FINAL REPORT

Foundation Investigation and Design Report

DETAIL DESIGN OF SOUTH INNISFIL CREEK DRAIN
HIGHWAY 400 TRENCHLESS INSTALLATIONS
RECONSTRUCTION OF HIGHWAY 400 / 89 INTERCHANGE
TOWN OF INNISFIL, ONTARIO
MTO ASSIGNMENT NO. 2015-E-0038, GWP 2438-13-00

Submitted to:

Morrison Hershfield Limited
Suite 120, 1005 Skyview Drive
Burlington, Ontario L7P 5B1

Submitted by:

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

LATITUDE: 44.206826°
LONGITUDE: -79.658281°

GEOCRES No. (31D-776)

1668512/7000 Rev.0

August 4, 2021

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO), to provide detailed design foundation investigation for the proposed trenchless installation of new culverts below Highway 400 in the Town of Innisfil, Ontario. Four new culverts are proposed to be located adjacent to the existing twin 4.62 m span corrugated steel pipe (CSP) arch culverts (Culvert Site No. 30-399/C) and existing 2.10 m diameter CSP culvert, as shown on the attached Drawing 1.

The purpose of this investigation was to obtain subsurface soil and shallow groundwater information at the site by means of a limited number of boreholes and geotechnical laboratory testing. The factual data contained in this report pertains to a specific project as described herein and is not applicable to any other project or site location. If the project is modified in concept, location or elevation, Golder should be given an opportunity to confirm that the information provided in this report is still valid.

2.0 PROJECT AND SITE DESCRIPTION

The site of the existing and proposed new culverts is located on Highway 400, about 800 m north of the Highway 400/89 Interchange. A golf course is located to the east of Highway 400 and agricultural lands are located to the west of Highway 400. Reive Boulevard, which is aligned in a north/south direction and runs parallel to Highway 400, is located directly east of Highway 400 and is owned and maintained by the Town of Innisfil.

The culverts crossing Highway 400 at this location facilitate the drainage of the South Innisfil Creek, which flows southwest from Innisfil, crosses Highway 400 and then extends southwest before connecting with Bailey Creek in New Tecumseth. The creek at this location is referred to as the South Innisfil Creek Drain (SICD).

The proposed new culverts are required to accommodate modifications / lowering of the SICD and provide additional hydraulic capacity to convey the 2-year storm event across Highway 400. There are three existing culverts that run below Highway 400 at the site (twin 4.62 m span CSP arch culverts and one 2.1 m diameters CSP culvert). The twin 4.62 m CSP arch culverts were extended to the west in late 2020 as part of MTO’s Highway 400/89 construction contract, as shown on Drawing 1.

To the east, the SICD watercourse has been slightly realigned to pass under a new bridge on Reive Boulevard. (constructed in late 2020 / early 2021 by the Town of Innisfil) and three culverts that previously allowed the SICD to flow beneath Reive Boulevard. have been removed. At the time of this report, it is understood that construction of the bridge and the SICD channel realignment/restoration is complete.

Based on the design drawings provided in April 2021 by MH titled “*Proposed Channel Grading*” for the Highway 400 and SICD improvements, the proposed trenchless installations consist of four 1.9 m inner diameter culverts between approximately 51 m and 66 m in length. Referring to Drawing 1, one new culvert is to be located north of the existing 2.1 m diameter culvert and three new culverts are to be located south of the existing twin arch culverts.

Along the proposed trenchless alignments, the topography indicates Highway 400 has been constructed as a raised embankment (about 1 m to 2.5 m above the adjacent ground) with the highway grade at about Elevation 227.7 m to 228.8 m and the adjacent ground surface near the embankment toes ranging from about Elevation 225.1 m to 227.2 m. The creek/watercourse invert near the existing culverts is at about Elevation 223.5 m on west (outlet) side and about Elevation 224 m to 224.5 m on the east (upstream) side. The proposed new culverts will be slightly lower and have an invert at about Elevation 222.5 m.

3.0 EXPLORATION PROCEDURES

3.1 Previous 2000 Geotechnical Investigation

A preliminary foundation investigation was carried out by Golder in 2000 for five culverts crossing Highway 400 between Highway 11 and 89. The results of this investigation are contained in a report titled:

- "Preliminary Foundation Investigation and Design Report, Culverts, Structure Sites 30-399, 571, 572, 573 & 415, Highway 400 Widening from 1 km South of Highway 89 to Highway 11, G.W.P. 30-95-00, Agreement No. 3005-A-000074", dated December 2001, Golder Associates Ltd. (GEOCRES No. 31D00-482).

Two relevant boreholes from this investigation, designated as Boreholes C-1 and C-2, were advanced on the west and east sides of the Highway 400 lanes near the twin arch culverts. The borehole locations are shown on Drawings 1 and 2, and the borehole records and laboratory testing results are presented in Appendix A.

3.2 Previous 2019 Geotechnical Investigation (Reive Boulevard)

A previous geotechnical investigation was performed by Peto MacCallum Ltd. on behalf of the Town of Innisfil along Reive Boulevard. As part of the investigation, two boreholes were advanced for the design of the new bridge over the SICD. The boreholes, designated BH 1 and BH 2, were located north and south of the three existing culverts crossing under Reive Boulevard in the vicinity of the SICD. The Town of Innisfil provided a copy of the borehole location plan and the borehole logs which are included in Appendix A.

The boreholes (BH 1 and BH 2) are shown on Drawing 1 for information purposes and are located outside of the proposed trenchless operations for this project.

3.3 Previous 2018 Geotechnical Investigation

Golder completed a geotechnical investigation in 2018 as part of the current assignment for detail design of the culvert extensions to the twin arch culverts (Site 30-399/C) associated with the reconstruction of the Highway 400 / 89 interchange and the results are presented in the following report:

- "Foundation Investigation and Design Report for Culvert Extensions (Structure Site Nos. 30-399/C and 30-568/C), Reconstruction of Highway 400/89 Interchange, G.W.P. 2438-13-00" dated August 2018, prepared by Golder Associates Ltd. (GEOCRES No. 31D-708).

Boreholes CE-05 to CE-08 were advanced on the west side of Highway 400, north and south of the existing three culverts. The locations of these boreholes are shown on Drawings 1 and 2. The borehole records and geotechnical laboratory testing results are presented in Appendix B and C, respectively.

3.4 Current Borehole Investigation

The most recent borehole exploration was carried out by Golder between January 15 and February 1, 2021 during which time ten boreholes (designated as Boreholes CR-01 to CR-10) were advanced in the vicinity of the proposed trenchless crossing alignments. The locations of these boreholes are shown on Drawings 1 and 2. The borehole records and geotechnical laboratory testing results are presented in Appendix B and C, respectively.

The current Golder investigation was carried out using a D90 track- or truck-mounted drill rig supplied and operated by Walker Drilling of Utopia, Ontario. Boreholes were advanced 210 mm outer diameter (108 mm inner diameter) hollow stem augers. Soil samples were generally obtained at 0.75 m and 1.5 m intervals, however, samples were obtained at 0.6 m intervals (i.e. continuously) between the depths of about 3.0 m and 6.7 m which was estimated to be within the anticipated tunnel profile. Soil samples were obtained using nominal 50 mm outside diameter and

35 mm inside diameter split-spoon samplers driven by an automatic hammer mounted on the drill rig, performed in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586[1]). Considering the inside diameter of the split-spoon samplers, soil particles larger than 35 mm are not retrievable.

To permit monitoring of the groundwater levels at the site, a standpipe piezometer was installed in Boreholes CR-04, CR-05, CR-07 and CR-09. The piezometers consist of a 50 mm diameter PVC pipe with a slotted screen sealed within a sand filter pack. The borehole and annulus surrounding the pipe above the sand pack was filled with bentonite, topped with a mixture of sand and cement at grout surface and secured within either a flush-mount casing or monument casing. The remaining boreholes were backfilled upon completion of drilling in general accordance with Ontario Regulation 903 Wells (as amended); and the highway pavement surface was re-instated with cold patch asphalt at Boreholes CR-01, CR-02 and CR-08.

Field work was observed on a full-time basis by a member of Golder's engineering staff who arranged for the clearance of underground utilities through public agencies, supervised the sampling and in situ testing operations, and logged the boreholes. The samples were transported to Golder's geotechnical laboratory for additional review and classification testing on selected samples; selected samples were also submitted to Bureau Veritas for analytical testing of corrosion-related parameters.

The borehole locations and ground surface elevations for Boreholes CR-01 to CR-10 were obtained using a GPS unit (Trimble Geo 7x), having a horizontal accuracy of approximately 0.02 m and a vertical accuracy of approximately 0.02 m. The locations provided on the Borehole Records in Appendix B and shown on Drawings 1 and 2 are relative to the MTM NAD83 Zone 10 coordinate system and the ground surface elevations are referenced to CGVD28 Geodetic datum benchmark.

The location, ground surface elevation, and drilled depth for the relevant boreholes (current and previous investigations) are summarized in the table below.

Reference Investigation	Borehole Designation	MTM NAD83 Zone 10 (Geographic)		Ground Surface Elevation (m)	Total Borehole Depth (m)
		Northing, m (Latitude, °)	Easting, m (Longitude, °)		
Golder, 2000	C-1	4896326.9 (44.206842)	292177.2 (-79.657948)	226.5	9.6
	C-2	4896322.8 (44.206804)	292130.0 (-79.658539)	227.2	9.8
Golder, 2018	CE-05	4896321.52 (44.206792)	292123.53 (-79.658620)	227.2	15.9
	CE-06	4896292.80 (44.206534)	292139.56 (-79.658418)	226.9	15.9
	CE-07	4896324.81 (44.206820)	292137.66 (-79.658400)	228.8	8.2

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

Reference Investigation	Borehole Designation	MTM NAD83 Zone 10 (Geographic)		Ground Surface Elevation (m)	Total Borehole Depth (m)
		Northing, m (Latitude, °)	Easting, m (Longitude, °)		
	CE-08	4896299.57 (44.206600)	292146.44 (-79.658300)	228.7	17.4
Golder, 2021	CR-01	4896309.71 (44.206687)	292161.23 (-79.658148)	228.5	14.3
	CR-02	4896344.26 (44.206997)	292144.35 (-79.658360)	228.6	14.3
	CR-03	4896317.22 (44.206754)	292179.89 (-79.657914)	226.0	12.8
	CR-04	4896350.72 (44.207056)	292158.96 (-79.658177)	227.6	14.3
	CR-05	4896326.62 (44.206839)	292185.36 (-79.657846)	225.1	12.8
	CR-06	4896366.74 (44.207200)	292167.44 (-79.658071)	226.7	12.8
	CR-07	4896285.01 (44.206464)	292149.82 (-79.658290)	228.9	14.3
	CR-08	4896294.58 (44.206550)	292162.31 (-79.658133)	228.5	14.3
	CR-09	4896303.65 (44.206632)	292175.91 (-79.657964)	228.4	14.3
	CR-10	4896315.69 (44.206741)	292188.05 (-79.657812)	225.5	12.8

4.0 SUBSURFACE CONDITIONS

4.1 Regional Geology

The project area is located within the Peterborough Drumlin Field physiographic region, as delineated in The Physiography of Southern Ontario (Chapman and Putman, 1984)[2]. The surficial soils in the Peterborough Drumlin Field consist primarily of gravelly sand till or sand and gravel deposits. Drumlins (glacially-shaped hills) are more frequent in the southern portion of the section of the Peterborough Drumlin Field traversed by Highway 400. Deposits of silt, clay or peat may be found in the low-lying areas between drumlins. The Lindsay and Verulam Formations which underly the Peterborough Drumlin Field consists mainly of fossiliferous limestone.

[2] Chapman, L.J. and Putman, D.F., 1984, The Physiography of Southern Ontario, Ontario Geological Society, Special Volume 2, Third Edition. Accompanied by Map p. 2715, Scale 1:600,000.)

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the relevant boreholes advanced during the current and previous investigations are presented on the borehole records provided in Appendix A and B. The borehole records also present details of the standpipe piezometer installations and water level readings, and the results of geotechnical laboratory testing. Lists of abbreviations and symbols are provided in Appendix A and B to assist in the interpretation of the borehole records. The results of the in-situ field tests (i.e. SPT "N"-values) as presented on the borehole records and in this section are uncorrected. The geotechnical laboratory testing plots are contained in Appendix C. The results of the analytical testing of soil samples by Bureau Veritas Laboratories (BVL) are presented in Appendix D and summarized in Section 4.4.

The stratigraphic boundaries shown on the borehole records and on the stratigraphic profile on Drawings 1 and 2 are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs, and therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations.

Based on the boreholes advanced north and south of the existing culverts, the subsurface conditions generally consist of cohesive and granular embankment fill underlain by a clayey silt layer (characterized as glacial till or lacustrine deposit with till-like grain size distributions) with saturated layers / interlayers of sandy silt to silty sand, silt, and sand, underlain by a deposit of clayey silt. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Topsoil

An approximately 0.3 m to 1.0 m thick layer of topsoil was encountered at ground surface in Borehole C-1, C-2, CE-05, CE-06, CR-03, CR-05, CR-06, and CR-10.

The SPT "N"-values measured within the topsoil ranged from 3 blows to 18 blows per 0.3 m of penetration, suggesting a soft to very stiff consistency / very loose to compact level of compactness.

4.2.2 Asphalt

An approximately 216 mm to 250 mm thick layer of asphalt was encountered at the road surface of Highway 400 in Boreholes CE-07, CE-08, CR-01, CR-02, CR-04, CR-08, and CR-09.

4.2.3 Silt to Sand and Gravel (Fill)

A 1.2 m to 4.9 m thick layer of non-cohesive fill, comprised of silt to sand and gravel was encountered underlying the topsoil in Borehole CE-05; below the asphalt in Boreholes CE-07, CE-08, CR-01, CR-02, CR-04, CR-08 and CR-09; underlying the clayey silt fill in Boreholes CR-03 and CR-10; and at surface in Borehole CR-07. The non-cohesive fill layer extended to depths ranging from 1.7 m to 4.9 m below ground surface (Elevation 227.1 m to 222.3 m). The silt to sand and gravel fill was observed to be interlayered with clayey silt fill in Boreholes CR-04 and CR-07. Trace organics / rootlets were observed within the cohesionless fill samples in Boreholes CR-03, CR-07, CR-09, and CR-10. In Borehole CR-07, wood pieces were encountered within the fill deposit below a depth of 4.3 m (Elevation 224.6 m).

The SPT "N"-values measured within the non-cohesive fill ranged from 2 blows to 71 blows per 0.3 m of penetration, indicating a very loose to very dense level of compactness. It is noted that the higher "N"-values were typically encountered at shallow depth in the Winter months and may have been partially frozen at the time of sampling.

The water content measured on samples of the non-cohesive fill ranged from about 2% to 49%, but values were generally less than 25%. The higher water contents were measured in the fills that were observed to contain organics. An organic content test was carried out on a sample of the non-cohesive fill in Borehole CR-09 (identified as containing organics) and measured an organic content of about 5%, indicating portions of the non-cohesive fill contain trace organics.

The results of grain size distribution testing carried out on eleven samples of the granular fill are shown on Figure C1A and C1B in Appendix C.

Atterberg limits testing was carried out on three samples of the non-cohesive fill. The results of one test indicate the fill is non-plastic and the remaining two tests measured liquid limits of about 14%, plastic limits of about 11% and 12%, and plasticity indices of about 2% and 3%. The Atterberg limits test results are shown on Figure C2 in Appendix C and indicate that portions of the sandy silt to silty sand fill are slightly plastic but generally non-plastic.

4.2.4 Clayey Silt to Clayey Silt-Silt and Sand (Fill)

A 0.3 m to 3.9 m thick layer of cohesive fill, comprised of clayey silt to clayey silt-silt and sand was encountered underlying the topsoil in Boreholes C-1, C-2, CE-06, CR-03 and CR-10; underlying the non-cohesive fill in Boreholes CR-01and CR-08; and interlayered within the non-cohesive fill in Boreholes CR-04 and CR-07. The cohesive fill layer extended to depths ranging from 1.0 m to 4.3 m below ground surface (Elevation 226.2 m to 224.1 m). The cohesive fill contained variable amounts of sand but was generally sandy. Trace organics were encountered in Boreholes C-1, CR-7 and CR-8 and wood pieces were observed in samples of the cohesive fill in Borehole CR-8.

The SPT “N”-values measured within the cohesive fill range from 4 blows to 24 blows per 0.3 m of penetration suggesting a firm to very stiff consistency. One higher SPT “N”-value of 58 blows per 0.3 m of penetration was measured at one location near ground surface in the Winter and may have been frozen.

The water content measured on samples of the cohesive fill ranged from about 13% to 35%.

The results of grain size distribution testing carried out on five samples of the cohesive fill are shown on Figure C3 in Appendix C.

Atterberg limits testing was carried out on four samples of the cohesive fill and measured liquid limits ranging from about 17% to 34%, plastic limits ranging from about 11% to 29%, and plasticity indices ranging from about 4% to 8%. The Atterberg limits test results are summarized on Figure C4 in Appendix C and indicate the cohesive fill is generally a clayey silt of low plasticity. One sample was classified as a silt of slight plasticity.

4.2.5 Organic Silt to Sandy Organic Silt / Peat

A 0.2 m to 2.0 m thick deposit of organic silt to sandy organic silt was encountered below the fill in Boreholes C-1 and CR-03 and below the topsoil in Borehole CR-05. The deposit was described as fibrous peat in the previous investigation (Borehole C-1). The deposit was encountered at depths ranging from 1.0 m to 3.7 m below ground surface (Elevation 224.2 m to 222.3 m) and extended to depths ranging from 3.0 m to 3.9 m below ground surface (Elevations 223.1 to 222.1 m).

The SPT “N”-values measured within the organic deposit generally range from 1 blow to 12 blows per 0.3 m of penetration, with one distinct SPT “N”-value measurement of 66 blows per 0.3 m of penetration in Borehole C-1, generally indicating a very loose to compact level of compactness.

The water content measured on samples of the organic deposit ranged from about 61% to 122%. Organic content tests were conducted on two samples of the organic deposit and measured organic contents of about 6% and 12%.

4.2.6 Upper Clayey Silt to Sandy Clayey Silt-Silt (Till / Till-Like)

A 1.0 m to 8.0 m thick deposit of clayey silt to sandy clayey silt-silt till was encountered below the fill layers in Boreholes C-2, CE-05 to CE-08, CR-02, and CR-04; below the organic deposit in Boreholes CR-03; and interlayered within the sandy silt to silty sand deposit (described in Section 4.2.7) in Boreholes CR-06 to CR-09. Boreholes CE-05 to CE-08 (from the 2018 investigation) interpreted this upper clayey silt layer as a lacustrine deposit with till-like grain size distribution characteristics. Given the similar characteristics, the clayey silt deposit is interpreted as a till in Boreholes CE-05 and CE-07 in the stratigraphic section on Drawing 2 based on the till designation of the same deposit in adjacent boreholes completed during the current investigation. The clayey silt contained cobble fragments in samples collected from Borehole CR-02 and given that the soils are considered to be glacially derived, cobbles and boulders should be expected within the deposit. The cohesive deposit was encountered at depths ranging from 1.5 m to 5.2 m (Elevation 226.5 m to 222.1 m) and extended to depths ranging from 4.9 m to 11.7 m (Elevations 221.6 to 217.0 m). A layer of non-cohesive silt till (0.8 m thick) was encountered above the clayey silt-silt till in Borehole CR-02 at a depth of 2.2 m (Elevation 226.4 m) and extended to a depth of 3.0 m (Elevation 225.6 m).

The SPT “N”-values measured within the cohesive deposit ranged between 11 and 91 blows per 0.3 m of penetration suggesting a stiff to hard consistency. The SPT “N”-value measured within the silt till layer was 20 blows per 0.3 m of penetration indicating a compact level of compactness.

The water content measured on samples of the cohesive deposit ranged from about 11% to 25%.

The results of grain size distribution testing carried out on twenty-one samples of the cohesive deposit are shown on Figure C5A to C5C in Appendix C. The grain size distribution results from Borehole C-2 are shown in Appendix A. The results of the grain size distribution testing indicate a consistent well graded pattern suggesting the deposit is glacially derived.

Atterberg limits testing was carried out on nineteen samples of the cohesive deposit and measured liquid limits ranging from about 16% to 32%, plastic limits ranging from about 12% to 17%, and plasticity indices ranging from about 4% to 17%. The Atterberg limits test results are summarized on Figure C6A to C6C in Appendix C and indicate the deposit is of low plasticity. The Atterberg test results for Borehole C-2 are shown in Appendix A.

The water content measured on a sample of the silt till layer was about 18%. The results of grain size distribution testing carried out on one sample of the silt till layer are shown on Figure C7 in Appendix C.

4.2.7 Silt to Sandy Silt to Silty Sand

A 0.3 m to 8.8 m thick deposit of silt to sandy silt to silty sand was encountered below the topsoil in Borehole CR-06; below the fills in Boreholes CR-01, CR-07, CR-08, CR-09 and CR-10; below the organic soils in Borehole CR-05; and below the cohesive glacial till in Boreholes CE-6, CE-8, CR-02, CR-03 and CR-04. The deposit was encountered at depths ranging from 0.7 m to 8.7 m below ground surface (Elevation 226.0 m to 218.8 m) and extended to depths ranging from about 7.2 m to 13.3 m below ground surface (Elevations 220 to 215.6 m). The sandy silt to silty sand deposit was observed to be interlayered with the clayey silt till in Boreholes CE-8, CR-06, CR-07, CR-08 and CR-09 and within the lower clayey silt layer in CR-05. Interlayers of silt (ranging from 0.4 m to 4.6 m thick) were encountered within the sandy silt to silty sand deposit in Boreholes CR-05 and CR-10, and between the upper and lower clayey silt deposits in Borehole CE-06. The silt layers were encountered at depths ranging from 4.5 m to 6.2 m below ground surface (Elevation 221.3 m to 218.9 m). The sandy silt to silty sand layer contained variable amounts of organics near the interface with the fill layer in Boreholes CR-1, CR-7, CR-8 and CR-9. Sand seams / interlayers were encountered within the silty sand to sandy silt deposit are discussed in the next section.

The SPT “N”-values measured within the silt to sandy silt to silty sand ranged between 3 and 49 blows per 0.3 m of penetration indicating a very loose to dense state of compactness.

The water content measured on samples of the silt to sandy silt to silty sand deposit ranged from about 16% to 45%. The higher water contents were typically measured on samples that contained organics and/or clayey silt interlayers near the interface with the overlaying fill layer in Boreholes CR-01, CR-07, CR-08 and CR-09. Organic content tests were carried out on two samples of the sandy silt to silty sand deposit containing organics in Boreholes CR-01 and CR-07 and measured an organic content of about 4%.

The results of grain size distribution testing carried out on fourteen samples of the sandy silt to silty sand are shown on Figures C8A to C8C in Appendix C. The results of grain size distribution testing carried out on five samples of the silt interlayers are shown on Figure C9 in Appendix C.

Atterberg limits testing carried out on one sample of the silt and sand in Borehole CE-08 was non-plastic. Atterberg limits testing carried out on three samples of the silt interlayers measured liquid limits of about 16% to 19%, plastic limits of about 14% to 16%, and plasticity indices of about 1% to 4%. The Atterberg limits test results are summarized on Figure C10 in Appendix C and indicate the silt interlayers are slightly plastic.

4.2.8 Sand - Interlayers

Sand seams / interlayers (ranging from less than 0.1 m to 3.9 m thick) were encountered in Boreholes C-1, CE-05, CE-07, CE-08, CR-01, CR-03, CR-09 and CR-10. The sand seams / interlayers were encountered within the sandy silt to silty sand deposit in Boreholes CR-01, CR-03, CR-09 and CR-10; below the organic deposit in Borehole C-1; and within the clayey silt deposits in Boreholes CE-05, CE-07 and CE-08. Sand seams were encountered in the silty sand layer below the fill deposit in Boreholes CR-09 and CR-10. The top of the sand layers at the other boreholes were encountered at depths ranging from 3.4 m to 12.7 m (Elevation 223.1 m to 216.0 m) and extended to depths ranging from 7.2 m to 13.3 m below ground surface (Elevations 221.3 m to 215.4 m). Borehole CE-07 was terminated within the sand interlayer at a depth of 8.2 m (Elevation 220.6 m) after penetrating for a thickness of 1.0 m.

The SPT “N”-values measured within the sand interlayers ranged between 4 and 80 blows per 0.3 m of penetration indicating a very loose to very dense level of compactness.

The water content measured on samples of the sand ranged from about 16% to 20%, with one higher value of about 31% measured on a sample that contained trace organics.

The results of grain size distribution testing carried out on seven samples of the sand seams / interlayers are shown on Figure 1 in Appendix A and Figure C11 in Appendix C.

Atterberg limits testing was carried out on two samples of the sand seam / interlayer and showed that the sand is non-plastic.

4.2.9 Lower Clayey Silt to Clayey Silt-Silt

A lower deposit of clayey silt to clayey silt-silt was encountered below the sandy silt to silty sand deposit in Boreholes CE-08 and CR-01 to CR-10; and below the sand and silt interlayers in Boreholes C-1, CE-05 and CE-06. The deposit was previously designated as a till in Borehole C-1 from the previous investigation but has been reclassified as a lacustrine deposition (i.e. not a glacial till) based on additional information (well sorted grain size characteristics of samples at similar elevations) from adjacent boreholes from the current investigation. The top of the clayey silt to clayey silt-silt layer was generally encountered at depths ranging from 7.2 m to 13.3 m below ground surface (Elevation 220.0 m to 215.6 m), with the exception of Borehole CR-5 which contained thin interlayers

(0.1 m to 1.3 m thick) of clayey silt, silty sand, silt, and gravelly clayey sand from a depth of about 3 m to 7.2 m below ground surface before transitioning into a more homogenous lower clayey silt deposit at depth. All boreholes which encountered the clayey silt to clayey silt-silt deposit were terminated within the deposit at depths ranging from 9.6 m to 17.4 m (Elevations 216.9 m to 211.1 m) after penetrating the deposit for thicknesses between 1.0 m and 8.7 m. As described previously, various interlayers of sand and silt were encountered within the clayey silt to clayey silt-silt deposit as indicated in the table below.

Borehole I.D.	Soil Description	Elevation (m)	Thickness (m)
CR-05	Gravelly Clayey Sand	221.5 – 221.1	0.4
CR-05	Silt	220.6 – 220.2 218.9 – 217.9	0.4 1.0
CE-05	Sand	217.0 – 216.5	0.5
CE-06	Silt	221.3 – 216.7	0.4 – 4.7
CE-08	Sand	216.0 – 215.4	0.6

The SPT “N”-values measured within the clayey silt to clayey silt-silt deposit ranged between 14 and 83 blows per 0.3 m suggesting a stiff to hard consistency. One SPT “N”-value of 111 was measured at the bottom of the deposit in Borehole C-1 where sand seams/partings were encountered. The SPT “N”-value measured within the cohesive gravelly clayey sand interlayer was 25 blows per 0.3 m of penetration suggesting a very stiff consistency.

The water content measured on samples of the clayey silt to clayey silt-silt deposit ranged from about 16% to 24%. The water content measured on the gravelly clayey sand interlayer was about 14%.

The results of grain size distribution testing carried out on fifteen samples of the clayey silt to clayey silt-silt are shown on Figures C12A to C12C in Appendix C. The results of a grain size distribution test carried out one sample of the clayey sand interlayer in Borehole CR-05 are shown on Figure C14 in Appendix C.

Atterberg limits testing was carried out on thirteen samples of the clayey silt to clayey silt-silt and measured liquid limits ranging from about 18% to 32%, plastic limits ranging from about 14% to 18%, and plasticity indices ranging from about 4% to 16%. The Atterberg limits test results are summarized on Figures C13A and C13B in Appendix C and indicate the clayey silt to clayey silt-silt is of low plasticity.

4.3 Groundwater Conditions

The groundwater conditions observed in the open boreholes on completion of drilling operations are provided on the borehole records in Appendix A and Appendix B and may not represent stabilized groundwater conditions. Standpipe piezometers were installed in Boreholes CR-04, CR-05, CR-07, CR-09, C-1 and CE-05 to permit monitoring of the groundwater level at these locations.

The recorded groundwater levels are summarized in the table below. It should be noted that the groundwater level is subject to seasonal fluctuations and precipitation events and should be expected to be higher during wet seasons.

Borehole / Piezometer Designation	Screened Stratigraphy	Depth to Groundwater Level (m)	Groundwater Elevation (m)	Date of Measurement	Comments
CR-04	Clayey Silt Till	5.4 3.3	222.2 224.3	28-Jan-2021 10-Feb-2021	Open borehole Piezometer
CR-05	Silty Sand to Organic Silt to Silt to Clayey Silt	1.5 1.3	223.6 223.8	18-Jan-2021 10-Feb-2021	Open borehole Piezometer
CR-07	Clayey Silt to Silty Sand Fill / Clayey Silt Till	4.7 4.0	224.2 224.9	22-Jan-2021 10-Feb-2021	Open borehole Piezometer
CR-09	Sandy Silt Fill / Silty Sand to Clayey Silt Till	5.0 3.5	223.4 224.9	26-Jan-2021 10-Feb-2021	Open borehole Piezometer
CE-05	Clayey Silt / Sand seam	1.4 2.5	225.8 224.7	27-Feb-2018 5-Mar-2018	Open borehole Piezometer
C-1	Sand to Clayey Silt	4.6 1.6	221.9 224.9	26-Oct-2000 19-Mar-2001	Open borehole Piezometer

The groundwater levels will be influenced by the water level in the open channel of the South Innisfil Creek Drain that was measured to be at Elevation 224.4 m and 223.9 m (June 2017) near the inlet and outlet of the proposed crossings as indicated on the new construction layout drawing provided by MH on May 13, 2021.

4.4 Analytical (Corrosivity) Testing

Two soil samples were submitted for analysis of parameters used to assess the potential corrosivity of the site soil to construction materials such as steel and concrete. The details of the analytical tests are included in Appendix D and the results are summarized below:

Borehole (Sample / Run No.)	Material	Sample Depth (m)	Sample Elevation (m)	pH	Soluble Sulphate (µg/g)	Soluble Chlorides (µg/g)	Resistivity (ohm-cm)	Electrical Conductivity (µmho/cm)
CR-04 (Sample 4)	Clayey Silt Till	2.3 – 2.9	225.3 – 224.7	7.9	<20	660	730	1370
CR-07 (Sample 6)	Clayey Silt to Silt Fill	3.7 – 4.3	225.2 – 224.6	7.3	<20	2000	300	3340

5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Carter Comish, E.I.T. a geotechnical engineer-in-training with Golder. Mr. Kevin Bentley, P.Eng., an Associate and MTO Foundations Designated Contact with Golder and Ms. Lisa Coyne, P.Eng., a Principal and MTO Foundations Designated Contact with Golder, each conducted independent technical and quality control reviews of the report.

Signature Page

Golder Associates Ltd.

Carter Comish, E.I.T.
Geotechnical Analyst

Kevin Bentley, P.Eng.
Geotechnical Engineer, MTO Foundations Designated Contact and RAQS-Approved Tunnelling Specialist

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

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PART B

FOUNDATION DESIGN REPORT
DETAIL DESIGN OF SOUTH INNISFIL CREEK DRAIN
HIGHWAY 400 TRENCHLESS INSTALLATIONS
RECONSTRUCTION OF HIGHWAY 400 / 89 INTERCHANGE
TOWN OF INNISFIL, ONTARIO
MTO ASSIGNMENT NO. 2015-E-0038, GWP 2438-13-00

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 General

This section of the report provides a discussion and engineering recommendations for the foundation design aspects of the proposed trenchless installation of four culverts under Highway 400 as part of the South Innisfil Creek Drain (SICD) system in Innisfil, Ontario, as shown on Drawing 1.

This Foundation Design Report including the interpretation and recommendations are intended for the use of the MTO and its designers, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. Where comments are made on construction, they are provided only in order to highlight those aspects that could affect the design of the project. Contractors must make their own interpretation of the factual information provided in the Foundation Investigation Report (Part A of this report) as it may affect equipment selection, proposed construction methods and scheduling.

6.2 Proposed Tunnel Geometry and Anticipated Depth of Cover

Based on the design drawings provided in April 2021 by MH titled "*Proposed Channel Grading*" for the Highway 400 and SICD improvements, the proposed trenchless installations consist of four 1.9 m inner diameter culverts between approximately 51 m and 66 m in length. Referring to Drawing 1, one new culvert is to be located north of the existing 2.1 m diameter CSP culvert (north crossing) and three new culverts are to be located south of the existing twin steel arch culverts (south crossings).

Along the proposed trenchless alignments, the topography suggests Highway 400 has been constructed as a raised embankment (about 1 m to 2.5 m above the adjacent ground) with the highway grade at about Elevation 227.7 m to 228.8 m and the adjacent ground surface near embankment toes ranging from about Elevation 225.1 m to 227.2 m. The creek/watercourse invert near the existing culverts is at about Elevation 223.5 m on the west (outlet) side and about Elevation 224 m to 224.5 m on the east (upstream) side. The proposed new culverts will be slightly lower and have an invert at about Elevation 222.5 m.

The proposed culvert profiles are shown on Drawings 1 and 2 and indicate about 3.2 m to 4.4 m of soil cover between the highway surface and the top of pipe which is shown to be at about Elevation 224.5 m (assuming about 100 mm thick pipe/casing). Assuming the top of the casing / pipe is approximately equal to the crown of the cut diameter (assuming about 2.1 m diameter tunnel), the ratio of the existing soil cover to tunnel diameter ranges from about 1.7 to 2.1 along the alignment within the travelled portion of Highway 400. The soil cover to tunnel diameter decreases to about 1 near the embankment toes and anticipated shaft locations. Typically, a soil cover to tunnel diameter ratio of at least 3 is preferred; however, given that reducing the culvert diameter (increasing cover depth) would result in additional culverts / crossings being required, the number and diameter of the culverts has been optimized. Consideration has been given to lowering the culverts to allow for increased soil cover; however, it is understood that this is part of a gravity system and ultimately depends on hydraulic design of the SICD system upstream and downstream of the crossings.

It is assumed that a total of four to eight shafts will be required for the construction of the four crossings. One set of launch / retrieval shafts will be required for the north crossing. Given the close proximity of the three south crossings, it is likely that one large entry and exit shaft will be constructed to accommodate all three crossings; otherwise, the contractor may choose to construct three sets of separate launch / retrieval shafts.

6.3 Anticipated Ground Conditions

The results of the foundation investigations generally indicate subsurface conditions consist of embankment fill underlain by a clayey silt (till / till-like) layer with interlayers of sandy silt to silty sand, silt, and sand, underlain by a deposit of clayey silt. The cohesionless layers of silts and sands are more variable directly south of the existing culverts (Sections A-A’ and B-B’ on Drawings 1 and 2) as opposed to north of the existing culverts (Section C-C’ on Drawing 2).

Based on the proposed culvert alignments / profiles provided, the tunnel horizon (defined as 1.5 culvert diameters above and below the culvert alignment on Drawings 1 and 2) for the north crossing and south crossings are anticipated to encounter a mix of variable soil conditions as summarized below.

Proposed Trenchless Crossing Location	Reference Drawing	Anticipated Ground Conditions
North Culvert (low flow culvert - north of existing culverts)	2 (Section C-C’)	• Clayey Silt to Silt Fill, Silt and Sand to Gravelly Sand Fill, Clayey Silt, Clayey Silt Till, Silty Sand to Sand • Groundwater at about Elevation 225 m
South Culverts (three total) (high flow / overflow culverts - south of existing culverts)	1 (Section A-A’)	• Sandy Silt to Silty Sand Fill, Clayey Silt to Clayey Silt-Silt Fill, Sandy Silt to Silty Sand, Clayey Silt, Sandy Clayey Silt Till • Groundwater at about Elevation 225 m
	2 (Section B-B’)	• Clayey Silt Fill, Silty Sand Fill, Clayey Silt, Clayey Silt Till, Silt, Sandy Silt to Silty Sand, Sand, Organic Silt / Peat • Groundwater at about Elevation 225 m

Note: The culverts identified as “Low Flow” and “High Flow” are denoted in the drawing set provided by MH titled “Highway 400 & SCID Crossing”, dated August 2020

The behaviour of the anticipated subsurface soils within the tunnel horizon can be classified using Terzaghi’s Tunnelman’s Ground Classification system as modified by Heuer (1974)[3]. The behaviour of the soils anticipated to be present within the tunnel alignments are summarized below.

Trenchless Crossing	Soil	Tunnelman’s Ground Classification	
		Above Groundwater Level	Below Groundwater Level
North Culvert	Clayey Silt Fill, Clayey Silt, Clayey Silt Till	Firm to Slow Ravelling	Firm to Fast Ravelling
	Silt Fill, Silt and Sand to Gravelly Sand Fill, Silty Sand to Sand	Running to Cohesive-Running	Flowing
South Culverts	Clayey Silt Fill, Clayey Silt, Clayey Silt Till	Firm to Slow Ravelling	Fast
	Silty Sand Fill, Silt, Sandy Silt to Silty Sand, Sand, Organic Silt / Peat	Running to Cohesive-Running	Flowing

[3] Heuer, R.E. *Important Ground Parameters in Soft Ground Tunneling*. Proceedings of a Specialty Conference on Subsurface Explorations for Underground Excavation and Heavy Construction, ASCE, New York, page 41 to 55, 1974.

6.4 Subsurface Conditions Significantly Influencing Tunnelling

Trenchless installation will be primarily affected by the following factors associated with the subsurface conditions and groundwater conditions, namely:

- **The nature of the embankment fill**: For the north tunnel, a significant portion of the tunnel path is anticipated to be within the stiff to hard clayey silt to clayey silt till just below the embankment fill. For the south tunnels, the tunnel paths generally consist of a mix of stiff to hard clayey silt to clayey silt till and sandy silt to silty sand soil at the west and central sections, and transition to a predominantly silty sand fill and organic silt / peat at the east end. At the west limit of the crossings, the tunnel crown may encounter embankment fill consisting of clayey silt, silts and sands which form the majority of the Highway 400 embankment. The concern with fill at the tunnel face or near the tunnel crown, particularly beneath the highway, is that the compactness and gradation can sometimes be highly variable and, where it overlies less permeable soils, may be saturated. Such conditions can result in rapid changes in ground behaviour at the face and increased potential for loss of ground. This risk is increased near the east limit of the south crossings, where the full face of the tunnel path is within the saturated very loose to loose silt and sand fill which extends partially below the travelled portion of Highway 400. Any losses of ground could result in settlement at the highway grade or along the side-slopes of the embankment. Given the very loose to loose compactness of the fills on the east side, disturbance / densification of these materials due to tunnelling activities could also result in settlements to the highway.
- **Remnants of the original construction / creek bed buried in the fill particularly along the fill / native interface:** Cobble fragments were encountered in the clayey silt till in Borehole CR-2 and wood pieces / organics / peat were encountered near the fill / native interface (i.e., within the tunnel horizon) in Boreholes C-1, CR-3, CR-5, CR-7 and CR-8. Although not generally encountered or classified to be obstructions in the boreholes advanced for this crossing, the presence of cobbles and boulders and debris in the fill, cobbles and boulders in the native soils, and potentially tree stumps, roots or other woody debris / organics at and near the interface between fill and native soils from clearing and grubbing that may not have fully been removed at the time of construction of Highway 400, should be anticipated. In addition, the previous Creek bed may have been located north or south of the existing culverts (typically culverts are installed beside a creek crossing and then the creek diverted through the culverts) where the proposed new crossings are located; thus, trees / wood and other debris either remaining from original site clearing and preparation or carried down the stream may be present near the fill / native interface.
- **High Groundwater Levels / Saturated Cohesionless Deposits:** The groundwater levels measured in the piezometers at the site range from Elevation 223.8 m to 224.9 m in late February 2021. Considering the top of the tunnel is anticipated to be at Elevation 224.5, the tunnel horizon should be expected to be fully saturated. During wet periods of the year; seasonal fluctuations on the order of at least ±1 m should be expected.

A saturated cohesionless deposit or layers of silty sand to sandy silt are present along the tunnel face below the majority of Highway 400 at the south crossings. Saturated sand and silt layers / interlayers were encountered throughout the sandy silt to silty sand deposit within the central portion of the proposed culvert alignments (i.e., below the highway) along the south tunnel paths, near the bottom and crest of the tunnel. In the absence of active dewatering by vacuum well points or eductors along the entire alignment, the granular silty and sandy soils will flow in an unsupported excavation face. Referring to Section A-A' (Drawing 1), variable face conditions are anticipated with the lower half of the face in clayey silt till and the upper half of the face in sandy silt to silty sand, increasing the risk of ground loss if difficulties penetrating the clayey silt till are encountered the silts and sand will tend to flow and could result in "over-excavation" that could lead to settlements / sinkholes along the highway if the face of the tunnel is not adequately supported throughout all tunnelling activities. Given the variable nature of the fill / organics soils near the east and west limits, the fill / organics soils could also flow in the saturated conditions. The clayey silt / clayey silt till deposit should have a stand-up time ranging from a few minutes to several hours, depending on the degree of seepage, disturbance and presence (including frequency and thickness) of granular interlayers. The stand-up time of this material will likely be unpredictable and will be degraded where it overlies flowing ground. Trenchless methods that do not provide effective face support against running / flowing or ravelling granular soils should be prohibited.

The presence of the variable and mixed face conditions, obstructions within the fills and the glacial till, and high groundwater levels (saturated conditions) has been incorporated into the Trenchless NSSP provided in Appendix E to alert the Trenchless Contractor of the risks.

6.5 Trenchless Technology Options for Culvert Installations

Ultimately, the Contractor is responsible for choosing the method and equipment for the trenchless crossing installations, unless specific methods are prohibited based on ground conditions or other project criteria. Ground behaviour will be, in part, dependent on the installation method adopted, and this report provides guidance on the influence of ground behaviour on some possible installation methods.

Several trenchless installation methods were considered based on Golder's understanding of the proposed culvert design and constraints (e.g., soil conditions, diameter and length of crossings). The techniques considered include: traditional "jack and bore" systems, pipe ramming, microtunnelling, pilot tube microtunnelling, and tunnel boring machine (TBM). These construction methods are briefly described below.

- **Horizontal Auger Boring – "Jack and Bore":** In Ontario, a traditional "jack and bore" operation involves pushing a steel pipe (casing) horizontally into the ground by jacking while simultaneously cutting the ground with an auger head operating near the leading end of the steel pipe. The spoil is generally removed from within the casing using an auger boring machine. This method is applied to pipes generally less than about 2 m diameter. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. Jacking and receiving pits are required. Typically, there is limited ability to steer the casing during jacking. In some cases, contractors will run the auger cutting head in front of the lead end of the casing to advance the pipe in difficult ground; however, this approach can lead to high risks for ground losses (i.e., settlement and sinkholes). This method is also not feasible in running or flowing ground (dry or saturated sand and silt), especially with limited soil cover such as the case for this project.

  In some cases, traditional "jack and bore" equipment is supplemented with a specialized rotating cutting head, sometimes referred to as a "small boring unit". These cutting heads are welded to the lead end of steel casings and can sometimes include limited alignment adjustment capabilities. In the right ground conditions (e.g., hard glacial till), these small boring heads can be advantageous; however, these systems are not well suited to and should not be used in saturated and potentially flowing ground conditions. Further, these systems should not be confused with microtunnelling systems that operate using very different principles of ground support.

- **Pilot Tube Jack and Bore / Pilot Tube Microtunnelling:** Guided or pilot tube jack and bore (often referred to as pilot tube microtunnelling) employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and final pipes. As with traditional jack and bore systems, this method is applied to pipes generally less than about 2 m diameter. The guidance system comprises a target with LEDs mounted in the steering head of the equipment that is monitored through a TV monitor. The PTMT operation includes pilot boring and reaming; and since this technique is used for smaller size pipes, the equipment and space required for this operation is smaller than what is normally required for conventional micro-tunnelling. PTMT can obtain an accuracy of 10 mm per 100 m of pipe length; however, the accuracy depends on the ground conditions, the accuracy of the guidance system, and the operator's skill. There is a risk that the pilot tube could hit an obstruction (cobble, boulder, wood) in which case the pilot bore would need to be abandoned and attempted again at a different location. The "pilot tube" is advanced in a similar fashion to horizontal directional drilling with a guidance system used to control alignment and grade.

In this method, a bore hole is drilled with a steering head connected to pilot tubes whose size is smaller than the required casing size. A steering head is used for pilot boring and adjustment of alignment and grade, and the bore hole is subsequently enlarged by a reamer with an auger string inside the casing used to remove cuttings. Temporary casings, if applicable, or the final pipe follows the reamer into the ground. Configurations of "reamer" tools varies widely within the industry, with some including rotating cutting tools, while others are a simplified cage-like head that allows soils to be forced into the openings as the larger diameter pipe is pulled and pushed into the ground. These reamer systems can have a significant influence on both the feasibility and risks of using this method and should be evaluated with caution. Although this technique is sometimes referred to as "microtunnelling" or "guided auger boring", the effectiveness of any ground support provided to the tunnel face is highly dependent on the reamer / casing / auger configuration and ability to control / prevent soil loss in saturated silts and sands which could potentially suffer uncontrolled flow into the cutting or reaming heads and through / between the auger / casing system

- **Pipe Ramming:** Pipe ramming uses a pneumatic tool to hammer a steel pipe or casing into the ground. Typically, rammed pipes are smaller than about 2 m diameter. The pipe is almost always driven "open" to direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a small overcut to reduce friction between the casing and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting. Pipe ramming methods are also better suited for penetrating through/displacing potential obstructions, such as cobbles and boulders in comparison to jack and bore installation method, though this method can still be obstructed by cobbles and boulders depending on their size, number, and their positions relative to the pipe leading edge. Partial or full removal of materials from within the pipe, to facilitate driving, should not be carried out if the ground through which the pipe is being driven consists of saturated granular soils (silt, sand, gravel). As with traditional jack and bore methods, flowing ground conditions and/or operating the cleanout augers beyond, at or near the leading edge of the casing can result in significant ground losses, excessive surface settlement and, in some cases, sinkholes that propagate to the surface.
- **Microtunnelling Boring Machine (MTBM)**: MTBM is a method of installing pipes in bores ranging from about 0.6 m to 4.8 m in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic slurry at the cutting face to balance earth and water pressures to minimize ground losses. The process is essentially remote-controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry, and the necessity for personnel to enter the bore is eliminated. Microtunnelling equipment is generally more suited to tunnelling through overburden. Some MTBMs are promoted as being able to "crush" cobbles with internal cone crushing systems, while others have been promoted as capable of passing boulders of as much as one-third of the bore diameter; however, both approaches to managing larger stones can be highly problematic and incapable of completing construction in boulder ground. In addition, the presence of wood debris/ trees or stumps will present challenges to the microtunnelling operation. Large numbers of cobbles or wood / trees can "choke" these machines and result in failure of the bore.
- **Tunnel Boring Machine (TBM):** TBM tunnelling operations involve the advance of a steerable machine with a rotating cutter head that is jacked horizontally into the ground at the lead end of the pipe or temporary lining system. Tunnels constructed using a TBM can range from about 1.5 m to well over 15 m diameter. Successive

sections of temporary liner pipe or the final product pipe advance behind the TBM by pipe jacking. Alternatively, steel liner plates, steel ribs, and wood lagging or segmental precast concrete liner systems can be installed as the TBM advances. The spoil is removed from the tunnel as the TBM is advanced, using a combination of pressure relieving gates, screw augers (in some instances), conveyor belts, or mucking cars. The cutting head is driven and steered by an operator inside the TBM, and the TBM head and face may be partially open or provided with doors to allow for access to the face. Specialized Earth Pressure Balance (EPB) or slurry shield TBMs are available (as described above for micro-tunnelling systems), which pressurize the face of the excavation and improve face stability. Jacking and receiving pits are required. Locally, this method is generally used for construction in overburden, and open-faced machines have been used in cohesive and bouldery soils that exhibit significant "stand-up time" (e.g., glacial till). Excavations through sandy soils below groundwater levels typically require dewatering to maintain face stability when using open faced machines. For the current site, the presence of saturated sand and silts and variable fills would require an earth pressure or slurry pressure balance system.

- **Conventional Tunnelling using Hand Mining / Mechanical Equipment**: In this method, the tunnelling process is carried out by removing excavated soil from the front cutting face (open face) and installing a liner to form a continuous ground support structure. The soil may be excavated using hand mining techniques and shields. Alternatively, mechanically assisted excavation is accomplished by using special shields equipped with power excavation devices. Such soil cutting devices can be rotary cutter booms mounted on the front of the shield, modified hydraulic backhoes, or rotary boom cutters. The soil excavation rate of open-face mechanical excavation is much faster than that of hand mining. The liner may be installed using a two-pass system or a single pass where the culvert pipe is jacked in during excavation and provides both temporary and permanent support. For a one-pass system, typically a concrete pipe is jacked and used as the carrier pipe. With a two-pass system, a carrier pipe is installed between the entry and exit shaft after first installing a segmental temporary or primary liner. The primary liner may consist of steel ribs and wooden lagging or steel liner plates. The secondary liner can be composed of any suitable drainage pipe material. If the carrier pipe option is used, the annulus between the primary and secondary liners is grouted. Given that the method relies on an open face, it is generally not feasible in saturated non-cohesionless soils and/or running dry soils, although "hooded" shields can be used to reduce the potential for over-excavation / soil loss in such conditions. As such, the entire tunnel length would need to be dewatered for this option to be considered marginally feasible.

The feasibility, advantages, disadvantages, risks and relative costs for the trenchless options provided above are compared in Table 1 following the text of this report.

From a tunnelling methodology perspective, conventional "jack and bore" methods or tunnelling systems that use an "open face" present the highest risk and should be precluded in the Contract Documents. Similarly, some forms of "pilot-tube" auger boring or micro-tunnelling do not include appropriate means to control face excavation (e.g., slurry or muck pressure balance) and should also be precluded.

Conventional tunnelling using hand mining uses an open face system, thus, given the high groundwater level and adjacent creek leading to saturated cohesionless deposits encountered within and above the tunnel face, the entire length of the tunnel would need to be fully dewatered for this option to be even marginally feasible. Dewatering would require using a system such as closely spaced vacuum well points and/or eductors. Use of such a dewatering system would likely also require installation of dewatering systems from the highway level with shallow temporary trenches and deck plates to house the various header pipes and connections for the dewatering. Given the presence of the high groundwater levels and existing creek that will be flowing through the existing culverts during the trenchless crossing, it is possible that a groundwater cut-off system (e.g., sheetpiles) may also be required and it is not considered feasible for such a robust dewatering system to be installed within the context of the active highway and should be precluded as an option unless a robust dewatering system for all proposed crossings is included in the Contract Documents.

The subsurface conditions are suited to the pipe ramming option; however, if there is difficulty in advancing the leading pipe this may require more intervals of removing material inside the pipe in order to reduce the friction, particularly for pipe sizes larger than about 1.8 m, which is the case for this project. As the proposed culvert lengths are greater than 50 m and inner diameter requirement of 1,900 mm for the carrier pipe, drives might also require “telescoped” casings (casings of larger to progressively smaller sizes) that would require intermediate removal of soils and more complex installation or work from both ends, which may increase both the overall costs and risks related to this method. One of the challenges with pipe ramming is maintaining horizontal and vertical alignment, especially when telescoping casings are required. Pipe ramming is generally limited to diameters smaller than 2 m in Southern Ontario so these installations would be near the limit for local equipment and experience.

In the absence of wood obstructions along the tunnel path, microtunnelling with a slurry pressure balance machine (MTBM) would present the best option to control the face conditions and suit the planned pipe sizes; however, given the relatively short length of these culverts, microtunnelling may not be cost-effective. Relatively large wood obstructions (e.g., stumps, logs, or concentrated zones of buried brush), if they were to be encountered, could foul the equipment making progress slow, increase the risk of uncontrolled ground losses, or halt progress altogether. Although based on the results of the geotechnical investigation the risk is considered low, if fouling or halting of the trenchless equipment occurs, a rescue shaft would need to be constructed to retrieve the MTBM. For this reason, the Trenchless Contractor will need to develop a contingency plan to retrieve the MTBM and/or abandon the bore while keeping Highway 400 open to traffic, and this requirement has been incorporated into the Trenchless NSSP. This same concern applies to use of modern earth pressure balance (EPB) TBMs that use a screw conveyor to control discharge from the pressurized face chamber to the muck management systems; screw conveyors can also become readily fouled if significant amounts of wood fibres enter the TBM. Careful consideration of the slurry mix design / conditioning of the excavated soils and control of the balancing pressures must be considered to prevent soil loss or alternatively, reduce the potential for “blow out” conditions of any pressurized fluid / slurry (through cohesionless fills, backfill to existing sewers / culverts, and/or previous borehole locations). The large staging area for the separation plant will need to be taken into consideration in the contract documents. For pilot-tube microtunnellng where the method does not allow for slurry or fluid to be introduced at the lead edge of the casing / reamer, the full length of the tunnel will need to be fully dewatered using a system such as closely-spaced vacuum well points and/or eductors to be considered feasible, similar to the dewatering requirements for conventional hand mining operations as discussed previously. A detailed dewatering plan with possible groundwater cut-off system would need to be designed by the Contractor and accepted by the contract administrator / MTO and may not be practical given the high traffic volume on Highway 400.

For this project, an appropriate method of installing pipes in the order of 2 m cut diameter may be the use of conventional EPB TBMs that utilize pressure-relieving gates. These systems allow passage of some obstructions, depending on the size of the TBM face opening and the opening size of the pressure relieving gates. Provided proper face pressures are maintained during tunnel driving, this method may exhibit the best balance of cost and risk for this work. If such machines are used, the lining system must also be carefully chosen and constructed so that fine silt and sand soils are not driven through openings in the linings by groundwater flow. For example, use of steel ribs and wood lagging can result in ground losses if the circumference of the lagging is not protected with a non-woven geotextile filter fabric installed behind and concurrent with the lagging boards. Even so, fine sand and silt can exit through the filter fabrics where they are damaged or under sufficient water pressure and additional care during construction is required. Jacking of gasketed pre-fabricated pipe (concrete) or use of steel liner plates with appropriate gaskets or sealing at the joints would generally be preferable provided that the pipe / liners and TBM sizes are coordinated to limit the gap created between the cut and pipe diameters. This reduction in the annular gap is critical given the relatively low soil cover and will be directly related to settlements at the highway surface. For both the steel liner plate and steel ribs and lagging options, a cast-in-place concrete or secondary carrier pipe culvert will need to be installed as a "second pass" lining. "Second pass" pipes installed within a larger diameter temporary lining usually have to include grouting of the annular gap between the liners. Unless pre-cast concrete segmental liners are available in the right size, the length of this culvert likely does not justify the additional costs for such a custom-sized lining system.

In this case, given the various limitations of tunnelling systems and related risks, we recommend that the specifications for any trenchless methods be adapted specifically for this project. An example NSSP is provided in Appendix E that precludes jack and bore operations and specifies that the trenchless technique must provide a closed, pressurized face to balance earth and groundwater.

6.6 Tunnel Lining Design

The design of the tunnel lining will need to consider all load cases, including hydrostatic water pressures, soil loads and seismic loads (if applicable). The design of the temporary liners is the responsibility of the Contractor and must be compatible with and not compromise the permanent carrier pipe design.

Both a one-pass system (jacked pipe liner is also used as the final carrier pipe) or two-pass system (a slightly larger pipe liner, typically steel or concrete can be jacked and the carrier pipe inserted within the pipe liner and annulus grouted) are feasible at the site. The choice to use a one or two pass system will be up to the Contractor and will depend on the type and accuracy of the equipment and guidance system being used and tolerable limits of the culvert as specified in the contract documents.

6.7 Launch and Receiving Shafts

The design and construction of the temporary tunnel shafts are the responsibility of the Contractor. It is anticipated that the launch shafts for a typical TBM/MTBM will consist of either 6 m to 9 m circular shafts or 5 m wide by 7 m long rectangular shafts for each individual crossing with slightly smaller dimensions for the receiving shafts. For the three south crossings, depending on the spacing, it may be more economical to design and construct a single large rectangular launch / retrieval shaft about 15 m wide by 7 m long.

6.7.1 Temporary Excavation for Shaft Construction

Excavations will be required for construction of the launch and retrieval shafts which are anticipated to extend about 5 m to 6 m below ground surface (Elevation 221.5 m). The soils anticipated to be encountered at the proposed shafts are presented below.

Trenchless (Culvert) Crossing	Shaft Location (Relevant Borehole)	Anticipated Soils During Excavation
North Crossing	East Shaft (CR-04, CR-06)	Topsoil, Silty Sand, Silty Sand to Clayey Silt Fill, Clayey Silt Till
	West Shaft (C-2, CE-05)	Topsoil, Clayey Silt to Silt Fill, Clayey Silt Till, Clayey Silt

Trenchless (Culvert) Crossing	Shaft Location (Relevant Borehole)	Anticipated Soils During Excavation
South Crossings	East Shaft (C-1, CR-05, CR-03, CR-10)	Topsoil, Clayey Silt Fill, Sandy Silt to Silty Sand Fill, Organic Silt to Peat, Sandy Silt to Silty Sand, Sand, Gravelly Clayey Sand, Clayey Silt to Clayey Silt-Silt
	West Shaft (CE-06, CR-07)	Topsoil, Clayey Silt to Clayey Silt-Silt Fill, Silty Sand Fill, Clayey Silt, Silt, Clayey Silt to Sandy Clayey Silt Till

All temporary excavations must be carried out in accordance with the latest version of the *Ontario Occupational Health and Safety Act for Construction Projects (OHSA)*, as amended. According to OHSA, the soil classification and corresponding safe excavation side slopes for the existing fill and native soils to be excavated for shaft construction are summarized below. The steepest slopes provided in the table below are applicable to excavations which require a worker to access and are more than 1.2 m deep. Care must also be taken during excavation to ensure that adequate support is provided for any existing structures, roadways and underground services located adjacent to the excavations.

Soil Description	Above/Below Groundwater	OHSA Soil Type	Steepest Temporary Excavation Side Slope
Clayey Silt to Clayey Silt-Silt Fill (Firm to Very Stiff)	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 4	3 Horizontal : 1 Vertical
Silty Sand to Sandy Silt Fill (Very Loose to Compact)	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 4	3 Horizontal :1 Vertical
Organic Silt to Peat (Very Loose to Compact/Firm)	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 4	3 Horizontal :1 Vertical
Silt, Silty Sand to Sandy Silt, Sand Layers / Interlayers (Very Loose to Very Dense)	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 4	3 Horizontal :1 Vertical
Gravelly Clayey Sand (Very Stiff)	Below	Type 4	3 Horizontal :1 Vertical
Clayey Silt to Clayey Silt-Silt, Clayey Silt Till (Firm to Hard)	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 3	1 Horizontal :1 Vertical

To maintain temporary excavation stability, excavated materials should be placed away from the edge of the excavation at a distance equal to the depth of the excavation or greater. In addition, stockpiling of the material should be prohibited adjacent to the excavation to minimize surcharge loading near the excavation crest. Where sufficient space is not available to stockpile the excavated material at the project site, off-site disposal of the excess soil would need to be arranged as per the latest environmental regulations.

6.7.2 Temporary Protection Systems for Shafts

Temporary protection systems will be required to facilitate construction of the shafts where space and/or property restrictions limit open cut excavation. Given the space limitations on both the east and west sides of Highway 400 due to the location of Reive Boulevard, existing culverts, and the creek, temporary protection systems are anticipated. The temporary protection systems should be designed and constructed in accordance with Support Systems as per the latest version of the OHSA and Ontario Provincial Standard Specification (OPSS) OPSS.PROV

539 (*Temporary Protection Systems*) and OPSS.PROV 404 (*Support Systems*). The lateral movement of the protection systems should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any adjacent utilities or structures, if present, can tolerate this magnitude of deformation.

For conceptual design purposes, conventional solider pile and lagging, sheet pile, diaphragm walls or sunken caissons are considered feasible as temporary support systems in the overburden for circular and rectangular shafts at this site. Groundwater control / seepage will also need to be considered and it is recommended that a watertight protection system be used to control and reduce impacts to the surrounding groundwater level during dewatering.

Recommended values of the geotechnical parameters for use in design of temporary shoring are provided below. Where both drained and undrained parameters are provided, the shoring design should be checked and verified using each independent analytical method (drained vs undrained).

Stratigraphic Unit	Bulk Unit Weight, g (kN/m^3)	Drained Parameters		Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients[2]		
		Effective Unit Weight, g' (kN/m^3)	Angle of Internal Friction, φ (degrees)		Passive, K_p	Active, K_a	At-rest, K_o
Clayey Silt to Clayey Silt-Silt Fill (Firm to Very Stiff)	19	9	28	50	2.8	0.36	0.53
Silty Sand to Sandy Silt Fill (Very Loose to Compact)	19	9	28	--	2.8	0.36	0.53
Organic Silt to Peat (Very Loose to Compact/Firm)	14	4	27	25	2.6	0.39	0.56
Silt, Silty Sand to Sandy Silt (Very Loose to Very Dense)	20	10	30	--	3.0	0.33	0.50
Silt (Compact / Very Stiff to Hard)	20	10	35	150	3.7	0.27	0.43
Gravelly Clayey Sand (Very Stiff)	20	10	35	150	3.7	0.27	0.43
Clayey Silt to Clayey Silt-Silt, Clayey Silt Till (Stiff to Hard)	21	11	33	150	3.4	0.29	0.46

Notes:

1. The design groundwater level may be assumed to be at Elevation 225 m at the east and west shaft locations. Depending on the time of year, the design groundwater level should be adjusted based on seasonal fluctuations. Effective unit weight should be used for design accordingly.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.

The loading from adjacent structures and construction equipment as well as any material stockpiles within a distance defined by a projected 1 horizontal to 1 vertical line drawn from the bottom of the excavation to the existing ground surface should be included as a surcharge. The geotechnical engineering parameters provided above are considered appropriate for design of the temporary ground support systems with respect to the ultimate conditions, and do not account for control of ground displacements. If control of ground displacements is critical it may be necessary to use factored parameter values and/or a more detailed interpretation of the factual information will be required by the Contactor's shoring designer / engineer.

If jacked pipe is selected as the preferred alternative, a thrust block will need to be incorporated into the design of the launch shaft. Although the design and construction of the thrust block are the contractor's responsibility, the passive resistance of the soil can be used to design the thrust block; however, soil anchors and/or additional resistance may be required to achieve the required resistance to jack the pipes the full length of the pipe run.

6.7.3 Groundwater/Surface Water Control

Temporary excavations for shaft construction are anticipated to extend to about Elevation 221.5 (1 m below the bottom of the tunnel). The actual depth will depend on the Contractors tunnelling method and equipment. The groundwater conditions in the piezometers at the site measured water levels ranging from Elevation 223.8 m to 224.9 m in late February 2021. The creek water level was measured to be at about Elevation 224.4 m and 223.9 m upstream and downstream of the crossings respectively. As such, excavations for the east and west shafts will extend about 3.5 m below the measured groundwater level.

Where excavations extend below the groundwater level, advance dewatering ahead of the excavation is recommended to allow for a more stable and controlled excavation to reduce the risk of an unstable base and/or heaving due to unbalance water pressures. An active groundwater control system using an adequate number and depth of wells outside (or inside) the excavation could be considered. Groundwater levels should be lowered at least 1 m below the base of the shaft excavations to provide a stable excavation and preparation of the base of the shafts in dry conditions. Consideration should be given to installing a relatively watertight protection system and sealing the sides and base of the shaft to create a watertight structure, taking into consideration and designing against any buoyancy concerns or any dewatering requirements for the selected trenchless method. Alternatively, the protection system could include provision for some water infiltration to be collected by designated drains / pipes with an adequate number of sumps and pumps (or wells) at the base to keep the shaft dry during trenchless operations. The potential impacts of dewatering to the adjacent South Innisfil Creek and any adjacent existing utilities / structures (e.g. settlements related to dewatering) must be taken into consideration and effectively mitigated in the contractors dewatering work plan. In particular, the new Reive Boulevard bridge north abutment may be located within the zone of influence for dewatering of the north crossing east shaft; thus, any dewatering systems must limit settlements to less than 25 mm (to be confirmed by Region).

The tunnel eye seals at the launch and retrieval shafts will need to be designed in collaboration with the temporary shoring designer to ensure that the systems are compatible and groundwater pressures (and any drilling slurry / lubricants used for tunnelling operations) are adequately controlled in these critical areas.

Any surface water flow and/or natural drainage paths near the shafts / excavations must be diverted away from and/or around the excavation at all times. A temporary diversion or groundwater cut-off system may be required and could be incorporated into the shaft temporary shoring design. At the north crossing, the east shaft is located near / within the South Innisfil Creek; thus, temporary diversion (cofferdam or dam and pump upstream) will need to be considered. Dewatering and flow diversion operations must be in accordance with OPSS.PROV 517 (Dewatering), as modified by MTO's SP 517F01 (Temporary Flow Passage System), a copy of which has been included in Appendix E. Given the lack of nearby infrastructure and dwellings, a preconstruction survey for the Reive Boulevard bridge and Highway 400 pavement grade within 50 m from the trenchless crossing is required. Further, referencing the fill-ins for SP 517F01, the dewatering design engineer and the design checking engineer require a minimum five-years experience designing similar systems. The remaining fill-in information related to the minimum design storm return period and return period flow estimates have been filled in by MH's Hydrology and Drainage Engineer(s).

For the permanent culvert structures, erosion protection at the inlet / outlet should be provided with sufficient size rip-rap or alternative erosion control measures as specified / designed by the hydraulic / drainage engineers. Given that the trenchless method and tunnel diameter may range depending on the Contractors selected method, it is recommended that a tolerance be provided in the Contract document to allow a lower invert level of the culvert (i.e. allow culvert to be lowered) to maintain an adequate soil cover during trenchless operations and allow more economical trenchless / tunnel alternatives (with slightly larger or smaller internal diameter) to be considered by the Contractor.

6.8 Tunnelling / Trenchless Settlement Estimates

Settlement above tunnelled or trenchless installations are typically described as exhibiting the shape of an inverted normal distribution curve ("bell curve") with the maximum settlement at the centreline of the trenchless installation, tapering to near zero at some distance from the centreline. The ground surface settlement troughs above the culvert pipe are estimated to extend about 2 m on each side of its alignment for the proposed 1.9 m diameter culvert. The estimated ground surface/pavement settlement directly above the centreline of a single trenchless crossing is calculated to be about 25 mm assuming 2% volume loss for a predominantly cohesionless soil cover (minimum 3.5 m thick). Settlements are expected to increase where adjacent culverts are installed in close proximity to one another (south crossings) due to the overlapping zone of influence. For the south crossings, it is recommended that the spacing between adjacent crossings be as far apart as practically possible, but no closer than 1 tunnel diameter between the maximum outside diameter of the cut faces. The estimated settlements assume an approximate 2 m diameter tunnel with an overcut of not more than 20 mm (i.e., difference between tunnel cut radius and outer pipe/liner radius) and the tunnelling method and equipment are properly selected (i.e. pressurized face) with good quality work carried out by an experience contractor. To limit the risk of excessive settlements, it is recommended that the top of the tunnel be specified to be no higher than Elevation 224.5 m and that the overcut annulus be specified to be no greater than 20 mm for the crossings. In addition, given the estimated settlement, it is recommended that the review and alert levels for settlement monitoring (discussed in the next section) be set to at least 37.5 mm and 50 mm respectively to account for cumulative settlement at the south crossings. These requirements have been incorporated into the Trenchless NSSP in Appendix E. Settlement monitoring should be carried out as discussed in the next section and the results checked during construction by an independent foundation specialist. The impact of the trenchless installations to the existing pavement structure will need to be assessed during and following the settlement monitoring period and depending on the results, the pavement grade may need to be reinstated.

6.9 Instrumentation and Monitoring Program

6.9.1 Settlement Monitoring

Settlements associated with trenchless installation methods are typically of two types:

- Large settlements: These settlements are the result of loss of ground due to over-excavation caused by the inability to control adverse ground condition or due to the tunnelling operator's errors or equipment problems. Large settlements can lead to the creation of voids and/or sinkholes above the installed pipe.
- Systematic settlements: These settlements are primarily caused by the collapse of the annular space between the pipe and the bore annulus or by deformation of the soils ahead of the advanced bore.

The magnitude of such settlement is highly dependent on the construction procedures utilized (i.e., bore size, cutting head / shoe diameter, final reamer size, depth of installation, drilling fluid, lubrication/annular grouting procedures, etc.). Nonetheless, even with careful workmanship, some post construction settlement may occur as a result of the tunnel installation, especially at this site where challenging soil conditions are present and soil cover to tunnel diameter ratios are low (i.e., generally below 2). Therefore, provisions for settlement monitoring should be made in the Contract Documents for monitoring of ground response prior to, during, and after installation to:

- Document the effects of the tunnel installation on the overlying highway (Highway 400 at this project site) and associated utilities (median storm sewer) that could impact operation of the highway;
- Obtain prior warning of ground movements that could occur due to the construction methods and equipment or unforeseen ground conditions;
- Verify the contractor's compliance with the ground movement limits imposed in the contract; and
- Allow adjustments to be made to the tunnelling methods such that the ground movement limits established are not exceeded.

The proposed settlement monitoring instrumentation program is shown on Drawing 3 and generally follows the guideline outlined in detail in the NSSP titled "*Pipe Installation by Trenchless Method*" in Appendix E. The settlement monitoring instrumentation comprises the following:

- 56 Surface Monitoring Points (SMP) installed as arrays of three points at intervals of about 5 m along centreline of tunnels.
- 12 In-Ground Settlement Monitoring Points installed beyond the traffic lanes of Highway 400 at intervals of about 5 m along centreline of tunnels.

For any structures that are settlement sensitive, consideration should be given to include additional monitoring points / markers at these locations for due diligence purposes. Such structures would include the recent headwall constructed as part of the existing CSP arch extensions on the west side (about 5 m from nearest south crossing centreline), and the Highway 400 median storm sewer (500 mm diameter pipe) that crosses the north crossing alignment with about 1.8 m of soil cover between the top of tunnel and bottom of sewer. The monitoring program may need to be modified further based on the contractors selected method and any special provisions included in the Contract. Given that many of the survey points are located on Highway 400, the frequency of required readings and the need to establish an appropriate elevated vantage point relative to the SMP locations, consideration should be given to incorporating a Robotic Total Station. In addition, and as previously discussed, monitoring of the recently constructed Reive Boulevard Bridge may be required depending on the proximity to the shaft (temporary protection system) locations in accordance with OPSS.PROV 539.

It is also recommended to measure, to the extent practicable and possible, the weight or volume of ground removed from beneath paved areas which should be compared to the theoretical cut hole volume on a frequency of at least once per 3 m section of tunnel installed. Measuring excavated ground volumes will be difficult because the soil discharge systems on some systems are not readily conducive to such measurements. However, on-site observations of construction operations and measurements of grout and/or lubricant volumes should assist in identifying atypical conditions that could be indicative of unacceptable ground losses.

Given the elevated risk and estimated magnitudes of settlement for this project, contingency plans for traffic management and road repair / remediation (e.g. injecting grout or padding) should be in-place to rapidly mitigate or limit any distress to the overlying highway embankment and pavement, if needed. In addition, given the close proximity of the existing median storm sewer to the north crossing tunnel, a contingency plan to manage any storm water that could collect and potentially overflow / impact the operation of the highway should be in-place, if needed. These precautions have been incorporated into the NSSP in Appendix E.

6.9.2 Vibration Monitoring

The need / requirement for carrying out vibration monitoring should be considered for construction operations during trenchless installation and/or during installation of temporary protection systems / shafts, to ensure that construction techniques and associated vibration levels experienced at nearby structures and utilities are maintained below tolerable levels. The recommended maximum peak particle velocity (PPV) measured on various structures should be confirmed with the owners; however, typical limits are as follows:

- for conventional commercial/industrial buildings, 50 mm/s;
- for private residential structures built using conventional wood framing and drywall, 25 mm/s; and
- utilities, bridge structures, box culverts, 10 mm/s.

The nearest structures located within a distance of about 30 m from the shaft / tunnel location should be assessed for sensitivity to vibrations (and possibly settlements) for due diligence purposes. This would include the nearby bridge structure carrying Rieve Boulevard over South Innisfil Creek and any existing utilities near the shaft / tunnel location. Given the bridge was recently constructed (end of 2020), the embankments and foundations may still be experiencing post-construction settlements / movements and may not have stabilized, this will need to be taken into consideration if the bridge is to be monitored. It is considered good practice to conduct pre- and post-construction condition surveys and vibration monitoring at existing structures within an approximately 30 m radius of any trenchless or shaft installation, and in some cases agencies may choose to expand the radius beyond that anticipated for attenuation of construction-induced vibrations, to mitigate potential claims from property owners.

6.10 Corrosion Potential

The potential for sulphate attack and corrosion on the liner / carrier pipe and/or shaft linings (if applicable) from the surrounding soils are discussed in the following paragraphs; however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of CSA A23.1-14 Section 4.1.1 "*Durability Requirements*" are followed when designing concrete and steel/ductile iron elements. The design of the culverts should consider the results of the analytical laboratory testing, the potential for corrosion, and the corrosion susceptibility of pipe materials in general accordance with Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014) for selection of materials.

Given that the culverts are proposed to be located underneath Highway 400, the materials may be exposed to de-icing salts and selection of the exposure class should consider this in the selection of cement type for use in concrete, as required.

The two tested soil samples have a pH of 7.3 and 7.9 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to the culvert durability. The resistivity was calculated to be 300 ohm-cm and 730 ohm-cm, which indicates that the corrosiveness potential is Severe (R < 2,000 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014).

6.11 Monitoring Well Decommissioning

Four groundwater monitoring wells (at Boreholes CR-04, CR-05, CR-07 and CR-09) were installed to permit monitoring of the groundwater level at the site. Ontario Regulation (O. Reg.) 903 amended by O. Reg. 128/03 of the Ontario Water Resources Act requires that monitoring wells are properly abandoned/decommissioned by qualified personnel. The abandonment of the wells should be included in the Contract Documents and an NSSP "Well Decommissioning" has been provided in Appendix E for this purpose.

7.0 CLOSURE

This Geotechnical Investigation and Design Report was prepared by Mr. Carter Comish, E.I.T. a geotechnical engineer-in-training with Golder. Mr. Kevin Bentley, P.Eng., an Associate, MTO Foundations Designated Contact and RAQS-approved tunnelling specialist with Golder conducted a technical and quality control reviews of the report. Ms. Lisa Coyne, P.Eng., Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality review of the report.

Signature Page

Golder Associates Ltd.

Carter Comish, E.I.T.
Geotechnical Analyst

Kevin Bentley, P.Eng.
Geotechnical Engineer, MTO Foundations Designated Contact and RAQS-Approved Tunnelling Specialist

Lisa Coyne, P.Eng
Principal, Independent QC Reviewer

CC/KJB/SJB/LCC/ml

https://golderassociates.sharepoint.com/sites/12201g/6 - deliverables/fnds/sicd trenchless investigation/final report/1668512 scid-r-rev.0 fidr 2021aug4.docx

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Occupational Health and Safety Act and Regulation for Construction Projects (as amended).

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 Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 517 Construction Specification for Dewatering

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.PROV 404 Construction Specification for Support Systems

Table 1: Comparison of Trenchless Alternatives

Trenchless Technology	Feasibility	Advantages	Disadvantages	Relative Costs	Risks
Jack and Bore or Pilot Tube Jack and Bore (Pilot Tube Microtunnelling) without pressurized face	■ Method should be precluded	■ Accuracy improved significantly with use of pilot tube ■ Face access if advanced dewatering is carried out	■ Greater than 1.8 m tunnel diameter is a rare size for jack and bore operations in Ontario and near the maximum size of locally available equipment / casings. ■ Limited accuracy unless pilot tube method is used ■ These systems cannot manage saturated silt and sand soils and are of high risk for ground losses in conditions such as those at the project site ■ Dewatering of shafts and full trenchless alignment to below invert of tunnel required. ■ Jacking / thrust Block required	■ Lower cost although dewatering requirement for shafts and along entire tunnel alignment will increase overall capital cost	■ Even with dewatering along the entire alignment, high risk of cohesionless (silts and sands) soils present within full face and above tunnel crown to run / flow leading to soil loss and settlements or sink holes within travelled Highway 400 lanes ■ Concentrations of cobbles and boulders or large boulders, tree limbs, stumps, etc. (typically encountered near fill / native interface or in previous creek channels) could obstruct operations. Obstructions may require abandonment of crossing or shaft excavation from the highway surface to remove obstruction.
Pipe Ramming	■ Marginally Feasible	■ Dewatering not be required (with exception of shafts and possibly near start and end of crossing) ■ Thrust block / jacking frame not required ■ Installation could be advanced without significant removal of soils prior to full casing penetration through embankment (if no obstructions and/or high friction not experienced) ■ Relatively smaller site operations footprint. ■ Better than other low-cost technologies for penetrating ground that includes limited numbers of cobbles and small boulders or obstructions. ■ Limited steering control / accuracy and could be deflected by obstructions ■ Face access if advanced dewatering is carried out	■ For 1.9 m inner diameter culvert, casing diameter / shoe of greater than 2 m is anticipated. The diameter and 50+ m length is near the maximum limit of conventional pipe ramming equipment / experience in Ontario. ■ Combination of ground density, final pipe diameter and length of installation may be near the upper limit of feasibility for a single pipe installation – telescoping casing sizes or use of additional smaller diameter pipes may assist with feasibility. ■ Saturated silt to sand interlayers will be susceptible to flowing and may cause uncontrolled loss of soil into casing during installation if adequate soil plug cannot be maintained ■ Density of ground in some areas may encourage premature removal of soils from within the casing. ■ Alignment control can be difficult when penetrating soils of differing densities or when encountering cobbles and boulders or obstructions	■ Lowest cost for tunnelling, although dewatering for shafts will increase total capital cost	■ Due to relatively high SPT N values in clayey silt till and anticipated high friction in saturated sands / silts, there is high potential that the casing will require frequent clean-out / removal of soil to reduce the friction. If too much of soil plug is removed there is a risk of saturated granular soil flowing into pipe due to high groundwater table and lack of face support which could lead to settlement or sink holes in overlying Highway 400 ■ Concentrations of cobbles and boulders or large boulders, tree limbs, stumps, etc. (typically encountered near fill / native interface or in previous creek channels) could obstruct operations. Obstructions may require abandonment of crossing or shaft excavation from the highway surface to remove obstruction. ■ Higher vibrations from pipe driving compared to other methods can lead to densification and settlement of loose granular / organic materials surrounding and overlying pipe and result in settlement of highway surface and/or increased friction.
Microtunnel Boring Machine (MTBM)	■ Feasible	■ No dewatering required (with exception of shafts) ■ Best method for controlling ground losses at the face, provided appropriate slurry pressures and viscosities are used during tunnelling ■ High accuracy and desired tunnel alignment / profile can readily be achieved ■ Reduced vibration and noise levels compared to pneumatic and percussive methods ■ For this size of microtunnel, face access may be possible.	■ Relatively large site operations footprint to accommodate separation plant and equipment. ■ If unexpected ground conditions are encountered at the site (e.g., buried wood debris), microtunnel boring machine may become obstructed. Significant delays and costs may be required to mobilize alternative tunnel methods to the site or rescue an obstructed machine with a shaft from the highway surface. ■ Jacking / Thrust Block required ■ Fastest rate of advance	■ Highest cost ■ Tunnelling method may not be cost effective given the short length of the crossings, but may be partially offset by the number of crossings in same general area	■ In the absence of buried wood, stumps, etc. that could "clog" the machine, this method is the lowest risk option that could lead to settlements, major disturbance or emergency closure of Highway 400 ■ Risk of slurry causing "blow-out" on highway surface from existing boreholes, cohesionless fills / layers, and weak organic soils if slurry mix design (viscosity) and pressure is carefully controlled and monitored. ■ Low risk of buried wood, stumps, etc. that could "clog" machine based on borehole information.
Earth Pressure Balance (EPB) Tunnel Boring Machine (TBM)	■ Feasible	■ No dewatering required (with exception of shafts) ■ Potentially a good method for controlling ground losses at the face provided that an appropriate closed-face EPB TBM is selected and operated at appropriate face pressures with appropriate muck management systems ■ Relatively high accuracy and desired tunnel alignment / profile can readily be achieved ■ Reduced vibration and noise levels compared to pneumatic and percussive methods. ■ Face access if advanced dewatering is carried out	■ If unexpected ground conditions are encountered at the site (e.g., buried wood debris), a screw conveyor or pressure relieving gates TBM could become obstructed. Significant delays and costs may be required to mobilize alternative tunnel boring machine to the site or rescue an obstructed machine with a shaft from the highway surface. ■ Jacking / Thrust Block likely required ■ If larger tunnel cut diameter is required due to available TBM equipment, a "two-pass" system may be required and grouting annulus will be required	■ Higher cost compared to pipe ramming but lower than microtunnelling unless "two-pass" system is required which will increase costs.	■ Low risk of jacking pressures or fluid pressures causing "blow-out" on highway surface from existing boreholes, cohesionless fills / layers, and weak organic soils if slurry mix design and pressure is carefully controlled and monitored. ■ Low risk of buried wood, stumps, etc. that could "clog" machine based on borehole information. ■ Tunnel cut diameter / pipe may need to be oversized depending on available TBM equipment in the area. Oversized cut tunnel will lead to reduced soil cover to diameter ratio and will result in larger internal diameter that may impact hydraulics. Larger diameter could result in "two-pass" system which would increase time and cost.

Trenchless Technology	Feasibility	Advantages	Disadvantages	Relative Costs	Risks
Hand Mining or Mechanically Assisted Tunnelling with Hooded Shield and Dewatering (open face)	■ Marginally Feasible	■ Relatively small site operations footprint ■ Capability to readily address obstructions in the face ■ High accuracy and desired alignment can readily be achieved ■ Face access if advanced dewatering is carried out	■ Dewatering of shafts and advanced dewatering for full length of tunnel required. Presence of adjacent creek flowing through existing culverts and cohesionless soils may require groundwater cut-off system(s) for dewatering efforts to be effective. ■ Labour intensive: due to presence of sands and silts and variable fills / organic soils which may be saturated, the Contractor's selected equipment and methods must provide effective control of the stability of the face (e.g., advanced dewatering, use of hooded shield, fore-poling, retractable breast plates with doors, etc.) ■ Slowest rate of production	■ Higher cost than jack and bore but lower than microtunnelling and TBM, however, additional costs for dewatering full tunnel alignment will increase total capital cost	■ Dewatering (e.g., closely spaced vacuum well points and/or eductors) may or may not be effective and groundwater cut-off system (e.g., sheetpiles) may be required. Likely requires temporary trenching and deck plates or other traffic protection at roadway surface for dewatering header pipes and wells within the Highway 400 travelled portion along each trenchless alignment. ■ Interlayered saturated silt to sand is susceptible to flowing and running (even with dewatering) and risk of ground losses that could lead to settlements of Highway 400. ■ Inadequate dewatering could lead to significant ground losses due to flowing cohesionless soils and sink holes within Highway 400

DRAWINGS

MINISTRY OF TRANSPORTATION, ONTARIO

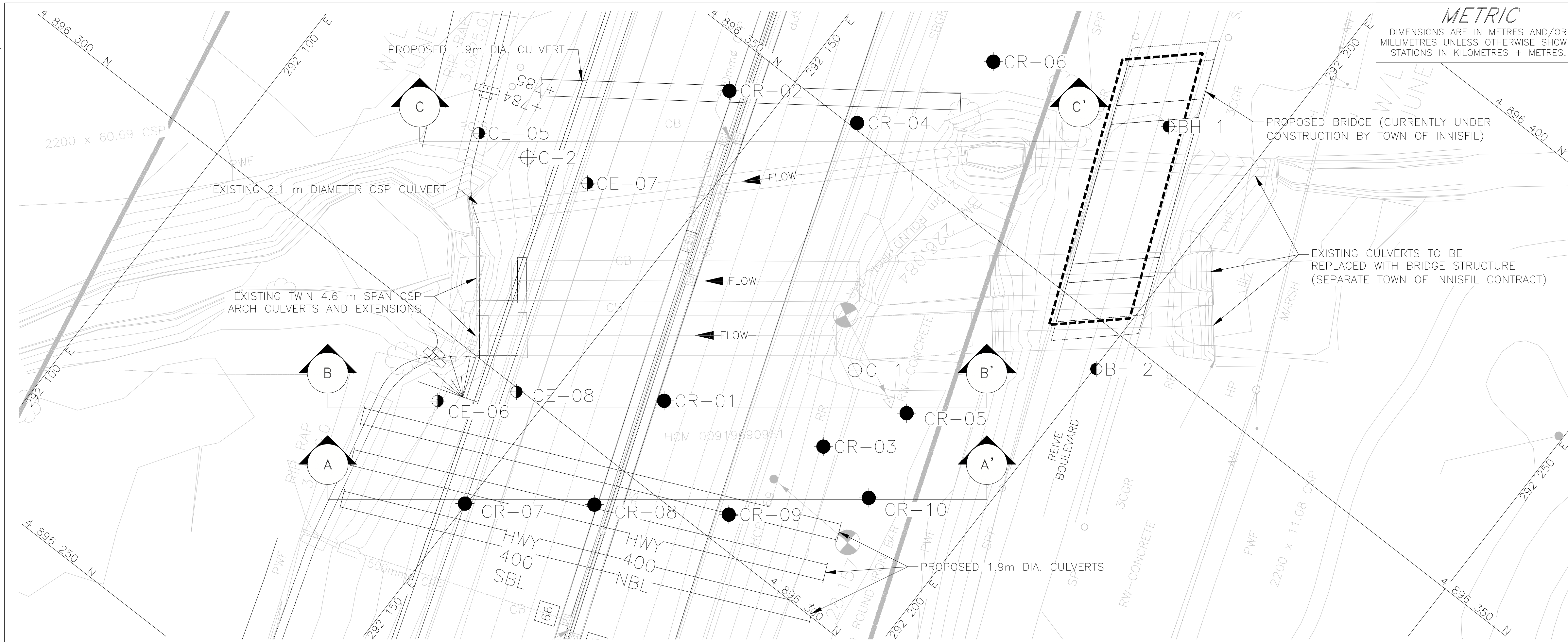
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2438–13–00

SHEET

HIGHWAY 400/89 INTERCHANGE
SOUTH INNISFIL CREEK DRAIN
BOREHOLE LOCATIONS PLAN AND SOIL STRATA

GOLDER
MEMBER OF WSP



PLAN
SCALE
6 0 6 12 m

KEY PLAN
SCALE
1 0 1 2 km

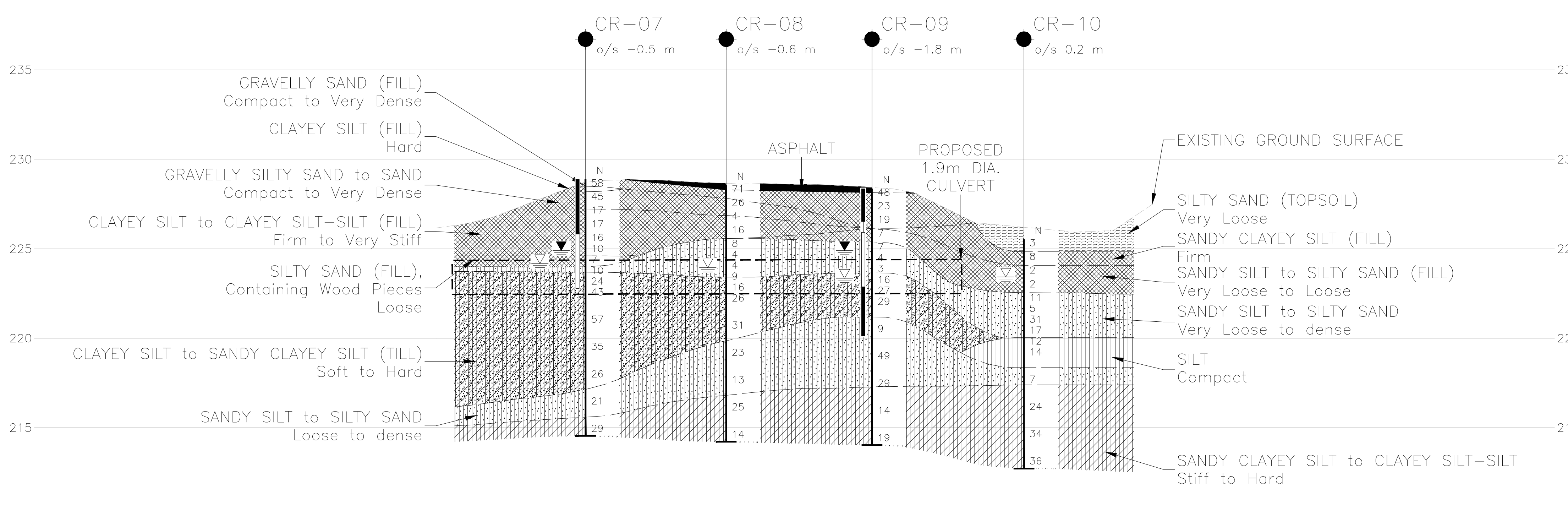
LEGEND

- Borehole – Current Investigation
- Borehole – Advanced by Peto MacCallum in 2019
- Borehole – Advanced in 2018
- Borehole – Previous (GEOCRES No. 31D00–482)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on FEBRUARY 10, 2021
- WL upon completion of drilling

Site Coordinates Lat/Long: 44.206826/–79.658281

BOREHOLE CO–ORDINATES (NAD 83 MTM ZONE 10)

No.	ELEVATION	NORTHING	EASTING
BH 1	228.5	4896373.6	292189.1
BH 2	228.2	4896345.0	292200.2
C–1	226.5	4896326.9	292177.2
C–2	227.2	4896322.8	292130.0
CE–05	227.2	4896321.5	292123.5
CE–06	226.9	4896292.8	292139.6
CE–07	228.8	4896324.8	292137.7
CE–08	228.7	4896299.6	292146.4
CR–01	228.5	4896309.7	292161.2
CR–02	228.6	4896344.3	292144.4
CR–03	226.0	4896317.2	292179.9
CR–04	227.6	4896350.7	292159.0
CR–05	225.1	4896326.6	292185.4
CR–06	226.7	4896366.7	292167.4
CR–07	228.9	4896285.0	292149.8
CR–08	228.5	4896294.6	292162.3
CR–09	228.4	4896303.7	292175.9
CR–10	225.5	4896315.7	292188.1



A–A CROSS–SECTION
1

HORIZONTAL SCALE
6 0 6 12 m
3 0 3 6 m
VERTICAL SCALE

L.C. COYNE — LICENSED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO — July 30, 2021

K. J. BENTLEY — LICENSED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO — July 30, 2021

NOTES

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

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

REFERENCE

Base plans provided in digital format by MH, drawing file no. Channel Alignment Option 2_recover.dwg, received January 05, 2021.
Proposed culvert locations provided in digital format by MH, drawing file no. ACAD-SICD Crossing Refined.dwg, received May 17, 2021.

NO.	DATE	BY	REVISION

Geocres No. 31D–776

HWY. 400/89		PROJECT NO. 1668512	DIST.
SUBM'D. CC	CHKD. CC	DATE: 07/30/2021	SITE:
DRAWN: DD/TR	CHKD. KJB	APPD. LCC	DWG. 1

PLOT DATE: August 4, 2021
FILENAME: S:\Clients\MTO\Hwy_400_and_Hwy_89_Interchange\99_PROJ\1668512_Detailed_Design\40_PROD\0014_South_Innisfil_Creek_Drain\1668512-0014-BC-0001.dwg

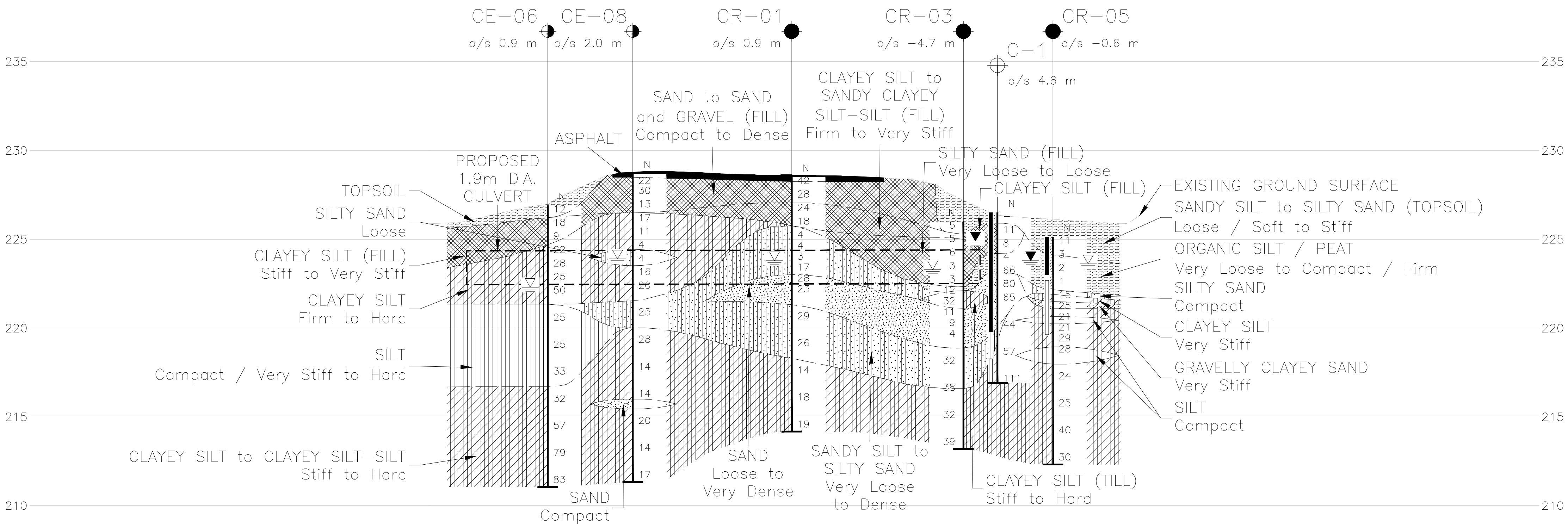
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2438-13-00

HIGHWAY 400/89 INTERCHANGE
SOUTH INNISFIL CREEK DRAIN
SOIL STRATA

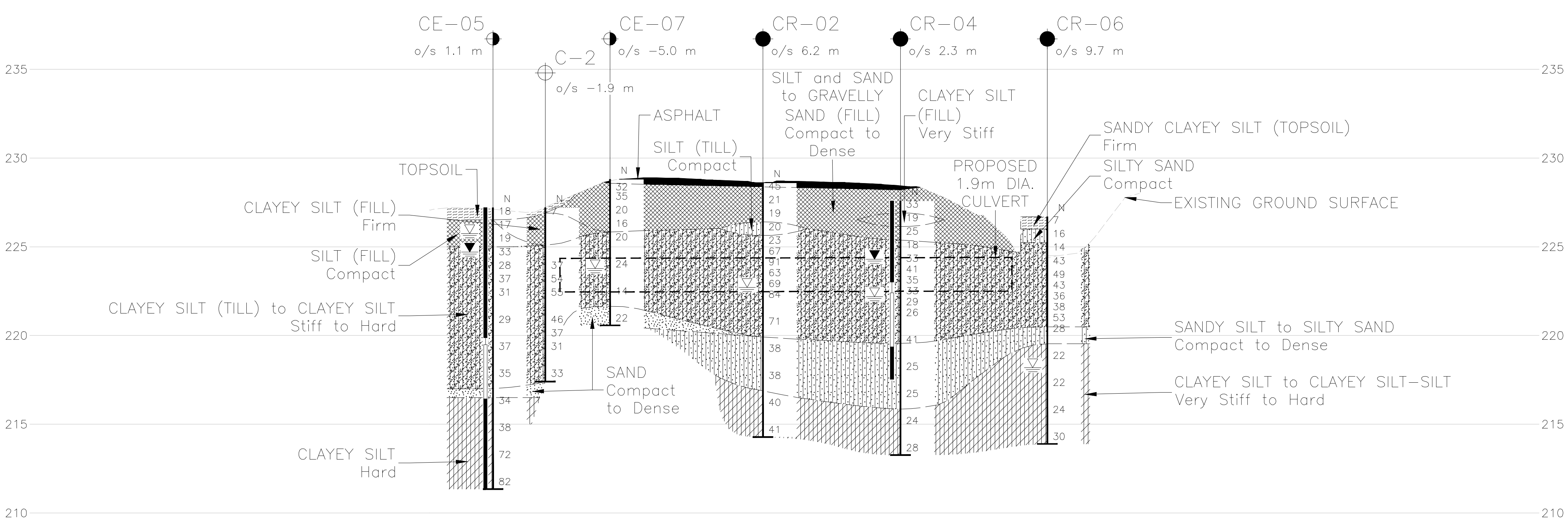
SHEET

GOLDER MEMBER OF WSP



B-B CROSS-SECTION

HORIZONTAL SCALE 6 0 6 12 m
VERTICAL SCALE 3 0 3 6 m



C-C CROSS-SECTION

HORIZONTAL SCALE 6 0 6 12 m
VERTICAL SCALE 3 0 3 6 m

LEGEND

- Borehole – Current Investigation
- Borehole – Advanced in 2018
- Borehole – Previous (GEOCRES No. 31D00-482)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on MARCH 19, 2001, FEBRUARY 5, 2018 and FEB 10, 2021
- WL upon completion of drilling

Site Coordinates Lat/Long: 44.206826/-79.658281

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 10)

No.	ELEVATION	NORTHING	EASTING
C-1	226.5	4896326.9	292177.2
C-2	227.2	4896322.8	292130.0
CE-05	227.2	4896321.5	292123.5
CE-06	226.9	4896292.8	292139.6
CE-07	228.8	4896324.8	292137.7
CE-08	228.7	4896299.6	292146.4
CR-01	228.5	4896309.7	292161.2
CR-02	228.6	4896344.3	292144.4
CR-03	226.0	4896317.2	292179.9
CR-04	227.6	4896350.7	292159.0
CR-05	225.1	4896326.6	292185.4
CR-06	226.7	4896366.7	292167.4

NOTES

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Proposed culvert locations provided in digital format by MH, drawing file no. ACAD-SICD Crossing Refined.dwg, received May 17, 2021.

LICENSED PROFESSIONAL ENGINEER L.C. COYNE July 30, 2021 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER K. J. BENTLEY July 30, 2021 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31D-776

HWY. 400/89	PROJECT NO. 1668512		DIST.
SUBM'D. CC	CHKD. CC	DATE: 07/30/2021	SITE:
DRAWN: TR	CHKD. KJB	APPD. LCC	DWG. 2

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

CONT No.
GWP No. 2438–13–00

SHEET

HIGHWAY 400/89 INTERCHANGE
SOUTH INNISFIL CREEK DRAIN
SETTLEMENT MONITORING LOCATION PLAN

GOLDER
MEMBER OF WSP

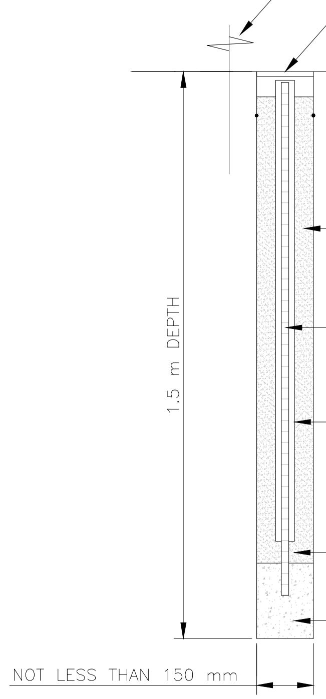
PLAN
SCALE
6 0 6 12 m

KEY PLAN
SCALE
1 0 1 2 km

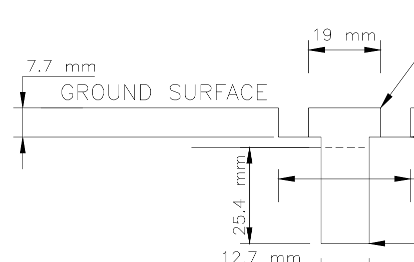
LEGEND

⊞	Surface Monitoring Point
■	In–Ground Monitoring Point

Site Coordinates Lat/Long: 44.206826/–79.658281



IN–GROUND MONITORING POINT INSTALLATION DETAIL (TYP.)
NOT TO SCALE



SURFACE MONITORING POINT INSTALLATION DETAIL (TYP.)
NOT TO SCALE

REFERENCE
Base plans provided in digital format by MH, drawing file no. Channel Alignment Option 2_recover.dwg, received January 05, 2021.
Proposed culvert locations provided in digital format by MH, drawing file no. ACAD–SICD Crossing Refined.dwg, received May 17, 2021.

NOTES
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LICENSED PROFESSIONAL ENGINEER L.C. COYNE July 30, 2021 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER K. J. BENTLEY July 30, 2021 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31D–776

HWY. 400/89		PROJECT NO. 1668512	DIST.
SUBM'D. CC	CHKD. CC	DATE: 07/30/2021	SITE:
DRAWN: TR	CHKD. KJB	APPD. LCC	DWG. 3

PLOT DATE: August 4, 2021
FILENAME: S:\Clients\MTO\Hwy_400_and_Hwy_89_Interchange\99_PROJ\1668512_Detailed_Design\40_PROD\0014_South_Innisfil_Creek_Drain\1668512–0014–BG–0003.dwg

APPENDIX A

Previous Investigations (Golder 2000 and PML 2019)

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
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
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 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	c_u, s_u kPa	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.

S:\FINALDAT\ABBREV\2000\LOFA-D00.DOC

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
F factor of safety
V volume
W weight

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 stresses (major, intermediate, minor)
σ_{oct} mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ shear stress
u porewater pressure
E modulus of deformation
G shear modulus of deformation
K bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$ bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$ dry density (dry unit weight)
$\rho_w(\gamma_w)$ density (unit weight) of water
$\rho_s(\gamma_s)$ density (unit weight) of solid particles
γ' unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R relative density (specific gravity)of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e void ratio
n porosity
S degree of saturation

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

(a) Index Properties (con't.)

w water content
w_l liquid limit
w_p plastic limit
I_P 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)

(c) 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

(d) Consolidation (one-dimensional)

C_c compression index (normally consolidated range)
C_r recompression index (overconsolidated range)
C_S swelling index
C_α coefficient of secondary consolidation
m_v coefficient of volume change
c_v coefficient of consolidation
T_v time factor (vertical direction)
U degree of consolidation
σ'_p pre-consolidation pressure
OCR Overconsolidation ratio $= \sigma'_p/\sigma'_{vo}$

(e) Shear Strength

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

Notes: 1. $\tau = c' + \sigma' \tan\phi'$
2. Shear strength = (Compressive strength)/2

Ministry of Transportation Ontario

RECORD OF BOREHOLE No C-1

METRIC

PROJECT 001-1143F
W.P. 30-95-00
DIST Central HWY 400
DATUM Geodetic

LOCATION N 4896326.9; E 292177.2
BOREHOLE TYPE 108mm ID SOLID STEM AUGERS AND CASING
DATE Oct.26/2000

ORIGINATED BY PKS
COMPILED BY LCC
CHECKED BY ASP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
226.5	GROUND SURFACE					
0.0	Topsoil	1	AS			
225.9 / 0.6	Clayey Silt, trace to some sand, trace gravel, trace to some organics (Fill) Stiff Brown Moist	2	SS	11	~17	
		3	SS	8		
224.2 / 2.3	Fibrous Peat Firm Black Moist	4	SS	4	61.1	
223.1 / 3.4	Sand, some silt, trace gravel Dense to very dense Grey Wet	5	SS	66		
		6	SS	80	~16	0 83 17 0
		7	SS	65		
		8	SS	44	~21	
219.2 / 7.3	Clayey Silt, trace sand and gravel, occasional sand seams/partings (Till) Hard Grey Moist	9	SS	57		
216.9		10	SS	111	~19	
9.6	END OF BOREHOLE					

Notes:
1. Water level in open borehole at 4.6m depth (Elev.221.9m) upon completion of drilling.
2. Water level in piezometer at 1.6m depth (Elev.224.9m) on March 19, 2001.

Elevation scale: 226, 225, 224, 223, 222, 221, 220, 219, 218, 217

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L
UNIT WEIGHT γ kN/m³

+[3], X[3]: Numbers refer to Sensitivity   O [3%] STRAIN AT FAILURE

RECORD OF BOREHOLE No C-2

1 OF 1 **METRIC**

PROJECT 001-1143F

W.P. 30-95-00

DIST Central HWY 400

DATUM Geodetic

LOCATION N 4896322.8; E 292130.0

BOREHOLE TYPE 108mm ID SOLID STEM AUGERS AND CASING

DATE Nov.1/2000

ORIGINATED BY AZ

COMPILED BY LCC

CHECKED BY ASP

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.2	GROUND SURFACE						
0.0	Topsoil	1	SS	7	227		
226.9 / 0.3	Clayey Silt, some sand (Fill)				226		
225.1 / 2.1	Clayey Silt, some sand, trace gravel (Till) Hard Grey Moist				225		
		2	SS	37	224		
		3	SS	54	223	Wp–w–WL plotted	2 11 55 32
		4	SS	55	222		
		5	SS	46		o	
		6	SS	37	221		
					220		
		7	SS	31	219	o	
		8	SS	33	218		
217.4 / 9.8	END OF BOREHOLE						

Note:
1. Open borehole dry upon completion of drilling.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

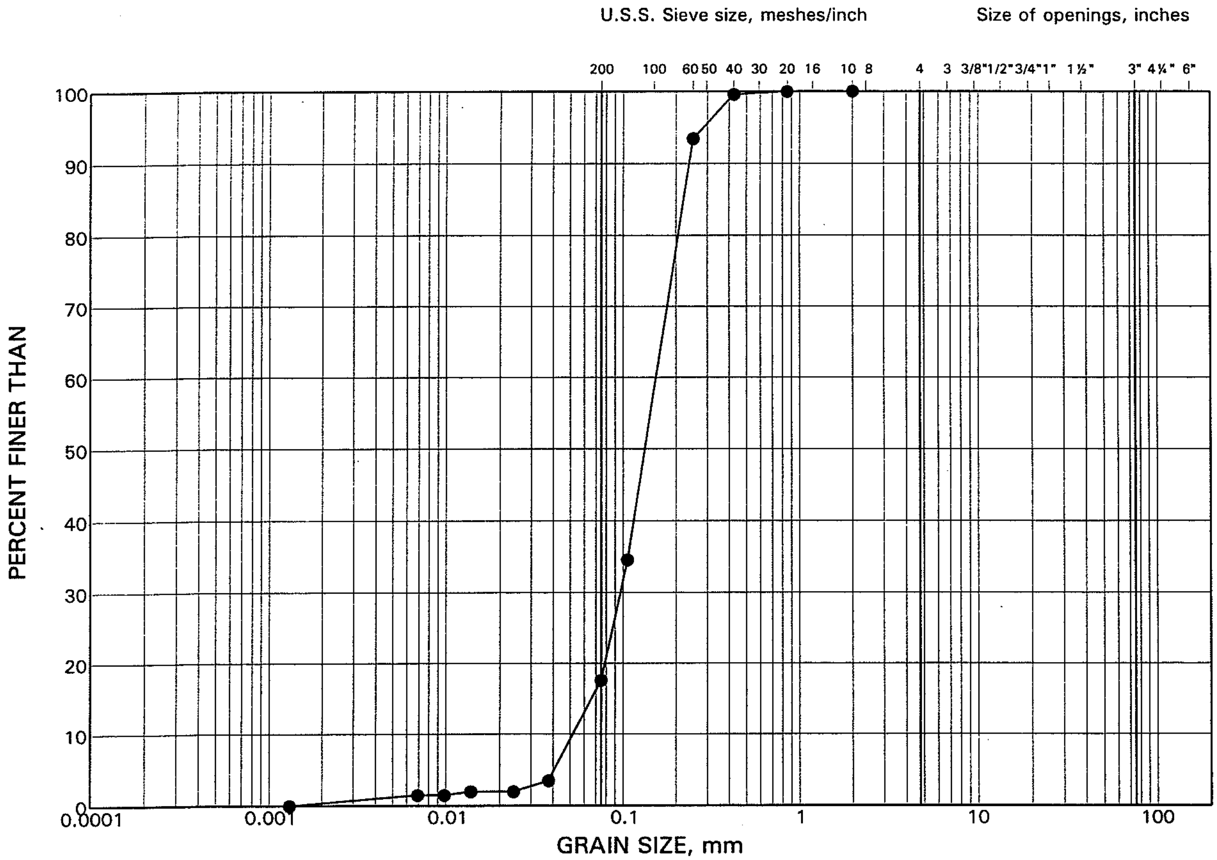
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

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

GRAIN SIZE DISTRIBUTION
Sand

FIGURE 1



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

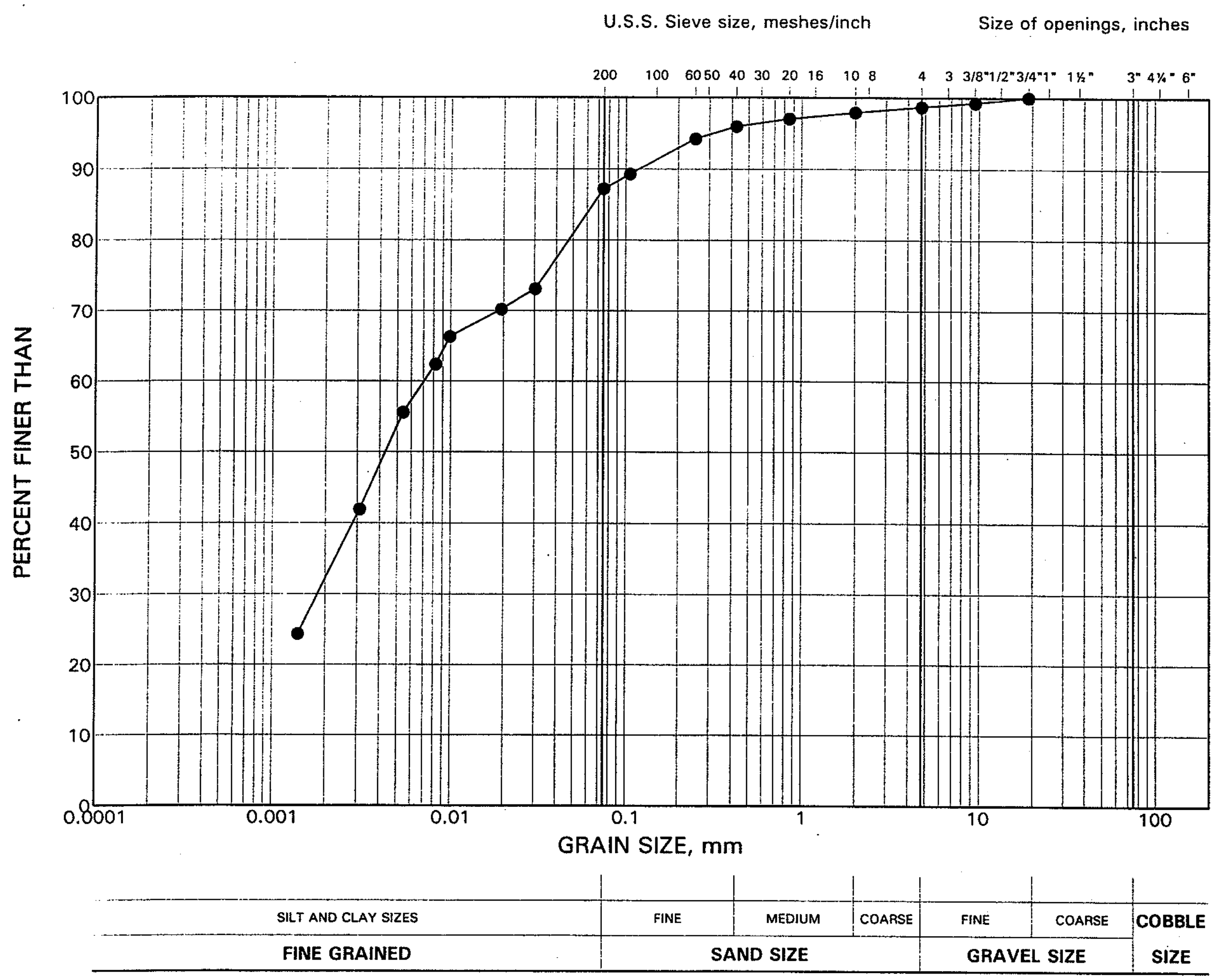
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C-1	6	222.2

Golder Associates

GRAIN SIZE DISTRIBUTION
Clayey Silt (Till)

FIGURE 2



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	C-2	3	222.8

Golder Associates

APPENDIX B

Golder (2018 and 2021) Investigation Borehole Records

GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CE-05

SHEET 1 OF 2

METRIC

PROJECT 1668512
G.W.P. 2438-13-00
DIST Central HWY 400
DATUM Geodetic (CGVD28)

LOCATION N 4896321.5; E 292123.5 MTM NAD 83 ZONE 10 (LAT. 44.206792; LONG. -79.658620)
BOREHOLE TYPE D25 Track-Mounted, 127 mm O.D. Solid Stem Augers
DATE February 22 and 27, 2018

ORIGINATED BY DF
COMPILED BY JIL
CHECKED BY SMM

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.2	GROUND SURFACE							
0.0	TOPSOIL (686 mm)	1	SS	18	227			
226.5 / 0.7	Silt, some sand, trace clay (FILL) Compact Mottled brown grey with oxidation stains Moist	2	SS	17	226	w ≈ 21	NP	0 16 78 6
		3	SS	19		w ≈ 21		
225.0 / 2.2	CLAYEY SILT, some sand, trace gravel Very stiff to hard Brown becoming grey below 3.1 m Wet	4	SS	33	225			
		5	SS	28	224	wP ≈ 13, w ≈ 13, wL ≈ 28		2 13 50 35
		6	SS	37	223			
		7	SS	31	222	w ≈ 14		
		8	SS	29	221			
		9	SS	37	220, 219			
		10	SS	35	218	wP ≈ 17, w ≈ 18, wL ≈ 30		0 0 60 40
	- Sand seam between depths of about 10.2 m and 10.7 m	11	SS	34	217, 216			
		12	SS	38	215	w ≈ 18		
		13	SS	72	214, 213			

Continued Next Page

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

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

GTA-MTO 001 S:\CLIENTS\MTO\HWY_400_AND_HWY_89_INTERCHANGE\02_DATA\GINT\HWY_400_AND_HWY_89_INTERCHANGE.GPJ GAL-GTA.GDT 8/4/21

RECORD OF BOREHOLE No CE-05

SHEET 2 OF 2 **METRIC**

PROJECT 1668512

G.W.P. 2438-13-00

LOCATION N 4896321.5; E 292123.5 MTM NAD 83 ZONE 10 (LAT. 44.206792; LONG. -79.658620)

ORIGINATED BY DF

DIST Central HWY 400

BOREHOLE TYPE D25 Track-Mounted, 127 mm O.D. Solid Stem Augers

COMPILED BY JIL

DATUM Geodetic (CGVD28)

DATE February 22 and 27, 2018

CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
211.4 15.9	CLAYEY SILT, some sand, trace gravel Very stiff to hard Brown becoming grey below 3.1 m Wet		14	SS	82		212		○ (approx. 22)		
	END OF BOREHOLE										

NOTES:

1. Water level measured in open borehole at a depth of about 1.4 m (Elev. 225.8 m) below ground surface upon completion of drilling.

2. Groundwater level measurements in piezometer:

Date	Depth (m)	Elev. (m)
05/03/18	2.5	224.7

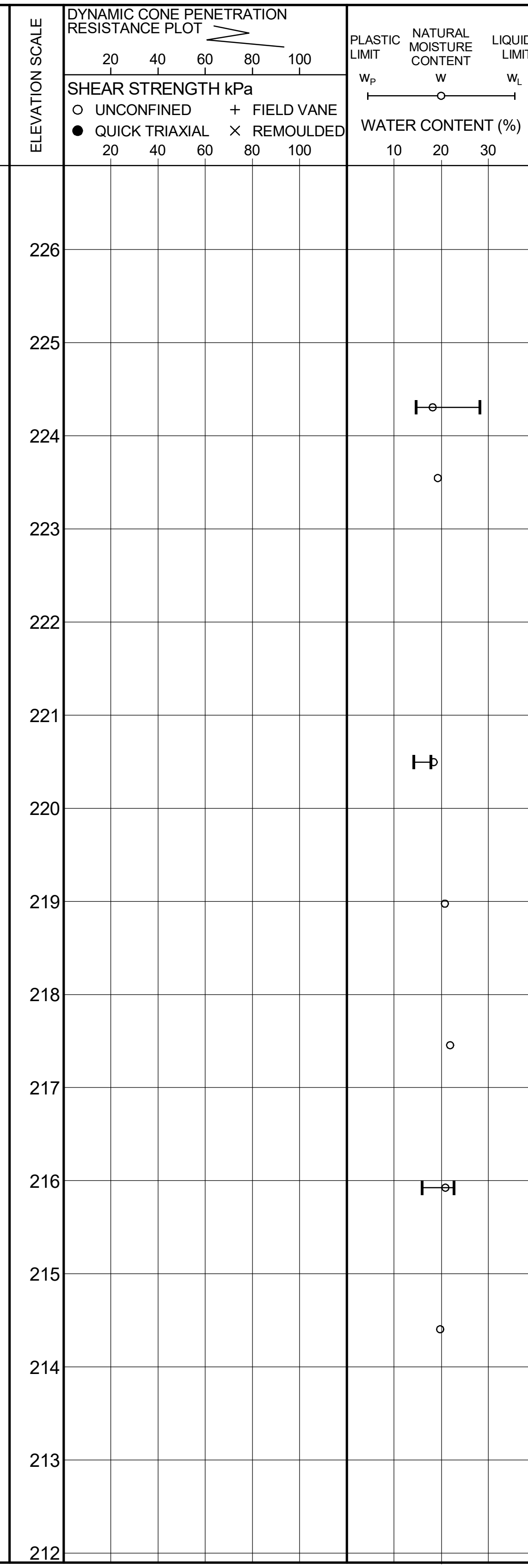
+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No CE-06

SHEET 1 OF 2 **METRIC**

PROJECT 1668512
G.W.P. 2438-13-00
LOCATION N 4896292.8; E 292139.6 MTM NAD 83 ZONE 10 (LAT. 44.206534; LONG. -79.658418)
ORIGINATED BY DF
DIST Central HWY 400
BOREHOLE TYPE D25 Track-Mounted, 127 mm O.D. Solid Stem Augers
COMPILED BY JIL
DATUM Geodetic (CGVD28)
DATE February 26, 2018
CHECKED BY SMM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
226.9	GROUND SURFACE									
0.0	TOPSOIL (686 mm)	1	SS	12						
226.2 0.7	Clayey silt, some sand, trace gravel (FILL) Stiff to very stiff Brown to black Moist	2	SS	18						
		3	SS	9						
224.7 2.2	CLAYEY SILT, some sand, trace gravel Very stiff to hard Grey Wet	4	SS	22			3	13	47	37
		5	SS	28						
		6	SS	25	∇ (approx. El. 222.3)					
		7	SS	50						
221.3 5.6	SILT, some clay, trace gravel, trace sand Very stiff to hard Grey Wet	8	SS	25			1	2	83	14
		9	SS	25						
		10	SS	33						
216.7 10.2	CLAYEY SILT Hard Grey Moist to wet	11	SS	32			0	0	77	23
		12	SS	57						
		13	SS	79						



Continued Next Page

+³, ×³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No CE-06

SHEET 2 OF 2

METRIC

PROJECT 1668512

G.W.P. 2438-13-00

LOCATION N 4896292.8; E 292139.6 MTM NAD 83 ZONE 10 (LAT. 44.206534; LONG. -79.658418)

ORIGINATED BY DF

DIST Central HWY 400

BOREHOLE TYPE D25 Track-Mounted, 127 mm O.D. Solid Stem Augers

COMPILED BY JIL

DATUM Geodetic (CGVD28)

DATE February 26, 2018

CHECKED BY SMM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
211.1	CLAYEY SILT Hard Grey Moist to wet		14	SS	83						
15.9	END OF BOREHOLE NOTES: 1. Water level measured in open borehole at a depth of about 4.6 m (Elev. 222.3) below ground surface upon completion of drilling.										

$+^{3}, \times^{3}$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No CE-07

SHEET 1 OF 1 **METRIC**

PROJECT 1668512

G.W.P. 2438-13-00 LOCATION N 4896324.8; E 292137.7 MTM NAD 83 ZONE 10 (LAT. 44.206820; LONG. -79.658400) ORIGINATED BY DF

DIST Central HWY 400 BOREHOLE TYPE D50 Track-Mounted, 203mm O.D. Hollow Stem Augers COMPILED BY JIL

DATUM Geodetic (CGVD28) DATE February 13, 2018 CHECKED BY SMM

ELEV / DEPTH (m)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
228.8	GROUND SURFACE					
0.0	ASPHALT (223 mm)					
0.2	Sand, some gravel, some silt, trace clay (FILL) Dense Brown Moist	1	SS	32		18 67 12 3
		2	SS	35		
227.4 1.5	Silt and sand, trace gravel, trace to some clay (FILL) Compact Mottled brown and grey Moist	3	SS	20		4 42 43 11
		4	SS	16		
225.8 3.0	CLAYEY SILT, some sand, trace gravel Very stiff to stiff Brown/grey to grey Moist	5	SS	20		
		6A 6B	SS	24	▽ (Elev. 223.8)	2 13 48 37
		7	SS	14		
221.6 7.2	SAND, trace to some silt Compact Grey Wet	8	SS	22		
220.6 8.2	END OF BOREHOLE					

Elevation scale: 228, 227, 226, 225, 224, 223, 222, 221

Dynamic cone penetration resistance plot: 20, 40, 60, 80, 100

Shear strength kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED — 20, 40, 60, 80, 100

Plastic limit W_P — Natural moisture content W — Liquid limit W_L; Water content (%): 10, 20, 30

Unit weight γ kN/m³

NOTES:

1. Water level measured in open borehole at a depth of about 5.0 m (Elev. 223.8) below ground surface upon completion of drilling.

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

GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CE-08

SHEET 1 OF 2

METRIC

PROJECT 1668512
G.W.P. 2438-13-00
DIST Central HWY 400
DATUM Geodetic (CGVD28)
LOCATION N 4896299.6; E 292146.4 MTM NAD 83 ZONE 10 (LAT. 44.206600; LONG. -79.658300)
BOREHOLE TYPE D50 Track-Mounted, 203mm O.D. Continuous Flight Hollow Stem Augers
DATE February 13, 2018
ORIGINATED BY DF
COMPILED BY JIL
CHECKED BY SMM

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ (kN/m³)	GR	SA	SI	CL
228.7	GROUND SURFACE									
0.0	ASPHALT (216 mm)									
0.2	Sand and gravel, trace to some silt, trace clay (FILL) Compact Mottled brown and grey Moist	1	SS	22			34	53	10	3
		2	SS	30						
227.3 1.5	Silt and sand, trace gravel, trace to some clay (FILL) Compact Grey Moist	3	SS	13			4	46	41	9
226.5 2.2	CLAYEY SILT, trace gravel Firm to very stiff Mottled brown and grey Moist	4	SS	17						
		5	SS	11						
		6A 6B	SS	4						
224.4 4.3	Silty SAND, some clay, contains organics Loose Mottled grey Moist	7	SS	4	∇					
223.5 5.2	CLAYEY SILT, trace gravel, trace sand Very stiff Grey Moist	8	SS	16						
		9	SS	20						
221.5 7.2	SILT and SAND, trace clay Compact Grey Wet	10	SS	25		NP	0	42	53	2
220.0 8.7	CLAYEY SILT, trace sand Stiff to very stiff Grey Moist to wet	11	SS	28						
		12	SS	14						
		13	SS	14						
216.0 12.7	SAND, some silt Grey Wet									
215.4 13.3	CLAYEY SILT, trace sand Stiff to very stiff Grey Wet	14	SS	20			0	1	71	28

Elevation scale: 228, 227, 226, 225, 224, 223, 222, 221, 220, 219, 218, 217, 216, 215, 214

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED; 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%): 10 20 30

Continued Next Page

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

GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CE-08

SHEET 2 OF 2 **METRIC**

PROJECT 1668512
G.W.P. 2438-13-00
LOCATION N 4896299.6; E 292146.4 MTM NAD 83 ZONE 10 (LAT. 44.206600; LONG. -79.658300)
ORIGINATED BY DF
DIST Central HWY 400
BOREHOLE TYPE D50 Track-Mounted, 203mm O.D. Continuous Flight Hollow Stem Augers
COMPILED BY JIL
DATUM Geodetic (CGVD28)
DATE February 13, 2018
CHECKED BY SMM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED)	WATER CONTENT (%) (w_P w w_L) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- *CONTINUED FROM PREVIOUS PAGE* ---										
	CLAYEY SILT, trace sand Stiff to very stiff Grey Wet		15	SS	14		213				
							212				
211.3			16	SS	17				○		
17.4	END OF BOREHOLE NOTES: 1. Water level measured in open borehole at a depth of about 4.8 m (Elev. 223.9 m) below ground surface upon completion of drilling.										

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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_400_AND_HWY_89_INTERCHANGE\02_DATA\GINT\HWY_400_AND_HWY_89_INTERCHANGE.GPJ GAL-GTA.GDT 8/4/21

RECORD OF BOREHOLE No CR-01

SHEET 1 OF 2 **METRIC**

PROJECT 1668512

G.W.P. 2438-13-00 LOCATION N 4896309.7; E 292161.2 MTM NAD 83 ZONE 10 (LAT. 44.206687; LONG. -79.658148) ORIGINATED BY JD

DIST Central HWY 400 BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers COMPILED BY CC

DATUM Geodetic (CGVD28) DATE January 24 to 25, 2021 CHECKED BY KJB

ELEV / DEPTH (m)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
228.5	GROUND SURFACE											
0.0	ASPHALT (250 mm)	1A	SS	42		228						
0.3	Gravelly SAND (SP), trace fines (FILL) Dense Brown Dry	1B										
		2	SS	28			○ (approx. 5)					
227.1 / 1.5	SAND (SP-SM), trace gravel, trace fines (FILL) Compact to dense Grey Moist	3	SS	24		227						
	Sandy CLAYEY SILT-SILT (CL-ML), trace gravel (FILL) Very stiff Brown to grey wet	4A	SS	18		226	⊢● (approx. 12–18)		6	23	54	17
225.8 / 2.7	Sandy SILT (ML), trace gravel; trace organics, contains silt interlayers Very loose to compact Grey Moist to Wet	4B										
		5	SS	4		225	○ (approx. 22)		0	19	73	8
		6	SS	4								
		7	SS	3	∇	224	○ (approx. 38)	OC=4.4%	0	31	67	2
		8	SS	17								
223.0 / 5.5	SAND (SP-SM), some fines Compact Grey Moist	9	SS	28		223						
		10	SS	23		222	○ (approx. 20)	NP	0	88	12	0
221.3 / 7.2	SILT (ML) and Sand Compact Grey Moist					221						
		11	SS	29		220						
		12	SS	26		219	○ (approx. 19)		0	44	53	3
218.3 / 10.2	CLAYEY SILT-SILT (CL-ML), trace sand Stiff to very stiff Grey Wet					218						
		13	SS	14		217						
		14	SS	18		216	⊢● (approx. 15–20)		0	3	69	28
		15	SS	19		215						
214.2 / 14.3												

Dynamic Cone Penetration Resistance Plot: 20, 40, 60, 80, 100. Shear Strength kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED: 20, 40, 60, 80, 100. Plastic limit W_P, Natural moisture content W, Liquid limit W_L; Water content (%): 10, 20, 30. Remarks & grain size distribution (%): GR SA SI CL.

Continued Next Page

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

GOLDER
MEMBER OF WSP

RECORD OF BOREHOLE No CR-01

METRIC

PROJECT 1668512

G.W.P. 2438-13-00

LOCATION N 4896309.7; E 292161.2 MTM NAD 83 ZONE 10 (LAT. 44.206687; LONG. -79.658148)

ORIGINATED BY JD

DIST Central HWY 400

BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers

COMPILED BY CC

DATUM Geodetic (CGVD28)

DATE January 24 to 25, 2021

CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE NOTES: 1. Open Borehole caved to 6.0 m below ground surface (Elevation 222.5 m) on completion of drilling. 2. Water level measured at 4.7 m below ground surface (Elevation 223.8 m) in open borehole on completion of drilling.										

+ 3, × 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CR-02

SHEET 1 OF 2

METRIC

PROJECT 1668512

G.W.P. 2438-13-00

LOCATION N 4896344.3; E 292144.4 MTM NAD 83 ZONE 10 (LAT. 44.206997; LONG. -79.658360)

ORIGINATED BY JD

DIST Central HWY 400

BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers

COMPILED BY CC

DATUM Geodetic (CGVD28)

DATE January 31 and February 1, 2021

CHECKED BY KJB

ELEV DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
228.6	GROUND SURFACE								
0.0	ASPHALT (230 mm)	1A	SS	45					
0.3	SAND (SP) and Gravel (FILL), Dense, Brown, Dry	1B							
	SILTY SAND (SM) to SAND (SP-SM), trace fines (FILL), Compact to dense, Brown, Moist	2	SS	21					
		3	SS	19					
226.4 / 2.2	SILT (ML), some sand, trace gravel (TILL), Compact, Brown with oxidization staining, Moist	4	SS	20		2	16	78	4
225.6 / 3.0	Sandy CLAYEY SILT-SILT (CL-ML), trace gravel (TILL), Very stiff, Brown, Moist	5	SS	23		1	32	51	16
224.9 / 3.7	CLAYEY SILT (CL), some sand, trace gravel, containing cobble fragments (TILL), Hard, Brown to grey, Moist	6	SS	67		0	19	45	36
		7	SS	91					
		8	SS	63		1	12	47	37
		9	SS	69	∇ (water level)	3	11	48	38
		10	SS	84					
		11	SS	71					
219.9 / 8.7	SILTY SAND (SM), Dense, Grey, Wet	12	SS	38		0	74	21	5
		13	SS	38					
216.9 / 11.7	CLAYEY SILT (CL), trace sand, Hard, Grey, Wet	14	SS	40		0	1	60	39
		15	SS	41					
214.3 / 14.3									

Continued Next Page

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (228 to 215); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CR-02

SHEET 2 OF 2 **METRIC**

PROJECT 1668512

G.W.P. 2438-13-00 | LOCATION N 4896344.3; E 292144.4 MTM NAD 83 ZONE 10 (LAT. 44.206997; LONG. -79.658360) | ORIGINATED BY JD

DIST Central HWY 400 | BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers | COMPILED BY CC

DATUM Geodetic (CGVD28) | DATE January 31 and February 1, 2021 | CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE NOTES: 1. Open borehole caved to 13.4 m below ground surface (Elevation 215.2 m) on completion of drilling. 2. Water level measured at 5.9 m below ground surface (Elevation 222.7 m) in open borehole on completion of drilling.										

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

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GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CR-03

SHEET 1 OF 1 **METRIC**

PROJECT 1668512

G.W.P. 2438-13-00 LOCATION N 4896317.2; E 292179.9 MTM NAD 83 ZONE 10 (LAT. 44.206754; LONG. -79.657914) ORIGINATED BY JD

DIST Central HWY 400 BOREHOLE TYPE D90 Track-Mounted, 108mm I.D. Hollow Stem Augers COMPILED BY CC

DATUM Geodetic (CGVD28) DATE January 15, 2021 CHECKED BY KJB

ELEV / DEPTH (m)	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	UNIT WEIGHT γ (kN/m³)	GR	SA	SI	CL
226.0	GROUND SURFACE										
0.0	SILTY SAND (SM), trace gravel, containing rootlets (TOPSOIL) Loose Dark brown Moist	1	SS	5							
225.3 / 225.0 1.0	Sandy CLAYEY SILT (CL) (FILL) Firm Brown Wet	2A 2B	SS	5							
	SILTY SAND (SM), trace organics and rootlets to a depth of 3.8 m (FILL) Very loose to loose Black to grey Moist to wet	3	SS	6							
		4	SS	3	∇	45.6		0	73	25	2
		5A 5B	SS	3							
222.3 / 3.9	ORGANIC SILT (OL) Compact Black Wet - Silty sand layers encountered between depths of 3.8 m and 3.9 m	6A 6B 6C	SS	12		122.3	OC=11.6%				
		7	SS	32				0	18	46	36
221.1 / 4.9	CLAYEY SILT (CL), some sand, trace gravel (TILL) Stiff to hard Grey Wet	8	SS	11				0	88	12	0
	SAND (SP-SM), some fines Loose to compact Grey Moist to wet	9	SS	9							
		10	SS	4				0	89	11	0
218.8 / 7.2	SILTY SAND (SM) Very dense Grey Moist	11	SS	32				0	73	25	2
216.6 / 9.4	CLAYEY SILT (CL), trace sand Hard Grey Wet	12A 12B	SS	38							
		13	SS	32				0	1	64	35
		14	SS	39							
213.2 / 12.8	END OF BOREHOLE										

Elevation scale: 225, 224, 223, 222, 221, 220, 219, 218, 217, 216, 215, 214

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

REMARKS & GRAIN SIZE DISTRIBUTION (%)

NOTES:

1. Open borehole caved to 3.5 m below ground surface (Elevation 222.5 m) on completion of drilling.

2. Water level measured at 2.7 m below ground surface (Elevation 223.3 m) in open borehole on completion of drilling.

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

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GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CR-04

SHEET 1 OF 2 **METRIC**

PROJECT 1668512
G.W.P. 2438-13-00
DIST Central HWY 400
DATUM Geodetic (CGVD28)
LOCATION N 4896350.7; E 292159.0 MTM NAD 83 ZONE 10 (LAT. 44.207056; LONG. -79.658177)
BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers
DATE January 27 and 28, 2021
ORIGINATED BY JD
COMPILED BY CC
CHECKED BY KJB

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
227.6	GROUND SURFACE
0.0	ASPHALT (230 mm)
	Gravelly SAND (SP), trace fines (FILL) Dense Brown Moist
226.9 / 0.7	SILTY SAND (SM) (FILL) Dense Grey Moist
226.2 / 1.5	CLAYEY SILT (CL), some sand (FILL) Very stiff Grey Moist
225.4 / 2.2	Sandy SILT (ML), trace gravel (FILL) Compact Grey Moist
	CLAYEY SILT (CL), some sand, trace gravel (TILL) Very stiff to hard Grey with oxidation staining Wet
219.6 / 8.0	SILTY SAND (SM) Compact to dense Grey Moist to wet
215.9 / 11.7	CLAYEY SILT (CL) Very stiff Grey Wet
213.3 / 14.3	

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1A / 1B	SS	33				
2	SS	19				
3A / 3B	SS	25	0	19	75	6
4	SS	18				
5	SS	33	2	12	52	34
6	SS	41				
7	SS	35	1	14	48	37
8	SS	33	1	13	47	39
9	SS	29				
10	SS	26	0	14	46	40
11	SS	41				
12	SS	25	0	63	35	2
13	SS	25				
14	SS	24				
15	SS	28	0	0	63	37

ELEVATION SCALE: 227, 226, 225, 224, 223, 222, 221, 220, 219, 218, 217, 216, 215, 214

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED; 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

RECORD OF BOREHOLE No CR-04

METRIC

PROJECT 1668512
G.W.P. 2438-13-00
LOCATION N 4896350.7; E 292159.0 MTM NAD 83 ZONE 10 (LAT. 44.207056; LONG. -79.658177)
ORIGINATED BY JD
DIST Central HWY 400
BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers
COMPILED BY CC
DATUM Geodetic (CGVD28)
DATE January 27 and 28, 2021
CHECKED BY KJB

SOIL PROFILE		SAMPLES						DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR SA SI CL
	--- *CONTINUED FROM PREVIOUS PAGE* ---										
	END OF BOREHOLE NOTES: 1. Open borehole caved to 10.0 m below ground surface (Elevation 217.6 m) on completion of drilling. 2. Water level measured at 5.4 m below ground surface (Elevation 222.2 m) in open borehole on completion of drilling. 3. Water level observations in piezometer: Date Depth (m) Elev. (m) 10/02/21 3.3 224.3										

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

GOLDER
MEMBER OF WSP

RECORD OF BOREHOLE No CR-05

SHEET 1 OF 2 **METRIC**

PROJECT 1668512
G.W.P. 2438-13-00
LOCATION N 4896326.6; E 292185.4 MTM NAD 83 ZONE 10 (LAT. 44.206839; LONG. -79.657846)
ORIGINATED BY JD
DIST Central HWY 400
BOREHOLE TYPE D90 Track-Mounted, 108mm I.D. Hollow Stem Augers
COMPILED BY CC
DATUM Geodetic (CGVD28)
DATE January 18, 2021
CHECKED BY KJB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
225.1	GROUND SURFACE					
0.0	Sandy SILT (ML), containing rootlets (TOPSOIL) Soft to stiff Brown with oxidation staining Wet	1	SS	11		
224.1 1.0	Sandy ORGANIC SILT (OL) Very loose Brown to black Moist	2A 2B	SS	3		
		3	SS	2	62.3 OC=5.9%	
		4	SS	1		
222.1 3.0	SILTY SAND (SM) Compact Grey Wet	5A 5B	SS	15		3 52 44 1
221.6	CLAYEY SILT (CL) Very stiff Grey Wet					
221.1 4.0	Gravelly CLAYEY SAND (SC) Very stiff Grey Wet	6A 6B	SS	25		31 41 24 4 / 0 4 81 15
220.6 4.5	CLAYEY SILT (CL), trace sand Very stiff Grey Moist	7A 7B	SS	21		0 10 87 3
220.2 4.9	SILT (ML), trace sand Compact Grey Moist to wet	8	SS	21		
	CLAYEY SILT-SILT (CL-ML), trace sand Very stiff Grey Wet	9	SS	29		0 4 76 20
218.9 6.2	SILT (ML), some sand Compact Grey Moist	10A 10B	SS	28		0 18 81 1
217.9 7.2	CLAYEY SILT (CL), trace sand Very stiff to hard Grey Wet	11	SS	24		
		12	SS	25		
		13	SS	40		0 0 53 47
		14	SS	30		
212.3 12.8						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L
UNIT WEIGHT γ kN/m³

Continued Next Page

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

GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CR-05

SHEET 2 OF 2 **METRIC**

PROJECT 1668512

G.W.P. 2438-13-00 LOCATION N 4896326.6; E 292185.4 MTM NAD 83 ZONE 10 (LAT. 44.206839; LONG. -79.657846) ORIGINATED BY JD

DIST Central HWY 400 BOREHOLE TYPE D90 Track-Mounted, 108mm I.D. Hollow Stem Augers COMPILED BY CC

DATUM Geodetic (CGVD28) DATE January 18, 2021 CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE NOTES: 1. Open borehole caved to 2.1 m below ground surface (Elevation 223.0 m) on completion of drilling. 2. Water level measured at 1.5 m below ground surface (Elevation 223.6 m) in open borehole on completion of drilling. 3. Water level observations in piezometer: Date Depth (m) Elev. (m) 10/02/21 1.3 223.8										

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

GOLDER
MEMBER OF WSP

RECORD OF BOREHOLE No CR-06

SHEET 1 OF 1

METRIC

PROJECT 1668512

G.W.P. 2438-13-00

LOCATION N 4896366.7; E 292167.4 MTM NAD 83 ZONE 10 (LAT. 44.207200; LONG. -79.658071)

ORIGINATED BY JD

DIST Central HWY 400

BOREHOLE TYPE D90 Track-Mounted, 108mm I.D. Hollow Stem Augers

COMPILED BY CC

DATUM Geodetic (CGVD28)

DATE January 20, 2021

CHECKED BY KJB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
226.7	GROUND SURFACE					
0.0	Sandy CLAYEY SILT (CL), containing rootlets and organics (TOPSOIL) Firm Brown Wet	1	SS	7		
226.0 / 0.7	SILTY SAND (SM) Compact Brown-grey with oxidation staining Moist	2	SS	16		
225.3 / 1.5	CLAYEY SILT (CL), some sand to sandy, trace gravel (TILL) Stiff to hard Brown with oxidation staining Moist	3	SS	14	w	5 25 53 17
		4	SS	43		
		5	SS	49		
		6	SS	43	w, Wp–WL	3 12 45 40
		7	SS	36		
		8	SS	38	w, Wp–WL	1 13 46 40
		9	SS	53	w, Wp–WL	8 11 45 36
220.5 / 6.2	Sandy SILT (ML) to SILTY SAND (SM) Compact Grey Moist	10A 10B 10C	SS	28		
219.5 / 7.2	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML), trace to some sand Very stiff to hard Grey Moist	11	SS	22	w	0 10 85 5
		12	SS	22		
		13	SS	24	w, Wp–WL	0 0 55 45
		14	SS	30		
213.9 / 12.8	END OF BOREHOLE					

Groundwater level symbol (▽) shown at approx. elevation 218.2.

NOTES:

1. Open borehole caved to 11.0 m below ground surface (Elevation 215.7 m) on completion of drilling.

2. Water level measured at 8.5 m below ground surface (Elevation 218.2 m) in open borehole on completion of drilling.

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; ELEVATION SCALE 226–214.

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

GOLDER
MEMBER OF WSP

Foundation Design

RECORD OF BOREHOLE No CR-07

SHEET 1 OF 2 **METRIC**

PROJECT 1668512			
G.W.P. 2438-13-00	LOCATION N 4896285.0; E 292149.8 MTM NAD 83 ZONE 10 (LAT. 44.206464; LONG. -79.658290)	ORIGINATED BY JD	
DIST Central HWY 400	BOREHOLE TYPE D90 Track-Mounted, 108mm I.D. Hollow Stem Augers	COMPILED BY CC	
DATUM Geodetic (CGVD28)	DATE January 22, 2021	CHECKED BY KJB	

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
228.9	GROUND SURFACE
0.0	Gravelly SAND (SW), trace silt (FILL) Very dense Brown Moist
228.5	
228.2 0.7	CLAYEY SILT (CL), trace sand (FILL) Hard Brown Wet
227.3 1.7	Gravelly SILTY SAND (SM) (FILL) Compact to dense Brown Moist CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML) and Sand, trace gravel, trace organics (FILL) Stiff to very stiff Grey-black Moist - Silt seam at 4.0 m depth
224.6 4.3	SILTY SAND (SM), trace gravel, trace organics, containing wood pieces (FILL) Loose Dark Grey Moist
224.0	
223.7 5.2	Sandy SILT (ML), containing organics Compact Brown-black Wet CLAYEY SILT (CL), trace to some sand, trace gravel (TILL) Stiff to hard Grey Moist to wet
219.2 9.8	Sandy CLAYEY SILT (CL) (TILL) Very stiff Grey Wet
217.2 11.7	Sandy SILT (ML) to SILT (ML) and sand Compact Grey Wet
215.6 13.3	CLAYEY SILT (CL), some sand Very stiff Grey Wet
214.6 14.3	

SAMPLES

NUMBER	TYPE	"N" VALUES	WATER CONTENT NOTE	GR	SA	SI	CL
1A 1B	SS	58					
2	SS	45		30	58	9	3
3A 3B	SS	17					
4	SS	17		1	26	61	12
5	SS	16					
6	SS	10		0	41	53	6
7	SS	7	46.6	1	74	22	3
8A 8B	SS	10	45.1 OC=4.2%				
9	SS	24		6	12	44	38
10	SS	43					
11	SS	57					
12	SS	35					
13	SS	26					
14	SS	21		0	42	52	6
15	SS	29					

GROUND WATER CONDITIONS | ELEVATION SCALE: 228, 227, 226, 225, 224, 223, 222, 221, 220, 219, 218, 217, 216, 215

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

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

Continued Next Page

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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_400_AND_HWY_89_INTERCHANGE\02_DATA\GINT\HWY_400_AND_HWY_89_INTERCHANGE.GPJ GAL-GTA.GDT 8/4/21

GOLDER MEMBER OF WSP

RECORD OF BOREHOLE No CR-07

SHEET 2 OF 2 **METRIC**

PROJECT 1668512

G.W.P. 2438-13-00 LOCATION N 4896285.0; E 292149.8 MTM NAD 83 ZONE 10 (LAT. 44.206464; LONG. -79.658290) ORIGINATED BY JD

DIST Central HWY 400 BOREHOLE TYPE D90 Track-Mounted, 108mm I.D. Hollow Stem Augers COMPILED BY CC

DATUM Geodetic (CGVD28) DATE January 22, 2021 CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE NOTES: 1. Open borehole caved to 9.8 m below ground surface (Elevation 219.1 m) on completion of drilling. 2. Water level measured at 4.7 m below ground surface (Elevation 224.2 m) in open borehole on completion of drilling. 3. Water level observations in piezometer: Date Depth (m) Elev. (m) 10/02/21 4.0 224.9										

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

GOLDER
MEMBER OF WSP

RECORD OF BOREHOLE No CR-08

SHEET 1 OF 2 **METRIC**

PROJECT	1668512
G.W.P.	2438-13-00
LOCATION	N 4896294.6; E 292162.3 MTM NAD 83 ZONE 10 (LAT. 44.206550; LONG. -79.658134)
ORIGINATED BY	JD
DIST	Central
HWY	400
BOREHOLE TYPE	D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers
COMPILED BY	CC
DATUM	Geodetic (CGVD28)
DATE	February 1, 2021
CHECKED BY	KJB

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
228.5	GROUND SURFACE
0.0 / 228.2	ASPHALT (250 mm)
227.8 / 0.7	Gravelly SAND (SP/GP), trace fines (FILL) Very dense Brown Dry
226.8 / 1.7	SAND (SP), trace fines (FILL) Compact to very dense Grey Moist
225.5 / 3.0	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML), some sand to sandy, trace gravel, trace organics, containing wood pieces (FILL) Firm to very stiff Grey Moist
223.4 / 5.1	SILTY SAND (SM) to sandy SILT (ML), trace organics Very loose to loose Grey Moist to wet - 200 mm sandy clayey silt lense encountered at a depth of 3.7 m
219.8 / 8.7	CLAYEY SILT (CL), some sand, trace gravel (TILL) Stiff to hard Grey Moist to wet
216.8 / 11.7	SILTY SAND (SM) to SILT (ML) and sand, containing clayey silt pockets at 9.6 m depth Compact Grey Moist to wet
214.2 / 14.3	Sandy CLAYEY SILT (CL) Stiff to very stiff Grey Wet

Continued Next Page

SAMPLES AND REMARKS

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	GR	SA	SI	CL
1A / 1B	SS	71						
2	SS	26						
3A / 3B	SS	4			1	35	48	16
4A / 4B	SS	16			0	20	69	11
5A / 5B	SS	8						
6A / 6B	SS	4			0 / 0	37 / 60	53 / 34	10 / 6
7	SS	4	∇	40.2				
8A / 8B	SS	9			0 / 1	70 / 13	26 / 48	4 / 38
9	SS	16						
10	SS	26			2	13	47	38
11	SS	31						
12A / 12B	SS	23						
13	SS	13			0	38	56	6
14	SS	25						
15	SS	14						

ELEVATION SCALE: 228 – 215

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m^3

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

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

RECORD OF BOREHOLE No CR-08

SHEET 2 OF 2 **METRIC**

PROJECT 1668512			
G.W.P. 2438-13-00	LOCATION N 4896294.6; E 292162.3 MTM NAD 83 ZONE 10 (LAT. 44.206550; LONG. -79.658134)		ORIGINATED BY JD
DIST Central HWY 400	BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers		COMPILED BY CC
DATUM Geodetic (CGVD28)	DATE February 1, 2021		CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE NOTE: 1. Water level measured at 4.6 m below ground surface (Elevation 223.9 m) in open borehole on completion of drilling										

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

RECORD OF BOREHOLE No CR-09

SHEET 1 OF 2 **METRIC**

PROJECT 1668512
G.W.P. 2438-13-00
DIST Central HWY 400
DATUM Geodetic (CGVD28)
LOCATION N 4896303.7; E 292175.9 MTM NAD 83 ZONE 10 (LAT. 44.206632; LONG. -79.657964)
BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers
DATE January 25 to 26, 2021
ORIGINATED BY JD
COMPILED BY CC
CHECKED BY KJB

ELEV / DEPTH (m)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS	GR	SA	SI	CL
228.4	GROUND SURFACE								
0.0	ASPHALT (220 mm)								
0.2	Gravelly SAND (SP), trace fines (FILL) Compact to dense Moist Brown	1	SS	48					
		2	SS	23					
		3	SS	19					
226.2 / 2.2	Sandy SILT (ML), some gravel, trace organics (FILL) Loose Brown Moist	4	SS	7	OC=4.7%	14	33	44	9
225.4 / 3.0	SILTY SAND (SM), trace gravel, trace organics, contains sand layers Very loose to loose Grey to dark grey Moist	5	SS	7					
		6	SS	4	NP	1	78	19	2
		7A / 7B	SS	3					
223.7 / 4.7	CLAYEY SILT (CL), some sand, trace gravel (TILL) Soft to very stiff Grey Wet	8	SS	16		1	13	48	38
		9	SS	27					
		10	SS	29		0	14	46	40
221.2 / 7.2	SILTY SAND (SM) Loose to dense Grey Moist to wet	11	SS	9					
		12	SS	49		0	62	35	3
		13A / 13B	SS	29					
217.3 / 11.1	CLAYEY SILT-SILT (CL-ML), trace sand Stiff to very stiff Grey Wet	14	SS	14		0	3	81	16
		15	SS	19					
214.1 / 14.3									

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (228 to 215); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

GOLDER
MEMBER OF WSP

RECORD OF BOREHOLE No CR-09

METRIC

PROJECT 1668512

G.W.P. 2438-13-00

LOCATION N 4896303.7; E 292175.9 MTM NAD 83 ZONE 10 (LAT. 44.206632; LONG. -79.657964)

ORIGINATED BY JD

DIST Central HWY 400

BOREHOLE TYPE D90 Truck-Mounted, 108mm I.D. Hollow Stem Augers

COMPILED BY CC

DATUM Geodetic (CGVD28)

DATE January 25 to 26, 2021

CHECKED BY KJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE										

NOTES:

1. Open borehole caved to 8.2 m below ground surface (Elevation 220.2 m) on completion of drilling.

2. Water level measured at 5.0 m below ground surface (Elevation 223.4 m) in open borehole on completion of drilling.

3. Water level observations in piezometer:

Date	Depth (m)	Elev. (m)
10/02/21	3.5	224.9

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

Foundation Design

GOLDER
MEMBER OF WSP

RECORD OF BOREHOLE No CR-10

SHEET 1 OF 1 **METRIC**

PROJECT 1668512
G.W.P. 2438-13-00 LOCATION N 4896315.7; E 292188.1 MTM NAD 83 ZONE 10 (LAT. 44.206741; LONG. -79.657812) ORIGINATED BY JD
DIST Central HWY 400 BOREHOLE TYPE D90 Track-Mounted, 108mm I.D. Hollow Stem Augers COMPILED BY CC
DATUM Geodetic (CGVD28) DATE January 19, 2021 CHECKED BY KJB

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
225.5	GROUND SURFACE						
0.0	SILTY SAND (SM), containing rootlets (TOPSOIL) Very loose Brown Moist	1	SS	3			
224.8 / 0.7	Sandy CLAYEY SILT (CL) (FILL) Firm Brown with oxidation staining Wet	2	SS	8			
224.1 / 1.5	SILTY SAND (SM), trace organics (FILL) Very loose Brown Moist	3	SS	2	▽	49.4	0 70 27 3
		4	SS	2			
222.5 / 3.0	SILTY SAND (SM), trace gravel Loose to dense Grey Moist to wet - Contains sand interlayers from 4.5 m to 5.5 m	5	SS	11			7 47 41 5
		6	SS	5			
		7	SS	31			8 80 9 3
		8	SS	17			0 80 19 1
220.0 / 5.5	SILT (ML) of slight plasticity, trace sand Compact Grey Moist to wet	9	SS	12			
		10	SS	14			0 4 86 10
218.3 / 7.2	SILTY SAND (SM) Loose Grey Wet	11A 11B	SS	7			
217.4 / 8.1	CLAYEY SILT (CL), trace sand Very stiff to hard Grey Wet	12	SS	24			0 1 83 16
		13	SS	34			0 0 68 32
		14	SS	36			
212.7 / 12.8	END OF BOREHOLE						

NOTES:

1. Open borehole caved to 4.3 m below ground surface (Elevation 221.2 m) on completion of drilling.

2. Water level measured at 2.1 m below ground surface (Elevation 223.4 m) in open borehole on completion of drilling.

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; ELEVATION SCALE 225–213.

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

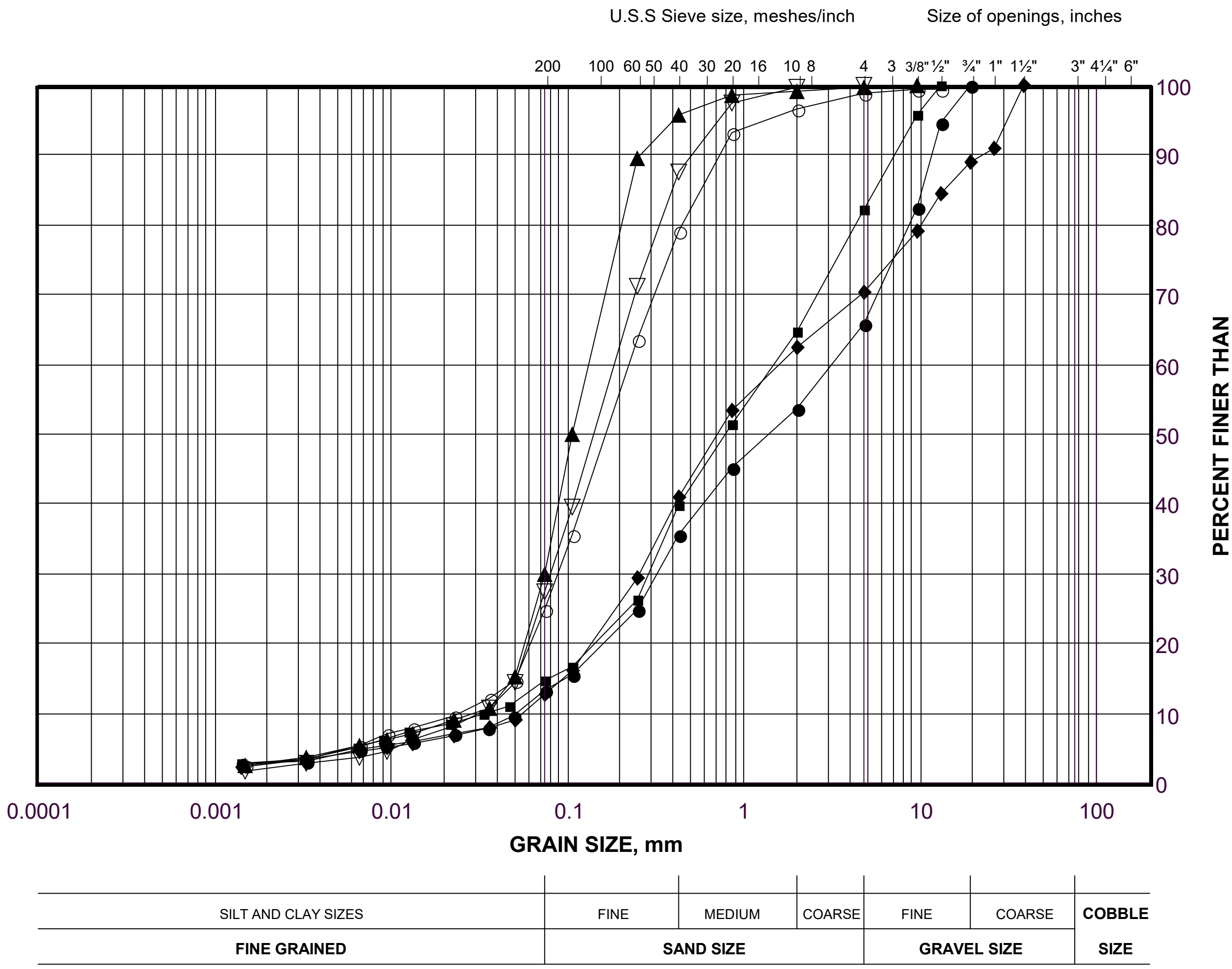
APPENDIX C

Golder (2018 and 2021) Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

SILTY SAND (SM) to Gravelly SAND (SW-SM) (FILL)

FIGURE C1A



LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-08	1	228.3
■	CE-07	1	228.4
◆	CR-07	2	227.8
▲	CR-10	3	223.7
▽	CR-03	4	223.4
○	CR-07	7	224.3

Project Number: 1668512

Checked By: CC

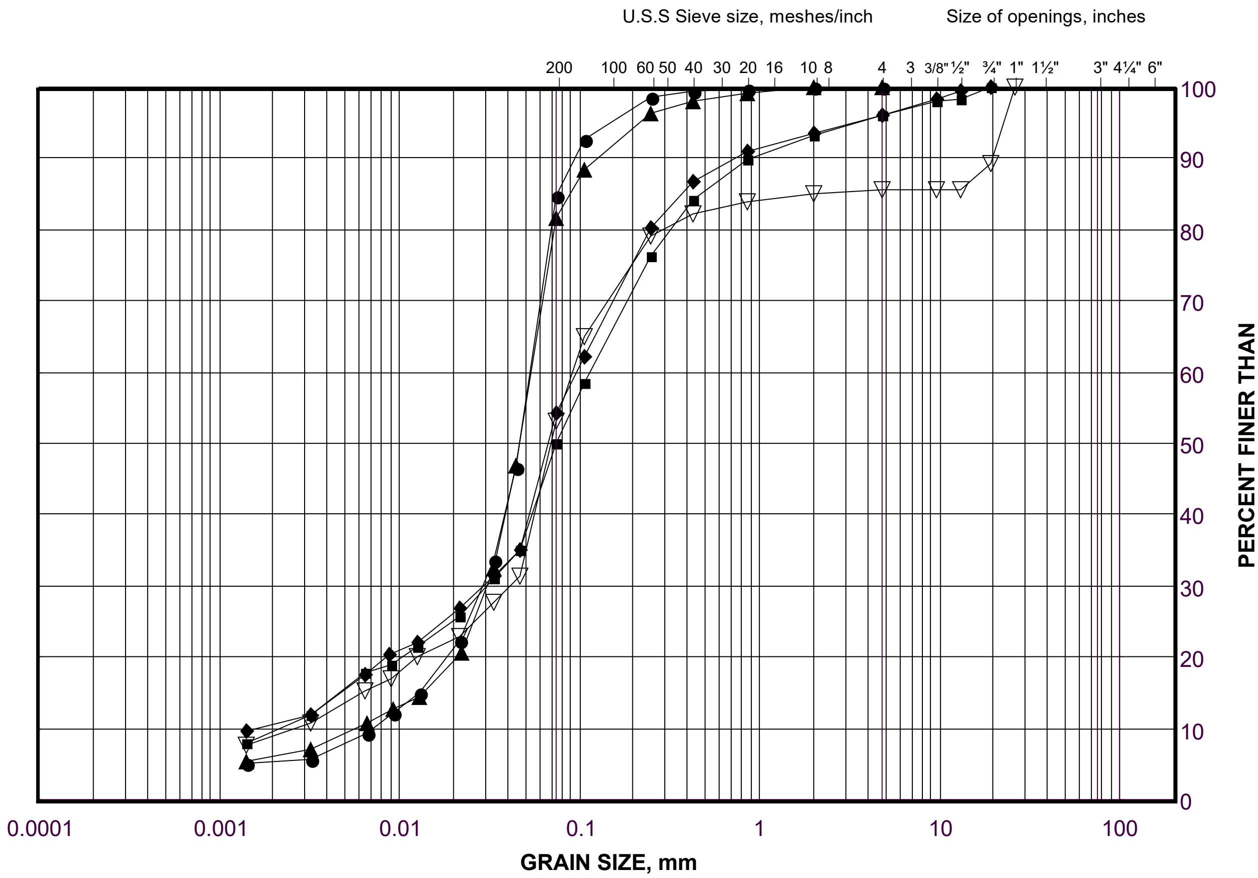
Golder Associates

Date: 14-May-21

GRAIN SIZE DISTRIBUTION

SILT (ML) to Sandy SILT (ML) (FILL)

FIGURE C1B



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

LEGEND

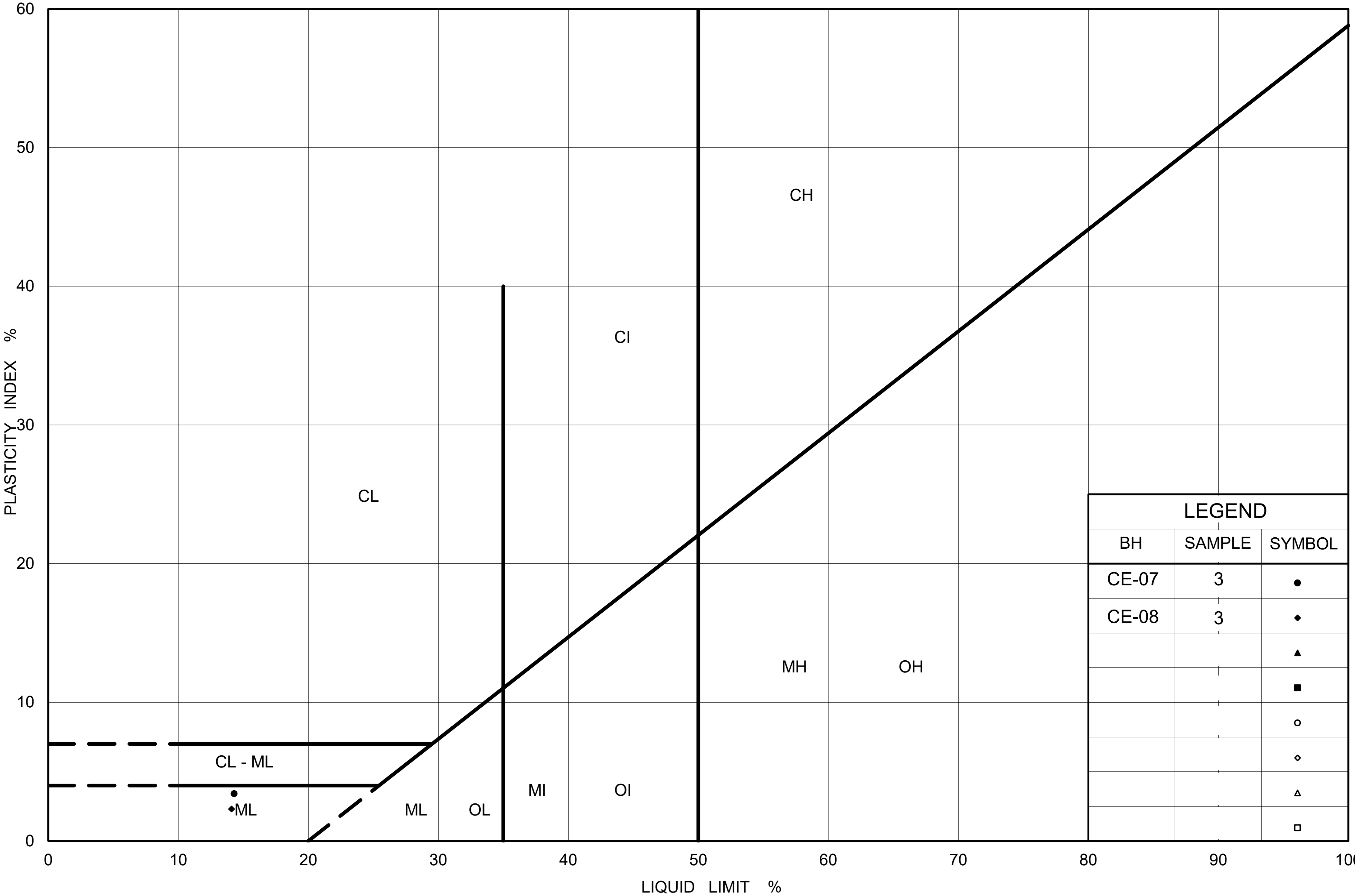
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-05	2	226.1
■	CE-08	3	226.9
◆	CE-07	3	227.0
▲	CR-04	3A	225.7
▽	CR-09	4	225.8

Project Number: 1668512

Checked By: CC

Golder Associates

Date: 14-May-21



LEGEND		
BH	SAMPLE	SYMBOL
CE-07	3	●
CE-08	3	◆
		▲
		■
		○
		◇
		△
		□

Ministry of Transportation

Ontario

PLASTICITY CHART
SANDY SILT (ML) to SILTY SAND (SM) (FILL)

Figure No. C2

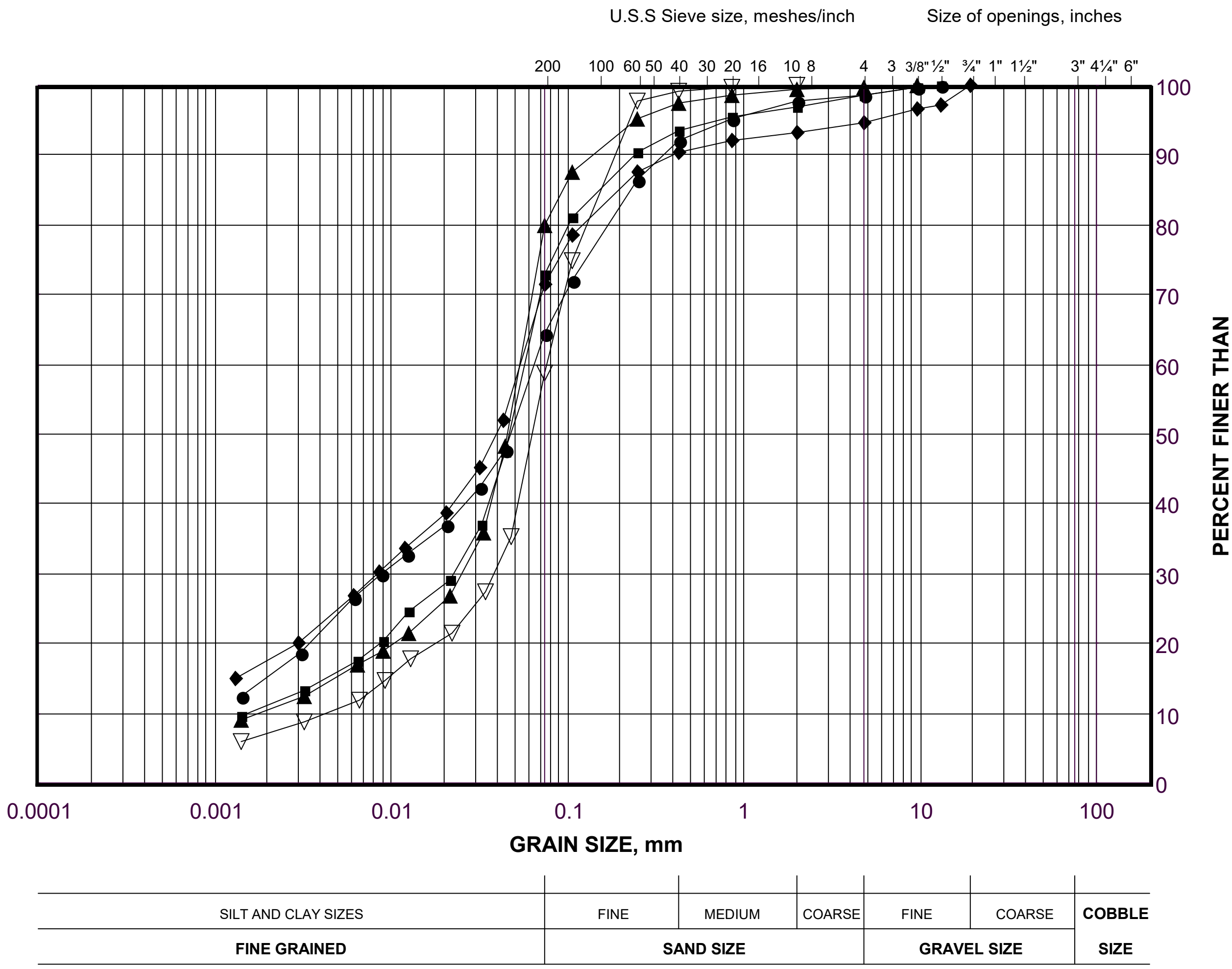
Project No. 1668512

Checked By: CC

GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) to Sandy CLAYEY SILT-SILT (CL-ML) (FILL)

FIGURE C3



LEGEND

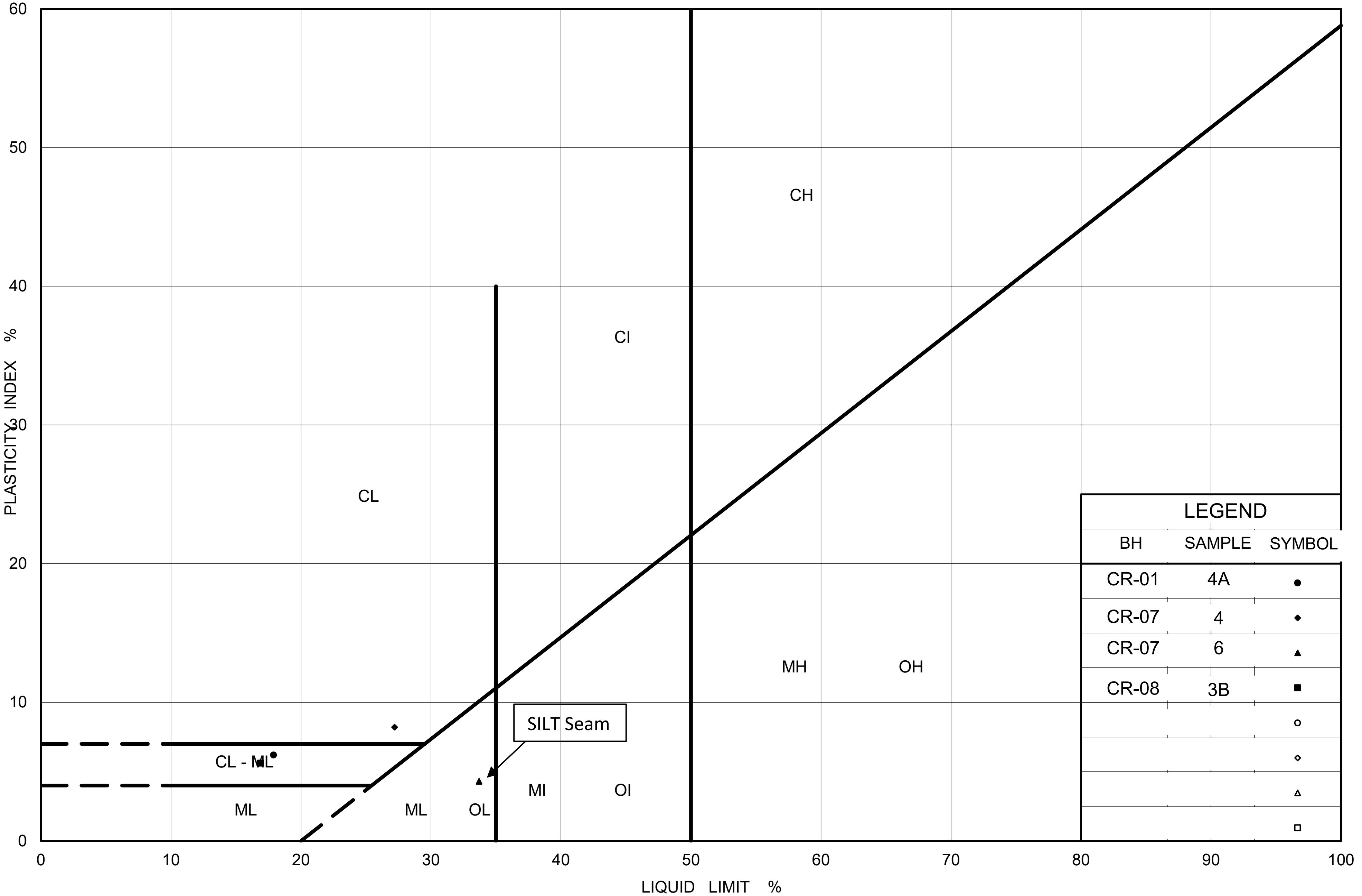
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-08	3B	226.5
■	CR-07	4	226.3
◆	CR-01	4A	226.0
▲	CR-08	4B	225.8
▽	CR-07	6	224.9

Project Number: 1668512

Checked By: CC

Golder Associates

Date: 14-May-21

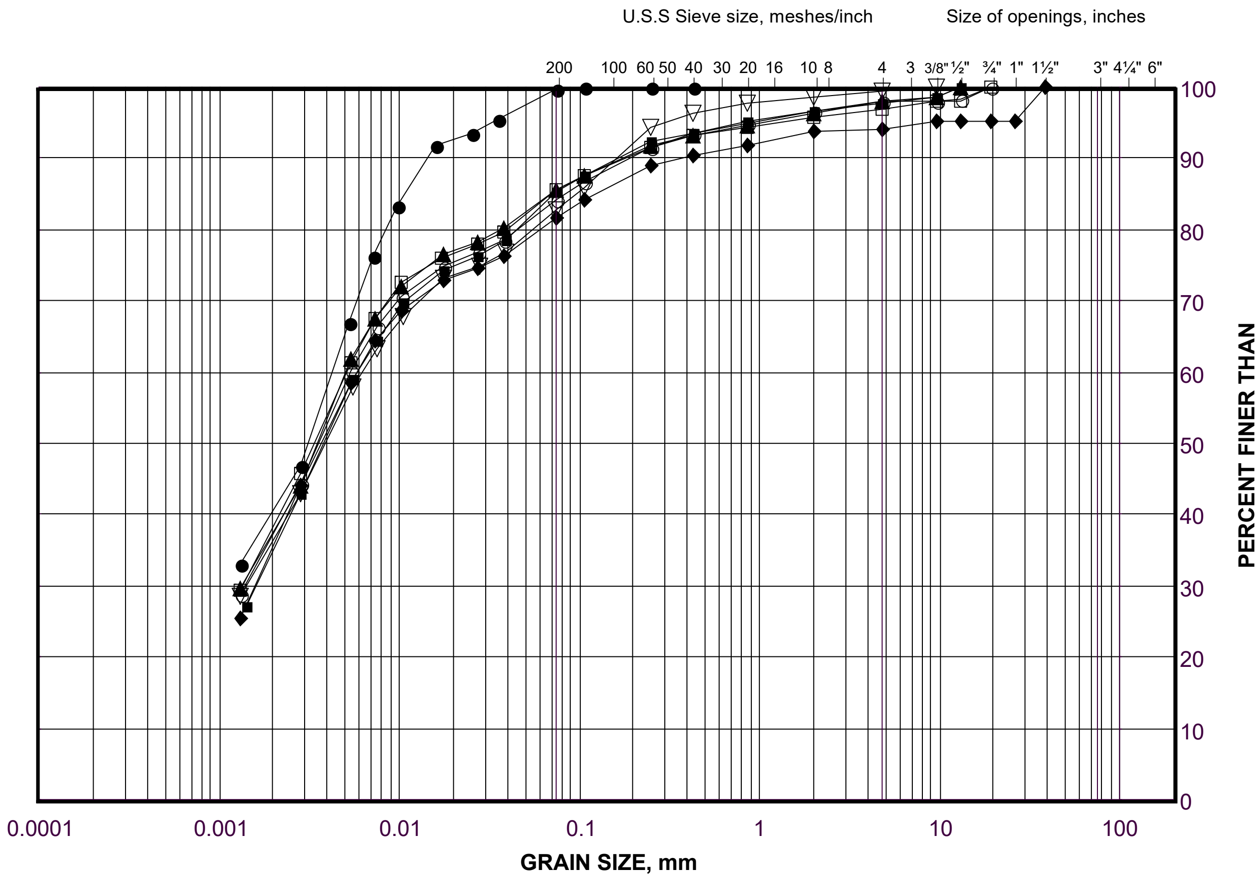


Ministry of Transportation Ontario	**PLASTICITY CHART** CLAYEY SILT (CL) to Sandy CLAYEY SILT-SILT (CL-ML) (FILL)	Figure No. C4 Project No. 1668512 Checked By: CC

GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) (TILL)

FIGURE C5A



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-05	10	217.8
■	CE-05	5	223.8
◆	CR-02	6	224.6
▲	CE-07	6	224.0
▽	CR-03	7	221.4
❍	CR-02	8	223.4
□	CR-02	9	222.8

Project Number: 1668512

Checked By: CC

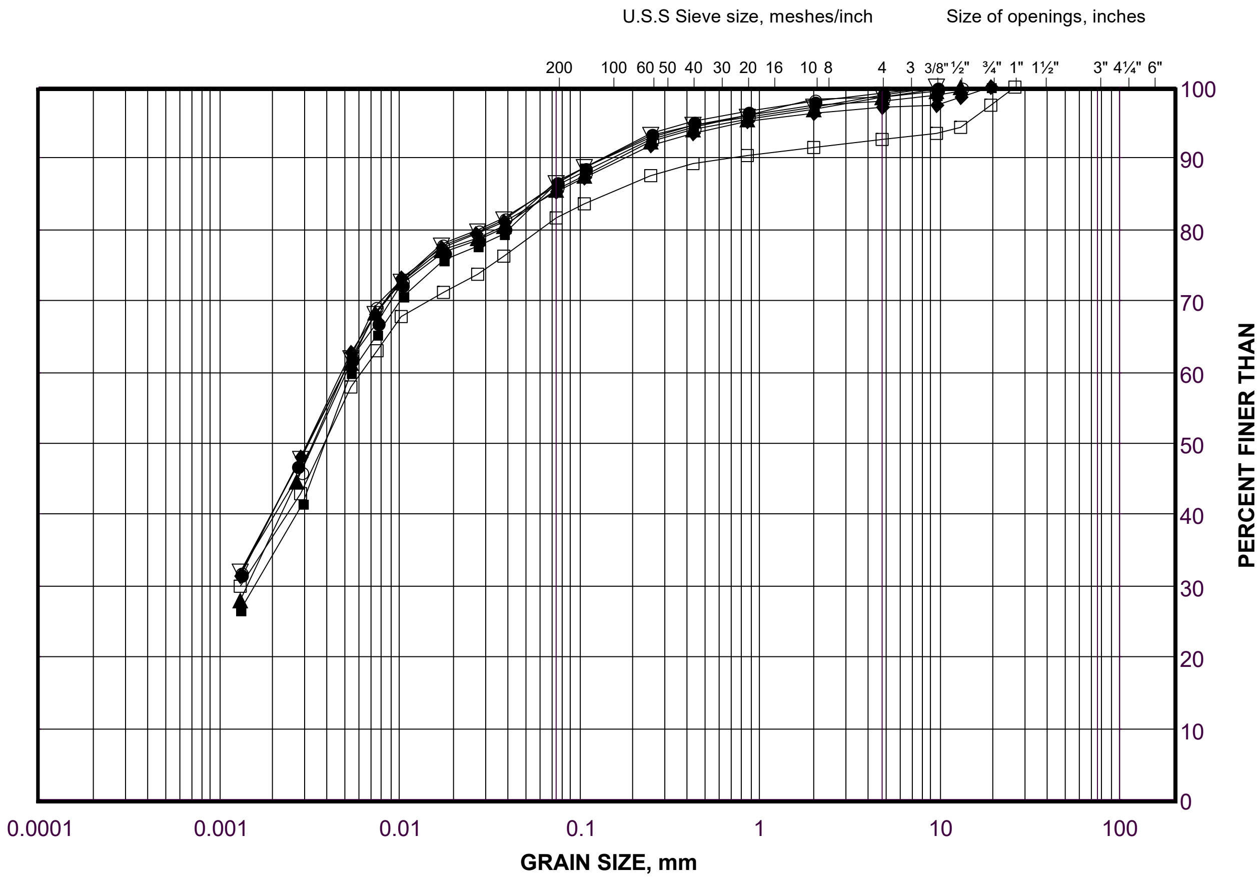
Golder Associates

Date: 05-May-21

GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) (TILL)

FIGURE C5B



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-04	10	221.2
■	CR-04	5	224.2
◆	CR-06	6	222.7
▲	CR-04	7	223.0
▽	CR-06	8	221.5
❍	CR-04	8	222.4
□	CR-06	9	220.9

Project Number: 1668512

Checked By: CC

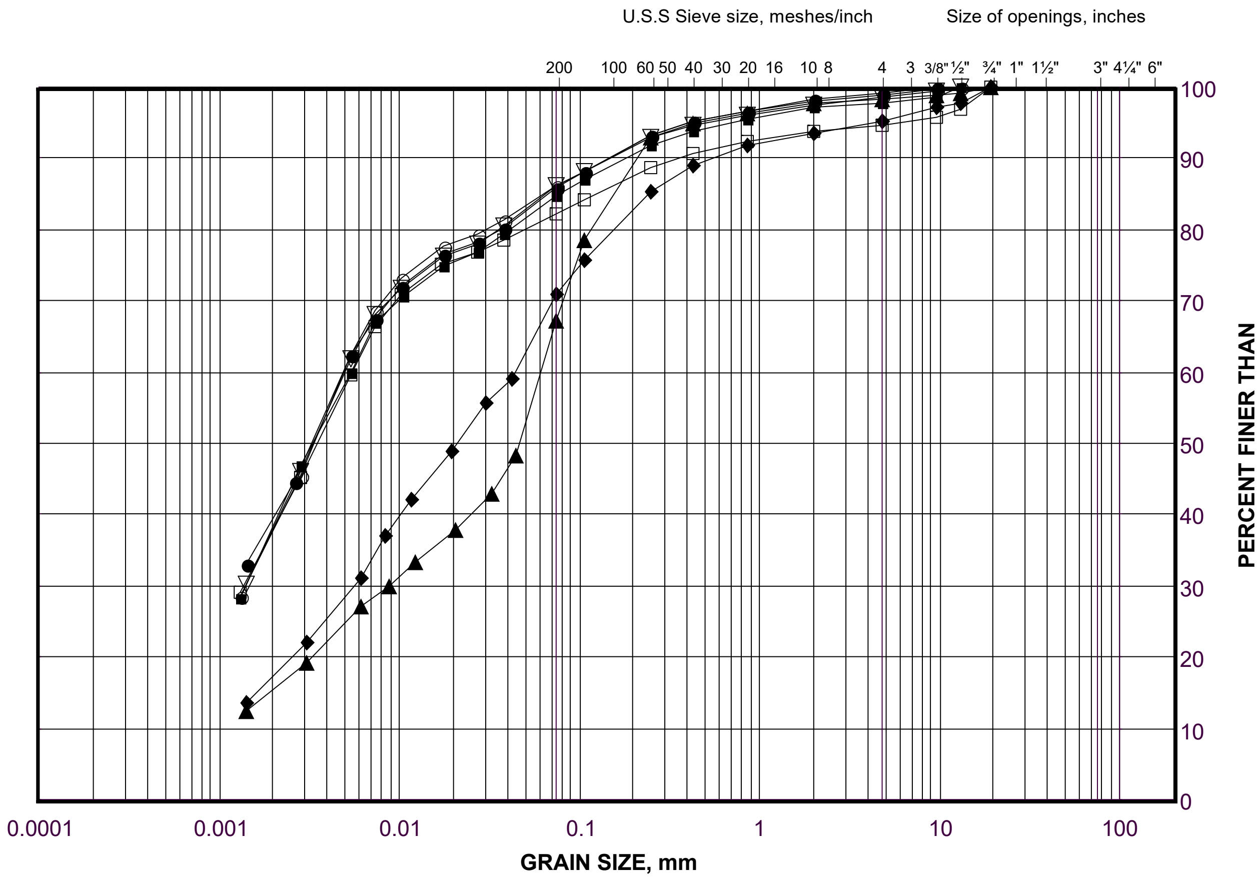
Golder Associates

Date: 05-May-21

GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) to Sandy CLAYEY SILT-SILT (CL-ML) (TILL)

FIGURE C5C



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-09	10	221.9
■	CR-08	10	222.1
◆	CR-06	3	224.9
▲	CR-02	5	225.3
▽	CR-09	8	223.2
❍	CR-08	8B	223.2
□	CR-07	9	223.1

Project Number: 1668512

Checked By: CC

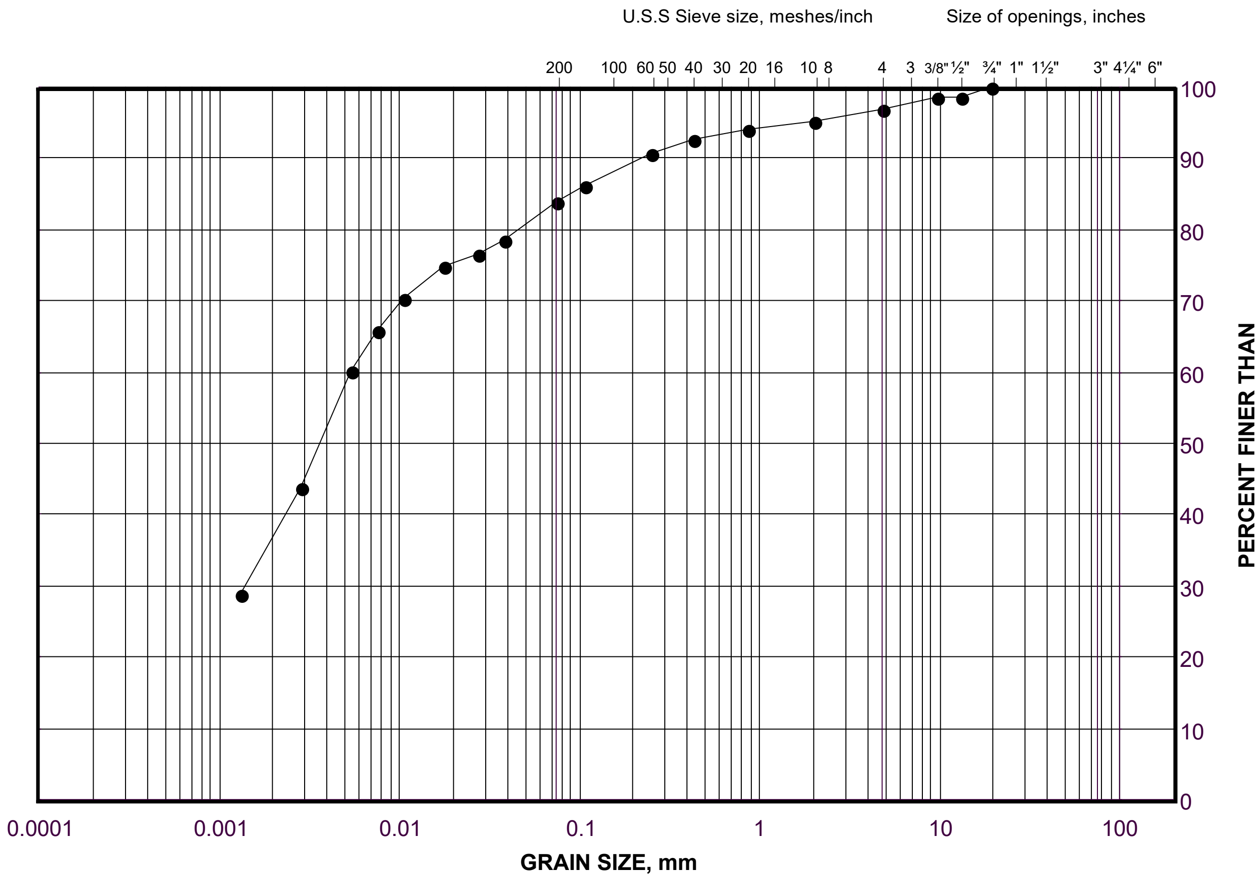
Golder Associates

Date: 05-May-21

GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) to Sandy CLAYEY SILT-SILT (CL-ML) (TILL)

FIGURE C5D



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

LEGEND

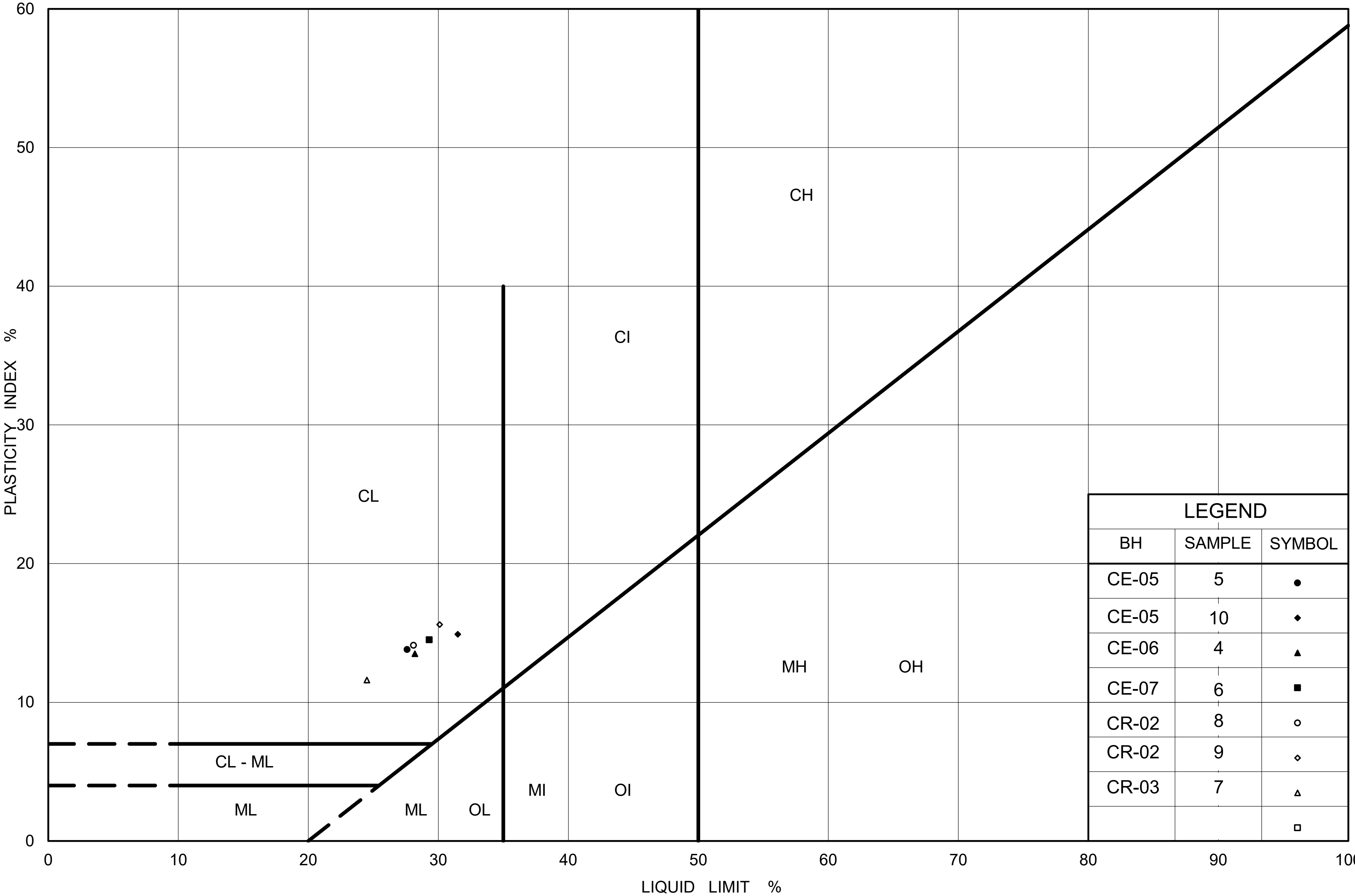
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-06	4	224.3

Project Number: 1668512

Checked By: CC

Golder Associates

Date: 14-May-21



Ministry of Transportation

Ontario

PLASTICITY CHART

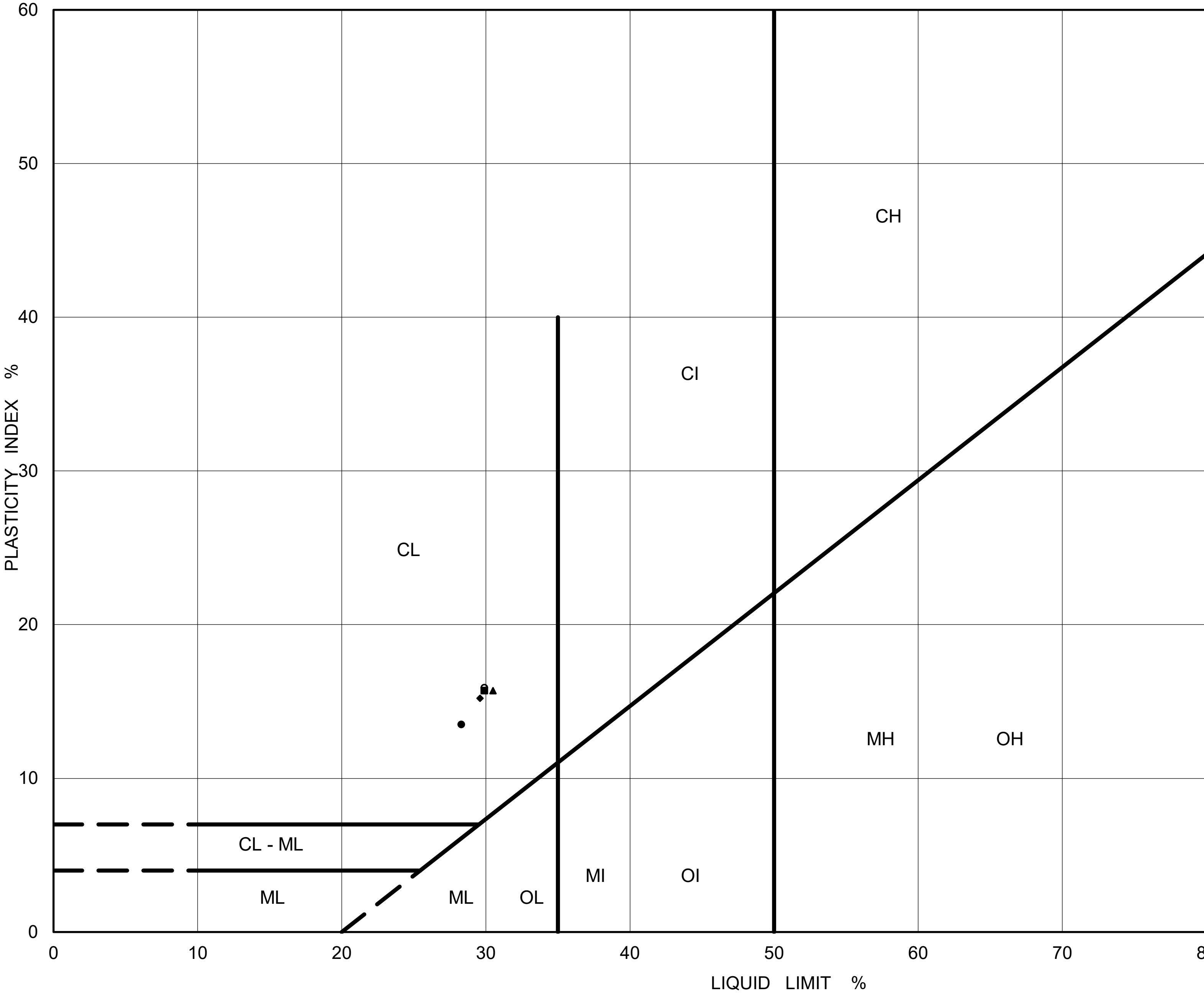
CLAYEY SILT (CL) (TILL)

Figure No. C6A

Project No. 1668512

Checked By: CC

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
CR-04	5	●
CR-04	8	◆
CR-06	6	▲
CR-06	8	■
CR-06	9	○
		◇
		△
		□

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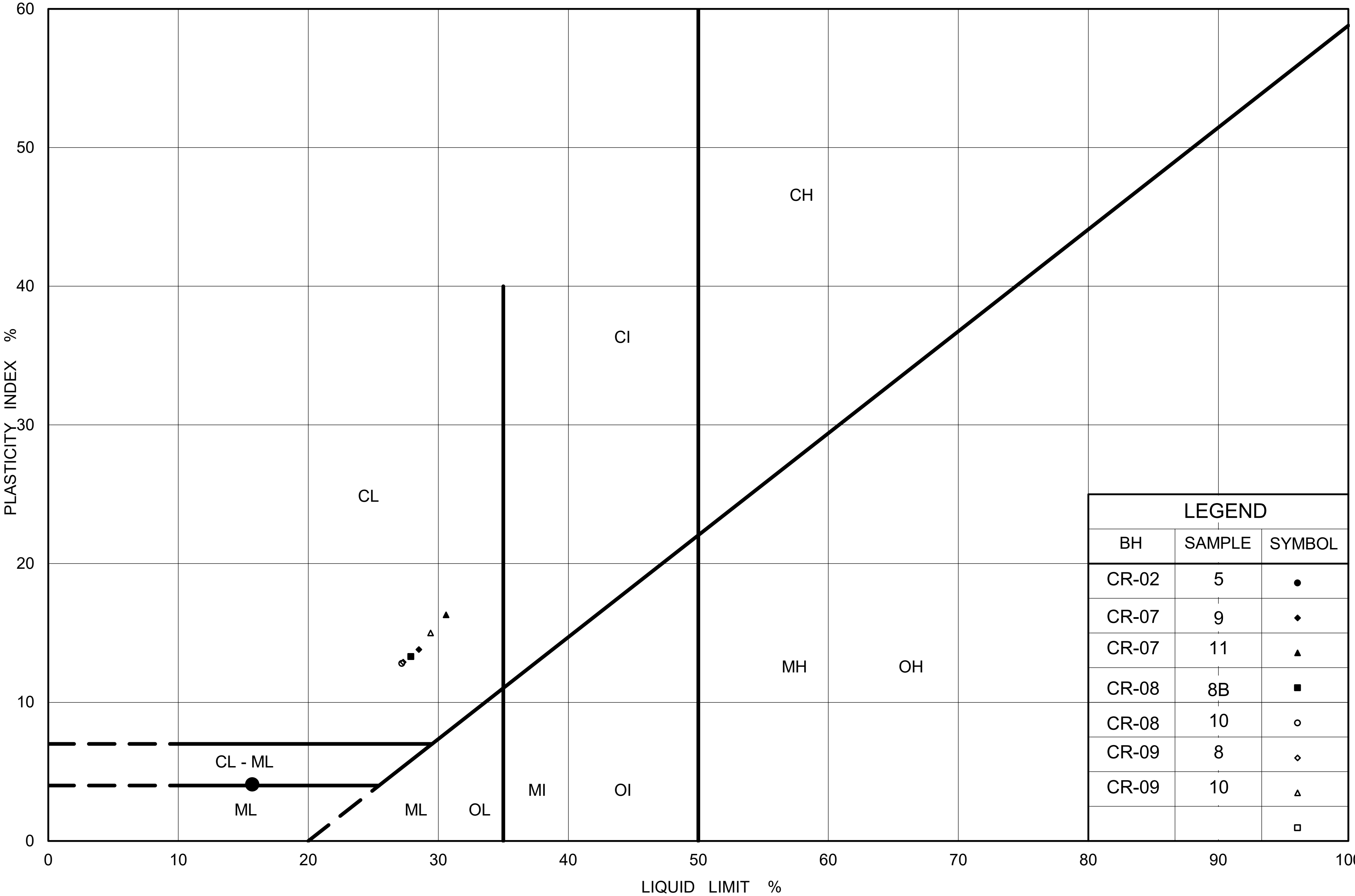
PLASTICITY CHART
CLAYEY SILT (CL) (TILL)

Figure No. C6B

Project No. 1668512

Checked By: CC

Oct 75, FF-S-21



Ministry of Transportation

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PLASTICITY CHART

CLAYEY SILT (CL) to Sandy CLAYEY SILT-SILT (CL-ML) (TILL)

Figure No. C6C

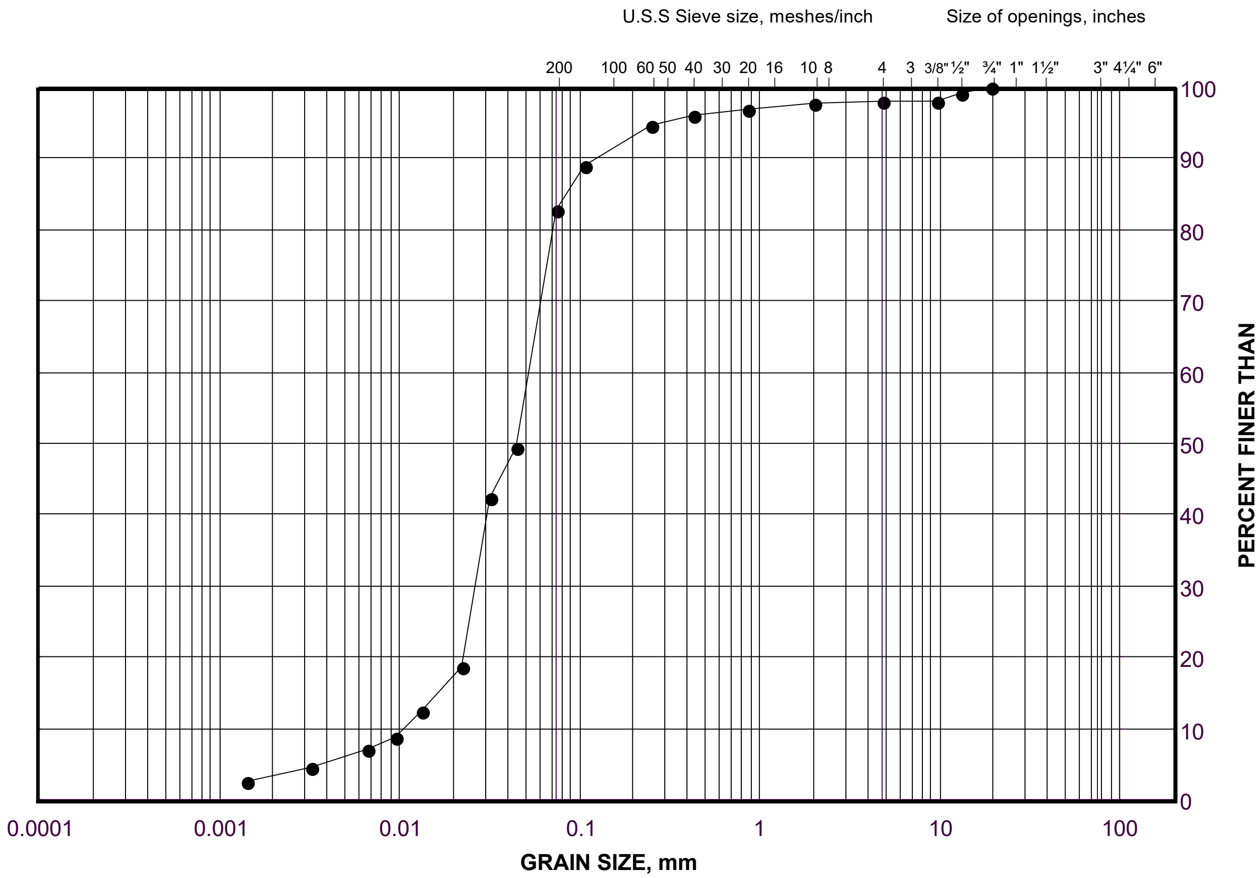
Project No. 1668512

Checked By: CC

GRAIN SIZE DISTRIBUTION

SILT (ML) (TILL) - Interlayer

FIGURE C7



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-02	4	226.0

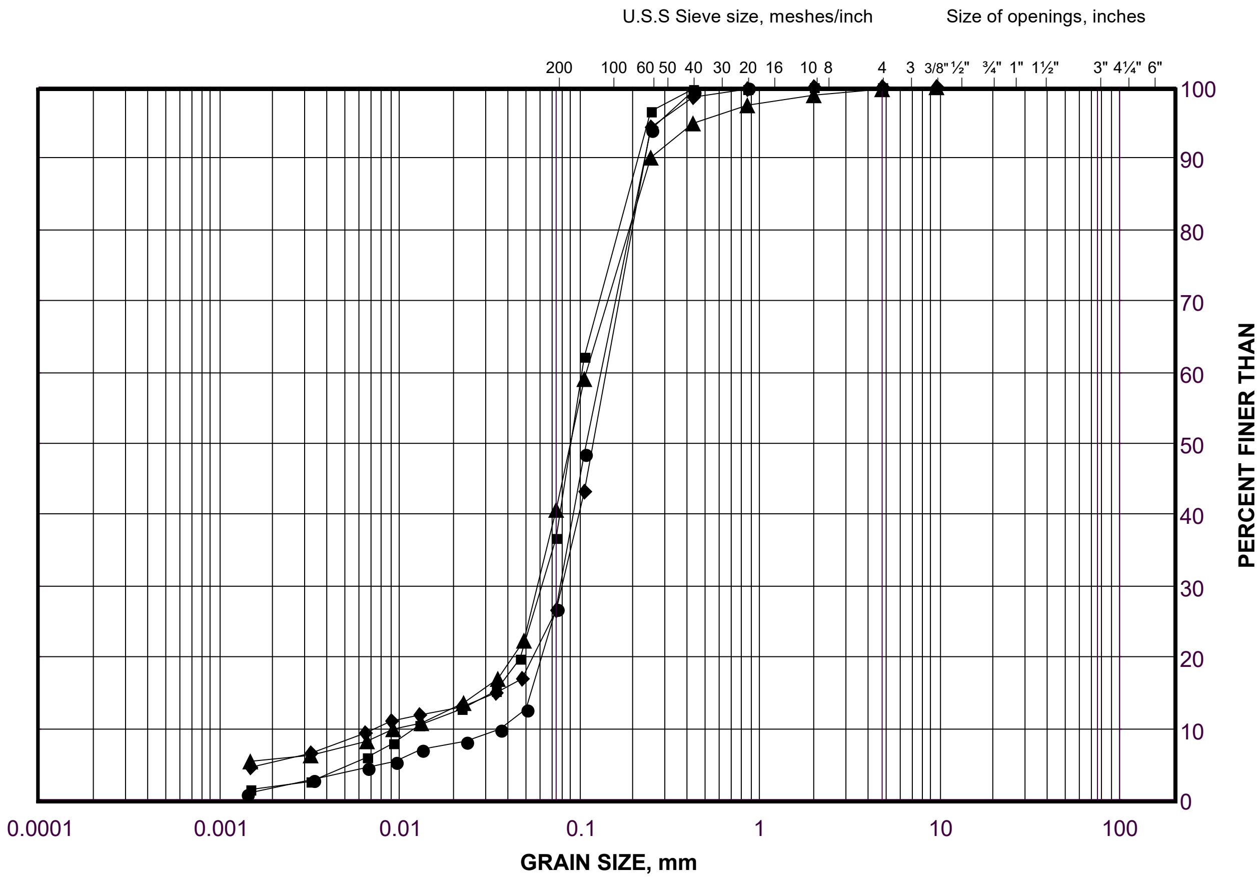
Project Number: 1668512

Checked By: CC

Golder Associates

Date: 05-May-21

GRAIN SIZE DISTRIBUTION SILTY SAND (SM)	FIGURE C8A



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-03	11	218.1
■	CR-04	12	218.1
◆	CR-02	12	219.2
▲	CR-08	6B	224.4

Project Number: 1668512

Checked By: CC

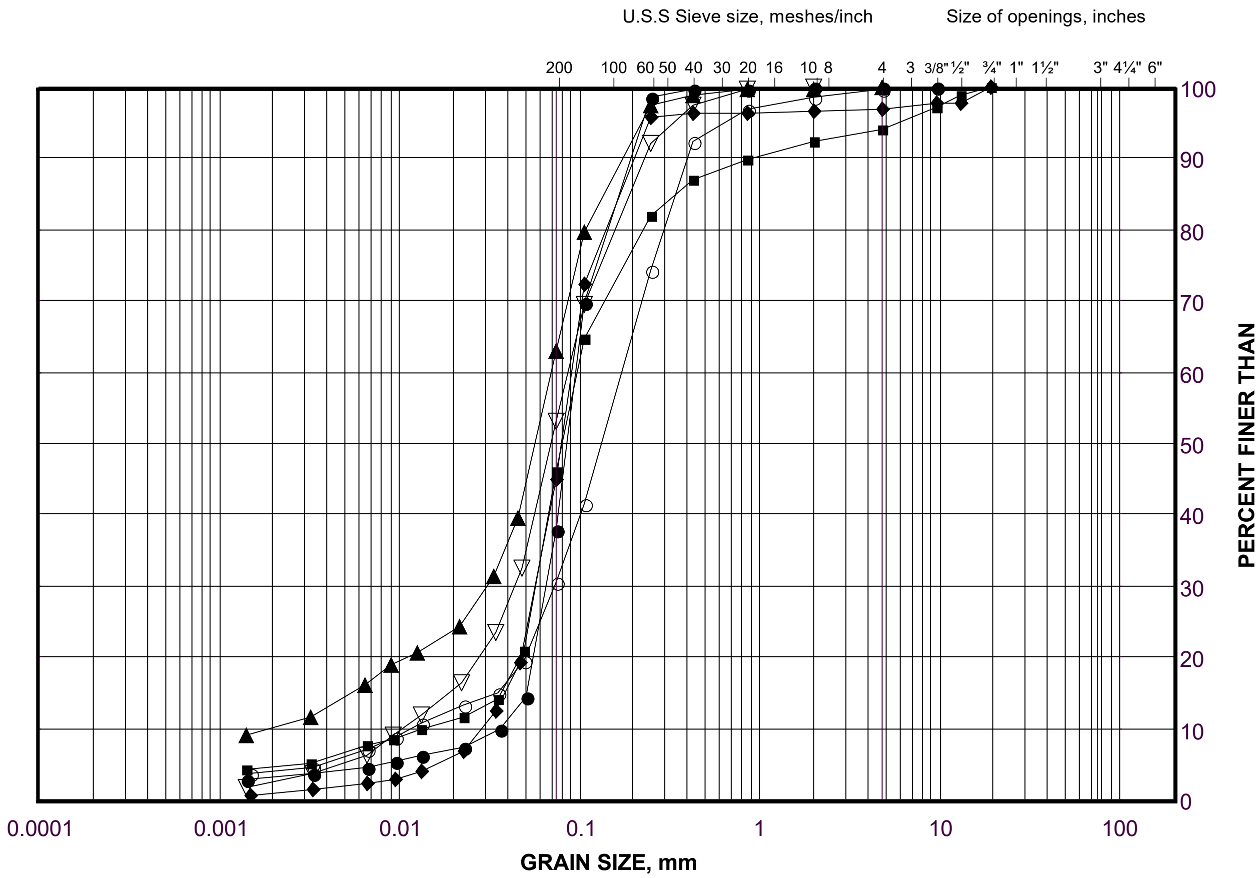
Golder Associates

Date: 14-May-21

GRAIN SIZE DISTRIBUTION

Sandy SILT (ML) to SILTY SAND (SM)

FIGURE C8B



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-09	12	218.9
■	CR-10	5	222.2
◆	CR-05	5A	221.7
▲	CR-08	6A	224.5
▽	CR-01	7	223.9
❍	CR-08	8A	223.3

Project Number: 1668512

Checked By: CC

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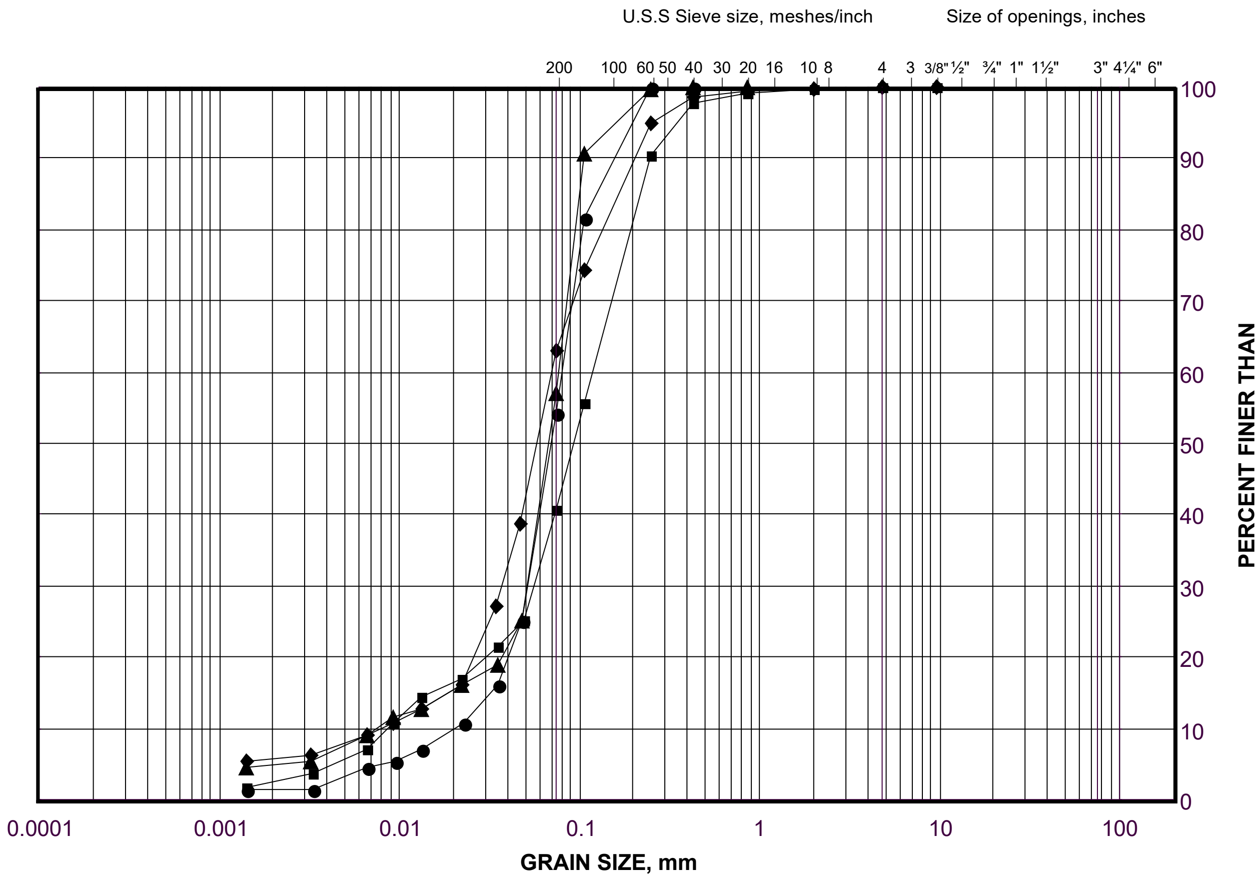
Date: 14-May-21

GRAIN SIZE DISTRIBUTION

Sandy SILT (ML) to SILT (ML) and sand

FIGURE C8C



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-08	10	220.8
■	CR-01	12	219.1
◆	CR-08	13	217.6
▲	CR-07	14	216.4

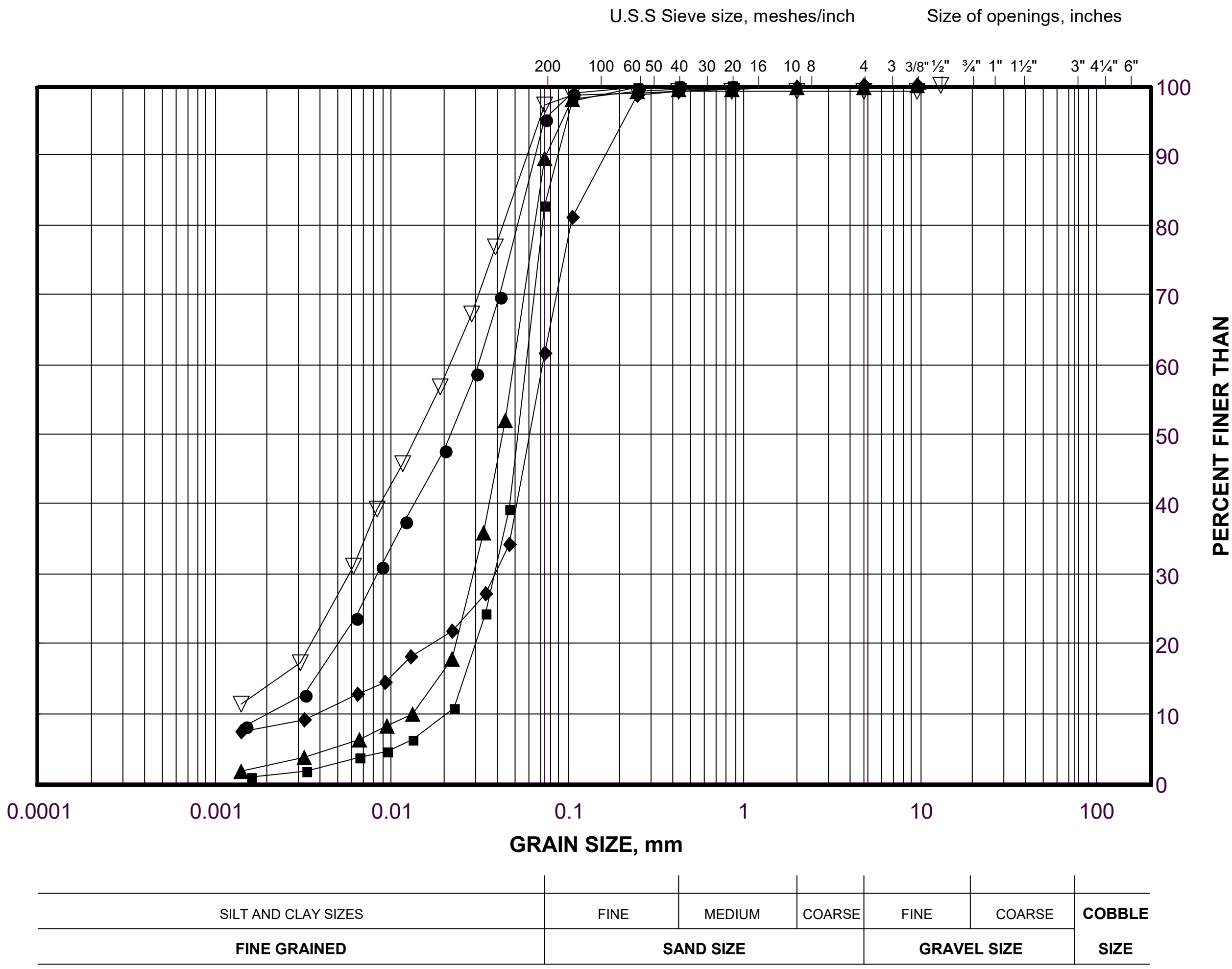
Project Number: 1668512

Checked By: CC

Golder Associates

Date: 14-May-21

GRAIN SIZE DISTRIBUTION SILT (ML) - Interlayers	FIGURE C9



LEGEND

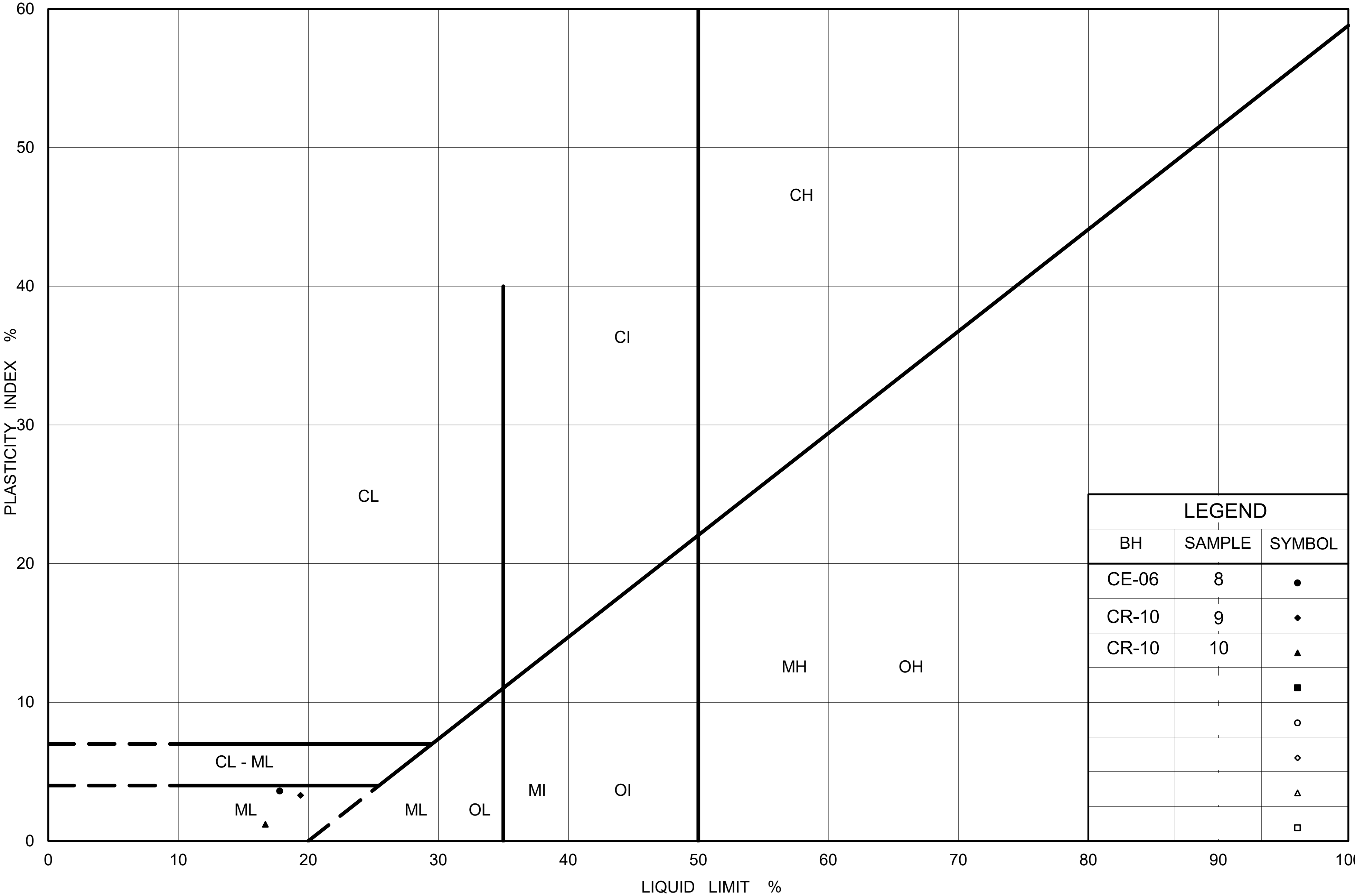
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-10	10	219.1
■	CR-05	10B	218.5
◆	CR-01	5	225.1
▲	CR-05	7B	220.4
▽	CE-06	8	220.5

Project Number: 1668512

Checked By: CC

Golder Associates

Date: 14-May-21



LEGEND		
BH	SAMPLE	SYMBOL
CE-06	8	●
CR-10	9	◆
CR-10	10	▲
		■
		○
		◇
		△
		□

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PLASTICITY CHART

SILT (ML) - Interlayer

Figure No. C10

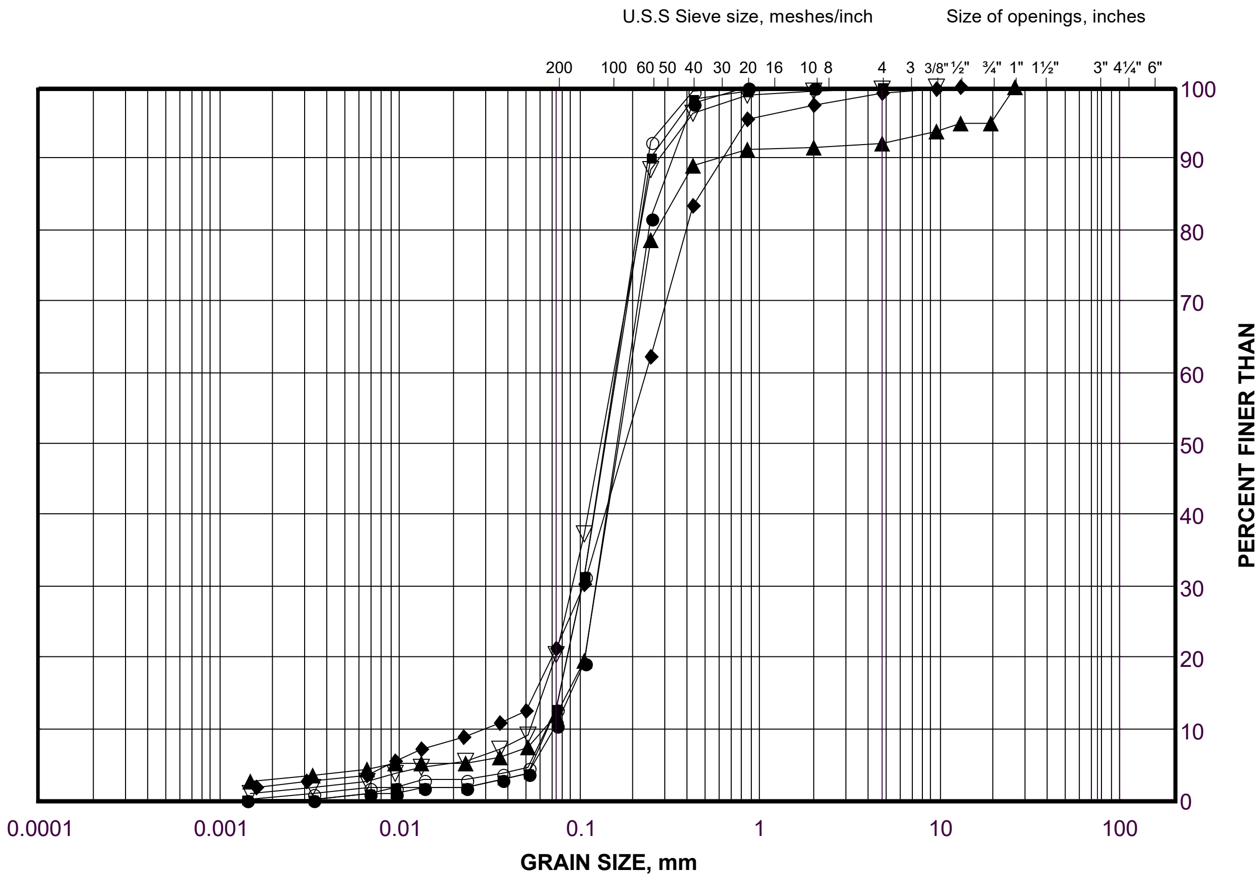
Project No. 1668512

Checked By: CC

GRAIN SIZE DISTRIBUTION

SAND (SP) - Interlayers/ Seams

FIGURE C11



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-03	10	219.6
■	CR-01	10	222.1
◆	CR-09	6	224.4
▲	CR-10	7	220.9
▽	CR-10	8	220.3
❍	CR-03	8	220.8

Project Number: 1668512

Checked By: CC

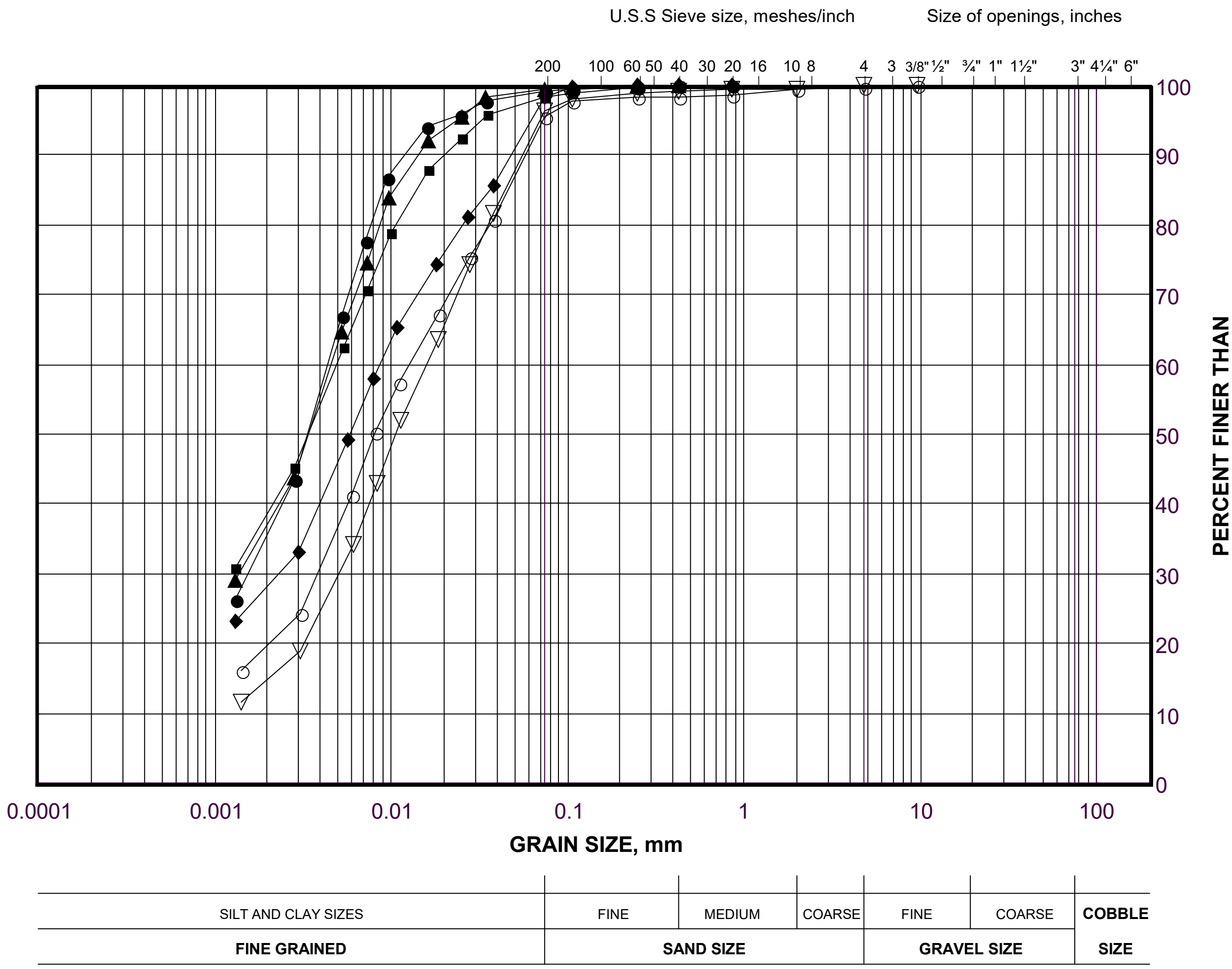
Golder Associates

Date: 14-May-21

GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML)

FIGURE C12A



LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-03	13	215.0
■	CR-02	14	216.1
◆	CE-08	14	214.7
▲	CR-04	15	213.6
▽	CR-05	6B	220.9
❍	CR-05	9	219.3

Project Number: 1668512

Checked By: CC

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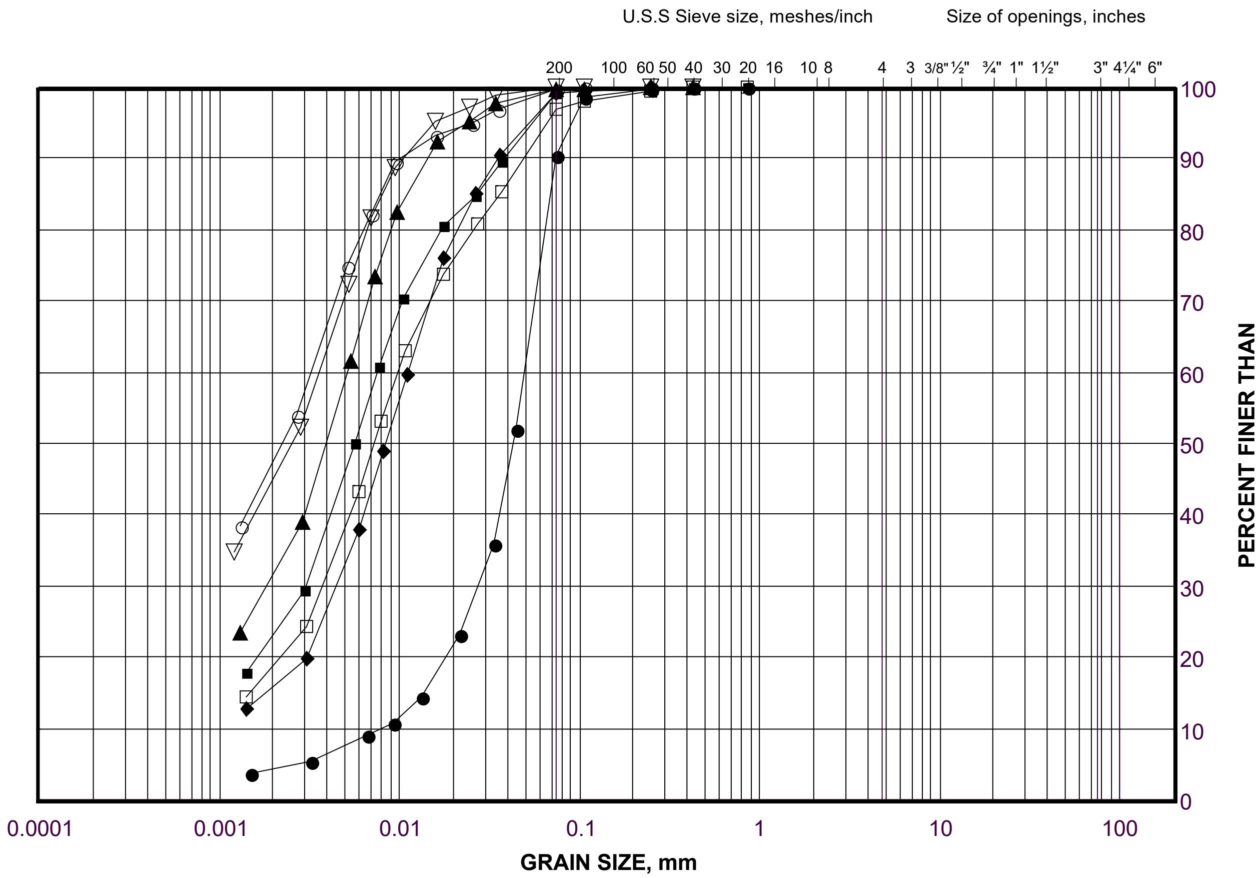
Date: 14-May-21

GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML)

FIGURE C12B



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-06	11	218.8
■	CE-06	11	215.9
◆	CR-10	12	216.1
▲	CR-10	13	214.5
▽	CR-06	13	215.7
❍	CR-05	13	214.1
☐	CR-01	14	216.0

Project Number: 1668512

Checked By: CC

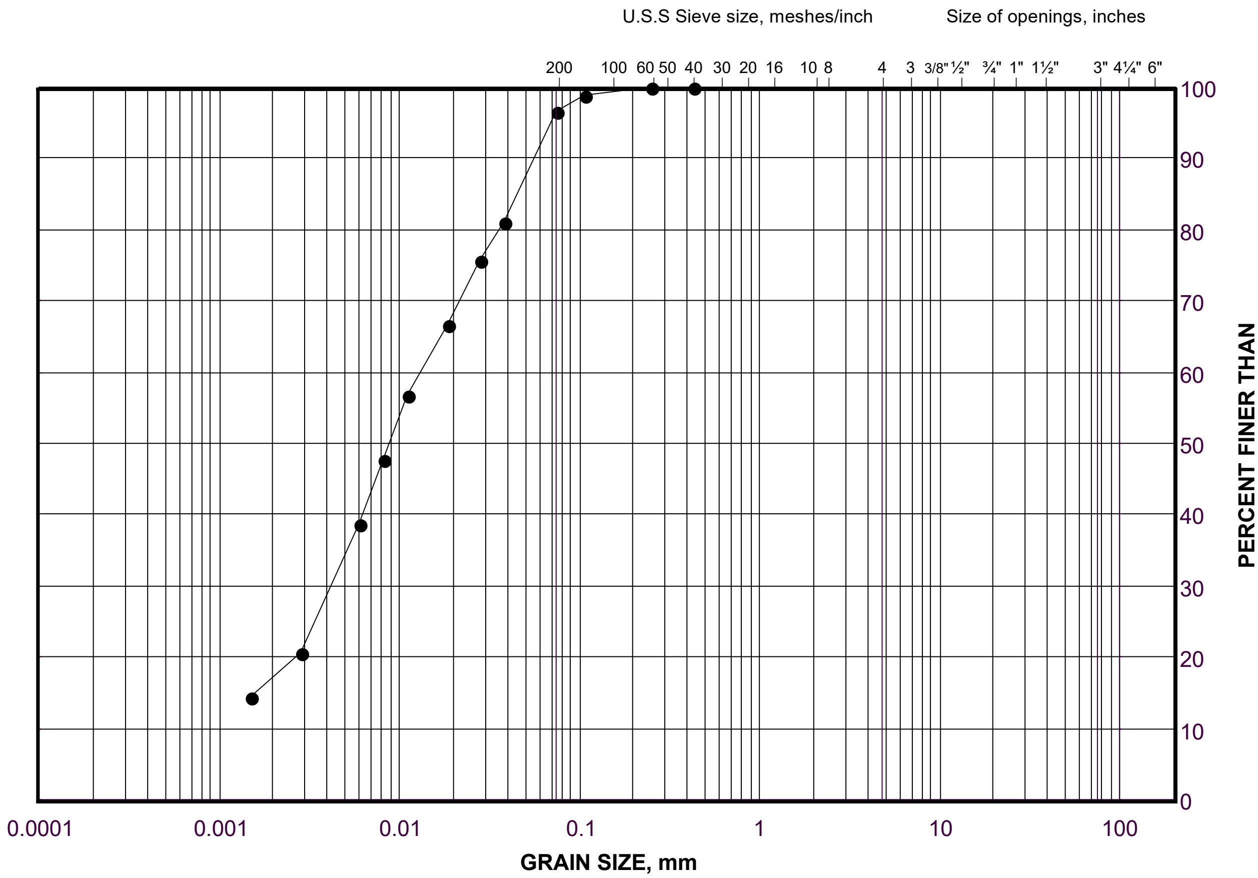
Golder Associates

Date: 14-May-21

GRAIN SIZE DISTRIBUTION

CLAYEY SILT-SILT (CL-ML)

FIGURE C12C



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

LEGEND

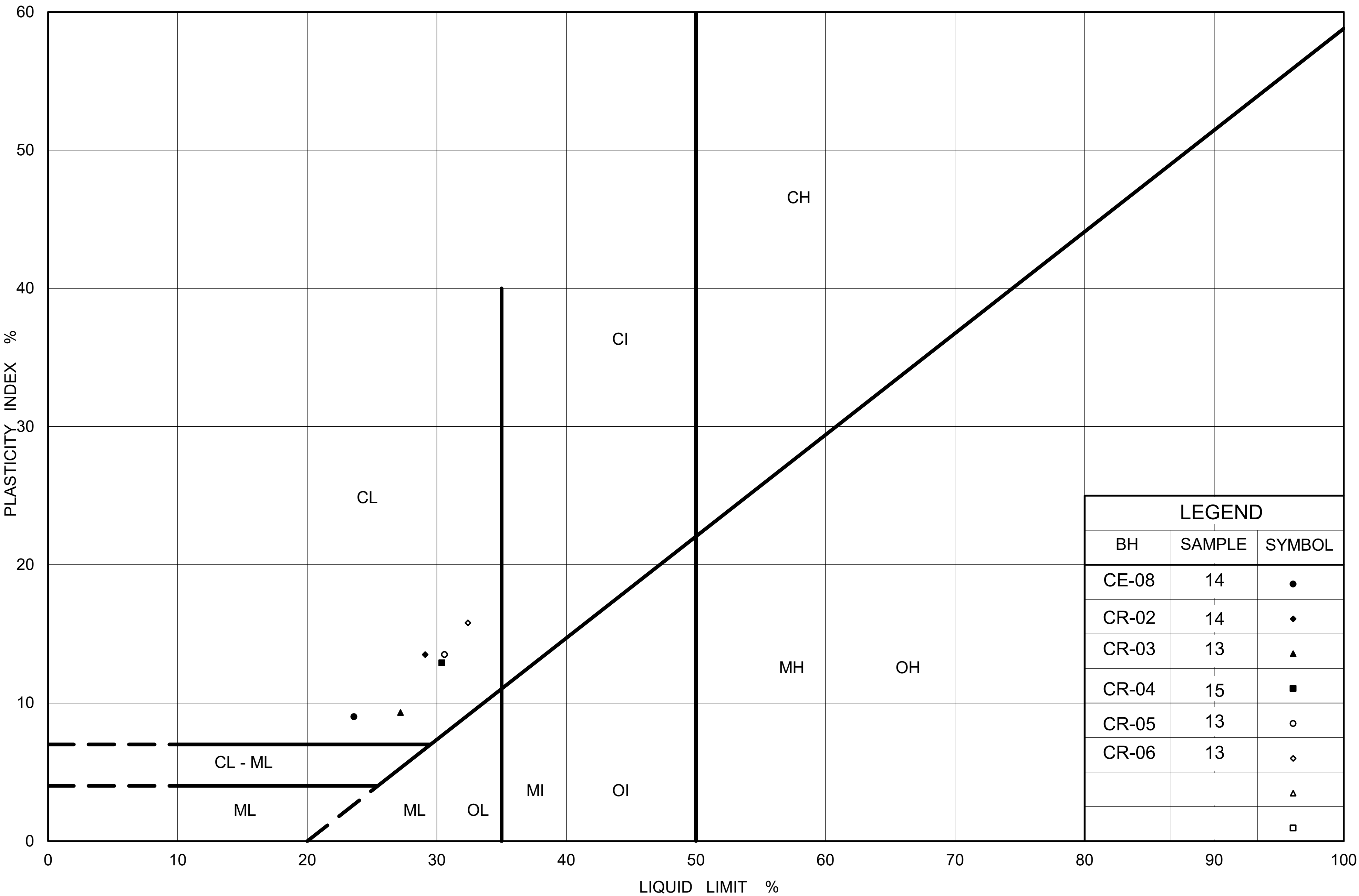
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-09	14	215.9

Project Number: 1668512

Checked By: CC

Golder Associates

Date: 05-May-21



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PLASTICITY CHART

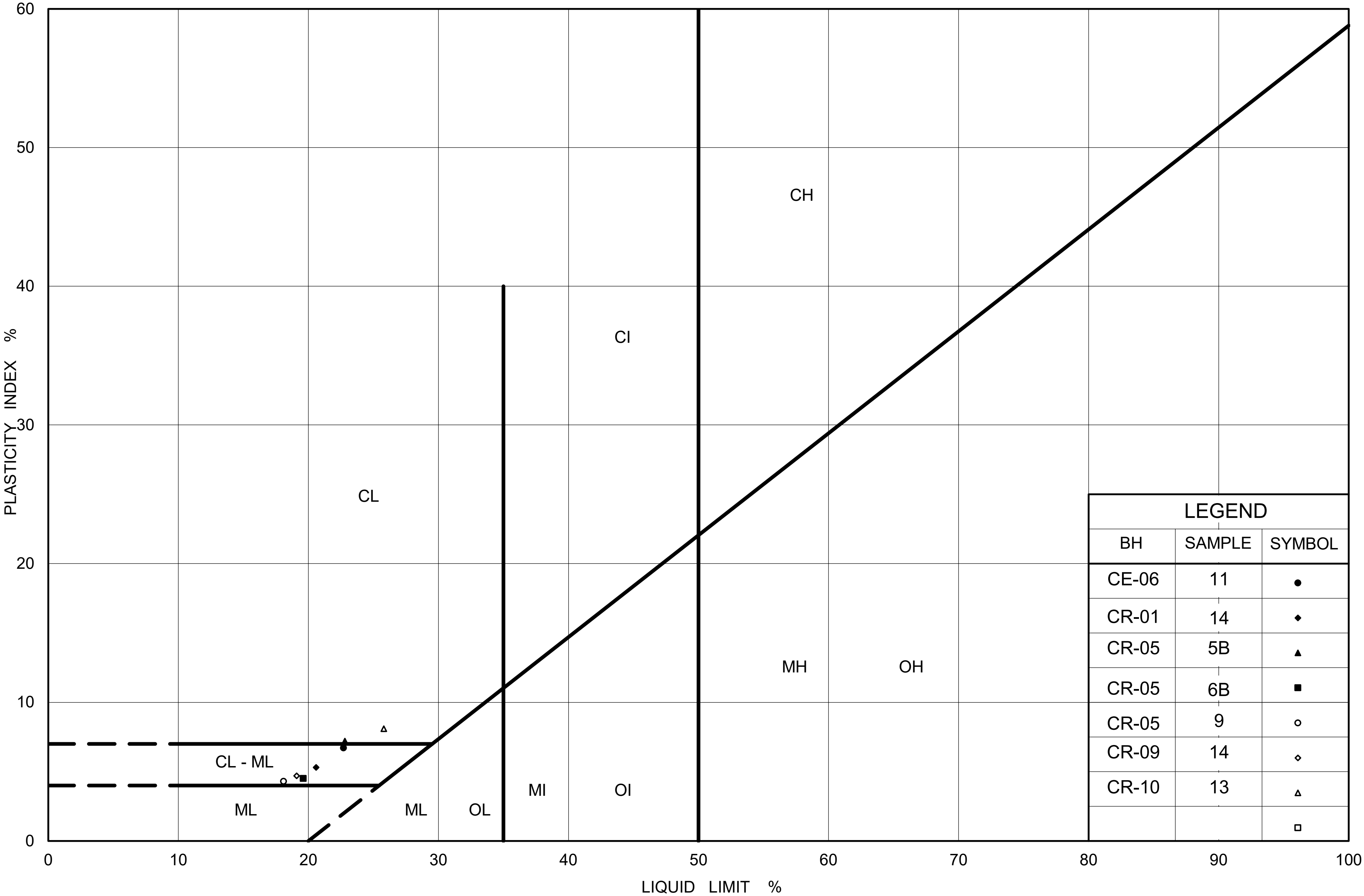
CLAYEY SILT (CL)

Figure No. C13A

Project No. 1668512

Checked By: CC

Oct 75, FF-S-21



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Ontario

PLASTICITY CHART

CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML)

Figure No. C13B

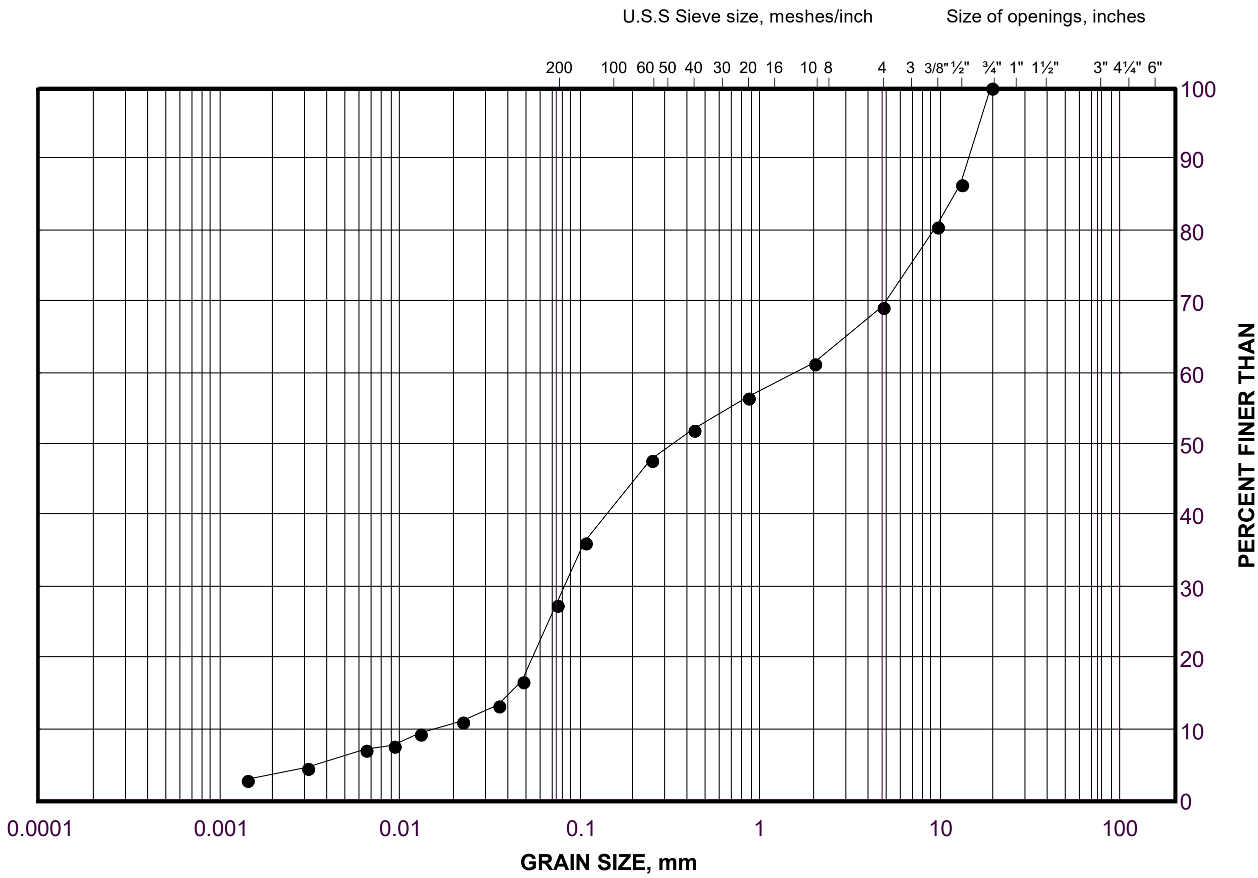
Project No. 1668512

Checked By: CC

GRAIN SIZE DISTRIBUTION

Gravelly CLAYEY SAND (SC)

FIGURE C14



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CR-05	6A	221.1

Project Number: 1668512

Checked By: CC

Golder Associates

Date: 05-May-21

APPENDIX D

Analytical Laboratory Test Results

Your Project #: 1668512
Your C.O.C. #: n/a

Attention: Carter Comish

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2021/02/17
Report #: R6521921
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C136906
Received: 2021/02/10, 17:10

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (20:1 extract)	2	2021/02/16	2021/02/16	CAM SOP-00463	SM 23 4500-Cl E m
Conductivity	2	2021/02/16	2021/02/16	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	2	2021/02/12	2021/02/12	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	2	2021/02/10	2021/02/16	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	2	2021/02/16	2021/02/17	CAM SOP-00464	EPA 375.4 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested. When sampling is not conducted by Bureau Veritas, results relate to the supplied samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Bureau Veritas Laboratories 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.bvlabs.com

Your Project #: 1668512
Your C.O.C. #: n/a

Attention: Carter Comish

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2021/02/17
Report #: R6521921
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C136906
Received: 2021/02/10, 17:10

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Ema Gitej, Senior Project Manager
Email: emese.gitej@bureauveritas.com
Phone# (905)817-5829
==
This report has been generated and distributed using a secure automated process.
BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

SOIL CORROSIVITY PACKAGE (SOIL)

BV Labs ID		OUX519		OUX520		
Sampling Date		2021/02/10		2021/02/10		
COC Number		n/a		n/a		
	UNITS	**CR-04-SA4-7'.6"-9'.6"**	**RDL**	**CR-07-SA6-12'-14'**	**RDL**	**QC Batch**
Calculated Parameters						
Resistivity	ohm-cm	730		300		7194961
Inorganics						
Soluble (20:1) Chloride (Cl-)	ug/g	660	20	2000	80	7201782
Conductivity	umho/cm	1370	2	3340	2	7201892
Available (CaCl2) pH	pH	7.87		7.34		7198510
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	<20	20	7201785

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

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Microbiology testing is conducted at 6660 Campobello Rd. Chemistry testing is conducted at 6740 Campobello Rd.

BV Labs Job #: C136906
Report Date: 2021/02/17

Golder Associates Ltd
Client Project #: 1668512
Sampler Initials: SK

TEST SUMMARY

BV Labs ID: OUX519
Sample ID: CR-04-SA4-7'.6"-9'.6"
Matrix: Soil

Collected: 2021/02/10
Shipped:
Received: 2021/02/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7201782	2021/02/16	2021/02/16	Deonarine Ramnarine
Conductivity	AT	7201892	2021/02/16	2021/02/16	Tarunpreet Kaur
pH CaCl2 EXTRACT	AT	7198510	2021/02/12	2021/02/12	Neil Dassanayake
Resistivity of Soil		7194961	2021/02/16	2021/02/16	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7201785	2021/02/16	2021/02/17	Deonarine Ramnarine

BV Labs ID: OUX520
Sample ID: CR-07-SA6-12'-14'
Matrix: Soil

Collected: 2021/02/10
Shipped:
Received: 2021/02/10

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	7201782	2021/02/16	2021/02/16	Deonarine Ramnarine
Conductivity	AT	7201892	2021/02/16	2021/02/16	Tarunpreet Kaur
pH CaCl2 EXTRACT	AT	7198510	2021/02/12	2021/02/12	Neil Dassanayake
Resistivity of Soil		7194961	2021/02/16	2021/02/16	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	7201785	2021/02/16	2021/02/17	Deonarine Ramnarine

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GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	10.7°C

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
7198510	Available (CaCl2) pH	2021/02/12			100	97 - 103			0.40	N/A
7201782	Soluble (20:1) Chloride (Cl-)	2021/02/16	NC	70 - 130	104	70 - 130	<20	ug/g	0.85	35
7201785	Soluble (20:1) Sulphate (SO4)	2021/02/17	114	70 - 130	102	70 - 130	<20	ug/g	NC	35
7201892	Conductivity	2021/02/16			104	90 - 110	<2	umho/cm	0.82	10

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Anastassia Hamanov, Scientific Specialist

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Work Order

6740 Campobello Road, Mississauga, Ontario L5N 2L8
Phone: 905-817-5700 Fax: 905-817-5779 Toll Free: 800-563-6266
CAM FCD-01191/6

CHAIN OF CUSTODY RECORD

Page 1 of 1

Invoice Information
Company Name: Golder Associates Ltd
Contact Name: Accounts Payable
Address: 6925 Century Ave, Suite 100, Mississauga ON L5N 7K2
Phone: 905 567 4444 Fax:
Email: Canada Accounts payable Invoices@golder.com

Report Information (if differs from invoice)
Company Name: Golder Associates Ltd.
Contact Name: Canten Cornish.
Address:
Phone: 905-567-4444 x 2020 Fax:
Email: Canten_cornish@golder.com.

Project Information (where applicable)
Quotation #:
P.O. #/ AFE#:
Project #: 1668512
Site Location:
Site #:
Site Location Province:
Sampled By: SK

Turnaround Time (TAT) Required
[✓] Regular TAT (5-7 days) Most analyses
PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS
Rush TAT (Surcharges will be applied)
[ ] 1 Day [ ] 2 Days [ ] 3-4 Days
Date Required:
Rush Confirmation #:

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BUREAU VERITAS LABORATORIES' DRINKING WATER CHAIN OF CUSTODY

Regulation 153
[ ] Table 1 [ ] Res/Park [ ] Med/ Fine
[ ] Table 2 [ ] Ind/Comm [ ] Coarse
[ ] Table 3 [ ] Agri/ Other
[ ] Table ____
FOR RSC (PLEASE CIRCLE) Y / N

Other Regulations
[ ] CCME [ ] Sanitary Sewer Bylaw
[ ] MISA [ ] Storm Sewer Bylaw
[ ] PWQO Region ____
[ ] Other (Specify)
[ ] REG 558 (MIN. 3 DAY TAT REQUIRED)
[ ] REG 406 Table ____

Include Criteria on Certificate of Analysis: Y / N

SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

Analysis Requested

	SAMPLE IDENTIFICATION	DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI	BTEX/ PHC F1	PHCs F2 - F4	VOCs	REG 153 METALS & INORGANICS	REG 153 ICPMS METALS	REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B)	Corrosivity								HOLD- DO NOT ANALYZE
1	CR-04-SA4-7'6"-9'6"	2021/02/10	PM	SOIL	1								X								
2	CR-07-SA6-12'-14'	〃	〃	〃	1								X								
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LABORATORY USE ONLY

CUSTODY SEAL Y / N Present	Intact	COOLER TEMPERATURES
N	N	8/11/13

COOLING MEDIA PRESENT: (Y) / N

COMMENTS

RELINQUISHED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)
SHANTANU KAR	2021/02/10	5:00	PREETHA JAYANTHAN	2021/02/10	17:10

10-Feb-21 17:10
Ema Gitej
C136906
KSE ENV-1151

APPENDIX E

Special Provisions

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHOD

1.0 SCOPE

This Special Provision covers the requirements for the installation of pipes by a selected trenchless method.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 182 Environmental Protection for Construction in Waterbodies and On Waterbody Banks
OPSS 401 Trenching, Backfilling, and Compacting
OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403 Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404 Construction Specification for Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 490 Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 491 Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 510 Construction Specification for Removal
OPSS 517 Construction Specification for Dewatering
OPSS 539 Construction Specification for Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004 Material Specification for Aggregates - Miscellaneous
OPSS 1350 Material Specification for Concrete - Materials and Production
OPSS 1440 Steel Reinforcement for Concrete
OPSS 1802 Material Specification for Smooth Walled Steel Pipe
OPSS 1820 Material Specification for Circular and Elliptical Concrete Pipe
OPSS 1840 Material Specification for Non-Pressure Polyethylene (PE) Plastic Pipe Products

CSA Standards

A3000 Cementitious Materials Compendium
B182.6 Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
B182.8 Profile Polyethylene (PE) Storm Sewer and Drainage Pipe and Fittings

B182.13	Profile Polypropylene (PP) Sewer Pipe and Fittings for Leak-proof Sewer Applications
C22.1	Canadian Electrical Code
W59	Welded Steel Construction

American Society for Testing and Materials (ASTM) International Standards

A 252M-19	Standard Specification for Welded and Seamless Steel Pipe Piles
C-33	Standard Specification for Concrete Aggregates.
C-39	Standard Test method for Compressive Strength of Cylindrical Concrete
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025	General Requirements for the Competence of the Testing and Calibration Laboratories

3.0 DEFINITIONS

For the purpose of this Special Provision, the following definitions apply:

Annular Space means the space between the inside edge of the opening and the outside edge of the penetrating item or inserted pipe.

Auger Jack & Bore means a method of forming a horizontal bore in the subsurface by simultaneously or alternately jacking into the ground a casing pipe and rotating a cutter head at the lead end of an auger flight with removal of material from inside the casing by using continuous-flight augers.

Backreamer or Reamer means a cutting head suitably designed for the subsurface conditions that is attached to drilling equipment and used to enlarge the bore

Bore Path means a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Boulder Number Ratio (BNR) means the number of individual boulders per m^3 of cumulative boulder volume.

Boulder Volume Ratio (BVR) means the ratio between the cumulative volume of boulders and the volume of the material excavated.

Design Engineer means the Engineer retained by the Contractor who produces the design and Working Drawings and other engineering documents required of the Contractor. The Design Engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and Working Drawings.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades, rams, shovels, breaker bars, etc.) or a "digger" type shield with a hydraulic excavator arm or "road-header" rock cutting machine to remove materials from inside the shield and liner pipe.

Drilling Fluids means a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Hydraulic Fracture or "Frac Out" means a condition where the drilling fluid's pressure in the bore is sufficient to fracture the soil and/or rock materials and allow the drilling fluids to migrate to the surface at an unplanned location.

Earth Pressure Balance (EPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of mixed earth, rock and any drilling fluids or additives (spoil) as maintained by and in a chamber behind the cutting face of a tunnel boring machine through which spoil can pass only by manner of controlled-load relieving gates or an internal screw-conveyor that is separate from subsequent spoil conveyance systems (e.g., flight augers, belt conveyor, spoil bucket rail cars, etc.). Trenchless systems that apply pressure to the excavated face of the ground only through mechanical and jacking forces on metal parts of the machinery (e.g., steel parts of cutting tools, adjustable gates or doors at cutting face, etc.) will not be considered equivalent to EPB systems.

Excavation means all materials encountered regardless of type and extent and shall include removal of natural soil, boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA) means areas specified in the Contract Documents that are prohibited from entry or use.

Fill means man-made mixture of previously placed or handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Guidance System means an electronic system capable of indicating the position, depth and orientation of the drill head during the directional drilling process.

Hand Mining means a method of forming a horizontal bore in the subsurface by simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or "Jack and Mine") or a "digger" type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Horizontal Directional Drilling (HDD) means a surface-launched trenchless technology for the installation of pipes, conduits, and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final steps of the process.

Inadvertent Returns means the unexpected flow of fluids, saturated materials (or flowing soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation means the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Microtunnelling means an underground method of constructing a passage by using a microtunnelling boring machine (MTBM) or hand mining using a shield to support the opening.

MTBM means a microtunnelling boring machine.

Pilot Bore means the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe means pipe culverts, pipe storm and sanitary sewers, watermain pipe, conduits, and ducts.

Pipe Jacking means a method for installing steel casing, concrete pipe or other acceptable material in the subsurface utilizing hydraulically operated jacks of adequate number and capacity for the smooth and uniform advancement of the casing or pipe.

Pipe Ramming means a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Project Superintendent means an individual representing the Contractor that oversees the trenchless or tunnelling operation qualified to provide the services specified in the Contract Documents.

Pullback means that part of the HDD method in which the drilling equipment is pulled back through the bore path to the entry point.

Reaming means a process for enlarging the bore path.

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m^3 or greater.

Shaft means an excavation used as entry and/or exit points, alternatively called entry/exit pits, from which the trenchless method is initiated for the installation of the pipe product.

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a tunnel boring machine (TBM) or microtunnelling boring machine (MTBM), through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

Slurry means a mixture of soil and/or rock cuttings, and drilling fluid.

Soil means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Spoil means mix of earth cuttings, rock cuttings, water (groundwater or added water), bentonite, polymers and/or other additives that is discharged from the trenchless construction systems.

Strike Alert means a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

TBM means a tunnel boring machine.

Trenchless Contractor means the subcontractor retained by the Prime Contractor qualified to provide the services specified in the Contract Documents.

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnelling boring machine (MTBM) operated by personnel at a remote control station or excavation using a shield to support the opening and protect workers.

Zone of Influence means a zone defined by lines projected outward and upward at 45 degrees from horizontal to the ground surface from the vertical and horizontal alignment of the pipe constructed using trenchless/tunnel methods.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

The Contractor shall determine the most appropriate method of trenchless installation for each pipe crossing for each location within the terms of this specification.

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with the Contract Documents. Specifically, the trenchless contractor is alerted of the following conditions:

- Mixed-Face Conditions: For the north tunnel, a significant portion of the tunnel path is anticipated to be within the stiff to hard clayey silt to clayey silt till just below the embankment fill. For the south tunnels, the tunnel paths generally consist of a mix of stiff to hard clayey silt to clayey silt till and saturated sandy silt to silty sand soil at the west and central sections, and transition to a predominantly variable silty sand fill and organic silt / peat at the east end. At the west limit of the crossings, the tunnel crown may encounter embankment fill consisting of variable clayey silt, silts and sand (saturated) fills which form the majority of the Highway 400 embankment.

- Obstructions: Cobble fragments were encountered in the clayey silt till in Borehole CR-2 and wood pieces / organics / peat were encountered near the fill / native interface (i.e., within the tunnel horizon) in Boreholes C-1, CR-3, CR-5, CR-7 and CR-8. The presence of cobbles and boulders and debris in the fill, cobbles and boulders in the native soils, and potentially tree stumps, roots or other woody debris / organics at and near the interface between fill and native soils from clearing and grubbing that may not have fully been removed at the time of construction of Highway 400, should be anticipated. In addition, the previous Creek bed may have been located north or south of the existing culverts (typically culverts are installed beside a creek crossing and then the creek diverted through the culverts) where the proposed new crossings are located; thus, trees / wood and other debris either remaining from original site clearing and preparation or carried down the stream may be present near the fill / native interface.

- High Groundwater Levels / Saturated Cohesionless Deposits: The groundwater levels measured in the piezometers at the site range from Elevation 223.8 m to 224.9 m in late February 2021. Considering the top of the tunnel is anticipated to be at Elevation 224.5, the tunnel horizon should be expected to be fully saturated. During wet periods of the year;

seasonal fluctuations on the order of at least +/- 1 m should be expected.

The detailed design of the installation method selected to carry out the Work as specified in the Contract Documents shall be completed.

A soil cover to cut tunnel diameter ratio of 2 shall be maintained below the travelled portion of Highway 400 and top of the cut tunnel diameter shall not be higher than Elevation 224.5 m. The overcut dimension (difference between cutterhead diameter and outside pipe diameter) shall be limited such that ground surface settlements are within the tolerances provided in Section 7.08.

The trenchless installation method shall be slurry microtunnelling using a continuous slurry pressure balance system to provide support to the excavated face of the ground and resistance to groundwater inflow. As such, earth pressure balance Tunnel Boring Machines, jack and bore, guided auger bore or any open face trenchless method shall not be permitted for this project.

Each single trenchless installation shall be carried out continuously (24-hour operation) without any stoppage until the crossing is completed.

4.02 Submission Requirements

4.02.01 Qualifications

As part of the tender submission, the name and qualifications of the Trenchless Contractor and MTBM Operator shall be provided as per below. At least two weeks prior to construction, the names of the Project Superintendent, and Trenchless Contractor and MTBM Operator shall be confirmed and submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of ten (10) years experience on projects with similar scope and complexity.

During construction, the Project Superintendent shall not be changed without written permission from the Contract Administrator. A proposal to change the Project Superintendent shall be submitted at least one week prior to the actual change in Project Superintendent.

4.02.01.02 Trenchless Contractor

The Trenchless Contractor and MTBM operator shall have a minimum of ten (10) years experience on microtunneling / tunnelling projects with similar scope and complexity. The Trenchless Contractor shall provide three (3) examples of where microtunnelling was used successfully below arterial highways / roadways or settlement sensitive structures in similar subsurface conditions and soil cover depths. The Trenchless Contractor shall provide at least one (1) example of where a slurry microtunnelling project of similar diameter / size was executed successfully in similar subsurface conditions.

4.02.02 Working Drawings

Three (3) sets of Working Drawings for the selected trenchless installation method, and a Request to Proceed shall be submitted to the Contract Administrator two weeks (2) prior to the commencement of the Work or as per the Contract Documents.

The trenchless installation operation shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

Information and details shown on the Working Drawings shall include, but not limited to the following:

a) Plans and Details:

   i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work.
   ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the Work.
   iii. A list of personnel, including backup personnel, and their qualifications and experience.
   iv. A traffic control plan.
   v. A safety plan including the company safety manual and emergency procedures.
   vi. The Working Area layout.
   vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
   viii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
   ix. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan, detailing emergency procedures in the event that the fluid management plan fails.
   x. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
   xi. Excavated materials disposal plan.
   xii. Locations of protection systems.
   xiii. Contingency plans for the following potential conditions:
      - Unforeseen obstructions causing stoppage.
      - Deviation from required alignment and grade.
      - Extended service disruption.
      - Damage to the existing Utilities and methods of repair.
      - Soil heaving or settlement.
      - Contaminated soil or water.
      - Alignment passing through buried structures.

b) Designs:

   i. Primary Liner/Secondary Liner design (e.g. steel liner plates, steel ribs and wood lagging, and steel casing etc.).

ii. Design assumption and material data when materials other than those specified are proposed for use.

iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

iv. Minimum depth of cover for trenchless installation appropriate for the highway type and pipe diameter, maximum excavation diameter, maximum annulus, alignment and grade tolerance etc.

v. Detailed subsurface conditions along the proposed path or within the footprint of the trenchless technology equipment or pits/shafts.

c) Materials:

i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.

ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance (EPB), Slurry Pressure Balance (SPB).

iii. Manufacturer data sheets for drilling systems.

iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (MTBM) operations.

v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.

vi. Compressive strength of concrete pipe products.

vii. Pipe class for all steel pipe products.

viii. Steel for Permanent Casings:

- One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
- Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
- The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.

ix. Slurry, drilling fluids, and tunnelling fluids:

- Type, source, and physical and chemical properties of bentonite, polymer or other additives;
- Source of water;
- Method of mixing;
- Water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;

- Details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunneling fluids or EPB spoils; and
- Method of disposal of the slurry, drilling fluids and associated spoil.

d) Upstream/Downstream Portal Installation Procedure:

i. Access shaft or entry/exit pit details, as applicable.

ii. Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

i. Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in.

ii. Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;

ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;

iii. Equipment and methods for removal of cobbles and boulders;

iv. Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, Slurry Pressure Balance (SPB) and Earth Pressure Balance (EPB) pressures;

v. Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;

vi. Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;

vii. Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;

viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;

ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

Methods, equipment, frequency and repeatability (accuracy and precision) of data collection to be employed for measuring and monitoring shall be submitted for:

i. Maintaining the alignment of the installation;

ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;

iii. Jacking forces on pipes, linings and cutting tools;

iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.

v. Grout injection pressures and volumes;

vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.); and

vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction.

4.02.03 As-Built Drawings

As-built drawings shall be submitted to the Contract Administrator in a reproducible format prior to the Contract completion.

The as-built drawings shall be dated and bear the seal and signature of the Design Engineer and Design Checking Engineer.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

The product shall be concrete pipe, steel pipe or high density polyethylene pipe as specified.

All joints shall be suitable for jacking operations as specified in the Working Drawings.

Fittings shall be suitable and compatible with the class and type of pipe with which they will be used.

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

Steel casing pipe shall meet a straightness tolerance of 1.5 mm/m. When placed anywhere on the pipe parallel to the pipe axis, there shall not be a gap more than 1.5 mm between a 1 m long straightedge and the pipe.

5.01.03 High Density Polyethylene Pipe

High density polyethylene (HDPE) pipe according to OPSS 1840 shall be used in accordance with ASTM D3350.

Fittings shall be according to CAN/CSA-B182.6 or ASTM F894 and suitable for the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed according to the manufacturer's recommended procedures and ASTM D2657. Where conflicts exist between the manufacturer's instructions and ASTM D2657, the manufacturer's instructions are to be followed.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified on the Working Drawings.

5.03 Steel Reinforcement

Steel reinforcement for concrete work shall be according to OPSS 1440.

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

Selection of drilling fluid type shall be based on the soils encountered in the subsurface investigation.

The drilling fluids shall be mixed according to the manufacturer's recommendations.

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated subsurface conditions. The viscosity of slurry used for SPB tunnelling shall be no less than 40 seconds Marsh Funnel viscosity, as defined by ASTM D6910, measured prior to introduction of groundwater and spoil and as required to ensure:

a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding ground and groundwater pressures at excavation face;

b) lubricate installation of primary liners as required;

c) transport spoil through pipe systems.

5.06 Grout

Purging grout shall conform to the requirements of OPSS 1004 and be wetted with only sufficient water to make the mixture plastic.

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Except in the case of dewatering to at least 1 m below the tunnel/bore invert for the full length of the pipe alignment, Auger Jack & Bore shall not be used and will not be permitted where subsurface conditions indicate that saturated gravel, sand and silt soils may be encountered at pipe level or within one pipe diameter above or below outside pipe dimensions.

Pipe Auger Jack & Bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the Works.

The lead end of the auger shall be maintained at least one pipe diameter inside the lead end of the casing. The auger cutting tools shall not extend to or beyond the lead end of the casing at any time unless specific exception is provided by the Ministry prior to construction. Submittals shall identify anticipated jacking forces for advancing casing ahead of leading edge of auger cutting tools in addition to friction forces that are to be overcome by jacking systems.

6.02 Pipe Ramming

Pipe Ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The Pipe Ramming hammer(s) shall be capable of driving the pipe casing from the entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the Works.

6.03 Horizontal Directional Drilling

6.03.01 General

The Horizontal Directional Drilling (HDD) equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.

b) Have drill rod that is suitable for both the drill and the product pipe installation.

c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.

d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.

e) Contain a guidance system to accurately guide boring operations.

f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.

g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein. Specific details of the Tunnelling equipment included in the submission shall be provided for:

a) rock or boulder breaking and removal;

b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;

c) jacking systems;

d) alignment control systems;

Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use. Use of explosives is prohibited without specific application and acceptance by the Ministry prior to construction.

6.05 Microtunnelling Equipment

The Contractor shall be responsible for selecting Microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils that will be encountered.

The Contractor shall employ Microtunnelling equipment that will be capable of handling the various anticipated ground conditions.

The MTBM shall also be capable of controlling loss of soil ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:

   i. Allows for operation of the system without the need for personnel to enter the microtunnel.
   ii. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
   iii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by product pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
   iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
   v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
   vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
   vii. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
   viii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
   ix. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.

b) Active Direction Control – The Contractor shall provide a MTBM that includes an active direction control system with the following features:

   i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference.
   ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
   iii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

a) Has the main jacks mounted in a jacking frame located in the launch shaft.

b) Has a jacking frame that successively pushes towards a receiving shaft, a string of product pipe that follows the microtunnelling excavation equipment.

c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.

d) The main jack station may be complemented with the use of intermediate jacking stations as required.

e) Has a capacity at least 20 % greater than the calculated maximum jacking load.

f) Develops a uniform distribution of jacking forces on the end of the casing pipe.

g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.

h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.

i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

The Contractor shall determine the type of spoil separation equipment needed for each drive based on the geotechnical information available and other project constraints.

6.05.03 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.

Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

7.0 CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting the work. The proposed method of pipe installation to be used by the Contractor shall be subject to the limitations presented in the following subsections.

The Contractor's Engineer shall supervise the work at all times.

A Request to Proceed shall be submitted to the Contract Administrator upon completion of each of the following operations and prior to commencement of each subsequent operation and no less than 2 weeks prior to the commencement of the trenchless installation.

a) Site Surveying (see Clause 4.02)
b) Excavation for pits including dewatering of excavations
c) Jacking / Ramming / Directional Drilling of Casing / Liner
d) Installation of the Product
e) Grouting Operations

Operations a) to e) shall not proceed until the Contract Administrator has issued a Notice to Proceed for each proceeding operation.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each Working Day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

The Contractor shall submit records of the alignment and depth of the installation to the Contract Administrator at the completion of the installation.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS 539.

Where the stability, safety, or function of an existing roadway, railway, watercourse, other works, ESA’s, or proposed works may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contractor, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, procedures, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer’s recommendations for transporting, unloading, storing, and handling of materials shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment, the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS 539.

7.01.10 Dewatering

The work of this section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

The Contractor is alerted that cobbles and boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles and boulders shall be expected to be routine and will not be considered obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor's expected method of and schedule for removal.

As indicated in Section 4.02.02, the Trenchless Contractor shall provide a contingency plan to accompany working drawings in the event that tunnelling is obstructed / halted. As part of the contingency plan, the requirement to rescue the MTBM and abandon the tunnel shall be included such that impacts to Highway 400 and the travelled lanes are limited. As part of any contingency plan (e.g. rescue shafts to retrieve MTBM), Highway 400 Northbound and Southbound traffic shall remain open at all times.

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180.

Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.

b) A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

d) Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be watertight and according to OPSS 1820, and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner, the space between the liner and the wall of the excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

The annular space between the liner and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.03 Pipe Ramming Installation

For Pipe Ramming installation the following requirements apply:

- Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.
- A Ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has passed fully through and beyond the zone of influence of any overlying infrastructure.
- Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator.
- Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed.
- The annular space between the liner pipe and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

For Horizontal Directional Drilling (HDD), the Contractor shall ensure that during pilot hole drilling the maximum degree of deviation or "dog-leg" shall be 2.5 degrees per 9 m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor's sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.04.02 Site Preparation

Site preparation shall be according to OPSS 490 and as specified herein.

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for HDD operations are to be made. All activities shall be confined to designated Working Areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

If a drill hole beneath highways, roads, watercourses or other infrastructure must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence and subsurface water conveyance.

The Contractor shall maintain drilling fluid pressure and circulation throughout the HDD process, including during the initial pilot bore and during the reaming process.

The Contractor shall, at all times and for the entire length of the installation alignment, be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates, and pressures.

7.04.04 Drilling Fluid Losses to Surface ("Frac-Out")

To reduce the potential for hydraulic fracturing of the hole during horizontal directional drilling, a minimum depth of cover of 5 m shall be maintained between the top of pipe and the surface of any pavements or beds of water courses. Sections of the pipe close to the entry and exit pit with less than 5 m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled for the full length of the bore to prevent frac-out for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Once a fluid loss or frac-out event is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to collect all fluids discharged to surface, mitigate and prevent additional fluid loss.

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.01 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be contravened.

Product shall be allowed to recover to static conditions from thermal and installation stresses before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully Reaming the bore to the required diameter, the product pipe shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product pipe is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product pipe shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator.

The pull back and Reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to ensure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the walls of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7. 05 Tunnelling Installation

7.05.01 General

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall provide ventilation and lighting in accordance with OHSA requirements for the entire length of the tunnel installed as tunneling progresses.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the Work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.02 Tunnelling Method

The Tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the Tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.03 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the wall of the excavated volume shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. If an unexpanded liner is used, the space outside the liner plates shall be filled at least daily.

7.05.04 Secondary Liner

7.05.04.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property. Grout mix design shall be chemically and thermally compatible with all pipe systems.

7.06 Microtunnelling

7.06.01 General

Excavation of soil, rock and fill shall be done in a manner to control and prevent groundwater inflow to the tunnel.

The MTBM shall be capable of fully supporting the face and shall accommodate the removal of boulders and other obstructions from the face. Continuous ground support shall be maintained during excavation.

The tunnel is to be kept well drained at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times.

In the event that excavation threatens to endanger personnel, the Work, adjacent property, roadways, railways, waterways, or the public in any way, the Contractor shall cease excavation. The Contractor shall then evaluate the methods of construction and revise as necessary to ensure the safe continuation of the Work.

The Contractor shall maintain the tunnel excavation line and grade to provide for construction of the product within the specified tolerances.

7.06.02 Method of Installation

The installation procedure to be used shall be subject to the following limitations:

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.

- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour Working Days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

The space between the casing and the wall of the excavation shall be kept filled with lubricant during the pipe jacking operation. Upon completion of pipe jacking, the space between the casing and the wall of the excavation shall be filled with grout that is compatible with the casing.

The casing shall act as a support system to maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the casing.

The casing shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting.

7.07 Instrumentation and Monitoring

7.07.01 General

The Contractor shall furnish, install and monitor Surface Monitoring Points (SMP) and In-Ground Monitoring Points at the locations shown on the Contract Drawings.

The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation. Given that the majority of surface monitoring points are located on Highway 400, consideration can be given to using a robotic total station surveying system.

7.07.02 Surface Settlement Monitoring Points

Surface settlement monitoring points shall be installed on the traffic lanes and shoulders to monitor settlement and stability. The surface settlement monitoring points shall be installed centred on the tunnel alignment as arrays of three points at intervals of 5 m or less and off-set a lateral distance of 1.5 m on either side of the tunnel centerline.

Surface settlement monitoring points shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the Contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.03 In-Ground Settlement Monitoring Points

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals. In-ground settlement monitoring points shall be located at intervals of 5 m or less along the tunnel alignment.

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface or below frost penetration depth, whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.04 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two (2) weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field identification. The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation. Instruments damaged by the Contractor's operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.05 Monitoring and Reporting Frequency

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the following time intervals:

a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);

b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and

c) Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrator for information purposes on a weekly basis.

Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07.06 Benchmarks

Two independent benchmarks shall be used for all settlement monitoring surveying and shall be located sufficiently outside the zone of influence such that the benchmarks are not influenced by any trenchless or other construction activity or weather conditions (e.g., frost heave). All surveying shall be reported using the geodetic datum and coordinate system as defined in the Contract Documents.

7.08 Criteria for Assessment of Roadway Subsidence/Heave

Prior to tunnelling operations and as part of the Contractors submission of Baseline Readings to the Contract Administrator, a pre-planned Emergency Response Plan (ERP) shall be provided in case alert levels are exceeded or in the event that excessive settlements or sinkholes suddenly form within or near the travelled highway surface. An emergency plan for traffic management and highway repair / remediation must be in-place to rapidly mitigate or limit any distress to the overlying highway embankment and pavement, as needed. In addition, given the relatively close proximity of the existing median storm sewer at the north crossing alignment, a contingency plan to manage any storm water that could collect and potential overflow / impact the operation of the highway should be in place, if needed.

Based on the monitoring of the ground movement as specified in Subsections 4.02 and 7.07, the following represents trigger levels that define magnitude of movement and corresponding action:

a) Review Level: If a maximum value of 25 mm or 37.5 mm (for an single crossing or cumulative for the three south crossings respectively) relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the Contract Administrator and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

b) Alert Level: If a maximum value of 37.5 mm or 50 mm (for single crossing or cumulative for three south crossings) relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:

    i. The cause of the settlement has been identified.

    ii. The Contractor submits a corrective/preventive plan complete with a Request to Proceed.

    iii. Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.

    iv. Operations shall not proceed until the Contract Administrator has issued a Notice to Proceed for each corrective/preventive plan.

7.09 Certificate of Conformance

A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the installation of the pipe at each location. In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design Engineer and the Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor’s Submission and Design Requirements, sealed Working Drawings and Contract Documents.

8.0 QUALITY ASSURANCE

Regular meetings will be held between the Contractor, Trenchless Contractor, the Contract Administrator (including the Foundation Engineering Specialist), and the Ministry of Transportation such that progress, schedule, monitoring results and any construction challenges or concerns can be discussed. Meetings will be held weekly (remotely) during shaft installation and tunnelling activities and will target key milestones including Entry/Exit Portals, Tunnelling Equipment Set Up, Tunnel Excavation, Tunnel Structure/Pipe Installation, Tunnel Grouting and Tunnel Monitoring.

9.0 MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centreline of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10.0 BASIS OF PAYMENT

Payment at the Contract price shall be full compensation for all labour, Equipment, and Material required for excavation (regardless of material encountered), dewatering, sheathing and shoring, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

If a pipe is installed inside the pipe liner, payment for the pipe shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g., choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, Equipment, and Materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

NOTES TO DESIGNER:

* Insert the following fill-in: Any method that is not suitable shall be specified.

** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

*** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

**** Insert the following fill-in: Subsurface Condition Baseline Reporting that includes Boulder Volume Ratio (BVR), Boulder Number Ratio (BNR) shall be project specific and included in the Foundation Engineering TOR as selected during the scoping of the project.

***** Insert the following fill-in: Any known obstructions shall be specified.

****** Insert the following fill-in: The Instrumentation and Monitoring program shall be project specific. The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

******* Insert the following fill-in: Project specific Review and Alert Levels shall be provided if required.

******** Insert the following fill-in: Payment for removal of boulders exceeding Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material.

WARRANT: Always with this specification.

DECOMMISSION OF PIEZOMETERS - Item No.

Non-Standard Special Provision

Standpipe piezometers were installed in Boreholes CR-04, CR-05, CR-07 and CR-09 as part of the Foundation Investigation for the trenchless crossings. Details of the standpipe piezometers can be found within the Foundation Investigation Report included in the contract documents.

The standpipe piezometers have been left in place to allow for monitoring of groundwater levels up to the start of construction.

As part of the construction activities and prior to any trenchless operations, the contractor shall properly decommission the standpipe piezometers. The abandonment method for standpipe piezometers shall be in general accordance with the requirements of Ontario Regulation 903 Wells, as amended under the Ontario Water Resources Act. In addition, the contractor shall provide a written record of the decommissioning procedure to the Contract Administrator.

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.

DEWATERING SYSTEM - Item No.
TEMPORARY FLOW PASSAGE SYSTEM - Item No.

Special Provision No. 517F01 July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO's website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

<table>
<tr><td>IDF Curve Location</td><td colspan="2">Latitude: 44.204167</td><td colspan="4">Longitude: -79.654167</td></tr>
<tr><td colspan="7">Temporary Flow Passage Systems</td></tr>
<tr><td rowspan="2">Site Name / Station Reference</td><td rowspan="2">Minimum Return Period (Years)</td><td colspan="4">Return Period Flow Estimates (m^3/s)</td><td rowspan="2">Design Engineer Requirements (Note 1)</td></tr>
<tr><td>7Q20</td><td>2 Year</td><td></td><td></td></tr>
<tr><td>Hwy 400/South Innisfil Creek Drain</td><td>Base flow as defined by the 7Q20 low flow</td><td>0.23</td><td>13.43</td><td></td><td></td><td>Yes</td></tr>
<tr><td colspan="7">Dewatering Systems</td></tr>
<tr><td>Site Name / Station Reference</td><td colspan="5">Preconstruction Survey Distance (Note 2) (m)</td><td>Design Engineer Requirements (Note 1)</td></tr>
<tr><td>Highway 400/South Innisfil Creek Drain</td><td colspan="5">50</td><td>Yes</td></tr>
<tr><td colspan="7">Note:
1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.
2. “N/A” indicates a preconstruction survey is not required.</td></tr>
</table>

NOTES TO DESIGNER:

Designer Fill-in for Table A:

* Enter the latitude and longitude co-ordinates of the IDF Curve as obtained using the MTO IDF Curve Look up Tool. Create additional tables, as necessary, if more than one (1) IDF curve was used on the contract (i.e. on a very long contract there may be two IDF curves used to better represent rainfall events for two (2) different sections of the contract).

** Fill-in site name, work, and station reference as appropriate for the dewatering system and/or temporary flow passage system item locations.

*** For temporary flow passage system item locations, fill-in the minimum design storm return period for the site based on MTO Drainage Design Standard TW-1.

**** For temporary flow passage system item locations, fill-in the design flow rate estimates for the various return periods.

***** Insert “Yes” when recommended by the Foundation Engineer. Insert “No” otherwise.

****** Fill-in the required distance for preconstruction survey if recommended by the Foundation Engineer. Fill-in "N/A" if not recommended.

Table A (Sample)

<table>
<tr><td>IDF Curve Location</td><td colspan="3">Latitude: 44.974844</td><td colspan="3">Longitude: -79.769339</td></tr>
<tr><td colspan="7">Temporary Flow Passage Systems</td></tr>
<tr><td rowspan="2">Site Name /
Station Reference</td><td rowspan="2">Minimum
Return Period
(Years)</td><td colspan="4">Return Period Flow Estimates (m^3/s)</td><td rowspan="2">Design Engineer
Requirements
(Note 1)</td></tr>
<tr><td>2
Year</td><td>5
Year</td><td>10
Year</td><td>25
Year</td></tr>
<tr><td>Woods Creek Culvert
Rehabilitation</td><td>2</td><td>0.7</td><td>3.5</td><td>7.5</td><td>10.9</td><td>N/A</td></tr>
<tr><td>Site 32-145
Robbs Creek Culvert Replacement</td><td>10</td><td>1.6</td><td>7.6</td><td>17.4</td><td>25.2</td><td>Yes</td></tr>
<tr><td colspan="7">Dewatering Systems</td></tr>
<tr><td>Site Name /
Station Reference</td><td colspan="5">Preconstruction Survey Distance (Note 2)
(m)</td><td>Design Engineer
Requirements
(Note 1)</td></tr>
<tr><td>Site 32-145
Robbs Creek Culvert Replacement</td><td colspan="5">300</td><td>Yes</td></tr>
<tr><td colspan="7">Note:
1. "Yes" means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. "No" means a minimum experience level is not required for the design Engineer and design-checking Engineer.
2. "N/A" indicates a preconstruction survey is not required.</td></tr>
</table>

WARRANT: Always with these tender items.

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