Borehole Locations and Soil Strata

Drawing 6 – Ramp W-N: STA. 10+000 to STA. 10+100 (High Fill Area 5), Borehole Locations and Soil Strata

Drawing 7 – Ramp E-N: STA. 10+000 to STA. 10+210 (High Fill Area 6), Borehole Locations and Soil Strata



FIGURES

- Figure 1 – High Fill Area 1 – Highway 5: STA. 29+950, Static Global Stability Analysis
Figure 2 – High Fill Area 2 – Highway 5: STA. 30+040, Static Global Stability Analysis
Figure 3 – High Fill Area 3 – Ramp W-S: STA. 10+000, Static Global Stability Analysis
Figure 4 – High Fill Area 4 – Ramp E-S: STA. 10+010, Static Global Stability Analysis
Figure 5 – High Fill Area 5 – Ramp W-N: STA. 10+000, Seismic Global Stability Analysis
Figure 6 – High Fill Area 6 – Ramp E-N: STA. 10+025, Static Global Stability Analysis
Figure 7 – High Fill Area 1 – Highway 5: STA. 29+950, Static Global Stability Analysis
Figure 8 – High Fill Area 1 – Highway 5: STA. 29+950, Seismic Global Stability Analysis

APPENDICES

APPENDIX A Highway 5: STA. 29+850 to STA. 29+960 (High Fill Area 1) Record of Boreholes and Laboratory Test Results

Records of Boreholes	BH 1 and H5-1 to H5-5
Figure A1	Grain Size Distribution – Gravelly Silty Sand to Gravelly Sand to Sand and Gravel (FILL)
Figure A2	Grain Size Distribution – Clayey Silt (FILL)
Figure A3	Plasticity Chart – Clayey Silt to Clayey Silt with Sand (FILL)
Figure A4A	Grain Size Distribution – Clayey Silt (TILL)
Figure A4B	Grain Size Distribution – Clayey Silt (TILL)
Figure A5	Grain Size Distribution – Silty Clay (TILL)
Figure A6	Plasticity Chart – Clayey Silt to Silty Clay (TILL)

APPENDIX B Highway 5: STA. 30+040 to STA. 30+120 (High Fill Area 2) Record of Boreholes and Laboratory Test Results

Record of Boreholes	BH 5 and H5-6 to H5-8
Figure B1	Grain Size Distribution – Clayey Silt with Sand (FILL)
Figure B2	Plasticity Chart – Clayey Silt with Sand (FILL)
Figure B3	Grain Size Distribution – Clayey Silt to Clayey Silt with Sand (TILL)
Figure B4	Plasticity Chart – Clayey Silt (TILL)

APPENDIX C Ramp W-S: STA. 10+000 to STA. 10+140 (High Fill Area 3) Record of Boreholes and Laboratory Test Results

Record of Boreholes	WS-1 and WS-2
Figure C1	Grain Size Distribution – Clayey Silt (FILL)
Figure C2	Plasticity Chart – Clayey Silt (FILL)
Figure C3	Grain Size Distribution – Clayey Silt to Clayey Silt with Sand (TILL)
Figure C4	Plasticity Chart – Clayey Silt (TILL)



APPENDIX D Ramp E-S: STA. 10+000 to STA. 10+100 (High Fill Area 4)
Record of Boreholes and Laboratory Test Results

Record of Boreholes	ES-1 to ES-3
Figure D1A	Grain Size Distribution – Sand and Gravel (FILL)
Figure D1B	Grain Size Distribution – Sand and Silt (FILL)
Figure D2	Plasticity Chart – Sand and Silt (FILL)
Figure D3	Grain Size Distribution – Silty Clay (FILL)
Figure D4	Plasticity Chart – Silty Clay (FILL)
Figure D5	Grain Size Distribution – Clayey Silt (TILL)
Figure D6	Plasticity Chart – Clayey Silt (TILL)

APPENDIX E Ramp W-N: STA. 10+000 to STA. 10+100 (High Fill Area 5)
Record of Boreholes and Laboratory Test Results

Record of Boreholes	WN-1 and WN-2
Figure E1	Grain Size Distribution – Clayey Silt to Clayey Silt with Sand (TILL)
Figure E2	Plasticity Chart – Clayey Silt (TILL)

APPENDIX F Ramp E-N: STA. 10+000 to STA. 10+210 (High Fill Area 6)
Record of Boreholes and Laboratory Test Results

Record of Boreholes	EN-1 to EN-4
Figure F1	Grain Size Distribution – Clayey Silt to Clayey Silt with Sand (FILL)
Figure F2	Plasticity Chart – Clayey Silt to Clayey Silt with Sand (FILL)
Figure F3	Grain Size Distribution – Clayey Silt to Clayey Silt with Sand (TILL)
Figure F4	Plasticity Chart – Clayey Silt to Clayey Silt with Sand (TILL)

APPENDIX G Non-Standard Special Provisions



PART A

**FOUNDATION INVESTIGATION REPORT
HIGH FILL AREAS 1 TO 6
FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC) AND ASSOCIATED
MUNICIPAL ROADS, CITY OF HAMILTON
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2112-05-00**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by IBI Group (IBI) on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the proposed high fill embankments associated with the construction of a new interchange structure at the Highway 5 and Highway 6 intersection, which is to replace the existing Highway 5 and Highway 6 at-grade crossing. The proposed work is part of the overall assignment for the future Highway 5 and Highway 6 Interchange (IC) and associated Municipal Roads in the City of Hamilton, Ontario, which includes: high fill embankments for the Highway 5 and Highway 6 re-alignments and interchange ramps; rock cut slope assessment; culvert extensions and replacements; retaining walls; high mast lights and overhead signs.

The Terms of Reference (TOR) and the Scope of Work for the foundation engineering services are outlined in MTO's Request for Proposal, dated January 2010, which forms part of the Consultant's Assignment Number (Number 2008-E-0038) for this project. Golder's proposal for the foundation engineering services is contained in Section 6.8 of IBI's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Quality Control Plan for foundation engineering services for this project, dated September 10, 2012.

This report addresses the foundation investigation carried out for the proposed high fill embankments required for the construction of the Highway 5 over Highway 6 Interchange structure and the associated interchange ramps only. The purpose of this investigation is to establish the subsurface conditions at the high fill locations along the proposed re-aligned Highway 5 and the new ramp alignments by borehole drilling, in situ testing and laboratory testing on selected soil samples. The investigation areas are shown in plan on Drawing 1.

2.0 SITE DESCRIPTION

The proposed high fill embankments are located in the vicinity of the existing Highway 5 and Highway 6 intersection, which is located west of Waterdown and approximately 3 km north of the Highway 403/Highway 6 Interchange at Clappison's Corners in the City of Hamilton, Ontario. There are six (6) high fill areas, designated as Areas 1 through 6, which are generally located in order of increasing chainage in the direction of proposed traffic flow along the proposed Highway 5 and associated interchange ramp alignment corridors as shown on Drawing 1, following the text of this report. High Fill Areas 1 and 2 are located along the re-aligned Highway 5, immediately west and east of the proposed Highway 5/Highway 6 Interchange structure, and High Fill Areas 3 to 6 are located along the proposed interchange ramp alignments connecting Highway 5 to Highway 6 in the four interchange quadrants.

The existing Highway 5 alignment in the project area is oriented generally in a west-east direction extending through the City of Brantford to the west and the City of Mississauga to the east. The existing Highway 6 alignment is oriented generally in a north-south direction connecting with Highway 403 to the south and Highway 401 to the north of Highway 5, and was last widened in 2005. The proposed high fill embankments will allow for the existing at grade crossing to be modified to an interchange with the Highway 5 structure crossing over Highway 6 thus accommodating future traffic forecast, and involves re-alignment of Highway 5 slightly to the north and Highway 6 slightly to the east of their present locations, in the vicinity of the present crossing.

The topography across the project site consists of relatively flat terrain which slopes downward further to the south of the intersection along Highway 6 down the Niagara Escarpment. Highway 6 generally traverses the escarpment in a cut up to 15 m deep through excavated bedrock as it approaches the intersection with



Highway 5. Vegetation at the site is sparse, consisting of grass, small shrubs and isolated treed areas. Surplus material from the Queen Elizabeth Way (QEW) construction sites are stockpiled on the northwest quadrant of the intersection. Commercial facilities are present along the Highway 5 and Highway 6 corridors and residential properties are located along Highway 5 further to the west of the intersection.

The high fill sections investigated generally extend through open fields with localized sparsely treed areas, and some isolated paved former parking lots adjacent to the present crossing. The original ground surface within these areas varies between about Elevations 220.0 m and 226.3 m, referenced to Geodetic datum; a detailed description of each high fill area is presented in Sections 4.4 to 4.9.

3.0 INVESTIGATION PROCEDURES

3.1 Foundation Investigation

The field work for the detail foundation investigation of the high fill embankments was carried out between November 12 and 21, 2012 during which time a total of nineteen (19) sampled boreholes (designated as Boreholes H5-1 to H5-8, WS-1, WS-2, ES-1 to ES-3, WN-1, WN-2 and EN-1 to EN-4) were advanced at the locations of the high fill areas. As some of the proposed limits of the high fill areas are within the existing Highway 5 and Highway 6 right-of-ways, the boreholes were strategically located to cover the critical sections of the high fill areas while allowing for safe operation of the drill rigs. Two (2) boreholes (designated as Boreholes BH 1 and BH 5) advanced as part of the field investigation work carried out for the Highway 5 over Highway 6 Interchange Structure¹ were utilized to supplement the high fill investigation. The method of investigation of these supplemental boreholes are detailed in the above referenced report, however, the Record of Borehole sheets and the results of the laboratory testing for these boreholes are presented together with the boreholes and laboratory test results for the high fill areas in Appendix A to Appendix F.

The details of each high fill area and the locations of the boreholes advanced at each site are shown on Drawings 2 to 7 and are presented below.

Location / High Fill Area Designation	Reference Drawing	Station Limits	Boreholes Advanced	Reference Appendix
Highway 5 / High Fill Area 1	Drawing 2	29+850 to 29+960	6 Boreholes (BH 1 and H5-1 to H5-5)	A
Highway 5 / High Fill Area 2	Drawing 3	30+040 to 30+120	4 Boreholes (BH 5 and H5-6 to H5-8)	B
Ramp W-S / High Fill Area 3	Drawing 4	10+000 to 10+140	2 Boreholes (WS-1 and WS-2)	C
Ramp E-S / High Fill Area 4	Drawing 5	10+000 to 10+100	3 Boreholes (ES-1 to ES-3)	D
Ramp W-N / High Fill Area 5	Drawing 6	10+000 to 10+100	2 Boreholes (WN-1 and WN-2)	E
Ramp E-N / High Fill Area 6	Drawing 7	10+000 to 10+210	4 Boreholes (EN-1 to EN-4)	F

¹ Golder Associates Ltd. January 2014. *Foundation Investigation and Design Report, Highway 5 Over Highway 6 Interchange Structure, Future Highway 5/Highway 6 Interchange (IC) and Associated Municipal Roads, City of Hamilton, Ministry of Transportation, Ontario.* GWP 2112-05-00. GEOCRE No. 30M5-289.



The borehole investigation was carried out using a track-mounted CME 55 drill rig and a truck-mounted CME 75 drill rig, supplied and operated by DBW Drilling Ltd. of Ajax, Ontario. The boreholes were advanced through the overburden using 102 mm outside diameter (O.D.) solid stem augers or 152 mm outside diameter (O.D.) hollow stem augers. Soil samples were obtained at ground surface where practical and at intervals of depth of 0.75 m, using a 50 mm outer diameter (O.D.) split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)².

The boreholes drilled during this current investigation and the supplemental boreholes were advanced to depths ranging from 5.0 m to 6.6 m below existing ground surface, mostly to auger and/or split-spoon refusal (i.e. inferred bedrock).

The groundwater conditions and water levels in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in each of six (6) selected boreholes to permit monitoring of the water level at the high fill sites. Each installed piezometer consists of 19 mm diameter PVC pipe, with a 1.5 m slotted screen sealed within a filter sand pack at a select depth within the borehole. The boreholes and annulus surrounding the piezometer pipe above the screen and filter sand pack were backfilled to the ground surface with bentonite pellets. Piezometer installation details and water level readings are described on the Record of Borehole sheets included in Appendices A to F, which corresponds to High Fill Areas 1 to 6. All boreholes in which standpipe piezometer are not installed were backfilled to the ground surface with bentonite upon completion in accordance with Ontario Regulation 903, Wells (as amended). The boreholes advanced through the Highway 5 and Highway 6 asphalt were sealed at the surface with cold patch asphalt, up to approximately 0.3 m thick.

The field work was observed by members of Golder's engineering and technical staff, who located the boreholes in the field, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected samples in accordance with MTO and/or ASTM Standards, as applicable. The results of the laboratory testing are presented on the Record of Borehole sheets and shown on the laboratory figures contained in Appendices A to F.

The borehole locations and the ground surface elevations were staked and surveyed by Callon Dietz, a licensed surveying company retained by Golder Associates. Where the location of a borehole was moved due to site constraints, the as-drilled borehole location and ground surface elevation were surveyed by a member of our technical staff, referenced to the original borehole (survey) stake put down by Callon Dietz. The as-drilled borehole locations (positioned relative to MTM NAD 83 northing and easting coordinates) and the ground surface elevations (referenced to Geodetic datum) summarized below are provided on the individual Record of Borehole sheets and are shown on Drawings 2 to 7.

² ASTM D1586 – *Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soil.*



FOUNDATION REPORT – HIGH FILL AREAS 1 TO 6, FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC), GWP 2112-05-00

Location / High Fill Area Designation	Borehole Number	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing (m)	Easting (m)		
Highway 5 / High Fill Area 1	BH 1	4797035.5	270882.4	222.1	6.3
	H5-1	4796932.3	270815.2	222.5	5.0
	H5-2	4796952.4	270830.2	222.4	6.6
	H5-3	4796972.2	270845.4	222.1	6.6
	H5-4	4796992.2	270859.2	221.8	5.9
	H5-5	4797014.8	270871.0	221.6	5.7
Highway 5 / High Fill Area 2	BH 5	4797082.1	270915.5	222.7	5.2
	H5-6	4797086.5	270942.5	222.1	5.2
	H5-7	4797104.7	270959.6	222.6	5.3
	H5-8	4797122.7	270976.9	223.4	5.0
Ramp W-S / High Fill Area 3	WS-1	4796977.4	270880.3	222.1	6.3
	WS-2	4796968.4	270932.5	222.5	6.3
Ramp E-S / High Fill Area 4	ES-1	4797002.5	270841.8	220.0	6.2
	ES-2	4796989.6	270816.3	222.5	6.6
	ES-3	4796990.2	270798.5	226.3	6.6
Ramp W-N / High Fill Area 5	WN-1	4797099.2	270987.0	222.7	5.3
	WN-2	4797109.9	271008.8	223.1	5.0
Ramp E-N / High Fill Area 6	EN-1	4797131.6	270948.2	222.4	5.3
	EN-2	4797125.7	270923.8	222.2	5.3
	EN-3	4797126.1	270902.9	222.1	5.3
	EN-4	4797134.5	270875.4	222.2	5.4

3.2 Stockpiled Material Investigation

Surplus material from MTO Contract 2009-2015 for the Queen Elizabeth Way construction is currently stockpiled at the northwest quadrant of the existing Highway 5 and Highway 6 intersection. As part of the Pavement Engineering Scope of Work for this assignment, a field investigation and laboratory testing program was carried out on the stockpiled material to evaluate the suitability of the material for use as earth fill for this project. The results of the pavements field investigation, including the methodology and results of the laboratory testing are contained in the Pavement Investigation and Design Report³ for this project.

³ Golder Associates Ltd. 2014. *Pavement Investigation and Design Report*, Future Highway5/Highway 6 Interchange (IC) and Associated Municipal Roads, City of Hamilton, Ministry of Transportation, Ontario. GWP 2112-05-00. (In Progress)



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The study area is located on the Niagara Escarpment⁴, a topographic break that separates the two levels of the Niagara Peninsula, which is manifested in typically harder, resistant dolostone and limestone bedrock units forming vertical cliffs along the brow of the Escarpment, over the softer shale bedrock below. The Niagara Escarpment extends from the Niagara River to the northern tip of the Bruce Peninsula and is generally flanked by landscapes of glacial origin. Capping the Niagara Escarpment is the Lockport Formation consisting of white, grey and brown dolostone of Silurian Age (Karrow, 1987)⁵ at the crest underlain by the Rochester, Irondequoit, Reynales, Thorold, Grimsby and Cabot Head Formations consisting of grey to reddish brown shaley dolostone, limestone, siltstone and sandstone (Blair and McFarland, 1992)⁶.

Overburden within the study area is comprised primarily of glacial till mapped as the Halton Till which extends as a sheet in the Hamilton area, terminating in the Waterdown Moraines east of the Niagara Escarpment between the Lake Iroquois and the Trafalgar Moraine. The Halton Till is generally considered a fine-grained diamicton with minor fine-grained lacustrine sediments incorporated within the body of the unit, likely from glacial reworking of underlying lacustrine sediments. The Halton Till also contains cobbles and boulders and in some areas, “boulder pavements” (Watt, 1955)⁷ can be encountered where boulders are nested or concentrated within the till unit.

During the retreat of the last ice sheet, lakes were formed in depressions on the land surface in which were deposited sand, gravel, silt and clay materials. The last major meltwater system along the Escarpment occurred when the Waterdown Moraines were formed. Several channels among the Waterdown Moraines functioned at various times, feeding melt waters southwest toward glacial lakes to create lacustrine and outwash sand deposits.

4.2 General Overview of Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes, including the results of the in situ tests and the results of the laboratory tests carried out on selected soil samples are presented on the Record of Borehole sheets and the geotechnical laboratory test figures, presented in Appendices A to F for High Fill Areas 1 to 6, respectively. The results of the in situ field tests (i.e. SPT ‘N’-values) as presented on the Record of Borehole sheets and in Sections 4.4 to 4.9 are uncorrected.

The stratigraphic boundaries shown on the Record of Borehole sheets and on the high fill embankments centerline profiles on Drawings 2 to 7 are inferred from non-continuous sampling, observations of drilling

⁴ 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

⁵ Karrow, P.F. 1987. *Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario*, Ontario Geological Survey, Report 255. Ministry of Northern Development and Mines, Ontario.

⁶ Blair, R. and McFarland, S. 1993. *Regional Correlation of the Middle and Lower Silurian Stratigraphy of the Niagara Escarpment Area*, Proceedings of the 1992 Conference of the Canadian National Chapter, International Association of Hydrogeologists, Hamilton, Ontario, 659-696.

⁷ Watt, A.K. 1955. *Pleistocene Geology and Groundwater Resources of the Township of North York*, York County, Ontario Department of Mines, Sixty Fourth Annual report, Volume LXIV, Part 7.



progress, the results of Standard Penetration Tests and interpretation of the subsurface conditions. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected, however, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. The orientation (i.e. north, south, east, west) stated in the text of the report is typically referenced to the project north and the stations are referenced up-chainage along the proposed Highway 5 embankment and new interchange ramp alignments. In the project area, Highway 5 is oriented essentially west-east and Highway 6 is oriented north-south.

In general, the subsurface conditions encountered at the various borehole locations at the proposed high fill areas consist of a surficial layer of asphalt or topsoil over a deposit of fill associated with the construction of Highway 5 and Highway 6 pavement structures and associated ditches, underlain by a cohesive till deposit and underlain by inferred bedrock. The stratigraphy generally consists of:

- Surficial layers of asphalt or topsoil, underlain by deposits of grey to brown non-cohesive fill comprised of sandy silt, sand and silt, silty sand, silty sand and gravel, gravelly silty sand, gravelly sand and sand and gravel, in places containing trace organics, clayey silt seams/pockets, pieces of asphalt, bricks and concrete, which forms the granular base for the pavement structure. Underlying the non-cohesive fill deposits or topsoil/asphalt layers in some areas are deposits of cohesive fill comprised of dark brown to brown (to black at one location) clayey silt, clayey silt with sand and silty clay containing trace organics, topsoil, sand seams/pockets, pieces of asphalt.
- Cohesive till deposits of brown to grey clayey silt to clayey silt with sand and silty clay generally underlie the fill deposits and are in places underlain by inferred bedrock. The cohesive till deposits typically contain silt, sandy silt, silty sand and sand layers/seams, and cobbles and boulders (in places).

A general description of the stockpiled material and the detailed descriptions of the subsurface conditions at each investigated high fill area are provided in the following sections of this report.

4.3 Stockpiled Material

Based on the result of the pavement field investigation conducted on the stockpiled material, the soil generally consists of a layer of topsoil, underlain by an upper deposit of red to brown, firm, clayey silt trace to with sand and trace gravel, then underlain by a lower deposit of dark grey, firm, clayey silt with sand and trace to some gravel. Cobbles and boulders were noted within the stockpiled material and the samples obtained from the test pits were generally moist. The detailed description of the stockpile soil and the results of laboratory tests are provided in the Pavement Investigation and Design Report³ referenced in Section 3.2.

4.4 Highway 5: STA. 29+850 to STA. 29+960 (High Fill Area 1)

The plan and profile along the centerline of the proposed high fill embankment along Highway 5 west of Highway 6 showing the borehole locations and interpreted stratigraphy are presented on Drawing 2. The Record of Boreholes BH 1 and H5-1 to H5-5, and the laboratory test results completed for this high fill area are presented in Appendix A. The proposed embankment within this section of Highway 5 is generally about 8 m high, but could be up to 9 m high in places, relative to the existing ground surface which varies from about



Elevation 222.5 m at the western limit to about Elevation 220.5 m (within the ditch) at the eastern limit of this high fill area.

In summary, the subsurface conditions at this site as encountered in Boreholes BH 1 and H5-1 to HF-5 consist of asphalt or topsoil and fill underlain by a cohesive till deposit of stiff to hard clayey silt, as described below.

4.4.1 Asphalt

An approximately 200 mm thick layer of asphalt was encountered in Borehole BH 1 drilled through the pavement of the existing Highway 6 Southbound lane (SBL) shoulder, and an approximately 100 mm thick layer of prime surface treated asphalt was encountered in Boreholes H5-1, H5-2 and H5-4 advanced through the paved driveways adjacent to the existing Highway 5 Westbound lane (WBL) shoulder.

4.4.2 Topsoil

A layer of sand and silt topsoil about 0.7 m thick was encountered at the existing ground surface in Borehole H5-5 drilled near the ditch line of existing Highway 5. A Standard Penetration Test (SPT) “N”-value measured within the topsoil layer is 11 blows per 0.3 m of penetration, indicating a compact relative density.

4.4.3 Fill

A 0.7 m to 4.3 m thick deposit of fill associated with the construction of the highway and the adjacent ditches was encountered underlying either the asphalt/topsoil or at the ground surface in all the boreholes. The surface of the fill deposit ranges from about Elevations 222.4 m to 220.9 m. The upper layer of the fill as encountered in Boreholes BH 1, H5-1, H5-3 and H5-4 is generally non-cohesive, comprising of gravelly silty sand to gravelly sand some silt to sand and gravel trace silt; containing trace clay, trace organics and clayey silt pockets/seams. Underlying the non-cohesive fill and topsoil in all boreholes except Borehole H5-4 is a cohesive fill comprised of clayey silt trace sand to sandy, to clayey silt with sand; containing trace gravel to gravelly, trace organics, topsoil and pieces of asphalt.

The SPT “N”-values measured within the non-cohesive fill range from 4 blows to 29 blows per 0.3 m of penetration, indicating a loose to compact relative density. The SPT “N”-values recorded within the cohesive fill range from 6 blows to 56 blows per 0.3 m of penetration but typically less than 14 blows per 0.3 m of penetration, suggesting that the clayey silt to clayey silt with sand fill has a firm to hard (but typically firm to stiff) consistency.

The grain size distribution tests completed on three (3) samples of the gravelly silty sand to gravelly sand to sand and gravel fill, and on one (1) sample of the clayey silt fill are presented on Figure A1 and Figure A2, respectively, in Appendix A. Atterberg limits tests were carried out on two (2) samples of the cohesive fill and measured liquid limits of about 32 per cent and 34 per cent, plastic limits of about 16 per cent, and corresponding plasticity indices of about 16 per cent and 18 per cent. The results of the Atterberg limits tests are shown on a plasticity chart on Figure A3 in Appendix A and indicate that the cohesive fill consists of clayey silt of low plasticity. The natural moisture content measured on four (4) samples of the non-cohesive fill ranges from about 2 per cent to 9 per cent and the natural water content recorded on one (1) sample of the cohesive fill is about 15 per cent.



4.4.4 Clayey Silt Till

A cohesive till deposit comprised of predominantly clayey silt, sandy to some sand and trace gravel was encountered underlying the fill in all the boreholes. The deposit generally contains silt to sand seams and in Borehole H5-2, a localized layer of silty clay till was encountered overlying the clayey silt till deposit. The top of the till deposit ranges from about Elevations 221.4 m to 217.4 m and the thickness of the till deposit ranges from about 1.5 m to 5.9 m across the boreholes. Boreholes H5-1 and H5-2 were terminated within the cohesive till deposit whereas Boreholes BH 1 and H5-3 to H5-5 were terminated on refusal to further auger and/or split-spoon advancement.

The SPT “N”-values measured within the cohesive till range from 10 blows to 46 blows per 0.3 m of penetration, suggesting that the clayey silt to silty clay till has a stiff to hard consistency. SPT “N”-values of 12 blows per 0.05 m of penetration, 25 blows per 0.08 m of penetration and 20 blows per 0.1 m of penetration were recorded prior to termination of Boreholes BH 1, H5-3 and H5-5.

Grain size distribution tests were carried out on ten (10) samples of the clayey silt till deposit and the results are shown on Figures A4A and A4B in Appendix A. The result of grain size distribution test completed on one (1) sample of the silty clay till is presented on Figure A5. Atterberg limits tests were carried out on twelve (12) selected samples of the cohesive till deposit and measured liquid limits ranging from about 20 per cent to 36 per cent, plastic limits ranging from about 13 per cent to 19 per cent, and plasticity indices ranging from about 7 per cent to 18 per cent. These test results, which are plotted on a plasticity chart on Figure A6 in Appendix A, indicate that the cohesive till deposit consists of clayey silt of low plasticity to silty clay of intermediate plasticity. The natural moisture content measured on twenty one (21) selected samples of the till deposit ranges from about 11 per cent to 22 per cent.

4.4.5 Refusal

In Boreholes BH 1, H5-3 to H5-5, the bedrock surface is inferred by refusal to further split-spoon penetration and/or auger advancement at depths ranging from about 5.7 m to 6.6 m below ground surface, corresponding to between about Elevations 215.9 m and 215.5 m.

4.4.6 Groundwater Conditions

In general, the samples obtained from the boreholes were moist to wet. All open boreholes were observed to be dry upon completion of drilling operations except Borehole H5-2. A standpipe piezometer was installed in each of Boreholes H5-2 and H5-5 to permit monitoring of the groundwater level at this high fill site. Details of the piezometer installation and measured groundwater levels are shown on the Record of Borehole sheets in Appendix A. The groundwater levels measured in the open borehole and in the piezometers on February 13, 2013 are summarized below.



Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
H5-2	222.4	5.7 3.7	216.7 218.7	November 12, 2012 February 13, 2013	Open Borehole Piezometer
H5-5	221.6	1.7	219.9	February 13, 2013	Piezometer

The groundwater levels at this site are subject to seasonal fluctuations and precipitation events and should be expected to be higher during the spring season or during any period of heavy precipitation.

4.5 Highway 5: STA. 30+040 to STA. 30+120 (High Fill Area 2)

The plan and profile along the centerline of the proposed high fill embankment along Highway 5 east of Highway 6 showing the borehole locations and interpreted stratigraphy are shown on Drawing 3. The Record of Boreholes BH 5 and H5-6 to H5-8, and the laboratory test results completed for this high fill area are presented in Appendix B. The proposed embankment within this section of Highway 5 is up to about 8 m high relative to the existing ground surface which varies from about Elevation 221.7 m at the western limit to about Elevation 223.4 m at the eastern limit of the high fill area.

The subsoils at this site, as encountered in Boreholes BH 5 and H5-6 to H5-8, consist of asphalt or topsoil and fill underlain by a cohesive till deposit of generally stiff to hard clayey silt, in places containing cobbles and silty sand seams as described below.

4.5.1 Asphalt

An approximately 100 mm thick layer of prime surface treated asphalt was encountered in Boreholes H5-6 to H5-8 advanced through the paved shoulders along the north side of Highway 5.

4.5.2 Topsoil

A 100 mm thick layer of topsoil was encountered in Borehole BH 5 advanced within the open field at the north-east corner of the existing Highway 5/Highway 6 intersection.

4.5.3 Fill

A fill deposit approximately 1.3 m thick was encountered underlying the asphalt or topsoil layers in all boreholes between about Elevations 223.3 m and 221.6 m. The fill material is variable in composition, comprising a layer of non-cohesive grey to brown silty sand, trace clay, trace gravel and trace organics, to silty sand and gravel, to sand and gravel trace to some silt, containing pieces of concrete. The non-cohesive fill is underlain by a deposit of cohesive fill comprised of clayey silt, some sand and trace to some gravel, to clayey silt with sand and some gravel. The fill encountered in Boreholes BH 5 and H5-8 contains trace organics.



The SPT “N”-values measured within the non-cohesive fill range from 11 blows to 42 blows per 0.3 m of penetration, indicating a compact to dense relative density. The SPT “N”-values recorded within the cohesive fill range from 8 blows to 18 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

A grain size distribution test was carried out on one (1) sample of the clayey silt with sand fill and the result is presented on Figure B1 in Appendix B. An Atterberg limits test was conducted on a sample of the cohesive fill and measured a liquid limit of about 29 per cent, a plastic limit of about 14 per cent and a corresponding plasticity index of about 15 per cent. The result of the Atterberg limits test is shown on a plasticity chart on Figure B2 in Appendix B, and indicates that this material is clayey silt of low plasticity. The natural water content measured on two (2) samples of the non-cohesive fill is about 2 per cent and 5 per cent; the natural water content measured on three (3) samples of the cohesive fill ranges between about 13 per cent and 19 per cent.

4.5.4 Clayey Silt Till

A cohesive till deposit was encountered underlying the fill deposit in all the boreholes. The surface of the till deposit varies between about Elevations 222.0 m and 220.3 m and the thickness of the deposit is between about 3.6 m and 3.9 m. The cohesive till deposit is predominantly comprised of clayey silt, some sand, and trace to some gravel; the lower portion of the till deposit (below Elevation 218 m) is generally coarser comprised of clayey silt, sandy to with sand and silty sand seams. Cobbles were present within the lower portion of the deposit in Borehole BH 5. Borehole H5-8 was terminated within the till deposit.

The SPT “N”-values measured within the cohesive till deposit range from 11 blows to 57 blows per 0.3 m of penetration (but typically greater than 20 blows per 0.3 m of penetration), suggesting a stiff to hard (but typically very stiff to hard) consistency.

The results of grain size distribution tests completed on seven (7) samples of the clayey silt till deposit are presented together on Figure B3 in Appendix B. Atterberg limits tests were carried out on seven (7) selected samples of the cohesive till deposit and measured liquid limits ranging from about 22 per cent to 32 per cent, plastic limits ranging from about 13 per cent to 16 per cent and plasticity indices ranging from about 9 per cent to 15 per cent. These test results, which are plotted on a plasticity chart on Figure B4 in Appendix B, indicate that the cohesive till deposit consists of clayey silt of low plasticity. The natural moisture content measured on eleven (11) selected samples of the cohesive till deposit ranges from about 11 per cent to 42 per cent.

4.5.5 Refusal

In Boreholes BH 5, H5-6 and H5-7, the bedrock surface is inferred by refusal to further auger advancement at depths between about 5.2 m and 5.3 m below ground surface, corresponding to between about Elevations 217.3 m and 216.5 m.

4.5.6 Groundwater Conditions

In general, the samples taken in the boreholes were dry to wet. The groundwater levels in the open boreholes were measured upon completion of drilling operations and a standpipe piezometer was installed in each of Borehole H5-6 and H5-8 to permit monitoring of the groundwater level at this site. Details of the piezometer installation and the measured groundwater levels are shown on the Record of Borehole sheets in Appendix B.



The groundwater levels recorded in the open boreholes and in the piezometers on February 13, 2013 are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
BH 5	221.7	4.9	216.8	November 15, 2012	Open Borehole
H5-6	222.1	3.8 1.8	218.3 220.3	November 15, 2012 February 13, 2013	Open Borehole Piezometer
H5-7	222.6	5.0	217.6	November 15, 2012	Open Borehole
H5-8	223.4	4.8 2.1	218.6 221.3	November 14, 2012 February 13, 2013	Open Borehole Piezometer

The groundwater levels are subject to seasonal fluctuations and precipitation events and should be expected to be higher during the spring season or during any period of heavy precipitation.

4.6 Ramp W-S: STA. 10+000 to STA. 10+140 (High Fill Area 3)

The plan and profile along the centerline of the proposed interchange Ramp W-S embankment showing the borehole locations and interpreted stratigraphy are shown on Drawing 4. The Record of Boreholes WS-1 and WS-2, and the laboratory test results completed for this new high fill area are presented in Appendix C. The new interchange Ramp W-S is proposed to connect Highway 5 Eastbound lanes (EBL) to Highway 6 Southbound lanes (SBL) from STA. 10+000 to STA. 10+140, and is between about 4.5 m and 6.5 m high to about STA. 10+070. The existing ground surface along the proposed high fill embankment within the investigated portion of Ramp W-S varies from about Elevation 222.1 m at the western limit to about Elevation 222.5 m at the southern limit of the investigated area.

The subsurface soils encountered along the proposed interchange ramp consist of asphalt and fill underlain by a cohesive till deposit comprised of stiff to hard clayey silt, as described below.

4.6.1 Asphalt

An approximately 200 mm thick layer of asphalt was encountered in Boreholes WS-1 and WS-2 drilled through the pavement, at the existing Highway 5 and Highway 6 intersection.

4.6.2 Fill

An approximately 1.9 m and 1.2 m thick deposit of fill was encountered below the asphalt at about Elevations 221.9 m and 222.3 m in Boreholes WS-1 and WS-2, respectively. The fill encountered in the boreholes is comprised of an upper layer of non-cohesive sand and gravel to sandy silt, trace gravel and trace clay containing clayey silt seams, underlain by cohesive fill comprised of clayey silt, sandy to trace sand, some gravel containing sand seams.



A SPT “N”-value of 12 blows per 0.3 m of penetration was recorded within the sandy silt portion of the fill, indicating a compact relative density. The measured SPT “N” values within the clayey silt fill are 6 blows and 9 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

The result of a grain size distribution test carried out on one (1) sample of the clayey silt fill is presented on Figure C1 in Appendix C. An Atterberg limits test was carried out on one (1) sample of the cohesive fill and measured a liquid limit of about 26 per cent, a plastic limit of about 13 per cent and a corresponding plasticity index of about 13 percent indicating that the fill is comprised of clayey silt of low plasticity. The measured moisture content on one (1) sample of the clayey silt fill is about 13 per cent.

4.6.3 Clayey Silt Till

A cohesive till deposit was encountered underlying the fill in Boreholes WS-1 and WS-2. The top of this cohesive till deposit was encountered at about Elevations 220.0 m and 221.1 m and the thickness of the deposit is about 4.2 m and 4.9 m in the respective boreholes. The cohesive till deposit is generally comprised of clayey silt some sand to sandy, trace to some gravel containing sand seams in places. In Borehole WS-2, the lower portion of the till deposit grades to a clayey silt with sand.

The SPT “N”-values recorded within the cohesive till deposit range from 11 blows to 33 blows per 0.3 m of penetration, suggesting that the till deposit has a stiff to hard consistency. A SPT “N” value of 7 blows per 0.03 m of penetration and 5 blows per 0.08 m of penetration was recorded prior to termination of Boreholes WS-1 and WS-2, respectively.

Grain size distribution tests were carried out on three (3) selected samples of the clayey silt till and the results are presented on Figure C3 in Appendix C. Atterberg limits tests were performed on four (4) samples of the cohesive till and measured liquid limits between about 22 per cent and 32 per cent, plastic limits between about 12 per cent and 17 per cent, and the plasticity indices between about 10 per cent and 14 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure C4 in Appendix C and indicate this till deposit to consist of clayey silt of low plasticity. The measured water content on seven (7) selected samples of this till deposit ranges between about 12 per cent and 15 per cent.

4.6.4 Refusal

In Boreholes WS-1 and WS-2, the bedrock surface is inferred by refusal to further split-spoon penetration and auger advancement at a depth of about 6.3 m below ground surface, corresponding to about Elevations 215.8 m and 216.2 m at the respective boreholes.

4.6.5 Groundwater Conditions

The samples taken in the boreholes were generally moist to wet. Boreholes WS-1 and WS-2 were observed to be dry upon completion of drilling operations.

The groundwater levels at this site are subject to seasonal fluctuations and precipitation events and should be expected to be higher during the spring season or during any period of heavy precipitation.



4.7 Ramp E-S: STA. 10+000 to STA. 10+100 (High Fill Area 4)

The plan and profile along the centerline of the proposed interchange Ramp E-S embankment showing the borehole locations and interpreted stratigraphy are shown on Drawing 5. The Record of Boreholes ES-1 to ES-3, and the laboratory test results completed for this new high fill area are presented in Appendix D. The new interchange Ramp E-S is proposed to connect Highway 5 Westbound lanes (WBL) to Highway 6 Southbound lanes (SBL) from STA. 10+000 to STA. 10+100, and is generally between 4.5 m and 8.5 m high to about STA. 10+050, but could be up to about 9 m in places. The existing ground surface along the proposed high fill embankment within the investigated portion of Ramp E-S varies from about Elevation 220.0 m near the eastern limit to about Elevation 226.3 m at the southern limit of the investigated area.

The subsurface soils encountered along the proposed interchange ramp consist of asphalt and fill underlain by a cohesive till deposit comprised of brown to grey stiff to hard clayey silt till, as described below.

4.7.1 Asphalt

An approximately 100 mm thick layer of prime surface treated asphalt was encountered in Borehole ES-1 and ES-2 advanced through the paved driveway adjacent to the Highway 5/Highway 6 intersection.

4.7.2 Fill

A fill deposit associated with the construction of the paved driveway adjacent to the Highway 5/Highway 6 intersection was encountered below the asphalt in Boreholes ES-1 and ES-2, and from ground surface in Borehole ES-3 associated with the stockpile soil located north-west of the intersection. The surface of the fill deposit varies between about Elevations 226.3 m and 219.9 m, and the thickness of the fill varies between about 1.3 m and 3.7 m. The upper portion of the fill underlying the asphalt is non-cohesive and comprised of sand and silt, some clay and some gravel containing sand pockets, to sand and gravel, some silt and trace clay. The lower portion of the fill under the asphalt and an upper layer of stockpiled material is generally cohesive, comprised of clayey silt to silty clay, trace to some sand, trace gravel, trace organics and containing wood pieces in places.

The SPT “N”-values measured within the non-cohesive fill range from 7 blows to 23 blows per 0.3 m of penetration, indicating a loose to compact relative density. The SPT “N”-values recorded within the cohesive fill range from 9 blows to 15 blows per 0.3 m of penetration, suggesting a stiff consistency.

A grain size distribution test was carried out on one (1) sample of the sand and gravel fill and one (1) sample of the sand and silt fill, and the results are presented on Figures D1A and D1B in Appendix D. An Atterberg limits test was conducted on one (1) sample of the sand and silt fill and measured a liquid limit of about 16 per cent, a plastic limit of about 13 per cent and a corresponding plasticity index of about 3 per cent. The result of the Atterberg limits test is shown on a plasticity chart on Figure D2 in Appendix D, indicating the fines material to be silt of slight plasticity. The natural water content measured on two (2) samples of the non-cohesive fill is about 3 per cent and 11 per cent. For the cohesive fill, the grain size distribution of one (1) sample of the silty clay is presented on Figure D3 in Appendix D and the result of an Atterberg limits test completed on this sample is presented on Figure D4 in Appendix D. The Atterberg limits test yielded a liquid limit of about 36 per cent, a plastic limit of about 19 per cent and a corresponding plasticity index of about 17 per cent, indicating that a



component of the cohesive fill consists of silty clay of intermediate plasticity. The natural water content measured on two (2) samples of the cohesive fill is about 14 per cent and 20 per cent.

4.7.3 Clayey Silt Till

A cohesive till deposit comprised of brown to grey clayey silt, sandy to some sand and trace to some gravel was encountered underlying the fill deposit in all the boreholes. Boulders were also inferred (from auger grinding and split-spoon sampling) to be present within this deposit in Borehole ES-2. The surface of the cohesive till deposit was encountered at depths ranging from about 1.4 m to 3.7 m below ground surface (Elevations 218.6 m to 222.6 m, respectively) and the thickness of the cohesive till ranges from about 2.9 m to 4.8 m. Boreholes ES-2 and ES-3 were terminated within the till deposit.

The SPT “N”-values recorded within the cohesive till deposit range from 14 blows to 39 blows per 0.3 m of penetration, suggesting that the clayey silt till has a stiff to hard consistency. A SPT “N”-value of 30 blows per 0.03 m of penetration was recorded upon refusal to further split-spoon and auger advancement in Borehole ES-1.

Grain size distribution tests were carried out on six (6) selected samples of the cohesive till deposit and the results are provided on Figure D5 in Appendix D. Atterberg limits tests were performed on six (6) samples of the cohesive till and measured liquid limits ranging from about 26 per cent to 31 per cent, plastic limits ranging from about 14 per cent to 19 per cent and plasticity indices ranging from about 12 per cent to 14 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure D6 in Appendix D and indicate the till deposit to consist of clayey silt of low plasticity. The natural water content on eleven (11) selected samples of the cohesive till deposit ranges from about 12 per cent to 22 per cent.

4.7.4 Refusal

In Boreholes ES-1, the bedrock surface is inferred by refusal to further split-spoon penetration and auger advancement at a depth of about 6.2 m below ground surface, corresponding to Elevation 213.8 m.

4.7.5 Groundwater Conditions

The samples taken in the boreholes were generally moist to wet. The groundwater levels in the open boreholes were measured upon completion of drilling operations and Boreholes ES-1 and ES-3 were noted to be dry. A standpipe piezometer was installed in Borehole ES-3 to permit monitoring of the groundwater level at this site. Details of the piezometer installation and the measured groundwater levels are shown on the Record of Borehole sheets in Appendix D. The groundwater levels recorded in the open boreholes and in the piezometer on February 13, 2013 are summarized below.



Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
ES-2	222.5	5.9	216.6	November 13, 2012	Open Borehole
ES-3	226.3	3.5	222.8	February 13, 2013	Piezometer

The groundwater levels at this site are subject to seasonal fluctuations and precipitation events, and should be expected to be higher during the spring season or during any period of heavy precipitation.

4.8 Ramp W-N: STA. 10+000 to STA. 10+100 (High Fill Area 5)

The plan and profile along the centerline of the proposed interchange Ramp W-N showing the borehole locations and interpreted stratigraphy are shown on Drawing 6. The Record of Boreholes WN-1 and WN-2, and the laboratory test results completed for this new high fill area are presented in Appendix E. The new interchange Ramp W-N is proposed to connect Highway 5 Eastbound lanes (EBL) to Highway 6 Northbound lanes (NBL) from STA. 10+000 to STA. 10+100, and is between about 4.5 m and 5 m high to about STA. 10+025. The existing ground surface along the proposed high fill embankment within the investigated portion of Ramp W-N varies between about Elevation 222.7 m at the western limit to about Elevation 223.1 m at the northern limit of the investigated area.

The subsurface conditions encountered along the proposed high fill embankment consist of asphalt and fill associated with the construction of the existing Highway 5, underlain by a cohesive till deposit of stiff to hard clayey silt, as described below.

4.8.1 Asphalt

An approximately 200 mm to 300 mm thick layer of asphalt, part of the Highway 5 pavement structure was encountered in the two boreholes.

4.8.2 Fill

A 0.5 m and a 0.6 m thick layer of fill comprised of sand and gravel trace silt was encountered below the asphalt in both boreholes. The top of the fill was encountered at about Elevation 222.5 m and 222.8 m in Boreholes WN-1 and WN-2, respectively.

4.8.3 Clayey Silt Till

A cohesive till deposit was encountered underlying the fill in both boreholes. The till deposit is comprised of clayey silt, some sand, trace gravel and grades to clayey silt, sandy to with sand, some gravel below about Elevation 219.0 m. The surface of the cohesive till deposit is at about Elevations 221.9 m and 222.3 m, and the thickness of the deposit is about 4.5 m and 4.2 m in Boreholes WN-1 and WN-2, respectively. Borehole WN-2 was terminated within this deposit.



The SPT “N”-values measured within the cohesive till deposit range from 11 blows to 44 blows per 0.3 m of penetration, suggesting that the till deposit has a stiff to hard consistency.

The results of grain size distribution tests carried out on four (4) samples of the clayey silt till are presented on Figure E1 in Appendix E. Atterberg limits tests were carried out on four (4) samples of this till deposit and measured liquid limits ranging from about 24 per cent to 32 per cent, plastic limits ranging from about 13 per cent to 16 per cent and plasticity indices ranging from about 12 per cent to 17 per cent. The results of the Atterberg limits tests are shown on a plasticity chart on Figure E2 in Appendix E, and indicate that the till deposit consists of clayey silt of low plasticity. The natural water content measured on six (6) samples of this till deposit ranges from about 12 per cent to 15 per cent.

4.8.4 Refusal

The bedrock surface is inferred by refusal to further auger advancement in Borehole WN-1 at a depth of about 5.3 m below ground surface, corresponding to about Elevation 217.4 m.

4.8.5 Groundwater Conditions

The samples taken in the boreholes were moist. The groundwater levels in the open boreholes were measured upon completion of drilling operations and the details are provided on the Record of Borehole sheets in Appendix E, and are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
WN-1	222.7	4.4	218.3	November 20, 2012	Open Borehole
WN-2	223.1	4.4	218.7	November 20, 2012	Open Borehole

The groundwater levels at this site are subject to seasonal fluctuations and precipitation events and should be expected to be higher during the spring season or during any period of heavy precipitation.

4.9 Ramp E-N: STA. 10+000 to STA. 10+210 (High Fill Area 6)

The plan and profile along the centerline of the proposed interchange Ramp E-N embankment showing the borehole locations and interpreted stratigraphy are shown on Drawing 7. The Record of Boreholes EN-1 to EN-4 and the laboratory test results completed for this high fill area are presented in Appendix F. The new interchange Ramp E-N is proposed to connect the Highway 5 Westbound lanes (WBL) to the Highway 6 Northbound lanes (NBL) from STA. 10+000 to STA. 10+210, and is between about 4.5 m and 6.5 m high to about STA. 10+080. The existing ground surface along the proposed high fill embankment within the investigated portion of Ramp E-N varies from about Elevation 222.4 m near the eastern limit to about Elevation 222.1 m near the northern limit of the investigated area.



The subsurface conditions encountered along the proposed ramp alignment consist of a surficial layer of topsoil and fill underlain by a cohesive till deposit comprised of very stiff to hard clayey silt to clayey silt with sand, as described below.

4.9.1 Topsoil

A 200 mm to 300 mm thick layer of topsoil was encountered at the ground surface in all the boreholes.

4.9.2 Fill

An approximately 1.1 m to 1.9 m thick deposit of fill was encountered below the topsoil in all the boreholes and the surface of the fill deposit varies between about Elevations 222.1 m and 221.9 m. The fill deposit is generally cohesive, comprised of brown to dark brown clayey silt trace to some sand to clayey silt with sand, containing trace gravel, trace organics, sand pockets pieces of asphalt and topsoil. The upper 0.5 m of the fill in Borehole EN-3 consists of dark brown to brown sandy silt, trace clay, trace organics and contain pieces of brick.

The SPT “N”-values measured within the cohesive fill range from 5 blows to 12 blows per 0.3 m of penetration, suggesting a firm to stiff consistency. A SPT “N”-value of 9 blows per 0.3 m of penetration was recorded within the layer of sandy silt fill, indicating a loose relative density.

The grain size distribution test completed on two (2) samples of the clayey silt to clayey silt with sand fill are presented on Figure F1 in Appendix F. Atterberg limits tests were also performed on two (2) selected samples of the cohesive fill and measured liquid limits of about 30 per cent and 33 per cent, plastic limits of about 17 per cent and corresponding plasticity indices of about 13 per cent and 16 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure F2 in Appendix F, and indicate that the cohesive fill is a clayey silt of low plasticity. The natural water content measured on two (2) samples of the cohesive fill is about 14 per cent and 25 per cent.

4.9.3 Clayey Silt to Clayey Silt with Sand Till

A deposit of cohesive till comprised of clayey silt, with sand to trace sand trace to some gravel, sand seams and sand layers (in places) was encountered underlying the fill deposit in all the boreholes. The surface of the cohesive till deposit was encountered between about Elevations 221.0 m and 220.0 m, and the thickness of the till deposit varies between about 3.2 m and 3.9 m.

The SPT “N”-values recorded within the cohesive till deposit range from 16 blows to 48 blows per 0.3 m of penetration, suggesting that the cohesive till has a very stiff to hard consistency. A SPT “N”-value of 10 blows per 0.08 m of penetration was recorded upon refusal in Borehole EN-3.

The results of the grain size distribution tests completed on six (6) selected samples of the clayey silt to clayey silt with sand till are provided on Figure F3 in Appendix F. Atterberg limits tests were carried out on six (6) samples of the cohesive till deposit and measured liquid limits ranging from about 23 per cent to 32 per cent, plastic limits ranging from about 14 per cent to 17 per cent, and corresponding plasticity indices ranging from about 9 per cent to 16 percent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure F4 in Appendix F and indicate that the cohesive till deposit consist of clayey silt of low plasticity. The



natural water content measured on fourteen (14) samples of the cohesive till deposit ranges from about 13 per cent to 20 per cent.

4.9.4 Refusal

In the four boreholes, the bedrock surface is inferred by refusal to further split-spoon penetration and/or auger advancement at depths between about 5.3 m and 5.4 m below ground surface (between about Elevations 217.1 m and 216.8 m).

4.9.5 Groundwater Conditions

The samples taken in the boreholes were generally moist to wet. The groundwater levels in the open boreholes were measured upon completion of drilling operations and open Borehole EN-4 was dry. A standpipe piezometer was installed in Borehole EN-4 to permit monitoring of the groundwater level at this site. Details of the piezometer installation and measured groundwater levels are shown on the Record of Borehole sheets in Appendix F. The groundwater levels recorded in the open boreholes and in the piezometer on February 13, 2013 are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
EN-1	222.4	4.7	217.7	November 14, 2012	Open Borehole
EN-2	222.2	4.8	217.4	November 14, 2012	Open Borehole
EN-3	222.1	4.1	218.0	November 19, 2012	Open Borehole
EN-4	222.2	2.4	219.8	February 13, 2013	Piezometer

The groundwater levels at this site are subject to seasonal fluctuations and precipitation events and should be expected to be higher during the spring season or during any period of heavy precipitation.



5.0 CLOSURE

Mr. John Hagan, P.Eng., a pavement/geotechnical engineer with Golder supervised the field drilling program. This report was prepared by Ms. T. Veronica Ayetan, P.Eng., a geotechnical engineer with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted a technical review and quality control review of the report.

GOLDER ASSOCIATES LTD.



T. Veronica Ayetan, P.Eng.
Geotechnical Engineer



Jorge M.A. Costa, P.Eng.
Designated MTO Contact, Principal

TVA/JMAC/jl

\\golder.gds\gal\whitby\active_2010\1184 pavements materials\10-1184-0016 giffels ibi hwy 5 and 6 hamilton_foundations\7 - reports\final\high fill areas\10-1184-0016 14nov28 hwy 5 & 6
- high fill areas.docx



PART B

FOUNDATION DESIGN REPORT
HIGH FILL AREAS 1 TO 6

FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC) AND ASSOCIATED
MUNICIPAL ROADS, CITY OF HAMILTON
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2112-05-00



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides recommendations on the geotechnical aspects of design and construction for the high fill embankments as part of the overall development of the future Highway 5 and Highway 6 Interchange (IC) and associated Municipal Roads in the City of Hamilton, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the design engineers with sufficient information to assess the feasible alternatives and to carry out the design of the high fill embankments. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the design of the project. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Golder Associates Ltd. (Golder) was retained by IBI Group (IBI) on behalf of Ministry of Transportation, Ontario (MTO) to provide design recommendations for the proposed Highway 5/Highway 6 Interchange high fill embankments. The proposed development will include design and construction of six (6) high fill embankments, designated as High Fill Areas 1 to 6, to modify the existing Highway 5 and Highway 6 at-grade crossing to an interchange with the Highway 5 structure crossing over Highway 6 thus accommodating future traffic forecast. The new interchange will require re-alignment of Highway 5 slightly to the north and Highway 6 slightly to the east of their present locations, in the vicinity of the present crossing. High Fill Areas 1 and 2 are situated along the re-aligned Highway 5, immediately west and east of the proposed Highway 5/Highway 6 Interchange structure, and High Fill Areas 3 to 6 are located along the proposed interchange ramps connecting Highway 5 to Highway 6 in the four interchange quadrants. The locations of these high fill areas are shown on Drawing 1 following the text of this report.

6.2 High Fill Embankments

Based on the plan, vertical profiles and cross-section drawings of the proposed re-aligned Highway 5, Highway 6 and the new interchange ramps (Ramps W-S, E-S, W-N and E-N) provided by IBI (File Nos. T5&6-MNC-5 lane-New STA.dwg, T5&6_MPROF.dwg, Inroads-Cross Sections Hwy 5.dwg, Inroads-Cross Sections Hwy 6.dwg and Inroads-Cross Sections Ramps.dwg, dated between June 24, 2013 and February 19, 2014), it is understood that the new interchange construction will require high fill embankments ranging between about 4.5 m and 9 m high. Given the proposed re-alignment of Highway 5 and Highway 6 at this site, it is assumed that the existing highways will remain operational to live traffic during construction of the adjacent high fill embankments at the at-grade crossing. The details of the investigated area and their location relative to the proposed highway alignments and interchange ramps are summarized below.



FOUNDATION REPORT – HIGH FILL AREAS 1 TO 6, FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC), GWP 2112-05-00

High Fill Area Designation	Reference Drawing	Approximate Station Limits	Maximum Fill Height (m)
Highway 5 / High Fill Area 1	Drawing 2	29+850 to 29+960	9
Highway 5 / High Fill Area 2)	Drawing 3	30+040 to 30+120	8
Ramp W-S / High Fill Area 3	Drawing 4	10+000 to 10+140	6.5
Ramp E-S / High Fill Area 4	Drawing 5	10+000 to 10+100	9
Ramp W-N / High Fill Area 5	Drawing 6	10+000 to 10+100	5
Ramp E-N / High Fill Area 6	Drawing 7	10+000 to 10+210	6.5

Section 6.3 of this report summarize the methods used for the analysis of stability and settlement for critical sections of embankment construction for the re-aligned Highway 5 and the associated (new) interchange ramps, including the results of the analyses and recommendations on mitigating time-dependent settlements, as required. General aspects of subgrade preparation, embankment construction and the design/construction considerations for the proposed high fill embankments are presented in Sections 6.4 and 6.5.

6.2.1 Embankment Fill Types and Benching Requirements

Different embankment fill materials (i.e. suitable earth fill or granular fill and rock fill) provide relative advantages and disadvantages in terms of availability, weight (i.e. driving force and applied load to the founding subsoils), construction cost and time, ease of construction and post-construction performance.

The main advantage of using suitable earth fill or granular fill is the ease of construction and negligible post-construction settlement within the embankment fill itself if predominantly granular fill (non-cohesive soils) are used. If cohesive soils are used, post-construction settlements should be expected. The advantages of using rock fill to construct embankments includes the ability to achieve steeper side-slopes (which is typically required in areas with limited right-of-way), thus reducing the overall quantity of fill material required for the project, and also allowing for placement of fill materials in wet conditions. However, if rock fill is required from off-site rock borrow sources, the costs associated with importing the additional fill could outweigh the benefits. In addition, the utilization of rock fill for embankment construction results in some post-construction settlement of the embankment fill itself.

From a geotechnical/foundations perspective, earth fill (and/or granular fill) is compatible with the subsoils at this site, although it is understood that the high fill embankments are planned to be constructed of the surplus earth fill material from MTO Contract 2009-2015 that is currently stockpiled at the northwest quadrant of the existing Highway 5 and Highway 6 intersection, or of escarpment rock cut materials from widening Highway 6 and cuts for ramps and local access at this site. Further details on the stockpiled material and its suitability for re-use as earth borrow and the proposed escarpment rock cut fill are described in the following sections.

All embankment fill is to be placed and compacted in accordance with OPSS.PROV 206 (*Grading*).



6.2.1.1 Stockpiled Material – Earth Fill

It is understood that the surplus material from MTO Contract 2009-2015 for the Queen Elizabeth Way (QEW) construction that is currently stockpiled at the northwest quadrant of the existing Highway 5 and Highway 6 intersection is proposed to be re-used for the construction of the high fill embankments within the project limits.

Golder carried out a pavement field investigation and laboratory testing program on the stockpiled material to evaluate the suitability of the material for re-use as earth borrow on this project. The results of the pavement field investigation including the methodology, the results of the laboratory testing and the assessment of the suitability of the stockpiled material for re-use as earth (fill) borrow on this site are contained in Golder's Pavement Investigation and Design Report (2014).

In summary and as reported in the Golder's Pavement Design Report (2014), the stockpiled material consists of topsoil, clayey silt and clayey silt with sand. Cobbles and boulders were also observed in places within the clayey silt to clayey silt with sand materials. Comparing the results of the laboratory testing on the clayey silt to clayey silt with sand portion of the stockpiled material (i.e. the ranges of optimum moisture content and in-situ water content, Atterberg limits and the Standard Proctor Maximum Dry Density) to the criteria set out in OPSS.PROV 212 (*Earth Borrow*), the stockpiled material is considered suitable for re-use as earth borrow, provided the material is kept free of deleterious materials such as topsoil (currently overlying the cohesive soil), organics and highly frost susceptible soil. Given that the stockpiled clayey silt to clayey silt with sand soil is considered to be low to medium frost susceptible (MTO Pavement Design and Rehabilitation Manual, 2013), (Townsend and Csathy, 1963) and that the material consist of cohesive soil which will further undergo post-construction settlements if used as embankment earth fill, it is recommended that the stockpiled soil should only be used as engineered fill (for embankment construction) within a restricted zone below the frost penetration depth and in a non-/less-settlement sensitive areas where the embankment height/thickness of this fill zone is less than 4.5 m.

In addition, depending on the percentage of fines (silt/clay and sand) content, difficulties should be expected if placing and compacting such soils in wet or inclement weather conditions. Earth (or granular) fill required to augment the on-site stockpiled material to construct the proposed embankments for the six high fill areas will have to be imported from off-site sources and it should meet the criteria of OPSS.PROV 212 (*Earth Borrow*) or OPSS.PROV 1010 (*Aggregates*).

The potentially suitable stockpiled material referenced above, as tested from two select soil samples, exhibited optimum moisture content (OMC) for standard Proctor compaction of 14 per cent and 16 per cent and in-situ (natural) water content of 15 per cent and 17 per cent; the suitability of the stockpiled material for use as embankment fill (i.e. earth borrow) should be further assessed during construction as part of the Contract Administration QA/QC process, for compliance with OPSS.PROV 212 (*Earth Borrow*) and OPSS 501 (*Compacting*). The suitability of the stockpiled material from an environmental perspective was not investigated and therefore is not addressed herein.

In accordance with MTO's standard practice, for earth (or granular) fill embankments with embankment side slopes at 2 Horizontal to 1 Vertical (2H:1V), a minimum 2 m wide bench should be incorporated into the slope cross-section where the height of the embankment is equal to or greater than 8 m, such that the uninterrupted slopes does not exceed height of 8 m.



6.2.1.2 Escarpment Rock Cut – Rock Fill

It is further understood that rock fill from the escarpment rock cut proposed along the east side of Highway 6 (south of Highway 5), required to accommodate the widening and re-alignment of Highway 6 and the construction of the access ramps, will be re-used for the construction of the high fill embankments within the project limits.

Golder carried out a rock slope assessment of the current Niagara Escarpment rock cuts along Highway 6 to evaluate the potential stability conditions of the proposed new rock cuts (that will be exposed along the east side of the existing Highway 6 east cut) and to provide recommendations for the design of the new rock cuts required for the re-alignment of Highway 6. The results of the rock cut slope assessment, rock fall analyses, design and recommendations, including methodology for the rock cut excavation are contained in the Golder's Rock Cut Slope Assessment Report (2013).

In summary and as reported in the Golder's Rock Cut Slope Assessment Report (2013), the Niagara Escarpment along Highway 6 is a topographic break comprised of harder resistant dolostone and limestone units forming vertical cliffs along the brow of the Escarpment, over the softer red shale, sandstone and siltstone of the Silurian and Ordovician Period. These bedrock types are of various formations comprising of, the lower members of the Lockport Formation (including Goat Island Member and Gasport Member) which are present at the crest, underlain by the Rochester, Irondequoit, Reynales, Thorold, Grimsby and Cabot Head Formations.

Based on the description of the bedrock geology at the proposed escarpment rock cut, it is likely that the rock fill that will be available for re-use in the construction of the Highway 5/Highway 6 Interchange embankments will be comprised of various types of rock, grading from the harder dolostone/limestone to softer shale and that there will be no sorting and/or filtering of the various rock types. Therefore, since shale is generally susceptible to weathering, rapid degradation and erosion when exposed, which could result in settlement of the embankment, it is recommended that the shale component of the rock fill be broke-down prior to placement in the embankment mass in accordance with OPSS.PROV 206 (*Grading*) and SP 206F04 (*Rock Excavation, Grading*). Where rock fill is used for embankment construction, a steeper side slope at 1.25H:1V could be achieved. Further recommendations on the placement of rock fill for embankment construction are provided in Section 6.4.

It is noted that OPSD 202.010 (*Slope Flattening*) suggests that a 2 m wide bench be incorporated into the rock fill embankment side slope profile for uninterrupted slopes greater than 10 m high. Given that the maximum height of the rock fill approach embankment at the critical section is less than 10 m, the incorporation of a mid-height bench is not required at this site.

6.3 Embankment Stability and Settlement

The following sections outline the methodology used to evaluate embankment stability and the magnitude of settlement at the various high fill areas, the parameters used in the analyses for each of the critical section(s) and present the results of the stability and settlement analyses as well as potential design and construction alternatives to mitigate post-construction settlement.



6.3.1 Static Global Stability

6.3.1.1 Methodology

Stability analyses were performed for the critical sections of the proposed embankments in each high fill area, corresponding to the greatest embankment height and/or the maximum thickness of soft or loose, compressible cohesive soils. The global, internal and surficial stability of the embankments will depend on the slope geometry and largely on the properties of the existing subsoils. The stability analyses assume that all topsoil and near surface loose or soft soils containing organics and existing fill materials will be removed from the proposed new embankment footprint, the new fill will be placed and compacted on a competent, relatively undisturbed native soil subgrade and that suitable earth fill/rock fill will be used for construction of the embankment (as discussed in Section 6.2.1).

The stability of the critical section of each proposed new embankment section(s) was analyzed using limit equilibrium methods. The limit equilibrium slope stability analyses were performed using the commercially available software program “Slide” (Version 6.0), produced by Rocscience Inc., employing the Morgenstern-Price method of analysis. For all analyses, the factor of safety of numerous potential failure surfaces was computed in order to establish the minimum Factor of Safety (FoS) for the various embankment heights and geometries. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. A target minimum FoS of 1.3 is normally adopted for the design of embankment slopes under static conditions for MTO embankments. This minimum FoS, which is based on deep-seated, global failure surfaces that would affect the operation of the roadway, is considered adequate for the embankments at these sites considering the design requirements and the available field and laboratory test data.

6.3.1.2 Parameter Selection

The subsurface conditions encountered in each high fill embankment area are generally consistent across the sites and consist of a thin layer of topsoil, underlain by combinations of non-cohesive (granular) fill (comprised of sandy silt, sand and silt, silty sand, silty sand and gravel, gravelly silty sand, gravelly sand and sand and gravel) and cohesive fill (comprised of clayey silt, clayey silt with sand and silty clay), in turn underlain by cohesive till deposits (comprised of clayey silt, clayey silt with sand and silty clay). For the non-cohesive (granular) fill (where applicable), effective stress parameters were employed in the analyses assuming drained conditions. The effective stress parameters (effective friction angle and effective cohesion) for the topsoil and granular fill/soils were estimated from empirical correlations using the results of in-situ Standard Penetration Tests (SPTs), in conjunction with engineering judgement based on experience in similar soil conditions.

For cohesive deposits, both effective and total stress parameters (assuming undrained conditions) were employed in the analyses to determine the critical case. The total stress parameters (i.e. average mobilized undrained shear strength – s_u) for the cohesive soils were estimated from empirical correlations with the SPT results and laboratory (natural water content) test data, as proposed by Kulhawy and Mayne (1990) and Bowles (1984). These estimated values were further compared with the typical range of expected values for similar soil types, as outlined in the *Canadian Highway Bridge Design Code* (CHBDC, 2006) and adjusted, if necessary.

When developing the area-specific correlations of engineering parameters based on laboratory or field test data, the results from all high fill areas were combined to provide a larger set of parameters to evaluate. It was considered that all the high fill areas exhibited sufficiently similar soil mineralogy and geology that correlations based on all of the data would be justified. Having developed the area-specific correlations, the test results for each individual high fill area were examined and the design parameters were developed accordingly.



FOUNDATION REPORT – HIGH FILL AREAS 1 TO 6, FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC), GWP 2112-05-00

To account for the maximum embankment loading on the subgrade soils, the stability analyses were carried out on the basis that the new interchange high fill embankments will be constructed of suitable earth fill. The earth fill modeled is assumed to have a unit weight of 20 kN/m^3 and an effective friction angle of 30° , and the embankment geometry assumes side slopes no steeper than 2H:1V. For a typical assessment of an embankment constructed of rock fill (from the escarpment rock cut), the stability analysis was carried out with the rock fill assumed to have a unit weight of 19 kN/m^3 and an effective friction angle of 38° and the embankment sloped at 1.25H:1V. The piezometric conditions used in the analyses were based on the highest groundwater levels observed during and upon completion of drilling.

The simplified soil stratigraphy together with the associated strengths and unit weights employed for the different soil types in each critical section analyzed for each high fill area are presented below.

Hill Fill Area Designation	Soil Conditions	Bulk Unit Weight (kN/m^3)	Undrained Shear Strength (kPa)	Effective Friction Angle (degrees)	Comments
1 (STA. 29+950)	New Embankment (Earth) Fill	20	--	30	Embankment height at the critical section is approximately 8 m (with maximum height of 9 m relative to the ditch bottom).
	Compact Sand and Silt (Topsoil) – beyond toes	17	--	28	
	Existing Fill	20	65	28	
	Stiff to Hard Clayey Silt Till	21	150	35	
2 (STA. 30+040)	New Embankment (Earth) Fill	20	--	30	Maximum embankment height is approximately 8 m.
	Existing Fill	20	50	28	
	Stiff to Hard Clayey Silt Till	21	150	35	
3 (STA. 10+000)	New Embankment (Earth) Fill	20	--	30	Maximum embankment height is approximately 6.5 m.
	Existing Fill	20	65	28	
	Stiff to Hard Clayey Silt Till	21	150	35	
4 (STA. 10+010)	New Embankment (Earth) Fill	20	--	30	Embankment height is approximately 8.5 m at the critical section (may be up to 9 m at the eastern limit depending on the final grade).
	Existing Fill	20	65	28	
	Stiff to Hard Clayey Silt Till	21	150	35	
5 (STA. 10+000)	New Embankment (Earth) Fill	20	--	30	Maximum embankment height is approximately 5 m.
	Existing Fill	20	65	28	
	Stiff to Hard Clayey Silt Till	21	150	35	
6 (STA. 10+025)	New Embankment (Earth) Fill	20	--	30	Maximum embankment height is approximately 6.5 m.
	Existing Fill	20	50	28	
	Very Stiff to Hard Clayey Silt to Clayey Silt with Sand Till	21	150	35	



6.3.1.3 Results of Analyses

The stability analyses performed at the critical section(s) of High Fill Areas 1 to 6 indicate that after the construction of the Highway 5/Highway 6 Interchange embankments (including removal and replacement of any topsoil and existing fill with suitable earth fill and assuming appropriate subgrade preparation and proper placement and compaction of the embankment fill materials) with side slopes no steeper than 2H:1V, the embankments will have a FoS of 1.3 or greater for deep seated, global failure surfaces that would impact the operation of the highway. A check on the stability of a 9 m high fill embankment at Area 1 and Area 4 confirms that the FoS will be greater than 1.3 at these areas. The results of the static global stability analyses of the critical section for each area are presented on Figures 1 to 6.

In addition, the result of the stability check for an embankment constructed of rock fill (from the escarpment rock cut) at Area 1 is presented on Figure 7, indicating that the FoS will also be greater than 1.3.

6.3.2 Seismic Stability

Under earthquake conditions, the stability of the new embankment 2H:1V slopes is assessed using conventional pseudo-static seismic method of slope stability analysis under the earthquake-induced peak ground acceleration. A calculated FoS of 1.0 is considered appropriate for global stability of embankment under seismic conditions.

According to Table A3.1.1 of the *Canadian Highway Bridge Design Code 2006* (CHBDC 2006) and Table C4.2 of the *Commentary to the CHBDC*, this site is located in Seismic Zone 1 and for a 10 per cent probability of exceedance in 50 years, the site-specific zonal acceleration ratio (A) for the City of Hamilton is 0.05. This value is consistent with the calculated site-specific peak ground acceleration (PGA) of 0.05g based on the National Resources Canada (NRC) website. In accordance with Section 4.4.6 and Table 4.4 of CHBDC (2006) and based on the subsurface conditions at the site, the Site Coefficient (S) may be taken as 1.0, consistent with Soil Profile Type I, therefore an amplification of the ground motion is not required for design, resulting in a ground surface acceleration of approximately 0.05g. For the purpose of this study, a seismic coefficient value of 0.025g (50 per cent of the Peak Horizontal Acceleration as recommended by Hynes-Griffin, 1984) was used for design.

6.3.2.1 Results of Analyses

A seismic global stability analysis has been performed for the “worst case” high fill embankment area, at the approximately 8 m high embankment located within High Fill Area 1 between STA. 29+850 and STA. 29+960 using the parameters summarized in Section 6.3.1.2. Pseudo-static seismic slope stability analyses for a 2H:1V side slope inclination indicate that the new embankment slopes will have a FoS greater than 1.0 against deep-seated slope instability, using a peak ground acceleration of 0.025g. The result of the seismic stability analysis is presented on Figure 8.

Some shallow sloughing and toe failure could occur on the embankment side slopes during seismic events. This sloughing and toe failure is expected to be limited, would not impair the use of the highway, and would mainly be a maintenance issue. The potential for sloughing following seismic events could be reduced by providing well-vegetated side slopes, as recommended in Section 6.5.3.



6.3.3 Settlement

6.3.3.1 Methodology

Analyses were performed at the critical sections of the proposed 5 m to 9 m high fill embankments to estimate the magnitude of the expected settlements using the commercially available software program “Settle^{3D}” (Version 2.0), produced by Rocscience Inc. and hand/spreadsheet calculations. Critical sections generally correspond to the greatest new embankment height and/or the maximum thickness of soft, compressible cohesive soils. The settlement analysis assumes that all topsoil and near surface loose or soft soils containing organics and existing fill materials will be removed from the proposed new embankment footprint and the new embankment fill will be placed and compacted on a competent, relatively undisturbed native soil subgrade and that suitable earth fill/rock fill will be used for replacement of sub-excavated material (as discussed in Section 6.2.1).

The sources of settlement were considered to include:

- immediate settlement of the native stiff to hard clayey silt to clayey silt with sand (cohesive) till deposits underlying the embankment areas; and
- self-weight compression of the embankment fill materials (short-term and long-term).

The thickness of the compressible foundation soils and the height of each high fill embankment area vary along the proposed highway and ramp alignments, and as such the settlements along the length of a given alignment will similarly vary. Given that the analyses were carried out at the critical section(s) of each high fill area, the settlements estimated will generally represent the maximum value along a given section of the alignment.

6.3.3.2 Parameter Selection

The foundation soils underlying the new embankments upon removal of any near surface loose or soft soils and unsuitable existing fill, will consist of the replaced suitable earth fill and the stiff to hard cohesive till deposits.

The immediate compression of the foundation strata were assessed by estimating an elastic modulus of deformation based on the SPT ‘N’-values and empirical correlations found in literature by Bowles (1984) and Kulhawy and Mayne (1990). These estimated values were compared with the typical range of expected values for similar soil types, as outlined in CHBDC (2006) and adjusted, if necessary.

The unit weights and slope profiles for the embankment fill are as described in Section 6.3.1.2. The piezometric conditions used in the analyses are based on the highest groundwater levels noted during and upon completion of drilling.

The following summarizes the simplified stratigraphy, unit weight, the maximum thickness and deformation parameters employed for the foundation soils in the critical sections in each high fill area. For the purpose of analysis, earth fill has been considered for the construction of the high fill embankments.

Hill Fill Area Designation	Soil Conditions	Thickness (m)	Bulk Unit Weight (kN/m ³)	Elastic Modulus (E') (MPa)
1 (STA. 29+950)	Stiff to Hard Clayey Silt Till	3.6	21	75
2 (STA. 30+040)	Stiff to Hard Clayey Silt Till	3.8	21	75



FOUNDATION REPORT – HIGH FILL AREAS 1 TO 6, FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC), GWP 2112-05-00

Hill Fill Area Designation	Soil Conditions	Thickness (m)	Bulk Unit Weight (kN/m ³)	Elastic Modulus (E') (MPa)
3 (STA. 10+000)	Stiff to Hard Clayey Silt Till	4.9	21	75
4 (STA. 10+010)	Stiff to Hard Clayey Silt Till	4.5	21	75
5 (STA. 10+000)	Stiff to Hard Clayey Silt Till	4.5	21	75
6 (STA. 10+025)	Very Stiff to Hard Clayey Silt to Clayey Silt with Sand Till	3.9	21	75

6.3.3.3 Settlement Performance Requirements

The settlement performance criterion of design for the high fill embankments is in accordance with Sections 1.1 and 1.2 of MTO's "Embankment Settlement Criteria for Design", dated July 2010. In general, for new embankments approaching structural elements (such as Highway 5/Highway 6 bridge abutments) or where areas of compressible soils are located adjacent to areas of non-compressible soils or exposed bedrock, the more stringent settlement criterion associated with these transition points will apply in accordance with Section 1.2 of the MTO guideline. Therefore, the assumed post-construction settlement criterion over a 20-year period following completion of construction for the high fill sites is 50 mm for embankments beyond 25 m from the any abutment or rigid structure.

6.3.3.4 Settlement of Foundation Soils

Based on the results of the settlement analyses, the settlement of the foundation soils under the new approximately 5 m to 9 m high embankments that will be placed on the properly prepared subgrade is estimated to be less than 25 mm at each high fill area. This settlement is expected to occur relatively quickly during and immediately following construction of the embankment based on nature of the subgrade soils at the site.

6.3.3.5 Settlement of New Embankment Fill

Earth Fill

As discussed in Section 6.2.1.1, it is understood that MTO proposes to use material (earth fill) stockpiled at the north-west quadrant of the Highway 5/Highway 6 intersection for the construction of the high fill embankments. Provided that the new embankment material consists of suitable earth fill that is properly placed and compacted in accordance with OPSS.PROV 206 (*Grading*) and SP 206F06 (*Earth Excavation, Grading*), the magnitude of settlement of the embankment fill compression may range from 0.5 per cent to 1 per cent of the height of the embankment, that is between about 25 mm and 90 mm for the 5 m to 9 m high embankments at this site, assuming that approximately 98 per cent compaction of the embankment fill is achieved, relative to the material's Standard Proctor Maximum Dry Density (SPMDD). Consideration could be given to using granular fill for the embankment construction, to reduce the magnitude of settlement since the majority of settlement of granular fill materials will occur essentially during embankment construction, whereas the cohesive (non-granular) earth fill materials are expected to exhibit some additional settlement over time (after construction).



Further, as the material may be considered frost susceptible to some degree, it is recommended that this stockpiled material be used below the frost penetration depth and in non-/less-settlement sensitive areas (i.e. fill zone less than 4.5 m thick).

Rock Fill

As noted in Section 6.2.1.2, it is understood that escarpment rock cut materials (rock fill) may be used for construction of the high fill embankments, and as such, there will be settlement due to compression of the rock fill itself under self-weight, in addition to the settlement of the underlying foundation soil deposits as described in Section 6.3.3.4. The settlement of rock fill occurs as a result of re-arrangement of rock particles under load and wetting and as a result of localized crushing of rock particles at point contacts. The magnitude of short-term and long-term settlements of the rock fill largely depends on: the type of rock/strength of particles; size and shape of rock particles; gradation of rock fill; total height/thickness of rock fill; and the method of construction and sequence of placement (including lift thickness, compactive effort and state of packing).

In accordance with the MTO's "Guideline for Rock Fill Settlement and Rock Fill Quantity Estimates" dated September 2010, the magnitude of both the short-term and long-term post-construction settlement of the rock fill is a function of the height of fill as well as the method of fill placement (i.e. compacted versus dumped rock fill). Since the embankments at the high fill sites will generally be above the groundwater table, the rock fill should be placed in a controlled manner (i.e. not end-dumped) in accordance with OPSS.PROV 206 (*Grading*). Blading, dozing and 'chinking' the rock fill to break-down (weather) the shale component of the mixed rock fill and form a dense, compact mass is required to minimize voids and bridging and reduce settlements. For rock fill placed in this controlled (compacted) manner, the settlement of rock fill is expected to be nominal.

The short-term post-construction settlement of the compacted rock fill embankment is estimated to be up to about 0.5 per cent of the effective height of the rock fill embankment height up to about 5 m, and up to about 0.75 per cent of effective height of the rock fill embankment between 5 m and 10 m. For the long-term post-construction settlement of compacted rock fill embankment, the settlement is estimated to be up to about 0.1 per cent of effective height of the rock fill embankment height up to 15 m. The expected settlement of the rock fill embankment at the critical section (presented in Section 6.3.3.2) of each of the proposed high fill areas is provided below.

Hill Fill Area Designation	Effective Maximum Embankment Height (Thickness of Rock Fill) ¹ (m)	Estimated Short-Term Settlement of Rock Fill (mm)	Estimated Long-Term Settlement of Rock Fill (mm)	Total Settlement of Rock Fill (mm)
1	8.0 + 2.1 = 10.1	75	10	85
2	8.0 + 1.4 = 9.4	70	10	80
3	6.5 + 2.1 = 8.6	65	10	75
4	8.5 + 1.4 = 9.9	75	10	85
5	5.0 + 0.8 = 5.8	45	5	50
6	6.5 + 1.4 = 7.9	60	10	70

Note: ¹ Includes additional fill required after removal of topsoil/organics and existing fill (below grade) at the critical section



Approximately 90 percent of the short-term settlement of the rock fill estimated above is expected to occur within six (6) months following construction to the full height of the embankment and the remaining 10 percent (i.e. less than 10 mm) is expected to occur in the following (6) months. The long-term rock fill settlement is expected to occur from one (1) year following the completion of construction over the life of the embankment.

If rock fill is used for the construction of the high fill embankments at this site, in order to satisfy the total settlement performance criterion of 50 mm (as discussed in Section 6.3.3.3) over a 20-year period following the completion of the new embankment construction, the rock fill embankment at High Fill Areas 1 to 4 and 6, should be preloaded for a minimum of between 30 days and 60 days to allow for the part of the short-term settlement to occur. Preloading is not necessarily required at High Fill Area 5, but can be implemented together with the preloading requirements at the other high fill areas. The minimum preload period for each high fill area and the magnitude of the remaining short-term and long-term post-construction settlement of the rock fill after the preload period are presented below and summarized in Table 1.

Hill Fill Area Designation	Minimum Preload Period (days)	Remaining Estimated Short -Term Settlement of Rock Fill after Preload Period (mm)	Remaining Estimated Long -Term Settlement of Rock Fill after Preload Period (mm)
1	60	40	10
2	60	40	10
3	45	40	10
4	60	40	10
6	30	40	10

Due to the settlement of the subgrade, and settlement/compression of the rock fill embankments which is expected to occur during and upon completion of the embankment preload periods and subsequently during the design life of the rock fill embankments, there will be the need for regrading of the embankment to maintain the design grade/profile. As such, it is recommended that the rock fill embankments be constructed wider by about 1 m on each embankment side at the outset of construction to accommodate such a grade raise to make-up for the settlement that has occurred and to accommodate up to 200 mm thick future pavement overlays and still maintain the standard shoulder widths (which is consistent with the requirements of MTO "Northern Region Engineering Directive NRE 98-200").

6.4 Subgrade Preparation and Embankment Construction

6.4.1 Subgrade Preparation

Based on the information from the boreholes obtained during the field investigation, an approximately 100 mm to 300 mm layer of topsoil and/or asphalt was encountered immediately below the ground surface. The existing fills encountered at the boreholes consist of a heterogeneous mixture of very loose to compact (occasionally dense) non-cohesive fill and soft to stiff cohesive fill containing trace organics, asphalt, concrete and brick pieces and seams/pockets of mixed soils. Considering that the majority of the existing fills contain organics and



comprised of varying soil components, it is recommended that all topsoil, asphalt, organic matter and existing loose/soft fill materials be removed from within the new embankment footprint to minimize settlement and improve the long-term performance of the new embankments. In these areas, the exposed subgrade soils should be proof-rolled prior to fill placement in accordance with OPSS.PROV 206 (*Grading*).

Alternatively, the sub-excavated existing fill could be further re-used for grading as applicable, provided that it is placed and compacted as detailed in Section 6.4.2.

6.4.2 Embankment Construction

After stripping, the exposed subgrade soils should be inspected by the Quality Verification Engineer (QVE) prior to placement of the new embankment fill, proof rolled to identify soft/loosened areas, and any poorly performing areas should be sub-excavated and replaced with suitable backfill. A NSSP should be included in the Contract to address the subgrade inspection procedure prior to placement of the embankment new fill and suggested wording is included in Appendix G.

The new embankment fill should be placed in accordance with the OPSS.PROV 206 (*Grading*) and SP 206F06 (*Earth Excavation, Grading*) and compacted in accordance with OPSS 501 (*Compacting*) and SP 105S21 (*Amendment to OPSS 501*). Inspection and field density testing should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved. Where new embankments meet existing Highway embankments, benching of the existing fill/embankment side slopes should be carried out to “key in” the new fill materials, in accordance with OPSS 208.010 (*Benching of Earth Slopes*). The use of granular fill for construction of roadway embankments is recommended, since the majority of settlement of granular fills would occur during construction, however, suitable earth fill may also be used recognizing that some minor settlement of cohesive fills, if used, could occur post-construction. Side slopes for granular and earth fill embankments should be no steeper than 2H:1V.

In areas where the embankment construction and/or replacement of the existing fill will be below the groundwater level, the embankment fill should be comprised of granular material such as Granular B Type II (OPSS.PROV 1010) or rock fill. Construction of the fill embankment above the original ground surface (and water level) may then be continued by using conventional earth fill. If rock fill is used, a transition layer of Granular B Type II (minimum 1 m thick) should be placed between the rock fill and earth fill above it to reduce the potential for loss of fines.

Where the embankment is constructed of rock fill (from the escarpment rock cuts), placement of rock fill material should be carried out in accordance with the requirements as outlined in OPSS.PROV 206 (*Grading*) and SP 206SF04 (*Rock Excavation, Grading*). The rock fill should be carefully placed and compacted (not dumped); and blading, dozing and ‘chinking’ of the rock to form a dense, compact mass will be required to minimize voids and bridging. Side slopes for rock fill embankments should be no steeper than 1.25H:1V.

It is also recommended that the embankment design and construction include provisions for minimizing erosion of the side slopes due to surface water flow down the side-slopes, as noted in Section 6.5.3.



6.5 Design and Construction Considerations

6.5.1 Excavation

For temporary excavations, the existing cohesive and non-cohesive fills are considered to be Type 3 soils and the native cohesive till deposits that may be excavated (during sub-grade preparation) at this site are considered to be Type 2 soil according to the Occupational Health and Safety Act and Regulation for Construction Projects (OHSA) Ontario Regulation 213/91, Construction Projects (as amended). As such, temporary excavations in Type 2 soils should be carried out with walls sloped no steeper than at a gradient of 1H:1V to within 1.2 m of the bottom. Similarly, Type 3 soils should be excavated at slopes no steeper than a 1H:1V gradient to the base of the excavation. If groundwater seepage is encountered in the excavations and dewatering is not implemented or if sufficient time is not allowed for the soils to drain during excavation operations, temporary side-slopes should be no steeper than 2.5H:1V.

All excavations must be carried out in accordance with the latest edition of the Ontario Health and Safety Act (OHSA) O. Reg 213/91 (Construction Projects).

6.5.2 Obstructions (Cobbles and Boulders)

Cobbles and/or boulders were observed within the existing fill and cohesive till deposits encountered in the boreholes advanced at the proposed high fill areas, and in the test pits/boreholes advanced at the stockpiled area. Conventional excavation equipment should be suitable to fully excavate through the existing fill and/or native till deposits on site. However, the presence of cobbles/boulders may interfere with or slow the progress of stripping and excavation operations. It is recommended that a NSSP be included in the Contract Documents to alert the Contractor of these obstructions and to ensure that the Contractor is equipped to handle such obstructions. An example NSSP is included in Appendix G.

6.5.3 Control of Groundwater and Surface Water

Details of the groundwater levels encountered at each site during the field investigation are summarized in Sections 4.4 to 4.9. Excavations extending below the groundwater level are only anticipated to be required in High Fill Areas 1 and 4, to remove the existing fills. All other excavations are anticipated to extend to an elevation higher than the groundwater table. Perched water may be present within the surficial fill deposits above the stiff to hard cohesive till deposits; however it is expected that such seepage volumes will be minor and could be controlled by diversion channels, perimeter ditches/trenches and pumping from properly filtered sumps within the excavations.

Surface water should be directed away from the stripping areas and sub-excavations at all times. To facilitate construction operations in inclement weather, surface water runoff should be diverted away from construction areas by mountable curbs, gravity drainage and a system of interceptor trenches and directed into armoured outfalls/outlets designed to drain into roadside ditches. To maintain trafficability of construction equipment in wet weather conditions, a layer of free draining granular material may also be required to minimize disturbance of the subgrade.

Proper (surface water) erosion control measures should be implemented both during construction and permanently on the embankment side slopes. Temporary erosion and sediment control should be provided in accordance with OPSS 805 (*Temporary Erosion and Sediment Control Measures*). Topsoil should be placed on



all embankment fill side slopes in accordance with OPSS 802 (*Topsoil*), and covered with permanent erosion protection in accordance with OPSS 803 (*Sodding*) and/or OPSS 804 (*Seed and Cover*). It is recommended that topsoil and erosion protection should be placed in early summer to avoid wet periods of the year which may otherwise cause surficial sloughing of the topsoil material along the side-slopes and to allow for adequate time to establish vegetation prior to the fall/winter months.

6.5.4 Temporary Roadway Protection

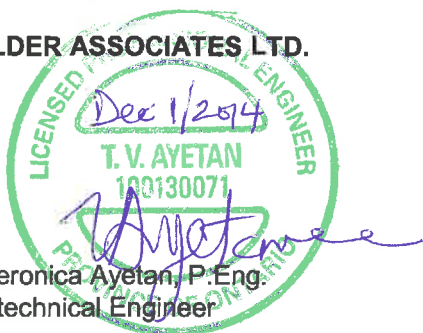
Depending on construction sequence, temporary roadway protection may be required during the excavation of the approximately 4.4 m deep existing fill and for the construction of the new high fill embankments in close proximity to the existing Highway 5/Highway 6 embankments as the existing highways will likely be maintained operational to traffic during the construction period. All temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (*Temporary Protection Systems*), constructed to meet Performance Level 2.



7.0 CLOSURE

This Foundation Design Report was prepared by Ms. T. Veronica Ayetan, P.Eng., a geotechnical engineer with Golder, with assistance provided by Mr. Al. Varshoi. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted a technical review and quality control review of the report

GOLDER ASSOCIATES LTD.



T. Veronica Ayetan, P.Eng.
Geotechnical Engineer



Jorge M.A. Costa, P.Eng.
Designated MTO Contact, Principal

AV/TVA/JMAC/jl

\\golder.gds\gal\whitby\active_2010\1184 pavements materials\10-1184-0016 giffels ibi hwy 5 and 6 hamilton_foundations\7 - reports\final\high fill areas\10-1184-0016 14nov28 hwy 5 & 6
- high fill areas.docx



REFERENCES

- Blair, R. and McFarland, S. 1993. *Regional Correlation of the Middle and Lower Silurian Stratigraphy of the Niagara Escarpment Area*, Proceedings of the 1992 Conference of the Canadian National Chapter, International Association of Hydrogeologists, Hamilton, Ontario, 659-696.
- Bowles, J.E. 1984. *Physical and Geotechnical Properties of Soils*, Second Edition. McGraw Hill Book Company, New York.
- Canadian Standards Association (CSA). 2006. *Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-06*. CSA Special Publication, S6.1 06.
- Chapman, L.J., and Putnam, D.F. 1984. *The Physiography of Southern Ontario*. Ontario Geological Survey, Special Volume 2, 3rd Edition. Ontario Ministry of Natural Resources. Accompanied by Map P.2715, Scale 1:600,000.
- Golder Associates Ltd. January 2014. *Foundation Investigation and Design Report, Highway 5 Over Highway 6 Interchange Structure*, Future Highway5/Highway 6 Interchange (IC) and Associated Municipal Roads, City of Hamilton, Ministry of Transportation, Ontario. GWP 2112-05-00. GEOCRE No. 30M5-289.
- Golder Associates Ltd. May 2014. *Pavement Investigation and Design Report*, Future Highway5/Highway 6 Interchange (IC) and Associated Municipal Roads, City of Hamilton, Ministry of Transportation, Ontario. GWP 2112-05-00 (In Progress).
- Golder Associates Ltd. November 2013. *Rock Cut Slope Assessment*, Highway5/Highway 6 Interchange (IC) and Associated Municipal Roads, City of Hamilton, Ministry of Transportation, Ontario. GWP 2112-05-00. GEOCRE No. 30M5-290.
- Hynes-Griffin M.E, Franklin A.G. 1984. *Rationalizing the Seismic Coefficient Method*. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi, 1984, Miscellaneous Paper GL-84-13.
- Karrow, P.F. 1987. *Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario*, Ontario Geological Survey, Report 255. Ministry of Northern Development and Mines, Ontario.
- Kulhawy, F.H. and Mayne, P.W. 1990. *Manual on Estimating Soil Properties for Foundation Design*. EL 6800, Research Project 1493 6. Prepared for Electric Power Research Institute, Palo Alto, California.
- National Resources Canada Website, *National Building Code of Canada Seismic Hazard*. www.nrccan.gc.ca.
- Townsend, D.L., and Csathy, T.I., 1963. *Compilation of Frost Susceptibility Criteria up to 1961*. Ontario Joint Highway Research Program, Department of Civil Engineering, Queen's University, Kingston, Ontario.
- Watt, A.K. 1955. *Pleistocene Geology and Groundwater resources of the Township of North York*, York County, Ontario Department of Mines, Sixty Fourth Annual report, Volume LXIV, Part 7.

Ministry of Transportation Ontario:

Pavement Design and Rehabilitation Manual, Second Edition, Section 3.2.5. March 2013.

Embankment Settlement Criteria for Design. July 2010.

Guideline for Rock Fill Settlement and Rock Fill Quantity Estimates. September 2010.

Northern Region Engineering Directive NRE 98-200. Northern Region Embankment Design Guidelines, October 1998.



Commercial Software

Slide (Version 6.0) by Rocscience Inc.

Settle^{3D} (Version 2.0) by Rocscience Inc.

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 206 Construction Specification for Grading

OPSS.PROV 212 Construction Specification for Earth Borrow

OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select

OPSS 501 Construction Specification for Compacting

OPSS 539 Construction Specification for Temporary Protection Systems

OPSS 802 Construction Specification for Topsoil

OPSS 803 Construction Specification for Sodding

OPSS 804 Construction Specification for Seed and Cover

OPSS 805 Construction Specification for Temporary Erosion and Sediment Control Measures

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010 Benching of Earth Slopes

OPSD 202.010 Slope Flattening Using Surplus Excavated Material on Earth or Rock Embankment

Construction Design Estimating and Documentation (CDED) Special Provisions (SP)

SP 206F04 Rock Excavation, Grading, Amendment to OPSS 206

SP 206F06 Earth Excavation, Grading; Amendment to OPSS 206

SP 105S21 Amendment to OPSS 501

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).

Ontario Occupational Health and Safety Act

Ontario Regulation 213 Construction Projects (as amended).



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 (Cohesionless) 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

	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



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

(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

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

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



TABLES



FOUNDATION REPORT – HIGH FILL AREAS 1 TO 6, FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE (IC), GWP 2112-05-00

TABLE 1 - SUMMARY OF HIGH FILL EMBANKMENTS FOUNDATION RECOMMENDATIONS

Foundation Investigation Limits (High Fill Area)	Proposed Maximum Fill Height	Topography and Subsurface Conditions	Sub-Excavation Requirement	Recommended Embankment Fill Type and Side Slope	Estimated Settlement (δ) ¹	Rock Fill Embankment ²	
						Estimated Post-Construction Settlement (δ)	Preferred Settlement Mitigation Option
Highway 5 STA. 29+850 to 29+960 (Area 1)	Up to 9 m	Relatively flat to gentle sloping terrain; layer of asphalt/topsoil and fill underlain by stiff to hard clayey silt till deposit.	Strip topsoil and asphalt layer; sub-excavate existing fill containing organics, asphalt pieces and a mixture of cohesive and non-cohesive fill up to about 4.4 m below ground surface.	Earth/Granular Fill with 2H:1V side-slopes	$\delta \leq 25$ mm	$\delta = 85$ mm	Preload Rock Fill embankment for 60 days. $\delta_{\text{remaining}} = 50$ mm
Highway 5 STA. 30+040 to 30+120 (Area 2)	Up to 8 m	Relatively flat to gentle sloping terrain; layer of asphalt/topsoil and fill underlain by stiff to hard clayey silt till deposit.	Strip topsoil and asphalt layer; sub-excavate existing fill containing organics, concrete pieces and a mixture of cohesive and non-cohesive fill up to about 1.4 m below ground surface.	Earth/Granular Fill with 2H:1V side-slopes	$\delta \leq 25$ mm	$\delta = 80$ mm	Preload Rock Fill embankment for 60 days. $\delta_{\text{remaining}} = 50$ mm
Ramp W-S STA. 10+000 to 10+140 (Area 3)	Up to 6.5 m	Relatively flat to gentle sloping terrain; layer of asphalt and fill underlain by stiff to hard clayey silt till deposit.	Strip asphalt layer; sub-excavate existing fill comprised of a mixture of cohesive and non-cohesive fill up to about 2.1 m below ground surface.	Earth/Granular Fill with 2H:1V side-slopes	$\delta \leq 25$ mm	$\delta = 75$ mm	Preload Rock Fill embankment for 45 days. $\delta_{\text{remaining}} = 50$ mm
Ramp E-S STA. 10+000 to 10+100 (Area 4)	Up to 9 m	Relatively flat to easterly sloping terrain; layer of asphalt and fill underlain by stiff to hard clayey silt till deposit.	Strip asphalt layer; sub-excavate existing fill containing organics, wood pieces and a mixture of cohesive and non-cohesive fill up to about 3.7 m below ground surface.	Earth/Granular Fill with 2H:1V side-slopes	$\delta \leq 25$ mm	$\delta = 85$ mm	Preload Rock Fill embankment for 60 days. $\delta_{\text{remaining}} = 50$ mm
Ramp W-N STA. 10+000 to 10+100 (Area 5)	Up to 5 m	Relatively flat to gentle sloping terrain; layer of asphalt and fill underlain by stiff to hard clayey silt till deposit.	Strip asphalt layer; sub-excavate existing fill comprised of a mixture of cohesive and non-cohesive fill up to about 0.8 m below ground surface.	Earth/Granular Fill with 2H:1V side-slopes	$\delta \leq 25$ mm	$\delta = 50$ mm	Not Applicable
Ramp E-N STA. 10+000 to 10+210 (Area 6)	Up to 6.5 m	Relatively flat to gentle sloping terrain; layer of topsoil and fill underlain by very stiff to hard clayey silt to clayey silt with sand till deposit.	Strip topsoil layer; sub-excavate existing fill containing organics, brick pieces, topsoil and a mixture of firm/compact cohesive and non-cohesive fill up to about 2.1 m below ground surface.	Earth/Granular Fill with 2H:1V side-slopes	$\delta \leq 25$ mm	$\delta = 70$ mm	Preload Rock Fill embankment for 30 days. $\delta_{\text{remaining}} = 50$ mm

Notes: ¹ Settlement of foundation soils at the critical section.

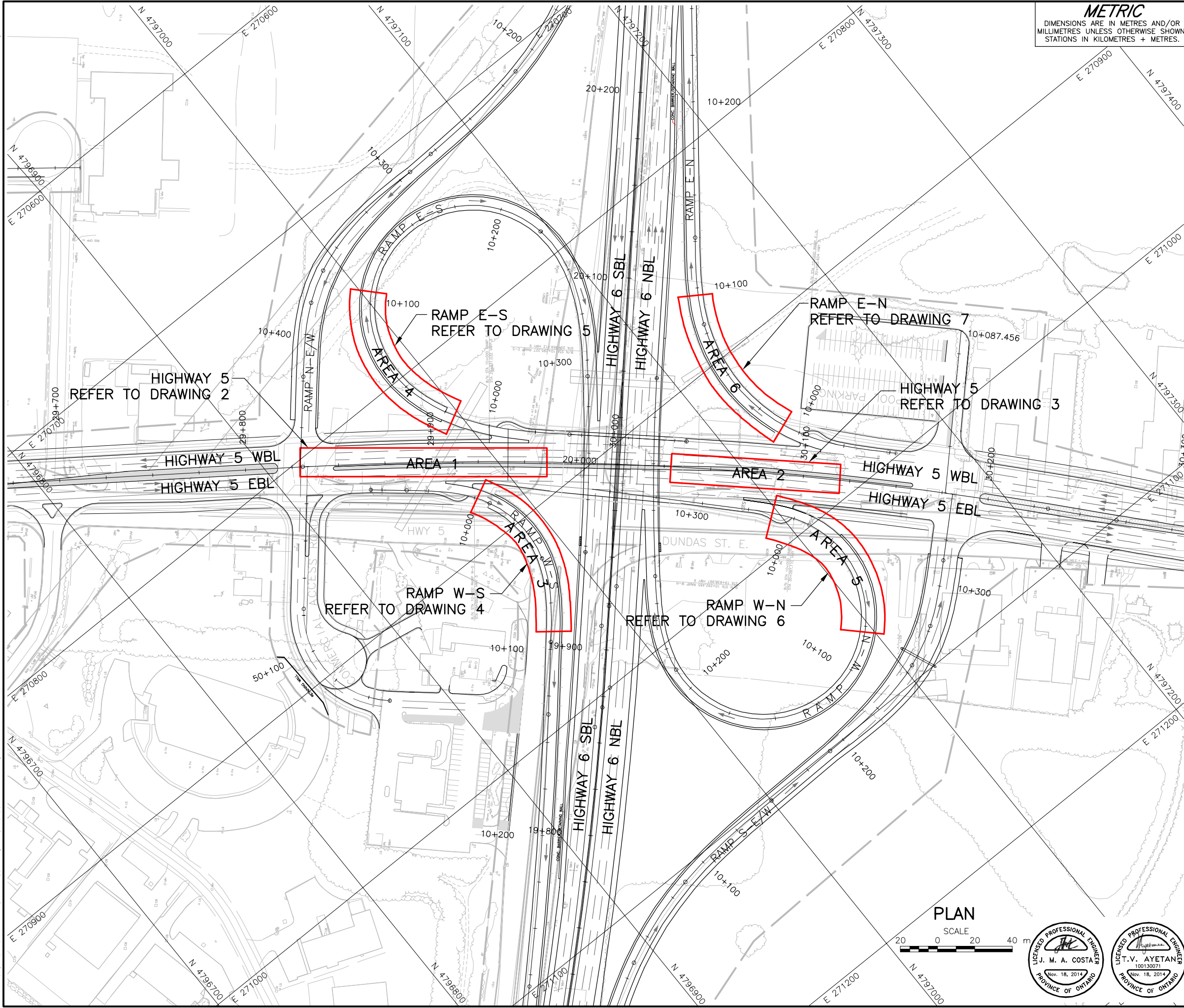
² Settlement of rock fill embankment itself at the critical section.

Prepared By: TVA

Reviewed By: JMAC



DRAWINGS



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

CONT No.
GWP No. 2112-05-00

HIGHWAY 5/HIGHWAY 6 INTERCHANGE
HIGH FILL AREAS 1 TO 6
INDEX PLAN

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

KEY PLAN
SCALE
2.5 0 2.5 5 km

LEGEND

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.

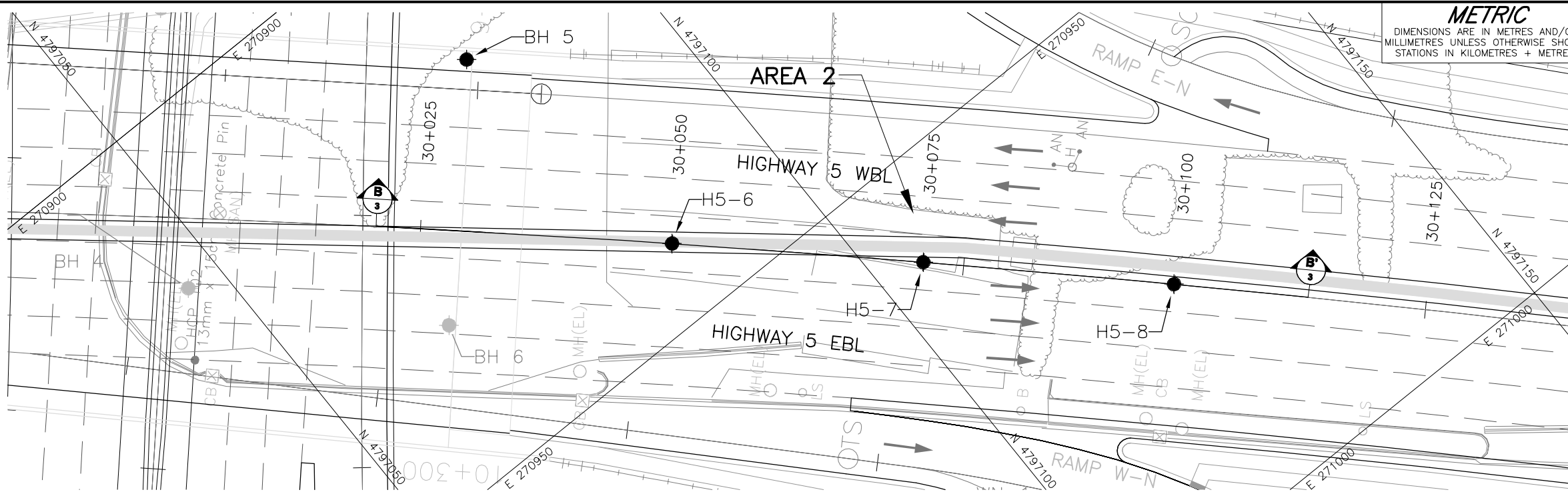
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE			
Base plans provided in digital format by IBI, drawing file no. T5&6-MNC-Slane-New STA.dwg, received June 24, 2013.			
NO.	DATE	BY	REVISION
Geocres No. 30M5-306			
HWY. 5 and 6		PROJECT NO. 10-1184-0016	
SUBM'D. TVA		DIST.	
DRAWN: DD/MR		SITE:	
CHKD.		APPD. JMAC	
DWG. 1			

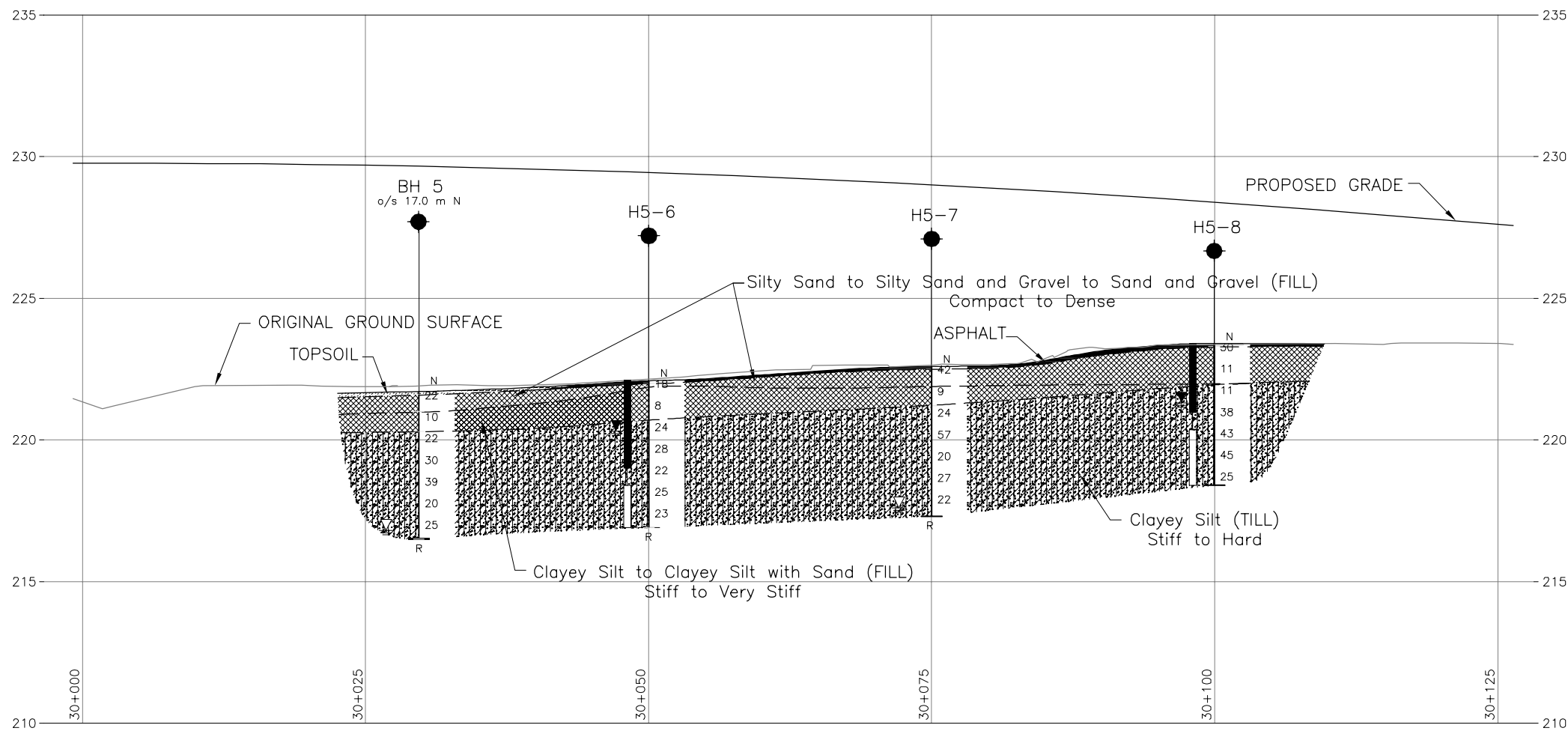
PLAN
SCALE
20 0 20 40 m

J. M. A. COSTA
Nov 18, 2014
PROVINCE OF ONTARIO

T. V. AYETAN
Nov 18, 2014
PROVINCE OF ONTARIO



PLAN
SCALE
5 0 5 10 m



CENTRELINE PROFILE
HIGHWAY 5
HORIZONTAL SCALE
5 0 5 10 m
VERTICAL SCALE
2 0 2 4 m

CONT No.
GWP No. 2112-05-00

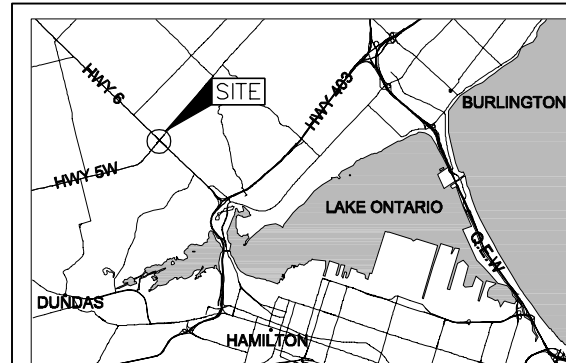
HIGHWAY 5/HIGHWAY 6 INTERCHANGE
HIGHWAY 5: STA. 30+040 to STA. 30+120
(HIGH FILL AREA 2)
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Refusal
- WL in piezometer, measured on Feb. 13, 2013
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BH 5	221.7	4797082.1	270915.5
H5-6	222.1	4797086.5	270942.5
H5-7	222.6	4797104.7	270959.6
H5-8	223.4	4797122.7	270976.9

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.

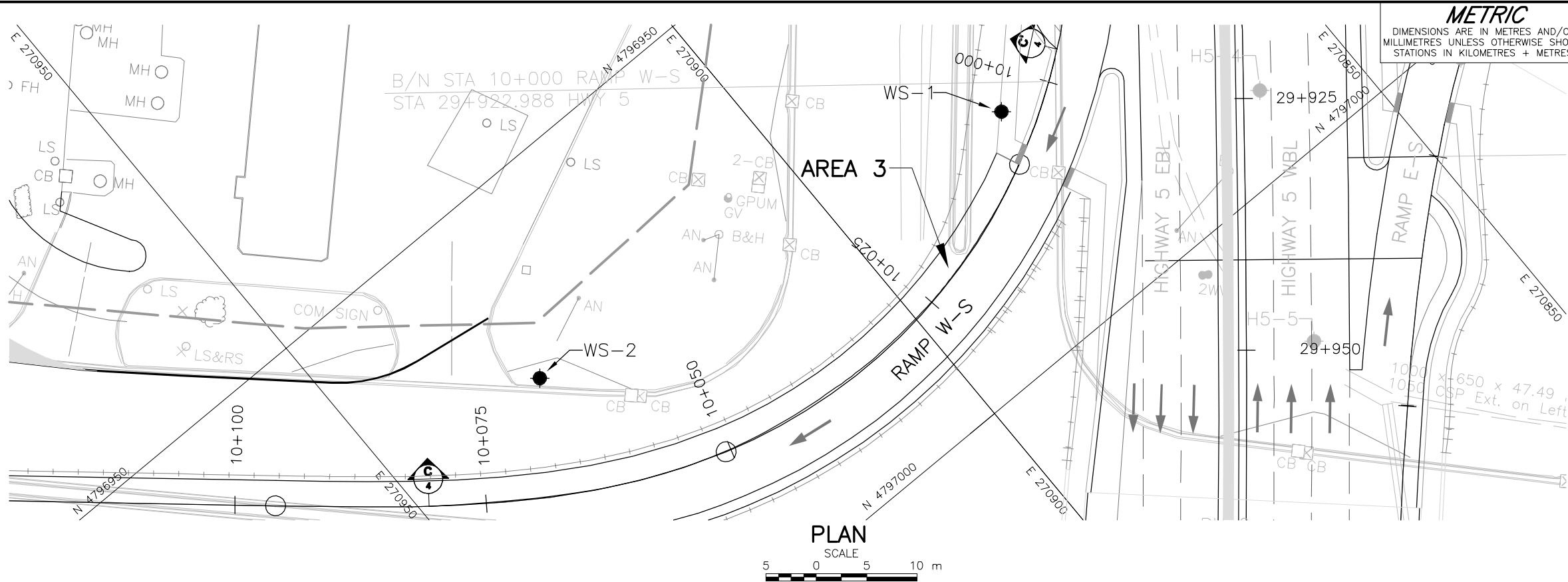
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

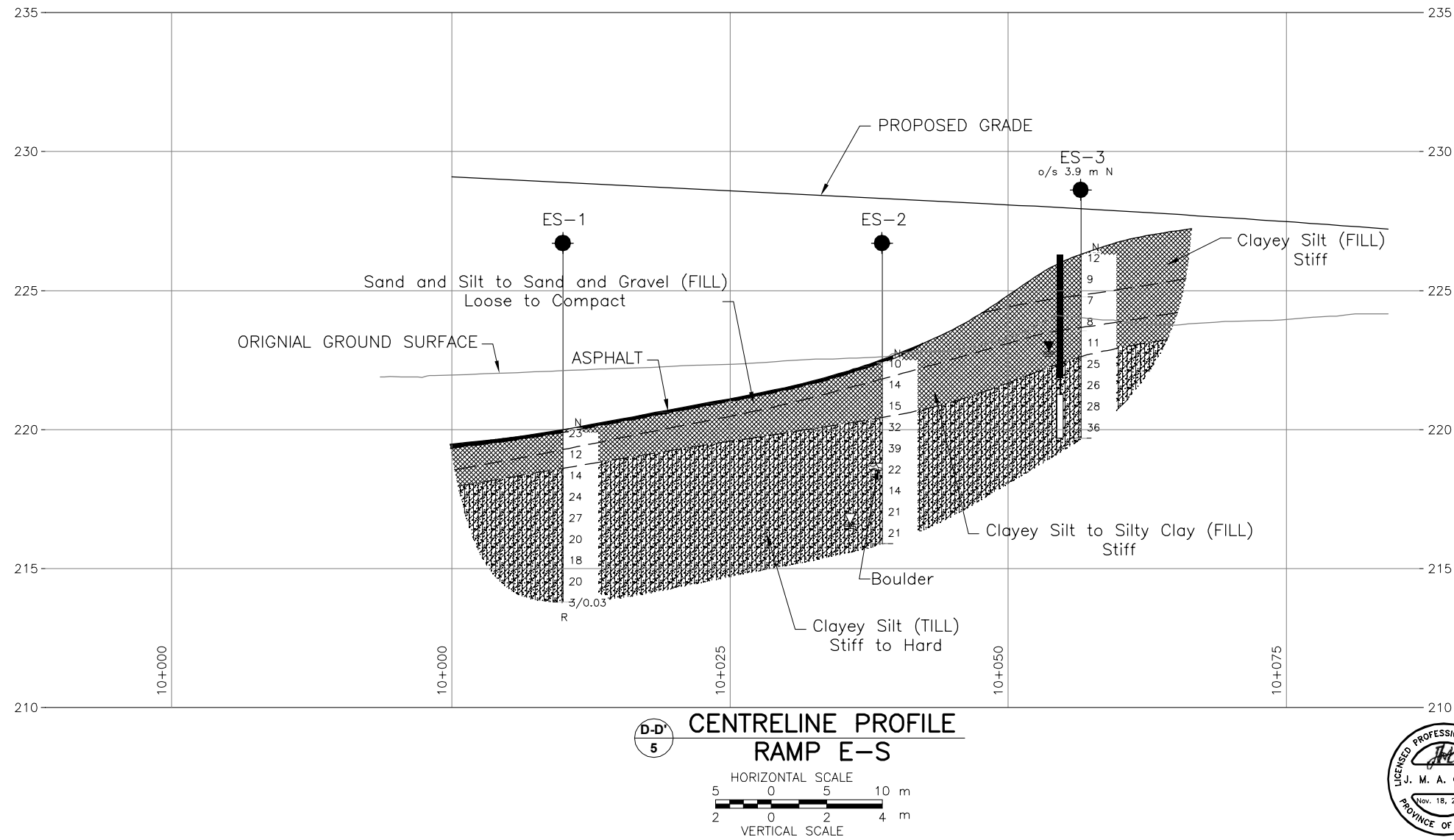
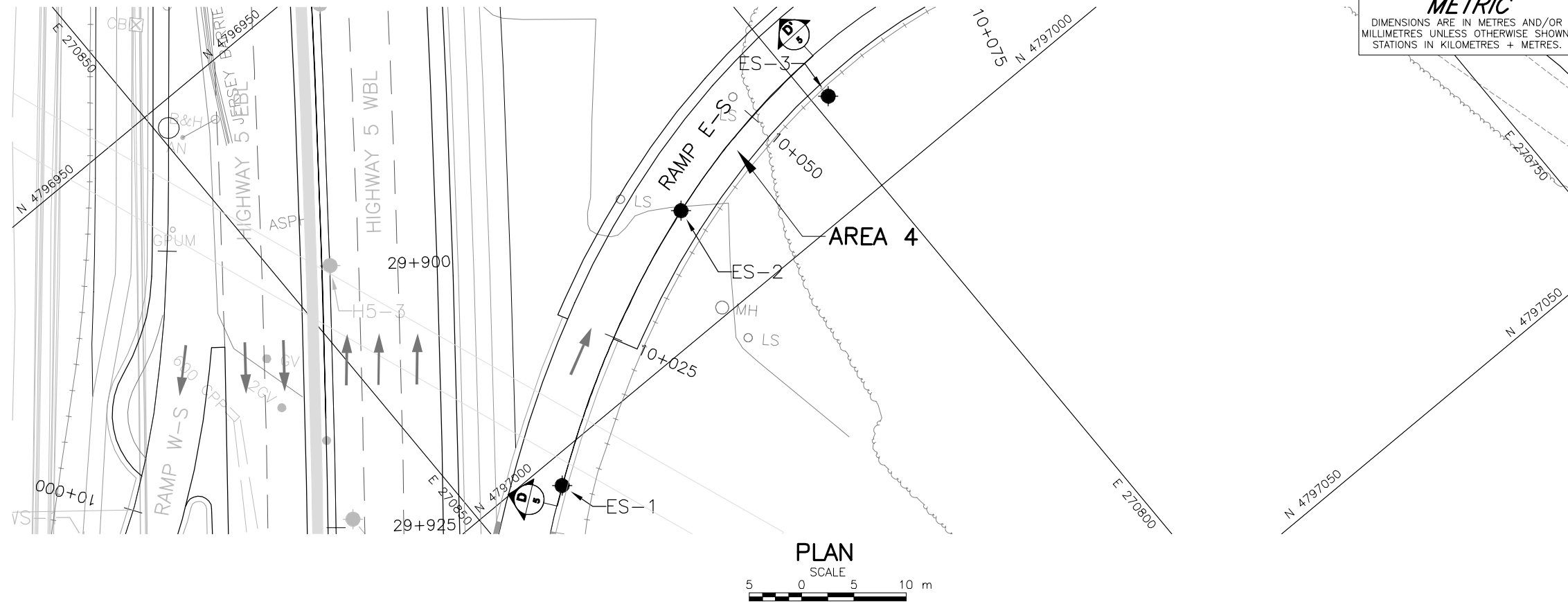
REFERENCE

Base plans provided in digital format by IBI, drawing file no. T5&6-MNC-Slone-New STA.dwg, received June 24, 2013 and Profile file no. T5&6_MPROF.dwg, received February 20, 2013.

NO.	DATE	BY	REVISION
Geocres No. 30M5-306			
HWY. 5 and 6			PROJECT NO. 10-1184-0016 DIST.
SUBM'D. TVA	CHKD. TVA	DATE: Jan. 2014	SITE:
DRAWN: DD/MR	CHKD.	APPD. JMAC	DWG. 3







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

CONT No.
 GWP No. 2112-05-00

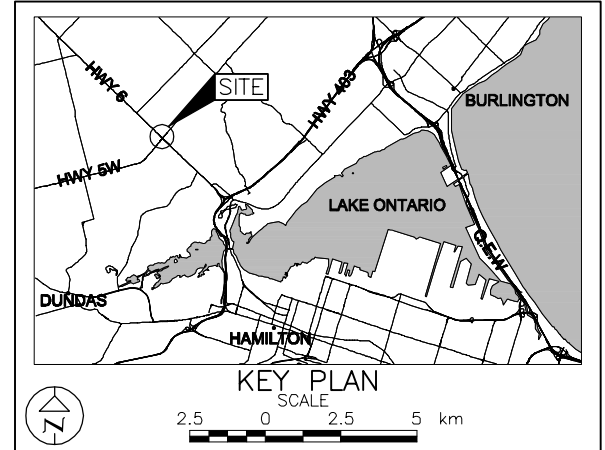
HIGHWAY 5/HIGHWAY 6 INTERCHANGE
 RAMP E-S: STA. 10+000 to STA. 10+100
 (HIGH FILL AREA 4)
 BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



Golder Associates Ltd.
 MISSISSAUGA, ONTARIO, CANADA



LEGEND

- Borehole - Current Investigation
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Refusal
- ≡ WL in piezometer, measured on Feb. 13, 2013
- ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
ES-1	220.0	4797002.5	270841.8
ES-2	222.5	4796989.6	270816.3
ES-3	226.3	4796990.2	270798.5

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.

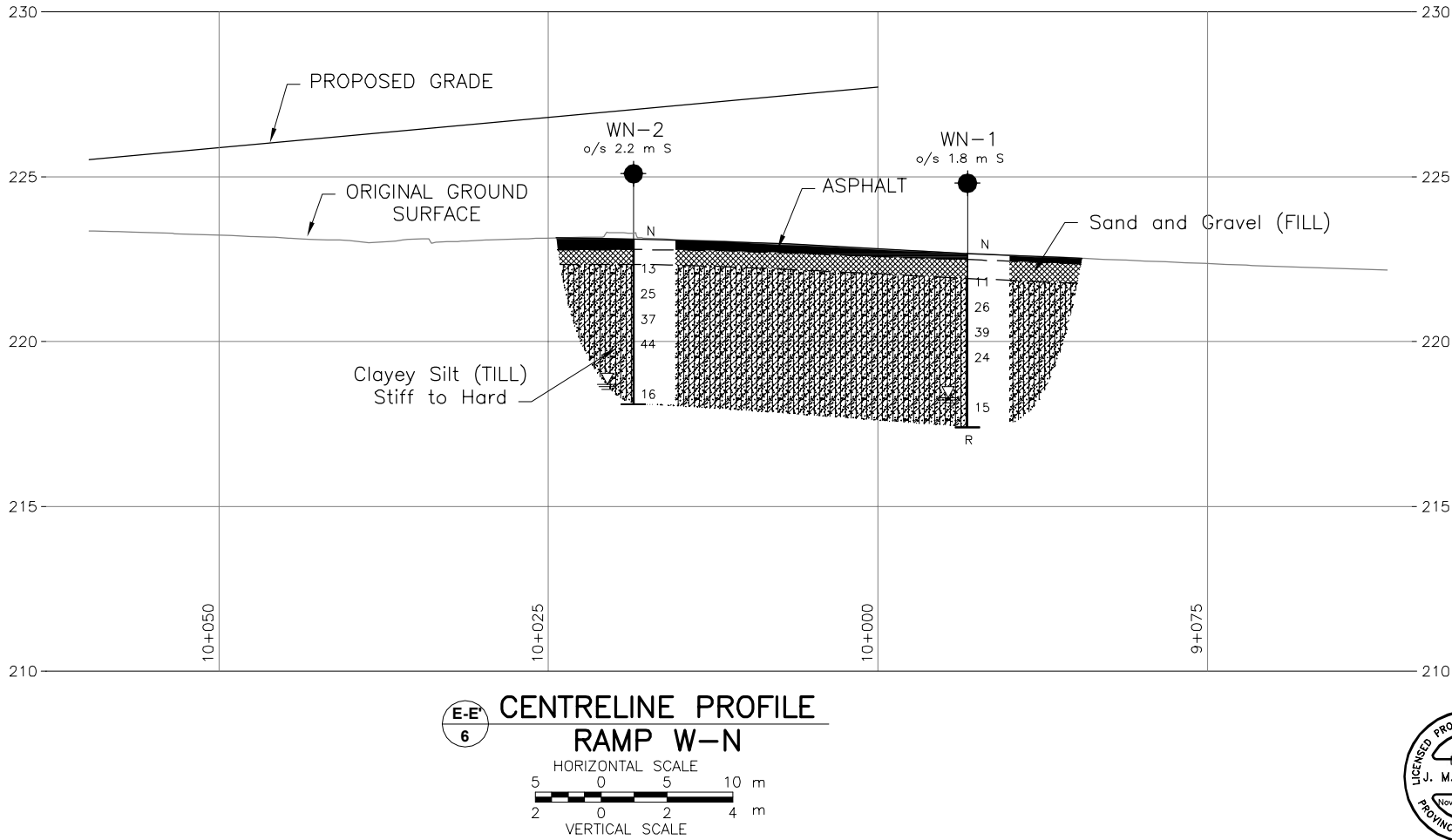
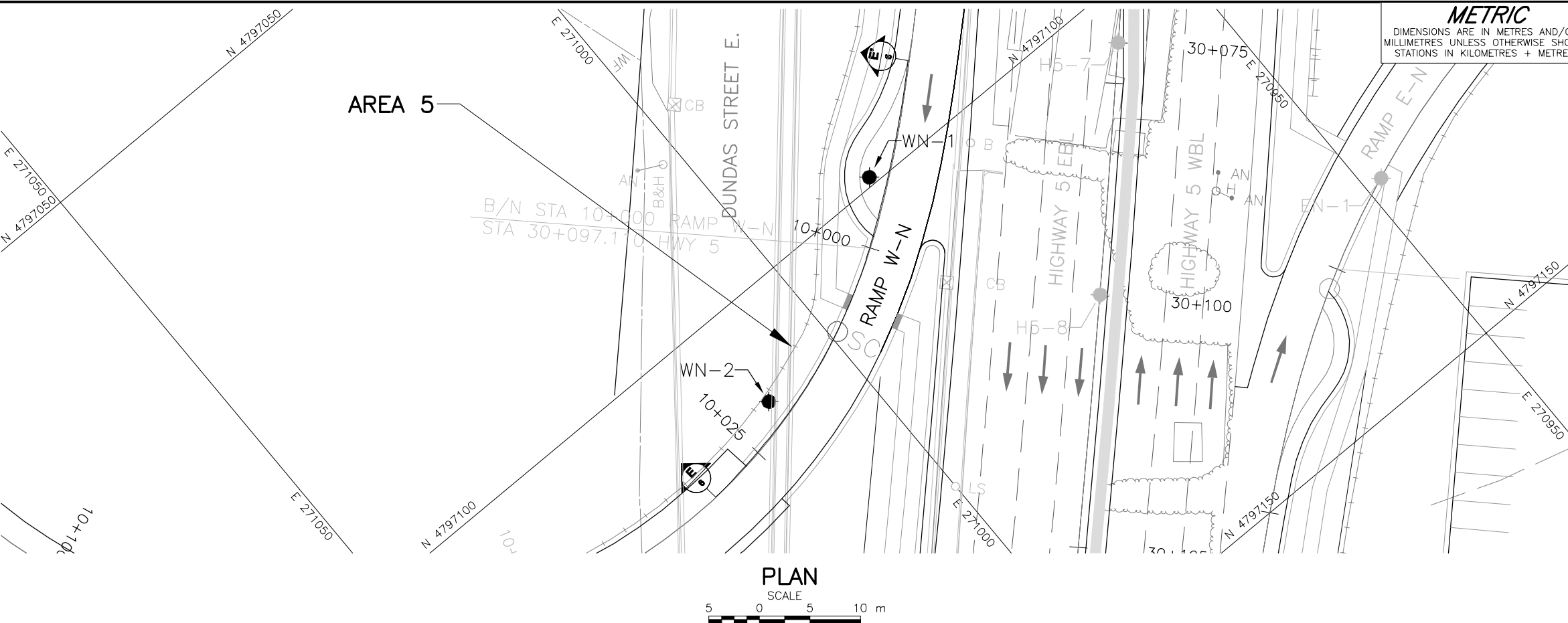
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by IBI, drawing file no. T5&6-MNC-5lane-New STA.dwg, received June 24, 2013.



NO.	DATE	BY	REVISION
Geocres No. 30M5-306			
HWY. 5 and 6		PROJECT NO. 10-1184-0016	DIST.
SUBM'D. TVA	CHKD. TVA	DATE: Jan. 2014	SITE:
DRAWN: DD/MR	CHKD.	APPD.	DWG. 5

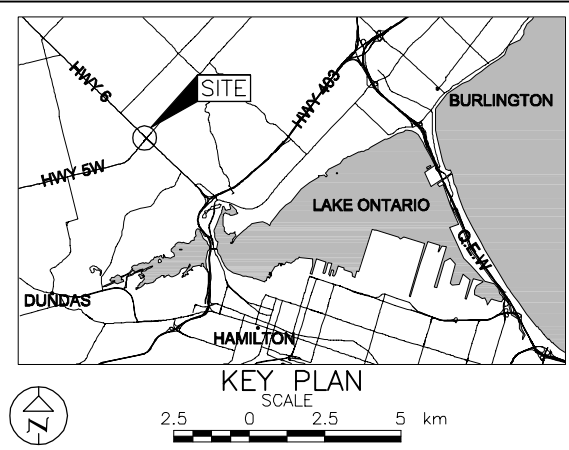
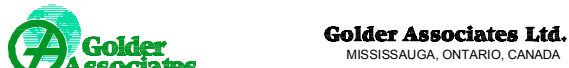


CONT No.
GWP No. 2112-05-00

HIGHWAY 5/HIGHWAY 6 INTERCHANGE
RAMP W-N: STA. 10+000 to STA. 10+100
(HIGH FILL AREA 5)

BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



LEGEND			
	Borehole - Current Investigation		
N	Standard Penetration Test Value		
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)		
R	Refusal		
	WL upon completion of drilling		

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
WN-1	222.7	4797099.2	270987.0
WN-2	223.1	4797109.9	271008.8

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.

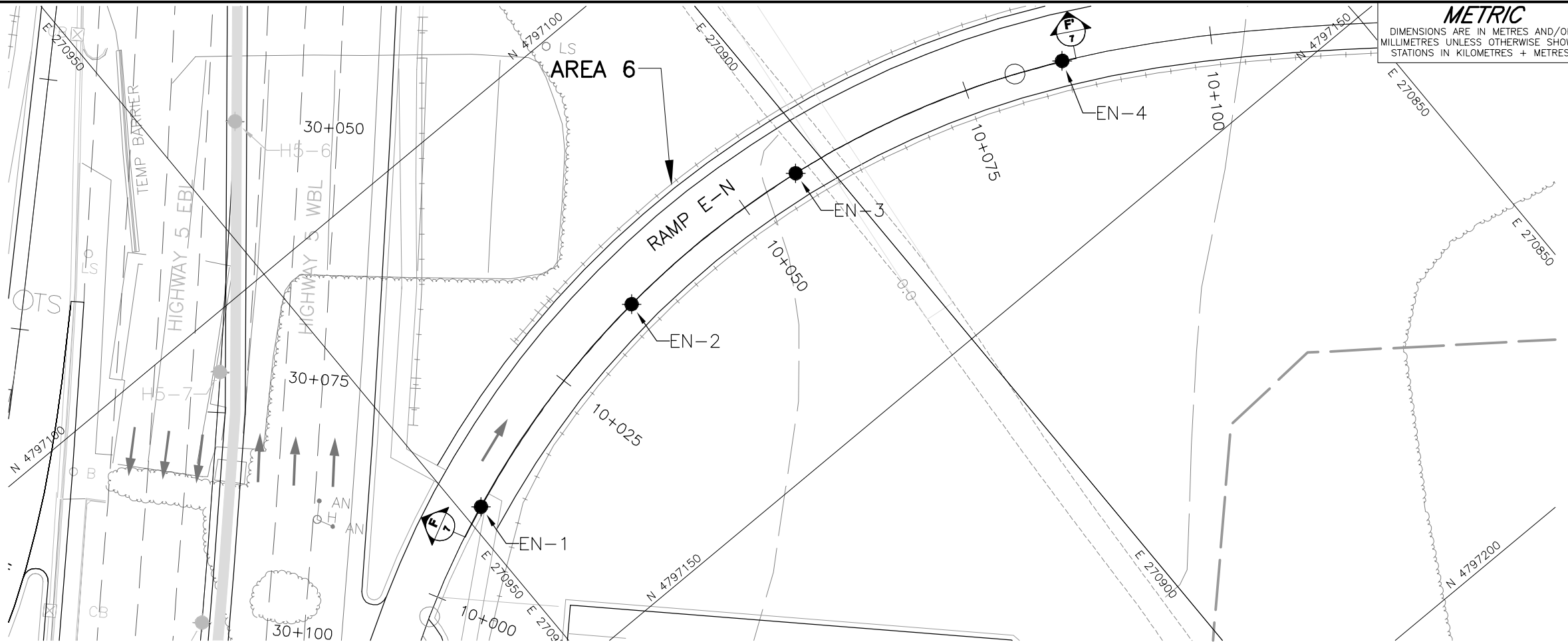
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

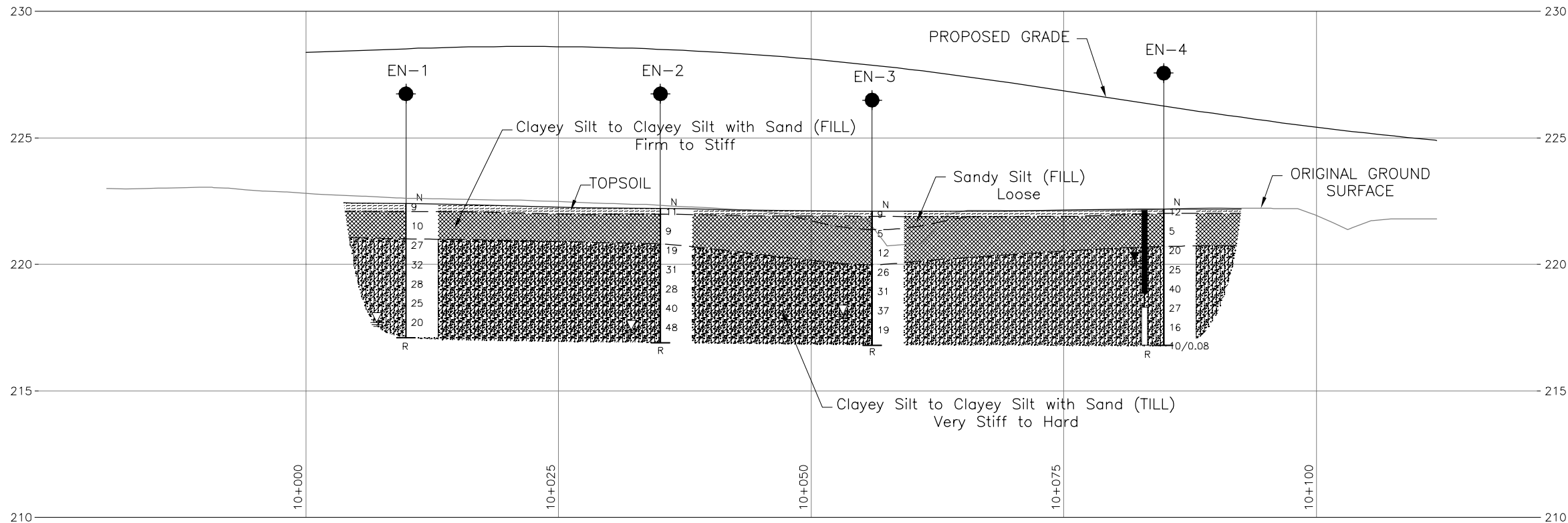
Base plans provided in digital format by IBI, drawing file no. T5&6-MNC-Slone-New STA.dwg, received June 24, 2013 and Profile file no. T5&6_MPROF.dwg, received February 20, 2013.



NO.	DATE	BY	REVISION
Geocres No. 30M5-306			
HWY. 5 and 6		PROJECT NO. 10-1184-0016	DIST.
SUBM'D T.V.A	CHKD. T.V.A	DATE: Jan. 2014	SITE:
DRAWN: DD/MR	CHKD.	APPD. JMAC	DWG. 6



PLAN
 SCALE
 5 0 5 10 m



CENTRELINE PROFILE
RAMP E-N
 HORIZONTAL SCALE
 5 0 5 10 m
 VERTICAL SCALE
 2 0 2 4 m

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

CONT No.
 GWP No. 2112-05-00

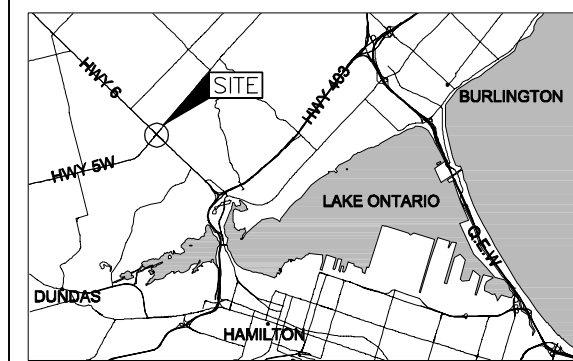
HIGHWAY 5/HIGHWAY 6 INTERCHANGE
 RAMP E-N: STA. 10+000 to STA. 10+210
 (HIGH FILL AREA 6)
 BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



Golder Associates Ltd.
 MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
 SCALE
 2.5 0 2.5 5 km

LEGEND

- Borehole - Current Investigation
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
 (Std. Pen. Test, 475 j/blow)
- R Refusal
- ≡ WL in piezometer, measured on Feb. 13, 2013
- ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
EN-1	222.4	4797131.6	270948.2
EN-2	222.2	4797125.7	270923.8
EN-3	222.1	4797126.1	270902.9
EN-4	222.2	4797134.5	270875.4

NOTES

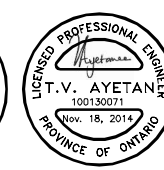
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by IBI, drawing file no. T5&6-MNC-Slone-New STA.dwg, received June 24, 2013 and Profile file no. T5&6_MPROF.dwg, received February 20, 2013.



NO.	DATE	BY	REVISION
Geocres No. 30M5-306			
HWY. 5 and 6		PROJECT NO. 10-1184-0016	DIST.
SUBM'D. TVA	CHKD. TVA	DATE: Jan. 2014	SITE:
DRAWN: DD/MR	CHKD.	APPD. JMAC	DWG. 7



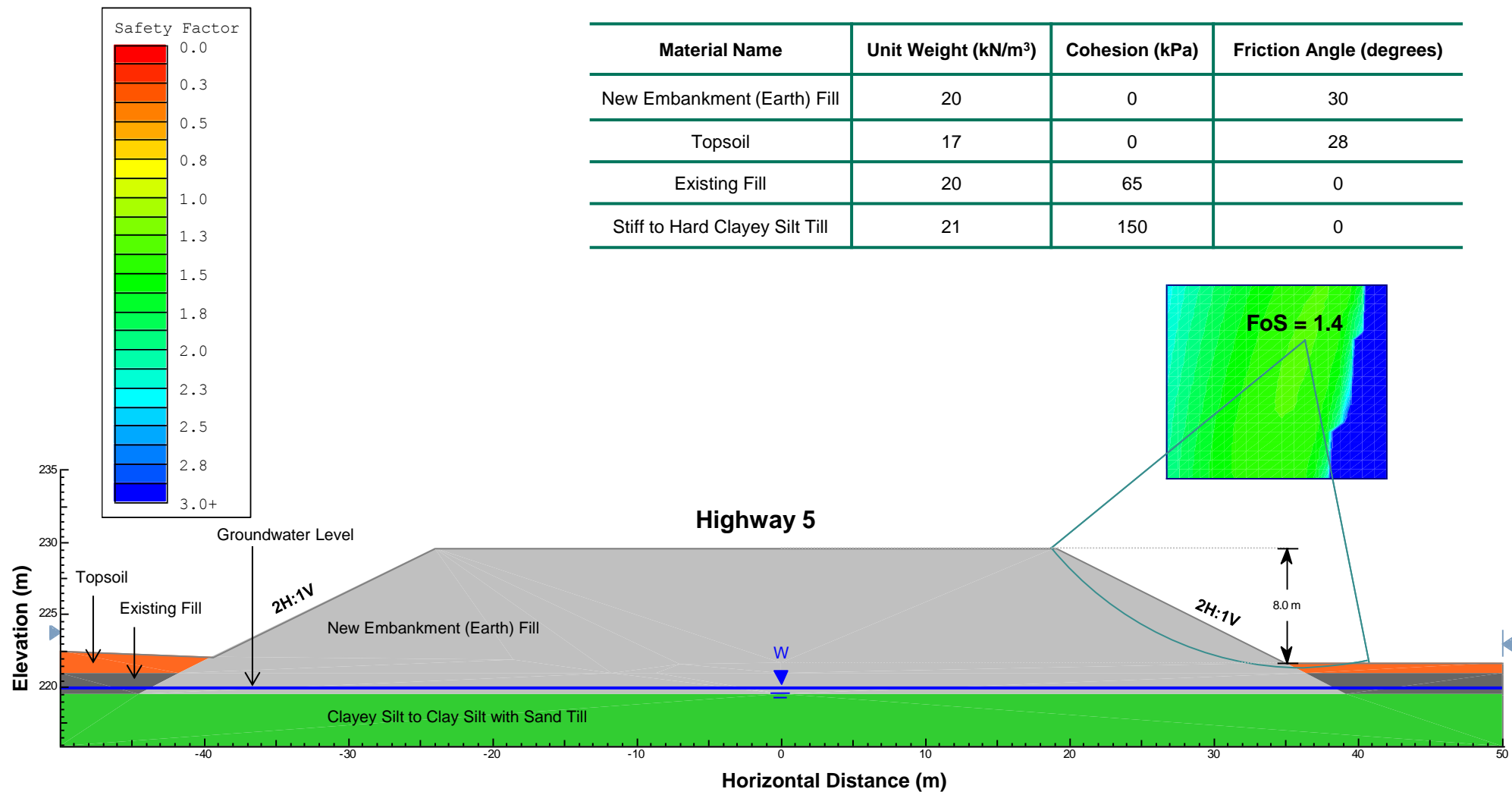
FIGURES



High Fill Area 1 – Highway 5 and Highway 6 IC Embankments

Highway 5: Station 29+950 – Static Global Stability

Figure 1

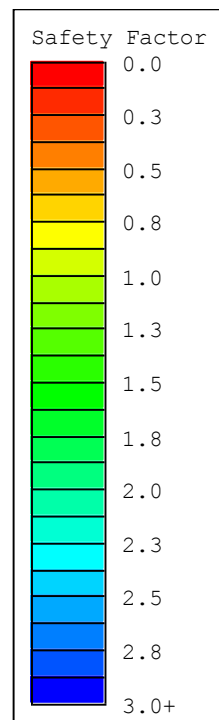




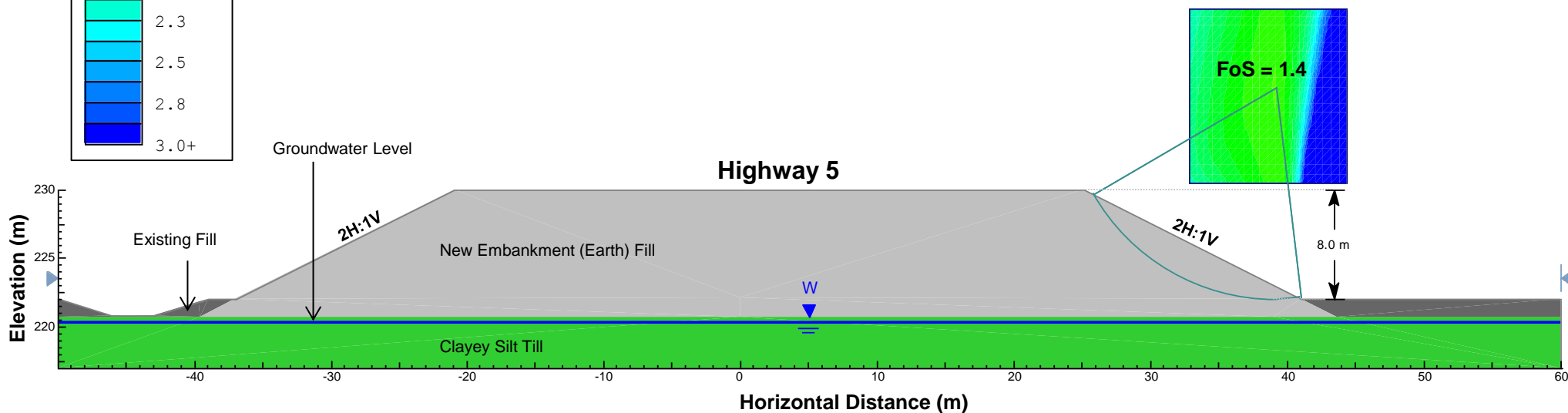
High Fill Area 2 – Highway 5 and Highway 6 IC Embankments

Highway 5: Station 30+040 – Static Global Stability

Figure 2



Material Name	Unit Weight (kN/m ³)	Cohesion (kPa)	Friction Angle (degrees)
New Embankment (Earth) Fill	20	0	30
Existing Fill	20	50	0
Stiff to Hard Clayey Till	21	150	0

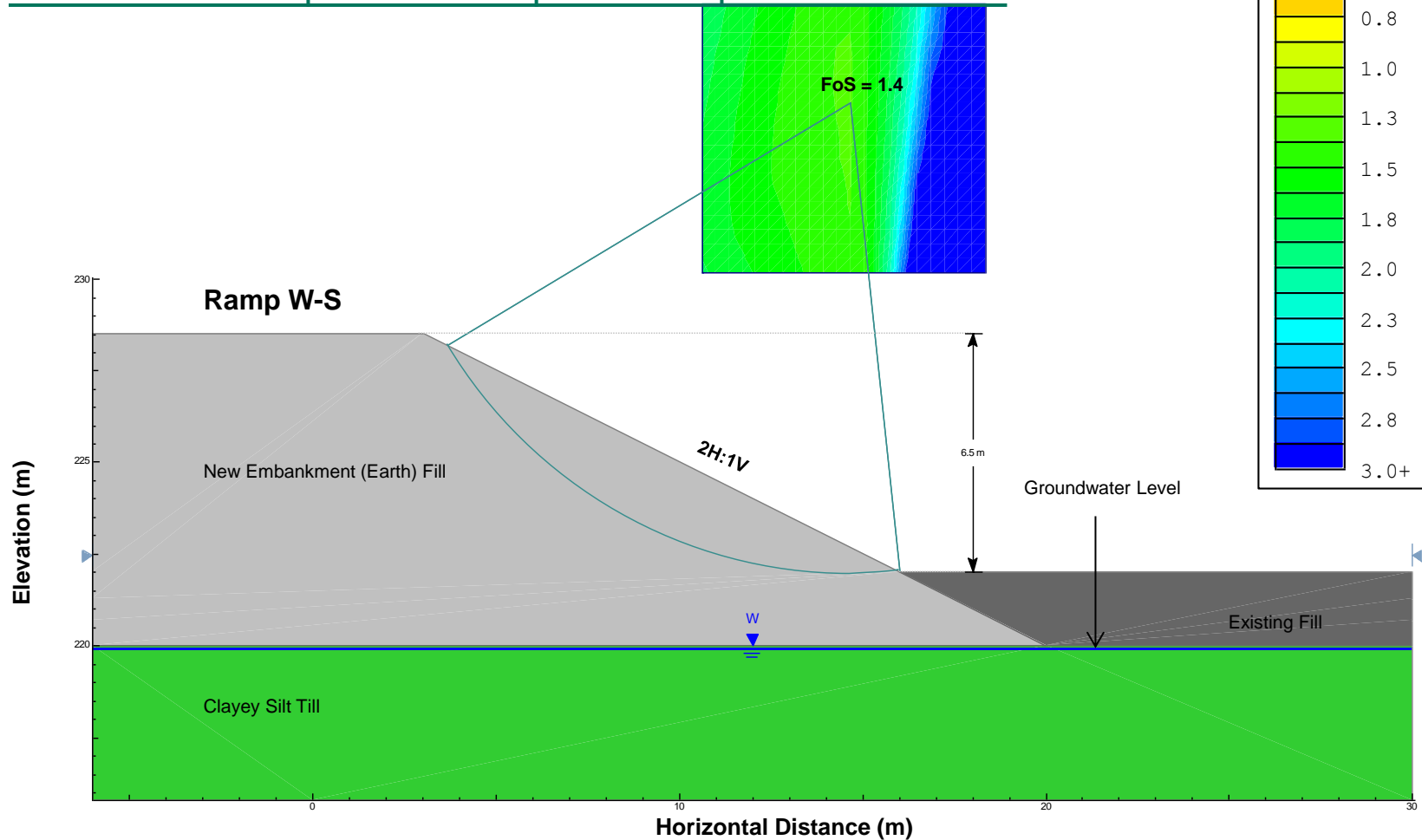
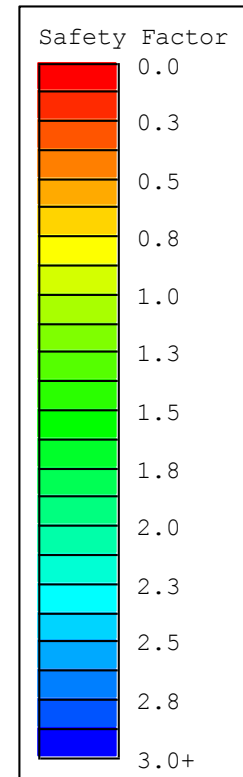




High Fill Area 3 – Highway 5 and Highway 6 IC Embankments Ramp W-S: Station 10+000 – Static Global Stability

Figure 3

Material Name	Unit Weight (kN/m ³)	Cohesion (kPa)	Friction Angle (degrees)
New Embankment (Earth) Fill	20	0	30
Existing Fill	20	65	0
Stiff to Hard Clayey Silt Till	21	150	0



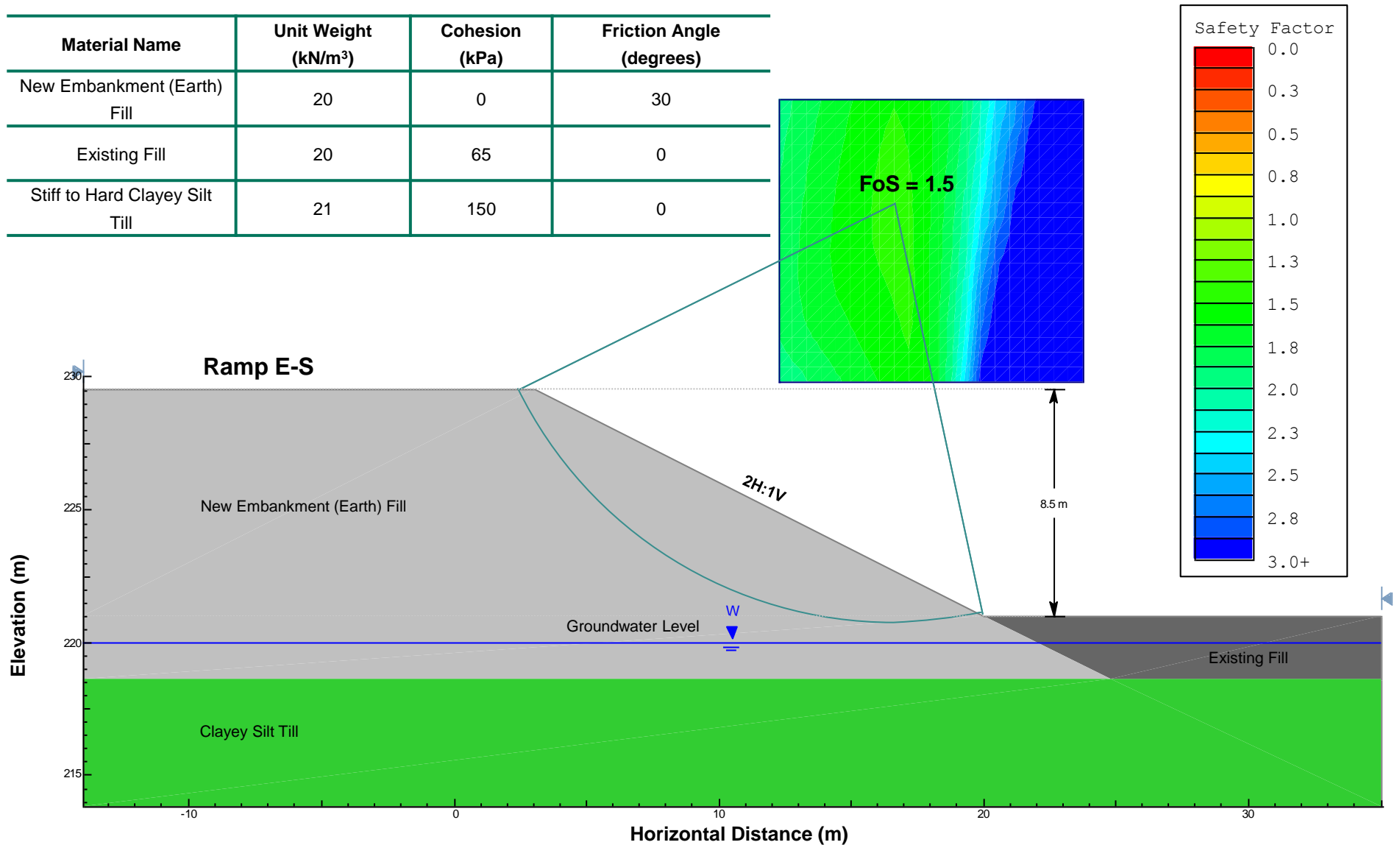


High Fill Area 4 – Highway 5 and Highway 6 IC Embankments

Ramp E-S: Station 10+010 – Static Global Stability

Figure 4

Material Name	Unit Weight (kN/m ³)	Cohesion (kPa)	Friction Angle (degrees)
New Embankment (Earth) Fill	20	0	30
Existing Fill	20	65	0
Stiff to Hard Clayey Silt Till	21	150	0



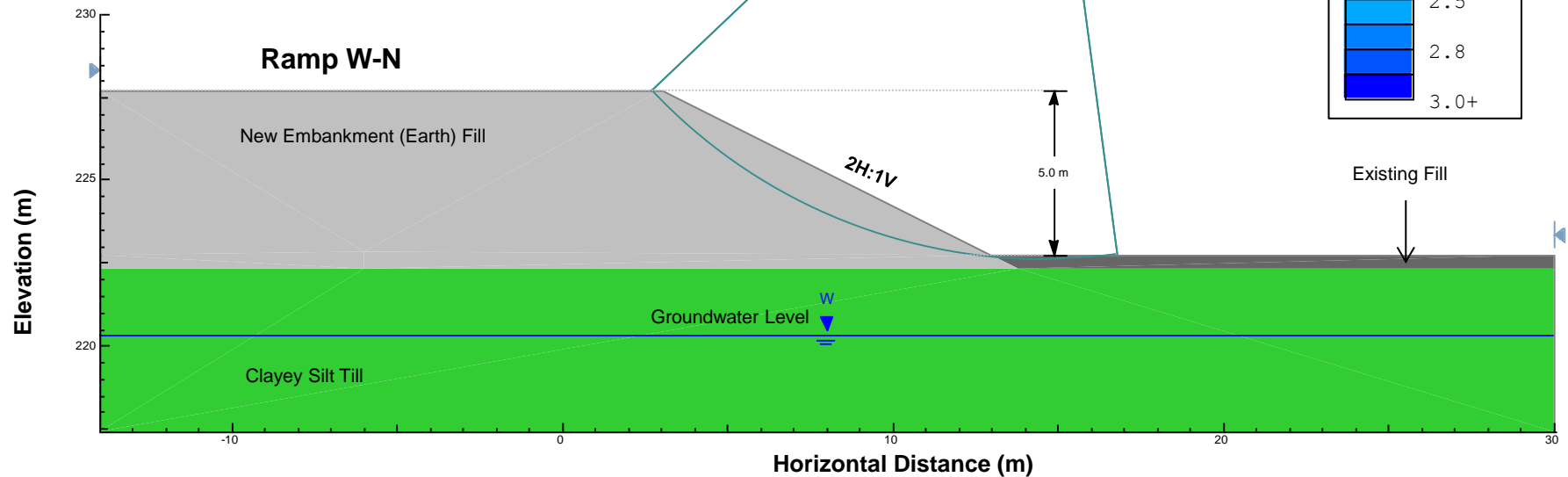
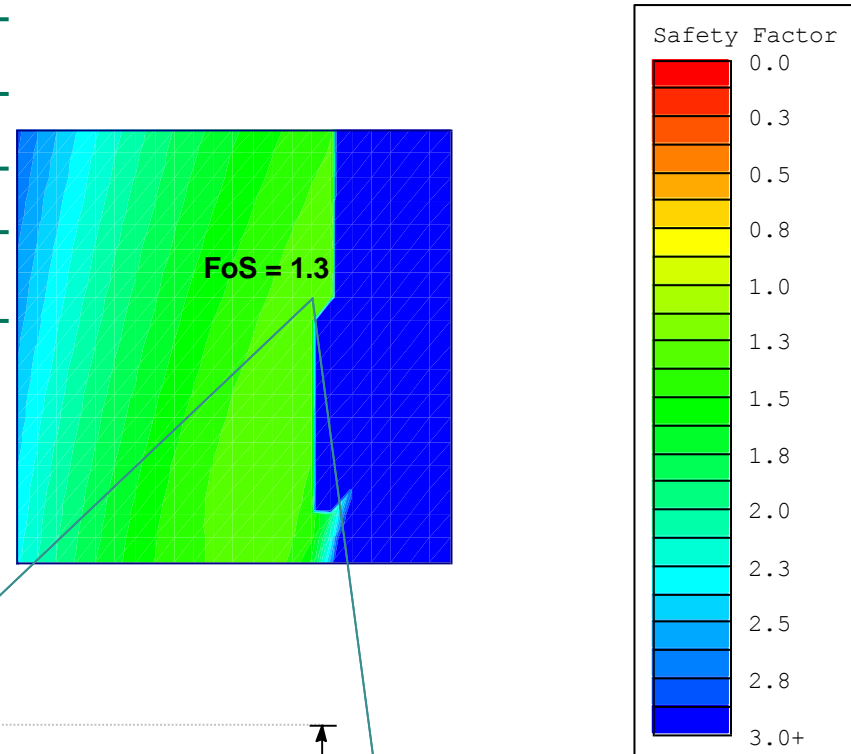


High Fill Area 5 – Highway 5 and Highway 6 IC Embankments

Ramp W-N: Station 10+000 – Static Global Stability

Figure 5

Material Name	Unit Weight (kN/m ³)	Cohesion (kPa)	Friction Angle (degrees)
New Embankment (Earth) Fill	21	0	30
Existing Fill	20	65	
Stiff to Hard Clayey Silt Till	21	150	0

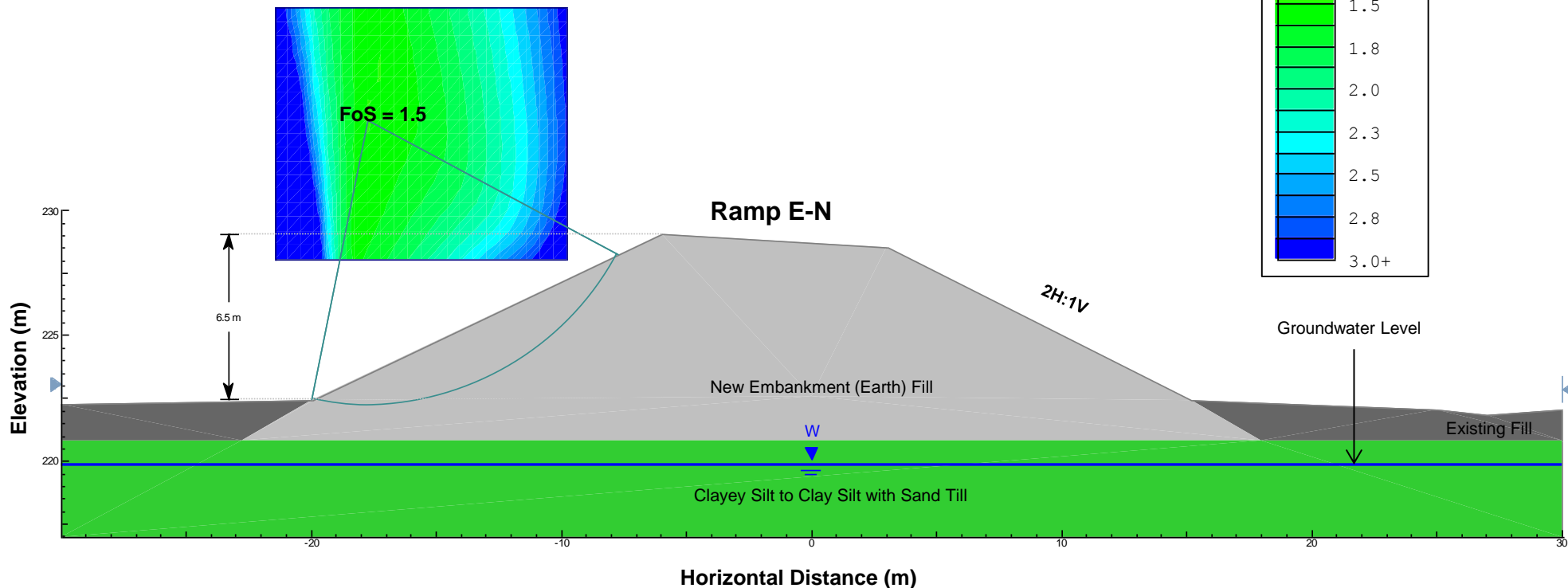
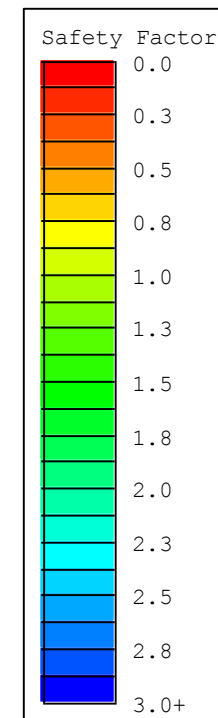




High Fill Area 6 – Highway 5 and Highway 6 IC Embankments Ramp E-N: Station 10+025 – Static Global Stability

Figure 6

Material Name	Unit Weight (kN/m ³)	Cohesion (kPa)	Friction Angle (degrees)
New Embankment (Earth) Fill	20	0	30
Existing Fill	20	0	28
Very Stiff to Hard Clayey Silt to Clayey Silt with Sand Till	21	0	35

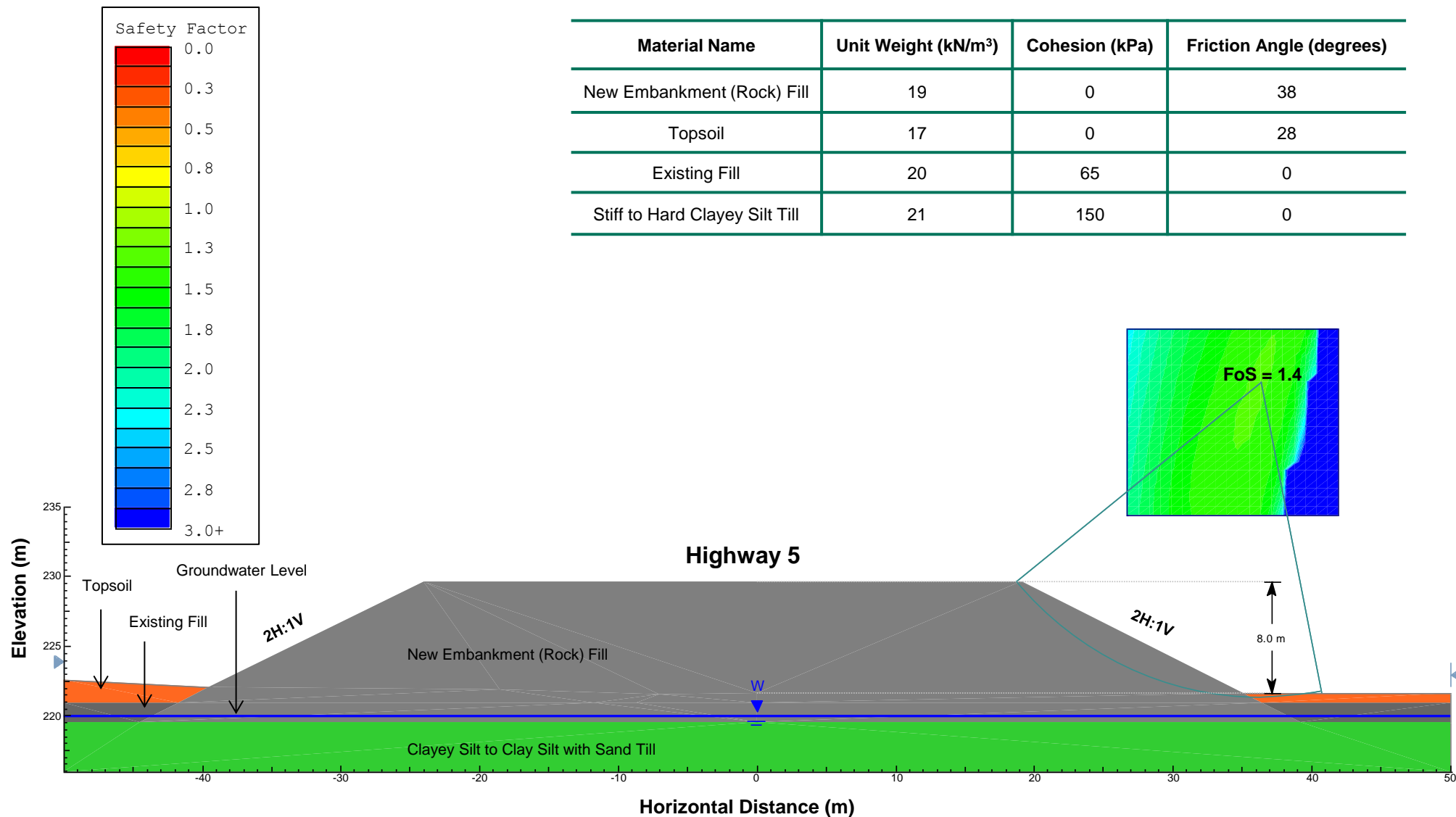




High Fill Area 1 – Highway 5 and Highway 6 IC Embankments Highway 5: Station 29+950 – Static Global Stability

Figure 7

Material Name	Unit Weight (kN/m ³)	Cohesion (kPa)	Friction Angle (degrees)
New Embankment (Rock) Fill	19	0	38
Topsoil	17	0	28
Existing Fill	20	65	0
Stiff to Hard Clayey Silt Till	21	150	0

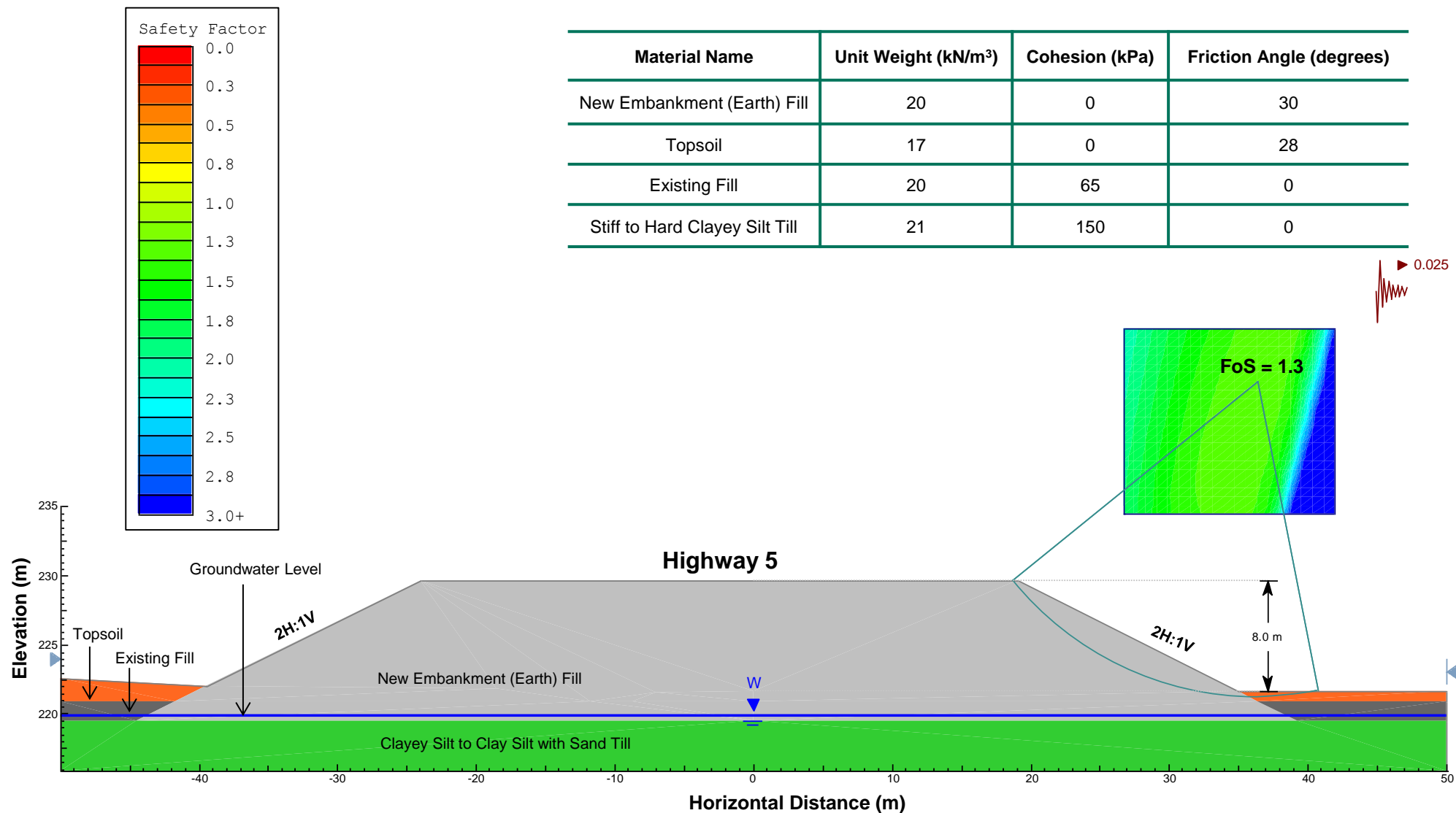




High Fill Area 1 – Highway 5 and Highway 6 IC Embankments

Highway 5: Station 29+950 – Seismic Global Stability

Figure 8





APPENDIX A

Highway 5: STA. 29+850 to STA. 29+960 (High Fill Area 1) Record of Boreholes and Laboratory Test Results

PROJECT 10-1184-0016			RECORD OF BOREHOLE No BH 1			SHEET 1 OF 1			METRIC							
G.W.P. 2112-05-00			LOCATION N 4797035.5 ; E 270882.4			ORIGINATED BY JBH										
DIST _____ HWY 5 & 6			BOREHOLE TYPE 102 mm O.D. Continuous Flight Solid Stem Augers			COMPILED BY BM										
DATUM Geodetic			DATE November 21, 2012			CHECKED BY TVA										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
222.1	GROUND SURFACE															
0.0	ASPHALT															
0.2	Sand and gravel, trace silt, cobbles at 0.5 m depth (FILL)															
221.3	Brown Moist															
0.8	Clayey silt, sandy, some gravel, trace organics and topsoil (FILL)		1	SS	8											21 29 34 16
	Stiff															
	Brown to black Moist		2	SS	9											
220.0																
2.1	CLAYEY SILT, sandy, trace gravel, sand seams to a depth of 2.7 m (TILL)		3	SS	16											1 25 49 25
	Stiff to very stiff															
	Brown to grey Moist		4	SS	21											
			5	SS	30											
			6	SS	15											
			7	SS	11											
			8	SS	12/0.05											
215.8	END OF BOREHOLE SPOON BOUNCING AND AUGER REFUSAL INFERRED BEDROCK															
6.3	NOTE: 1. Borehole dry upon completion of drilling															

PROJECT		10-1184-0016		RECORD OF BOREHOLE No H5-1		SHEET 1 OF 1		METRIC							
G.W.P.		2112-05-00		LOCATION		N 4796932.3; E 270815.2		ORIGINATED BY							
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY							
DATUM		Geodetic		DATE		November 12, 2012		CHECKED BY							
								TVA							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
222.5	GROUND SURFACE														
0.0	ASPHALT														
0.1	Gravelly silty sand, trace clay, clayey silt pockets and pieces of asphalt (FILL)		1	SS	14										21 44 28 7
221.8	Compact Brown Moist		2	SS	33										
0.7	Clayey silt with sand, gravelly, pieces of asphalt (FILL)														
221.1	Hard Brown Moist		3	SS	44										
1.4	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Brown to red Moist to wet		4	SS	32										
	----- sand seams Wet -----		5	SS	46										1 19 59 21
			6	SS	29										
			7	SS	32										
217.5	END OF BOREHOLE														
5.0	NOTE: 1. Borehole dry upon completion of drilling.														

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

PROJECT		10-1184-0016		RECORD OF BOREHOLE No H5-2		SHEET 1 OF 1		METRIC						
G.W.P.		2112-05-00		LOCATION		N 4796952.4 ; E 270830.2		ORIGINATED BY JBH						
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM						
DATUM		Geodetic		DATE		November 12, 2012		CHECKED BY TVA						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
222.4	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30				
0.0	ASPHALT													
0.1	Clayey silt, trace gravel, trace to some sand (FILL) Stiff to hard Brown Moist		1	SS	56									
			2	SS	14									
221.0														
1.4	SILTY CLAY, trace to some sand (TILL) Hard Brown Moist		3	SS	44									0 9 52 39
220.3														
2.1	CLAYEY SILT, sandy to some sand, trace gravel, silty sand and sandy silt seams to a depth of 3.5 m (TILL) Stiff to hard Brown Moist to wet		4	SS	30									
			5	SS	20									4 24 55 17
			6	SS	13									
			7	SS	18									2 20 50 28
			8	SS	20									
			9	SS	23									7 19 47 27
215.8	END OF BOREHOLE													
6.6	NOTES: 1. Water level in open borehole measured at a depth of 5.7 m below ground surface (Elev. 216.7 m) upon completion of drilling. 2. WATER LEVEL READINGS: Date Depth (mm) Elev. (m) 11/23/12 3.4 219.0 01/22/13 3.4 219.0 02/07/13 3.7 218.7 02/13/13 3.7 218.7													

PROJECT		10-1184-0016		RECORD OF BOREHOLE No H5-3		SHEET 1 OF 1		METRIC							
G.W.P.		2112-05-00		LOCATION		N 4796972.2 ; E 270845.4		ORIGINATED BY JBH							
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM							
DATUM		Geodetic		DATE		November 12, 2012		CHECKED BY TVA							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
222.1	GROUND SURFACE														
0.0	Sand and gravel, some silt, trace clay (FILL)		1A	SS	11										38 43 18 1
221.8	Compact Brown Moist		1B												
221.4	Clayey silt with sand, trace gravel, trace organics (FILL)		2	SS	12										
0.7	Stiff Brown Moist		3	SS	30										
	CLAYEY SILT, sandy, trace gravel (TILL)		4	SS	27										3 24 50 23
	Stiff to hard Brown to grey Moist		5	SS	32										3 27 47 23
			6	SS	18										
			7	SS	20										
			8	SS	17										
			9	SS	25/0.08										
215.5	END OF BOREHOLE SPOON BOUNCING / REFUSAL														
6.6	NOTE: 1. Borehole dry upon completion of drilling.														

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

PROJECT		10-1184-0016		RECORD OF BOREHOLE No H5-4		SHEET 1 OF 1		METRIC								
G.W.P.		2112-05-00		LOCATION		N 4796992.2 ; E 270859.2		ORIGINATED BY JBH								
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM								
DATUM		Geodetic		DATE		November 13, 2012		CHECKED BY TVA								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
221.8	GROUND SURFACE															
0.0	ASPHALT															
0.1	Gravelly sand, some silt, trace clay (FILL) Loose to compact Brown Moist		1	SS	29											
			2	SS	10											21 58 19 2
			3	SS	7											
			4	SS	4											
			5	SS	6											
			6	SS	7											
217.4	CLAYEY SILT, sandy, trace gravel (TILL) Stiff to very stiff Brown Moist		7	SS	10											
4.4			8	SS	18											3 26 47 24
215.9	END OF BOREHOLE AUGER REFUSAL															
5.9	NOTE: 1. Borehole dry upon completion of drilling.															

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

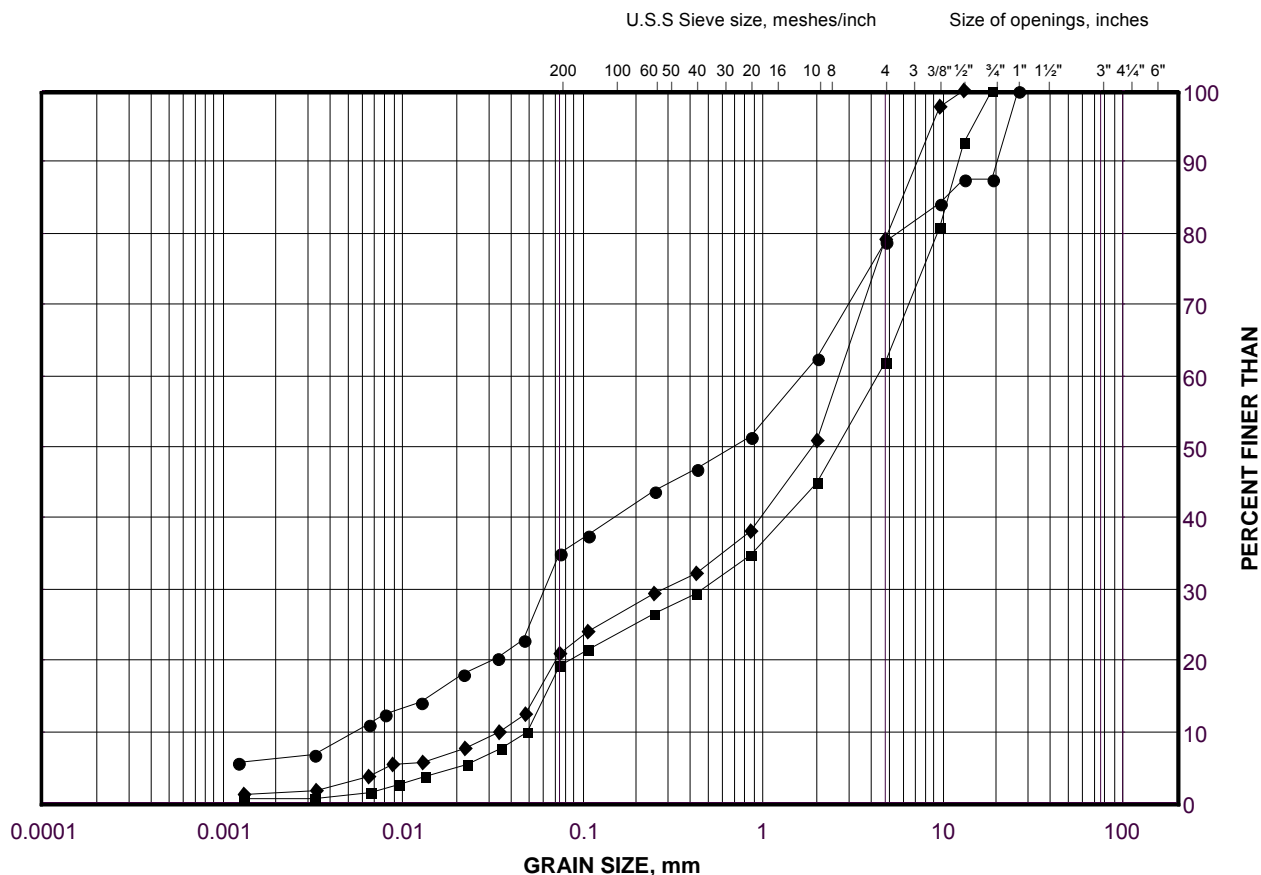
PROJECT		10-1184-0016		RECORD OF BOREHOLE No H5-5		SHEET 1 OF 1		METRIC																					
G.W.P.		2112-05-00		LOCATION		N 4797014.8; E 270871.0		ORIGINATED BY JBH																					
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM																					
DATUM		Geodetic		DATE		November 13, 2012		CHECKED BY TVA																					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL															
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)														
221.6	GROUND SURFACE																												
0.0	Sand and silt (TOPSOIL) Compact Dark brown Moist		1	SS	11																								
220.9																													
0.7	Clayey silt with sand, trace gravel, trace organics (FILL) Firm Brown Moist		2	SS	6																								
219.5			3	SS	7																								
2.1	CLAYEY SILT, sandy, trace gravel (TILL) Very stiff to hard Brown Moist		4	SS	16																								
			5	SS	31									2 24 44 30															
			6	SS	31																								
			7	SS	18									5 27 45 23															
215.9	END OF BOREHOLE AUGER REFUSAL INFERRED BEDROCK		8	SS	20/0.1																								
5.7																													
NOTES: 1. Borehole dry upon completion of drilling. 2. WATER LEVEL READINGS: <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>Date</th> <th>Depth (mm)</th> <th>Elev. (m)</th> </tr> </thead> <tbody> <tr> <td>11/23/12</td> <td>4.6</td> <td>217.0</td> </tr> <tr> <td>01/22/13</td> <td>2.2</td> <td>219.4</td> </tr> <tr> <td>02/07/13</td> <td>1.8</td> <td>219.8</td> </tr> <tr> <td>02/13/13</td> <td>1.7</td> <td>219.9</td> </tr> </tbody> </table>															Date	Depth (mm)	Elev. (m)	11/23/12	4.6	217.0	01/22/13	2.2	219.4	02/07/13	1.8	219.8	02/13/13	1.7	219.9
Date	Depth (mm)	Elev. (m)																											
11/23/12	4.6	217.0																											
01/22/13	2.2	219.4																											
02/07/13	1.8	219.8																											
02/13/13	1.7	219.9																											

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

GRAIN SIZE DISTRIBUTION

Gravelly Silty Sand to Gravelly Sand to Sand and Gravel (FILL)

FIGURE A1



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

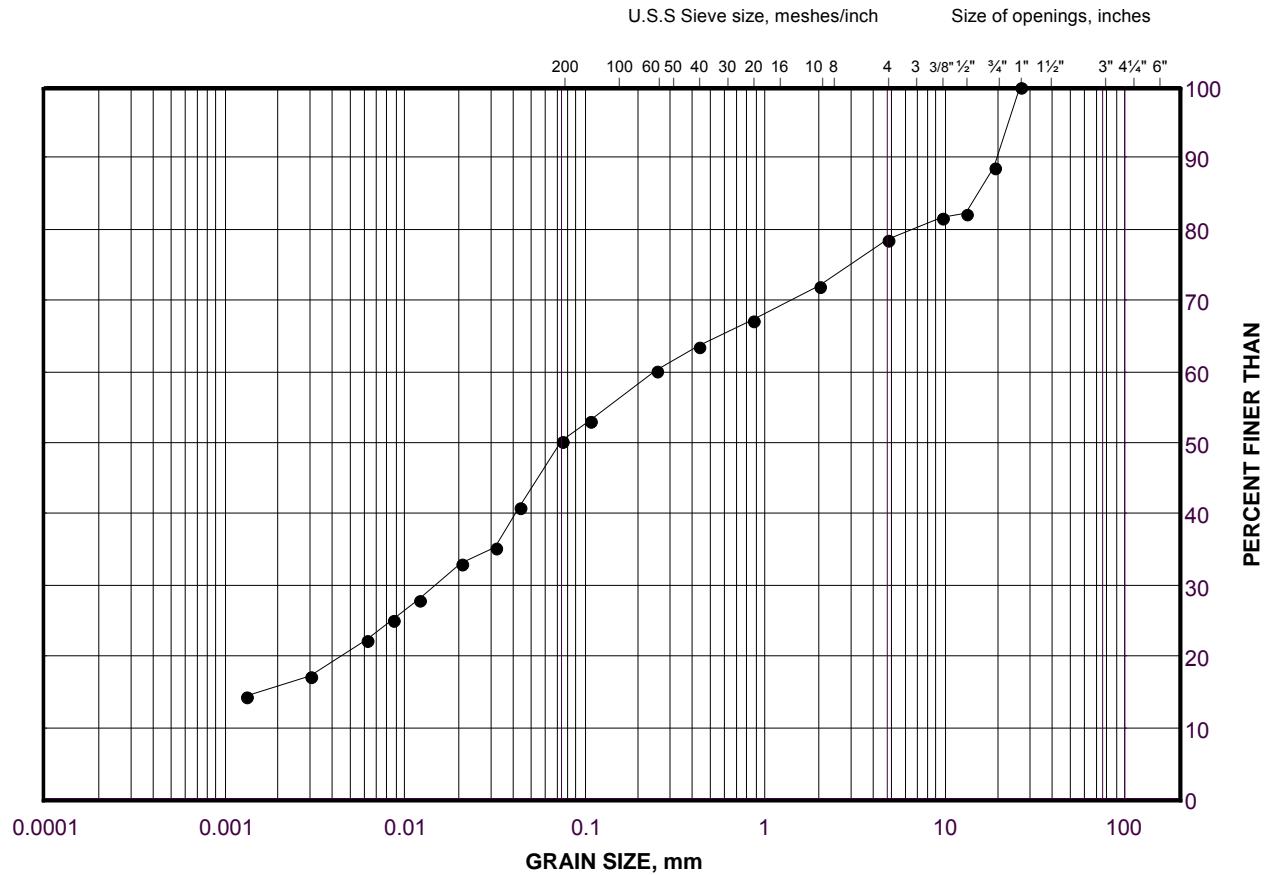
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	H5-1	1	222.2
■	H5-3	1A	221.8
◆	H5-4	2	220.8

GRAIN SIZE DISTRIBUTION

Clayey Silt (FILL)

FIGURE A2



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

LEGEND

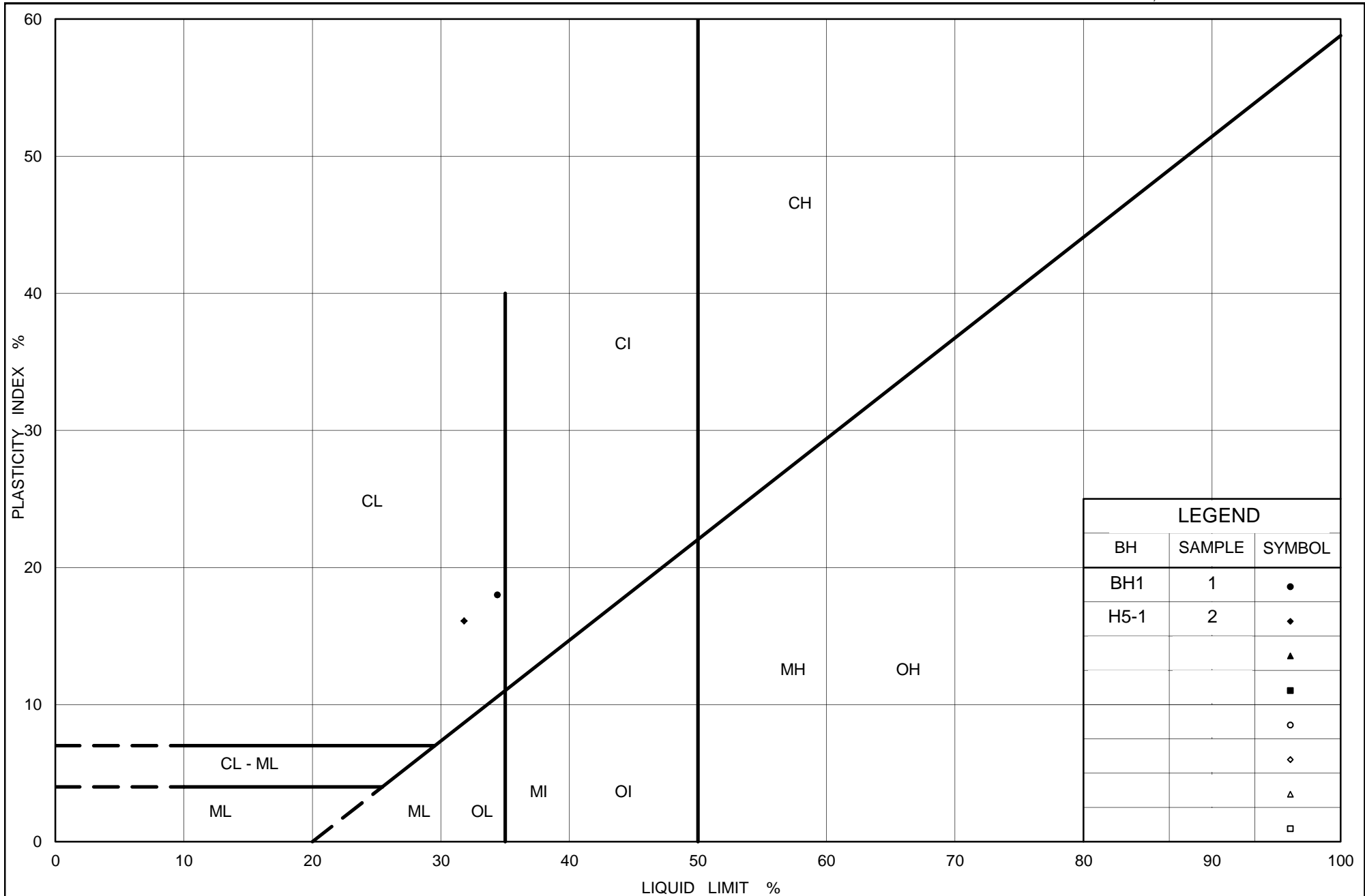
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	BH1	1	221.1

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 11-Feb-14



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Clayey Silt with Sand (FILL)

Figure No. A3

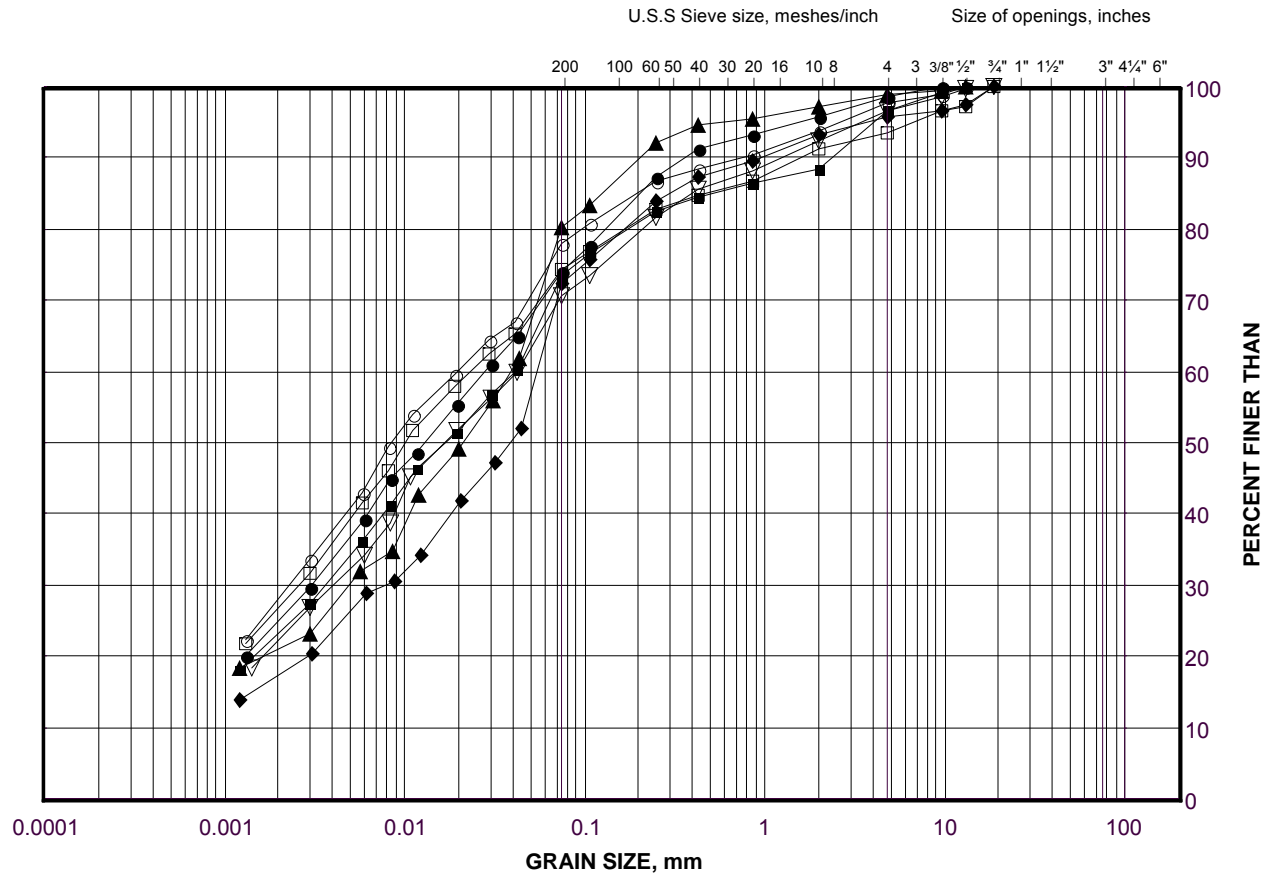
Project No. 10-1184-0016

Checked By: TVA

GRAIN SIZE DISTRIBUTION

Clayey Silt (TILL)

FIGURE A4A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BH1	3	219.6
■	H5-3	4	219.6
◆	H5-2	5	219.2
▲	H5-1	5	219.3
▽	H5-3	5	218.8
○	H5-2	7	217.7
□	H5-2	9	216.1

Project Number: 10-1184-0016

Checked By: TVA

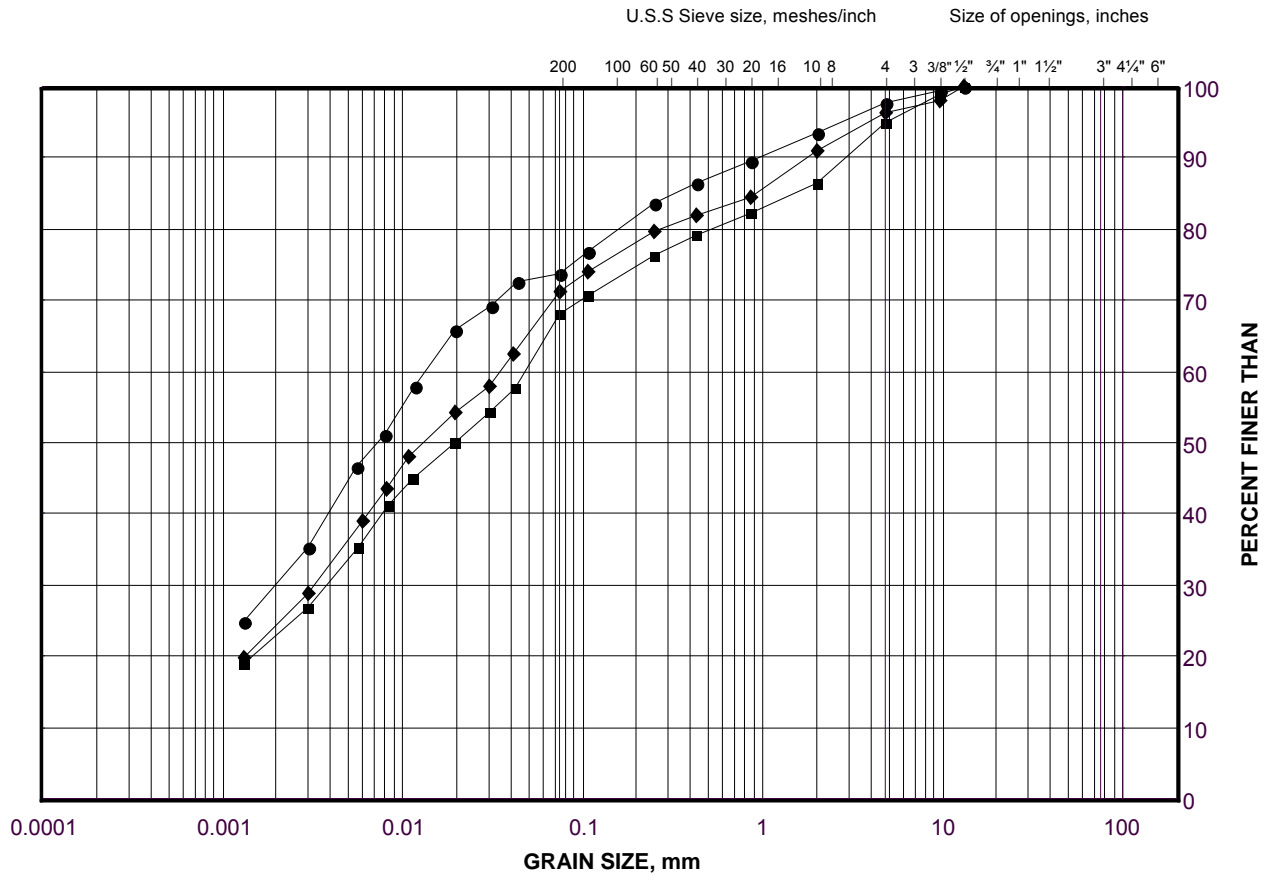
Golder Associates

Date: 11-Feb-14

GRAIN SIZE DISTRIBUTION

Clayey Silt (TILL)

FIGURE A4B



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	H5-5	5	218.3
■	H5-5	7	216.8
◆	H5-4	8	216.3

Project Number: 10-1184-0016

Checked By: TVA

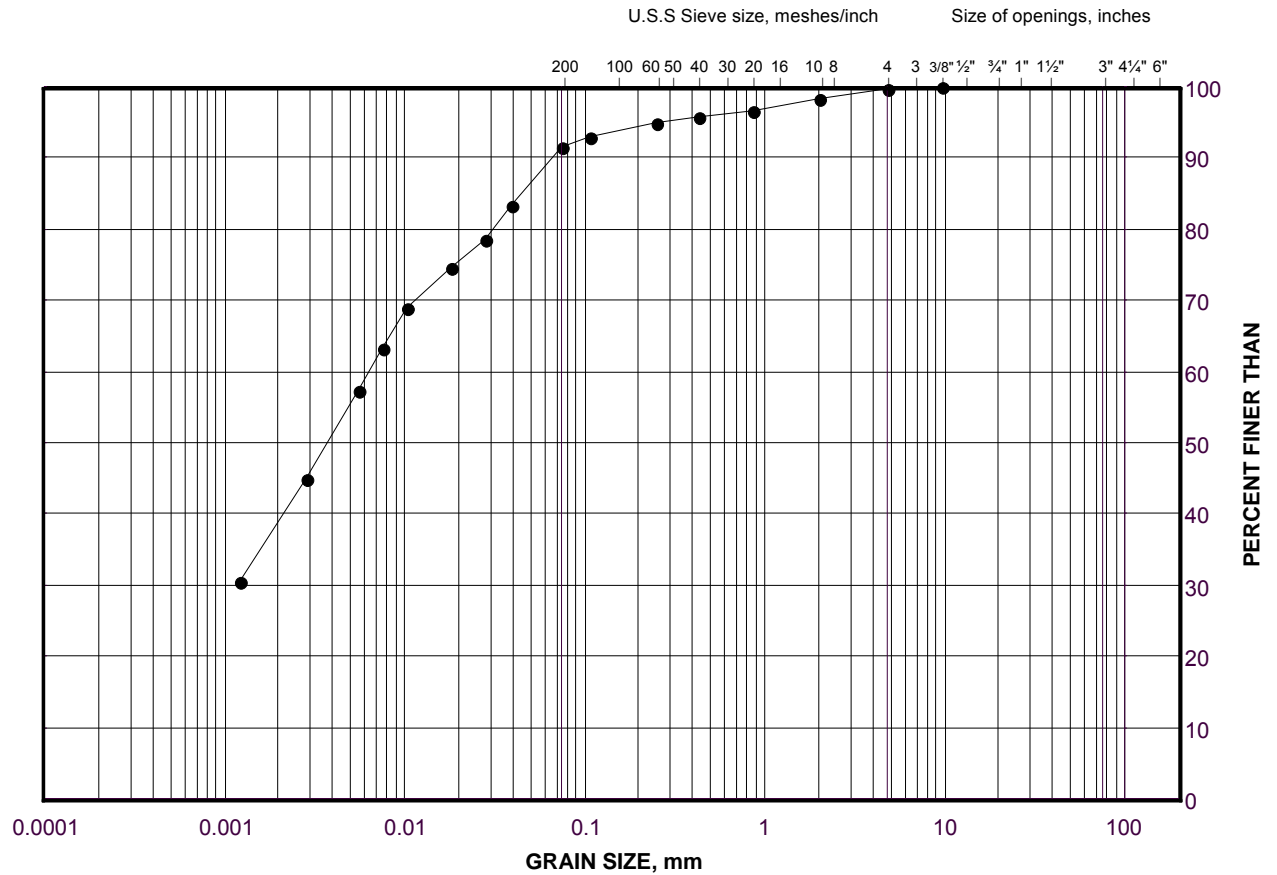
Golder Associates

Date: 11-Feb-14

GRAIN SIZE DISTRIBUTION

Silty Clay (TILL)

FIGURE A5



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

LEGEND

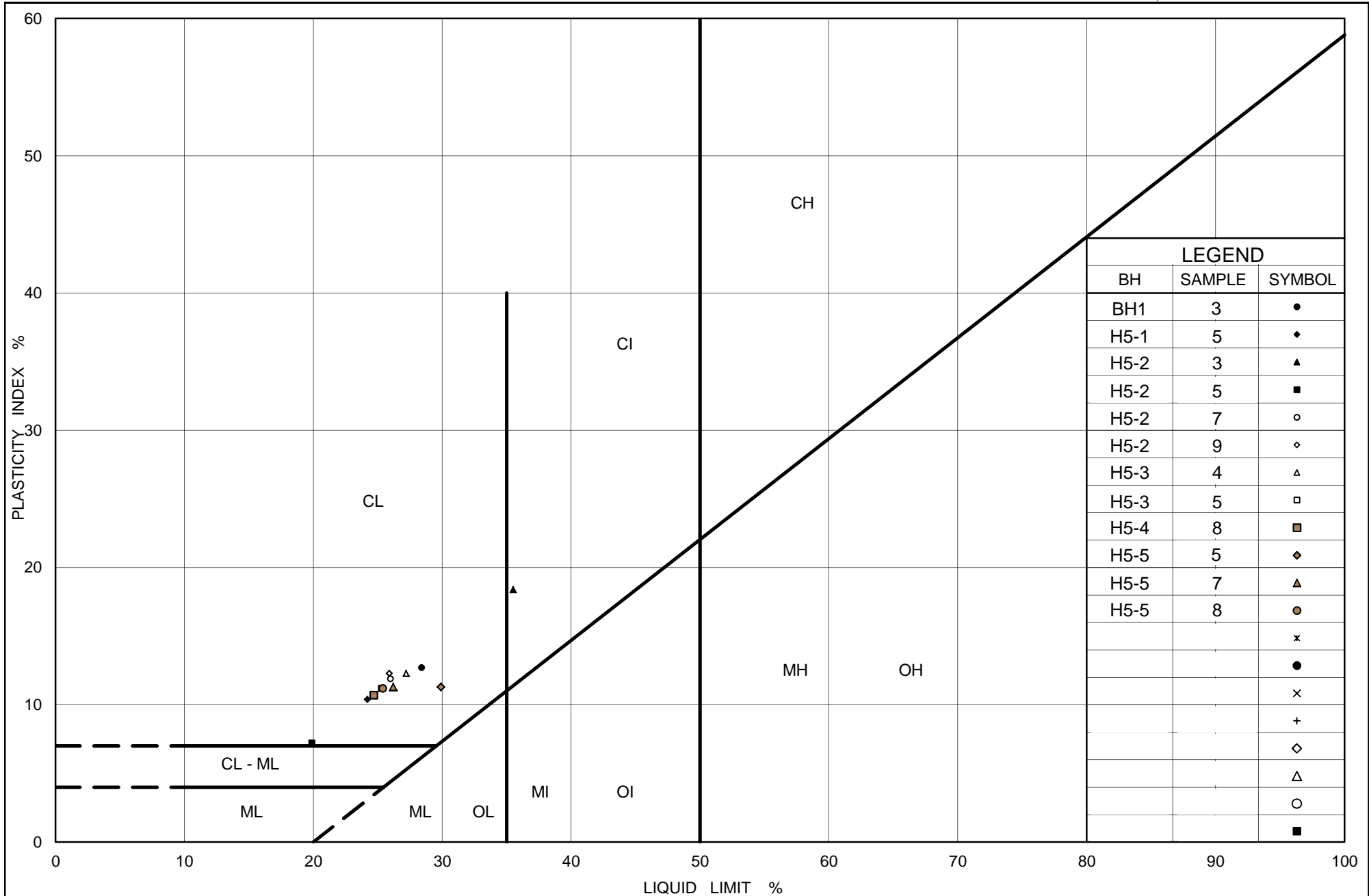
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	H5-2	3	220.7

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 11-Feb-14



Ministry of
Transportation

Ontario

PLASTICITY CHART

Clayey Silt to Silty Clay (TILL)

Figure No. A6

Project No. 10-1184-0016

Checked By: TVA



APPENDIX B

Highway 5: STA. 30+040 to STA. 30+120 (High Fill Area 2) Record of Boreholes and Laboratory Test Results

PROJECT 10-1184-0016			RECORD OF BOREHOLE No BH 5			SHEET 1 OF 1			METRIC							
G.W.P. 2112-05-00			LOCATION N 4797082.1 ; E 270915.5			ORIGINATED BY JBH										
DIST _____ HWY 5 & 6			BOREHOLE TYPE 102 mm O.D. Continuous Flight Solid Stem Augers			COMPILED BY BM										
DATUM Geodetic			DATE November 15, 2012			CHECKED BY TVA										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
221.7	GROUND SURFACE															
0.0	TOPSOIL															
0.1	Silty sand and gravel (FILL)		1	SS	22											
221.0	Compact Brown Dry		2	SS	10											
0.7	Clayey silt, some sand, trace gravel, trace organics (FILL)															
220.3	Stiff Brown Moist		3	SS	22											
1.4	CLAYEY SILT, some sand, trace gravel (TILL)															
	Very stiff to hard Brown to grey Moist		4	SS	30											
			5	SS	39											
			6	SS	20											
			7	SS	25											
216.5	END OF BOREHOLE AUGER REFUSAL INFERRED BEDROCK															
5.2	NOTE: 1. Water level in open borehole measured at a depth of 4.9 m below ground surface (Elev. 216.8 m) upon completion of drilling.															

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

PROJECT 10-1184-0016		RECORD OF BOREHOLE No H5-6		SHEET 1 OF 1		METRIC													
G.W.P. 2112-05-00		LOCATION N 4797086.5 ; E 270942.5		ORIGINATED BY JBH															
DIST _____ HWY 5 & 6		BOREHOLE TYPE 102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM															
DATUM Geodetic		DATE November 15, 2012		CHECKED BY TVA															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED			W _p W W _L WATER CONTENT (%)			γ kN/m ³			GR SA SI CL		
222.1	GROUND SURFACE							20 40 60 80 100											
0.0	ASPHALT																		
0.2	Sand and gravel, trace silt (FILL) Brown Moist		1	SS	18		222												
	Clayey silt with sand, some gravel (FILL) Stiff to very stiff Brown Moist		2	SS	8		221											19 34 36 11	
220.7																			
1.4	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff Brown to grey Moist		3	SS	24		220												
			4	SS	28													1 16 56 27	
	----- Silty sand seams -----		5A 5B	SS	22		219												
			6	SS	25		218												
			7	SS	23		217												
216.9	END OF BOREHOLE AUGER REFUSAL INFERRED BEDROCK																		
5.2	NOTES: 1. Water level in open borehole measured at a depth of 3.8 m below ground surface (Elev. 218.3 m) upon completion of drilling. 2. WATER LEVEL READINGS: Date Depth (mm) Elev. (m) 11/16/12 5.1 217.0 11/23/12 4.3 217.8 01/22/13 1.7 220.4 02/07/13 1.8 220.3 02/13/13 1.8 220.3																		

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD



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

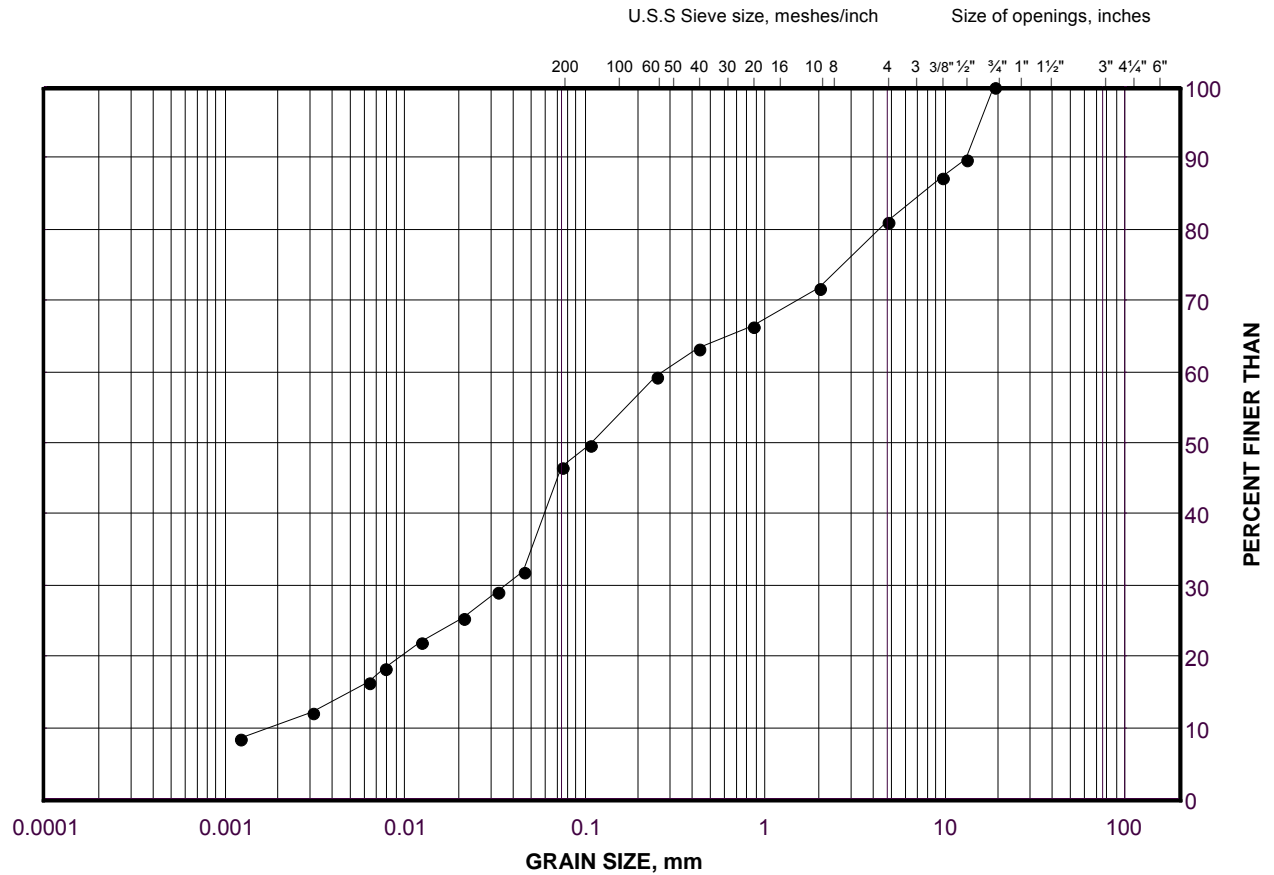
GGTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

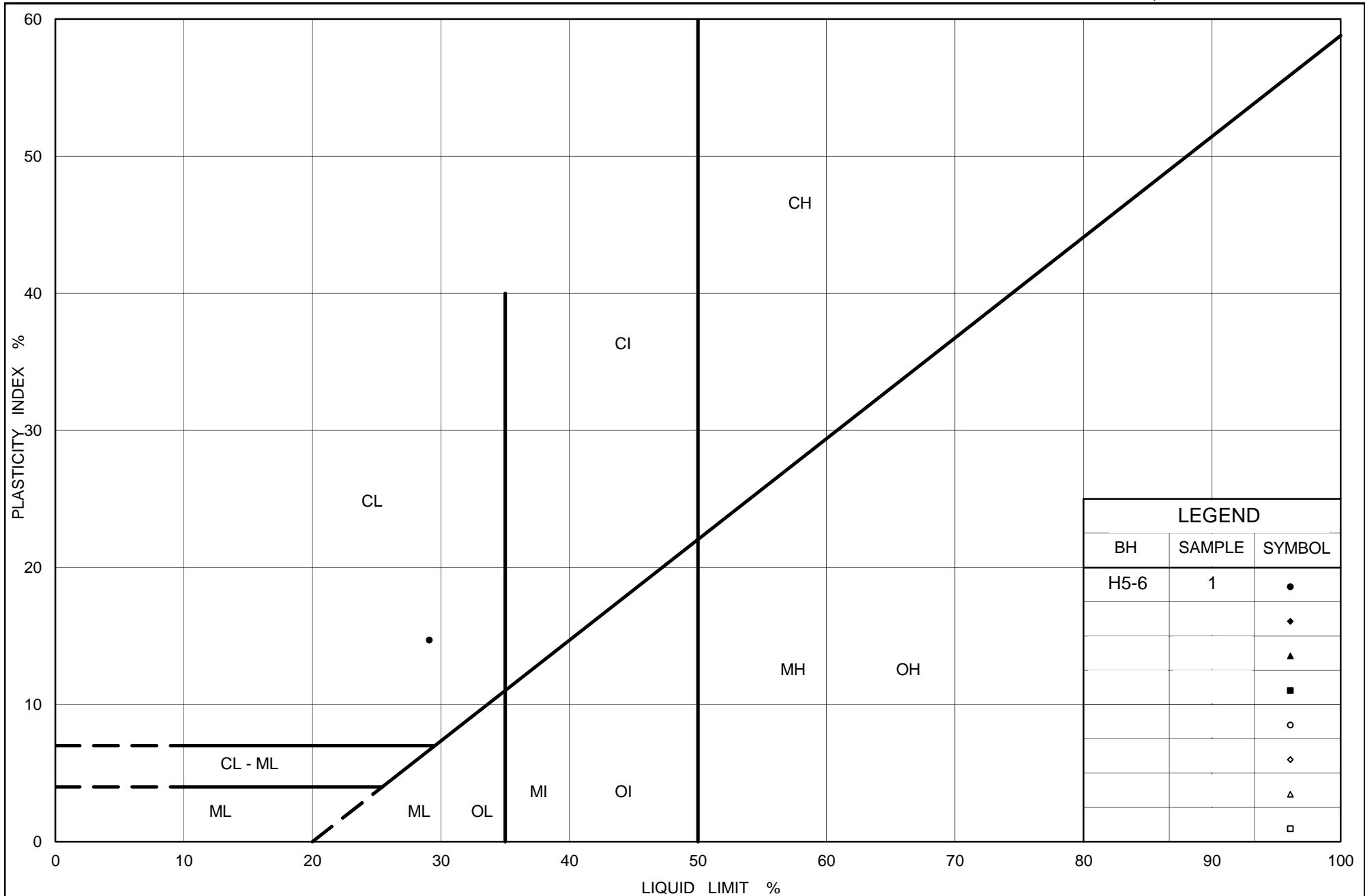
PROJECT		10-1184-0016		RECORD OF BOREHOLE No H5-8		SHEET 1 OF 1		METRIC											
G.W.P.		2112-05-00		LOCATION		N 4797122.7 ; E 270976.9		ORIGINATED BY											
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY											
DATUM		Geodetic		DATE		November 14, 2012		CHECKED BY											
								TVA											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL	
								20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	10 20 30	kN/m ³					
223.4	0.0	GROUND SURFACE																	
	0.1	ASPHALT		1	SS	30		223							o				
		Silty sand, trace clay, trace gravel, trace organics (FILL)		2	SS	11		222											
		Compact Brown Moist																	
222.0	1.4	CLAYEY SILT, some sand, trace gravel (TILL)		3	SS	11		221								o			
		Stiff to hard Brown Moist to wet		4	SS	38		220											
				5	SS	43		219											
				6	SS	45													
				7	SS	25													
218.4	5.0	END OF BOREHOLE																	
		NOTES:																	
		1. Water level in open borehole measured at a depth of 4.8 m below ground surface (Elev. 218.6 m) upon completion of drilling.																	
		2. WATER LEVEL READINGS:																	
		Date Depth (mm) Elev. (m)																	
		11/15/12 2.7 220.7																	
		11/16/12 4.6 218.8																	
		11/23/12 4.5 218.9																	
		01/22/13 2.2 221.2																	
		02/07/13 2.3 221.1																	
		02/13/13 2.1 221.3																	

GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand (FILL)

FIGURE B1





Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt with Sand (FILL)

Figure No. B2

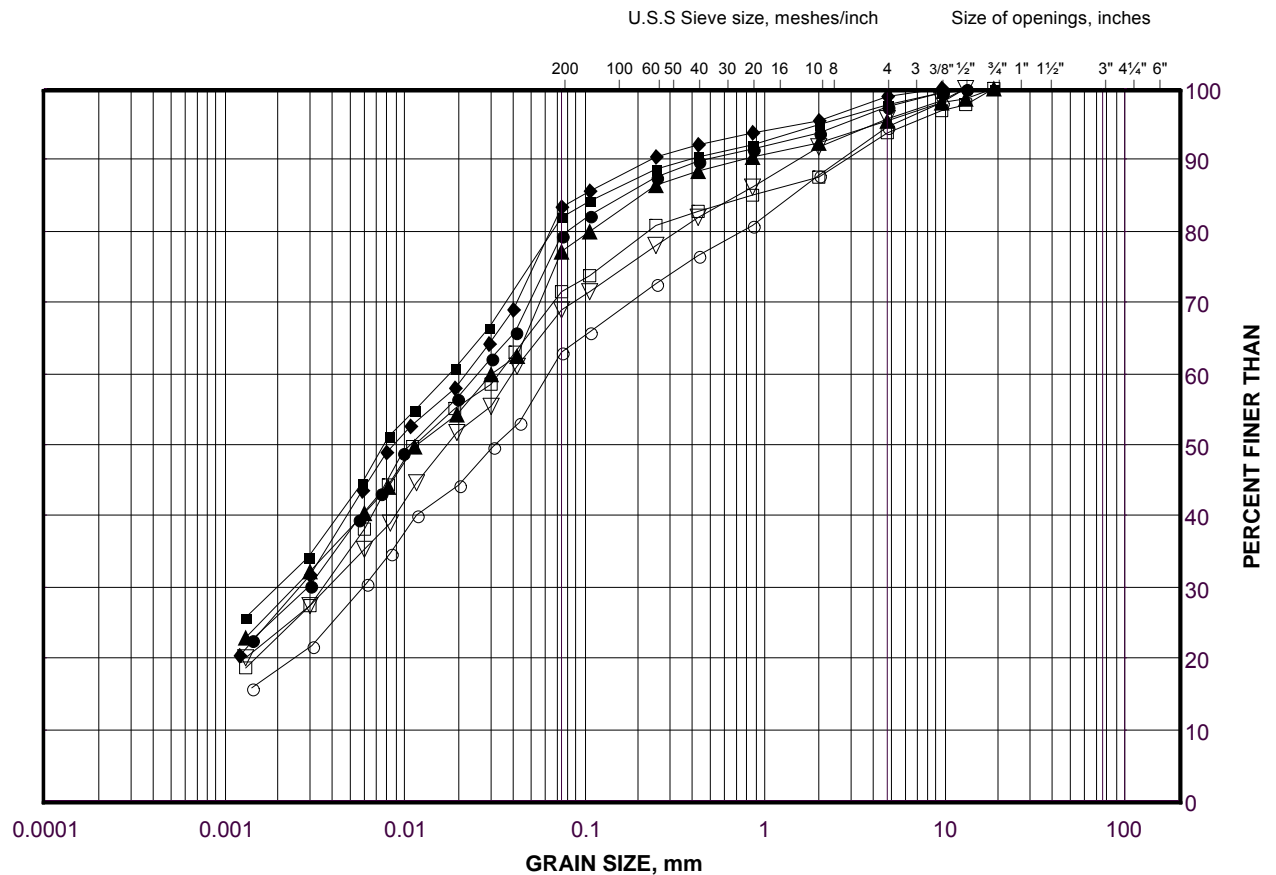
Project No. 10-1184-0016

Checked By: TVA

GRAIN SIZE DISTRIBUTION

Clayey Silt to Clayey Silt with Sand (TILL)

FIGURE B3



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

LEGEND

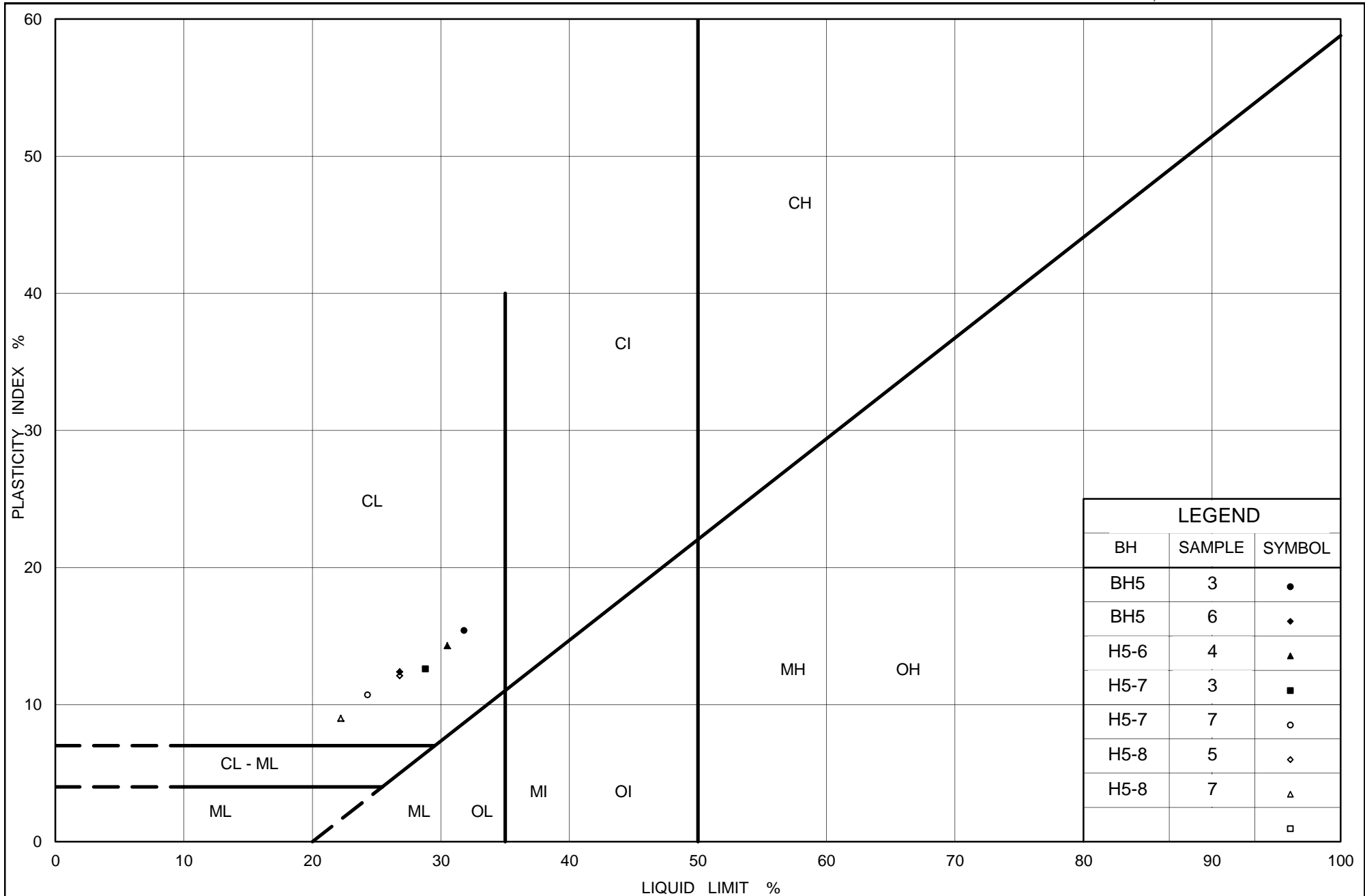
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	H5-7	3	220.8
■	BH5	3	219.9
◆	H5-6	4	219.6
▲	H5-8	5	220.1
▽	BH5	6	217.6
○	H5-8	7	218.6
□	H5-7	7	217.8

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 11-Feb-14



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt (TILL)

Figure No. B4

Project No. 10-1184-0016

Checked By: TVA



APPENDIX C

Ramp W-S: STA. 10+000 to STA. 10+140 (High Fill Area 3) Record of Boreholes and Laboratory Test Results



PROJECT	10-1184-0016	RECORD OF BOREHOLE No WS-1		SHEET 1 OF 1	METRIC
G.W.P.	2112-05-00	LOCATION	N 4796977.4 ;E 270880.3	ORIGINATED BY JBH	
DIST	HWY 5 & 6	BOREHOLE TYPE	102 mm O.D. Continous Flight Solid Stem Augers	COMPILED BY BM	
DATUM	Geodetic	DATE	November 21, 2012	CHECKED BY TVA	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	
222.1	GROUND SURFACE					
0.0	ASPHALT					
0.2	Sand and gravel, trace silt (FILL)					
221.3	Brown Moist					
0.8	Sandy silt, trace gravel, trace clay, clayey silt seams (FILL)		1	SS	12	
220.7	Compact Dark brown Moist					
1.4	Clayey silt, sandy, some gravel, sand seams (FILL)		2	SS	13	
220.0	Stiff Brown Moist					
2.1	CLAYEY SILT, some sand, trace gravel (TILL)		3	SS	22	
	Stiff to very stiff Brown to grey Moist		4	SS	27	
			5	SS	23	
			6	SS	19	
			7	SS	13	
215.8			8	SS	7/0.03	
6.3	END OF BOREHOLE SPoon BOUNCING AND AUGER REFUSAL INFERRED BEDROCK NOTE: 1. Borehole dry upon completion of drilling.					

DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
		Wp		w		WL		γ		GR SA SI CL	
SHEAR STRENGTH kPa											
○ UNCONFINED + FIELD VANE											
● QUICK TRIAXIAL × REMOULDED											
WATER CONTENT (%)		10		20		30					

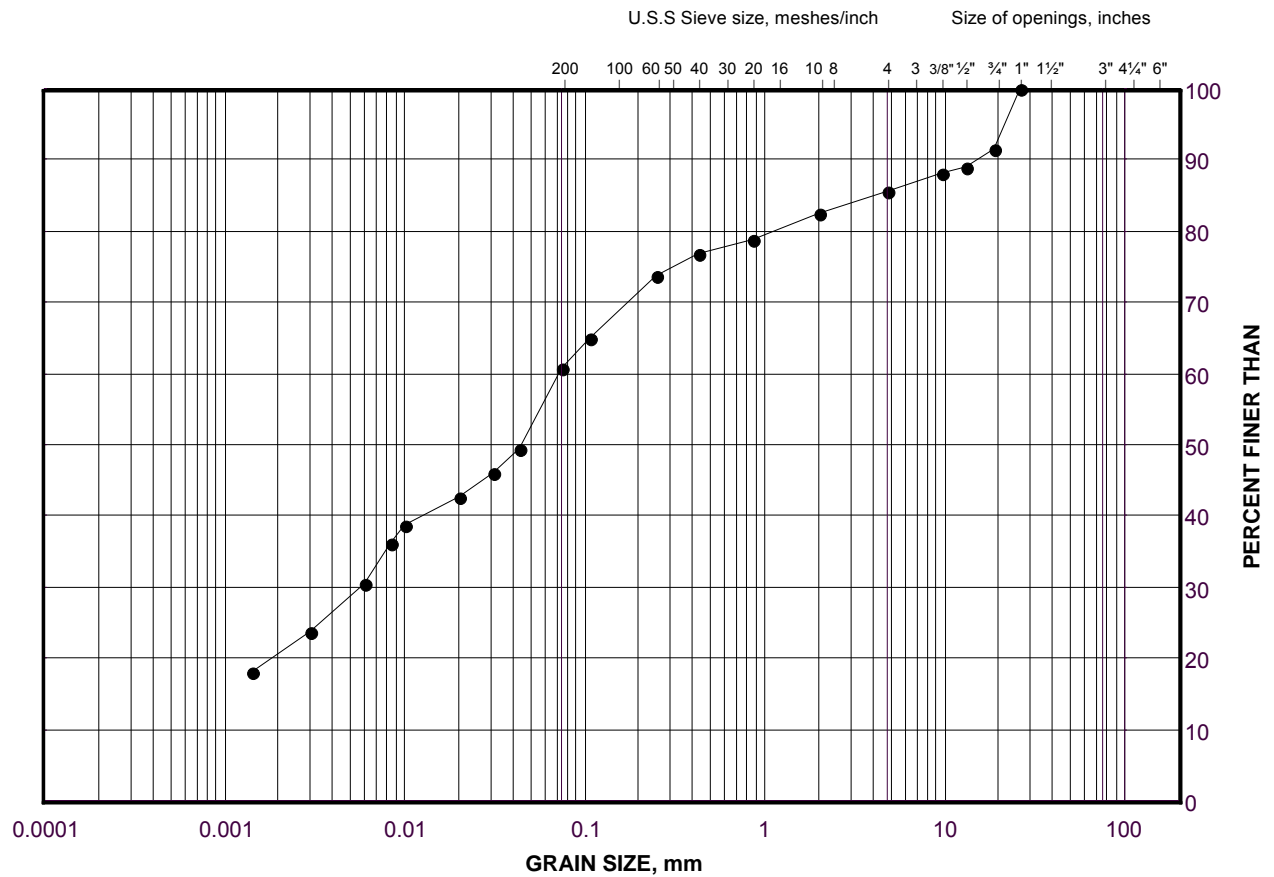
PROJECT		10-1184-0016		RECORD OF BOREHOLE No WS-2		SHEET 1 OF 1		METRIC						
G.W.P.		2112-05-00		LOCATION		N 4796968.4 ;E 270932.5		ORIGINATED BY JBH						
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM						
DATUM		Geodetic		DATE		November 21, 2012		CHECKED BY TVA						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
222.5	GROUND SURFACE													
0.0	ASPHALT													
0.2	Sand and gravel, trace silt (FILL) Brown Moist													
221.7														
0.8	Clayey silt, trace sand (FILL) Firm Brown Moist		1	SS	6									
221.1														
1.4	CLAYEY SILT, sandy, trace gravel, sand seams to a depth of 2.7 m (TILL) Stiff to hard Brown Moist		2	SS	19									
			3	SS	25									
			4	SS	33									
			5	SS	28									
			6	SS	13									
			7	SS	11									
			8	SS	5/0.08									
216.2	END OF BOREHOLE SPOON BOUNCING AND AUGER REFUSAL INFERRED BEDROCK													
6.3														
NOTE: 1. Borehole dry upon completion of drilling.														

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

GRAIN SIZE DISTRIBUTION

Clayey Silt (FILL)

FIGURE C1



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

LEGEND

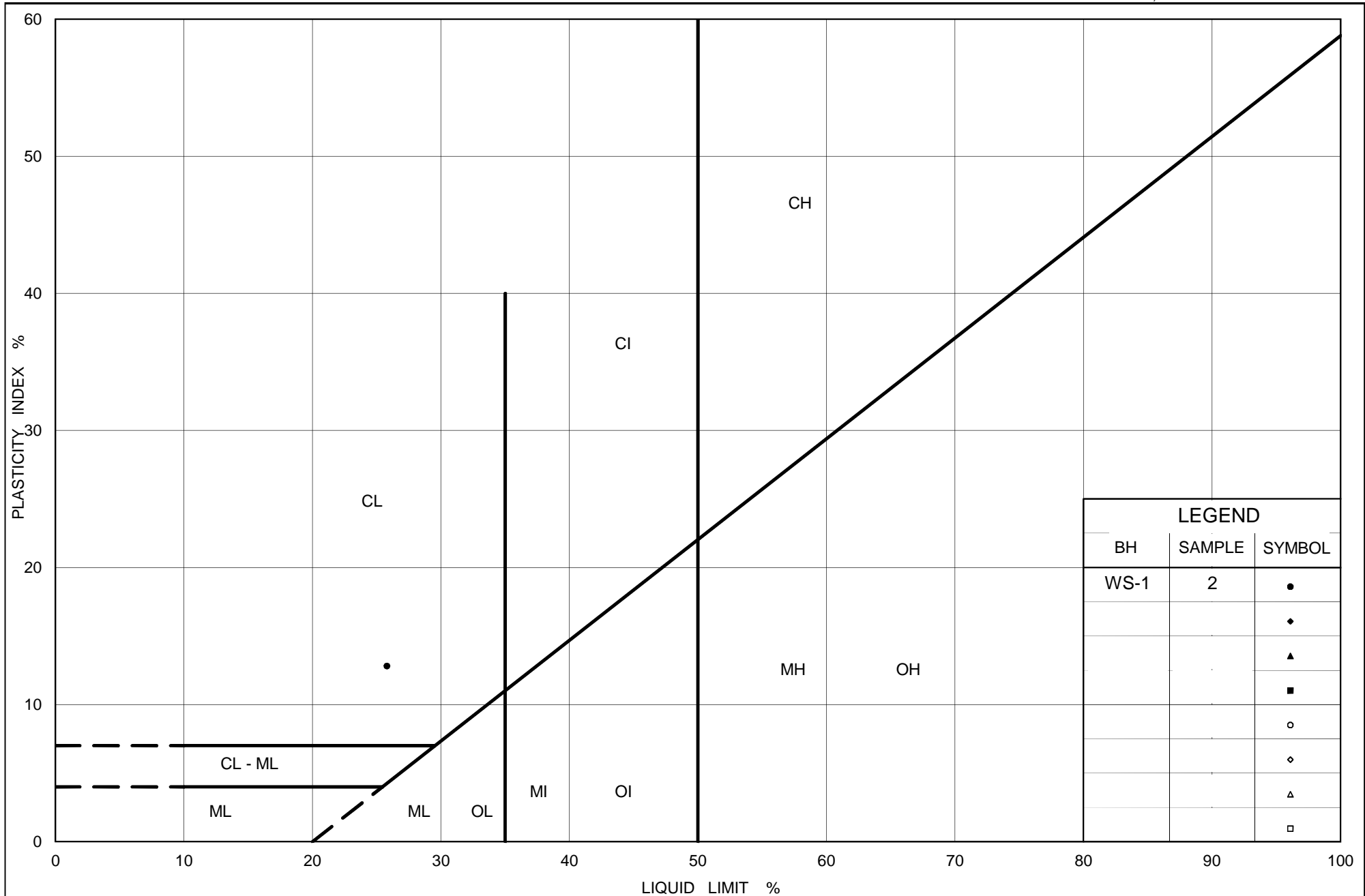
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	WS-1	2	220.4

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 11-Feb-14



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt (FILL)

Figure No. C2

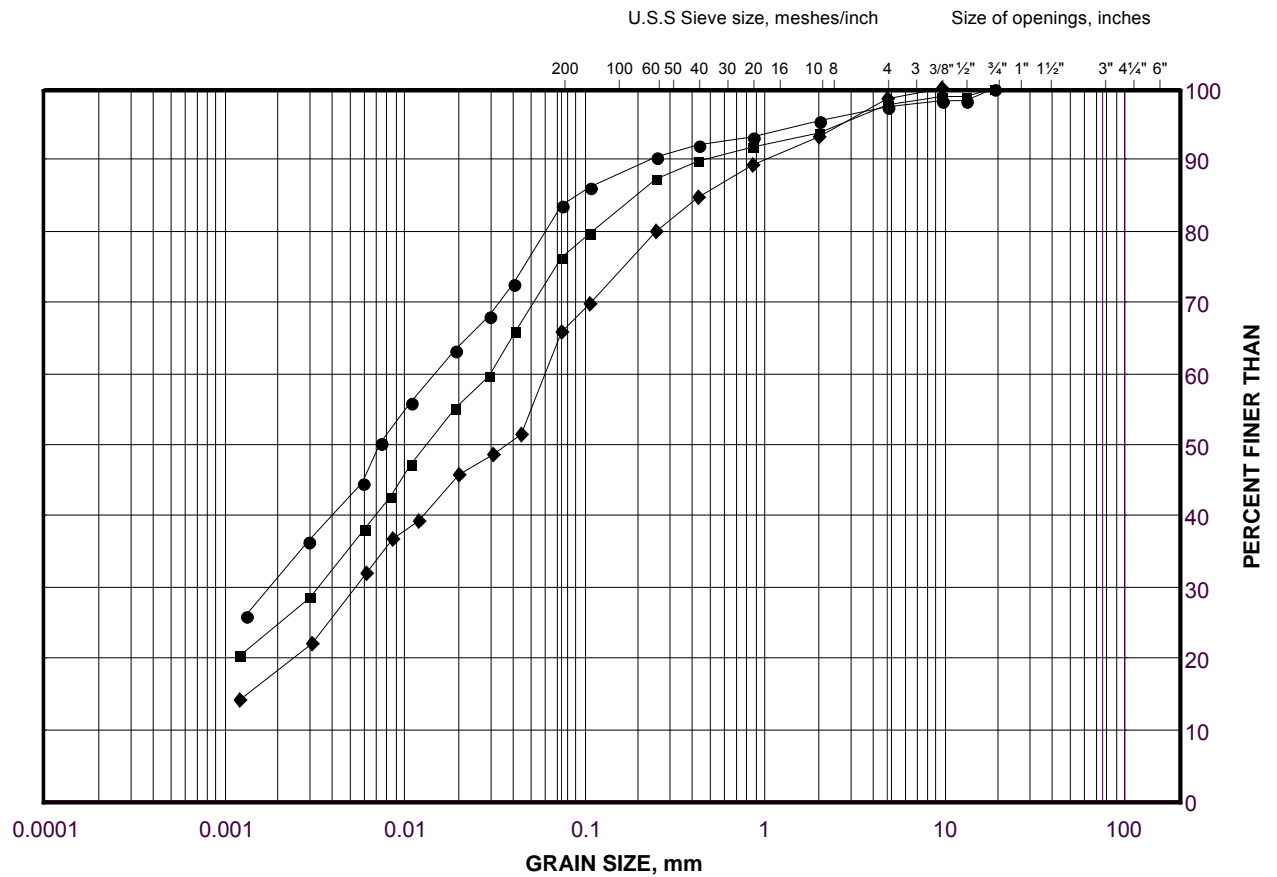
Project No. 10-1184-0016

Checked By: TVA

GRAIN SIZE DISTRIBUTION

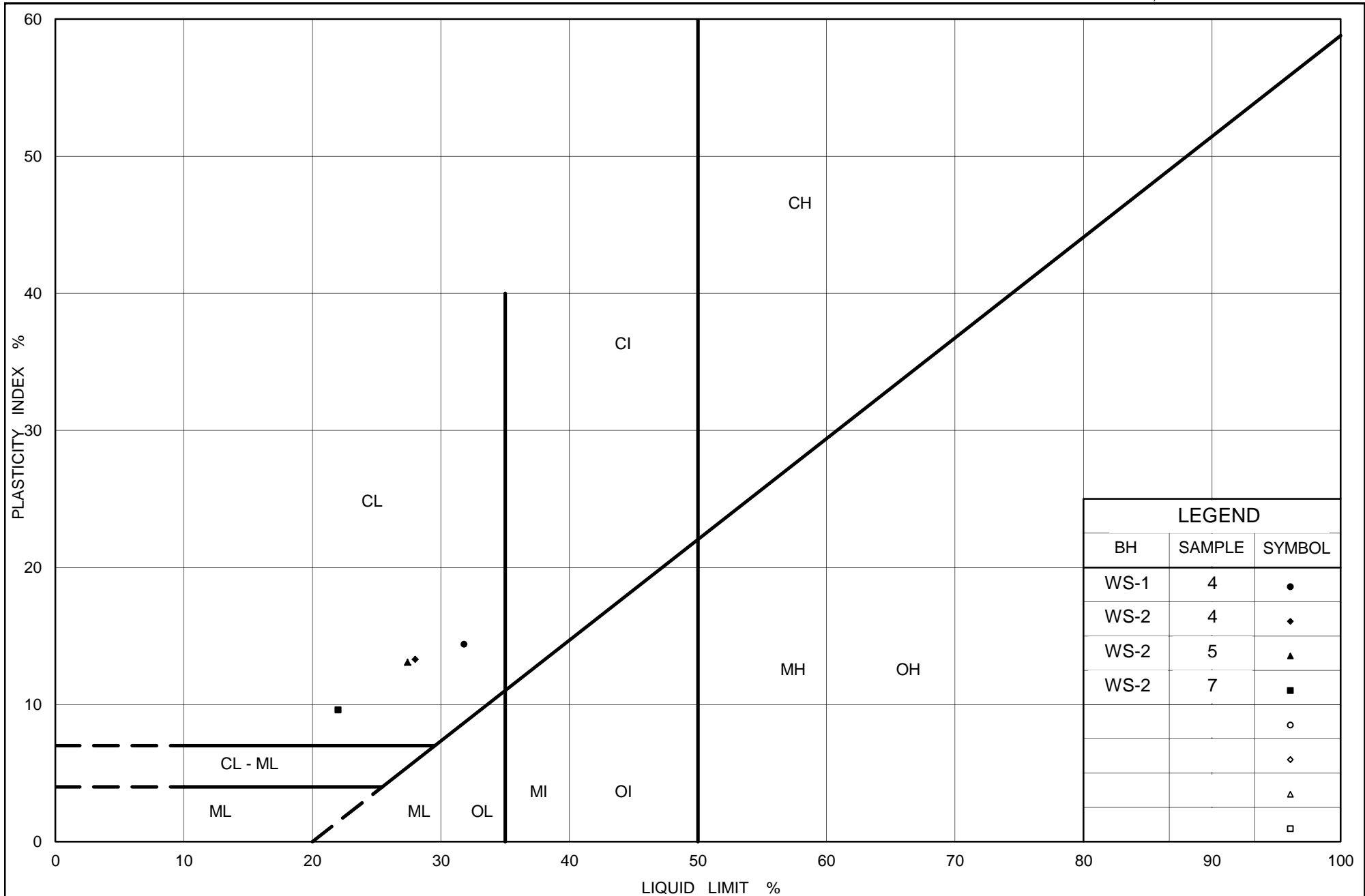
Clayey Silt to Clayey Silt with Sand (TILL)

FIGURE C3



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	WS-1	4	218.8
■	WS-2	5	218.5
◆	WS-2	7	216.9



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt (TILL)

Figure No. C4

Project No. 10-1184-0016

Checked By: TVA



APPENDIX D

Ramp E-S: STA. 10+000 to STA. 10+100 (High Fill Area 4) Record of Boreholes and Laboratory Test Results

PROJECT		10-1184-0016		RECORD OF BOREHOLE No ES-1		SHEET 1 OF 1		METRIC								
G.W.P.		2112-05-00		LOCATION		N 4797002.5; E 270841.8		ORIGINATED BY JBH								
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM								
DATUM		Geodetic		DATE		November 13, 2012		CHECKED BY TVA								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
220.0	GROUND SURFACE															
0.0	ASPHALT															
0.1	Sand and gravel, some silt, trace clay (FILL)		1	SS	23											53 32 13 2
219.3	Compact Brown Moist		2	SS	12											
0.7	Clayey silt, trace sand, trace organics (FILL)															
218.6	Stiff Brown Moist to wet		3	SS	14											
1.4	CLAYEY SILT, sandy to some sand, trace gravel (TILL)															
	Stiff to hard Brown to grey Moist		4	SS	24											1 18 52 29
			5	SS	27											
			6	SS	20											3 22 50 25
			7	SS	18											
			8	SS	20											
213.8	END OF BOREHOLE SPOON BOUNCING AND AUGER REFUSAL INFERRED BEDROCK		9	SS	370.03											
6.2	NOTE: 1. Borehole dry upon completion of drilling.															

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

PROJECT		10-1184-0016		RECORD OF BOREHOLE No ES-2		SHEET 1 OF 1		METRIC						
G.W.P.		2112-05-00		LOCATION		N 4796989.6 ; E 270816.3		ORIGINATED BY JBH						
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM						
DATUM		Geodetic		DATE		November 13, 2012		CHECKED BY TVA						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
222.5	GROUND SURFACE							20 40 60 80 100						
0.0	ASPHALT													
0.1	Sand and silt, some gravel (FILL)		1	SS	10									
221.8	Compact Brown Moist													
0.7	Silty clay, some sand, trace gravel, wood pieces (FILL)		2	SS	14									2 19 52 27
	Stiff Brown Moist to wet													
220.4			3	SS	15									
2.1	CLAYEY SILT, sandy, trace gravel													
	Stiff to hard Brown to grey Moist to wet		4	SS	32									
			5	SS	39									7 21 50 22
	Inferred boulder at a depth of 3.7 m													
			6	SS	22									
			7	SS	14									4 26 45 25
			8	SS	21									
			9	SS	21									
215.9	END OF BOREHOLE													
6.6	NOTE: 1. Water level in open borehole measured at a depth of 5.9 m below ground surface (Elev. 216.6 m) upon completion of drilling.													

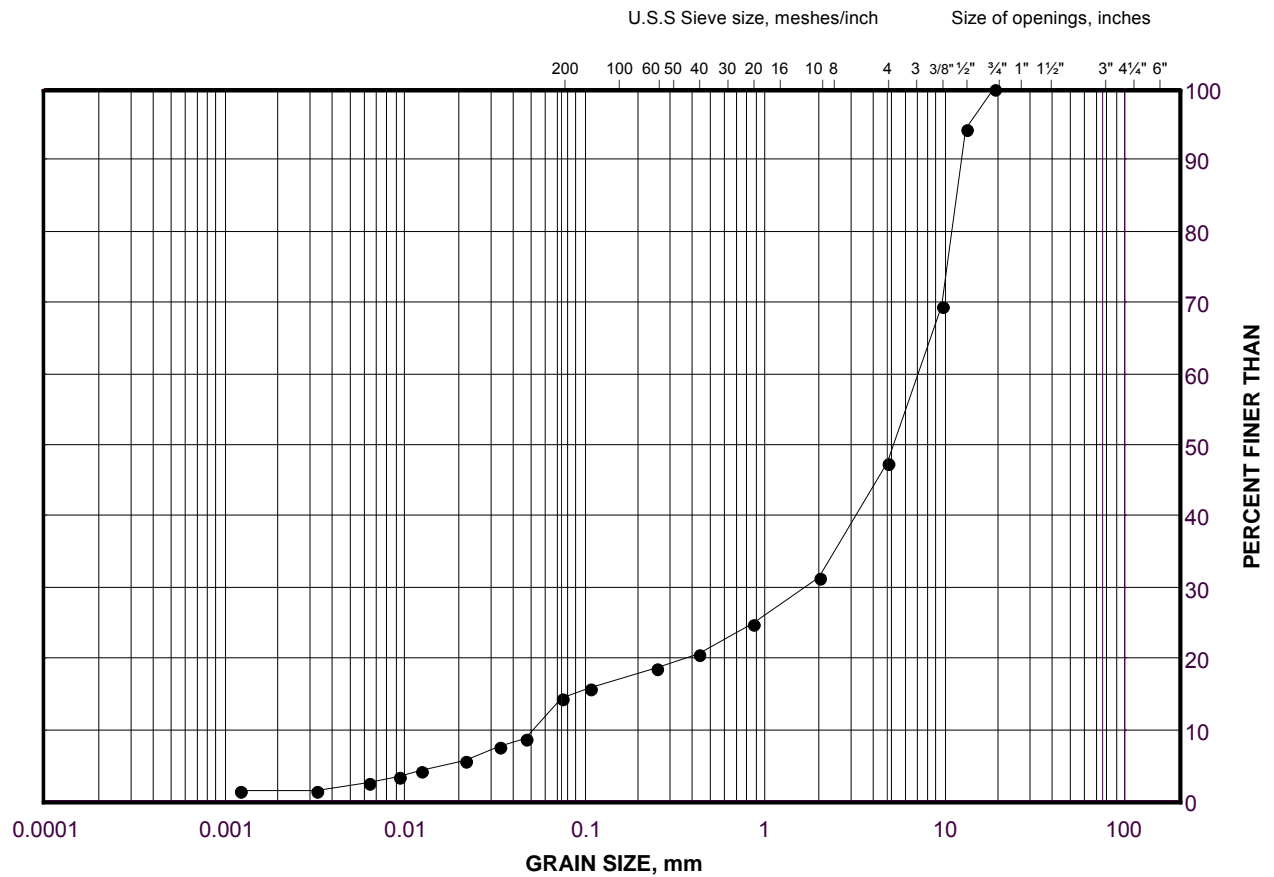
GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

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

GRAIN SIZE DISTRIBUTION

Sand and Gravel (FILL)

FIGURE D1A



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	ES-1	1	219.7

Project Number: 10-1184-0016

Checked By: TVA

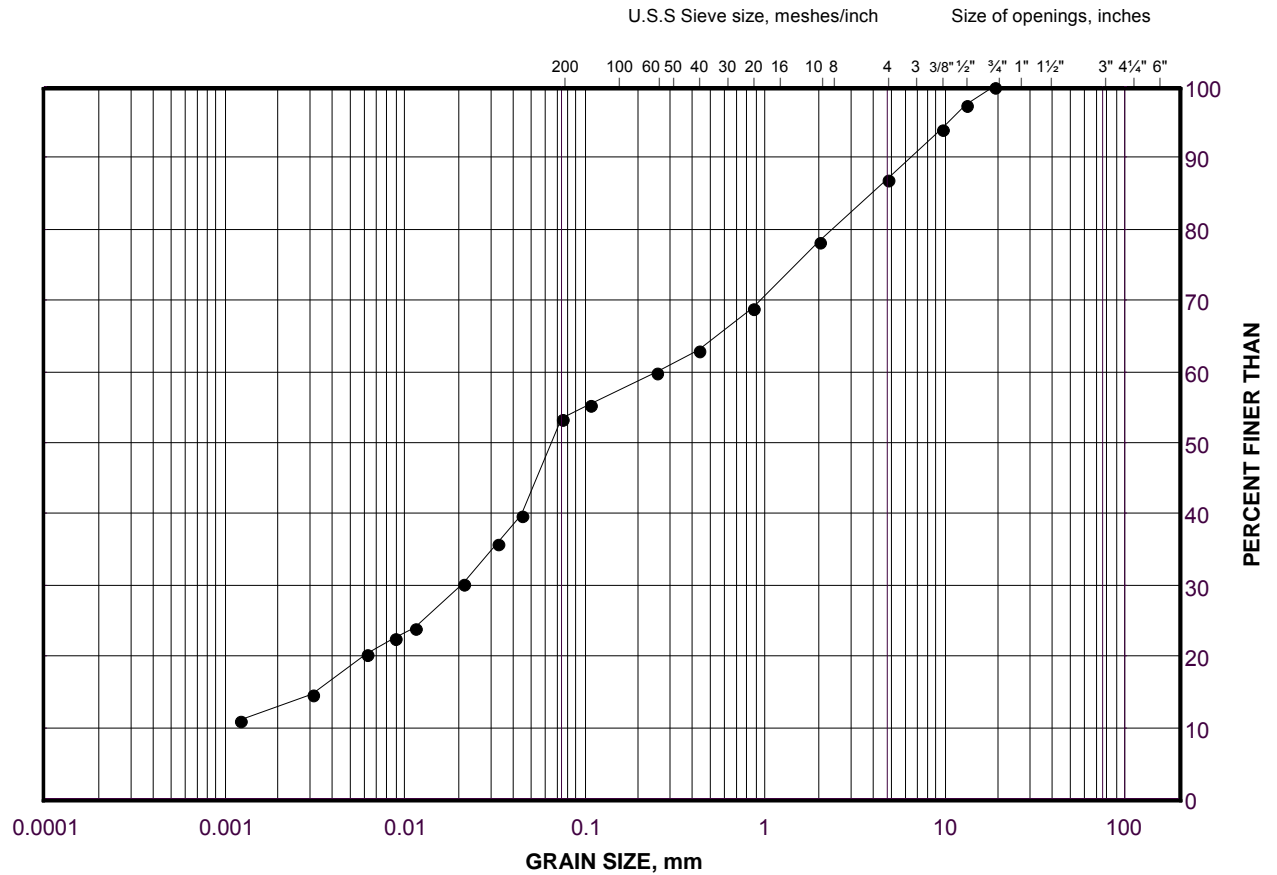
Golder Associates

Date: 11-Feb-14

GRAIN SIZE DISTRIBUTION

Sand and Silt (FILL)

FIGURE D1B



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

LEGEND

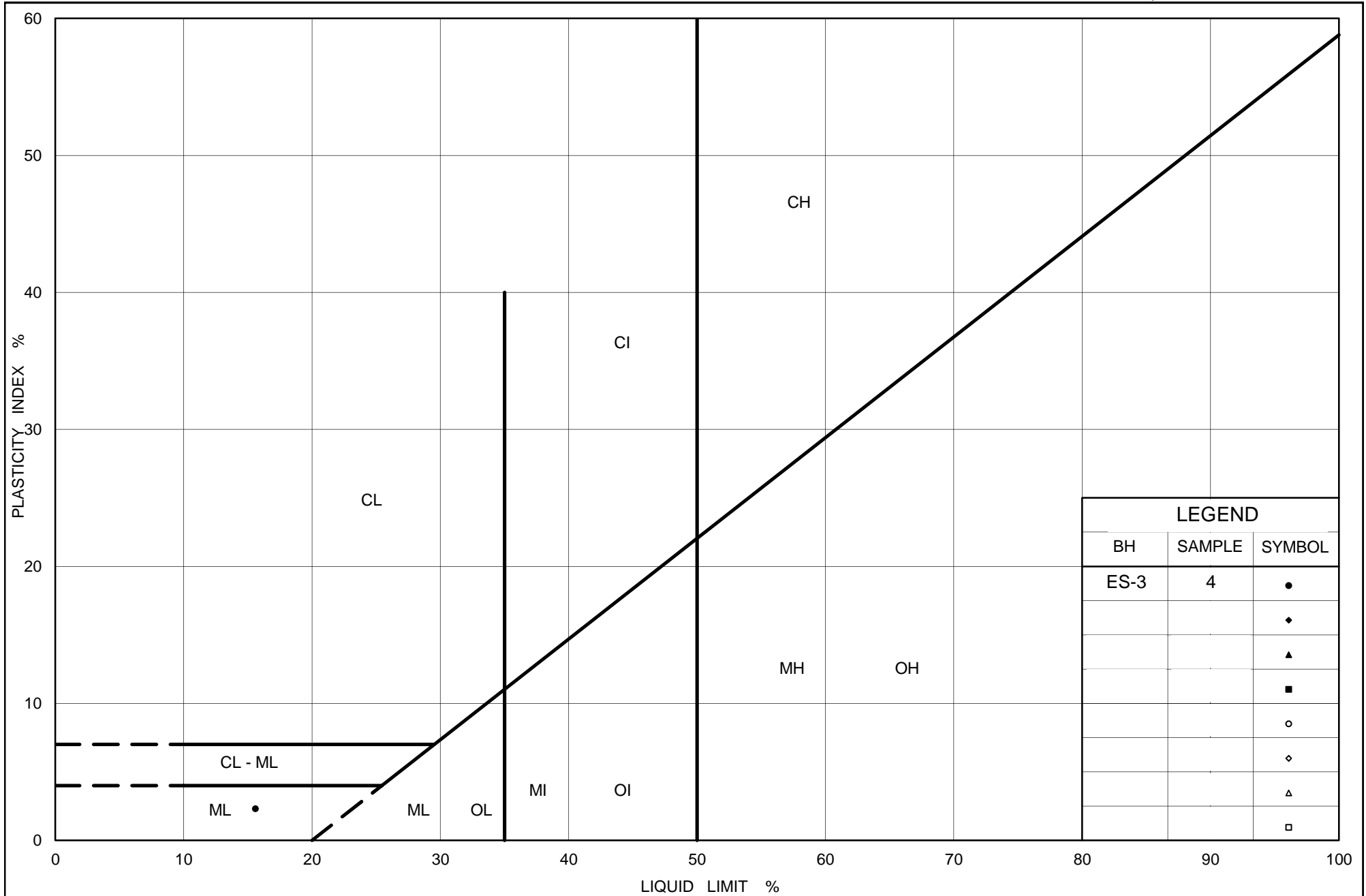
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	ES-3	3	224.6

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 11-Feb-14



Ministry of Transportation

Ontario

PLASTICITY CHART Sand and Silt (FILL)

Figure No. D2

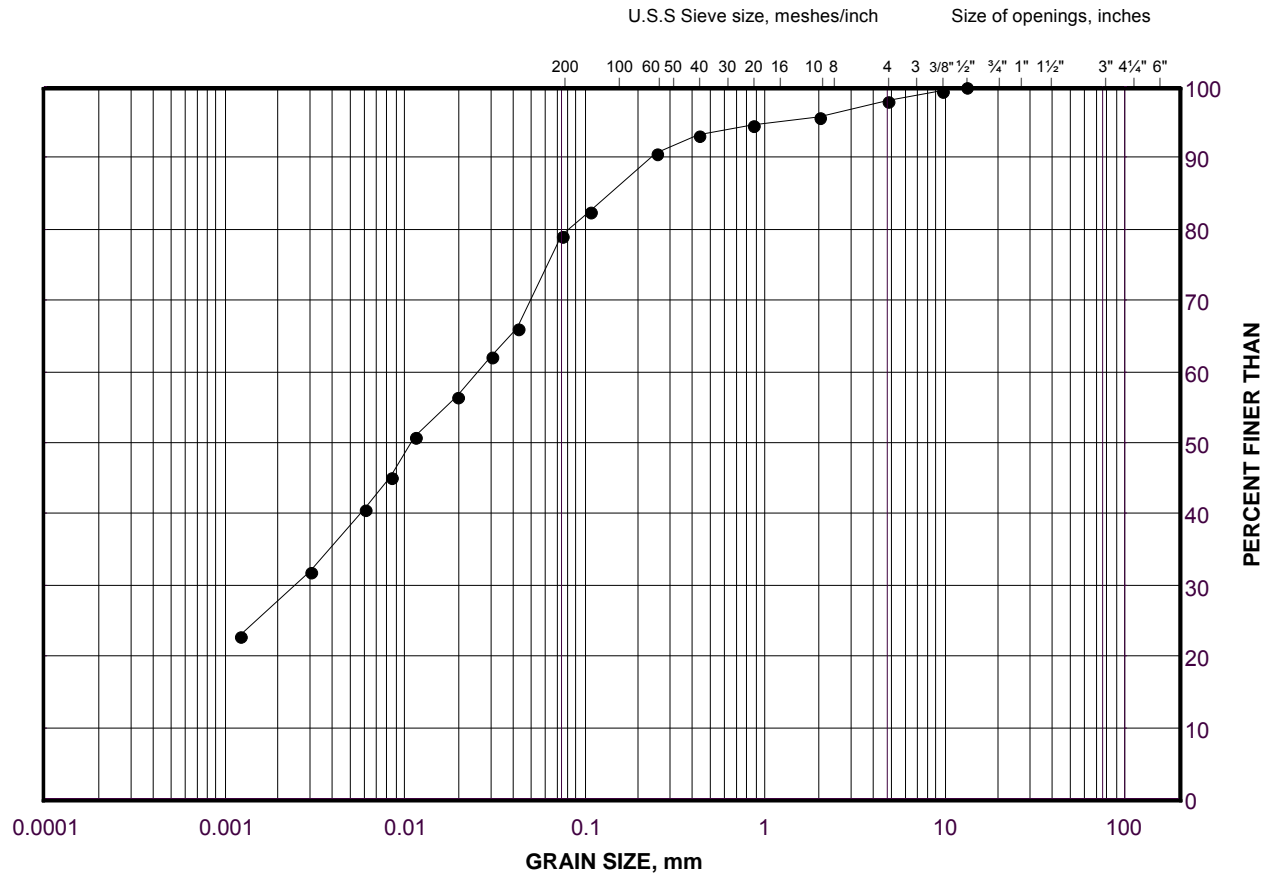
Project No. 10-1184-0016

Checked By: TVA

GRAIN SIZE DISTRIBUTION

Silty Clay (FILL)

FIGURE D3



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

LEGEND

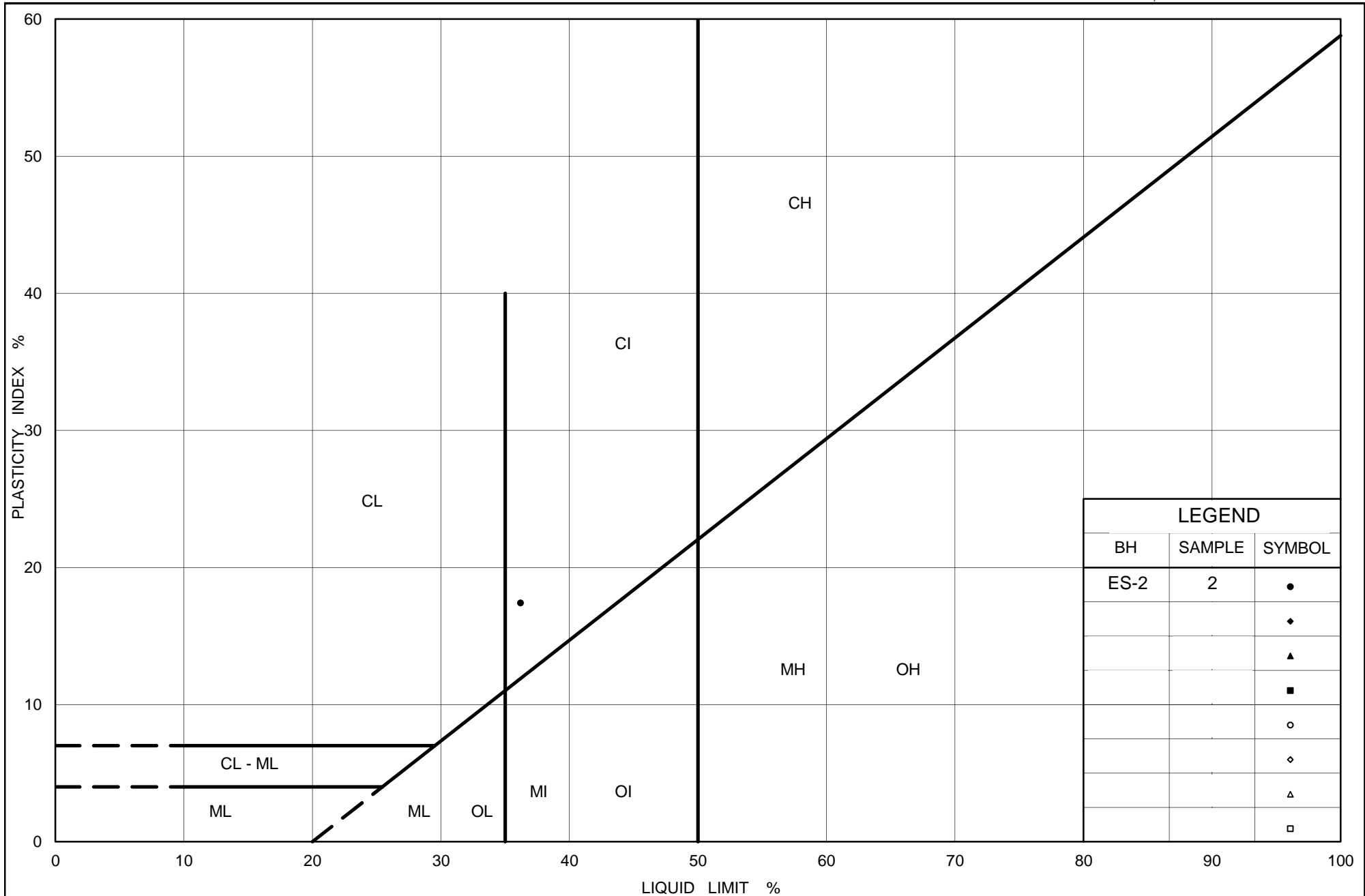
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	ES-2	2	221.5

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 11-Feb-14



Ministry of Transportation

Ontario

PLASTICITY CHART Silty Clay (FILL)

Figure No. D4

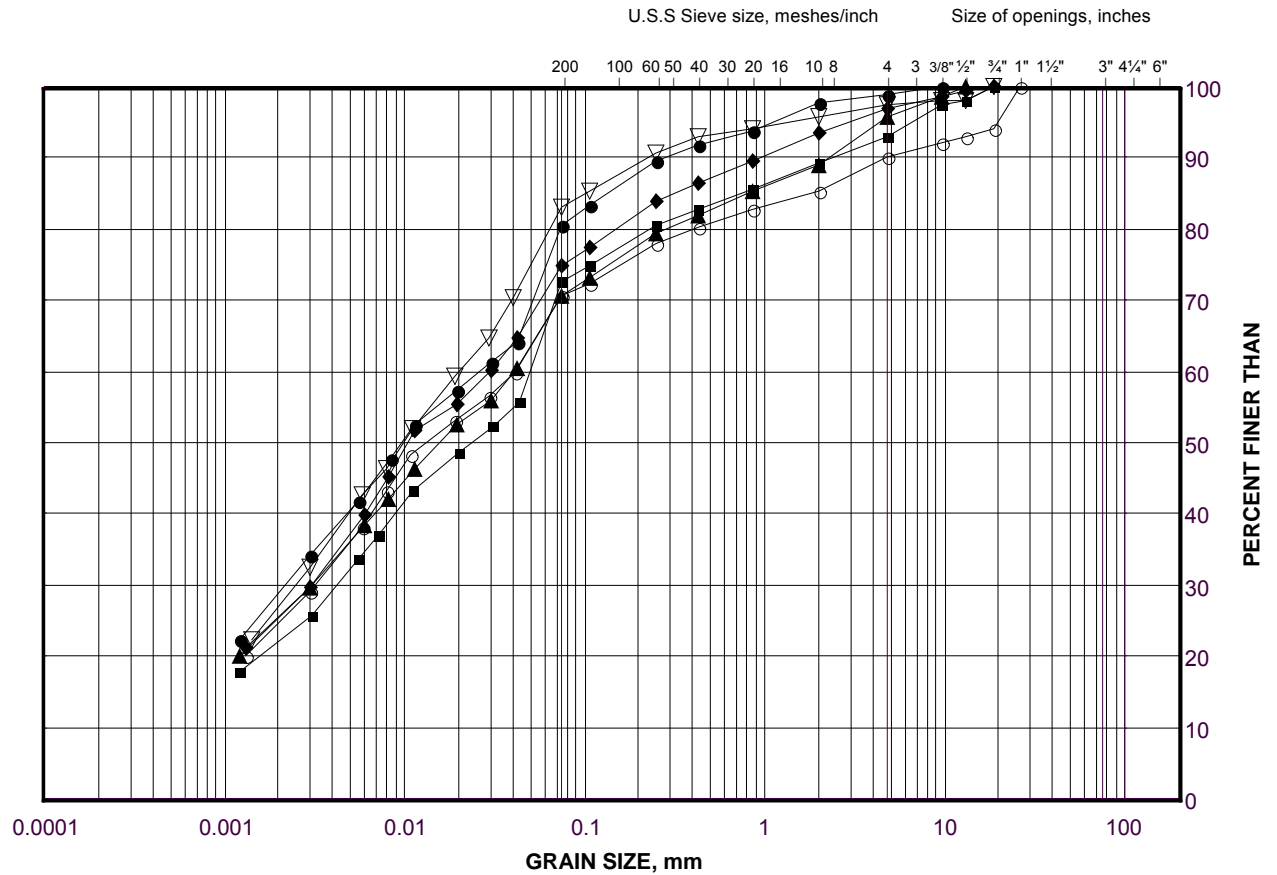
Project No. 10-1184-0016

Checked By: TVA

GRAIN SIZE DISTRIBUTION

Clayey Silt (TILL)

FIGURE D5



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

LEGEND

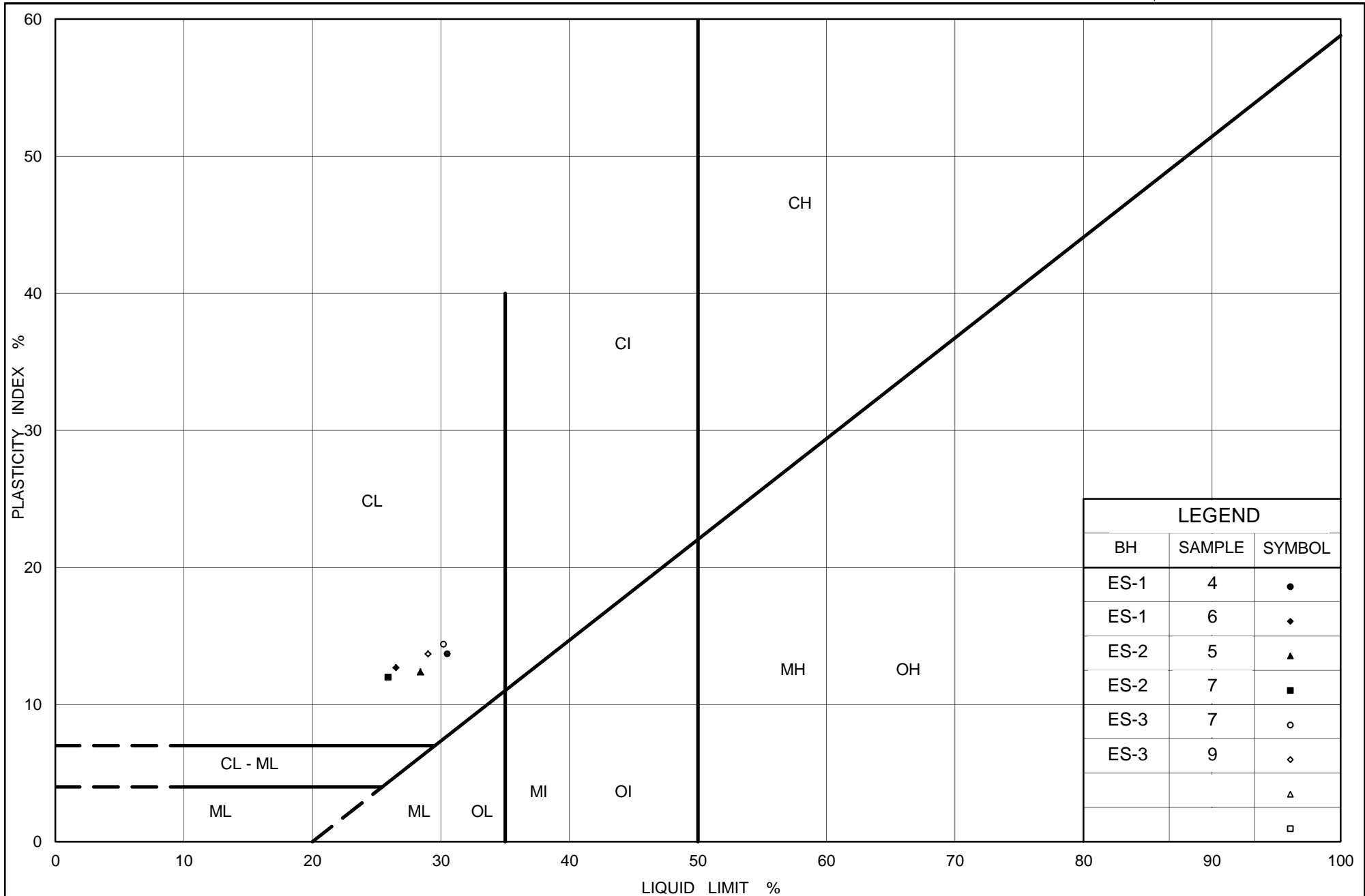
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	ES-1	4	217.5
■	ES-2	5	219.2
◆	ES-1	6	215.9
▲	ES-2	7	217.7
▽	ES-3	7	221.5
○	ES-3	9	219.9

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 11-Feb-14



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt (TILL)

Figure No. D6

Project No. 10-1184-0016

Checked By: TVA



APPENDIX E

Ramp W-N: STA. 10+000 to STA. 10+100 (High Fill Area 5) Record of Boreholes and Laboratory Test Results

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

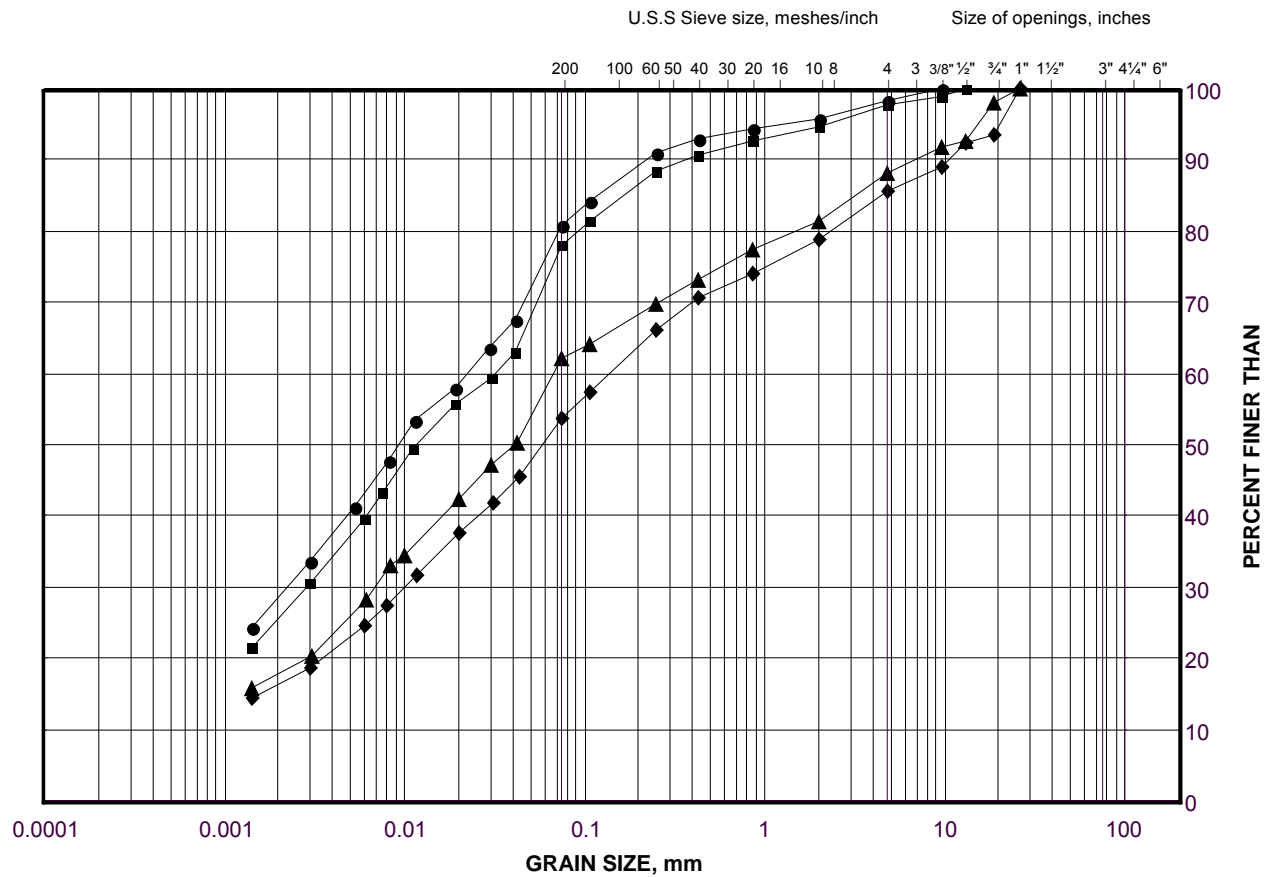
PROJECT 10-1184-0016		RECORD OF BOREHOLE No WN-2		SHEET 1 OF 1		METRIC																		
G.W.P. 2112-05-00		LOCATION N 4797109.9; E 271008.8		ORIGINATED BY JBH																				
DIST HWY 5 & 6		BOREHOLE TYPE 102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM																				
DATUM Geodetic		DATE November 20, 2012		CHECKED BY TVA																				
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																			
223.1	GROUND SURFACE																							
0.0	ASPHALT																							
0.3	Sand and gravel, trace silt (FILL) Brown Moist																							
222.3																								
0.8	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to hard Brown Moist		1	SS	13																			
			2	SS	25																			
			3	SS	37																			
			4	SS	44																			
	with SAND, some gravel																							
218.1			5	SS	16																			
5.0	END OF BOREHOLE																							
	NOTE: 1. Water level in open borehole measured at a depth of 4.4 m below ground surface (Elev. 218.7 m) upon completion of drilling.																							

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

GRAIN SIZE DISTRIBUTION

Clayey Silt to Clayey Silt with Sand (TILL)

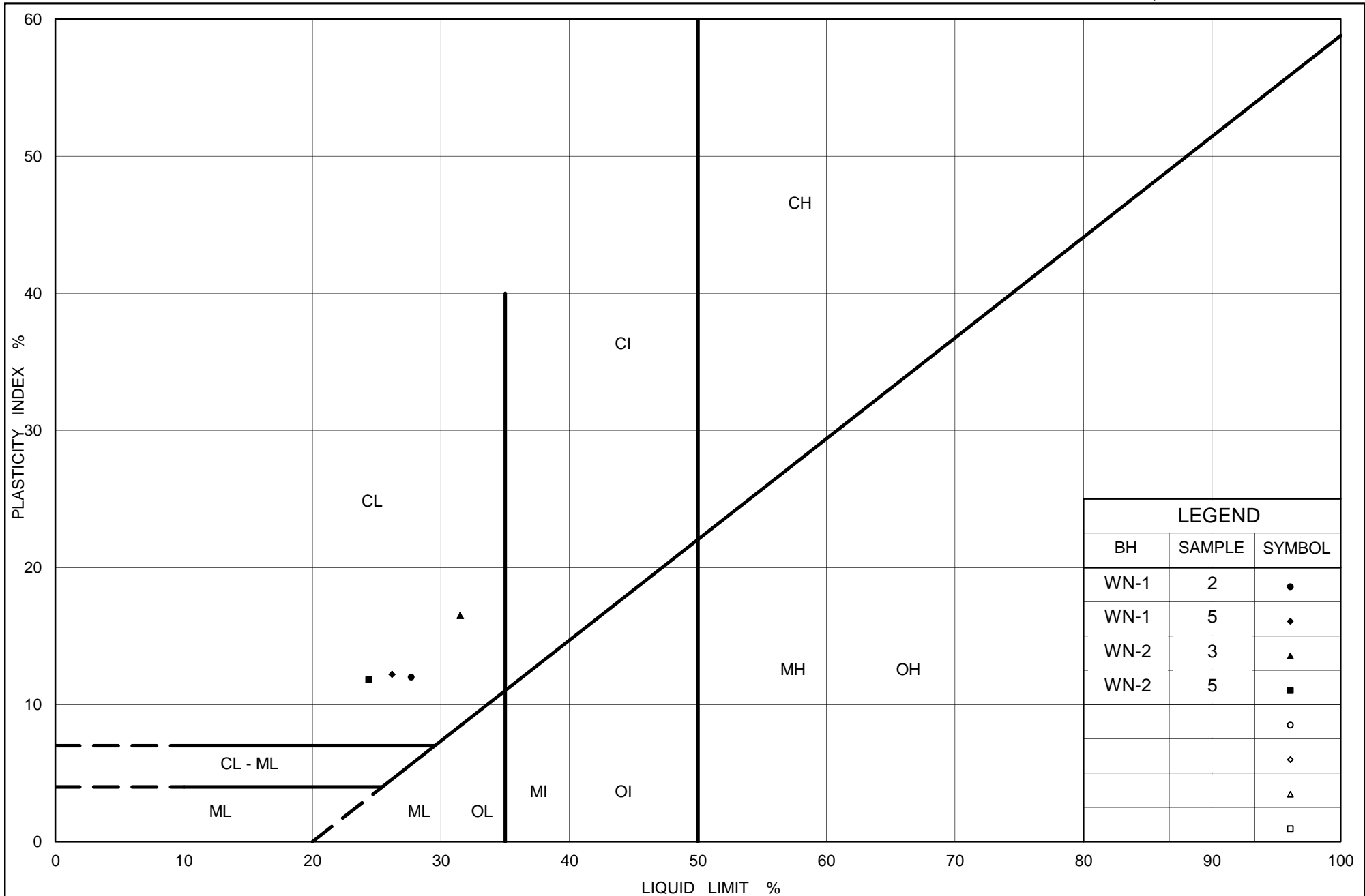
FIGURE E1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	WN-1	2	220.9
■	WN-2	3	220.6
◆	WN-2	5	218.4
▲	WN-1	5	218.9



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt (TILL)

Figure No. E2

Project No. 10-1184-0016

Checked By: TVA



APPENDIX F

Ramp E-N: STA. 10+000 to STA. 10+210 (High Fill Area 6) Record of Boreholes and Laboratory Test Results

PROJECT		10-1184-0016		RECORD OF BOREHOLE No EN-1		SHEET 1 OF 1		METRIC						
G.W.P.		2112-05-00		LOCATION		N 4797131.6; E 270948.2		ORIGINATED BY JBH						
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM						
DATUM		Geodetic		DATE		November 14, 2012		CHECKED BY TVA						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
222.4	GROUND SURFACE													
0.0	TOPSOIL		1	SS	9									
0.3	Clayey silt, sandy, trace gravel (FILL) Stiff Brown Moist		2	SS	10									1 23 59 17
221.0														
1.4	CLAYEY SILT with SAND, sand layers between depths of 2.3 m and 3.5 m (TILL) Very stiff to hard Brown Moist		3	SS	27									
			4	SS	32									0 34 46 20
			5	SS	28									
			6	SS	25									
			7	SS	20									
217.1	END OF BOREHOLE AUGER REFUSAL INFERRED BEDROCK													
5.3	NOTE: 1. Water level in open borehole measured at a depth of 4.7 m below ground surface (Elev. 217.7 m) upon completion of drilling.													

PROJECT		10-1184-0016		RECORD OF BOREHOLE No EN-2		SHEET 1 OF 1		METRIC																
G.W.P.		2112-05-00		LOCATION		N 4797125.7 ; E 270923.8		ORIGINATED BY JBH																
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM																
DATUM		Geodetic		DATE		November 14, 2012		CHECKED BY TVA																
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						60	80	100	20	40	60	80	100	10	20
222.2	GROUND SURFACE																							
0.0	TOPSOIL																							
0.2	Clayey silt with sand, trace gravel (FILL) Stiff Brown Moist		1	SS	11																			
			2	SS	9																			
220.8																								
1.4	CLAYEY SILT, trace to some sand, trace gravel (TILL) Very stiff to hard Brown Moist		3	SS	19																			
			4	SS	31																			
			5	SS	28																			
			6	SS	40																			
			7A 7B	SS	48																			
216.9	Wet																							
5.3	END OF BOREHOLE AUGER REFUSAL INFERRED BEDROCK																							
	NOTE: 1. Water level in open borehole measured at a depth of 4.8 m below ground surface (Elev. 217.4 m) upon completion of drilling.																							

PROJECT		10-1184-0016		RECORD OF BOREHOLE No EN-3		SHEET 1 OF 1		METRIC								
G.W.P.		2112-05-00		LOCATION		N 4797126.1 ; E 270902.9		ORIGINATED BY JBH								
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM								
DATUM		Geodetic		DATE		November 19, 2012		CHECKED BY TVA								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
222.1	GROUND SURFACE															
0.0	TOPSOIL															
0.2	Sandy silt, trace clay, trace organics and pieces of brick (FILL)		1	SS	9											
221.4	Loose Dark brown to brown Moist		2	SS	5											
0.7	Clayey silt, trace to with sand, trace gravel, trace organics, sand pockets and topsoil between depths of 1.0 m and 1.1 m (FILL)		3	SS	12											
220.0	Firm to stiff Brown Moist		4	SS	26											
2.1	CLAYEY SILT, sandy to some sand, trace to some gravel (TILL) Very stiff to hard Brown Moist		5	SS	31											
			6	SS	37											
			7A 7B	SS	19											
216.8	END OF BOREHOLE AUGER REFUSAL INFERRED BEDROCK															
5.3	NOTE: 1. Water level in open borehole measured at a depth of 4.1 m below ground surface (Elev. 218.0 m) upon completion of drilling.															

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

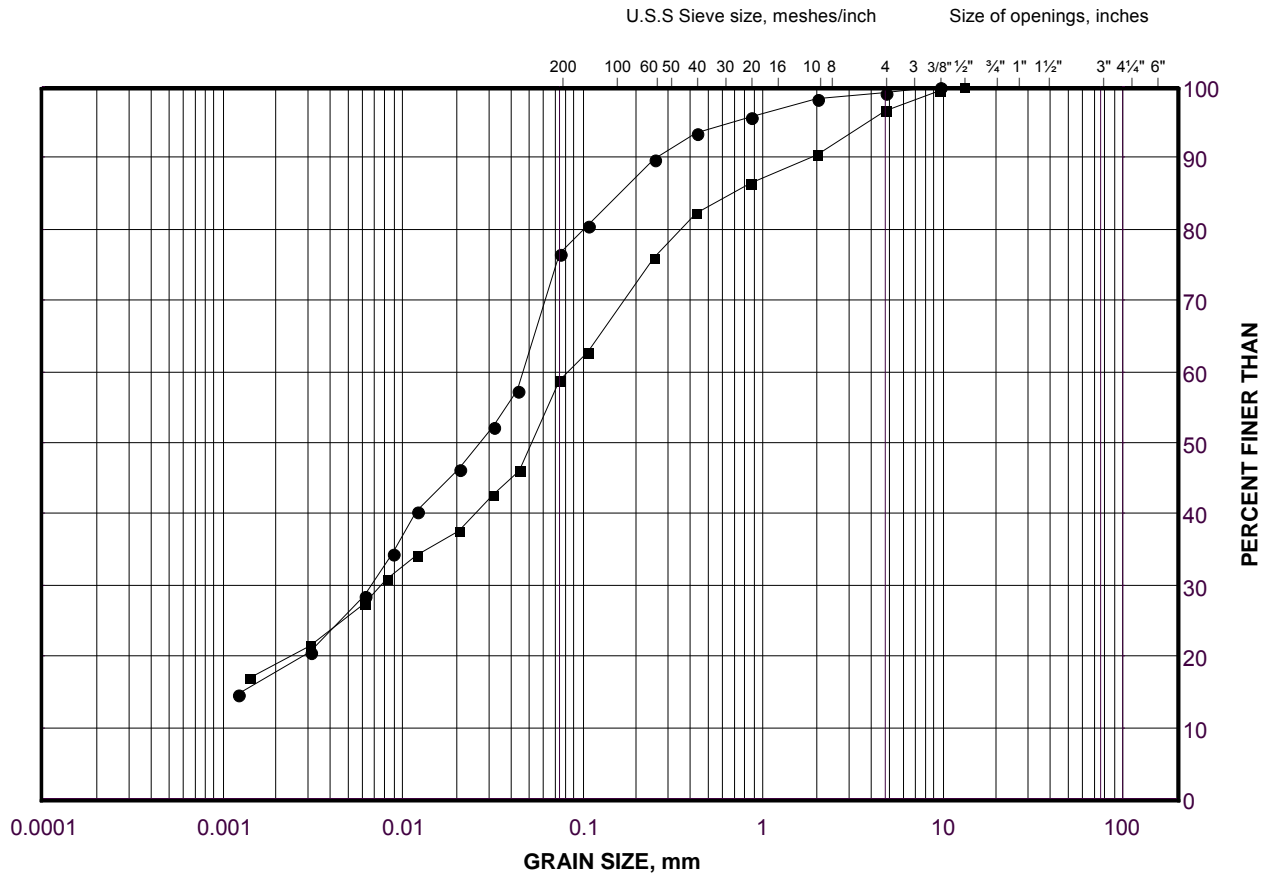
PROJECT		10-1184-0016		RECORD OF BOREHOLE No EN-4		SHEET 1 OF 1		METRIC						
G.W.P.		2112-05-00		LOCATION		N 4797134.5; E 270875.4		ORIGINATED BY JBH						
DIST		HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY BM						
DATUM		Geodetic		DATE		November 19, 2012		CHECKED BY TVA						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
222.2	GROUND SURFACE													
0.0	TOPSOIL													
0.2	Clayey silt with sand, trace gravel, asphalt pieces (FILL) Firm to stiff Brown to dark brown Moist		1	SS	12									
			2	SS	5									3 38 40 19
220.7														
1.5	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Brown to grey Moist		3	SS	20									
			4	SS	25									
			5	SS	40									
			6	SS	27									3 19 51 27
			7	SS	16									
			8	SS	10/0.08									
216.8	END OF BOREHOLE SPOON BOUNCING AND AUGER REFUSAL INFERRED BEDROCK													
5.4	NOTE: 1. Borehole dry upon completion of drilling. 2. WATER LEVEL READINGS: Date Depth (mm) Elev. (m) 11/23/12 4.3 217.9 01/22/13 2.1 220.1 02/07/13 2.6 219.6 02/13/13 2.4 219.8													

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 11/18/14 DD

GRAIN SIZE DISTRIBUTION

Clayey Silt to Clayey Silt with Sand (FILL)

FIGURE F1



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

LEGEND

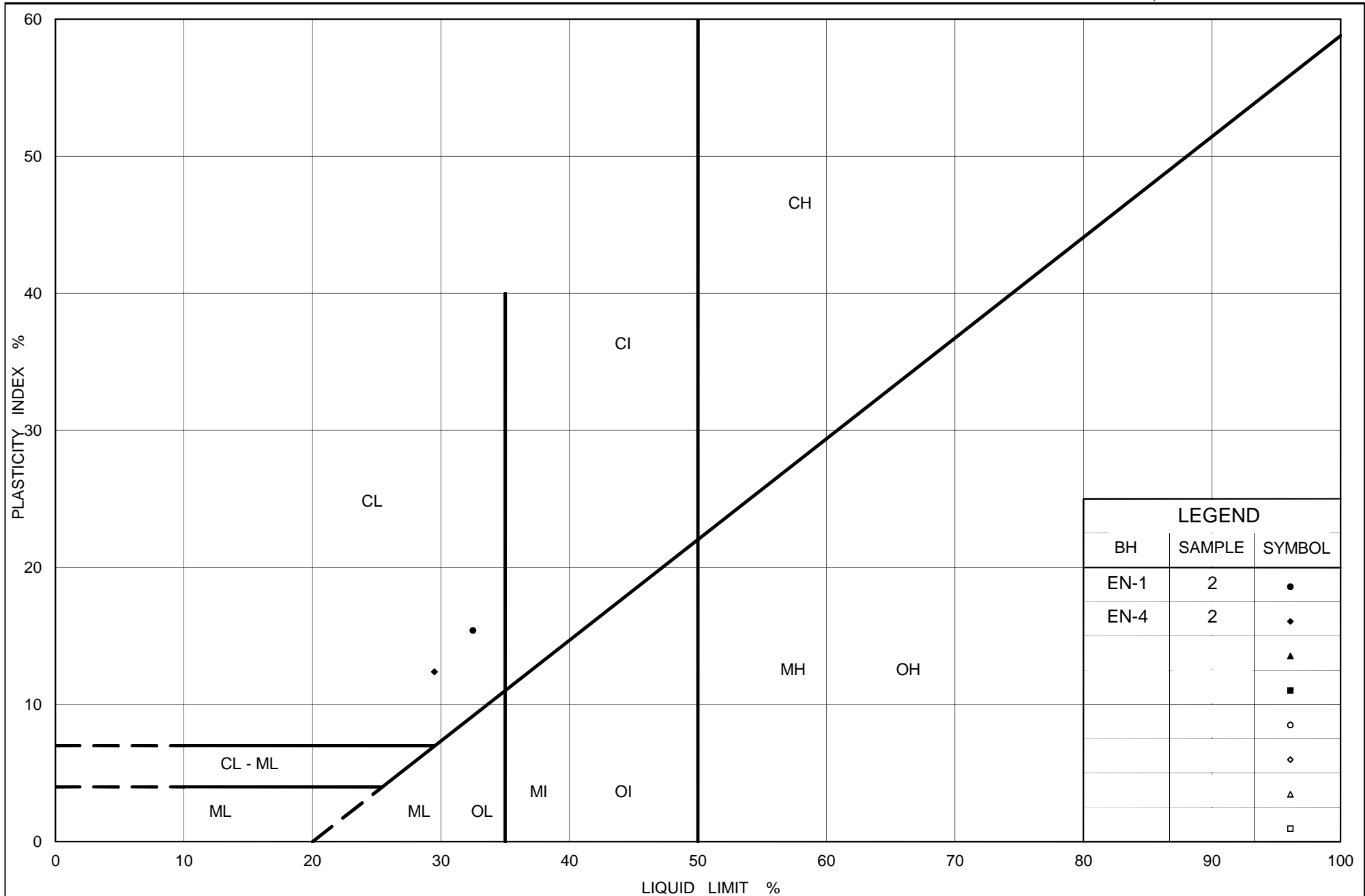
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	EN-1	2	221.4
■	EN-4	2	221.3

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 11-Feb-14



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Clayey Silt with Sand (FILL)

Figure No. F2

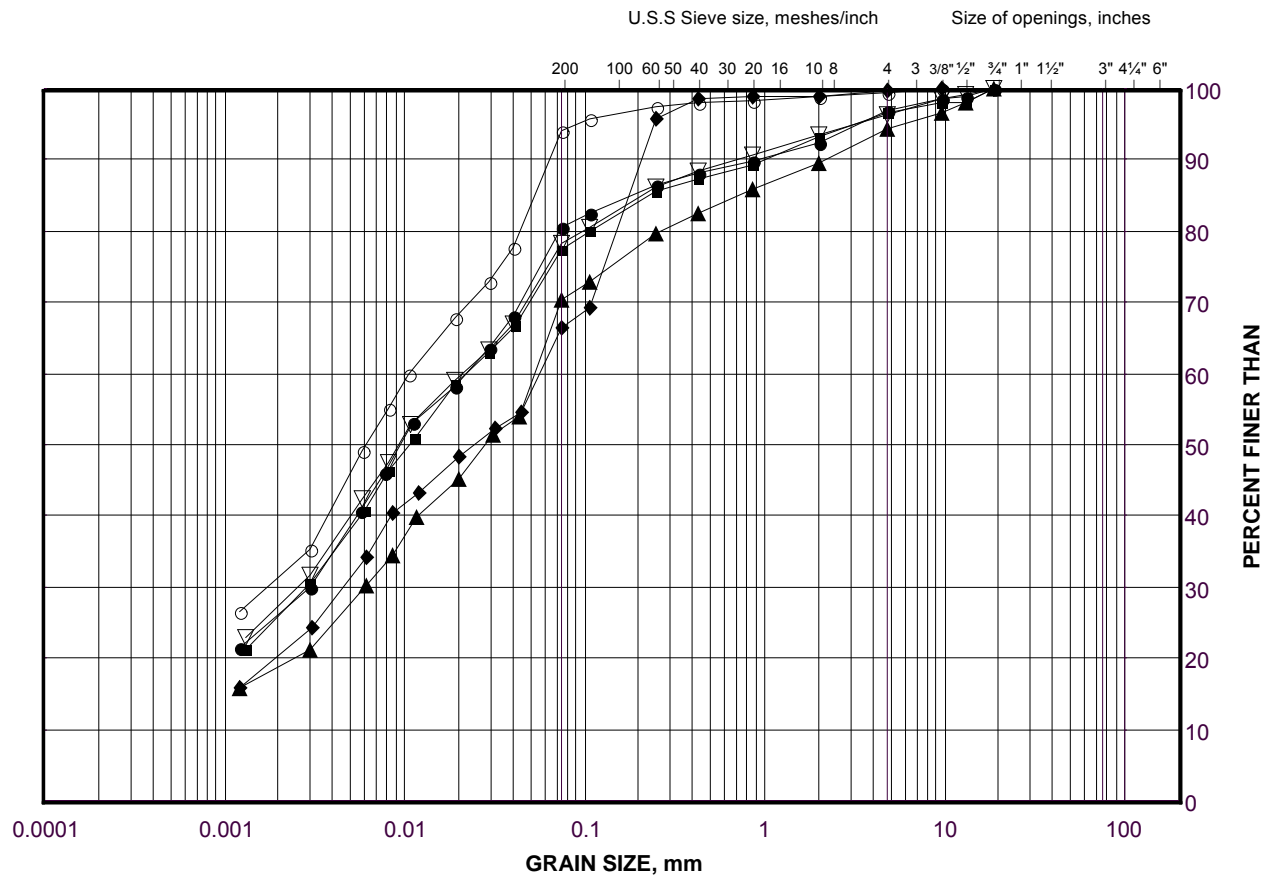
Project No. 10-1184-0016

Checked By: TVA

GRAIN SIZE DISTRIBUTION

Clayey Silt to Clayey Silt with Sand (TILL)

FIGURE F3



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

LEGEND

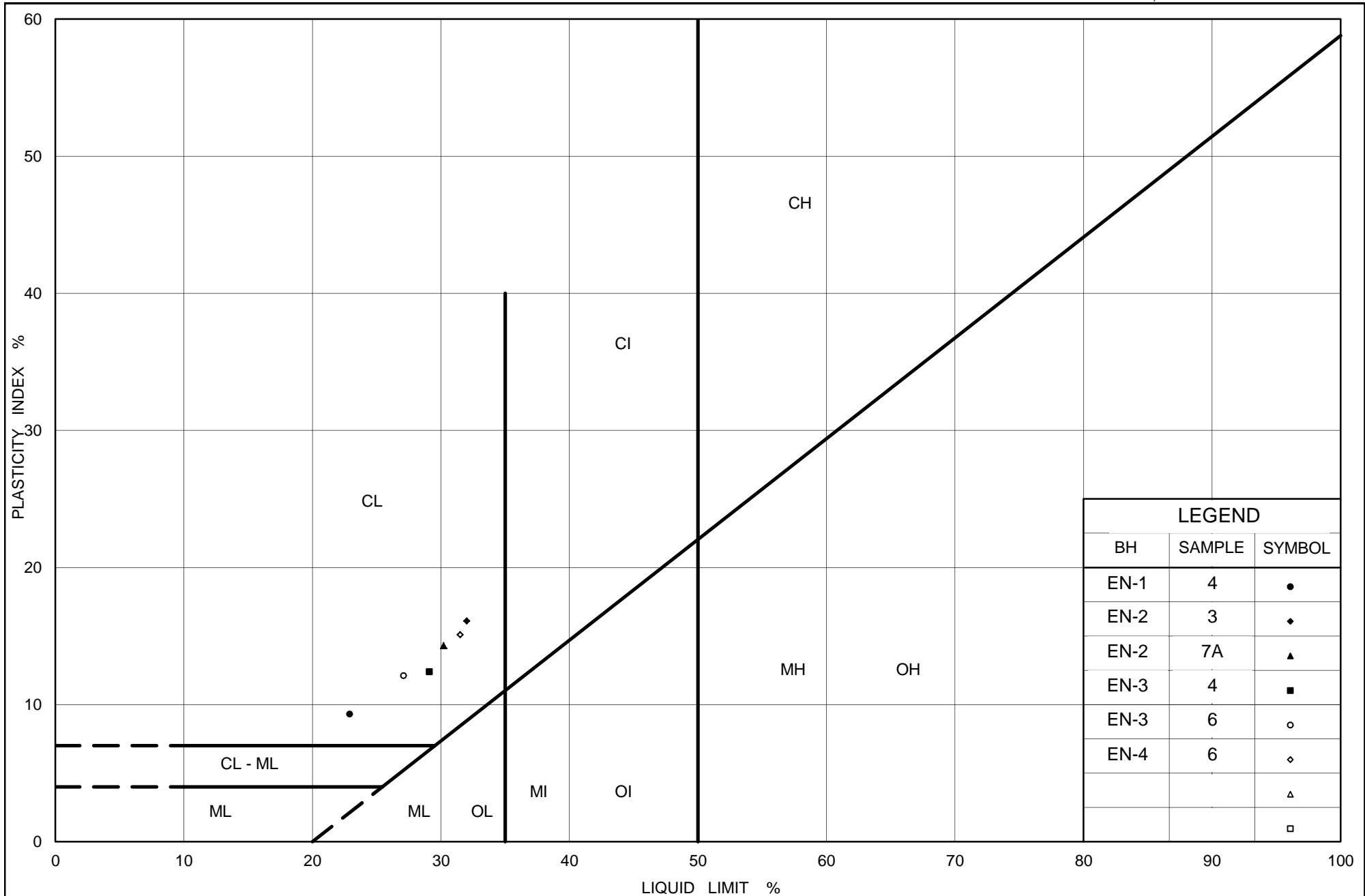
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	EN-2	3	220.5
■	EN-3	4	219.6
◆	EN-1	4	219.8
▲	EN-3	6	218.1
▽	EN-4	6	218.2
○	EN-2	7A	217.5

Project Number: 10-1184-0016

Checked By: TVA

Golder Associates

Date: 12-Feb-14



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Clayey Silt with Sand (TILL)

Figure No. F4

Project No. 10-1184-0016

Checked By: TVA



APPENDIX G

Non-Standard Special Provisions

SUBGRADE INSPECTION AT HIGH FILL EMBANKMENTS - Item No.

Non-Standard Special Provision

High Fill Embankments are located at Area 1 (STA. 29+850 to 29+960), Area 2 (STA. 30+040 to 30+120), Area 3 (STA. 10+000 to 10+140), Area 4 (STA. 10+000 to 10+100), Area 5 (STA. 10+000 to 10+100) and Area 6 (STA. 10+000 to 10+210).

The measured depth of topsoil/asphalt and existing fill layers containing organics that are to be stripped from the high fill areas is up to about 4.4m below ground surface. The plan limits of areas to be stripped are provided elsewhere in the Contract.

After stripping, the exposed subgrade soil shall be inspected by the Quality Verification Engineer (QVE) prior to placement of embankment fill, proofrolled to identify soft / loosened areas, and any poorly performing areas should be subexcavated and replaced with suitable backfill.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

\\\\golder.gds\\gal\\whitby\\active_2010\\1184 pavements materials\\10-1184-0016 giffels ibi hwy 5 and 6 hamilton_foundations\\7 - reports\\draft\\high fill areas\\appendices\\appendix
g\\10-1184-0016 nssp subgrade inspection.docx

OBSTRUCTIONS

Non-Standard Special Provision

The Contractor shall be aware that the existing granular fill (comprised of sandy silt to sand and gravel) and the native clayey silt to clayey silt with sand till deposit encountered at the high fill sites contain cobbles and boulders as inferred from grinding of augers and SPT sampler during borehole drilling, as detailed in the Record of Borehole sheets.

Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for sub-excavation and grading at the high fill areas.

END OF SECTION

\\golder.gds\gal\whitby\active_2010\1184 pavements materials\10-1184-0016 giffels ibi hwy 5 and 6 hamilton_foundations\7 - reports\draft\high fill areas\appendices\appendix
g\10-1184-0016 nssp obstructions.docx

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario, L5N 7K2
Canada
T: +1 (905) 567 4444

