REPORT

Preliminary Foundation Investigation and Design Report

Deep Cut and High Fill Areas
Highway 400 to Highway 404 Link (Bradford Bypass)
Simcoe County and York Region
MTO Assignment No. 2019-E-0048

Submitted to:

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PART A

PRELIMINARY FOUNDATION INVESTIGATION REPORT
DEEP CUT AND HIGH FILL AREAS
HIGHWAY 400 TO HIGHWAY 404 LINK (BRADFORD BYPASS)
MTO ASSIGNMENT NO. 2019-E-0048

1.0 INTRODUCTION

WSP Canada Inc. (formerly Golder Associates Ltd., now a member of WSP Canada Inc. and hereafter referenced as WSP) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed Bradford Bypass (BBP), a 16.3 km rural controlled access freeway connecting Highway 400 to Highway 404, in the County of Simcoe and Regional Municipality of York.

This report presents the results of limited foundation investigation carried out for planning and preliminary design at the proposed deepest cut areas (which includes a high fill area at one location) as shown on the Key Plan of Drawing 1 and 2 and summarized below.

- **Deep Cut – Area 1 (Station 14+600 to 15+500):** 900 m long deep cut area located between 10th Sideroad and County Road 4. The depth of proposed cut is up to about 26 m below existing ground surface.
- **Deep Cut / High Fill – Area 2 (Station 23+550 to 24+450)**: 900 m long section that transitions from a high fill (up to 15 m above existing ground surface) to a deep cut (up to 13 m below existing ground surface) located between 2nd Concession and Leslie Street.

Limited boreholes were advanced within the deep cut and high fill areas to support preliminary design for the overall project. Additional deep cut and high fill areas are proposed, and additional investigation will be required during detail design. Additional preliminary investigation at the deep cut / high fill areas is provided in the pavement investigation and design report (WSP Golder, 2023)[1].

2.0 SITE DESCRIPTION

2.1 Deep Cut – Area 1 (Station 14+600 to 15+500)

This deep cut area is located along the mainline alignment and includes the west portion of the BBP / County Road 4 interchange, just west of County Road 4 and east of the proposed future extension of Professors Day Drive. At this location a residential subdivision is located south of the BBP alignment and farm fields are located to the north. In general, the site of the deep cut consists of a gently sloping hill (high point of relief in the area) that is about 30 m higher than the ground surface at County Road 4 and divides the watershed in the area to the west and east. The ground surface also slopes down from north to south towards the residential subdivision. The existing ground surface is generally covered with grass / shrubs with some forested area as shown in Photographs 1 and 2 below.

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[1] WSP Golder. 2023. Preliminary Pavement Design Report. *Preliminary design of the Bradford Bypass from Highway 400 to Highway 404. Agreement Number 2019-E-0048*. Dated November 8, 2023.

Photograph 1 – Looking northwest towards deep cut area.

Photograph 2 – Looking west on top of deep cut area.

2.2 Deep Cut / High Fill – Area 2 (Station 23+550 to 24+450)

This area of the alignment includes a transition from a high fill to a deep cut and is located between 2nd Concession and Leslie Street. The existing ground surface is generally flat east of 2nd Concession where the proposed high fill area is located. In the central portion of the site (about Station 24+080 to 24+220) where the area transitions from a high fill to a deep cut, there is a rapid change in elevation with the existing ground surface rising about 30 m from west to east. The ground surface for the remainder of the deep cut site gently slopes downward towards Leslie Street to the west. The majority of the elevation change occurs from west to east, and the ground surface north and south of the proposed alignment is generally consistent (no significant slope north or south).

The high fill and deep cut area is generally located within existing farm fields, with the transition zone located in a forested area separating the fields. Photographs 3 and 4 are taken in the proposed high fill and deep cut areas, respectively.

Photograph 3 – Looking east within proposed high fill area

Photograph 4 – Looking south from top of proposed deep cut area.

3.0 INVESTIGATION PROCEDURES

3.1 Previous Pavement Investigation

Two boreholes designated PDC6 and PDC7 were advanced within the Deep Cut – Area 1 as part of the pavement investigation for the Bradford Bypass (WSP Golder, 2023)[1]. PDC6 and PDC7 were advanced to depths of 22 m and 28 m below ground surface within the proposed cut area to the north of the proposed alignment between April 3 and 10, 2023. The pavement logs are provided in Appendix A and their approximate locations are shown on Drawing 1.

In general, the boreholes encountered topsoil over a loose to very dense silty sand to sandy silt that transitioned to a silty clay to clayey silt at depth. Cobbles were inferred in the upper portion of the silty sand to sandy silt.

Standard Penetration Testing (SPT) was carried out in these boreholes and monitoring wells were installed. The SPT 'N'-Values obtained from PDC6 and PDC7 are presented on Drawing 1 and the details of the monitoring well screen depths and recorded water levels are provided in Section 4.3.

3.2 Current Investigation

The field work for the current investigation was carried out between May and June, 2022, December 2022 and February 2023, as part of the base scope investigation for the Bradford Bypass at which time two boreholes (designated Boreholes DC-01 and DC-02) were advanced in the Deep Cut - Area 1 and two boreholes (designated Boreholes DC-03 and DC-04) were advanced in the Deep Cut / High Fill - Area 2. A copy of the borehole records and laboratory testing are provided in Appendices B and C, respectively, and the location of the boreholes advanced during the current investigation are shown on Drawings 1 and 2.

Boreholes were generally advanced using 210 mm outside diameter (O.D.) hollow stem augers followed by wash-rotary techniques (advancement of tricone with water/drilling mud) using Diederich D-50 / D-150 and Acker Renegade track-mounted drills supplied and operated by Walker Drilling Inc. of Utopia, Ontario.

The wash-rotary technique was used in Boreholes DC-01 to DC-03 to counter-balance hydrostatic forces and reduce disturbance at the deeper sampling and testing interval. This method was not used in Borehole DC-04 to allow for larger soil samples to be obtained for the associated pavements investigation. Soil samples were generally obtained at 0.75 m, 1.5 m, and 3.0 m intervals of depth using a 50 mm O.D. split spoon sampler driven with an automatic hammer in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586 [2]), to obtain relatively undisturbed samples in the soil. The split-spoon samplers used in the investigation generally limit the maximum particle size that can be sampled and tested to about 35 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension would not be sampled or represented in the grain size distributions.

The water level was generally observed during drilling; however, in some cases the water level was not measured due to the introduction of water during drilling operations. Water level observations are noted on the drilling records. Standpipe piezometers were installed in Boreholes DC-02, DC-03, and DC-04. The installed piezometers consist of a 50 mm diameter PVC pipe, with a 1.5 m or 3 m long slotted screen within a filter sand pack. The boreholes and annulus surrounding the piezometer pipe above the filter sand pack were backfilled to near ground surface with

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[2] ASTM D1586 Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

bentonite pellets in general accordance with Ontario Regulation 903 Wells (as amended)[3]. The monitoring wells were capped with monument casings.

The field work was monitored on a full-time basis by a member of WSP's engineering staff who located the boreholes in the field, logged the boreholes, and examined the soil samples. The soil samples were identified in the field, placed in labelled containers, and transported to WSP's laboratory in Mississauga for further visual review and geotechnical laboratory testing. Index and classification testing consisting of natural moisture content, Atterberg limits and grain size distribution were conducted on selected samples. All laboratory tests were carried out in general accordance with MTO and / or ASTM Standards, as applicable.

The borehole locations were surveyed in the field by WSP personnel using a Trimble Geo 7X Global Positioning System (GPS) unit. The locations given on the borehole records and shown on Drawings 1 and 2 are positioned relative to NAD 83 MTM (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum (CGVD28 datum; HT2 Geoid Model). The borehole locations, including the geographic (Latitude / Longitude) coordinates, the ground surface elevations, and borehole depths are summarized below.

Borehole No.	NAD 83 MTM Northing (m) (Latitude, °)	NAD 83 MTM Easting (m) (Longitude, °)	Ground Surface Elevation (m)	Borehole Depth (m)
DC-01	4,887,754.5 (44.129762)	298,899.4 (-79.573736)	274.0	21.5
DC-02	4,887,732.2 (44.129560)	298,800.3 (-79.574974)	277.0	21.6
DC-03	4,889,831.9 (44.148479)	307,194.8 (-79.470065)	223.6	20.4
DC-04	4,889,960.1 (44.149632)	307,468.1 (-79.466647)	258.8	20.4

4.0 REGIONAL GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

These deep cut / fill sections along the Bradford Bypass are generally located within the border of three physiographic regions known as the Peterborough Drumlin field, Schomberg Clay Plains, and Simcoe Lowlands as delineated in The Physiography of Southern Ontario (Chapman and Putnam, 1984)4.

The Area 1 - Deep Cut / High Fill is located near the border of the Peterborough Drumlin field and Schomberg Clay Plains. The Peterborough Drumlin field region generally consists of calcareous till soils and is generally sandier (rather than stony) within Simcoe County. Many drumlins in this area are known to have shallow coverings of silt and fine sand which is probably wind-blown material. Deposits of clay typically lie between the drumlins in this area.

The Schomberg Clay Plain region consists of deep deposits of stratified clay and silt. In some areas, clay and silt varves (greater than 100 mm thick) are present with the clay layers typically containing up to 50% clay and 40%

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[3] Ontario Regulation 903 Wells (as amended)

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

silt, however, the behaviour is described to be more like that of silt than clay. The Simcoe silty clay and silt loams are described to be poorly drained.

The Area 2 – Deep Cut is located within the Simcoe Lowlands physiographic region that covers the central portion of the County of Simcoe. Following the retreat of the last glacial ice sheet, the lowland was flooded by the now extinct post-glacial Lake Algonquin. This past post-glacial lacustrine environment is marked by deep sand, silt and clay beds overlying glacial ground moraine material.

The subsurface conditions encountered during the previous and current investigations are generally consistent with the regional geology described above. The elongated hill formation at Deep Cut – Area 1 suggests the presence of a drumlin at this location.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes from the current investigation including piezometer installation details and water level readings, and the results of the in-situ and laboratory tests are provided on the borehole records in Appendix B. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the borehole records and in Section 4 are uncorrected and are based on use of an automatic hammer. The detailed results of the geotechnical laboratory testing on soil samples are presented on the laboratory test figures in Appendix C.

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 Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected.

4.2.1 Deep Cut – Area 1

In general, the soils encountered in the boreholes (DC-01 and DC-02) at this site consist of surficial layers of topsoil/reworked native underlain by near surface layers of compact to dense silty sand to firm to very stiff clayey silt-silt to clayey silt. A till deposit ranging from non-cohesive (silt and sand to silty sand) to cohesive (clayey silt-silt to clayey silt) was encountered below the near surface deposits. The till deposit was generally underlain by a clayey silt-silt to clayey silt deposit which is in turn underlain by a sandy silt to silty sand deposit.

More detailed descriptions of the major soil layers encountered in the boreholes are provided in the following sections.

4.2.1.1 Topsoil / Reworked Native

A 0.7 m thick layer of topsoil / reworked native (likely from farming activities) described as sandy silt to silt containing organics and rootlets was encountered in Boreholes DC-01 and DC-02 at ground surface (Elevation 274.0 m and 277.0 m, respectively). Materials designated as topsoil in this report were classified based solely on visual and textural evidence. Testing of organic content or for other soil nutrients was not carried out. Accordingly, materials classified as topsoil herein cannot necessarily be relied upon for support and growth of landscaping vegetation without supplemental soil fertility analyses.

The SPT ‘N’-values measured in the topsoil/reworked native were 9 and 22 blows per 0.3 m of penetration, indicating a loose to compact degree of compactness.

4.2.1.1 Upper Silty Sand

A 1.5 m thick layer of silty sand was encountered below the topsoil layer in Borehole DC-01, at a depth of 0.7 m (Elevation 273.4 m).

The SPT ‘N’-values measured within the silty sand deposit were 23 and 47 blows per 0.3 m of penetration, indicating a compact to dense degree of compactness.

The natural water content measured on a selected sample was about 8%.

Atterberg limits measured a liquid limit of 13%, a plastic limit of 12%, and a plasticity index of 1%, which indicates that the fines component of the deposit is a silt of slight plasticity. The results of the Atterberg limits test carried out on the sample of the fines portion of the silty sand deposit are shown on Figure C1-1 in Appendix A

Grain size distribution testing was carried out on a sample of the silty sand deposit and the results are shown on Figure C1-2 in Appendix C.

4.2.1.2 Clayey Silt to Sandy Clayey Silt

A 1.5 m thick layer of clayey silt to sandy clayey silt was encountered below the topsoil in Borehole DC-02 at a depth of 0.7 m (Elevation 276.3 m). A 0.3 m thick interlayer of silty sand was encountered within the deposit at a depth of 1.1 m below ground surface (Elevation 275.9 m).

The SPT ‘N’-values measured within the clayey silt to sandy clayey silt deposit were 7 and 22 blows per 0.3 m of penetration suggesting a firm to very stiff consistency.

The natural water content measured on a sample of the clayey silt deposit was about 21%.

The Atterberg limits testing on one sample measured a liquid limit of 29%, plastic limit of 22%, and plasticity index of 7% suggesting the deposit is a clayey silt of low plasticity. The results of the Atterberg limits testing are shown on Figure C1-3 in Appendix C.

The SPT ‘N’-value measured within the silty sand interlayer was 7 blows per 0.3 m of penetration indicating a loose degree of compactness. The natural water content measured on a sample of the silty sand interlayer was about 14%. Grain size distribution testing was carried out on a sample of the silty sand interlayer and the results are shown on Figure C1-2 in Appendix C.

4.2.1.3 Silt and Sand to Silty Sand - Till

A 5.0 m thick non-cohesive till deposit consisting of silt and sand to silty sand was encountered below the clayey silt to sandy clayey silt layer in Borehole DC-02 at a depth of 2.2 m (Elevation 274.8 m). Grinding during casing advancement was noted within the deposit between depths of 5.2 m and 5.9 m (Elevation 271.8 m and 271.1 m).

The SPT ‘N’-values measured within the non-cohesive till deposit range from 51 blows per 0.3 m of penetration to 100 blows for 0.06 m of penetration, indicating a very dense state of compactness.

The natural water content measured on selected samples of the non-cohesive till deposit range from about 7% to 10%.

Atterberg limits testing carried out on one sample measured a liquid limit of 13%, plastic limit of 11%, and plasticity index of 2% suggesting the fines component of the non-cohesive till deposit is a silt of slight plasticity. The results of the Atterberg limits testing are shown on Figure C1-4 in Appendix C.

Grain size distribution testing was carried out on select samples of the non-cohesive till deposit and the results are shown on Figure C1-5 in Appendix C.

4.2.1.4 Clayey Silt-Silt to Clayey Silt - Till

A 6.3 m thick cohesive till deposit consisting of clayey silt-silt to clayey silt, was encountered below the silty sand deposit in Borehole DC-01 at a depth of 2.2 m (Elevation 271.8 m). The deposit contains silt and sand seams throughout.

The SPT 'N'-values measured in this till deposit range from 41 to 170 blows per 0.3 m of penetration, suggesting a hard consistency.

The natural water content measured on selected samples ranges from about 11% to 18%.

Atterberg limits testing carried out on selected samples of the deposit measured a liquid limit ranging from 17% to 24%, plastic limit of 12% to 15%, and plasticity indices of 3% to 9% suggesting the cohesive till is generally a clayey silt-silt to clayey silt of low plasticity with silt seams. The results of the Atterberg limits testing are shown on Figure C1-6 in Appendix C.

Grain size distribution testing was carried out on selected samples of the till deposit and the results are shown on Figure C1-7 in Appendix C.

4.2.1.5 Gravelly Silty Sand

A 1.9 m thick layer of gravelly silty sand was encountered below the till in Borehole DC-01 at a depth of 8.5 m (Elevation 265.5 m).

The SPT 'N'-value measured within gravelly silty sand deposit was 100 blows for 0.13 m of penetration, indicating a very dense state of compactness.

The natural water content measured on a selected sample is about 8%.

Grain size distribution testing was carried out on a sample of the gravelly silty sand deposit and the results are shown on Figure C1-8 in Appendix C.

4.2.1.6 Clayey Silt to Clayey Silt-Silt

A 9.7 m and 7.6 m thick clayey silt-silt to clayey silt deposit, containing silt seams / interlayers was encountered below the till deposits in Boreholes DC-01 and DC-02, this deposit was encountered at a depth of 10.4 m and 7.2 m (Elevation 263.7 m and 269.8 m) respectively.

The SPT 'N'-values measured in the clayey silt to clayey silt-silt deposit range from 62 blows per 0.3 m of penetration to 100 blows per 0.13 m of penetration, suggesting a hard consistency.

The natural water content measured on selected samples of the clayey silt-silt to clayey silt range from about 12% to 23%.

Atterberg limits testing carried on selected samples of the deposit measured liquid limits ranging from 18% to 28%, plastic limits ranging from 12% to 16%, and plasticity indices ranging from 6% to 15% and indicate the deposit is generally a clayey silt to clayey silt-silt of low plasticity. Atterberg limits testing carried out on one sample within the clayey silt-silt to clayey silt deposit measured a liquid limit of 22%, a plastic limit of 19%, and a plasticity index of

3%, confirming the presence of a silt seam/interlayer of slight plasticity. The Atterberg limits testing results are shown on Figure C1-9 in Appendix C.

Grain size distribution testing was carried out on samples of the clayey silt to clayey silt-silt deposit and the results are shown on Figure C1-10 in Appendix C.

4.2.1.7 Sandy Silt to Silt and Sand

A sandy silt to silt and sand deposit containing clayey silt seams / interlayers was encountered below the clayey silt to clayey silt-silt deposit in Boreholes DC-01 and DC-02 at depths of 20.1 m and 14.8 m (Elevation 253.9 m and 262.2 m), respectively. The deposit was 5.3 m thick in Borehole DC-02. In Borehole DC-01, the layer was penetrated for a length of 1.4 m before the borehole was terminated within the deposit.

The SPT ‘N’-values measured within the sandy silt to silt and sand deposit ranged from 100 blows for 0.11 m of penetration to 100 blows for 0.13 m of penetration, indicating a very dense state of compactness.

The natural water content measured on a sample of the silt deposit was about 15%.

Atterberg limits performed on one sample measured a liquid limit of 14%, a plastic limit of 11%, and a plasticity index of 3% and indicate the deposit is a silt of slight plasticity. The Atterberg limits testing results are shown on Figure C1-11 in Appendix C.

Grain size distribution testing was carried out on two samples of the sandy silt to sand and sand deposit and the results are shown on Figure C1-12 in Appendix C.

4.2.1.8 Clayey Silt (Lower)

A lower clayey silt deposit was encountered below the silt deposit in Borehole DC-02 at a depth of 20.1 m (Elevation 256.9 m). The deposit was penetrated for a length of 1.5 m before the borehole was terminated.

The natural water content measured on a sample of the lower clayey silt deposit was about 19%.

Atterberg limits carried out on a sample of the deposit measured a liquid limit of 30%, a plastic limit of 17%, and a plasticity index of 13% and indicate the deposit is a clayey silt of low plasticity. The Atterberg limits testing results are shown on Figure C1-9 in Appendix C.

4.2.1.9 Previous Pavement Investigation

The pavement boreholes (PDC6 and PDC7) were advanced in the western portion of the deep cut at a higher elevation that the foundation boreholes (DC-01 and DC-02). This section provides a brief description of the soils encountered in the pavement boreholes which are generally consistent with the results of the current investigation.

The soils encountered in Borehole PDC6 consist of topsoil over interlayered non-cohesive soils ranging from silty sand to sandy silt to silty sand (inferred till) which is very dense beyond a depth of 1.5 m below ground surface. A sandy clayey silt to silty clay deposit was encountered below the interlayered non-cohesive deposit at a depth of about 20 m below ground surface and extending to borehole termination at a depth of about 22 m.

Borehole PDC7 encountered topsoil over silty sand (inferred till) which extends to about 7.6 m below ground surface. A silty sand to sand deposit was encountered below the till deposit at a depth of 7.6 m. A clayey silt to silty clay deposit containing sandy silt layers was encountered below the non-cohesive deposit at a depth of about 12.2 m, and a sandy silt deposit was encountered below the clayey silt deposit at a depth of 15.2 m. A cohesive clayey silt deposit was encountered at a depth of 19.8 m and extends to the borehole termination depth of 28 m.

4.2.2 Deep Cut - Area 2

In general, the soils encountered in Borehole DC-04 (advanced at the Deep Cut – Area 2 location) consist of a surficial layer of topsoil underlain by very stiff sandy clayey silt layer containing organics. Below the clayey silt, a deposit of very dense sandy silt till was encountered, underlain by a layer of very stiff to hard clayey silt-silt to clayey silt. Below the clayey silt-silt to clayey silt layer, interlayers of very dense silt, silty sand and silty gravel were encountered which were underlain by a clayey silt-silt deposit.

More detailed descriptions of the major soil layers encountered in Borehole DC-04 are provided in the following sections.

4.2.2.1 Topsoil

A 125 mm thick layer of topsoil consisting of sandy silt was encountered at ground surface (Elevation 258.8 m). Materials designated as topsoil in this report were classified based solely on visual and textural evidence. Testing of organic content or for other soil nutrients was not carried out. Accordingly, materials classified as topsoil herein cannot necessarily be relied upon for support and growth of landscaping vegetation without supplemental soil fertility analyses.

4.2.2.2 Sandy Clayey Silt

A 0.6 m thick sandy clayey silt deposit containing organics and rootlets was encountered below the topsoil. The sandy clayey silt deposit extends to a depth of about 0.7 m below ground surface (Elevation 258.1 m).

The SPT ‘N’-value measured in the sandy clayey silt deposit was 18 blows per 0.3 m of penetration, suggesting a very stiff consistency.

4.2.2.3 Sandy Silt Till

A 1.5 m thick sandy silt till deposit was encountered at a depth of 0.7 m (Elevation 258.1 m) underlying the sandy clayey silt deposit.

The SPT ‘N’-values measured in the sandy silt till were 67 and 81 blows per 0.3 m of penetration, indicating a very dense degree of compactness.

The natural water content measured on a sample of the sandy silt till deposit was about 6%.

Grain size distribution testing was carried out on a sample of the sandy silt till, and the results are shown on Figure C2-1 in Appendix C.

4.2.2.4 Clayey Silt-Silt to Clayey Silt

A 3.4 m thick cohesive deposit consisting of clayey silt to clayey silt-silt was encountered underlying the sandy silt till deposit at a depth of 2.2 m (Elevation 256.6 m).

The SPT ‘N’-values measured in the clayey silt to clayey silt-silt range from 22 to 63 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.

The natural water content measured on selected samples of the cohesive deposit range from about 12% to 22%.

Atterberg limits test were carried out on samples of the cohesive deposit and measured liquid limits of 26% and 15%, plastic limits of 15% and 12% corresponding plasticity indices of 11% and 3%, respectively. The results of the Atterberg limits testing confirm the deposit is a clayey silt of low plasticity and contains layers of silt of slight plasticity. The results of Atterberg limits testing are shown on Figure C2-2 in Appendix C.

4.2.2.5 Silt to Silty Sand and Silty Gravel

A 7.9 m thick deposit of silt to silty sand was encountered below the clayey silt to clayey silt-silt deposit at a depth of 5.6 m (Elevation 253.1 m). A 1.5 m thick layer of silty gravel was encountered within the silt to silty sand deposit at a depth of 7.2 m (Elevation 251.6 m). Auger grinding and augur refusal was encountered within the deposit at a depth of 6.7 m (Elevation 252.1 m) and auger grinding was also noted within the deposit at a depth of 12.2 m (Elevation 246.6 m).

The SPT ‘N’ values measured within the deposit range from 93 blows for 0.23 m of penetration to 50 blows per 0.05 m of penetration, indicating a very dense degree of compactness.

The natural water content measured on selected samples ranges from about 8% to 12%.

Grain size distribution testing was carried out on a sample of the silty sand portion of the deposit and the results are shown on Figure C2-3 in Appendix C.

4.2.2.6 Silt

A 5.8 m thick deposit of silt containing clayey silt seams / laminations was encountered below the silt to silty sand deposit.

The SPT ‘N’-values measured within the silt deposit range from 79 blows per 0.29 m of penetration to 50 blows for 0.13 m of penetration indicating a very dense degree of compactness.

The natural water contents measured on selected samples were about 16% and 23%.

An Atterberg limits test was conducted on one sample of the silt deposit and measured a liquid limit of 20%, plastic limit of 17%, and plasticity index of 3%. The results of the Atterberg limits test are presented on Figure C2-4 in Appendix C. A second Atterberg limits test was conducted on a sample of the silt deposit and indicated that the silt is non-plastic. The results of the Atterberg limits tests indicate that the deposit ranges from a silt of slight plasticity to a non-plastic silt.

Grain size distribution testing was carried out on two samples of the silt deposit and the results are shown on Figure C2-5 in Appendix C.

4.2.2.7 Clayey Silt-Silt

A clayey silt-silt deposit was encountered below the silt deposit at a depth of 19.3 m below ground surface (Elevation 239.5 m). The borehole was terminated in this layer after about 1.1 m of penetration.

The SPT ‘N’-value measured in the clayey silt-silt deposit was 69 blows per 0.3 m of penetration, suggesting a hard consistency.

The natural water content measured on selected sample was about 19%.

An Atterberg limits test was conducted on one sample of the clayey silt-silt deposit, and measured a liquid limit of 20%, plastic limit of 16%, and plasticity index of 4%, indicating the deposit is a clayey silt-silt of low plasticity. The results of the Atterberg limits test are presented on Figure C2-6 in Appendix C.

4.2.3 High Fill - Area 2

In general, the soils encountered at Borehole DC-03 (advanced at the High Fill – Area 2 location) consist of a surficial layer of topsoil underlain by compact to very dense silty sand to sandy silt. The sandy silt to silty sand layer is underlain by a stiff to hard clayey silt-silt to clayey silt deposit containing interlayers of very dense silt.

More detailed descriptions of the major soil layers encountered in Borehole DC-03 are provided in the following sections.

4.2.3.1 Topsoil

A 130 mm thick layer of topsoil consisting of sandy silt was encountered at ground surface (Elevation 223.6 m) in Borehole DC-03. Materials designated as topsoil in this report were classified based solely on visual and textural evidence. Testing of organic content or for other soil nutrients was not carried out. Accordingly, materials classified as topsoil herein cannot necessarily be relied upon for support and growth of landscaping vegetation without supplemental soil fertility analyses.

4.2.3.2 Sandy Silt to Silty Sand

A 3.1 m thick layer of sandy silt to silty sand was encountered below the topsoil.

The SPT ‘N’-values measured within the sandy silt to silty sand deposit range from 11 to 57 blows per 0.3 m of penetration, indicating compact to very dense degree of compactness.

The water content measured on two samples of the deposit were about 8% and 12%.

An Atterberg limits test was conducted on one sample of the sandy silt deposit and measured a liquid limit of 13%, plastic limit of 11%, and plasticity index of 2%, indicating the fines portion of deposit is a silt of slight plasticity. The results of the Atterberg limits test are presented on Figure C3-1 in Appendix C.

Grain size distribution testing was carried out on two samples of the sandy silt to silty sand deposit and the results are shown on Figure C3-2 in Appendix C.

4.2.3.3 Clayey Silt-Silt to Clayey Silt

A clayey silt-silt to clayey silt deposit was encountered below the sandy silt to silty sand deposit at a depth of 3.2 m (Elevation 220.4 m). The borehole was terminated in this layer after about 17.2 m of penetration. The deposit contains frequent silt and sand seams, with two major silt interlayers (about 1.5 m and 1.6 m thick) encountered at depths of 8.7 m and 11.7 m below ground surface (Elevation 214.9 m and 211.9 m).

The SPT ‘N’ values measured in the clayey silt-silt to clayey silt generally range from 56 to 115 blows per 0.3 m penetration suggesting a hard consistency. Lower SPT ‘N’-values of 11 blows and 19 blows per 0.3 m were measured in the upper 1.5 m of this deposit.

The natural water content measured on selected samples of the clayey silt-silt to clayey silt range from about 10% to 24%.

Atterberg limits testing carried out on two samples of the cohesive deposit measured a liquid limit of 23% and 25%, plastic limit of 13% and 19%, and plasticity indices of 6% and 10% indicating a clayey silt-silt to clayey silt of low plasticity. The results of Atterberg limits testing are shown on Figure C3-3 in Appendix C.

Grain size distribution testing was carried out on select samples of the clayey silt-silt to clayey silt deposit and the results are shown on Figure C3-4 in Appendix C.

The silt interlayers encountered within the cohesive deposit measured SPT ‘N’-values of 78 blows and 112 blows per 0.3 m of penetration, indicating a very dense state of compactness. The measured water content within the silt interlayers were about 20%. An Atterberg limits test carried out on a sample of the silt interlayer measured a liquid limit of 19%, a plastic limit of 17% and a plasticity index of 2%, indicating the interlayers are a silt of slight plasticity as shown on Figure C3-5 in Appendix C.

4.3 Groundwater Conditions

Standpipe piezometers were installed in Boreholes DC-02, DC-03 and DC-04 during the current investigation and in Boreholes PDC6 and PDC7 in the pavement investigation to allow monitoring of the groundwater level at the deep cut and high fill sites. The groundwater levels recorded in the piezometers are shown on the borehole records in Appendix B and are summarized below.

Borehole No. (Piezometer)	Ground Surface Elevation (m)	Depth (Elevation) of Screen Interval / Sand Pack (m)	Stratigraphy along Well Screen	Depth of Water Level (m)	Water Level Elevation (m)	Date of Water Level Reading
DC-02	277.0	3.1 – 6.1 (El. 273.9 m to 270.9)	Very Dense Silt and Sand to Silty Sand Till	3.6	273.4	December 8, 2023
DC-03	223.6	6.2 – 7.7 (El. 217.4 m to 215.9)	Hard Clayey Silt	7.2 [1]	216.4 [1]	December 5, 2022
				1.5	222.1	December 7, 2023
DC-04	258.8	15.2 – 18.3 (El. 243.6 m to 240.5 m)	Very Dense Silt	15.6	243.2	February 14, 2023
				13.7	245.1	December 7, 2023
PDC6	- [2]	10.7 – 13.7	Very Dense Silty Sand to Silty Sand (Inferred Till)	5.63	- [2]	May 31, 2023
PDC7	- [2]	7.6 – 10.7	Very Dense Silty Sand to Silty Sand (Inferred Till)	1.83	- [2]	May 31, 2023

Notes:

1. Water level measured on date of well installation and is not considered to be representative of stabilized ground water levels.
2. Elevation not surveyed.

The groundwater level observations at this site will be subject to seasonal fluctuations and precipitation events; the water levels should be expected to be higher during the spring season or during and following periods of heavy precipitation and snow melt.

5.0 CLOSURE

This Preliminary Foundation Investigation Report was prepared by Lina Mohamed and was reviewed by Madison Kennedy, P.Eng., a Geotechnical Engineer at WSP. Kevin Bentley, P.Eng., a Geotechnical Engineer with WSP and MTO Principal Foundations Contact conducted a technical and quality control review of the report.

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PART B

PRELIMINARY FOUNDATION DESIGN REPORT
DEEP CUT AND HIGH FILL AREAS
HIGHWAY 400 TO HIGHWAY 404 LINK (BRADFORD BYPASS)
MTO ASSIGNMENT NO. 2019-E-0048

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation recommendations for planning and preliminary design of select deep cut and high fill sections related to the proposed Bradford Bypass. The preliminary recommendations are based on interpretation of the factual data obtained from the boreholes advanced as part of the current foundations and pavements subsurface investigations.

The Preliminary Foundation Design Report (Part B of this report) including the discussion and preliminary recommendations are intended for the use of MTO and their designers for planning and preliminary design and shall not be relied upon for any other purpose or by any other parties, including the construction contractor or design-build proponents. Contractors undertaking the work must make their own interpretation based on the factual data presented in the Preliminary Foundation Investigation Report (Part A of this report) and may need to subsidise this information with additional investigation based on borehole and cut/fill locations. Where comments are made on construction, they are provided to highlight those aspects that could affect the concept and preliminary design of the project and for which special provisions may be required in the future Contract Documents. Those requiring information on aspects of detail design and construction must make their own interpretation of the factual information provided and supplement as necessary, as such interpretation may affect detail design, equipment selection, proposed construction methods, scheduling and the like.

6.2 Project Understanding

Two areas associated with the proposed deepest cuts (and associated high fill area at one deep cut location) along the proposed Bradford Bypass alignment were evaluated at this preliminary stage. The two deep cut and associated high fill areas are designated as Areas 1 and 2, as shown in Drawings 1 and 2, respectively. Based on the preliminary BBP alignment and profile provided by AECOM and cross-sections provided December 13, 2023, the maximum fill heights and cut depths in these two areas are summarised below.

Area Designation	Deep Cut / High Fill	Station Limits	Reference Drawing	Maximum Fill Height / Cut Depth
Area 1	Deep Cut	14+600 to 15+500	1	Cut up to 26 m
Area 2	High Fill	23+550 to 24+180	2	Fill up to 15 m
	Deep Cut	24+180 to 24+450	2	Cut up to 13 m

The deep cut and high fill areas typically extend beyond the station limits provided above, however, the deepest portion of the cuts where boreholes were advanced are within the station limits above.

There are more deep cut/high fill areas (i.e. defined as cuts or fills greater than 4.5 m in depth or height) along the proposed Bradford Bypass alignment; however, only Area 1 and 2 were selected for planning and preliminary design at this preliminary stage. Further discussion on future investigation and design at deep cut/high fill areas is included in Section 6.7.

6.3 General Foundation Design Context

6.3.1 Consequences and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code CAN/CSA S6-19* (CHBDC, 2019) and its *Commentary*, the proposed deep cut and high fill embankment areas may be classified as having large traffic volumes and their performance as having potential impacts on other transportation corridors, resulting in a “typical consequence level” associated with exceeding limit states design.

Based on the preliminary level of foundation investigation completed to date (see Part A of this report) in comparison to the degree of site understanding, the level of confidence for design of the deep cuts and high fill embankments has been assessed as a "low degree of site and prediction model understanding". The recommendations contained in this report are generalized for planning and ongoing preliminary design and further investigation will be required during detail design.

Accordingly, the ultimate limit state (ULS) and serviceability limit state (SLS) consequence factor, $\boldsymbol{\Psi}$, and geotechnical resistance factors, $\boldsymbol{\phi_{gu}}$ and $\boldsymbol{\phi_{gs}}$ for a low degree of site understanding, from Tables 6.1 and 6.2 of CHBDC (2019) have been used at this stage of preliminary design unless otherwise noted. During detail design, additional investigation and testing must be performed to increase the level of confidence and the geotechnical resistance factors modified as appropriate. In addition, reference is made to the MTO Material Engineering and Research Office (MERO) Memorandum #2020-01 (dated March 23, 2020) for developing future settlement and stability analyses during detail design, as applicable.

6.4 Deep Cuts

Deep Cut - Area 1 extends from about Station 14+600 to 15+500 along the proposed Bradford Bypass and has cuts extending up to 26 m below existing ground surface to achieve the proposed vertical roadway profile. Based on Boreholes DC-01, DC-02, PDC6 and PDC7 advanced along the eastern portion of Deep Cut - Area 1 (between about Station 14+800 to 15+220), the soils generally consist of surficial layers of topsoil/reworked native underlain by near surface layers of compact to dense silty sand to firm to very stiff clayey silt-silt to clayey silt. A till deposit ranging from non-cohesive (sandy silt to silty sand) to cohesive (clayey silt-silt to clayey silt) was encountered below the near surface deposits. The till deposit was generally underlain by interlayers of clayey silt-silt to clayey silt and sandy silt to silty sand.

Deep Cut - Area 2 extends from about Station 24+180 to 24+450 along the proposed Bradford Bypass and has cuts up to about 13 m below existing ground surface to achieve the proposed vertical roadway profile. In general, the subsurface soils (as encountered in Borehole DC-04) consist of a surficial layer of topsoil underlain by compact to very dense silty sand to sandy silt. The sandy silt to silty sand layer is underlain by a stiff to hard clayey silt-silt to clayey silt deposit containing interlayers of very dense silt.

In general accordance with MTO's standard practice, a minimum 2 m wide bench should be provided where deep cuts are greater than 6 m in height, such that the uninterrupted slope height does not exceed 6 m. Accordingly, 2 m wide benches were modelled approximately every 6 m in cut depth.

6.4.1 Global Stability

6.4.1.1 Methodology

Stability analysis was carried out at the proposed deepest cut location along Deep Cut - Area 1 and Deep Cut - Area 2.

Two-dimensional limit equilibrium slope stability analyses were performed using the commercially available program Slide2 (Version 9.020), developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. For all analyses, the Factors of Safety of numerous potential global stability circular failure surfaces were computed to establish the minimum Factor of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. The Factor of Safety is equal to the inverse of the product of the consequence factor, Ψ, and the geotechnical resistance factor, ϕ_{gu} (i.e. $FoS = 1/(\Psi \cdot \phi_{gu})$. Accordingly, given the limited geotechnical information at the site and typical consequence level, minimum target Factors of Safety of 1.4 and 1.6 have been used for the preliminary design of the deep cut slopes for the temporary short-term (total stress using undrained soil parameters) and permanent long-term (effective stress using drained soil parameters) conditions, respectively, as per Table 6.2 of CHBDC (2019) and MERO (2020). The circular failure surfaces evaluated for global stability typically extended from behind the crest (tableland) to beyond the toe and did not consider mid-height or shallow surficial failures along the face of the cut slopes.

6.4.1.2 Parameter Selection

For non-cohesive soils present at the site, the effective stress parameters employed in the analyses were estimated from empirical correlations based on the results of in situ Standard Penetration Tests (SPT). The correlations proposed by U.S. Navy (1986) were also employed, and the results were adjusted by engineering judgment based on experience in similar soil conditions at adjacent sites.

For cohesive deposits, total stress parameters were employed in the analyses assuming short-term undrained conditions (i.e. temporary conditions). The total stress parameters (i.e. average mobilized undrained shear strength – s_u) for the cohesive soils were assessed based on the results of in situ SPTs, and estimated from correlations with laboratory index test results (i.e., water content, liquid limit, etc.), where appropriate.

Effective stress parameters were also employed to evaluate the stability of the deep cuts based on long-term, drained conditions (i.e. permanent conditions). The effective stress parameters (i.e., effective friction angle, ϕ', and effective cohesion, c') for the cohesive deposits were estimated from empirical correlations based on the plasticity index, as appropriate.

The foundation engineering parameters for the major soil types encountered within the deep cut areas are summarized below.

Area (Reference Boreholes)	**Idealized Stratigraphic Unit**	**γ (kN/m^3)**	**φ' (°)**	**c' (kPa)**	**S_u (kPa)**
Deep Cut – Area 1 (DC-01 and DC-02, PDC6 and PDC7)	Loose to Dense Silty Sand	20	32	0	-
	Very Dense Silt and Sand to Silty Sand Till	21	34	0	-
	Hard Clayey Silt to Clayey Silt-Silt Till	21	34	5	150 to 200
	Very Dense Gravelly Silty Sand	20	34	0	-
	Hard Clayey Silt to Clayey Silt-Silt	19	32	5	150 to 200
	Very Dense Sandy Silt to Silt and Sand	20	34	0	-
Area 2 - Deep Cut (Borehole DC-04)	Very Stiff to Hard Clayey Silt to Clayey Silt-Silt	19	29	0	100 to 150
	Very Dense Sandy Silt Till	21	34	0	-
	Very Dense Silt	20	32	0	-
	Very Dense Silty Sand to Gravelly Silty Sand	20	33	0	-
	Hard Clayey Silt-Silt	19	30	0	150 to 200

where: γ = bulk unit weight
ϕ' = effective friction angle
c' = effective cohesion
S_u = undrained shear strength

The groundwater profile used in the analyses was based on the highest groundwater level measured in the piezometers in Boreholes PDC7 for Area 1 and DC-04 for Area 2. The analysis for Deep Cut - Area 2 was modelled using a high groundwater elevation of 245.0 m, which is below the level of the proposed cut at the deepest cut location. In Deep Cut - Area 1 the permanent groundwater level profile was estimated using the Steady-State Finite Element Analysis (FEA) integrated into Slide2. It is assumed that the groundwater profile in the vicinity of the deep cut will stabilize and the estimated permanent groundwater level profile was used for the analysis. The permanent groundwater level profile was generated based on the hydraulic conductivity of the major soil types that were estimated to range between $1x10^{-3}$ and $1x10^{-6}$ cm/s, a boundary condition equal to the measured high groundwater level at about 1.8 m below ground surface (Elev. 286.2 m) at the edge of the model furthest away from the deep cut (based on PDC7), and a boundary condition assuming groundwater seepage is collected in the future BBP ditch (Elev. 266.0 m) and drained away from the deep cut area. The stability analyses including the soil parameters and estimated future permanent groundwater level profile will need to be checked and revised during detail design when more geotechnical and hydrogeologic information is available.

6.4.1.3 Results of Analysis

The idealized stratigraphy for Deep Cut - Area 1 and Deep Cut – Area 2 are shown in Figures 1 and 2, and 3 and 4, respectively, as interpreted from the existing foundation and pavement boreholes. Figures 1a / 2a and 1b / 2b were modelled with a different idealized stratigraphy based predominantly on the different soil strata encountered in Boreholes DC-01 and DC-02. The results of the global stability analyses are summarized below and shown on the corresponding stability figures following the text of this report.

Area (Approximate Station)	Maximum Depth of Cut [1]	Cut Side-Slope (Horizontal: Vertical)	Factor of Safety[2]		Stability Figures
			Short-Term (Undrained) Conditions	Long-term (Drained) Conditions	
Area 1 - Deep Cut (STA. 14+950)	26 m	2H:1V	1.6-1.8	1.3-1.5	1a/b and 2a/b
		2.5H:1V	1.7-1.9	1.5-1.8	-
		3H:1V	1.9->2	1.7-1.9	-
Area 2 - Deep Cut (STA. 24+250)	13 m	2H:1V	>2	1.6	3 and 4
		2.5H:1V	>2	1.9	-

Notes:

1. Includes a 2 m bench approximately every 6 m in depth.
2. A range in FoS is provided at Deep Cut – Area 1 because two different idealize sections were modelled based on Boreholes PDC7, DC-01 and DC-02.

For Deep Cut - Area 1, the calculated Factor of Safety (FoS) for global stability for 2 Horizontal:1 Vertical (2H:1V) cut slopes (with 2 m wide benches every 6 m of depth) averages about 1.7 and 1.4 for short-term and long-term conditions, respectively, and meets the target FoS for short-term conditions but is less than the target for long-term conditions defined in the CHBDC (2019) for a low degree of understanding. The calculated FoS for global stability for 2.5H:1V slopes (with 2 m wide benches ever 6 m of depth) averages about 1.8 and 1.65 for short-term and long-term conditions, which meets the target FoS for a low degree of understanding.

During detail design, provided addition investigation and analysis is performed such that a 'typical' or 'high" degree of understanding is achieved, the target FoS for long-term conditions can be reduced to 1.4 or 1.3, respectively, which would result in an acceptable FoS for 2H:1V cut slopes, provided similar subsurface conditions are encountered and relief drains are provided to lower the groundwater level as required. It is important to note that the results of the global stability analyses and calculated FoS are highly dependent on the groundwater conditions (i.e. the future groundwater profile in proximity to the deep cut), which was estimated based on the existing information and assumptions stated earlier. The actual groundwater profile may be higher or lower than the preliminary profile used in the analyses, and this could increase or decrease the calculated FoS significantly. In addition, the temporary water level near the cut slope face during and shortly after excavation will need to be considered during detail design and will likely need to be drained / lowered in advance of excavation in order to maintain stable temporary slopes. Refer to the next section for more details on the preferred alternative and potential mitigation measures to control the groundwater level and achieve adequate FoS against slope instability for temporary and permanent conditions at Deep Cut – Area 1.

For Deep Cut - Area 2, the calculated FoS for global stability for 2H:1V cut slopes (with 2 m wide benches every 6 m of depth) will have a global Factor of Safety greater than or equal to 1.4 and 1.6 for short-term and long term conditions, respectively, and generally meets the target FoS defined in the CHBDC (2019) for a low degree of understanding.

6.4.1.4 Preferred Option and Stability Mitigation Measures

The results of the global stability analyses suggest that temporary and permanent conditions at the Deep Cut - Area 1 location may be challenging if 2H:1V side-slopes are used. The challenges are primarily related to the length and depth (up to 26 m) of the cut and the existing high groundwater level in the proposed cut area. The preferred option to meet global stability targets is to design shallower side-slopes at 2.5H:1V or 3H:1V, however, we understand that shallower side-slopes may not be feasible due to property constraints.

As a result, one or a combination of the following measures will be required if 2H:1V side-slopes are to be considered further during detail design.

- Additional site investigation and/or laboratory testing to achieve a ‘typical’ or ‘high’ degree of site understanding. This will allow for a higher geotechnical resistance factor and lower target factor of safety to be used for design.
- Groundwater / hydrogeological investigation and assessment be performed such that temporary and permanent groundwater levels and design groundwater profiles can be modeled and used for more accurate and detailed stability analyses.
- Design of temporary and/or permanent groundwater relief system such as trench drains / counterfort drains at the crest, slopes and toe of the deep cut that will lower groundwater levels and improve surficial and global stability of the deep cut.
- Design of retaining wall(s), possibly tiered or stepped, in order to reduce extents of the open cut to stay within property limits and achieve acceptable factor of safety against global instability.
- Design of diaphragm walls or cement bentonite cut-off walls to stabilize the cut slopes, control groundwater, and reduce extents of the open cut given the geometric constraints.

As mentioned in the previous section, permanent 2H:1V side-slopes are considered feasible, however, additional investigation and groundwater assessment, possibly combined with passive groundwater lowering or other mitigation measures, will be needed during detail design.

6.5 High Fill Embankment

The High Fill - Area 2 location is directly adjacent to the Deep Cut – Area 2 location. The proposed high fill embankment is up to about 15 m above the existing ground surface between Station 23+550 and 24+180 to achieve the proposed vertical highway profile. In general, the subsurface soils along the fill portion of Area 2, as encountered in Borehole DC-03, consist of a surficial layer of topsoil underlain by compact to very dense silty sand to sandy silt. The sandy silt to silty sand layer is underlain by a stiff to hard clayey silt-silt to clayey silt deposit containing interlayers of very dense silt.

The following sections summarise the design considerations for the high fill embankment.

6.5.1 Embankment Fill Types and Benching Requirements

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

Earth fill, if used, should meet the requirements for earth fill as per OPSS 212 (Borrow). The soil from the adjacent deep cut in Area 2 consists of sandy silt to silty sand, silt, and clayey silt to clayey silt-silt and can be considered for re-use as earth fill during detail design from both a geotechnical and environmental perspective. Additional information on potential re-use of soils from the deep cut areas is provided in the pavement investigation report.

Granular fill for construction of the new embankments should consist of OPSS.PROV 1010 (Aggregates) granular materials (i.e., Select Subgrade Material, Granular A or Granular B).

The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting) and OPSS.PROV 206 (Grading).

In accordance with MTO's standard practice, a minimum 2 m wide bench should be provided where embankment slopes are greater than 8 m in height, such that the uninterrupted slope height does not exceed 8 m, consistent with OPSD 202.010 (*Slope Flattening*).

To reduce erosion of the embankment side slopes due to surface water runoff, placement of topsoil and seeding should be carried out as soon as practicable after construction. Erosion protection should be in accordance with OPSS.PROV 803 (Vegetative Cover) and OPSS.PROV 804 (Temporary Erosion Control).

6.5.2 Foundation Soils - Engineering Parameter Selection

For non-cohesive soils present at the site, the effective stress parameters employed in the analyses were estimated from empirical correlations based on the results of in situ Standard Penetration Tests (SPT). The correlations proposed by U.S. Navy (1986) were also employed, and the results were adjusted by engineering judgment based on precedent experience in similar soil conditions.

For cohesive deposits, total stress parameters were employed in the analyses assuming short-term undrained conditions (i.e. temporary conditions). The total stress parameters (i.e. average mobilized undrained shear strength – s_u) for the cohesive soils were assessed based on the results of in situ SPTs, and estimated from correlations with laboratory index test results (i.e., water content, liquid limit, etc.), where appropriate.

Effective stress parameters were also employed to evaluate the stability of the embankments based on long-term, drained conditions (i.e. permanent conditions). The effective stress parameters (i.e., effective friction angle, ϕ', and effective cohesion, c') for the cohesive deposits were estimated from empirical correlations based on the plasticity index, as appropriate.

The immediate compression of the soils were modeled by estimating the elastic modulus of deformation (E') based on the soil classifications and SPT 'N'-values using empirical correlations, and the results were adjusted by engineering judgement base don precedent experience in similar soil conditions.

The foundation engineering parameters for the new embankment fill and major soil types encountered below the embankment footprint in the high fill area are summarized below.

Idealized Stratigraphic Unit (*Borehole DC-03*)	γ (kN/m^3)	φ' (°)	S_u (kPa)	E' (MPa)
New Granular Fill (Granular 'A' or 'B' Type II)	21	36	--	-
New Earth Fill	21	32	--	-
Compact to Very Dense Silt to Silty Sand	20	32	-	10 - 20
Stiff to Hard Clayey Silt	19	28	100	50 - 100
Very Dense Silt	19	32	-	50
Hard Clayey Silt-Silt	19	28	150	50 - 100

where: γ = bulk unit weight
ϕ' = effective friction angle
S_u = undrained shear strength
E'= modulus of deformation

The groundwater level used in the analysis was about Elevation 222.1 m, as measured in the piezometer in Borehole DC-03.

6.5.3 Global Stability

6.5.3.1 Methodology

Stability analysis was carried out at the critical location where the greatest proposed embankment height (up to 15 m above existing ground surface) is proposed.

Two-dimensional limit equilibrium slope stability analyses were performed using the commercially available program Slide2 (Version 9.020), developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. For all analyses, the Factors of Safety of numerous potential global circular failure surfaces were computed to establish the minimum Factor of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. The Factor of Safety is equal to the inverse of the product of the consequence factor, Ψ, and the geotechnical resistance factor, ϕ_{gu} (i.e. $FoS = 1/(\Psi \cdot \phi_{gu})$. Accordingly, given the limited geotechnical information at the site and typical consequence level, minimum target Factors of Safety of 1.4 and 1.6 have been used for the preliminary design of the high fill embankment slopes for the temporary (short-term) and permanent (long-term) conditions, respectively, as per Table 6.2 of CHBDC (2019) and MERO (2020). Both total stress and effective stress analyses were carried out at the critical high fill embankment section.

6.5.3.2 Results of Analysis

The global stability was assessed for a 15 m high embankment constructed of granular fill and earth fill, with side slopes between 2H:1V and 2.5H:1V. The results of the stability analyses are summarized below.

Embankment Fill Material	Fill Side Slope (Horizontal:Vertical)	Factor of Safety	
		Temporary (Undrained) Condition	Permanent (Drained) Condition
Granular Fill	2H:1V	1.7	1.7
Earth Fill	2H:1V	1.5	1.5

Embankment Fill Material	Fill Side Slope (Horizontal:Vertical)	Factor of Safety	
		Temporary (Undrained) Condition	Permanent (Drained) Condition
	2.25H:1V	1.6	1.6
	2.5H:1V	1.8	1.8

The results of the global stability analyses indicate that an embankment constructed of properly compacted granular fill and side slopes of 2 Horizontal to 1 Vertical (2H:1V) will achieve the required Factor of Safety of greater than 1.4 and 1.6 for short-term (undrained) condition and long term (drained) conditions, respectively. The results are shown on Figures 5 and 6 for the undrained and drained conditions, respectively.

The results of the global stability analyses indicate that for an embankment constructed of suitable earth fill (friction angle of at least 32˚), a Factor of Safety greater than 1.4 and 1.6 for short-term (undrained) condition and long term (drained) conditions, respectively, can be achieved with side slopes of 2.25H:1V. The results are shown on Figures 7 and 8 for the undrained and drained conditions, respectively.

During detail design, if additional investigation is carried out such that a ‘typical’ degree of site understanding applies, embankments constructed of suitable earth fill with 2H:1V side-slopes will meet the required Factor of Safety 1.3 and 1.5 for short-term (undrained) condition and long term (drained) conditions, respectively.

6.5.4 Settlement

A settlement analysis was carried out to estimate the magnitude of settlement due to the proposed new 15 m high embankment using the commercially available computer program Settle3 (Version 5.013) from RocScience Inc. The stress distribution calculations used in the settlement analysis were based on Westergaard’s (1938) solution. The soil parameters and elastic deformation moduli used in the analysis are provided in Section 6.5.2.

The settlement analysis assumes that topsoil, surficial deposits containing excess organic material, any disturbed soils (i.e., fill or reworked native material due to agricultural activities) or any other deleterious material have been removed and re-compacted or replaced with suitable granular or earth fill.

Based on the assessment, the settlement of the foundation soils under the new embankment is estimated to be between 100 mm and 200 mm. The settlement is expected to occur relatively quickly during and immediately following construction of the embankment given the predominantly cohesionless soils and presence of cohesionless seams/interlayers within the hard cohesive soils at the site.

In addition to the settlement of the foundation soils, settlement of the embankment fill itself is anticipated to occur during and after construction of the embankment. The amount of settlement will depend on the embankment materials used. The magnitude of fill compression is estimated to range from 0.5% to 1% of the height of the embankment assuming granular soil is used. If cohesive earth fill is used, the magnitude of fill compression is expected to be higher and in the range of 1% to 2% of the height of the embankment, and may be higher depending on the compressibility characteristics of the fill. In the case where granular fill is used for embankment construction, settlement of the fill itself is expected to occur essentially during embankment construction, whereas cohesive earth fill materials are expected to exhibit some additional settlement over time.

6.6 Design and Construction Considerations

6.6.1.1 Excavation

Permanent and temporary excavations for the proposed deep cuts will be made through the surficial topsoil / reworked native soil, loose to very dense silty sand to sandy silt, firm to hard clayey silt to clayey silt-silt, very dense sandy silt to silty sand (till), hard clayey silt to clayey silt-silt (till),and very dense silty gravel. In Deep Cut – Area 1, groundwater is anticipated to be within about 1.8 m to 5.6 m below ground surface and in Deep Cut – Area 2, groundwater is anticipated to be near or below the base of the proposed deep cut.

All excavations must be carried out in accordance with the latest edition of the Ontario Health and Safety Act (OHSA) Ontario Regulation 213, Construction Projects (as amended).

According to the regulation, the native firm to stiff cohesive soils and the loose to compact non-cohesive deposits are considered to be Type 3 soils above the water table and Type 4 soils below the water table. The very stiff to hard cohesive soils and the dense to very dense non-cohesive deposits are considered to be Type 2 soils above the water table and Type 3 soils below the water table.

Temporary excavations made in Type 2 soils should be carried out with walls sloped to within 1.2 m of the bottom with a slope having a minimum gradient of 1H:1V. Similarly, Type 3 soil should have a minimum 1H:1V gradient to the base of the excavation. Type 4 soils should have a minimum 3H:1V gradient to the base of the excavation.

6.6.1.2 Control of Groundwater

Details of the groundwater levels encountered in the monitoring wells at the two proposed deep cut areas are summarized in Section 4.3. Excavation below the groundwater level (more than 20 m below groundwater level) is anticipated to be required for Deep Cut - Area 1. The excavation at Deep Cut - Area 2 cut is anticipated to extend to an elevation higher than the groundwater table measured in Borehole DC-04; however, the groundwater level further east within the deep cut section will need to be investigated further during detail design. Perched groundwater may be present within the near surface soils and in non-cohesive layers above or within cohesive deposits.

Given the high groundwater table in Deep Cut - Area 1, drainage systems will be required to locally lower the groundwater table and reduce surface water infiltration. The drainage system could include features such as interceptor ditches, finger trenches / subdrains, and counterfort drains. The design of the drainage system for temporary and permanent conditions will need to be assessed during detail design. Given that the cut is up to about 26 m deep, advanced trenching prior to excavation may be required to increase stability of temporary slopes and allow passive drainage of the groundwater such that a permanent stabilized level is achieved prior to forming the final design slopes. At Deep Cut Area 1, if a passive drainage system is not implemented, or there is not sufficient time during construction to allow the cut slope to drain, an active dewatering system may be needed in advance of construction. A special provision will need to be included in the future contract documents to address temporary groundwater control and stability of the deep cut slopes during construction at the Deep Cut – Area 1 location.

The deep cut will result in permanent lowering of the groundwater table in the area. The impact of groundwater lowering and associated settlement of the existing ground surface or any structures within the zone of influence will need to be assessed during detail design.

6.6.1.3 Surface Water / Erosion Control

Surface water should be directed away from temporary and permanent excavation / deep cut areas at all times.

Drainage of surface water at the crest, along benches and at the toe of the proposed cut slope should be designed such that the surface water is directed into the overall drainage system and reduces erosion and infiltration. Additional benches may be considered to provide an adequate drainage system with the appropriate tie-ins. It is recommended that benches be designed with a slight black-slope (i.e., 1%) to contain and channel surface water flow and reduce the potential for surface water from progressing down the slope face leading to erosion and infiltration.

To reduce erosion on the permanent cut slopes due to surface water flow, it is recommended that topsoil and seeding be placed as soon as possible in accordance with OPSS.PROV 803 (Vegetative Cover). During construction, temporary erosion control may be required and should be in accordance with OPSS.PROV 804 (Temporary Erosion Control).

Given the current and estimated future stabilized groundwater table in Deep Cut - Area 1 is relatively near the existing and proposed ground surface, groundwater seepage to the face of the cut slope during and after construction is anticipated if mitigation measures are not implemented. In addition to the dewatering mitigation measures discussed in the previous section to control / lower the groundwater level, it is recommended that granular drainage blankets be incorporated into the design along areas of the slope face where erodible soils (e.g. silts and fine sands) are present. A combination of a passive dewatering program and staged construction implemented during construction will allow the groundwater to drain progressively, thereby reducing the risk of surficial instability along the side-slopes and disturbance/softening of the native soils. At erodible areas, gravel sheeting (as per OPSS.PROV 511, Rip-rap, Rock Protection, and Granular Sheeting) should be considered to further control erosion and slope face instability depending on the amount of time required for the slope to sufficiently drain (i.e., not actively seep) and for permanent groundwater levels to stabilize.

At Deep Cut Area 2 the stabilized groundwater table was measured to be below the base of the proposed cut. As such, active seepage and erosion through the cut face is not anticipated in this area.

6.6.1.4 Subgrade Preparation and Embankment Construction

Prior to placing any embankment fill, all topsoil, reworked native soil containing excessive organic matter and existing loose/soft soils should be stripped from the footprint in accordance with OPSS.PROV 206 (Grading). After stripping, the exposed subgrade soils should be inspected by qualified personnel prior to placement of embankment fill, proof-rolled to identify soft / loosened areas as appropriate, and any poorly performing areas should be subexcavated and replaced with suitable backfill.

New embankment fill should be placed and compacted in accordance with OPSS.PROV 206 (Grading) and OPSS 501 (Compacting).

6.6.1.5 Obstructions

The native non-cohesive and glacial till deposits encountered auger refusal, auger/casing grinding and high SPT ‘N’-values suggesting the presence of cobbles and boulders.

Conventional excavation equipment should be suitable for excavation of the deep cuts; however equipment will need to be adequately sized to excavate the very dense / hard native deposits encountered which could contain cobble to boulder sized obstructions. It should be anticipated that slow advancement/progress will be encountered in the very dense and hard deposits, particularly if boulders are encountered.

6.7 Recommendations for Future Work

The preliminary foundation recommendations provided in this report are based on the limited available subsurface information from foundation and pavement boreholes advanced near the proposed deep cut at Area 1 (Station 14+600 to 15+500) and deep cut and high fill at Area 2 (Station 23+550 to 24+450). Additional foundation investigation will be required at these areas as well as the other deep cut and high fill areas along the proposed BBP alignment. The additional investigation is recommended to be carried out such that the level of confidence for design meets a minimum "typical degree of site and prediction model understanding" for the deep cut and high areas. Consideration should also be given to meeting a "high degree of site and prediction model understanding" for the Deep Cut – Area 1 location to lower the target Factor of Safety for global stability if 2H:1V cut slopes are required for detail design.

The additional subsurface investigation will need to explore the subsurface soil and groundwater conditions along the deep cut and high fill sections. In particularly, additional geotechnical and hydrogeological investigations will be required in the Deep Cut - Area 1 location where cut depths are anticipated to be up to 26 m below existing ground surface with a high groundwater level. It is recommended that a sufficient number of complex geotechnical laboratory tests (i.e. triaxial testing and direct shear testing) be carried out to check and revise soil strength parameters for detailed stability analysis, to confirm that 2H:1V cut slopes are feasible. Additional boreholes and monitoring wells will need to be advanced at both the Deep Cut - Area 1 and Deep Cut / High Fill – Area 2 locations to further define the subsurface conditions and confirm the current groundwater regime within the cut areas. Boreholes should be advanced to sufficient depth to assess global stability and potential retaining wall(s) mitigation options at Deep Cut – Area 1 where property constraints exist. In general, pressuremeter testing and/or seismic Cone Penetration Tests (with dissipation testing) are recommended in the high fill section(s) to better predict the actual magnitudes and estimate time rates of settlement.

A hydrogeological study should be carried out at the Deep Cut - Area 1 location to better define the current groundwater levels, assess the impact of the deep cut excavation to the local groundwater levels, and estimate temporary and permanent groundwater levels during and post construction. The hydrogeological study should include the determination of the hydraulic conductivity / permeability of the native soils through in situ hydrogeological testing (e.g., slug testing (rising head / falling head tests), and conventional pump tests in monitoring wells). As discussed in Section 6.4.1.3, the stability analysis is sensitive to the groundwater level profile (during construction and permanent level following construction) and the determination of the hydrogeological properties of the native deposits and groundwater regime will be critical to the feasibility of the up to 26 m cut slope given the property constraints.

The suitability of the re-use of soils from the deep cut sections for placement in high fill sections on site should be evaluated during detail design. As assessment of potential seismic impacts and liquefaction should be included for the Deep Cut – Area 1 location.

It should be noted that this report provides preliminary recommendations for the deep cut and high fills between Station 14+600 to 15+500 (Area 1) and Station 23+550 and 24+450 (Area 2), however there are many other deep cut (cuts >4.5 m deep) and high fill (fill >4.5 m high) sections along the Bradford Bypass alignment which will need to be investigated and evaluated during detail design.

Additional foundation investigation and design should meet the general requirements outlined in the latest version of the *Guidelines for MTO Foundation Engineering Services*. The existing standpipe piezometers installed in Boreholes DC-02, DC-03, DC-04, PDC6 and PDC7 should be maintained operational to allow for continued monitoring of the groundwater level during detail design and up to construction at which time piezometers will need to be decommissioned in accordance with Ontario Regulation 903 (as amended). Additional piezometers, particularly in the Deep Cut Areas, should be installed along the alignment to provide additional information for assessment of dewatering and refinement of the stability analysis.

7.0 CLOSURE

This Preliminary Foundation Design Report was prepared by Madison Kennedy, P.Eng. a geotechnical engineer with WSP. Mr. Kevin Bentley, P.Eng. a Geotechnical Engineer with WSP and MTO Foundations Principal Contact conducted a technical and quality control review of the report.

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Geotechnical Engineer	*MTO Principal Foundations Contact*

MCK/KJB/al

https://golderassociates.sharepoint.com/sites/120387/project files/6 deliverables/foundations/deep cuts/final/19136074 -bbp_deepcuthighfill-pfidr_final-rev0_21dec23.docx

References

Canadian Standard Association (CSA) Group. *Canadian Highway Bridge Design Code* (CHBDC (2019)) and *Commentary* on CAN/CSA-S6-19.

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Westergaard, H.M. 1938. A problem of elasticity suggested by a problem in soil mechanics: Soft material reinforced by numerous strong horizontal sheets. Contributions to the Mechanics of Solids, Stephen Timoshenko 60th birthday anniversary volume, Macmillan, New York. Pages 268-277.

ASTM International

ASTM D1586	Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils

Ontario Provisional Standard Drawing:

OPSD 202.010	Slope Flattening Using Excess Material on Earth or Rock Embankment

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 212	Construction Specifications for Earth Borrow
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specifications for Rip-rap, Rock Protection, and Granular Sheeting
OPSS.PROV 803	Construction Specification for Vegetative Cover
OPSS.PROV 804	Construction Specification for Temporary Erosion Control
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Regulations

Ontario Regulation 213	Construction Projects (as amended)
Ontario Regulation 903	Wells (as amended)

Ministry of Transportation, Ontario

Provincial Engineering Memorandum #20201, Material Engineering and Research Office (MERO), March 23, 2020.

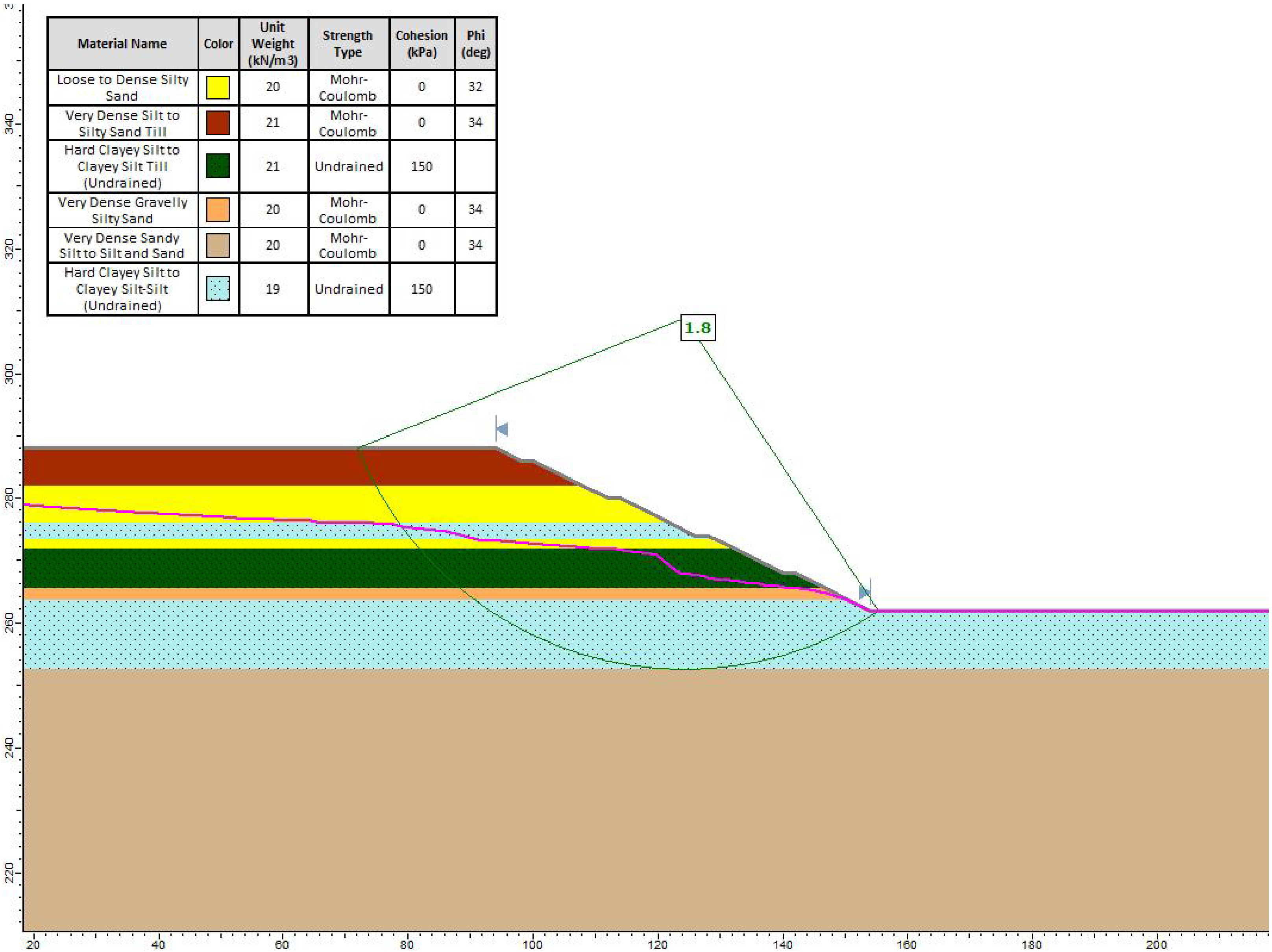
Guideline for MTO Foundation Engineering Services, Version 3, dated April 2022.

FIGURES

Global Stability Analysis Results (Undrained Condition)

Deep Cut – Area 1 (Approximately STA. 14+950) - Side Slopes 2H : 1V

Figure 1a



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Loose to Dense Silty Sand	🟨	20	Mohr-Coulomb	0	32
Very Dense Silt to Silty Sand Till	🟥	21	Mohr-Coulomb	0	34
Hard Clayey Silt to Clayey Silt Till (Undrained)	🟩	21	Undrained	150	
Very Dense Gravelly Silty Sand	🟧	20	Mohr-Coulomb	0	34
Very Dense Sandy Silt to Silt and Sand	🟫	20	Mohr-Coulomb	0	34
Hard Clayey Silt to Clayey Silt-Silt (Undrained)	▨	19	Undrained	150	

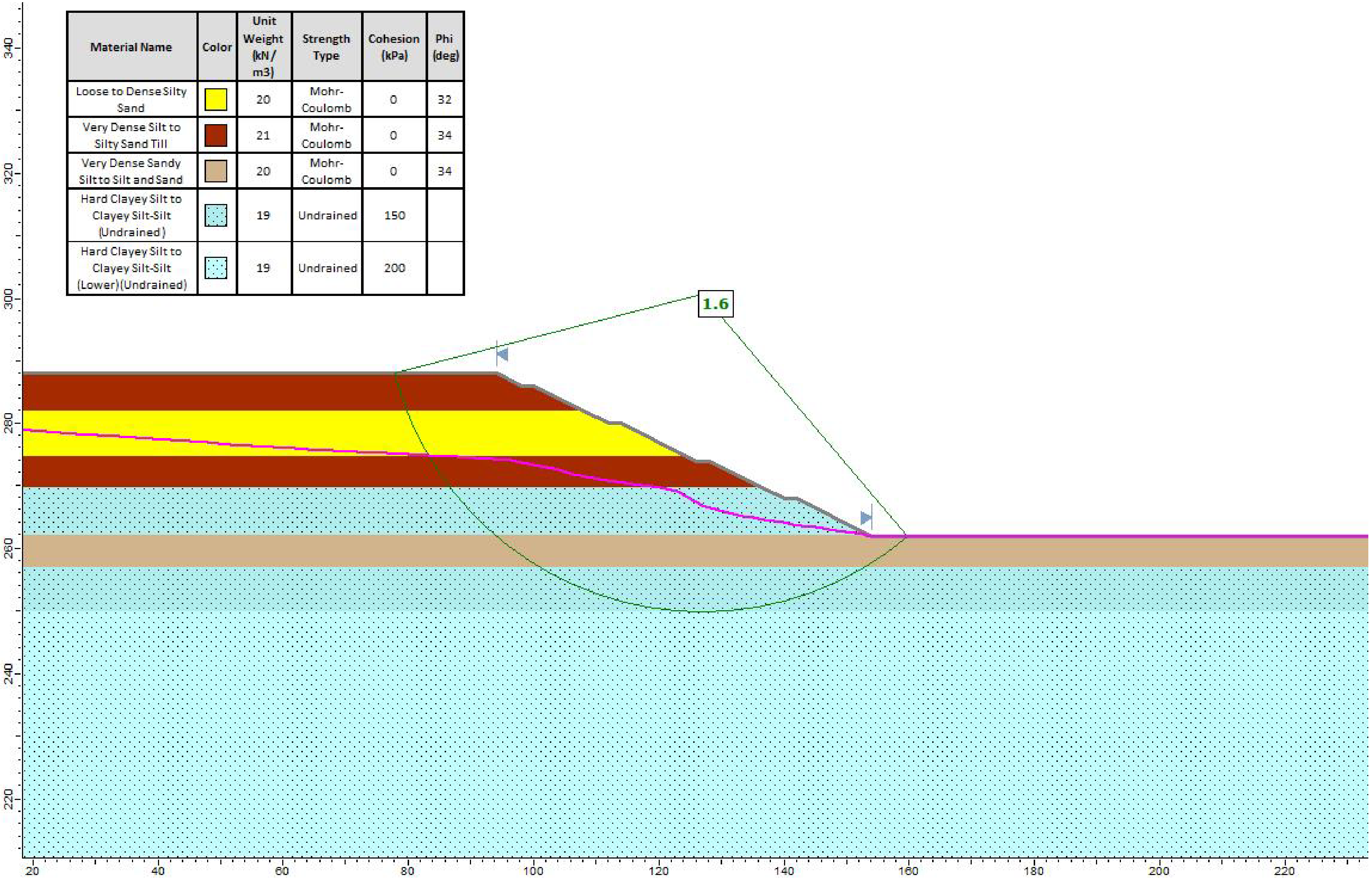
Date: December 2023
Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

Global Stability Analysis Results (Undrained Condition)

Deep Cut – Area 1 (Approximately STA. 14+950) - Side Slopes 2H : 1V

Figure 1b



Material Name	Color	Unit Weight (kN / m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Loose to Dense Silty Sand	🟨	20	Mohr-Coulomb	0	32
Very Dense Silt to Silty Sand Till	🟥	21	Mohr-Coulomb	0	34
Very Dense Sandy Silt to Silt and Sand	🟫	20	Mohr-Coulomb	0	34
Hard Clayey Silt to Clayey Silt-Silt (Undrained)	▨	19	Undrained	150	
Hard Clayey Silt to Clayey Silt-Silt (Lower)(Undrained)	▨	19	Undrained	200	

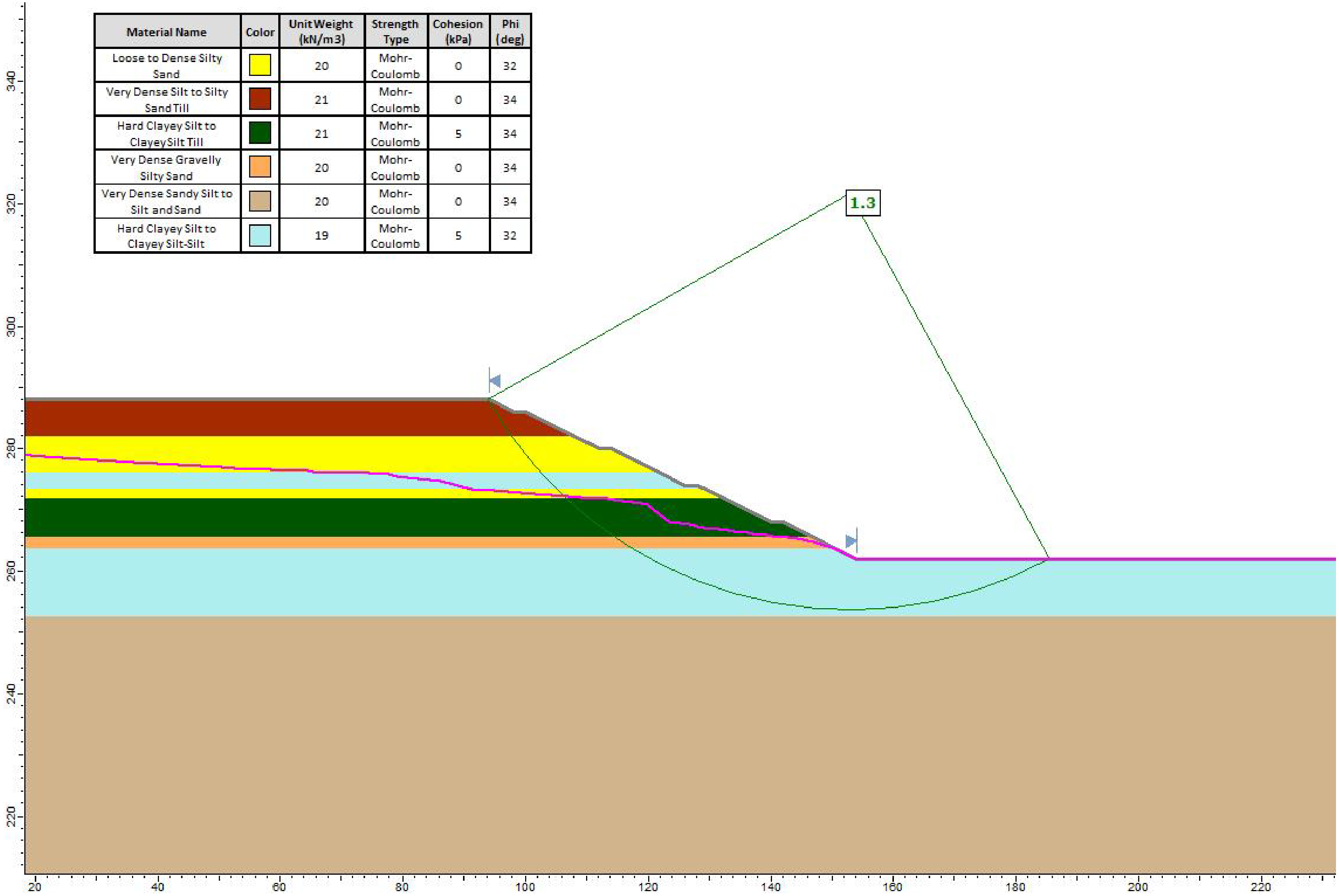
Date: December 2023

Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

Global Stability Analysis Results (Drained Condition)
Area 1 - Deep Cut (Approximately STA. 14+950) - Side Slopes 2H : 1V

Figure 2a



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Loose to Dense Silty Sand	🟨	20	Mohr-Coulomb	0	32
Very Dense Silt to Silty Sand Till	🟥	21	Mohr-Coulomb	0	34
Hard Clayey Silt to Clayey Silt Till	🟩	21	Mohr-Coulomb	5	34
Very Dense Gravelly Silty Sand	🟧	20	Mohr-Coulomb	0	34
Very Dense Sandy Silt to Silt and Sand	🟫	20	Mohr-Coulomb	0	34
Hard Clayey Silt to Clayey Silt-Silt	🟦	19	Mohr-Coulomb	5	32

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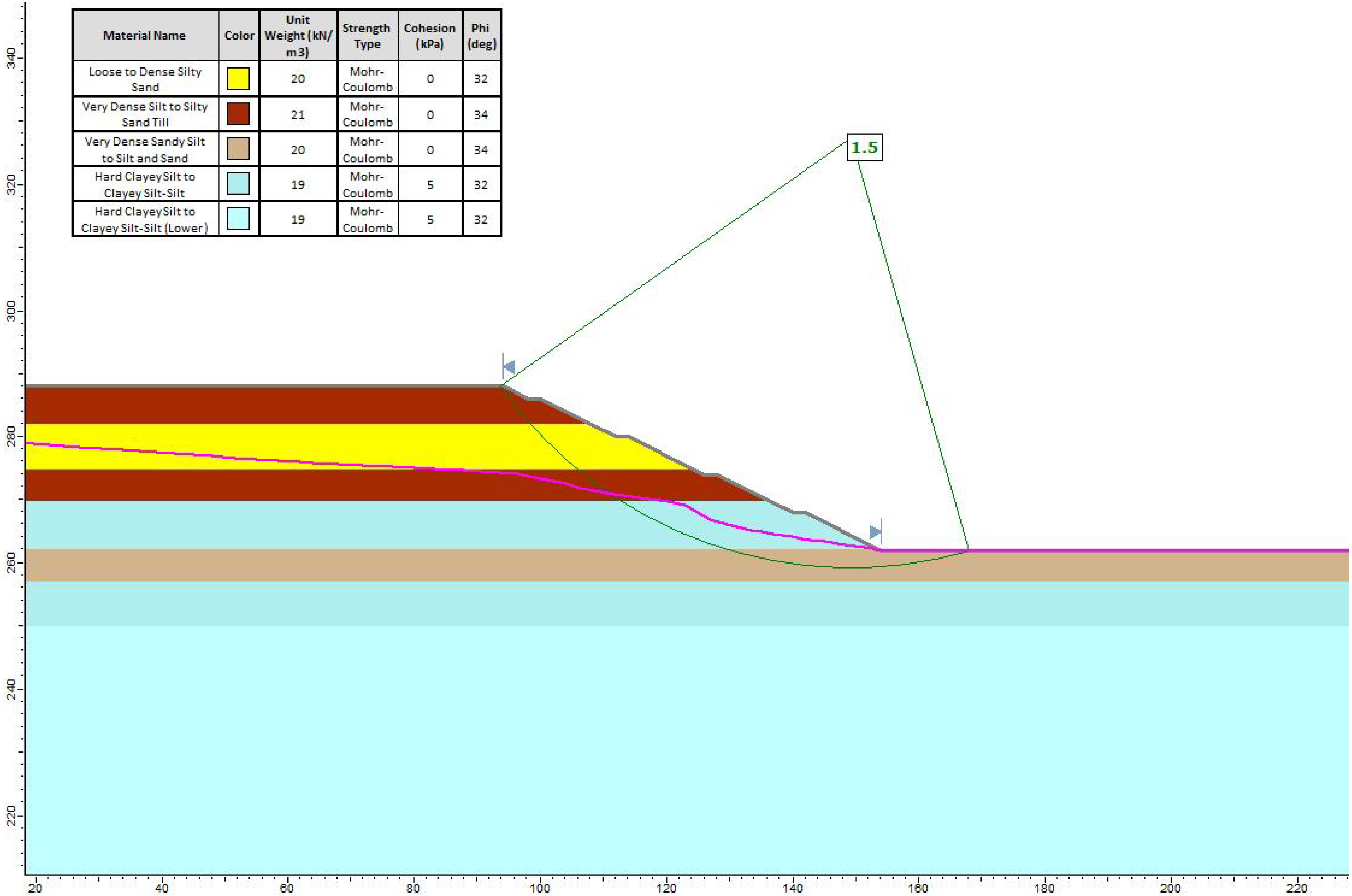
Global Stability Analysis Results (Drained Condition)

Area 1 - Deep Cut (Approximately STA. 14+950) - Side Slopes 2H : 1V

Figure 2b



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Loose to Dense Silty Sand	🟨	20	Mohr-Coulomb	0	32
Very Dense Silt to Silty Sand Till	🟥	21	Mohr-Coulomb	0	34
Very Dense Sandy Silt to Silt and Sand	🟫	20	Mohr-Coulomb	0	34
Hard Clayey Silt to Clayey Silt-Silt	🟦	19	Mohr-Coulomb	5	32
Hard Clayey Silt to Clayey Silt-Silt (Lower)	🟦	19	Mohr-Coulomb	5	32

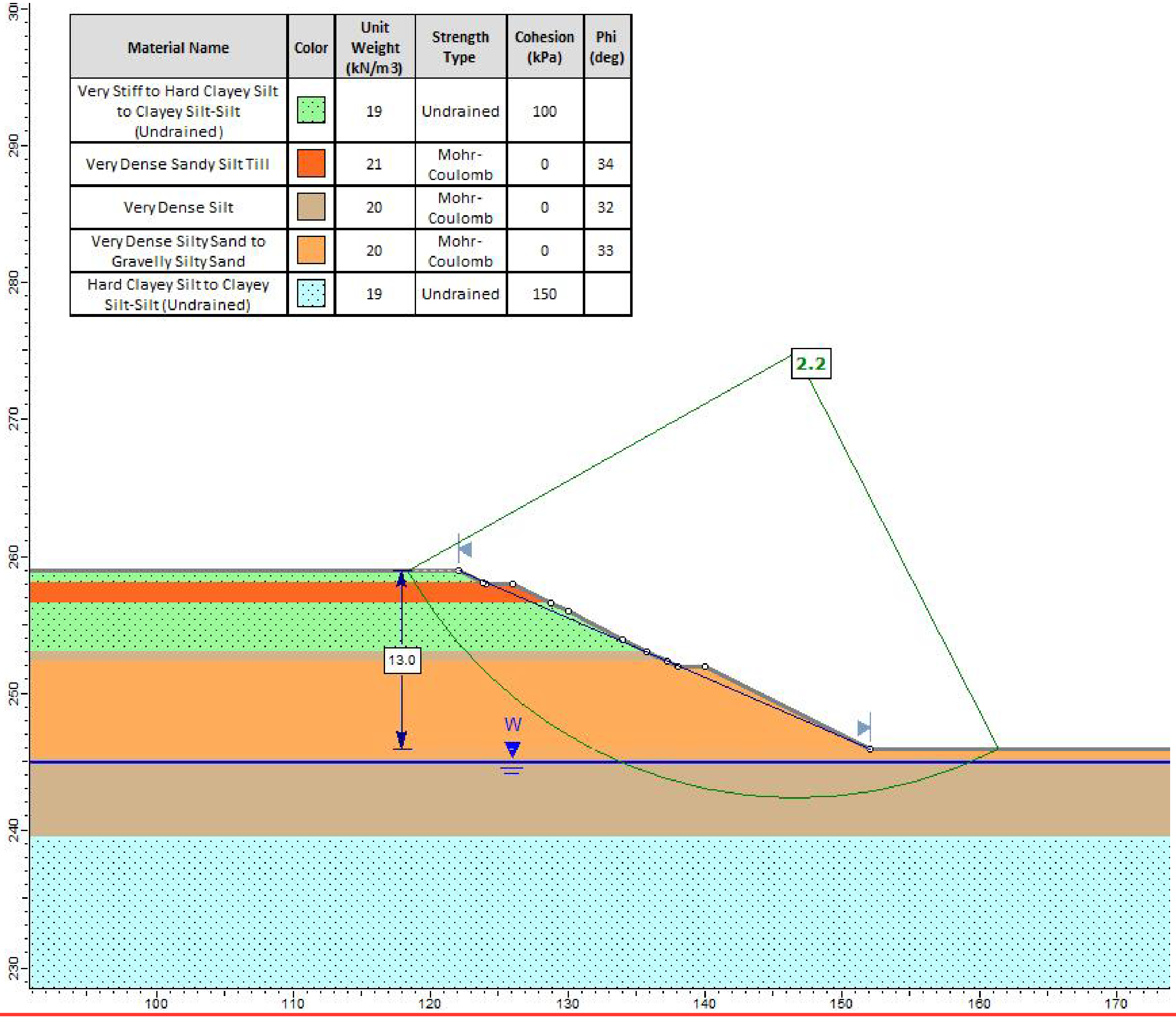
Date: December 2023

Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

Global Stability Analysis Results (Undrained Condition)
Area 2 - Deep Cut (Approximately STA. 24+250) - Side Slopes 2H : 1V

Figure 3



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Very Stiff to Hard Clayey Silt to Clayey Silt-Silt (Undrained)	🟩	19	Undrained	100	
Very Dense Sandy Silt Till	🟥	21	Mohr-Coulomb	0	34
Very Dense Silt	🟫	20	Mohr-Coulomb	0	32
Very Dense Silty Sand to Gravelly Silty Sand	🟧	20	Mohr-Coulomb	0	33
Hard Clayey Silt to Clayey Silt-Silt (Undrained)	🟦	19	Undrained	150	

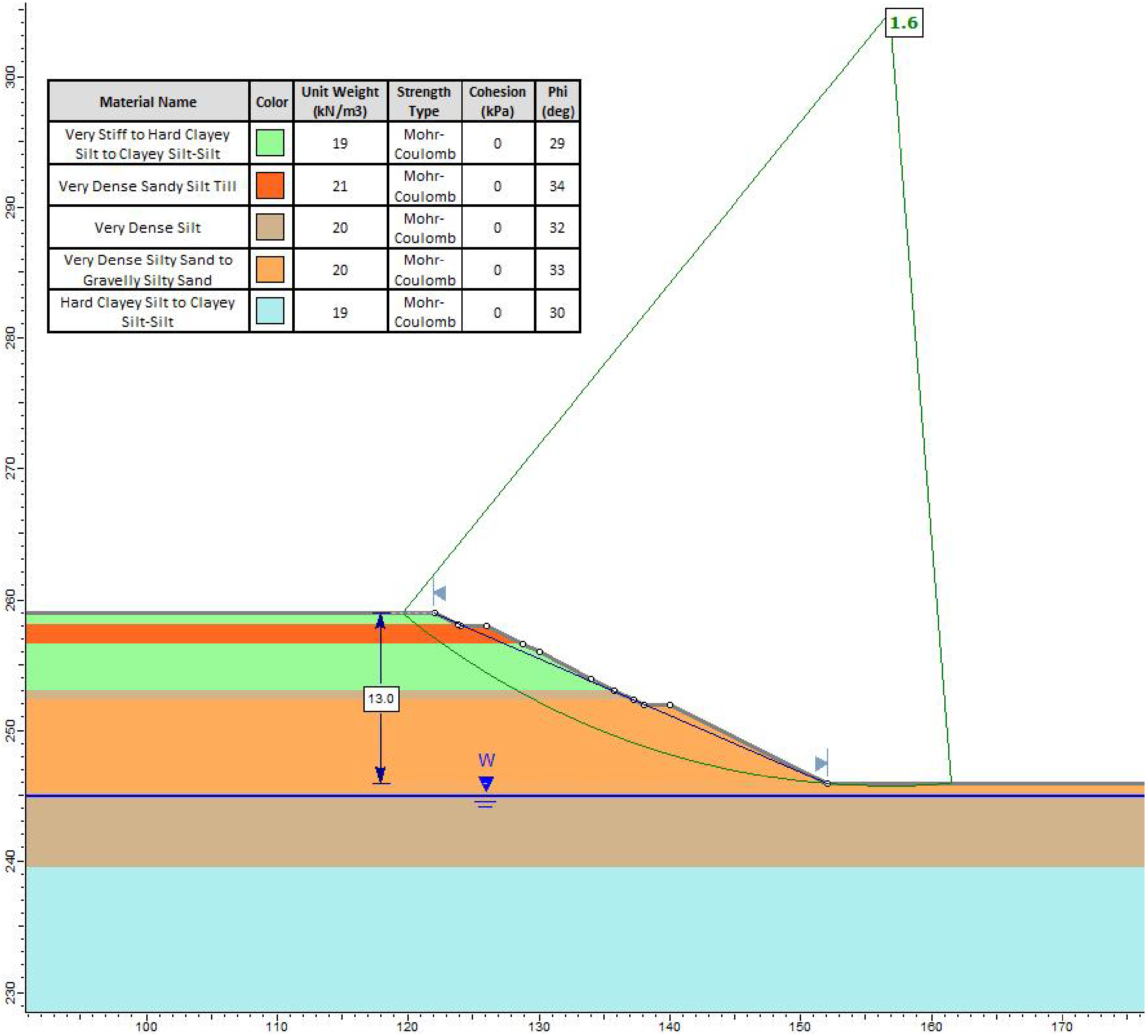
Date: December 2023

Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

Global Stability Analysis Results (Drained Condition)
Area 2 - Deep Cut (Approximately STA. 24+250) - Side Slopes 2H : 1V

Figure 4



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Very Stiff to Hard Clayey Silt to Clayey Silt-Silt	🟩	19	Mohr-Coulomb	0	29
Very Dense Sandy Silt Till	🟥	21	Mohr-Coulomb	0	34
Very Dense Silt	🟫	20	Mohr-Coulomb	0	32
Very Dense Silty Sand to Gravelly Silty Sand	🟧	20	Mohr-Coulomb	0	33
Hard Clayey Silt to Clayey Silt-Silt	🟦	19	Mohr-Coulomb	0	30

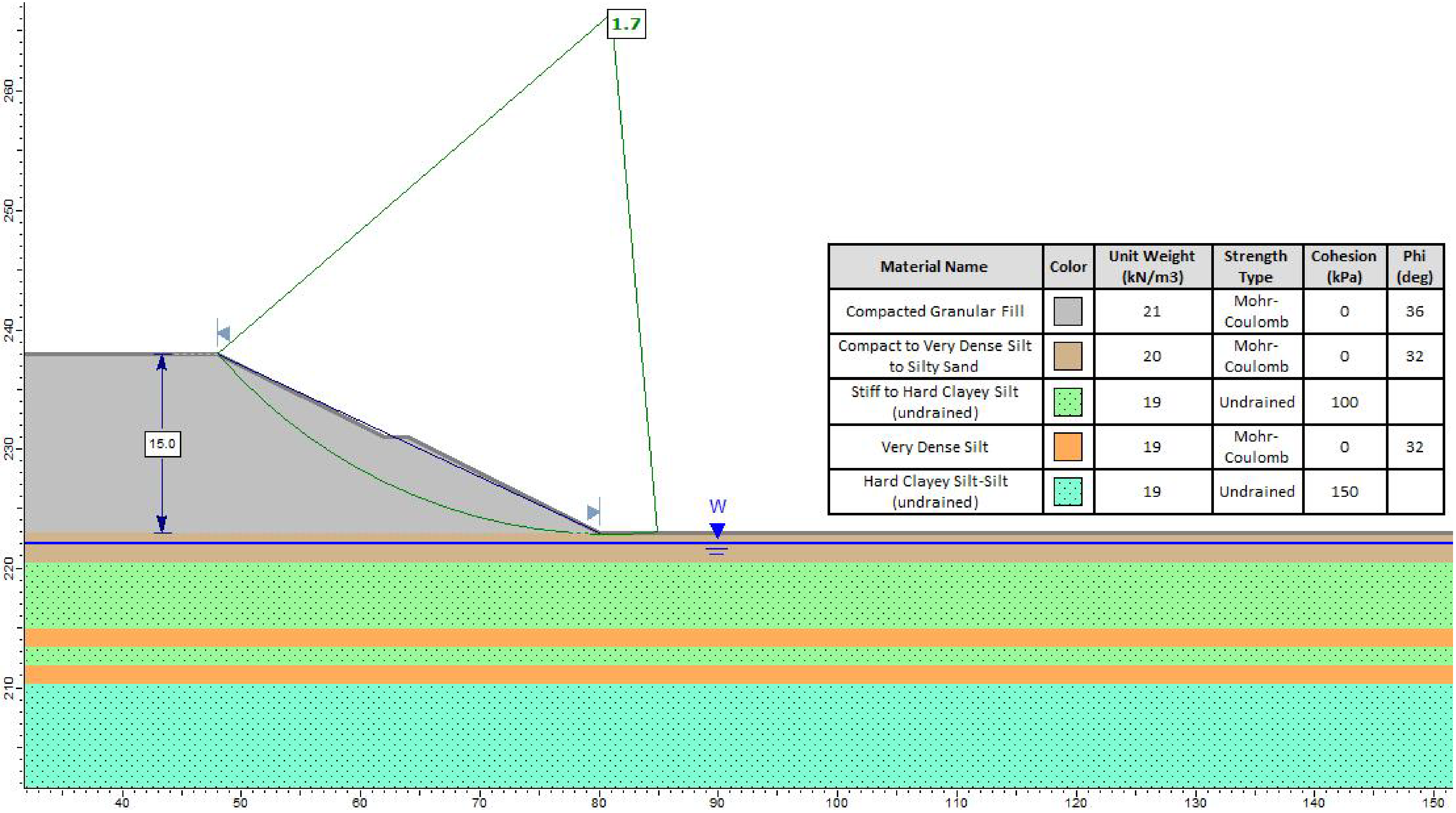
Date: December 2023
Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

Global Stability Analysis Results (Undrained Condition)

Area 2 - High Fill (Approximately STA. 23+930) – Granular Fill Side Slopes 2H : 1V

Figure 5



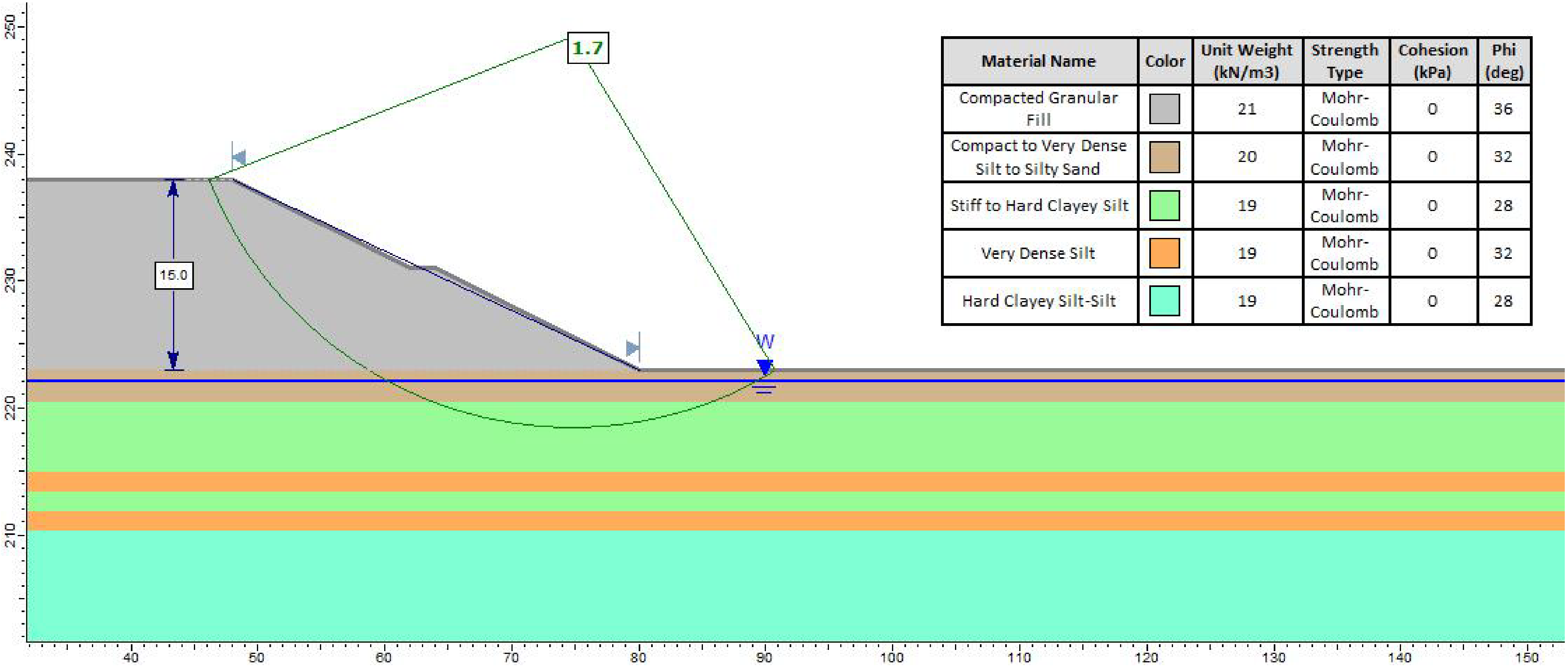
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Compacted Granular Fill	⬜	21	Mohr-Coulomb	0	36
Compact to Very Dense Silt to Silty Sand	🟫	20	Mohr-Coulomb	0	32
Stiff to Hard Clayey Silt (undrained)	🟩	19	Undrained	100	
Very Dense Silt	🟧	19	Mohr-Coulomb	0	32
Hard Clayey Silt-Silt (undrained)	🟦	19	Undrained	150	

Date: December 2023
Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

Global Stability Analysis Results (Drained Condition)
Area 2 - High Fill (Approximately STA. 23+930) – Granular Fill Side Slopes 2H : 1V

Figure 6



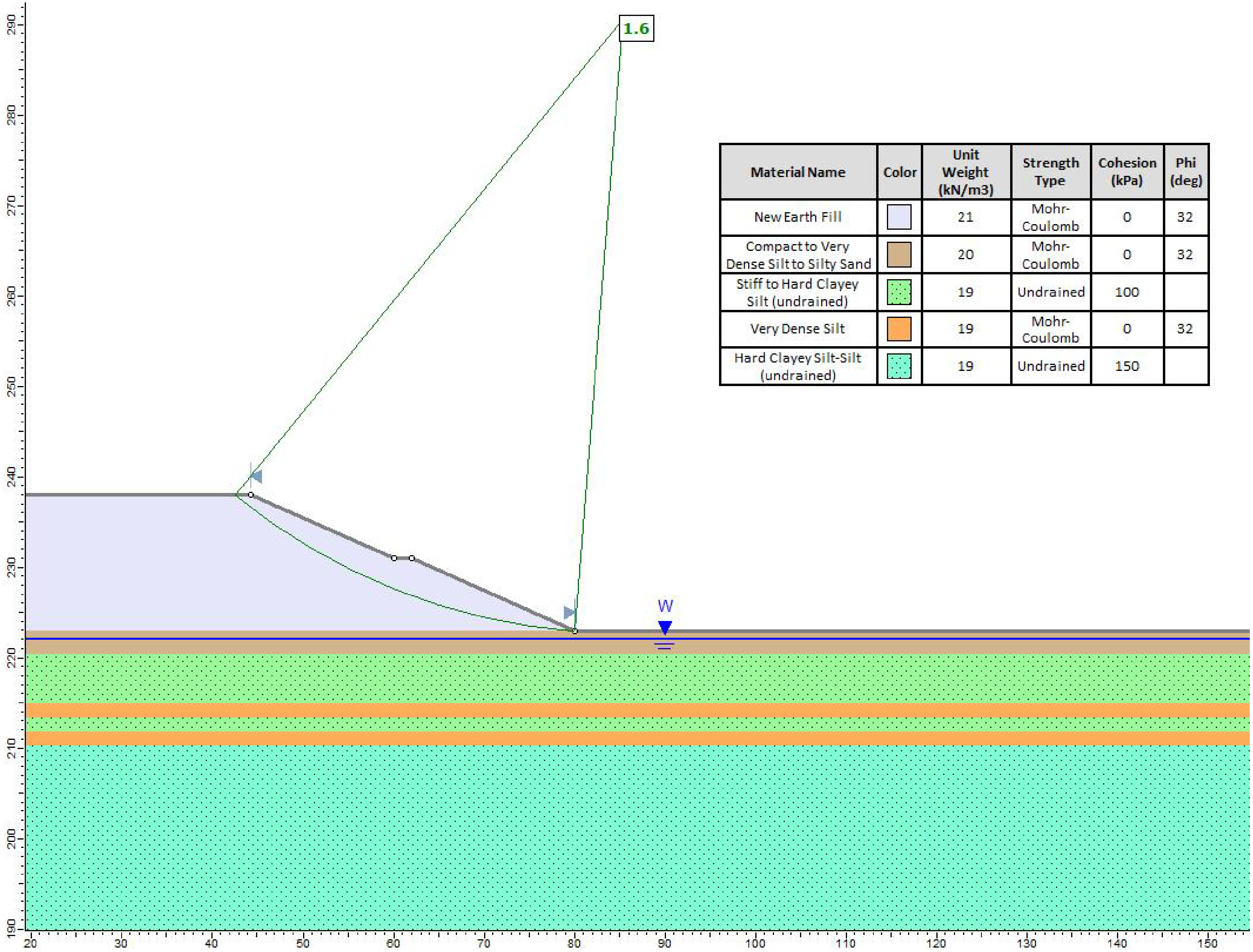
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Compacted Granular Fill	⬜	21	Mohr-Coulomb	0	36
Compact to Very Dense Silt to Silty Sand	🟫	20	Mohr-Coulomb	0	32
Stiff to Hard Clayey Silt	🟩	19	Mohr-Coulomb	0	28
Very Dense Silt	🟧	19	Mohr-Coulomb	0	32
Hard Clayey Silt-Silt	🟦	19	Mohr-Coulomb	0	28

Date: December 2023
Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

Global Stability Analysis Results (Undrained Condition)
Area 2 - High Fill (Approximately STA. 23+930) – Earth Fill Side Slopes 2.25H : 1V

Figure 7



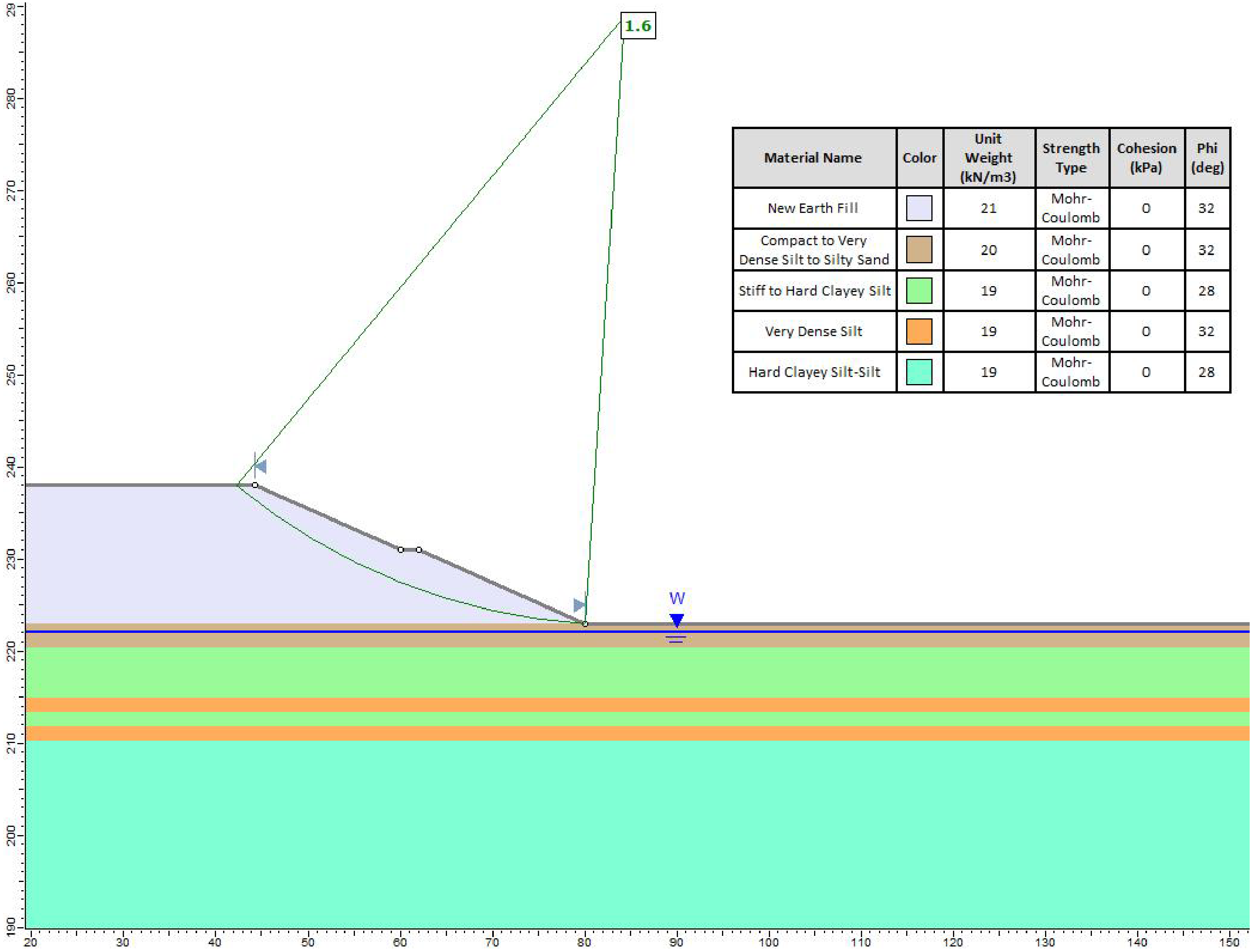
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
New Earth Fill	🟪	21	Mohr-Coulomb	0	32
Compact to Very Dense Silt to Silty Sand	🟫	20	Mohr-Coulomb	0	32
Stiff to Hard Clayey Silt (undrained)	🟩	19	Undrained	100	
Very Dense Silt	🟧	19	Mohr-Coulomb	0	32
Hard Clayey Silt-Silt (undrained)	🟦	19	Undrained	150	

Date: December 2023
Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

Global Stability Analysis Results (Drained Condition)
Area 2 - High Fill (Approximately STA. 23+930) – Earth Fill Side Slopes 2.25H : 1V

Figure 8



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
New Earth Fill	🟪	21	Mohr-Coulomb	0	32
Compact to Very Dense Silt to Silty Sand	🟫	20	Mohr-Coulomb	0	32
Stiff to Hard Clayey Silt	🟩	19	Mohr-Coulomb	0	28
Very Dense Silt	🟧	19	Mohr-Coulomb	0	32
Hard Clayey Silt-Silt	🟦	19	Mohr-Coulomb	0	28

Date: December 2023
Project No: 19136074

Analysis By: MCK **Reviewed By:** KJB

DRAWINGS

MINISTRY OF TRANSPORTATION, ONTARIO

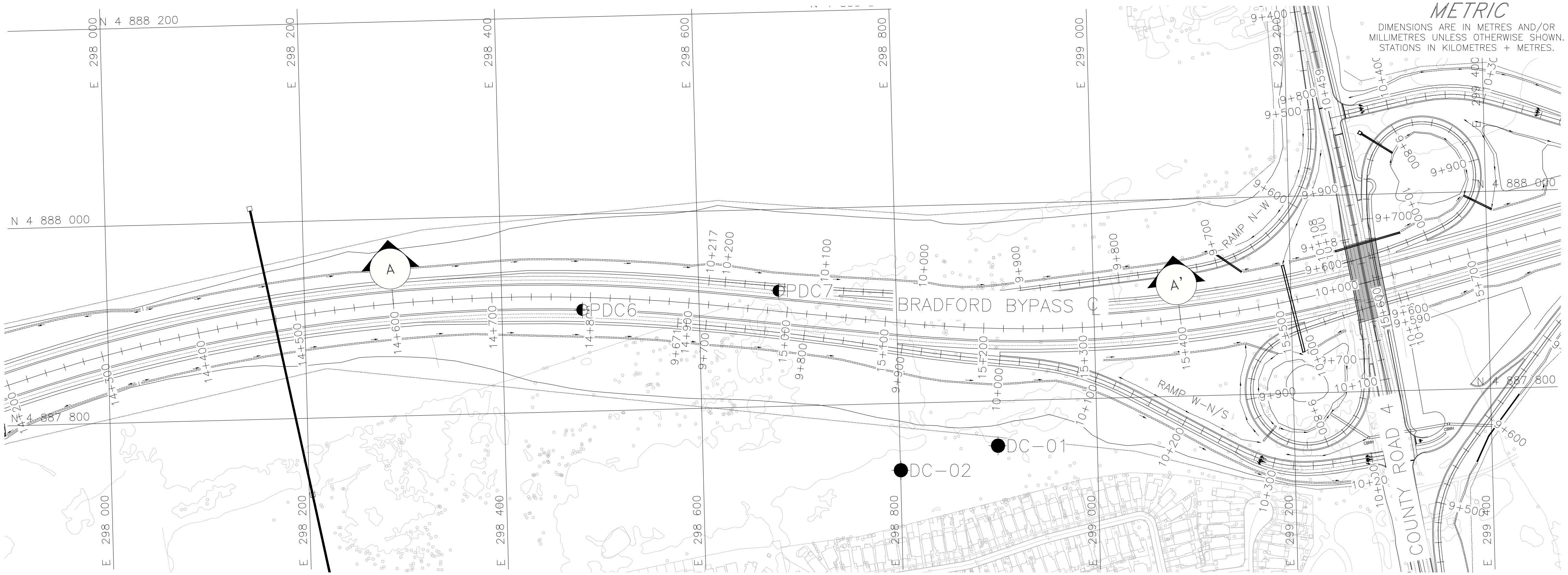
CONT No.
WP No.

BRADFORD BYPASS
DEEP CUT – AREA 1
BOREHOLE LOCATIONS AND SOIL STRATA

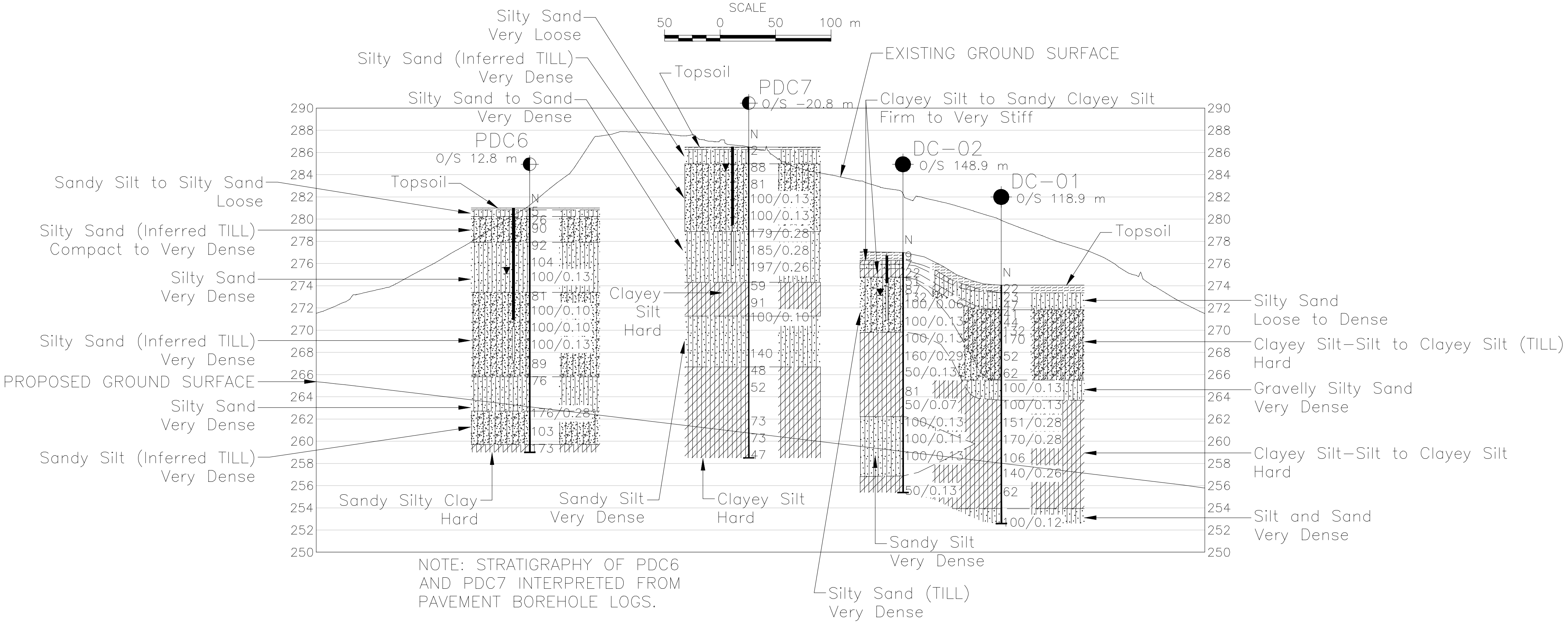
SHEET

wsp

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



PLAN
SCALE
50 0 50 100 m

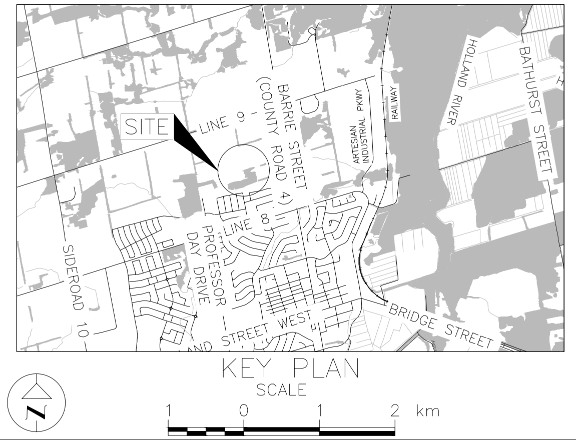


NOTE: STRATIGRAPHY OF PDC6 AND PDC7 INTERPRETED FROM PAVEMENT BOREHOLE LOGS.

A–A' PROFILE BRADFORD BYPASS ℄

VERTICAL SCALE
5 0 5 10 m

HORIZONTAL SCALE
50 0 50 100 m



KEY PLAN
SCALE

LEGEND

●	Borehole – Current Investigation
◐	Borehole – Pavement Investigation (WSP Golder, 2023)
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▼	WL in piezometer

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
DC-01	274.0	4887754.5	298899.4
DC-02	277.0	4887732.2	298800.3
PDC6	281.0	4887902.9	298481.7
PDC7	286.5	4887917.2	298681.0

The location and elevation of boreholes advanced during the WSP Golder (2023) pavement investigation are approximate

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 Aecom, drawing file no. X–Base_Bradford Bypass.dwg and BRADFORD BY–PASS OG_Combined.xml, received January 11, 2022.
Horizontal alignment provided in digital format by Aecom, drawing file no. X–60636190–C–DES–All Alignments.xml, received May 12, 2023.
Vertical alignment provided in digital format by Aecom, drawing file no. X–60636190–C–DES–BBP Mainline Profile.dwg, received May 16, 2023.
Design plan provided in digital format by Aecom, drawing file no. BBP Mainline Plan and Profile_To WSP_230705.dwg, received July 5, 2023.

M. C. KENNEDY
100547814
Dec. 21, 2023

K. J. BENTLEY
Dec. 21, 2023

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 31D04–004

HWY.		PROJECT NO. 19136074	DIST.
SUBM'D. KJB	CHKD. MCK	DATE: 12/19/2023	SITE:
DRAWN: DD	CHKD. MCK	APPD. KJB	DWG. 1

PLOT DATE: December 21, 2023
FILENAME: S:\Clients\MTO\Bradford_Bypass\99_PROJ\19136074_Aecom\40_PROD\0018_Deep_Cut_Area_1\19136074-0018-BG-0001.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

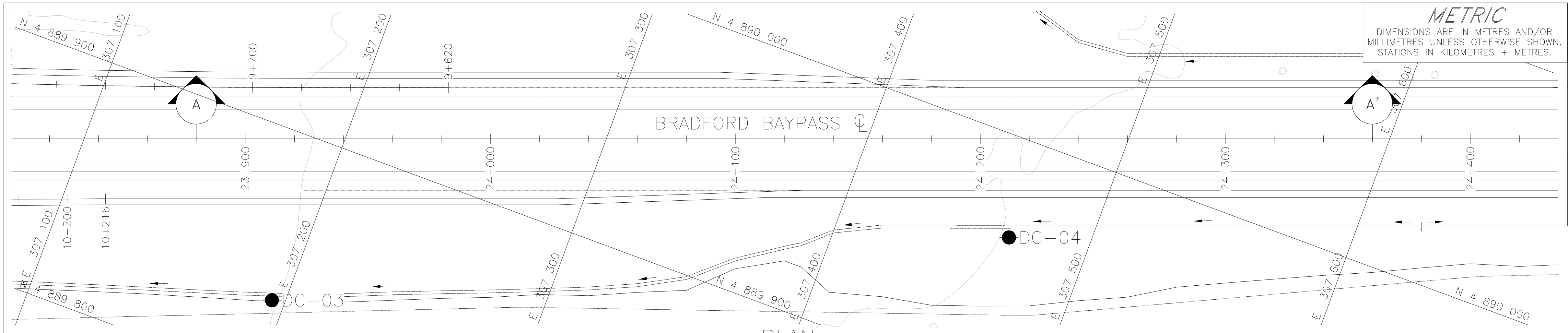
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

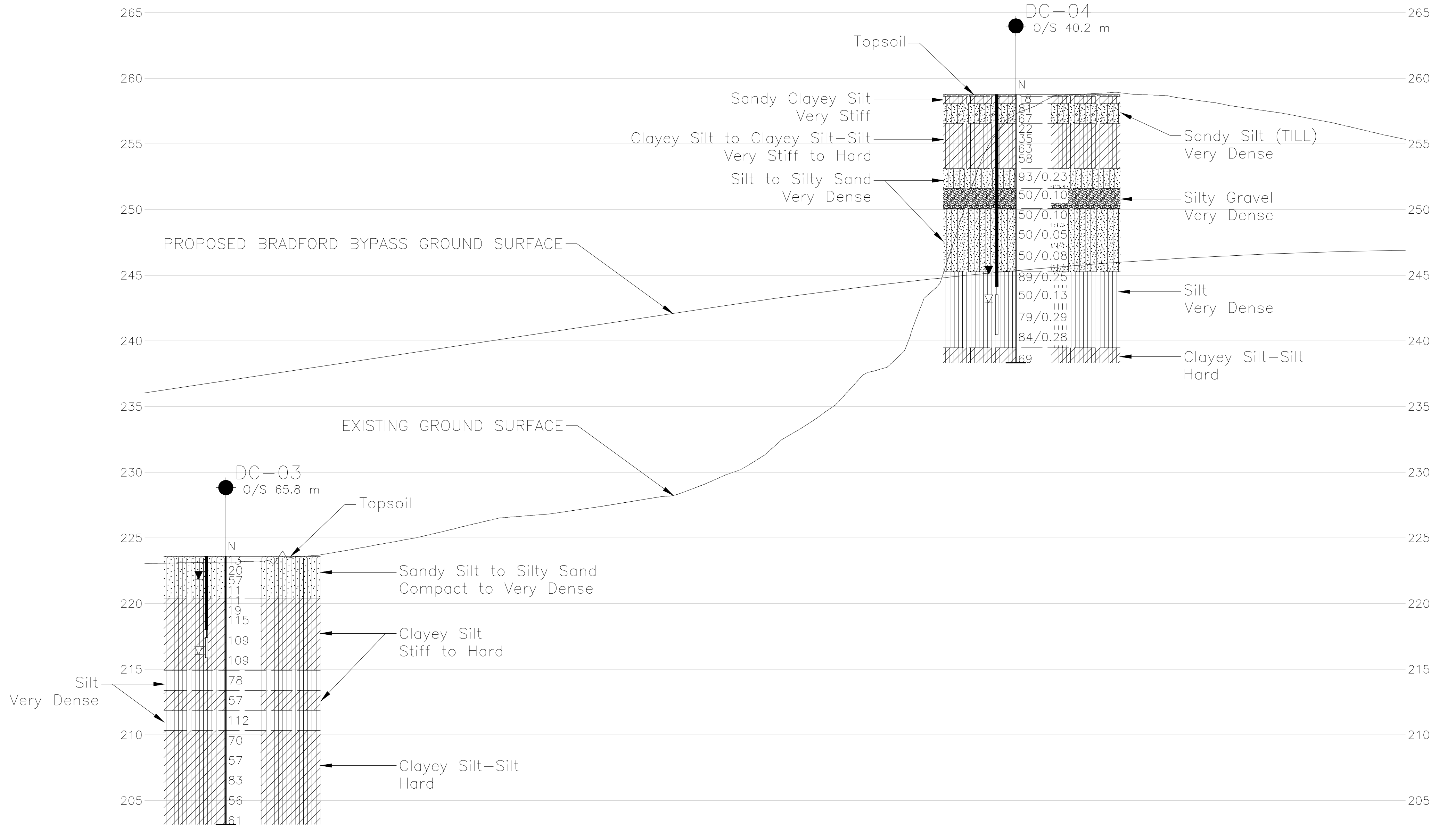
SHEET

BRADFORD BYPASS
DEEP CUT / HIGH FILL – AREA 2
BOREHOLE LOCATIONS AND SOIL STRATA

WSP



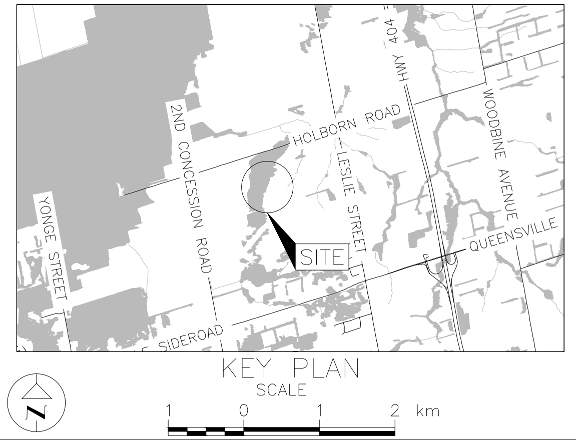
PLAN
SCALE
20 0 20 40 m



A–A' PROFILE BRADFORD BYPASS ℄

HORIZONTAL SCALE
20 0 20 40 m

VERTICAL SCALE
4 0 4 8 m



KEY PLAN
SCALE
1 0 1 2 km

LEGEND

●	Borehole – Current Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▼	WL in piezometer, measured on December 7, 2023
▽	WL upon completion of drilling

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
DC–03	223.6	4889831.9	307194.8
DC–04	258.8	4889960.0	307468.1

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 Aecom, drawing file no. X–Base_Bradford Bypass.dwg and BRADFORD BY–PASS OG_Combined.xml, received January 11, 2022.
Horizontal alignment provided in digital format by Aecom, drawing file no. X–60636190–C–DES–All Alignments.xml, received May 12, 2023.
Vertical alignment provided in digital format by Aecom, drawing file no. X–60636190–C–DES–BBP Mainline Profile.dwg, received May 16, 2023.
Design plan provided in digital format by Aecom, drawing file no. BBP Mainline Plan and Profile_To WSP_230705.dwg, received July 5, 2023.

M. C. KENNEDY
100547814
Dec. 21, 2023

K. J. BENTLEY
Dec. 21, 2023

NO.	DATE	BY	REVISION

Geocres No. 31D04–004

HWY.		PROJECT NO. 19136074	DIST.
SUBM'D. KJB	CHKD. MCK	DATE: 12/19/2023	SITE:
DRAWN: DD	CHKD. MCK	APPD. KJB	DWG. 2

PLOT DATE: December 21, 2023
FILENAME: S:\Clients\MTO\Bradford_Bypass\99_PROJ\19136074_Aecom\40_PROD\0019_Deep_Cut_Area_2\19136074–0019–BG–0002.dwg

APPENDIX A

Pavement Investigation (WSP Golder 2023)

BBP Mainline Supplemental Boreholes

Station 11+800 to 16+000, Referenced to C/L

Drilling Date: Jan to Apr, 2023

13+000 C/L D-0 PDC-5

0	-	300	Dk Br Si(y) Tps, Moist, Loose
300	-	1.52	Dk Br Sa(y) Si Tr Cl, Moist, Loose
1.52	-	3.05	Red Br Sa & Si Tr Gr Tr Cl, Moist, Loose*
3.05	-	4.57	Gry Sa(y) Si Tr Gr Tr Cl, Moist, Dense
4.57	-	6.10	Br Gry Sa & Si Tr Gr Tr Cl, Moist, Fr Wat @ 5.18, Sat, V Dense**
6.10	-	7.62	Gry Sa(y) Si Tr Cl, Sat, V Dense
7.62	-	8.23	Br Gry Si(y) Sa Tr Gr Tr Cl, Sat, V Dense***

* Sample Depth =1.52 - 3.05
Passing 4.75 mm =99 %
2.00 mm =99 %
425 um =95 %
75 um =56 %
5 um =14 %
2 um =8 %
w =13 %
WL = 19 % WP =15 % IP = 4 %
Classification =ML
Frost Susc. =MSFH
'K' Factor =0.35
Std. Proctor MWD =2203 kg/m³
MDD =2008 kg/m³
w opt =10 %

** Sample Depth =4.57 - 5.18
Passing 4.75 mm =96 %
2.00 mm =94 %
425 um =91 %
75 um =51 %
5 um =12 %
2 um =7 %
w =11 %
Classification =ML
Frost Susc. =LSFH
'K' Factor =0.30

*** Sample Depth =7.62 - 8.23
Passing 4.75 mm =97 %
2.00 mm =94 %
425 um =88 %
75 um =45 %
5 um =12 %
2 um =7 %
w =7 %
Classification =SM
Frost Susc. =LSFH
'K' Factor =0.25

14+800 C/L D-0 PDC-6

0	-	180	Dk Br Si(y) Tps, Moist, Loose
180	-	280	Br Sa(y) Si, Moist, Loose
280	-	760	Br Si(y) Sa So Gr, Moist, Loose
760	-	1.52	Br Gry Si(y) Sa So Gr Occ Cob, Moist, Comp
1.52	-	3.05	Br Gry Si(y) Sa So Gr Occ Cob, Moist, V Dense
3.05	-	7.62	Gry Si(y) Sa So Gr, Moist, Fr Wat @ 3.60, Sat, V Dense
7.62	-	15.24	Gry Si(y) Sa So Cl Occ Cob, Sat, V Dense*
15.24	-	18.29	Gry Si(y) Sa So Gr, Sat, V Dense
18.29	-	21.34	Gry Sa(y) Si Tr Gr Occ Cob, Sat, V Dense
21.34	-	21.95	Gry Sa(y) Si(y) Cl Tr Gr, Wet, Hard

* Sample Depth =12.19 - 13.72
Passing 4.75 mm =100 %
2.00 mm =98 %
425 um =87 %
75 um =41 %
5 um =15 %
2 um =10 %
w =32 %
Classification =SM
Frost Susc. =LSFH
'K' Factor =0.25
Std. Proctor MWD =2220 kg/m³
MDD =2057 kg/m³
w opt =8 %

BBP Mainline Supplemental Boreholes

Station 11+800 to 16+000, Referenced to C/L

Drilling Date: Jan to Apr, 2023

15+000 C/L D-0 PDC-7

0	- 230	Dk Br Sa(y) Tps, Moist, V Loose
230	- 1.52	Br Si(y) Sa So Gr, Moist, Fr Wat @ 1.07, Sat, V Loose
1.52	- 6.10	Br Si(y) Sa So Gr Occ Cob, Sat, V Dense
6.10	- 7.62	Gry Si(y) Sa So Gr Occ Cob, Sat, V Dense
7.62	- 9.14	Gry Si(y) Sa, Sat, V Dense
9.14	- 10.67	Gry Sa Tr Si Tr Cl, Sat, V Dense
10.67	- 12.19	Gry Si(y) Sa, Sat, V Dense
12.19	- 15.24	Gry Cl(y) Si, Wet, Hard
15.24	- 18.29	Gry Sa(y) Si, Sat, V Dense
18.29	- 19.81	Gry Sa(y) Si Tr Cl, Wet, Hard*
19.81	- 24.38	Gry Cl(y) Si Tr Sa, Wet, Hard
24.38	- 28.00	Gry Cl(y) Si, Wet, Hard

* Sample Depth =18.29 - 19.81
Passing 4.75 mm =100 %
2.00 mm =100 %
425 um =98 %
75 um =66 %
5 um =14 %
2 um =9 %
w =39 %
Plasticity =Non-plastic
Classification =ML
Frost Susc. =MSFH
'K' Factor =0.45
Std. Proctor MWD =2135 kg/m³
MDD =1912 kg/m³
w opt =11 %

15+800 C/L D-0 PDC-9

0	- 1.52	Br Cl(y) Si Tr Gr Tr Sa, Moist, Firm*
1.52	- 3.65	Br Cl(y) Si So Sa Tr Gr, Moist, Firm**

* Sample Depth =0 - 610
w =20 %

** Sample Depth =1.52 - 2.13
Passing 4.75 mm =94 %
2.00 mm =92 %
425 um =88 %
75 um =75 %
5 um =22 %
2 um =16 %
w =15 %
WL = 23 % WP =15 % IP = 9 %
Classification =CL
Frost Susc. =MSFH
'K' Factor =0.50
Std. Proctor MWD =2119 kg/m³
MDD =1889 kg/m³
w opt =12 %

16+000 C/L D-0 PDC-10

0	- 3.65	Br Cl(y) Si So Sa Tr Gr, Moist, Firm*

* Sample Depth =0 - 610
w =23 %

** Sample Depth =1.52 - 2.13
Passing 4.75 mm =99 %
2.00 mm =98 %
425 um =96 %
75 um =88 %
5 um =52 %
2 um =28 %
w =10 %
WL = 28 % WP =16 % IP = 12 %
Classification =CL
Frost Susc. =LSFH
'K' Factor =0.45
Std. Proctor MWD =2120 kg/m³
MDD =1876 kg/m³
w opt =13 %

APPENDIX B

Borehole Records

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS
MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS[1,2]

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (*i.e.,* SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (*i.e.,* some sand)
≤ 10	trace (*i.e.,* trace fines)

1. Only applicable to components not described by Primary Group Name.
2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

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.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)
An 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 (u) and sleeve friction (f_s) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); 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

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , 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, Gs)
DS	direct shear test
GS	specific gravity
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 (FV)	field vane (LV-laboratory vane test)
γ	unit weight

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

COARSE-GRAINED SOILS

Compactness[1]

Term	SPT 'N' (blows/0.3m)[2]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

1. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.
2. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1,2] (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS
MINISTRY OF TRANSPORTATION, ONTARIO

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

w	water content
w_L or LL	liquid limit
w_P or PL	plastic limit
I_P or PI	plasticity index $= (w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
c'	effective cohesion
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
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 or 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

---

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

Ontario

RECORD OF BOREHOLE No. DC-01

Sheet 1 of 3

METRIC

PROJECT 19136074

G.W.P. Assignment No 2019-E-0048

LOCATION N 4887754.5; E 298899.4 NAD83 / MTM Zone 10 (LAT. 44.129762; LONG. -79.573736)

ORIGINATED BY DP

DIST Central HWY BBP - Deep Cut

BOREHOLE TYPE 210 mm Hollow Stem Auger; Mud Rotary

COMPILED BY ML

DATUM CGVD28 Surface Elevation:274.0 m

DATE May 27, 2022 - May 31, 2022

CHECKED BY KJB

SOIL PROFILE			SAMPLES											
ELEV. --------- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) × Field Vane ⊕ Remoulded ■ Pocket Pen ● Quick Triaxial ○ Unconfined	WATER CONTENT (%) PL NMC LL W_p W W_l |-------------o-------------| NP Nonplastic 20 40 60	UNIT WEIGHT γ kN/m³	GR	SA	SI CL	REMARKS
0.0 273.4	SILT (ML), some sand, trace gravel, trace rootlets (TOPSOIL / REWORKED NATIVE) Grey to mottled brown Moist Very Stiff		1	SS	22									
0.7	SILTY SAND (SM) of slight plasticity, trace gravel Compact to dense Brown to grey Moist		2	SS	23		273							
			3	SS	47		272		○▮		5	52	35 8	
271.8 2.2	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML), trace to some sand, trace gravel (TILL) contains silt and sand seams throughout Brown Moist Hard		4	SS	41		271		○—|		16	18	52 14	
			5	SS	44		270							
			6	SS	132				○					
	- 4.5 m: brown transitions to grey		7	SS	170		269		○H		1	20	69 10	
							268							
			8	SS	52		267							
265.5			9	SS	62		266		|—○—|					
8.5	Gravelly SILTY SAND (SM) Grey Moist Very Dense						265							
			10	SS	100/0.13				○		30	47	22 1	

Continued on Next Page

+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

Ontario

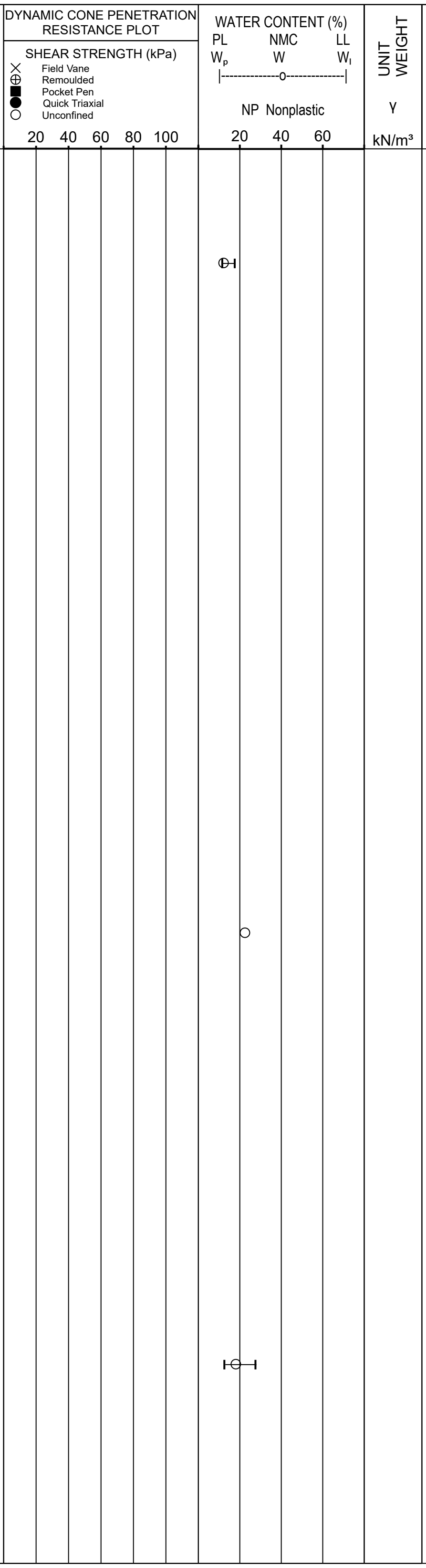
RECORD OF BOREHOLE No. DC-01

Sheet 2 of 3

METRIC

PROJECT	19136074				
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4887754.5; E 298899.4 NAD83 / MTM Zone 10 (LAT. 44.129762; LONG. -79.573736)	ORIGINATED BY	DP
DIST	Central HWY BBP - Deep Cut	BOREHOLE TYPE	210 mm Hollow Stem Auger; Mud Rotary	COMPILED BY	ML
DATUM	CGVD28 Surface Elevation:274.0 m	DATE	May 27, 2022 - May 31, 2022	CHECKED BY	KJB

SOIL PROFILE		SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL	REMARKS
ELEV. --------- DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES							
263.7 10.4	Gravelly SILTY SAND (SM) Grey Moist Very Dense										
	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML), trace to some sand, trace gravel Hard Grey Moist	11	SS	100/0.13			1	20	60	19	
						263					
						262					
		12	SS	151/0.28							
						261					
		13	SS	170/0.28							
						260					
						259					
		14	SS	106							
						258					
		15	SS	140/0.26							
						257					
						256					
		16	SS	62							
						255					



Continued on Next Page

+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

Ontario

wsp

PROJECT 19136074	**RECORD OF BOREHOLE**	**No. DC-01**	Sheet 3 of 3	**METRIC**	
G.W.P. Assignment No 2019-E-0048	LOCATION	N 4887754.5; E 298899.4 NAD83 / MTM Zone 10 (LAT. 44.129762; LONG. -79.573736)		ORIGINATED BY	DP
DIST Central HWY BBP - Deep Cut	BOREHOLE TYPE	210 mm Hollow Stem Auger; Mud Rotary		COMPILED BY	ML
DATUM CGVD28 Surface Elevation:274.0 m	DATE	May 27, 2022 - May 31, 2022		CHECKED BY	KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH (kPa) × Field Vane ⊕ Remoulded ■ Pocket Pen ● Quick Triaxial ○ Unconfined 20 40 60 80 100	WATER CONTENT (%) PL NMC LL W_p W W_l |-------------o-------------| NP Nonplastic 20 40 60	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL	REMARKS
ELEV. --------- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES										
253.9 20.1	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML), trace to some sand, trace gravel Hard Grey Moist SILT (ML) and SAND Very dense Grey Moist						253								
252.6			17	SS	100/0.12						0	43	42	15	
21.5	End of Borehole Note: 1. Switched from hollow stem augers to mud rotary at a depth of about 2.4 m bgs (El. 271.6 m). 2. Water not encountered during hollow stem augering and not recorded upon completion of drilling due to the introduction of drilling mud.						252 251 250 249 248 247 246 245								

+³, ×³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

Ontario **wsp**

RECORD OF BOREHOLE No. DC-02

Sheet 1 of 3 **METRIC**

PROJECT	19136074		
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4887732.2; E 298800.3 NAD83 / MTM Zone 10 (LAT. 44.12956; LONG. -79.574974)
ORIGINATED BY	DP		
DIST	Central	HWY	BBP - Deep Cut
BOREHOLE TYPE	210 mm Hollow Stem Auger; Mud Rotary	COMPILED BY	ML
DATUM	CGVD28 Surface Elevation:277.0 m	DATE	Jun 02, 2022 - Jun 06, 2022
CHECKED BY	KJB		

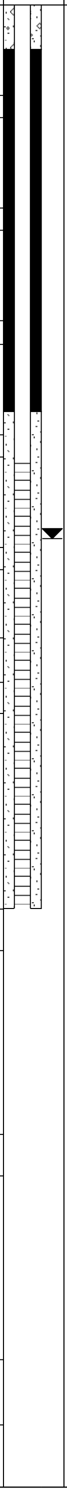
SOIL PROFILE

ELEV. --------- DEPTH	DESCRIPTION
0.0	Sandy SILT (ML), trace to some organics / rootlets (TOPSOIL / REWORKED NATIVE) Brown Moist Loose
276.3 0.7	CLAYEY SILT (CL), trace sand Brown Moist Firm
275.9 1.1	SILTY SAND (SM), trace gravel, trace clay Brown Moist Loose
275.5 1.4	Sandy CLAYEY SILT (CL), trace gravel Grey Moist Very stiff
274.8 2.2	SILT (ML) and SAND of slight plasticity to SILTY SAND (SM), trace gravel to gravelly (TILL) Brown to grey Moist Very dense - 5.2 to 5.9 m: grinding during casing advancement
269.8 7.2	CLAYEY SILT (CL), trace sand, trace gravel, contains silt seams / interlayers Grey Moist Hard

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	9				
2A	SS	7				
2B			3	78	16	3
3	SS	22				
4	SS	51	5	42	48	5
5	SS	87				
6	SS	132				
7	SS	100/0.06				
8	SS	100/0.13	6	53	35	6
9	SS	100/0.13	0	1	90	9
10	SS	160/0.29				

GROUNDWATER CONDITIONS

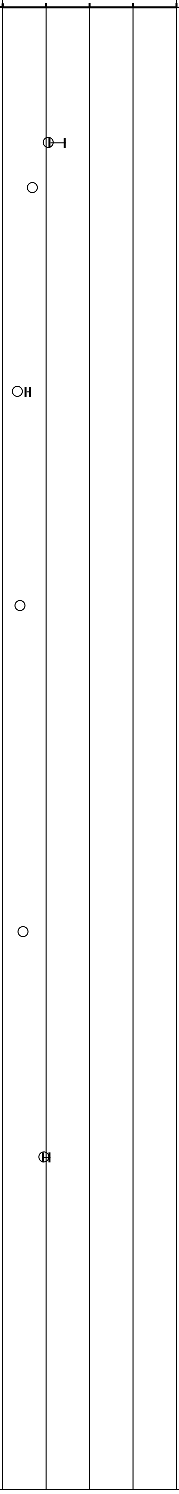


ELEVATION SCALE: 276, 275, 274, 273, 272, 271, 270, 269, 268

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa)
X Field Vane
⊕ Remoulded
■ Pocket Pen
● Quick Triaxial
○ Unconfined

WATER CONTENT (%)
PL NMC LL
W_p W W_l
|-------------o-------------|
NP Nonplastic



UNIT WEIGHT γ kN/m³

REMARKS

Continued on Next Page

+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

RECORD OF BOREHOLE No. DC-02

Sheet 2 of 3

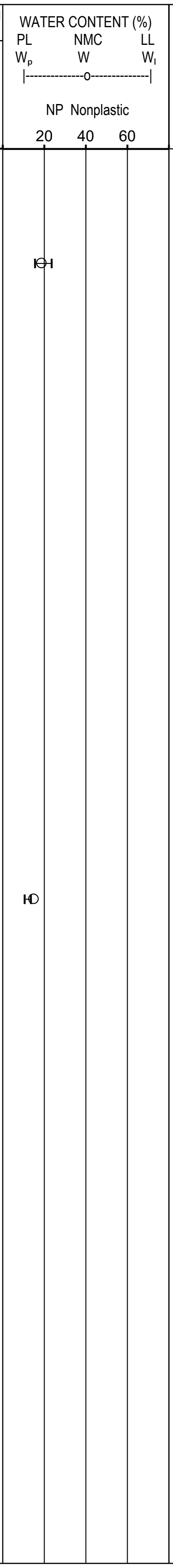
METRIC

PROJECT	19136074				
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4887732.2; E 298800.3 NAD83 / MTM Zone 10 (LAT. 44.12956; LONG. -79.574974)	ORIGINATED BY	DP
DIST	Central HWY BBP - Deep Cut	BOREHOLE TYPE	210 mm Hollow Stem Auger; Mud Rotary	COMPILED BY	ML
DATUM	CGVD28 Surface Elevation:277.0 m	DATE	Jun 02, 2022 - Jun 06, 2022	CHECKED BY	KJB

SOIL PROFILE		SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL	REMARKS
ELEV. --------- DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES							
	CLAYEY SILT (CL), trace sand, trace gravel, contains silt seams / interlayers Grey Moist Hard										
		11	SS	50/0.13			0	0	69	31	
						266					
						265					
		12	SS	81							
						264					
		13	SS	50/0.07							
						263					
262.2 14.8	Sandy SILT (ML) of slight plasticity, trace gravel, contains clayey silt seams / interlayers Grey Moist Very Dense					262					
		14	SS	100/0.13			6	34	50	10	
						261					
		15	SS	100/0.11							
						260					
						259					
		16	SS	100/0.13							
						258					

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): ○ Unconfined ● Quick Triaxial ■ Pocket Pen ⊕ Remoulded × Field Vane



UNIT WEIGHT γ kN/m³

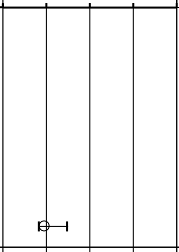
Continued on Next Page

+³, x³ : Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

Ontario

PROJECT	19136074	**RECORD OF BOREHOLE No. DC-02**	Sheet 3 of 3		**METRIC**
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4887732.2; E 298800.3 NAD83 / MTM Zone 10 (LAT. 44.12956; LONG. -79.574974)	ORIGINATED BY	DP
DIST	Central HWY BBP - Deep Cut	BOREHOLE TYPE	210 mm Hollow Stem Auger; Mud Rotary	COMPILED BY	ML
DATUM	CGVD28 Surface Elevation:277.0 m	DATE	Jun 02, 2022 - Jun 06, 2022	CHECKED BY	KJB

SOIL PROFILE		SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) X Field Vane ⊕ Remoulded ■ Pocket Pen ● Quick Triaxial ○ Unconfined	WATER CONTENT (%) PL NMC LL W_p W W_l |--------o--------| NP Nonplastic 20 40 60	UNIT WEIGHT γ kN/m³	GR SA SI CL	REMARKS
ELEV. --------- DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES							
	Sandy SILT (ML) of slight plasticity, trace gravel, contains clayey silt seams / interlayers Grey Moist Very Dense										
256.9 20.1	CLAYEY SILT (CL), trace to some sand, trace gravel Grey Moist Hard					256					
		17	SS	50/0.13							
255.4 21.6	End of Borehole					255					
						254					
						253					
						252					
						251					
						250					
						249					
						248					

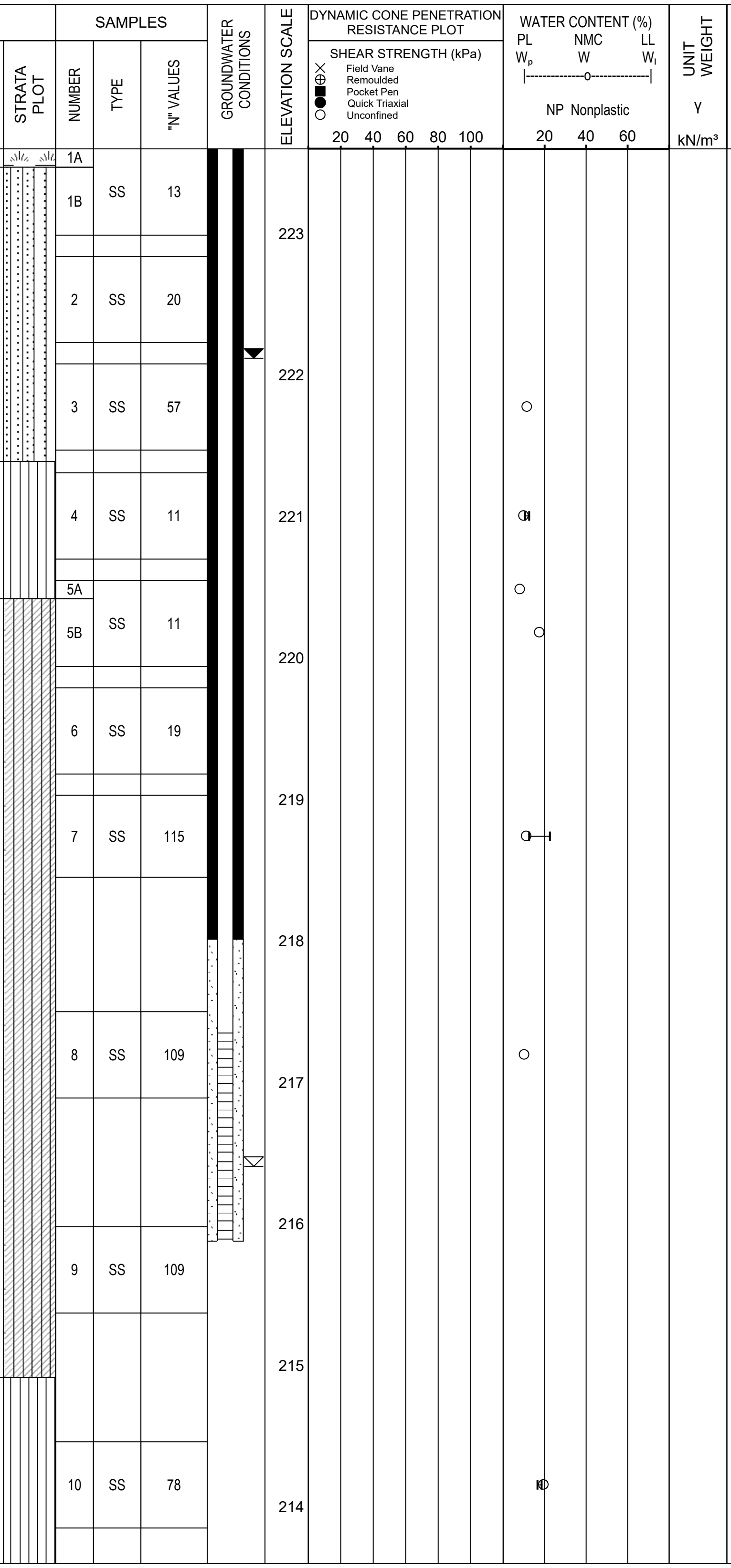


Note:
1. Switched from hollow stem augers to mud rotary at about 2.4 m bgs (274.6 m).
2. Borehole advanced to a depth of 9.8 m before refusal. Borehole then moved approximately 1.5 m west of original borehole location and borehole was advanced using mud rotary with samples taken below a depth of 9.8 m.
3. Water level not recorded upon completion of drilling.
4. A monitoring well was installed 1 m west of borehole location.
5. Water level in piezometer measured at a depth of 3.6 m (Elev. 273.4 m) on December 8, 2023

+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

PROJECT	19136074	**RECORD OF BOREHOLE No. DC-03**	Sheet 1 of 3	**METRIC**	
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4889831.9; E 307194.8 NAD83 / MTM Zone 10 (LAT. 44.148479; LONG. -79.470065)	ORIGINATED BY	DR
DIST	Central HWY BBP - Deep Cut	BOREHOLE TYPE	210 mm O.D. Hollow Stem Augers; Mud Rotary	COMPILED BY	AM
DATUM	CGVD28 Surface Elevation:223.6 m	DATE	Dec 01, 2022 - Dec 02, 2022	CHECKED BY	KJB

SOIL PROFILE		SAMPLES			GR	SA	SI	CL	REMARKS
ELEV. --------- DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES					
0.0	Sandy SILT (TOPSOIL 130 mm)	1A							
223.5 0.1	SILTY SAND (SM) Compact to very dense Brown; oxidation staining present Moist	1B	SS	13					
		2	SS	20					
		3	SS	57	0	62	35	3	
221.4 2.2	Sandy SILT (ML) of slight plasticity, trace gravel Compact Grey Moist	4	SS	11	3	35	53	9	
220.4 3.2	CLAYEY SILT (CL), some sand, trace gravel, contains silt seams Stiff to hard Grey Moist	5A							
		5B	SS	11					
		6	SS	19					
		7	SS	115	4	14	62	20	
		8	SS	109					
		9	SS	109					
214.9 8.7	SILT (ML), some sand Very Dense Grey Moist	10	SS	78					



Continued on Next Page

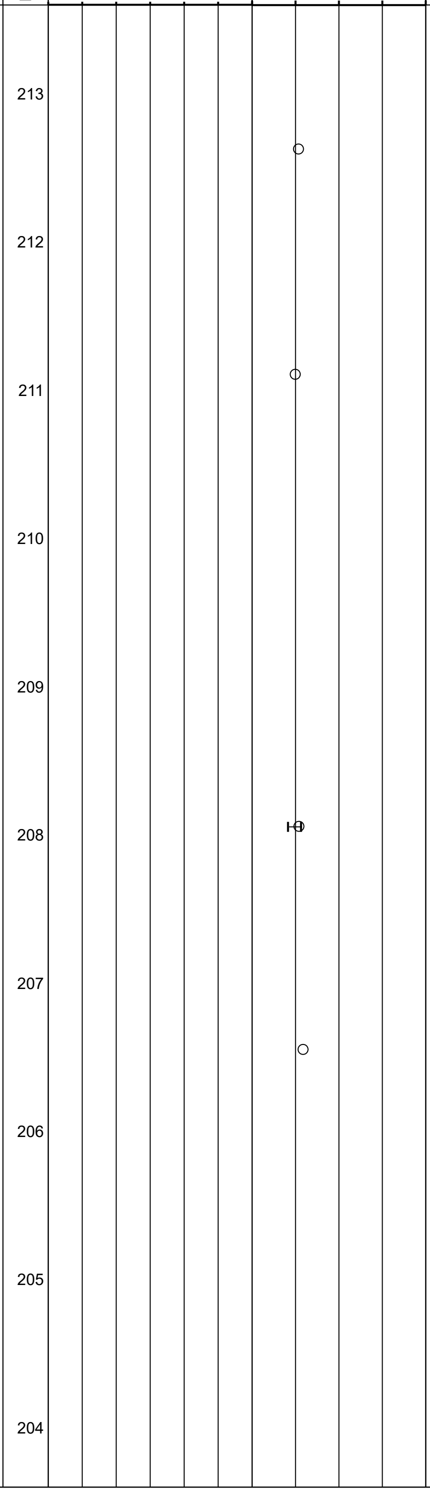
+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

Ontario

PROJECT	19136074	**RECORD OF BOREHOLE No. DC-03**	Sheet 2 of 3		**METRIC**
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4889831.9; E 307194.8 NAD83 / MTM Zone 10 (LAT. 44.148479; LONG. -79.470065)	ORIGINATED BY	DR
DIST	Central HWY BBP - Deep Cut	BOREHOLE TYPE	210 mm O.D. Hollow Stem Augers; Mud Rotary	COMPILED BY	AM
DATUM	CGVD28 Surface Elevation:223.6 m	DATE	Dec 01, 2022 - Dec 02, 2022	CHECKED BY	KJB

SOIL PROFILE | SAMPLES | GROUNDWATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 | SHEAR STRENGTH (kPa) ○ Unconfined ● Quick Triaxial ■ Pocket Pen ⊕ Remoulded × Field Vane 20 40 60 80 100 | WATER CONTENT (%) PL W_p NMC W LL W_l |--------o--------| NP Nonplastic 20 40 60 | UNIT WEIGHT γ kN/m³ | GR SA SI CL | REMARKS

ELEV. --------- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	SILT (ML), some sand Very Dense Grey Moist								
213.4 10.2	CLAYEY SILT (CL), contains silt seams Hard Grey Moist								
			11	SS	57				
211.9 11.7	SILT (ML), trace sand Very dense Grey Wet								
			12	SS	112				
210.3 13.3	CLAYEY SILT-SILT (CL-ML), contains silt and sand seams Hard Grey Moist								
			13	SS	70				
			14	SS	57	0	0	77	23
			15	SS	83				
			16	SS	56				



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+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

PROJECT 19136074

RECORD OF BOREHOLE No. DC-03

Sheet 3 of 3

METRIC

G.W.P. Assignment No 2019-E-0048
LOCATION N 4889831.9; E 307194.8 NAD83 / MTM Zone 10 (LAT. 44.148479; LONG. -79.470065)
ORIGINATED BY DR
DIST Central HWY BBP - Deep Cut
BOREHOLE TYPE 210 mm O.D. Hollow Stem Augers; Mud Rotary
COMPILED BY AM
DATUM CGVD28 Surface Elevation:223.6 m
DATE Dec 01, 2022 - Dec 02, 2022
CHECKED BY KJB

SOIL PROFILE			SAMPLES									
ELEV. --------- DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT SHEAR STRENGTH (kPa) X Field Vane ⊕ Remoulded ■ Pocket Pen ● Quick Triaxial ○ Unconfined 20 40 60 80 100	WATER CONTENT (%) PL NMC LL W_p W W_l |-------------o-------------| NP Nonplastic 20 40 60	UNIT WEIGHT γ kN/m³	GR SA SI CL	REMARKS
203.2 20.4	CLAYEY SILT-SILT (CL-ML), contains silt and sand seams Hard Grey Moist	▨	17	SS	61							
	End of Borehole						203					
							202					
							201					
							200					
							199					
							198					
							197					
							196					
							195					
							194					

Note:

1. Water level not recorded upon completion of drilling due to the introduction of drilling mud.
2. A monitoring well was installed approximately 1.8 m south of Borehole DC-03 (N 307,194.71; E 4,889,829.59;).
3. Water level in piezometer measured at a depth of 7.2 m (Elev. 216.4 m) upon completion of well installation on December 5, 2022.
4. Water level in piezometer measured at a depth of 1.5 m (Elev. 222.1 m) on December 7, 2023

+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

Ontario

wsp

RECORD OF BOREHOLE No. DC-04

Sheet 1 of 3

METRIC

PROJECT	19136074				
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4889960; E 307468.1 NAD83 / MTM Zone 10 (LAT. 44.149632; LONG. -79.466647)	ORIGINATED BY	TT
DIST	Central HWY BBP - Deep Cut	BOREHOLE TYPE	210 mm O.D. Hollow Stem Auger	COMPILED BY	MCK
DATUM	CGVD28 Surface Elevation:258.8 m	DATE	Feb 13, 2023 - Feb 14, 2023	CHECKED BY	KJB

SOIL PROFILE

ELEV. --------- DEPTH	DESCRIPTION
0.0	TOPSOIL (125 mm)
258.6 0.1	Sandy CLAYEY SILT (CL), trace gravel, trace organics / rootlets Very stiff Dark brown
258.1 0.7	Sandy SILT (ML), trace to some gravel (TILL) Very dense Brown Moist
256.6 2.2	CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML) trace sand, contains sand and silt seams / interlayers Very stiff to hard Brown Moist
253.1 5.6	SILT (ML) of slight plasticity, trace sand Very dense Brown Moist
252.4 6.4	SILTY SAND (SM), trace gravel Very dense Brown Moist - 6.7 m: Auger grinding and auger refusal. Moved borehole 1m southeast and continued.
251.6 7.2	SILTY GRAVEL (GM), some sand Very dense Greyish brown Dry
250.1 8.7	SILTY SAND (SM), some gravel Very dense Brown Dry

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	18				
2	SS	81				
3	SS	67	7	40	43	10
4	SS	22				
5	SS	35				
6	SS	63				
7	SS	58				
8A	SS	93/0.23				
8B			5	55	(40)	
9	SS	50/0.10				
10	SS	50/0.11				

ELEVATION SCALE: 258, 257, 256, 255, 254, 253, 252, 251, 250, 249

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa)
- × Field Vane
- ⊕ Remoulded
- ■ Pocket Pen
- ● Quick Triaxial
- ○ Unconfined

WATER CONTENT (%): PL W_p |--------o--------| LL W_l, NMC W; NP Nonplastic; 20 40 60

UNIT WEIGHT γ kN/m³

GROUNDWATER CONDITIONS

REMARKS

Continued on Next Page

+³, x³ : Numbers refer to Sensitivity   o³% STRAIN AT FAILURE

Ontario

PROJECT 19136074	**RECORD OF BOREHOLE No. DC-04**	Sheet 2 of 3	**METRIC**
G.W.P. Assignment No 2019-E-0048	LOCATION N 4889960; E 307468.1 NAD83 / MTM Zone 10 (LAT. 44.149632; LONG. -79.466647)	ORIGINATED BY TT	
DIST Central HWY BBP - Deep Cut	BOREHOLE TYPE 210 mm O.D. Hollow Stem Auger	COMPILED BY MCK	
DATUM CGVD28 Surface Elevation:258.8 m	DATE Feb 13, 2023 - Feb 14, 2023	CHECKED BY KJB	

ELEV. --------- DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ Unconfined ● Quick Triaxial ■ Pocket Pen ⊕ Remoulded ✕ Field Vane	WATER CONTENT (%) PL W_p, NMC W, LL W_l; NP Nonplastic; 20 40 60	UNIT WEIGHT γ kN/m³	GR SA SI CL	REMARKS
	SILTY SAND (SM), some gravel Very dense Brown Dry									
	- 10.7 m: no sample recovered in split-spoon	11	SS	50/0.05	248					
					247					
	- 12.2 m: Auger grinding	12	SS	50/0.08						
					246					
245.3 13.5	SILT (ML), trace to some sand, contains clayey silt seams / laminations Very dense Brown Wet									
		13	SS	89/0.25	245					
					244					
		14	SS	50/0.13			○ NP		0 5 92 3	
					243					
		15	SS	79/0.29	242					
					241					
		16	SS	84/0.28			H○		0 0 90 10	
					240					
239.5 19.3	CLAYEY SILT-SILT (CL-ML) trace sand Hard Grey Moist to wet				239					

Continued on Next Page

+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

Ontario

RECORD OF BOREHOLE No. DC-04

Sheet 3 of 3

METRIC

PROJECT	19136074				
G.W.P.	Assignment No 2019-E-0048	LOCATION	N 4889960; E 307468.1 NAD83 / MTM Zone 10 (LAT. 44.149632; LONG. -79.466647)	ORIGINATED BY	TT
DIST	Central HWY BBP - Deep Cut	BOREHOLE TYPE	210 mm O.D. Hollow Stem Auger	COMPILED BY	MCK
DATUM	CGVD28 Surface Elevation:258.8 m	DATE	Feb 13, 2023 - Feb 14, 2023	CHECKED BY	KJB

SOIL PROFILE			SAMPLES			GROUNDWATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ Unconfined ● Quick Triaxial ■ Pocket Pen ⊕ Remoulded × Field Vane	WATER CONTENT (%) PL NMC LL W_p W W_l NP Nonplastic 20 40 60	UNIT WEIGHT γ kN/m³	GR SA SI CL	REMARKS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES							
	CLAYEY SILT-SILT (CL-ML) trace sand Hard Grey Moist to wet		17	SS	69				⊢o			
238.3 20.4	End of Borehole						238					
							237					
							236					
							235					
							234					
							233					
							232					
							231					
							230					
							229					

Note:

1. Borehole advanced to a depth of 6.7 m before auger refusal. Borehole then moved approximately 1 m south east of original borehole location and samples were taken below a depth of 7.6 m.
2. Groundwater first encountered at a depth of 13.7 m bgs (245.1 m).
3. Bulk samples collected from augers while drilling from 6.1 m to 7.6 m and from 12.2 m to 13.7 m to support pavement investigation.
4. Water level measured in borehole at a depth of 18.6 m (El. 240.2 m) upon completion of drilling.
5. Monitoring well installed about 8 m northwest of borehole.
6. Borehole dry prior to well installation. Water level in piezometer measured at a depth of 15.6 m (Elev. 243.2 m) upon completion of well installation on February 14, 2023.
7. Water level in piezometer measured at a depth of 13.7 m (Elev. 245.1 m) on December 7, 2023

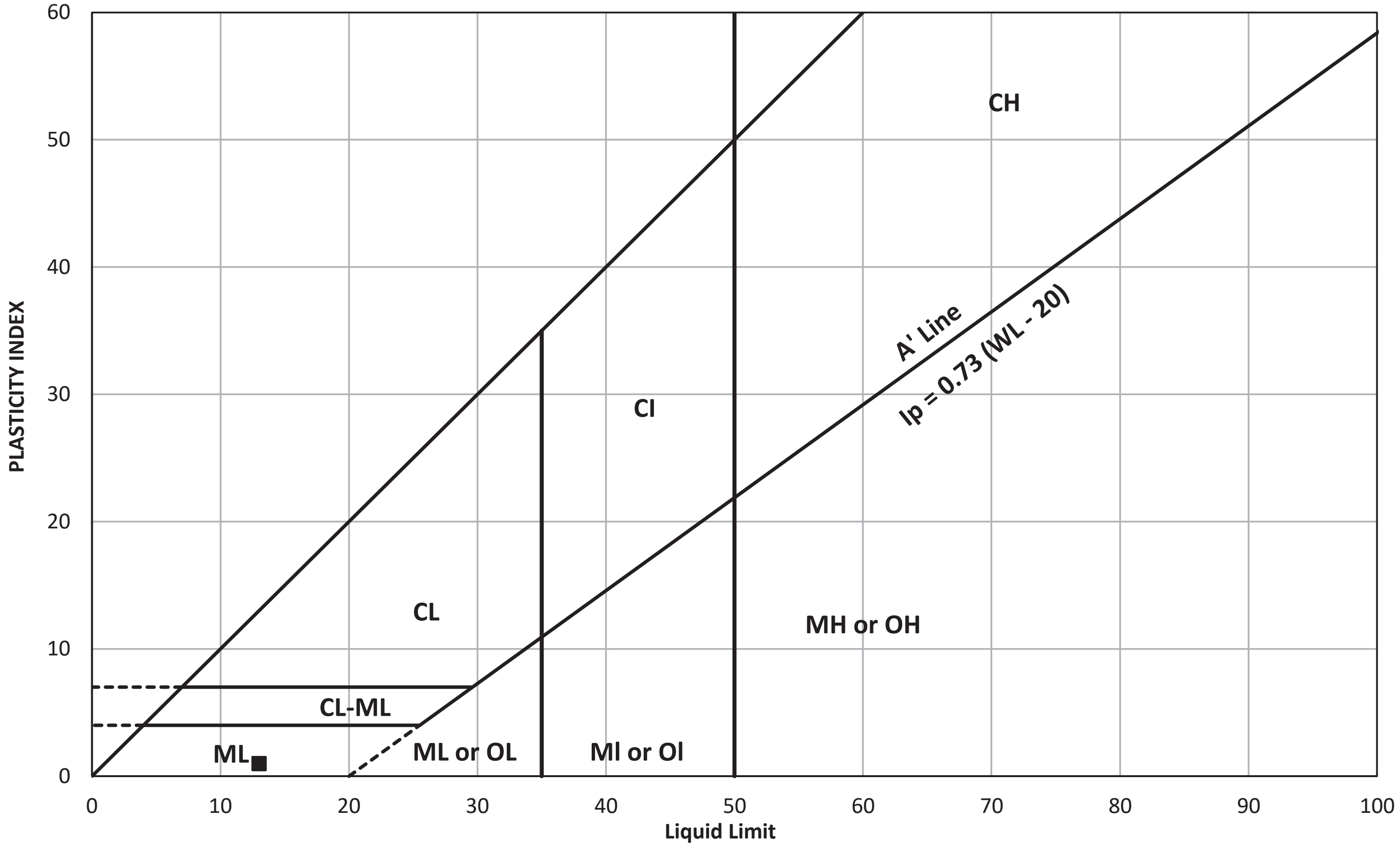
+³, x³ : Numbers refer to Sensitivity o³% STRAIN AT FAILURE

APPENDIX C

Geotechnical Laboratory Test Results

Deep Cut – Area 1

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-01	3	272.5 to 271.9	8.2	13	12	1

CLIENT
AECOM / MTO

PROJECT
Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT
wsp

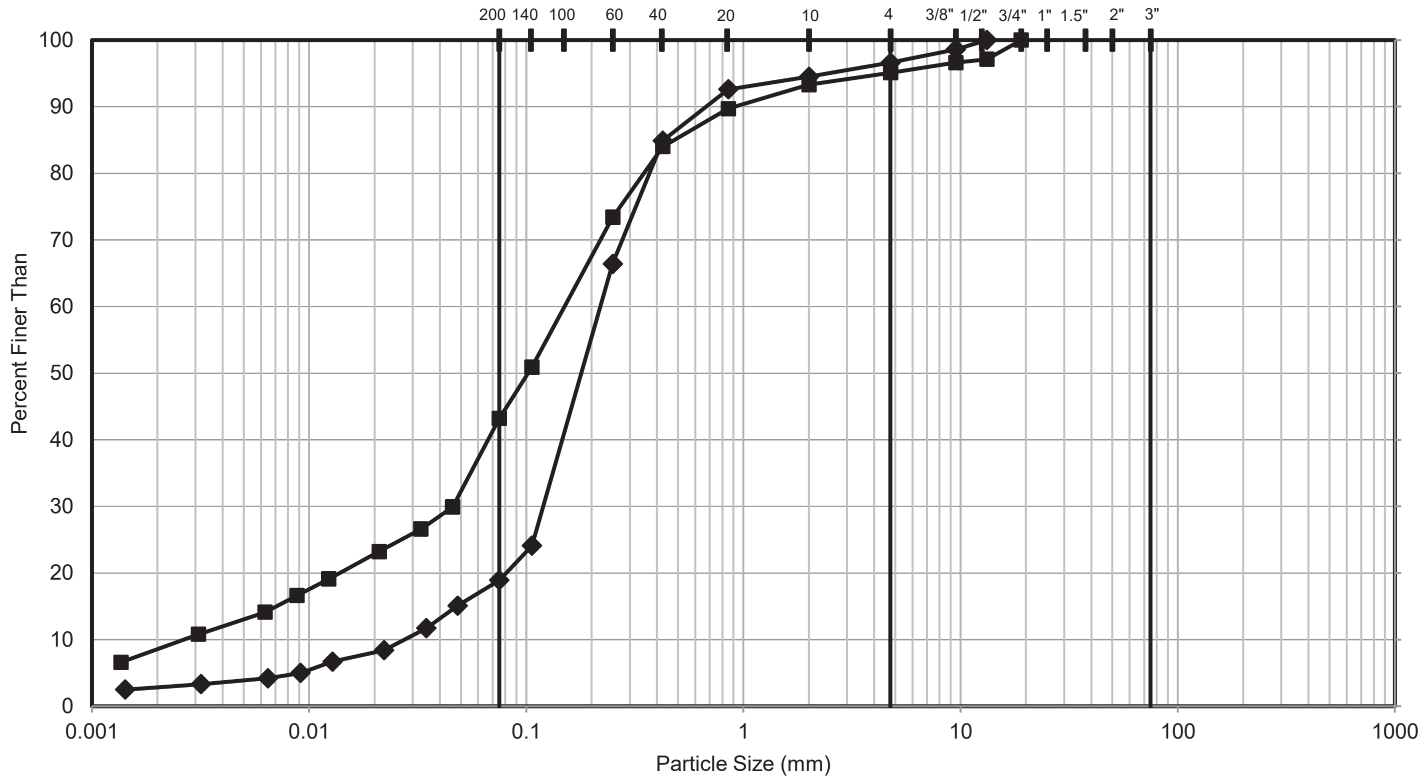
YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE
Plasticity Chart - SILTY SAND (SM)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-1

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-AL.xlsm

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-01	3	1.5 - 2.1	272.5 to 271.9
◆	DC-02	2B	1.1 - 1.4	275.9 to 275.6

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

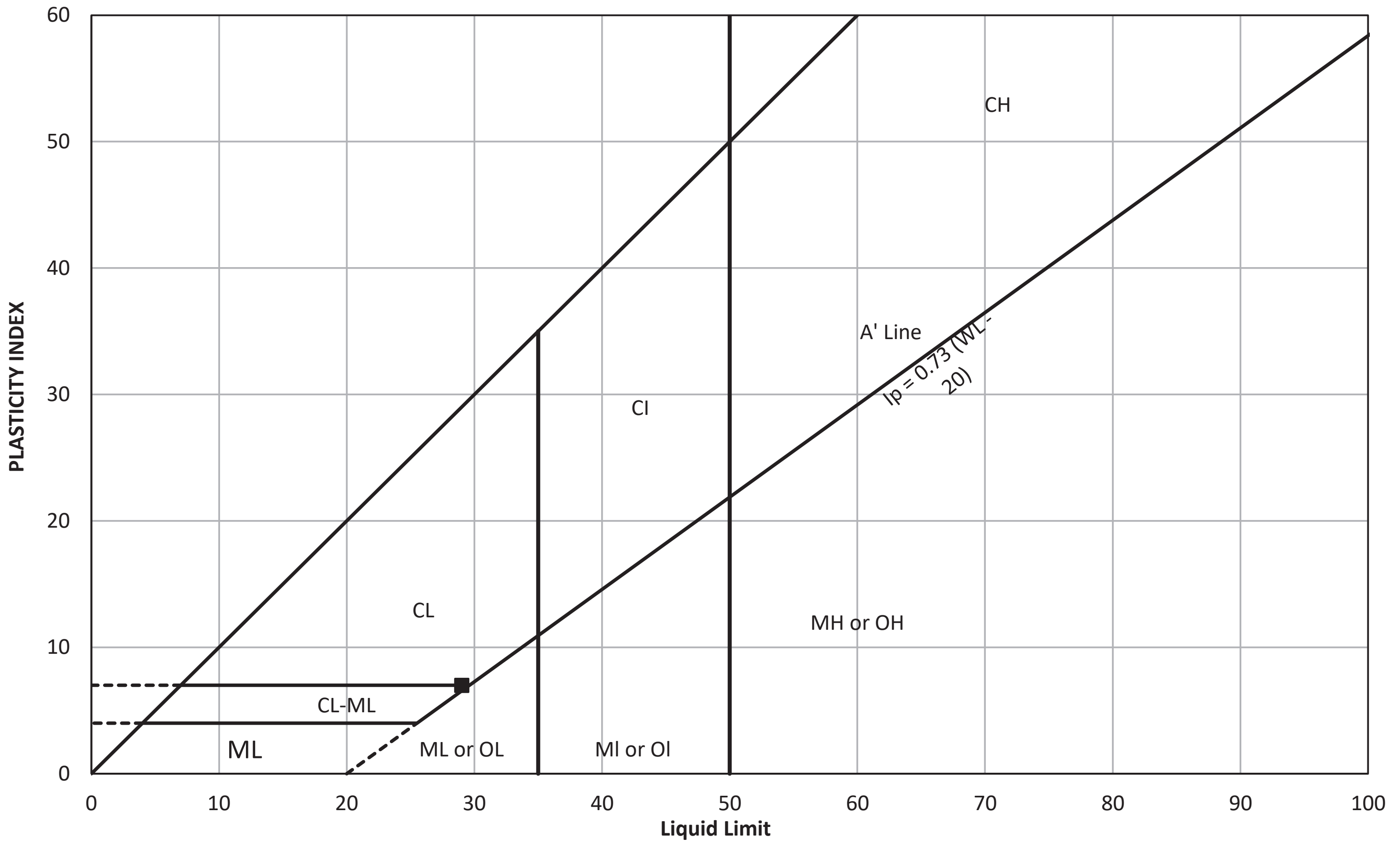
TITLE

Grain Size Distribution - SILTY SAND (SM)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-2

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-GSD.xlsm

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-02	2A	276.2 to 275.9	21.2	29	22	7

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

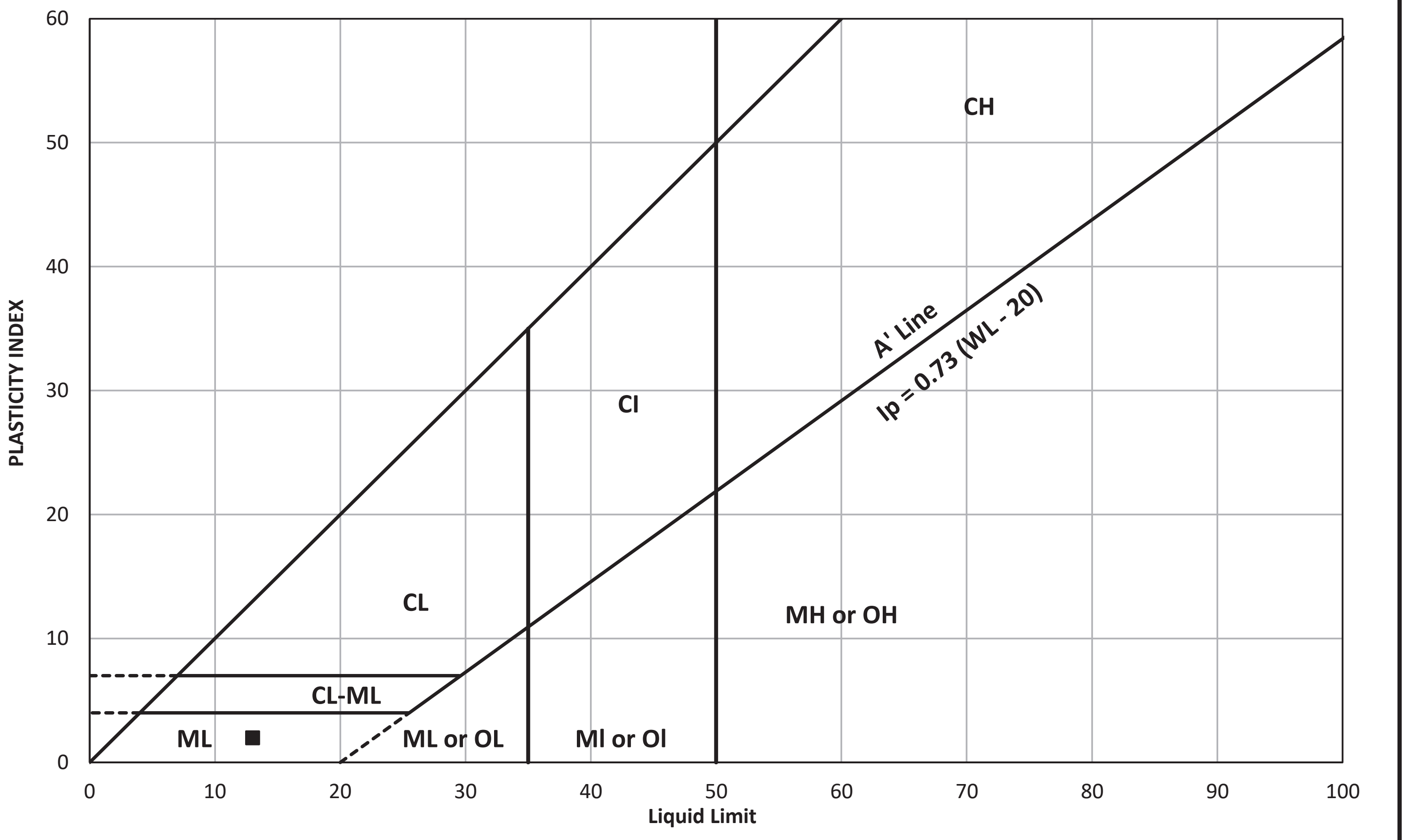
TITLE

Plasticity Chart - CLAYEY SILT (CL)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-3

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-AL.xlsm

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-02	4	274.7 to 274.1	7	13	11	2

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

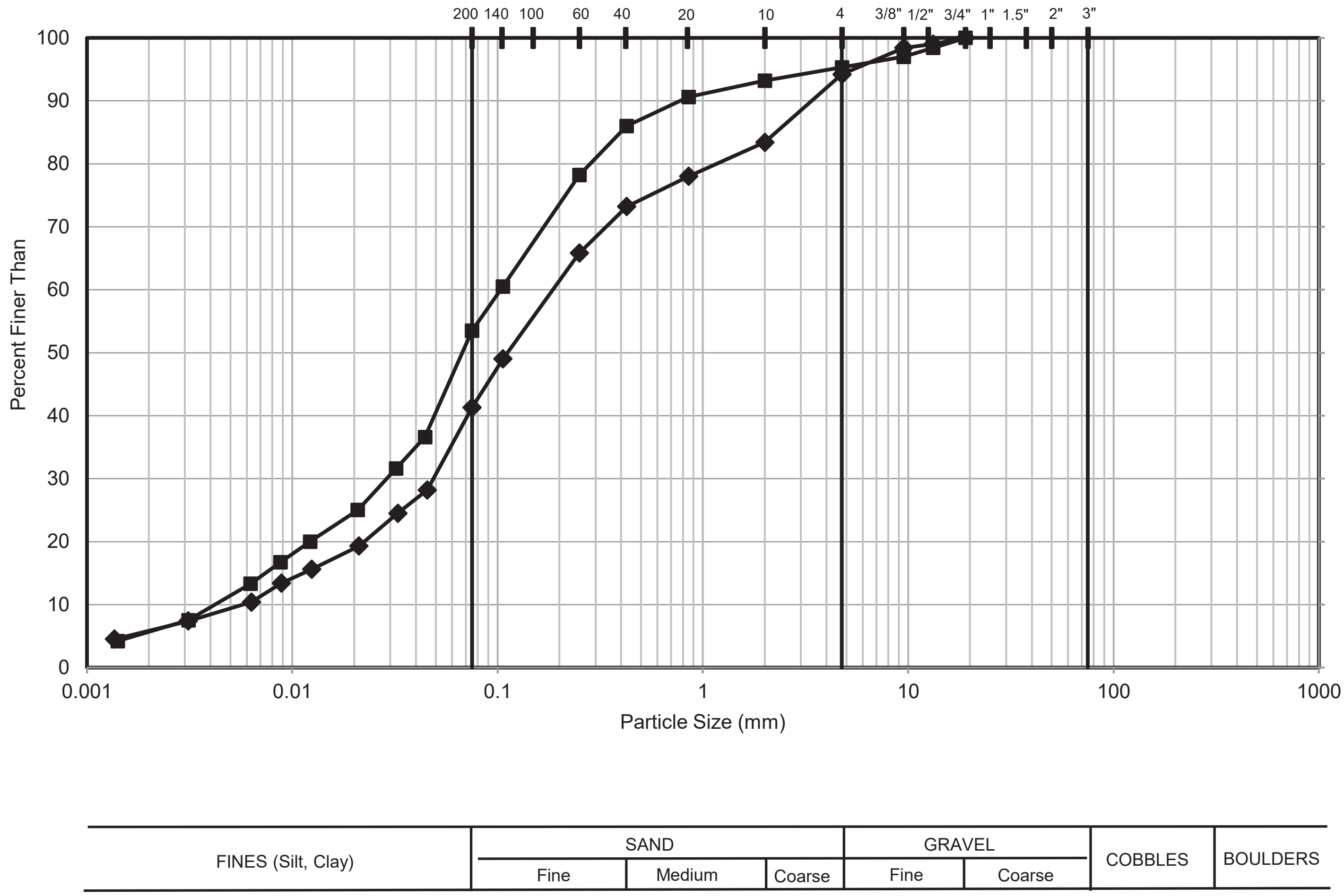
TITLE

Plasticity Chart - SILT and Sand (ML) to SILTY SAND (SM) - TILL

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-4

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-AL.xlsm

GRAIN SIZE DISTRIBUTION



Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-02	4	2.3 - 2.9	274.7 to 274.1
◆	DC-02	8	6.1 - 6.4	270.9 to 270.6

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

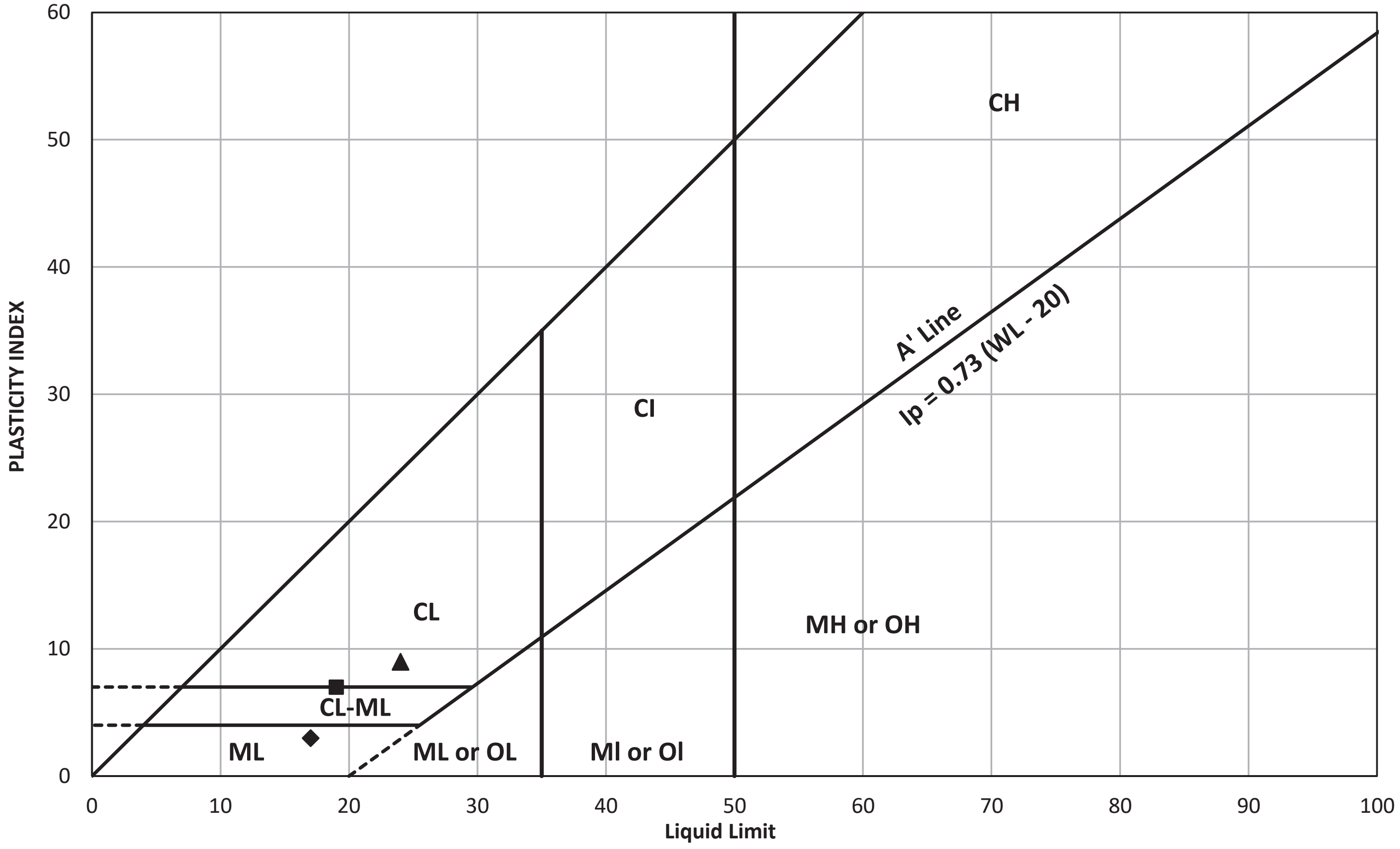
TITLE

Grain Size Distribution - SILT and Sand (ML) to SILTY SAND (SM) - TILL

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-5

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-GSD.xlsm

PLASTICITY CHART

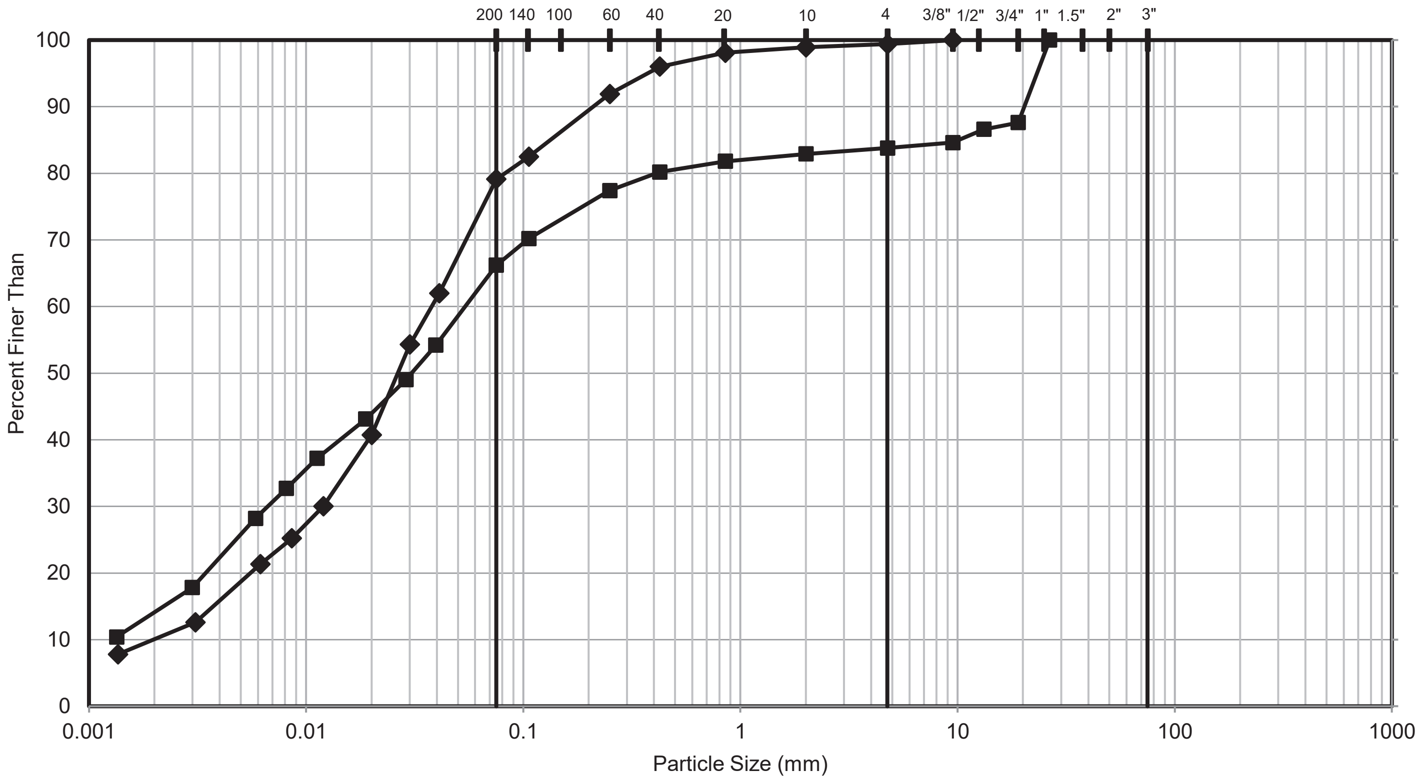


Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-01	4	271.8 to 271.1	10.9	19	12	7
◆	DC-01	7	269.5 to 268.9	11.6	17	14	3
▲	DC-01	9	266.4 to 265.8	17.9	24	15	9

CLIENT AECOM / MTO		PROJECT Bradford Bypass - Deep Cut / High Fill Areas	
CONSULTANT wsp	YYYY-MM-DD 2023-12-14 DESIGNED N/A PREPARED MCK REVIEWED KJB APPROVED KJB	TITLE Plasticity Chart - CLAYEY SILT-SILT (CL-ML) to CLAYEY SILT (CL) - TILL	
		PROJECT NO. 19136074	CONTROL 1000 · REV. 0 · FIGURE C1-6

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-AL.xlsm

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-01	4	2.3 - 2.9	271.8 to 271.1
◆	DC-01	7	4.6 - 5.2	269.5 to 268.9

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

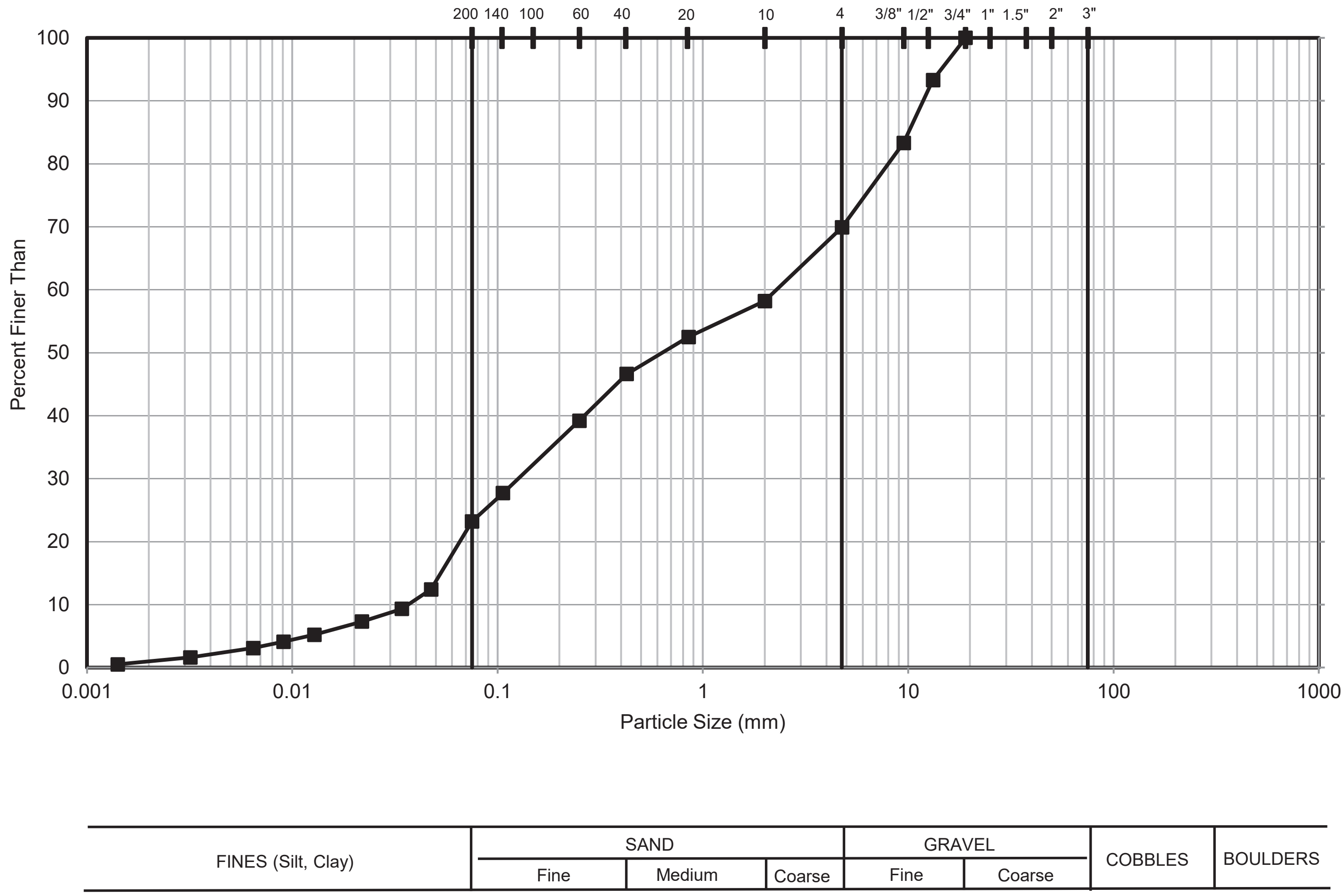
TITLE

Grain Size Distribution - CLAYEY SILT-SILT (CL-ML) to CLAYEY SILT (CL) - TILL

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-7

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-GSD.xlsm

GRAIN SIZE DISTRIBUTION



Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-01	10	9.1 - 9.4	264.9 to 264.6

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

wsp

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

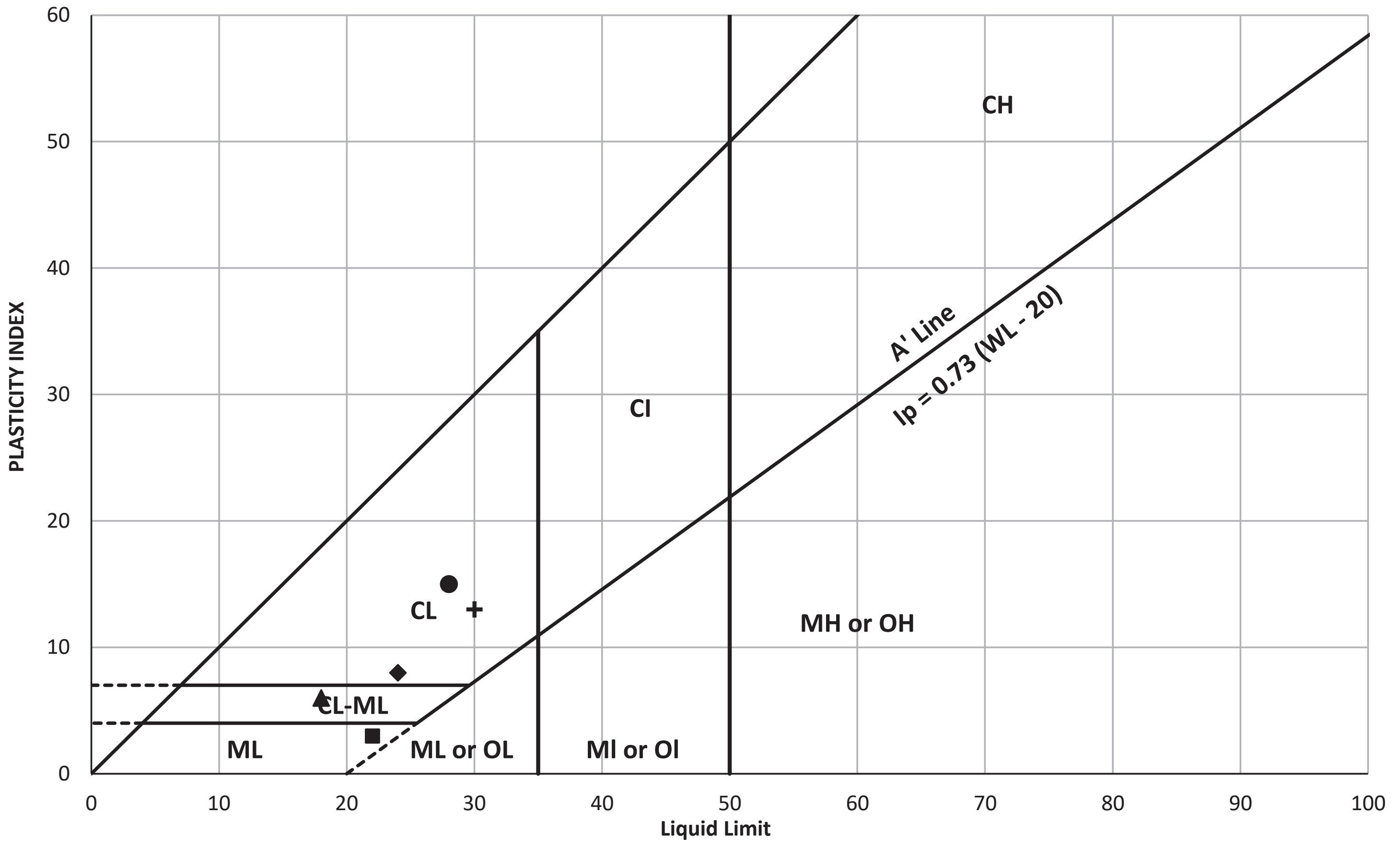
TITLE

Grain Size Distribution - Gravelly SILTY SAND (SM)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-8

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-GSD.xlsm

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-02	9	269.4 to 269.1	19.2	22	19	3
◆	DC-02	11	266.3 to 266.0	18.8	24	16	8
▲	DC-01	11	263.4 to 263.1	12.4	18	12	6
●	DC-01	16	255.8 to 255.1	18.3	28	13	15
+	DC-02	17	255.7 to 255.4	19.2	30	17	13

CLIENT
AECOM / MTO

PROJECT
Bradford Bypass - Deep Cut / High Fill Areas

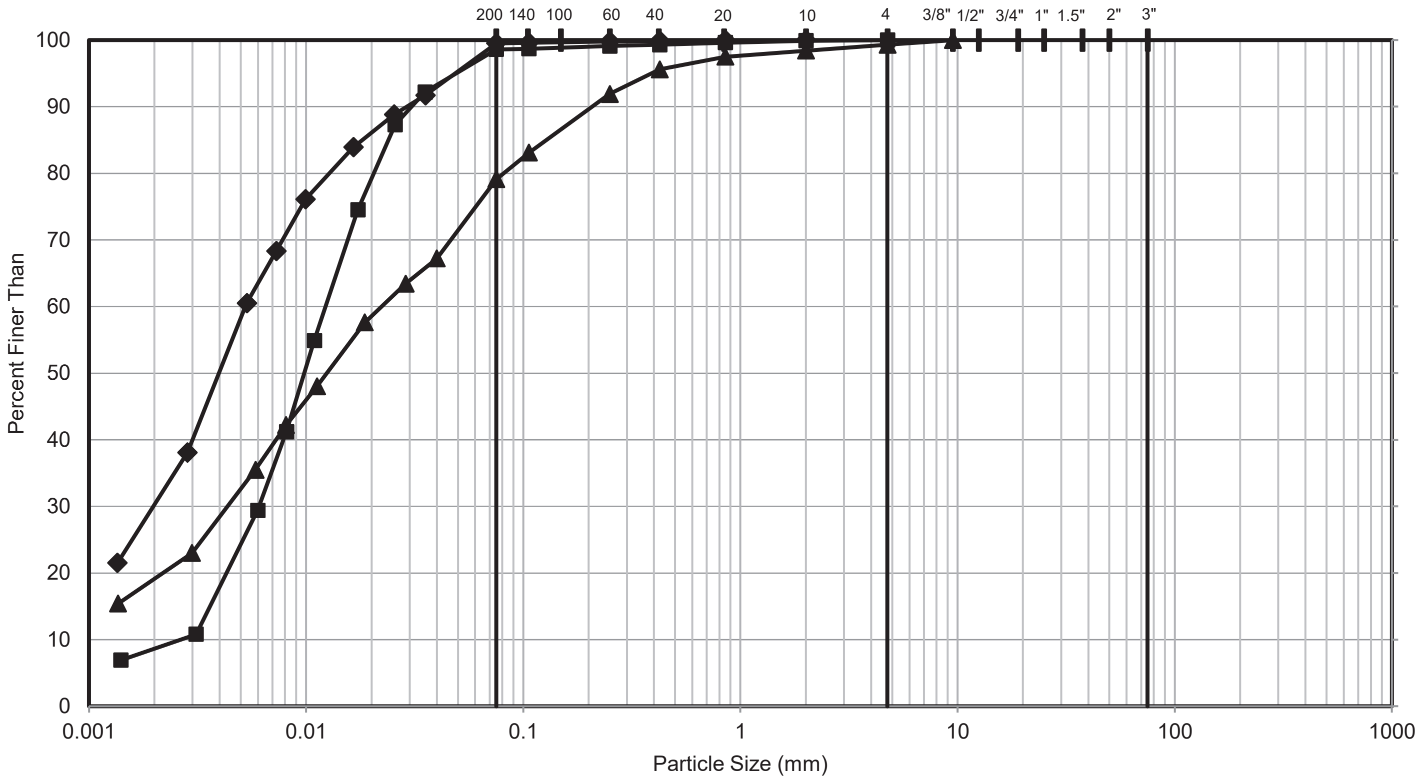
CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE
Plasticity Chart - CLAYEY SILT-SILT (CL-ML) to CLAYEY SILT (CL)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-9

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-02	9	7.6 - 7.9	269.4 to 269.1
◆	DC-02	11	10.7 - 11.0	266.3 to 266.0
▲	DC-01	11	10.7 - 11.0	263.4 to 263.1

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

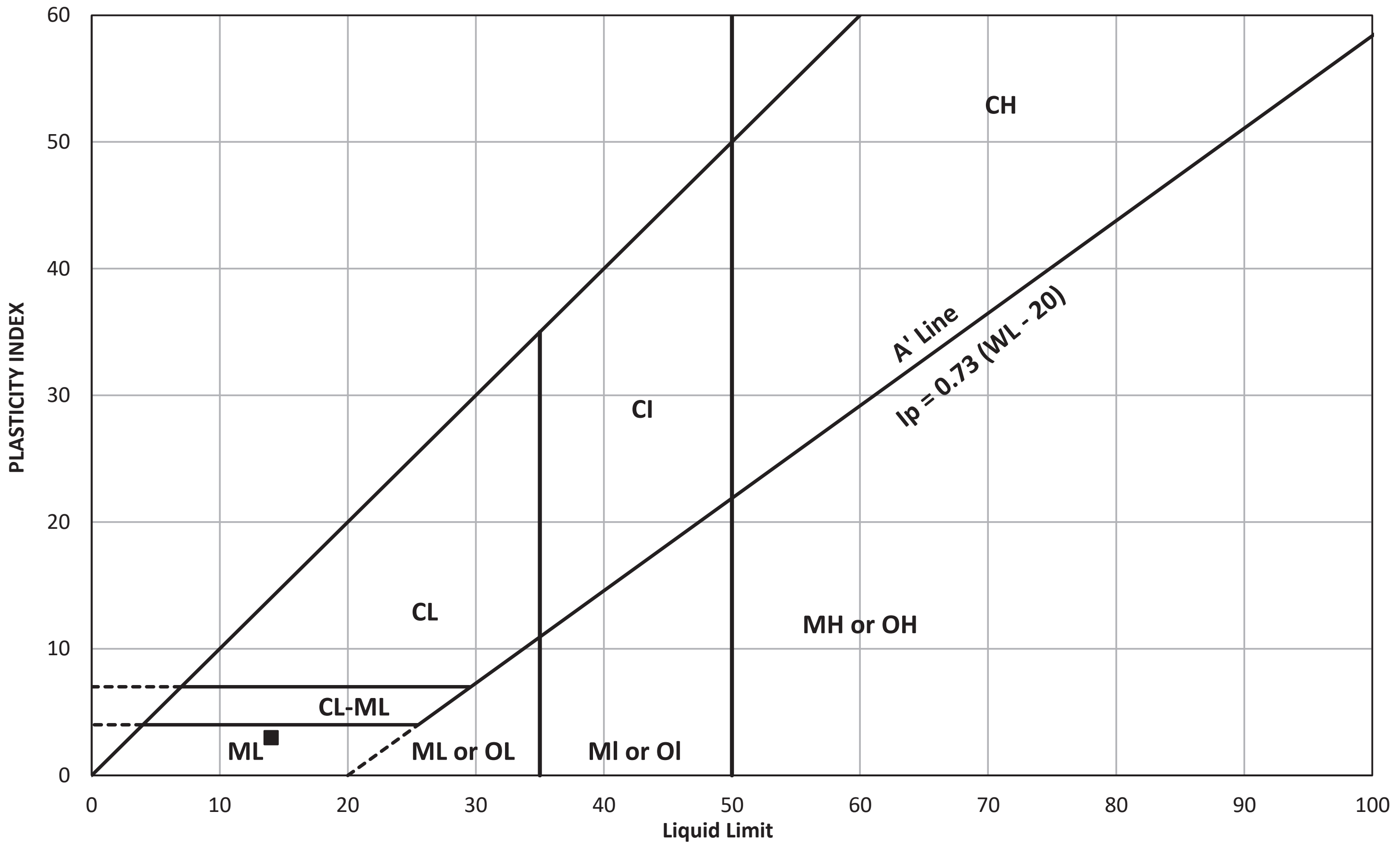
TITLE

Grain Size Distribution - CLAYEY SILT-SILT (CL-ML) to CLAYEY SILT (CL)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-10

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-GSD.xlsm

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-02	14	261.8 to 261.6	15	14	11	3

CLIENT
AECOM / MTO

PROJECT
Bradford Bypass - Deep Cut / High Fill Areas

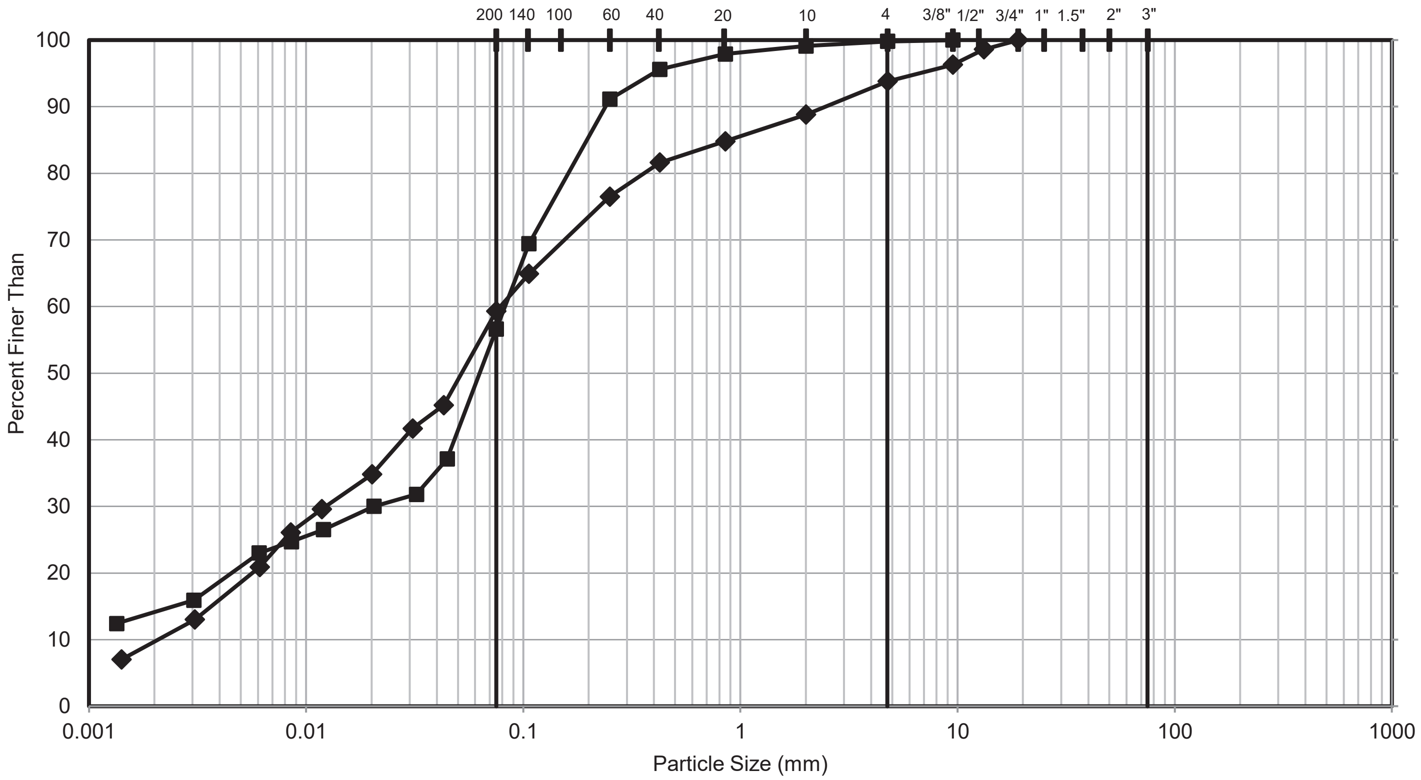
CONSULTANT
wsp

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE
Plasticity Chart - Sandy SILT (ML) to SILT and Sand (ML)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-11

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-01	17	21.3 - 21.5	252.7 to 252.6
◆	DC-02	14	15.2 - 15.4	261.8 to 261.6

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

wsp

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE

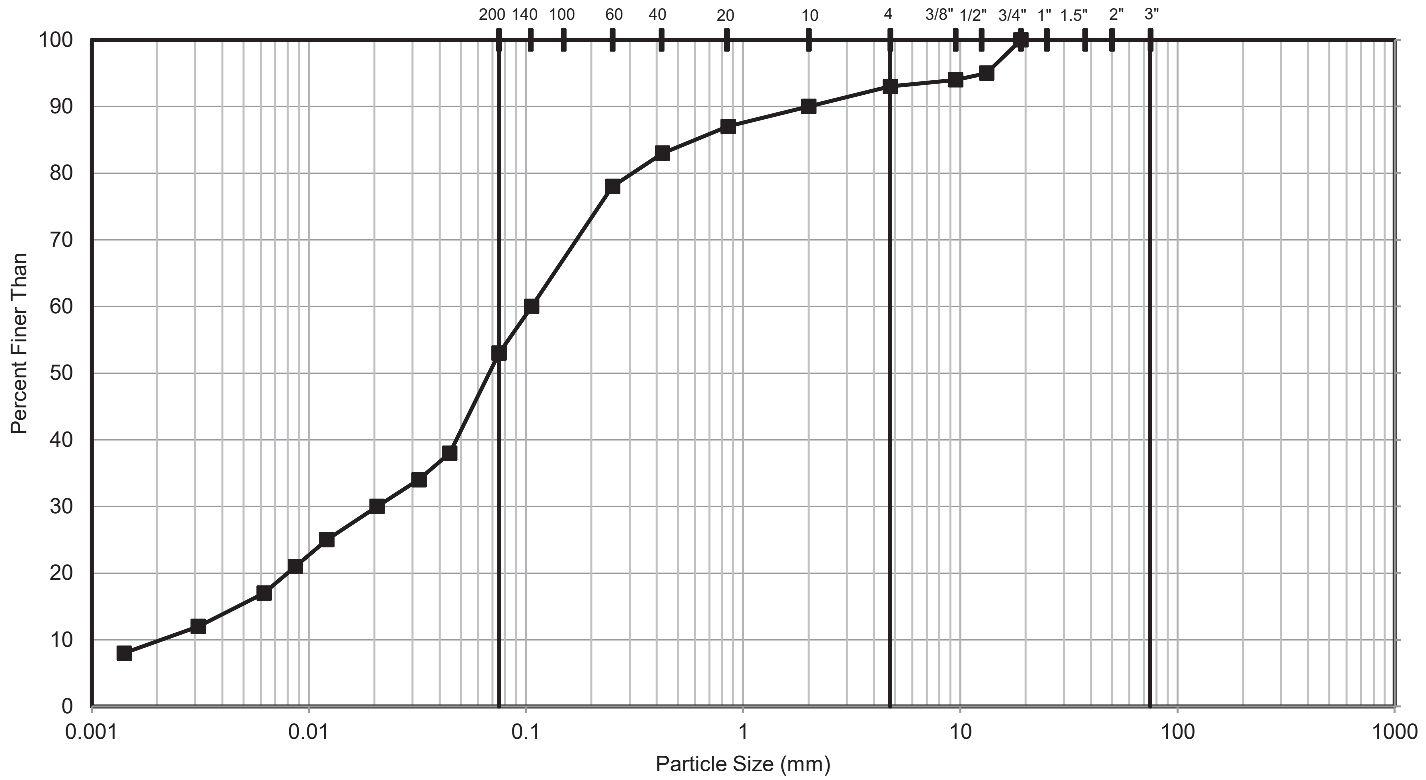
Grain Size Distribution - Sandy SILT (ML) to SILT and Sand (ML)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C1-12

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 1-GSD.xlsm

Deep Cut – Area 2

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-04	3	1.5 - 2.1	257.2 to 256.6

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

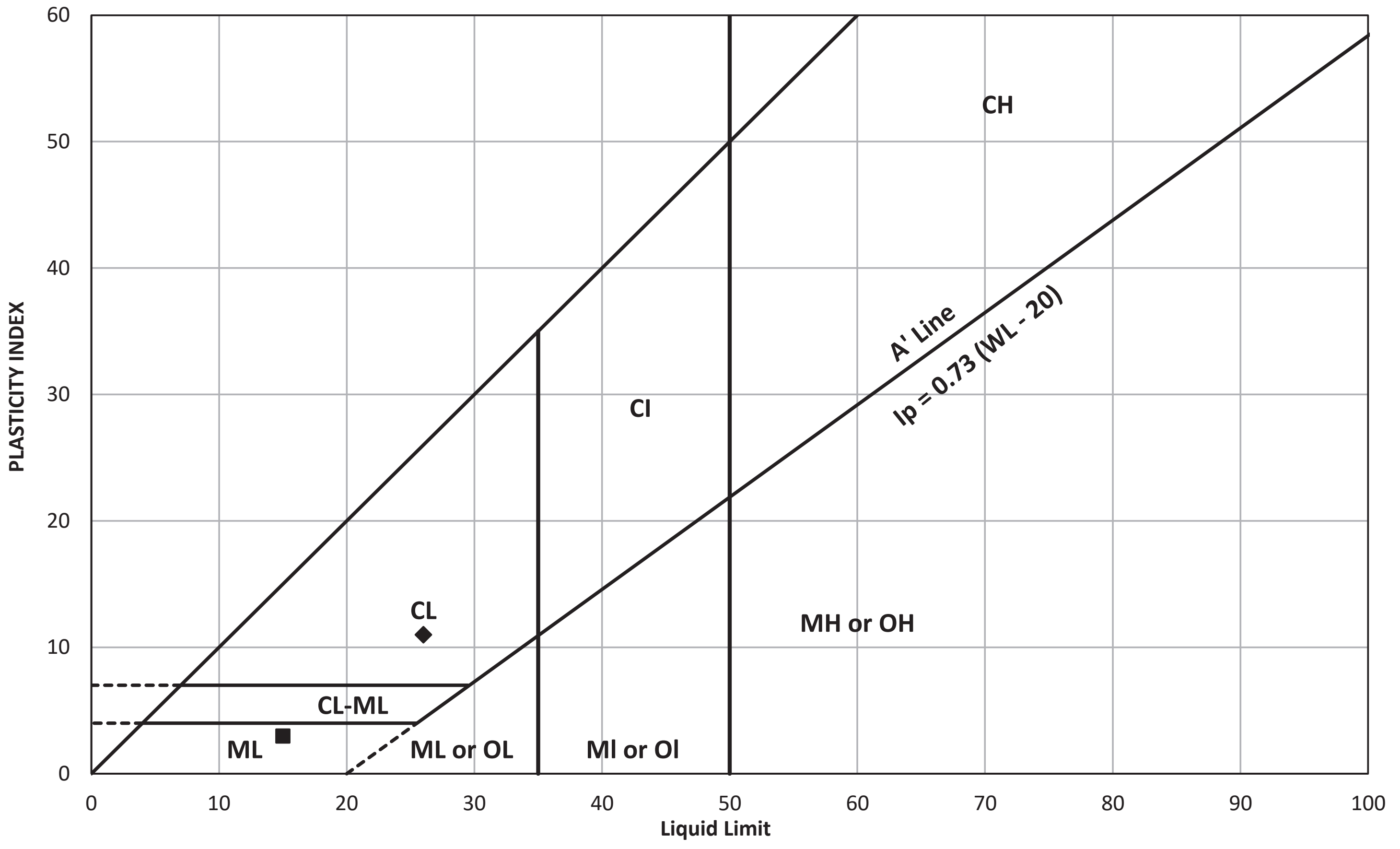
TITLE

Grain Size Distribution - Sandy SILT (ML) - TILL

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C2-1

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 2-GSD.xlsm

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-04	4	256.5 to 255.9	11.6	15	12	3
◆	DC-04	7	254.2 to 253.6	17	26	15	11

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

wsp

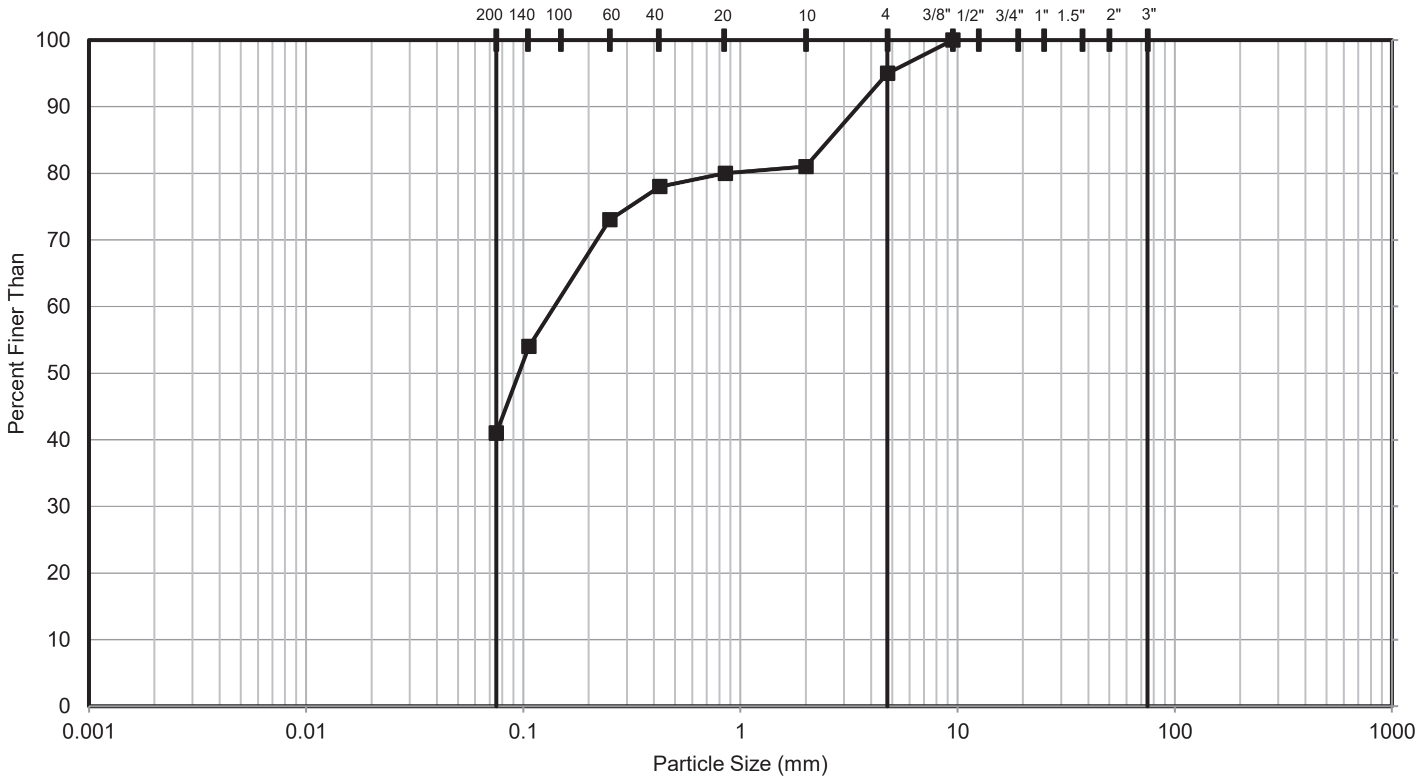
YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE

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

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C2-2

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

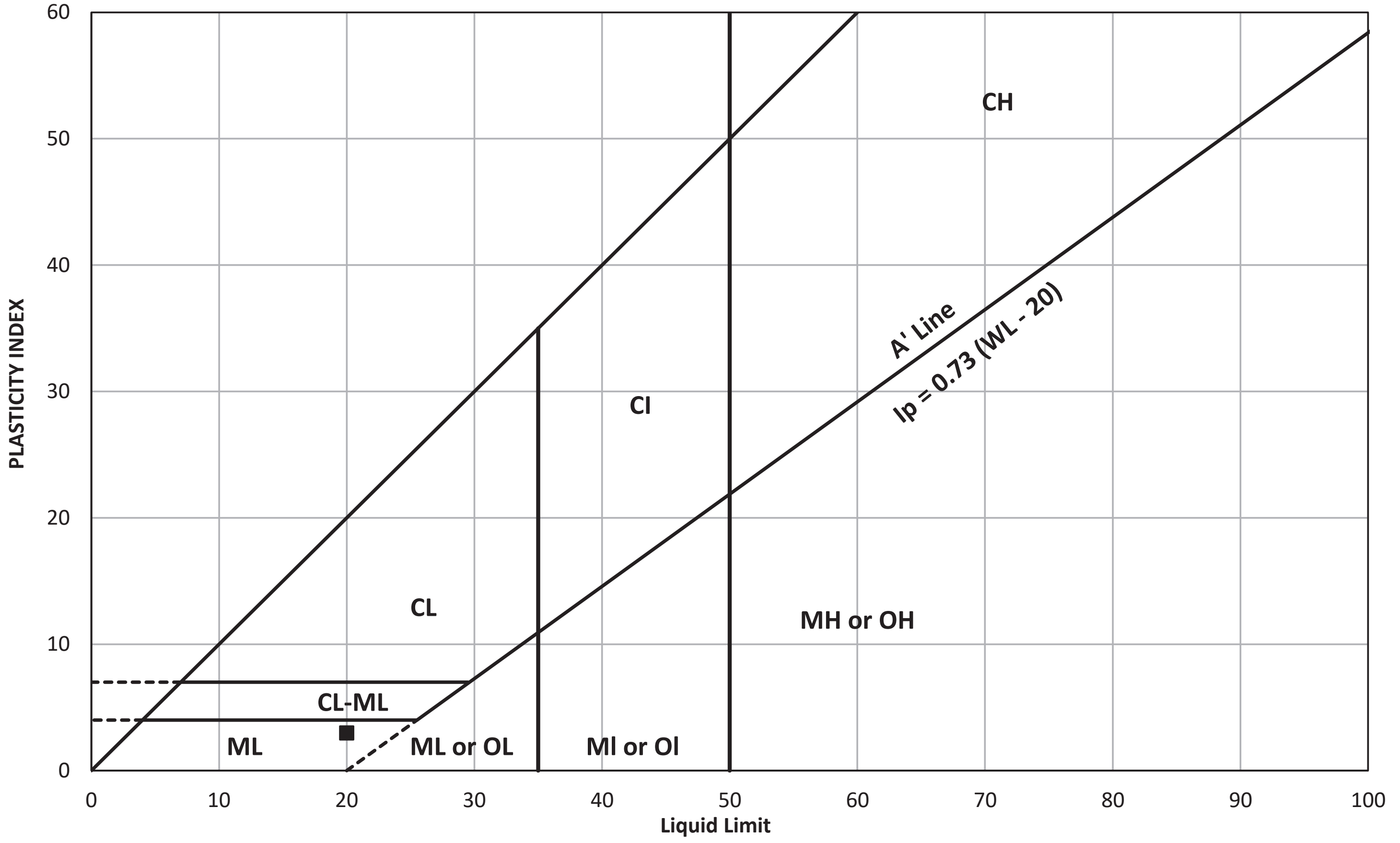
Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-04	8B	6.4 - 6.5	252.4 to 252.3

CLIENT AECOM / MTO	PROJECT Bradford Bypass - Deep Cut / High Fill Areas
CONSULTANT	TITLE Grain Size Distribution - SILTY SAND (SM)

YYYY-MM-DD 2023-12-14
DESIGNED N/A
PREPARED MCK
REVIEWED KJB
APPROVED KJB

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C2-3

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-04	16	240.5 to 240.0	22.5	20	17	3

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

wsp

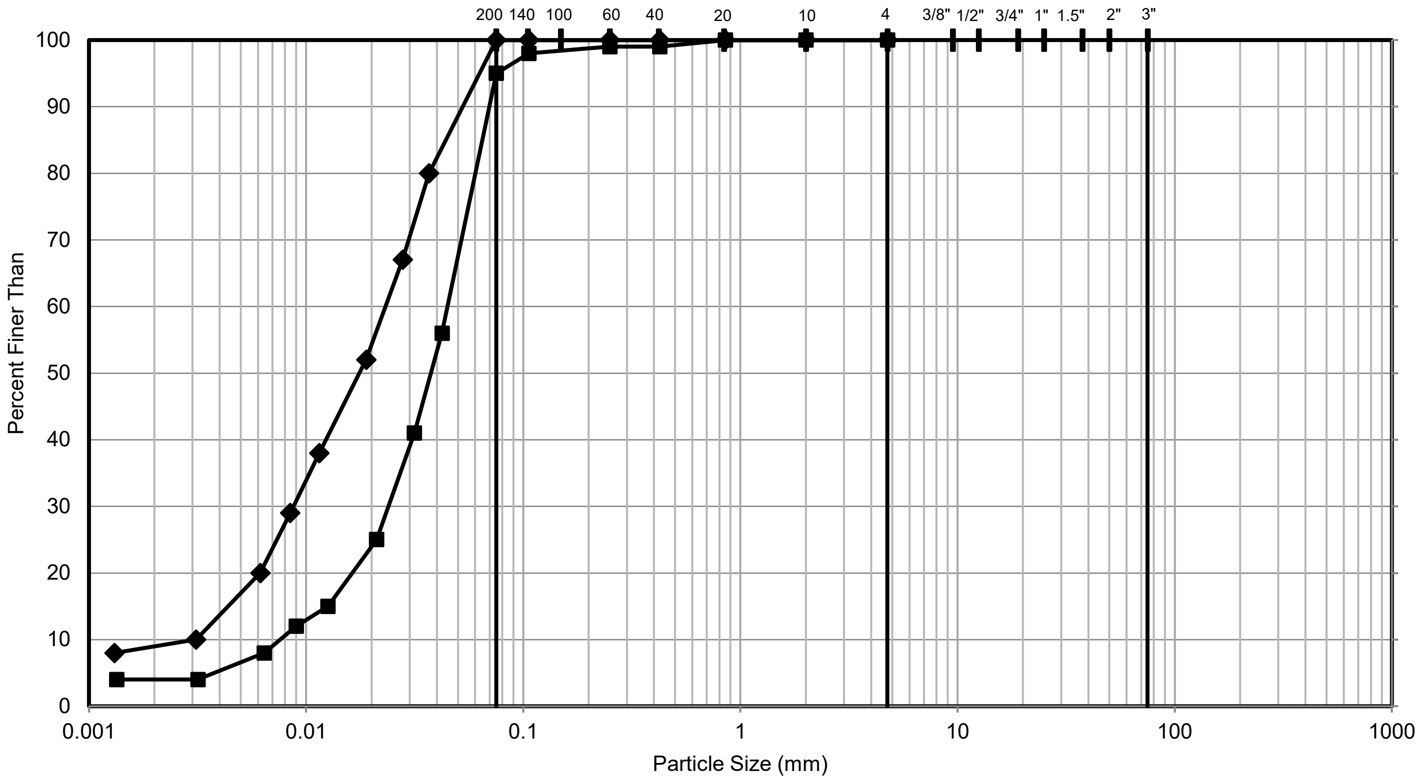
YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE

Plasticity Chart - SILT (ML)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C2-4

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-04	14	15.2 - 15.4	243.5 to 243.4
◆	DC-04	16	18.3 - 18.7	240.5 to 240.0

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

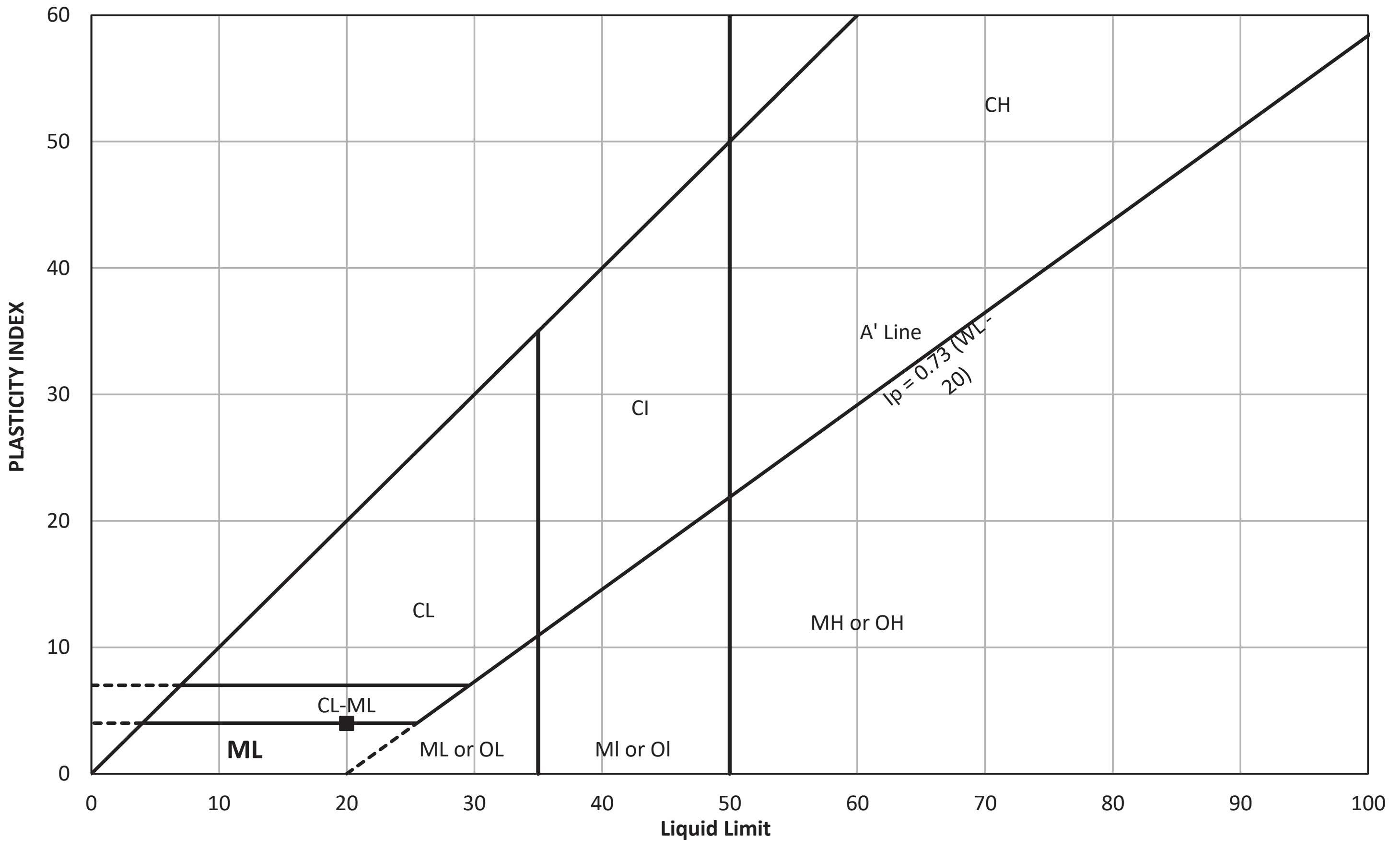
TITLE

Grain Size Distribution - SILT (ML)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C2-5

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 2-GSD.xlsm

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-04	17	239.0 to 238.3	19	20	16	4

CLIENT AECOM / MTO	PROJECT Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

wsp

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

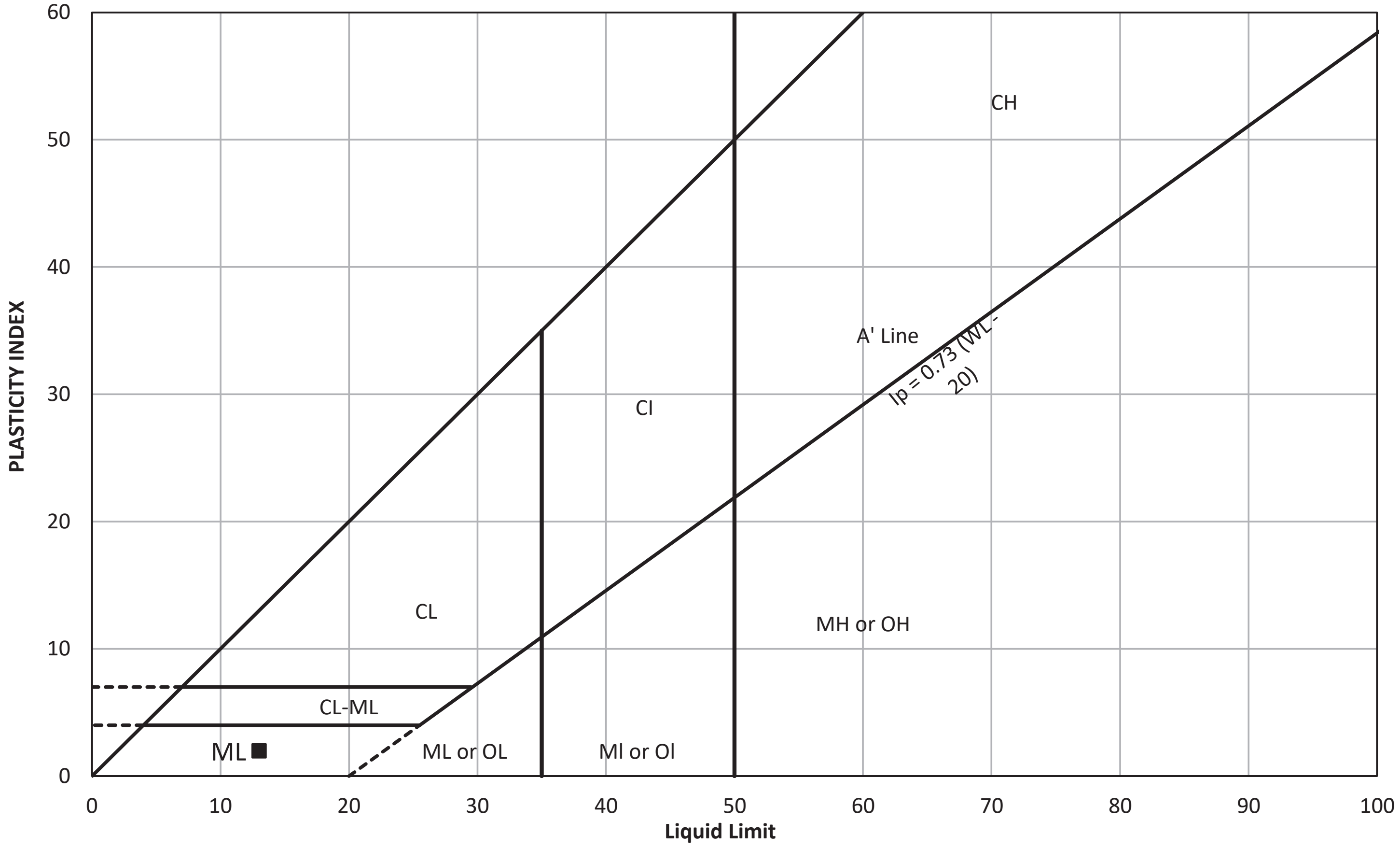
TITLE

Plasticity Chart - CLAYEY SILT-SILT (CL-ML)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C2-6

High Fill – Area 2

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-03	4	221.3 to 220.7	10	13	11	2

CLIENT
AECOM / MTO

PROJECT
Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT
wsp

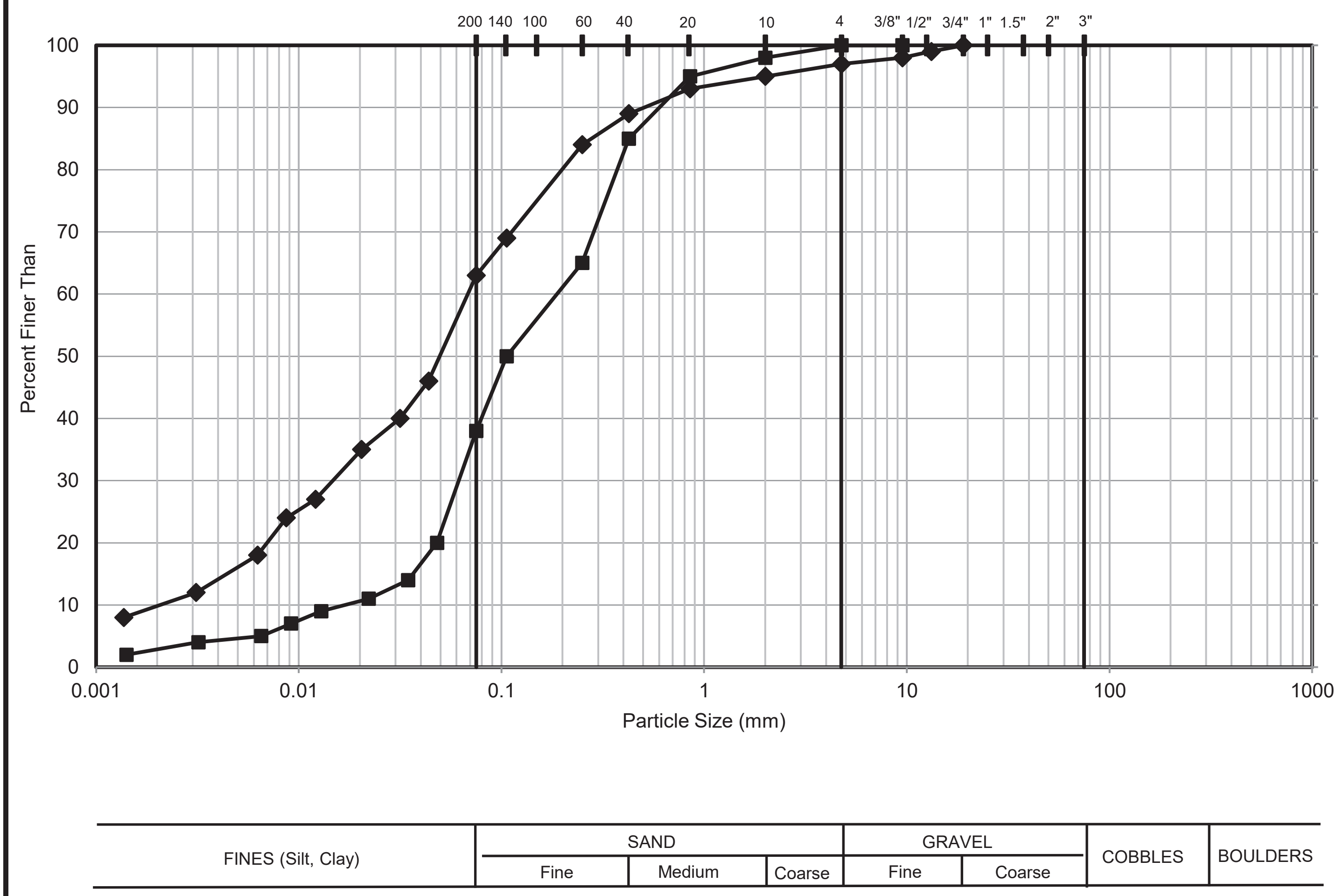
YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE
Plasticity Chart - Sandy SILT (ML)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C3-1

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 2-AL.xlsm

GRAIN SIZE DISTRIBUTION



Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-03	3	1.5 - 2.1	222.1 to 221.5
◆	DC-03	4	2.3 - 2.9	221.3 to 220.7

CLIENT
AECOM / MTO

PROJECT
Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

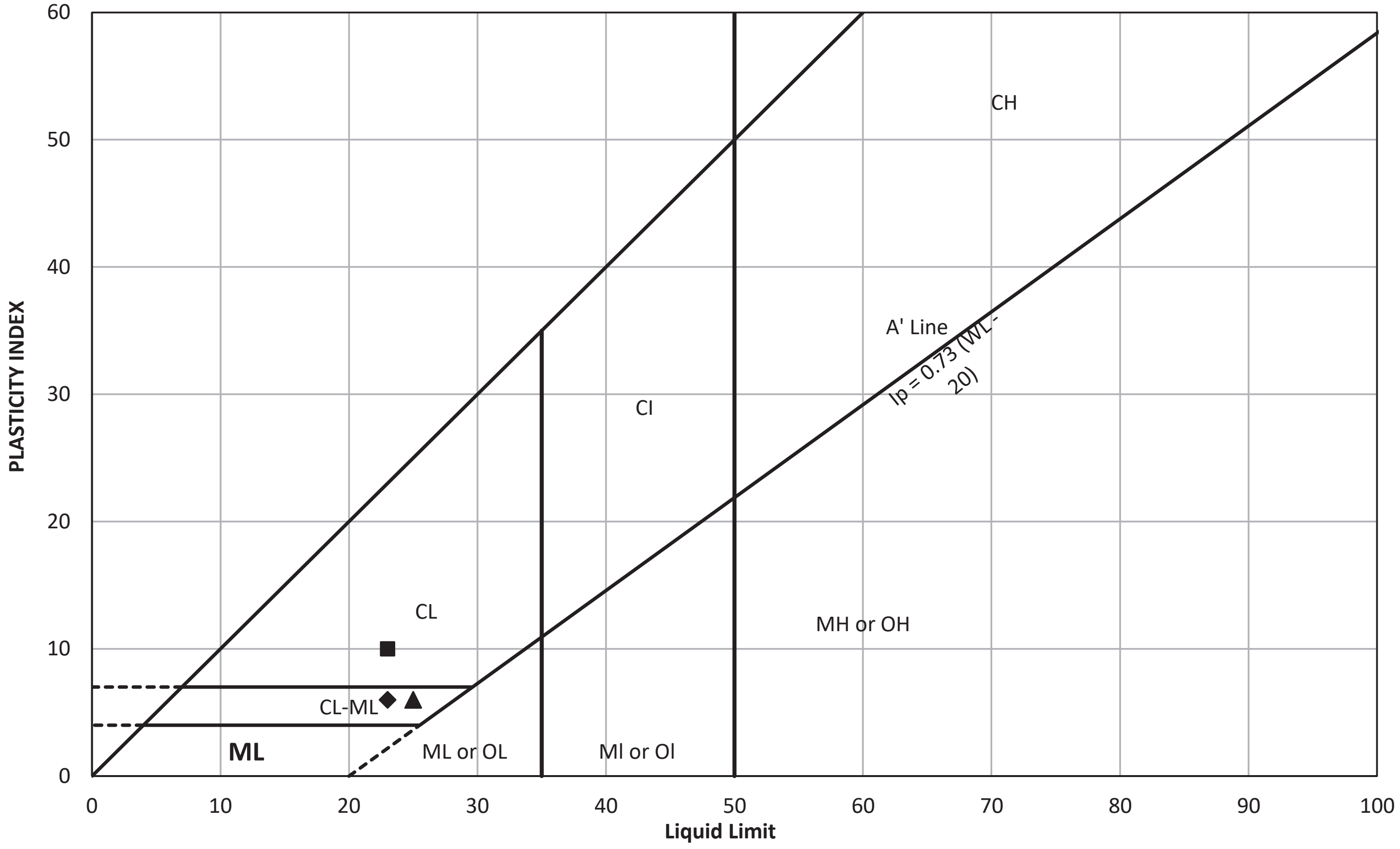
YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE
Grain Size Distribution - Sandy SILT (ML) to SILTY SAND (SM)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C3-2

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 2-GSD.xlsm

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-03	7	219.0 to 218.5	11.3	23	13	10
◆	DC-03	14	208.4 to 207.8	21.8	23	17	6
▲	DC-03	17	203.8 to 203.2	23.1	25	19	6

CLIENT
AECOM / MTO

PROJECT
Bradford Bypass - Deep Cut / High Fill Areas

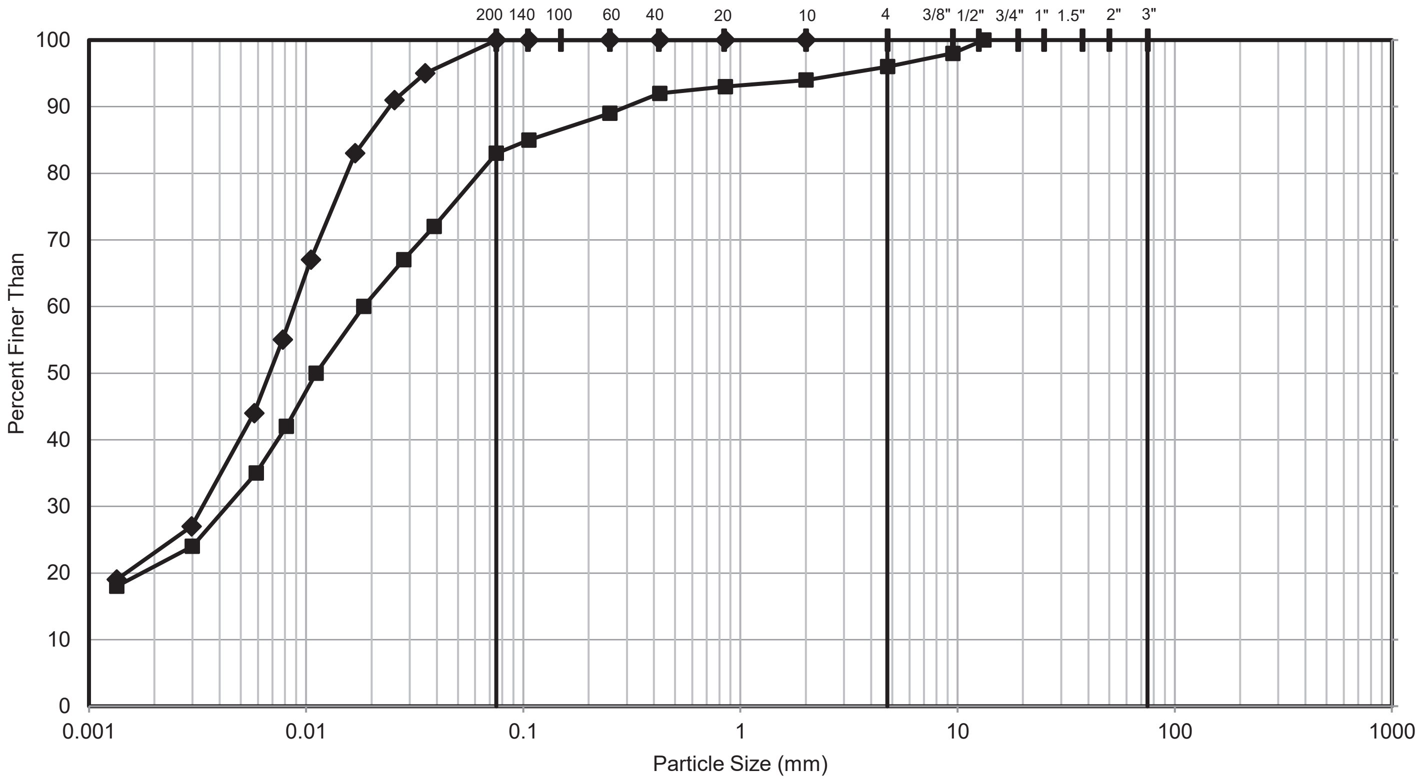
CONSULTANT
wsp

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE
Plasticity Chart - CLAYEY SILT-SILT (CL-ML) to CLAYEY SILT (CL)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C3-3

GRAIN SIZE DISTRIBUTION



FINES (Silt, Clay)	SAND			GRAVEL		COBBLES	BOULDERS
	Fine	Medium	Coarse	Fine	Coarse		

Symbol	Sample Location	Sample Number	Depth (m)	Elevation (m)
■	DC-03	7	4.6 - 5.2	219.0 to 218.5
◆	DC-03	14	15.2 - 15.9	208.4 to 207.8

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

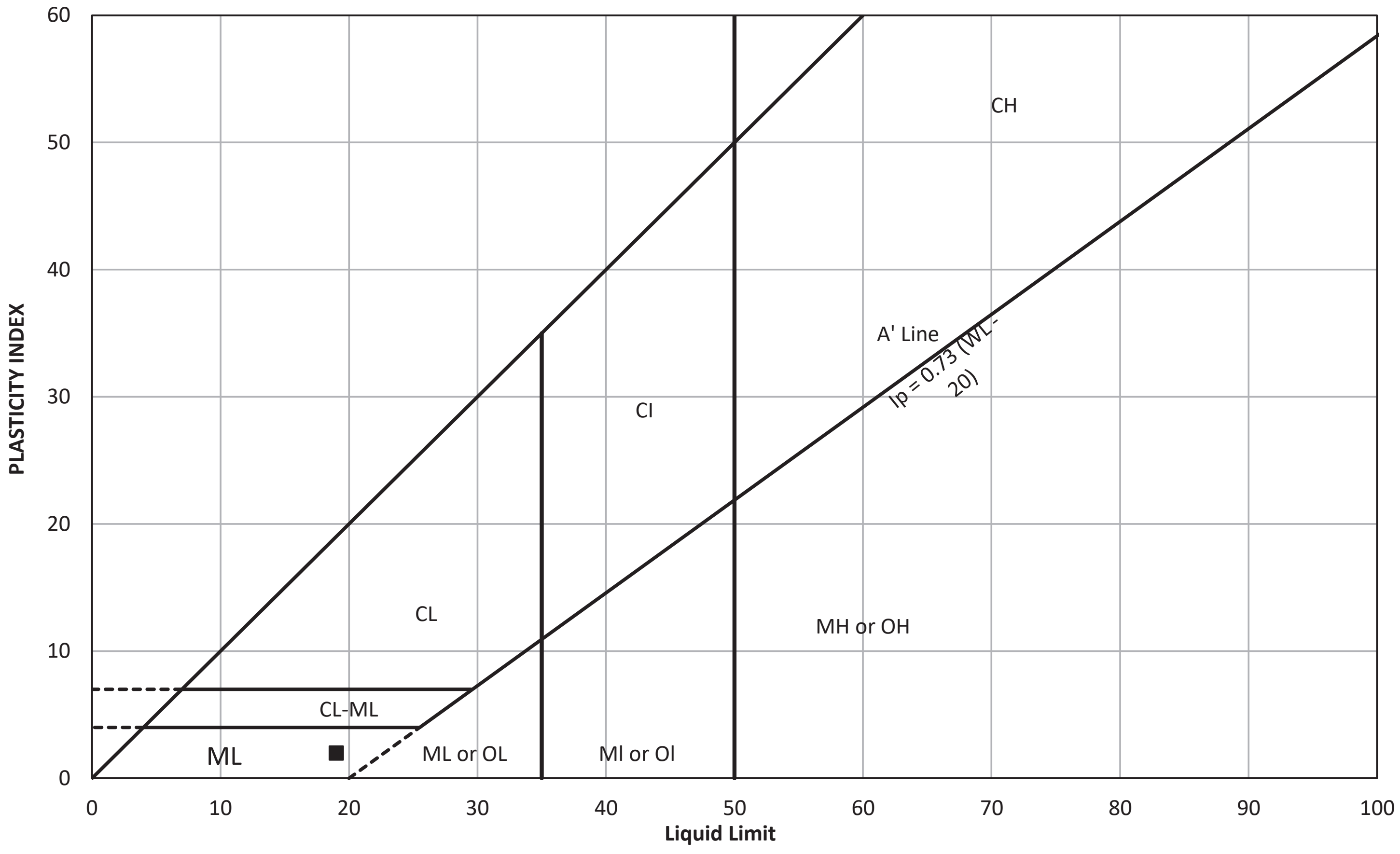
TITLE

Grain Size Distribution - CLAYEY SILT-SILT (CL-ML) to CLAYEY SILT (CL)

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C3-4

PATH: https://golderassociates.sharepoint.com/sites/120387/Project Files/6 Deliverables/Foundations/Deep Cuts/Appendix C - Lab Testing | FILE NAME: Deepcut-Area 2-GSD.xlsm

PLASTICITY CHART



Symbol	Sample Location	Sample / Specimen Number	Elevation (m)	Natural Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
■	DC-03	10	214.5 to 213.9	19.6	19	17	2

CLIENT

AECOM / MTO

PROJECT

Bradford Bypass - Deep Cut / High Fill Areas

CONSULTANT

wsp

YYYY-MM-DD	2023-12-14
DESIGNED	N/A
PREPARED	MCK
REVIEWED	KJB
APPROVED	KJB

TITLE

Plasticity Chart - SILT (ML) - Interlayer

PROJECT NO.	CONTROL	REV.	FIGURE
19136074	1000	0	C3-5

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