



Foundation Investigation and Design Report

VARIOUS CREEK CULVERT EXTENSIONS, HIGHWAY 3 WIDENING AND SAFETY ENHANCEMENTS 1.2 KM EAST OF ESSEX COUNTY ROAD 23 TO 1.1 KM EAST OF ESSEX COUNTY ROAD 34, TOWNSHIPS OF GOSFIELD NORTH / GOSFIELD SOUTH, DISTRICT OF CHATHAM, TOWN OF KINGSVILLE, ESSEX COUNTY, ONTARIO, MINISTRY OF TRANSPORTATION, ONTARIO, GWP 3021-18-00

**SITE NO.: 06X-0420/C0, 06X-0421/C0, 06X-0422/C0, 06X-0423/C0
06X-0426/C0, 06X-0427/C0, 06X-0429/C0, 06X-0432/C0**

Site NO.	Latitude	Longitude
06X-0420/C0	42.141773	-82.789997
06X-0421/C0	42.129369	-82.770415
06X-0422/C0	42.128920	-82.770742
06X-0423/C0	42.127865	-82.768205
06X-0426/C0	42.119725	-82.756535
06X-0427/C0	42.114946	-82.751028
06X-0429/C0	42.101778	-82.736576
06X-0432/C0	42.090308	-82.723864

13 January 2021

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Part A

FOUNDATION INVESTIGATION REPORT

**CULVERT EXTENSIONS AND REPLACEMENT, HIGHWAY 3 WIDENING AND SAFETY
ENHANCEMENTS – WINDSOR TO LEAMINGTON, ONTARIO
MTO, GWP 3021-18-00**

**SITE NOs: 06X-0420/C0, 06X-0421/C0, 06X-0422/C0, 06X-0423/C0
06X-0426/C0, 06X-0427/C0, 06X-0429/C0, 06X-0432/C0**

1. Introduction

GHD Limited (GHD) was retained by the Ministry of Transportation, Ontario (MTO) to provide preliminary and design-build ready foundation engineering services for extension/replacement of eight culverts between Essex Road 23 and Essex Road 34 in the Town of Kingsville, County of Essex, Ontario. The location of the culverts is shown on the Key Plan on Drawing 1. The list of culverts with the corresponding site numbers, and the approximate culvert location and stationing are summarized in Table 1.

Table 1 *List of Culvert Structures*

Culvert No.	Approximate Station (m)	Road/Highway
06X-0420/C0	12+500	Concession Road 9
06X-0421/C0	14+625	Highway 3
06X-0422/C0	14+650	Concession Road 8
06X-0423/C0	14+870	Highway 3
06X-0426/C0	16+170	Highway 3
06X-0427/C0	16+900	Highway 3
06X-0429/C0	10+015	Highway 3
06X-0432/C0	11+661	Highway 3

Note: * Culvert No. 06X-0426/C0 will be relocated 25 m to the east, with a replacement length of 63.2 m.

The purpose of this investigation is to establish the subsurface soil and groundwater conditions at the proposed culvert extensions/replacement by borehole drilling and geotechnical and analytical laboratory testing on selected soil samples.

The Terms of Reference (TOR) and the scope of work for this project are identified within the agreement of services as amended between MTO and GHD for Consultant's Assignment Number 3017-E-0012. The work has been carried out in accordance with the requirements of *Guideline for Foundation Engineering Services, Version 2.0, October 2020*, prepared by the MTO.

2. Site Description

The culvert sites addressed in this report are located from about Concession Road 9 to about 1,200 m east of Essex Road 29 (Division Road) along either Highway 3 or intersecting Concession Roads 8 and 9, in the Township of Gosfield North, Ontario. Detailed below is a general description of the location of each culvert:

- Culvert No. 06X-0420/C0 is located on Concession Road 9, about 50 m south of the intersection with Highway 3.
- Culvert No. 06X-0421/C0 is located just west of the intersection between Highway 3 and Concession Road 8.
- Culvert No. 06X-0422/C0 is located on Concession Road 8, about 80 m south of the intersection between Highway 3 and Concession Road 8.
- Culvert No. 06X-0423/C0 is located approximately 220 m east of the intersection between Highway 3 and Concession Road 8.
- Culverts Nos. 06X-0426/C0, 06X-0427/C0 and 06X-0429/C0 are located between Essex Road 27 (Belle River Road) and Essex Road 29 (Division Road); and,

- Culvert No. 06X-0432/C0 is located about 600 m east of the intersection between Highway 3 and Essex Road 29 (Division Road).

The water in the culvert flows from north to south, with the exception of Culvert Nos. 06X-0427/C0 and 06X-0429/C0 where the water in the culvert flows to the west.

Highway 3 in the area serves as a regional corridor and major collector, connecting small rural and urban communities with Windsor and the United States. It is a two-lane road aligned mostly in the northwest-southeast direction. The culverts are situated in a rural-setting environment with generally a flat landscape. Land in the surroundings of the structures is used mainly for agricultural purposes and related farm facilities. There are few residential buildings immediately south of Culvert No. 06X-0429/C0 along Concession Road 6 and further north along Essex Road 29 (Division Road). A greenhouse structure and associated facilities also exist immediately south of the Culvert No. 06X-0432/C0.

The embankment slopes on culverts were covered by grass or other vegetation and observed to be stable, with no signs of erosion at most culvert locations. Signs of minor erosion at the toe of the embankment slopes was observed at the location of Culvert Nos. 06X-0422/C0 and 06X-0426/C0. General site and culvert conditions are shown in photographs (i.e., Photographs 1 to 16) presented in Appendix A.

3. Investigation Procedures

The geotechnical fieldwork for this investigation was carried out in two phases. Between April 27 and May 19, 2020 sixteen boreholes numbered as BH-20-01 to BH-16-20 (two boreholes at each structure), were advanced to depths between 9.8 m and 11.3 m below existing grade. The boreholes were advanced either, near or at the shoulder of the road and near the proposed south culvert extensions. The boreholes were advanced using a Diedrich D-50 track-mounted drill rig, equipped with continuous flight, solid stem augers supplied and operated by Altech Drilling and Investigative Services of Cambridge, Ontario.

Between October 4 and November 11, 2021, six boreholes (numbered BH-21-01 to BH-21-06, inclusive) were advanced at the location of Culvert Nos. 06X-0423/C0, 06X-0426/C0, 06X-0427/C0, 06X-0429/C0, 06X-0432/C0 to depths of between 11.3 m and 15.8 m below existing grade, near the end of the proposed north extensions. The boreholes were advanced using either a Diedrich D-50 track-mounted drill rig (for Boreholes BH-21-01, BH-21-03, and BH-21-06) or a truck-mounted drilling rig (for the remaining boreholes), equipped with hollow stem augers, supplied and operated by Direct Environmental Drilling Inc. of London, Ontario.

A summary of the field program including the borehole location, depth and termination elevation of the borehole is presented in Table 2. The location of the boreholes advanced at the culvert sites are shown on Drawings 2 to 9.

Table 2 *Summary of the Borehole Program*

Culvert Number	Borehole Number	Location	Location (MTM NAD 83, ZONE 11)		Borehole Depth (m)	Ground Surface Elevation (m)
			Northing (m) (Latitude, °)	Easting (m) (Longitude, °)		
06X-0420/C0	BH-20-01	NBL Shoulder of Concession Rd 9	4,666,959.4 (42.141783)	280,836.9 (-82.789905)	9.8	194.8
	BH-20-02	Near the east end of proposed culvert	4,666,946.7 (42.141670)	280,856.9 (-82.789663)	9.8	194.3
06X-0421/C0	BH-20-03	EBL Shoulder	4,665,573.4 (42.129352)	282,433.8 (-82.770533)	9.8	195.3

Culvert Number	Borehole Number	Location	Location (MTM NAD 83, ZONE 11)		Borehole Depth (m)	Ground Surface Elevation (m)
			Northing (m) (Latitude, °)	Easting (m) (Longitude, °)		
	BH-20-04	Near the south end of proposed culvert	4,665,539.7 (42.129048)	282,422.5 (-82.770669)	9.8	194.9
06X-0422/C0	BH-20-05	NBL Shoulder of Concession Rd 5	4,665,516.3 (42.128837)	282,413.7 (-82.770774)	9.8	194.5
	BH-20-06	Near the east end of proposed culvert	4,665,505.6 (42.128742)	282,445.9 (-82.770385)	9.8	194.4
06X-0423/C0	BH-20-07	EBL shoulder	4,665,404.5 (42.127837)	282,622.8 (-82.768241)	9.8	195.5
	BH-20-08	Near the south end of proposed culvert	4,665,399.6 (42.127792)	282,581.1 (-82.768745)	9.8	194.3
	BH- 21-01	Near the north end of proposed culvert	4,665,407.5 (42.127864)	282,642.3 (-82.768005)	13.6	194.9
06X-0426/C0	BH-20-09	EBL shoulder/original culvert location	4,664,521.8 (42.119915)	283,565.9 (-82.756802)	9.8	195.1
	BH-20-10	Near the south end of original culvert location	4,664,494.3 (42.119667)	283,549.3 (-82.757001)	11.3	193.3
	BH-21-02	Near the north end of proposed culvert	4,664,509.0 (42.119801)	283,607.0 (-82.756304)	15.8	195.7
06X-0427/C0	BH-20-11	EBL shoulder	4,663,965.9 (42.114922)	284,035.9 (-82.751097)	9.8	195.1
	BH-20-12	Near the south end of proposed culvert	4,663,975.9 (42.115011)	283,998.7 (-82.751668)	9.8	194.6
	BH-21-03	Near the north end of proposed culvert	4,663,959.4 (42.114864)	284,063.5 (-82.750763)	15.7	194.8
06X-0429/C0	BH-20-13	EBL shoulder	4,662,508.6 (42.101832)	285,219.3 (-82.736739)	9.8	195.3
	BH-20-14	Near the south end of proposed culvert	4,662,500.5 (42.101758)	285,185.7 (-82.737144)	11.3	194.7
	BH-21-04	Near the north end of proposed culvert	4,662,509.5 (42.101840)	285,243.3 (-82.736448)	15.8	195.0
	BH-21-05	Near the north end of proposed culvert	4,662,493.4 (42.101695)	285,254.3 (-82.736315)	15.8	195.3
06X-0432/C0	BH-20-15	EBL shoulder	4,661,218.0 (42.090237)	286,277.2 (-82.723907)	9.8	195.9
	BH-20-16	Near the south end of proposed culvert	4,661,205.3 (42.090123)	286,250.4 (-82.724231)	9.8	194.6
	BH-21-06	Near the north end of proposed culvert	4,661,226.8 (42.090317)	286,296.1 (-82.723679)	11.3	196.0

Prior to the start of the fieldwork, utility clearance procedures were implemented through Ontario One Call protocol, and fieldwork notification was sent to MTO West Region. Culvert No. 06X-0422/C0 is located on

Concession Road 8 and a road occupancy permit was obtained from the Town of Kingsville as the culvert is located beyond the limits of the MTO Right of Way (ROW). A project specific Health and Safety as well as Traffic Protection Plans were prepared before commencement of the fieldwork. In addition, the borehole locations were marked by GHD staff prior to drilling. All drilling activity, soil sampling and logging, and backfilling of boreholes were conducted under the full-time supervision of an experienced GHD geotechnical engineer.

Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using a 50 mm outer-diameter split-spoon sampler driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedures described in ASTM D1586¹. Where firm to stiff cohesive deposits were encountered, in-situ field vane shear tests were carried out using an MTO 'N'-size vane to assess the strength characteristics of these soils in accordance with ASTM D2573². In addition, relatively undisturbed samples were obtained using 76 mm outer diameter thin-walled Shelby tube (ASTM D1587)³. Soil samples obtained from the boreholes were inspected in the field immediately upon retrieval for type, texture, and color. All retrieved samples from the first phase of investigation were sealed in clean plastic bags and transported to the GHD laboratory in Whitby and Waterloo for further visual examination, and geotechnical laboratory tests.

Groundwater condition and water levels in the open boreholes were observed during drilling by visual examination of soil samples and drill rods as well as immediately following drill operations. Three monitoring wells were installed in Boreholes BH-21-01, BH-21-03 and BH-21-06 to permit monitoring of the groundwater level at the location of Culvert Nos. 06X-0423/C0, 06X-0427/C0, and 806X-0432/C0, respectively. The monitoring wells consist of 50 mm diameter PVC pipe with a slotted screen that was sealed above the screen. The borehole annulus surrounding the monitoring well was backfilled with sand and the remainder of the borehole was then backfilled with bentonite to or near the ground surface. Details of the monitoring well installation and water level readings are presented on the borehole records in Appendix B. The boreholes without monitoring wells were backfilled with bentonite and sealed at the top with compacted auger cuttings, in accordance with Ontario Regulation 903, (as amended).

Classification testing (i.e., water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. In addition, two one-dimensional consolidation (oedometer) tests were carried out in GHD Waterloo laboratory on selected samples of the cohesive deposit from the Shelby tube samples. All laboratory tests were conducted in accordance with MTO and/or American Society for Testing Materials (ASTM) standards, as appropriate.

In addition, one soil sample collected during the first phase of investigation from each culvert site and five samples from the second phase of investigation were submitted for analysis of a suite of parameters, including conductivity, resistivity, soluble chloride concentration, soluble sulphate concentration and pH. These samples were sent to Caduceon Environmental Laboratories (Caduceon) of Richmond Hill, Ontario for the first phase of investigation and to ALS Environmental Laboratory of Waterloo, Ontario for the second phase of investigation.

Surveying of the as-drilled borehole locations was conducted by Callon Dietz Inc. (Callon Dietz) of London, Ontario, subcontracted to GHD. Callon Dietz provided northing and easting in MTM NAD 83 (Zone 11) coordinates. The coordinates shown on borehole logs and any part of this report correspond to these northings and eastings. The ground surface elevations are referenced to Geodetic datum. The coordinates and ground surface elevation are presented in Table 2, on the borehole records and on Drawings 2 to 9.

¹ ASTM D1586-08a – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the soil.

² ASTM D2573-15 Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils

³ ASTM D1587 - Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes

4. Physiography and Regional Geology

The culvert structures are located within the Essex Clay Plain region, which is a subdivision of the St. Clair Clay Plain, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)⁴. The plain is a broad area of low relief and poor natural drainage. It comprised of silt-clay soils and extends on both sides of the St. Clair/Detroit River system from Lake Huron to Lake Erie, and encompasses nearly all of Essex County. The Essex County area underwent at least four cycles of glaciations during the Quaternary Period, although only deposits of the most recent Wisconsinan age are recognized in Essex County (Chapman and Putnam, 1984). The surface geology is characterized by a clay plain with localized veneers of fine sand. This clay plain consists of a glaciolacustrine deposit made up of silty clay to clayey silt materials of less than 10 m in thickness. The glaciolacustrine deposits are underlain by a thicker glacial till. A thin layer of discontinuous sand and silt locally separates the glaciolacustrine deposit from the glacial till. Sand layers also occur sporadically within the till deposit. Throughout the Essex Clay Plain, the sand and clay soils together extend to a depth of 30 m to 60 m before encountering a bedrock (Chapman and Putnam, 1984).

The rock units in the area are sedimentary rocks consisting of limestone, dolostone and shale of the Michigan Basin sequence belonging to the Dundee Formation and Detroit River Group.

5. Subsurface Conditions

Details of the subsurface and groundwater conditions at each culvert location as encountered in the boreholes advanced during the investigation, the details of the monitoring well installations and the summary of the geotechnical laboratory testing are presented on the Records of Borehole provided in Appendix B. The *Notes on Borehole and Test Pit Reports* are also included in Appendix B to assist in the interpretation of the borehole records. The results of the geotechnical laboratory testing are contained in Appendix C. The results of in-situ field tests (i.e., SPT “N” values), as presented on the borehole records and in the sub-sections of Section 5 are uncorrected.

The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling, observations of drilling progress and the results of the Standard Penetration Tests and in-situ vane shear tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations; however, the factual data presented in the borehole records governs any interpretation of the site conditions. It should be noted that the interpreted stratigraphy shown on Drawings 2 to 8 is a simplification of the subsurface conditions.

A more detailed description of the subsurface conditions encountered in the boreholes advanced near each culvert location is provided in the following subsections.

5.1 Culvert No. 06X-0420/C0

The fieldwork for the foundation investigation at Culvert No. 06X-0420/C0 consisted of Boreholes BH-20-01 and BH-20-02 advanced at the shoulder of Concession Road 9 and near the end of the proposed culvert extension, respectively (see Drawing 2).

⁴ Chapman, L.J. and Putman, D.F., 1984, *The Physiography of Southern Ontario*, Ontario Geological Society, Special Volume 2, Third Edition. Accompanied by Map p. 2715, Scale 1:600,000.)

In summary, the subsurface conditions at borehole locations consist of a surficial layer of topsoil or fill material underlain by a cohesive till deposit extending to the maximum depth of investigation at 9.8 m below ground surface (Elevation 184.5 m).

5.1.1 Topsoil

A 0.3 m thick layer of topsoil was encountered in Borehole BH-20-02. The topsoil was dark brown to black in color, moist to wet, and was generally clayey silt in texture and contains traces of sand, gravel and rootlets.

5.1.2 Fill

A 0.7 m thick layer of granular fill consisting of sand and gravel, some silt was encountered in Borehole BH-20-01, immediately below the ground surface.

The Standard Penetration Test (SPT) “N” value recorded within the fill was 23 blows per 0.3 m of penetration, indicating a compact compactness condition.

The water content measured on a sample of the fill was 9 per cent.

5.1.3 Clayey Silt to Silty Clay (Till)

A cohesive till deposit consisting of an upper silty clay layer underlain by clayey silt, some sand and trace gravel, was encountered beneath the fill material in Borehole BH-20-01 and beneath the topsoil in Borehole BH-20-02 at depths of 0.3 m and 0.7 m below ground surface, respectively. Boreholes BH-20-01 and BH-20-02 terminated in the till deposit at a depth of 9.8 m below ground surface (Elevations 185.0 m and 184.5 m), respectively. Within samples of the cohesive till deposit discontinuous 0.1 m thick layers of fine sand and silt were observed.

The SPT “N” values recorded within the cohesive till deposit range from 7 blows to 30 blows per 0.3 m of penetration, suggesting a firm to hard consistency.

Atterberg limits tests were carried out on five samples of cohesive till deposit and measured liquid limits between about 31 per cent and 46 per cent, plastic limits between about 16 per cent and 20 per cent, and plasticity indices between about 15 per cent and 26 per cent. The higher plasticity results were measured in the silty clay till deposit and the lower plasticity values were measured in the clayey silt till deposit. Based on these values, the upper portion of the till deposit may be classified as silty clay of medium to high plasticity and beneath the silty clay till deposit the till is classified as clayey silt with medium plasticity below depths of 1.5 m and 2.2 m below ground surface in Boreholes BH-20-2 and BH-20201, respectively. The results of the Atterberg limits tests are shown on the plasticity chart on Figure C1-1 in Appendix C.

Grain size distribution testing was carried out on five samples of cohesive till and the results are shown on Figure C1-2 in Appendix C.

The water content measured on of samples of the cohesive till range between 15 per cent and 26 per cent.

5.2 Culvert No. 06X-0421/C0

The fieldwork at Culvert No. 06X-0421/C0 consisted of the completion of Boreholes BH-20-03 and BH-20-04 advanced at the shoulders of Highway 3 and Concession Road 8 (near to the end of the proposed culvert), respectively (see Drawing 3).

In summary, the subsurface conditions at borehole locations consist of a layer of fill material underlain by a cohesive till deposit extending to the maximum depth of investigation of 9.8 m below ground surface (Elevation 185.1 m).

5.2.1 Fill

At ground surface granular fill material consisting of sand and gravel with trace to some amounts of fines was encountered in Boreholes BH-20-03 and BH-20-04 and extended to depths of 1.4 m and 1.1 m below ground surface (Elevations 193.9 m and 193.8 m), respectively.

The SPT “N” values within the fill range from 8 blows to 16 blows per 0.3 m of penetration, indicating loose to compact compactness condition.

Grain size distribution test was carried out on a sample of the granular fill material and the results are shown on Figure C2-1 in Appendix C.

The water content measured on four samples of the granular fill range from 2 per cent to 4 per cent.

5.2.2 Clayey Silt to Silty Clay (Till)

Underlying the fill material, a cohesive till deposit consisting of silty clay underlain by clayey silt, some sand and trace gravel, was encountered in Boreholes BH-20-03 and BH-20-04 at depths of 1.4 m and 1.1 m below ground surface (Elevations 193.9 m and 193.8 m), respectively. Boreholes BH-20-03 and BH-20-04 terminated in the till deposit at a depth of 9.8 m below ground surface (Elevation 185.5 m and 185.1 m), respectively. Within samples of the cohesive till deposit discontinuous 0.1 m thick layers of fine sand and silt were observed.

The SPT “N” values recorded within the cohesive till range from 8 blows to 28 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

Atterberg limits tests were carried out on four samples of cohesive till and measured liquid limits between about 34 per cent and 38 per cent, plastic limits between about 14 per cent and 19 per cent, and plasticity indices between about 18 per cent and 20 per cent. Based on these values, the upper portion of the till deposit may be classified as silty clay of medium to high plasticity and beneath the silty clay till deposit the till is classified as clayey silt with medium plasticity below depths of 2.8 m and 2.2 m below ground surface in Boreholes BH-20-03 and BH-20-04, respectively. The results of the Atterberg limits tests are shown on the plasticity chart on Figure C2-2 in Appendix C.

Grain size distribution test was carried out on four samples of the cohesive till and the results are provided on Figure C2-3 in Appendix C.

The water content measured on of samples of the cohesive till range between 17 per cent and 25 per cent.

5.3 Culvert No. 06X-0422/C0

The fieldwork at Culvert No. 06X-0422/C0 consisted of Boreholes BH-20-05 and BH-20-06 advanced at the shoulders of Concession Road 8 and near the end of the proposed culvert, respectively (see Drawing 4).

In summary, the subsurface conditions at borehole locations consist of topsoil/fill material underlain by a cohesive and granular till deposit extending to the maximum depth of investigation of 9.8 m below ground surface (Elevation 184.6 m).

5.3.1 Topsoil

A 0.4 m thick layer of topsoil was encountered in Borehole BH-20-06 at ground surface. The topsoil consists of clayey silt, trace sand and gravel and rootlets.

5.3.2 Fill

At ground surface in Borehole BH-20-05 a 0.3 m thick granular fill layer consisting of sand and gravel with trace to some fines was encountered.

The SPT “N” value recorded within the granular fill material was 10 blows per 0.3 m of penetration, indicating a compact compactness condition.

The water content measured on a sample of the granular fill was 5 per cent.

5.3.3 Clayey Silt to Silty Clay (Till)

Underlying the fill material, a cohesive till deposit consisting of silty clay underlain by clayey silt, some sand and trace gravel, was encountered in Boreholes BH-20-05 and BH-20-06 at depths of 0.3 m and 0.4 m below ground surface (Elevations 194.2 m and 194.0 m), respectively. Boreholes BH-20-05 and BH-20-06 terminated in the till deposit at a depth of 9.8 m below ground surface (Elevation 184.7 m and 184.6 m), respectively. The till deposit in Borehole BH-20-06 between depths of 5.6 m and 7.2 m below ground surface (Elevation 188.8 m and 187.2 m) was described as silt and sand, trace to some clay. Within samples of the cohesive till deposit discontinuous 0.1 m thick layers of fine sand and silt were observed.

The SPT “N” values recorded within the till deposit range from 5 blows to 18 blows per 0.3 m of penetration, suggesting a firm to very stiff consistency.

Atterberg limits tests were carried out on four samples of cohesive till deposit and measured liquid limits between about 35 per cent and 51 per cent, plastic limits between about 18 per cent and 21 per cent, and plasticity indices between about 16 per cent and 30 per cent. Based on these values, the upper portion of the till deposit may be classified as silty clay of medium to high plasticity and beneath the silty clay till deposit the till is classified as clayey silt with medium plasticity below depths of 2.1 m and 2.9 m below ground surface in Boreholes BH-20-05 and BH-20-06, respectively. The results of the Atterberg limits tests are shown on the plasticity chart on Figure C3-1 in Appendix C.

Grain size distribution tests carried out on four samples of cohesive till deposit and the results are provided on Figure C3-2 in Appendix C. Grain size distribution tests carried out on one sample of silt and sand till deposit and the results are provided on Figure C3-3 in Appendix C.

The water content measured on samples of the cohesive till deposit range between about 17 per cent to 24 per cent and the water content measured on a sample of the silt and sand till deposit was about 23 per cent.

5.4 Culvert No. 06X-0423/C0

The fieldwork for the foundation investigation at Culvert No. 06X-0423/C0 consisted of Boreholes BH-20-07, BH-20-08 and BH-21-01 advanced at the shoulder of Highway 3, near the proposed south and north end of the culvert extension (see Drawing 5).

In summary, the subsurface conditions at borehole locations consist of topsoil/fill material underlain by a cohesive till deposit extending to depths of between 9.8 m and 13.6 m below ground surface (Elevation 185.7 m and 181.3 m).

5.4.1 Topsoil

A 0.3 m thick layer of topsoil was encountered in Borehole BH-20-08 at ground surface. The topsoil consisted of clayey silt, trace sand and gravel and rootlets.

5.4.2 Fill

At ground surface in Boreholes BH-20-07 and BH-21-01 fill material consisting of sand to sand and gravel, some fines was encountered and extended to depths of 1.1 and 0.8 m below ground surface (Elevations 194.4 m and 194.1 m), respectively. Underlying the granular fill material, a layer of cohesive fill consisting of silty clay with sand to silty clay was encountered in Boreholes BH-20-07 and BH-21-01 and extended to depths of 3.0 m and 2.3 m below ground surface (Elevations 192.5 m and 192.6 m), respectively.

The SPT “N” values recorded within the granular fill material were 5 blows and 9 blows per 0.3 m of penetration, indicating a loose compactness condition. The SPT “N” values within the silty clay fill material range from 3 blows to 8 blows, per 0.3 m of penetration., suggesting a soft to stiff consistency.

Atterberg limits test were carried out on a sample of cohesive fill material and measured a liquid limit of 45 per cent, a plastic limit of 19 per cent, and a plasticity index of 26 per cent, indicating a silty clay of medium plasticity. These results of the Atterberg limits test are shown on the plasticity chart on Figure C4-1 in Appendix C.

Grain size distribution tests carried out on one sample of granular fill material and one sample of the cohesive fill material are shown on Figures C4-2 and C4-3 in Appendix C, respectively.

The water content measured on samples of the granular fill material range between about 3 per cent to 15 per cent and the water content measured on samples of the cohesive fill material range between about 16 per cent and 24 per cent.

5.4.3 Clayey Silt (Till)

Underlying the fill material in Boreholes BH-20-07 and BH 21-01, and underlying the topsoil in Borehole BH 20-08, a cohesive till deposit consisting of clayey silt, some sand and trace gravel, was encountered at depths of between 0.3 m and 3.0 m below ground surface (between Elevations 194.0 m and 192.5 m). Boreholes BH-20-07, BH-20-08 and BH-21-01 terminated in the till deposit at depths of between 9.8 m and 13.6 m below ground surface (Elevation 185.7 m and 181.3 m). Within samples of the cohesive till deposit discontinuous 0.1 m thick layers of fine sand and silt were observed.

The SPT “N” values recorded within the cohesive till deposit range from 4 blows to 31 blows per 0.3 m of penetration. The SPT “N” values generally decrease with depth within the till deposit. In-situ vane tests were carried out within this deposit measured undrained shear strengths ranging from about 80 kPa to greater than 100 kPa and the sensitivity ranges from about 1.7 to 2.3. The in-situ field vane test results together with the SPT “N” values indicate that the clayey silt till deposit predominately has a firm to hard consistency.

Atterberg limits tests were carried out on six samples of cohesive till deposit and measured liquid limits between about 31 per cent and 34 per cent, plastic limits between about 13 per cent and 18 per cent, and plasticity indices between about 13 per cent and 20 per cent. The results of the Atterberg limits tests shown on the plasticity chart on Figure C4-4 in Appendix C indicate that the cohesive deposit can be classified as clayey silt of low plasticity.

Grain size distribution tests carried out on three samples of cohesive till deposit and the results are provided on Figure C4-5 in Appendix C.

The water content measured on samples of the cohesive till deposit range between about 14 per cent to 24 per cent.

5.5 Culvert No. 06X-0426/C0

The fieldwork for the foundation investigation at Culvert No. 06X-0426/C0 consisted of Boreholes BH-20-09, BH-20-10 and BH-21-02, advanced at the shoulder of Highway 3, near the proposed south and north end of the culvert extension (see Drawing 6).

In summary, the subsurface conditions encountered at borehole locations consist of granular fill material underlain by cohesive till deposit extending to the maximum depth of investigation of 15.8 m (Elevation 179.8).

5.5.1 Fill

A 0.7 m to 1.5 m thick granular fill consisting of gravelly sand to sand and gravel, some silt was encountered in Boreholes BH-20-09 and BH-21-02, immediately below the ground surface.

The SPT “N” values recorded within the fill ranges between 11 blows and 53 blows per 0.3 m of penetration, indicating compact to very dense compactness condition.

The water content measured on samples of the granular fill ranged between 5 per cent and 9 per cent.

5.5.2 Clayey Silt to Silty Clay (Till)

A cohesive till deposit consisting of silty clay underlain by clayey silt, some sand and trace gravel, was encountered in Borehole BH-20-10 at ground surface and in Boreholes BH-20-09, and BH-21-02 underlying the fill material at depths of 0.7 m and 1.5 m below ground surface (Elevations 194.4 m and 194.2 m), respectively. Boreholes BH-20-09, BH-20-10 and BH-21-02 terminated in the till deposit at a depth of between 9.8 m and 15.8 m below ground surface (Elevation 185.3 m and 179.9 m), respectively. Within samples of the cohesive till deposit discontinuous 0.1 m thick layers of fine sand and silt were observed.

The SPT “N” values recorded within the cohesive till ranged from 5 blows to 29 blows per 0.3 m of penetration. In-situ vane tests were carried out within this deposit measured undrained shear strengths ranging from about 82 kPa to greater than 100 kPa and the sensitivity ranges from about 1.6 to 1.8. The in-situ field vane test results together with the SPT “N” values indicate that the clayey silt till deposit predominately has a firm to very stiff consistency.

Atterberg limits tests were carried out on ten samples of cohesive till deposit and measured liquid limits between about 31 per cent and 46 per cent, plastic limits between about 15 per cent and 30 per cent, and plasticity indices between about 13 per cent and 23 per cent. The results of the Atterberg limits tests shown on the plasticity chart on Figure C5-1 in Appendix C indicate that the cohesive deposit consists of low plasticity clayey silt to medium plasticity silty clay.

Grain size distribution tests carried out on seven samples of cohesive till deposit and the results are provided on Figure C5-2 in Appendix C.

The water content measured on samples of the cohesive till deposit range between about 17 per cent to 28 per cent.

In addition, a consolidation test carried out on a sample of the clayey silt till from a Shelby tube obtained from Borehole BH-21-02, and the results are summarized in Table 6. The results of the consolidation test are presented on Figure C5-3 in Appendix C.

Table 3 Consolidation Parameters – Borehole BH-21-02

Borehole No. and Sample No.	Sample Depth / Elevation (m)	σ_{vo}'	σ_p'	Void Ratio (e_0)	Compression Indices		OCR	Average C_v
					Cr	Cc		
BH 21-02 TW-1	7.6 – 8.2 (188.1 – 187.5)	141.7	153	0.57	0.010	0.116	1.1	4.5

Where: σ_{vo}' is the in-situ vertical effective overburden stress in kPa
 σ_p' is the preconsolidation stress in kPa
OCR is the overconsolidation ratio
 e_0 is the initial void ratio
Cc is the compression index
Cr is the recompression index
 C_v is the coefficient of consolidation in m^2/year

5.6 Culvert No. 06X-0427/C0

The fieldwork for the foundation investigation at Culvert No. 06X-0427/C0 consisted of Boreholes BH-20-11, BH-20-12 and BH-21-03 advanced at the shoulder of Highway 3, near the proposed south and north end of the culvert extension (see Drawing 7).

In summary, the subsurface conditions at borehole locations consist of fill and topsoil underlain by a cohesive till extending to the maximum depth of investigation of 15.7 m (Elevation 179.1).

5.6.1 Topsoil

A 0.3 m thick layer of topsoil was encountered in Borehole BH-20-12 at ground surface. The topsoil consisted of clayey silt, trace of sand and gravel and rootlets.

5.6.2 Fill

At ground surface in Boreholes BH-20-11 and BH-21-03 fill material consisting of sand to sand and gravel, some fines was encountered and extended to depths of 1.4 and 0.8 m below ground surface (Elevations 193.7 m and 194.0 m), respectively. Underlying the granular fill material, a layer of cohesive fill consisting of silty clay trace to some sand was encountered in Boreholes BH-20-11 and BH-21-03 and extended to depths of 3.0 m and 2.3 m below ground surface (Elevations 192.15 m and 192.5 m), respectively.

The SPT “N” values recorded within the granular fill material ranged from 10 blows to 29 blows per 0.3 m of penetration, indicating a compact compactness condition. The SPT “N” values recorded within the cohesive fill material ranged from 3 blows to 9 blows per 0.3 m of penetration, suggesting a soft to stiff consistency.

Atterberg limits test were carried out on a sample of cohesive fill material and measured a liquid limit of 55 per cent, a plastic limit of 22 per cent, and a plasticity index of 33 per cent, indicating a silty clay of high plasticity. The results of the Atterberg limits test are shown on the plasticity chart on Figure C6-1 in Appendix C.

Grain size distribution tests carried out on one sample of granular fill material and one sample of the cohesive fill material are shown on Figures C6-2 and C6-3 in Appendix C, respectively.

The water content measured on samples of the granular fill material range between about 7 per cent to 24 per cent and the water content measured on samples of the cohesive fill material range between about 18 per cent and 30 per cent.

5.6.3 Clayey Silt to Silty Clay (Till)

A cohesive till deposit consisting of silty clay underlain by clayey silt, some sand and trace gravel, was encountered underlying the cohesive fill material in Boreholes BH-20-11 and BH-21-03 and underlying the topsoil in Borehole BH-20-12 at depths of 0.3 m and 3.0 m below ground surface (Elevations 194.3 m and 192.1 m). Boreholes BH-20-11, BH-20-12 and BH-21-03 terminated in the cohesive till deposit at depths of between 9.8 m and 15.7 m below ground surface (Elevation 185.3 m and 179.1 m). Within samples of the cohesive till deposit discontinuous 0.1 m thick layers of fine sand and silt were observed.

The SPT “N” values recorded within the cohesive till deposit ranged from 2 blows to 32 blows per 0.3 m of penetration. In-situ vane tests were carried out within this deposit measured undrained shear strengths ranging from about 73 kPa to greater than 100 kPa and the sensitivity ranges from about 1.7 to 2.8. The in-situ field vane test results together with the SPT “N” values indicate that the cohesive till deposit predominately has a firm to hard consistency.

Atterberg limits tests were carried out on six samples of cohesive till deposit and measured liquid limits between about 25 per cent and 41 per cent, plastic limits between about 13 per cent and 20 per cent, and plasticity indices between about 12 per cent and 21 per cent. The results of the Atterberg limits tests shown on the plasticity chart on Figure C6-4 in Appendix C indicate that the cohesive deposit consists of low plasticity clayey silt to medium plasticity silty clay.

Grain size distribution tests carried out on five samples of cohesive till deposit and the results are provided on Figure C6-5 in Appendix C.

The water content measured on samples of the cohesive till deposit range between about 17 per cent to 27 per cent.

5.7 Culvert No. 06X-0429/C0

The fieldwork for the foundation investigation at Culvert No. 06X-0429/C0 consisted of Boreholes BH-20-13, BH-20-14, BH-21-04 and BH-21-05. These boreholes were advanced at the shoulder of Highway 3 (BH-20-13), near the end of the proposed south extension (BH-20-14), and near the end of proposed north extension (BH-21-04 and BH-21-05) (see Drawing 8).

In summary, the subsurface conditions at borehole locations consists of topsoil or fill underlain by a cohesive and granular till deposit extending to the maximum depth of investigation of 15.8 m (Elevation 179.2).

5.7.1 Topsoil

Topsoil was encountered in Boreholes BH-20-14 and BH-21-04 at ground surface and extended to a depth of 0.4 m and 0.2 m below ground surface. The topsoil consists of clayey silt, trace of sand and gravel and rootlets.

5.7.2 Fill

A 0.7 m thick layer of granular fill material consisting of sand and gravel, some clay, trace silt was encountered in Borehole BH-20-13 at ground surface. Underlying the topsoil in Borehole 21-04 and at ground surface in Borehole BH-21-05 a 0.7 m thick layer of silty clay fill material, some sand, trace to some gravel was encountered.

The SPT “N” values recorded within the granular fill material was 6 blows per 0.3 m of penetration, indicating a loose compactness condition. The SPT “N” recorded values within the silty clay fill material was 2 blows and 10 blows per 0.3 m of penetration, suggesting a soft to stiff consistency.

The water content measured on a sample of the granular fill material was about 10 per cent and the water content measured on samples of the cohesive fill material was about 22 per cent.

5.7.3 Clayey Silt and Sand to Silty Clay (Till)

Underlying the topsoil and/or fill material, a cohesive till deposit consisting of silty clay underlain by clayey silt, some sand and trace gravel to clayey silt and sand, was encountered at depths of 0.4 m and 0.8 m below ground surface (Elevations 194.6 m and 193.2 m). Within the till deposit in Borehole BH-21-05 the till consists of sand and gravel and was encountered at depths of between 6.1 m to 7.6 m below ground surface (between Elevation 189.2 m and 187.7 m). Granular till consisting of sandy silt to sand was encountered in Boreholes BH-21-04 and BH-21-05 at a depth of 13.7 m below ground surface (between Elevation 181.6 m and 181.3 m). Boreholes BH-21-04 and BH-21-05 terminated within this granular till deposit at a depth of 15.8 m below ground surface (between Elevations 179.5 m and 179.2 m). Boreholes BH-20-13 and BH-20-14 terminated in the cohesive till deposit at depths of between 9.8 m and 11.3 m below ground surface (Elevation 185.5 m and 183.4 m). Within samples of the cohesive till deposit discontinuous 0.15 m thick layers of fine sand and silt were observed.

The SPT “N” values recorded within the cohesive till deposit range from 4 blows to 58 blows per 0.3 m of penetration. In-situ vane tests were carried out within this deposit measured undrained shear strengths ranging from about 47 kPa to greater than 100 kPa and the sensitivity ranges from about 1.3 to 1.8. The in-situ field vane test results together with the SPT “N” values indicate that the cohesive till deposit predominately has a firm to hard consistency. The SPT “N” values recorded within the granular till deposit range from 7 blows to 80 blows per 0.3 m of penetration, suggesting a loose to very dense compactness condition.

The Atterberg Limit testing carried out on 13 samples of cohesive till gave liquid limit values ranging from 23% to 45%, plastic limit values ranging from 14% to 20%, resulting in plasticity index values ranging from 9% to 23%. Based on these values, the soil may be classified as clayey silt of low plasticity (CL) or silty clay of intermediate plasticity (CI) in the Unified Soil Classification System (USCS). The plasticity chart is provided on Figure C7-1 in Appendix C.

Atterberg limits tests were carried out on thirteen samples of cohesive till and measured liquid limits between about 23 per cent and 45 per cent, plastic limits between about 14 per cent and 20 per cent, and plasticity indices between about 9 per cent and 23 per cent. Based on these values, the upper portion of the till deposit may be classified as silty clay of medium plasticity and beneath the silty clay till deposit the till is classified as clayey silt with low plasticity. The results of the Atterberg limits tests are shown on the plasticity chart on Figures C7-1A and C7-1B in Appendix C.

Grain size distribution tests carried out on eight samples of cohesive till deposit and the results are provided on Figure C7-2 in Appendix C. Grain size distribution tests carried out on two samples of the granular till deposit and the results are provided on Figure C7-3 in Appendix C.

The water content measured on samples of the cohesive till deposit range between about 15 per cent to 37 per cent and the water content measured on samples of the silty sand to sand and gravel till deposit range between about 8 per cent to 26 per cent.

In addition, a consolidation test carried out on a clayey silt sample from Borehole BH-21-04, and the results are summarized in Table 10. The results of the consolidation test are presented on Figure C7-4 in Appendix C.

Table 4 Consolidation Test results - BH-21-04

Borehole No. and Sample No.	Sample Depth / Elevation (m)	σ_{vo}'	σ_p'	Void Ratio (e_o)	Compression Indices		OCR	Average C_v
					Cr	Cc		
BH-21-04 TW-2	6.1 – 6.7 188.9 – 188.4	125.5	145	0.64	0.010	0.116	1.16	3.7

Where: σ_{vo}' is the in-situ vertical effective overburden stress in kPa
 σ_p' is the preconsolidation stress in kPa
OCR is the overconsolidation ratio
 e_o is the initial void ratio
Cc is the compression index
Cr is the recompression index
 C_v is the coefficient of consolidation in m^2/year

5.8 Culvert No. 06X-0432/C0

The fieldwork for the foundation investigation at Culvert No. 06X-0432/C0 consisted of Boreholes BH-20-15, BH-20-16 and BH-21-06. These boreholes were advanced at the shoulder of Highway 3 (BH-20-11), near the end of the proposed south extension (BH-20-12), and near the end of proposed north extension (BH-21-03) (see Drawing 9).

In summary, the subsurface conditions at borehole locations consists of topsoil or fill underlain by a cohesive and granular till deposit extending to the maximum depth of investigation of 11.3 m (Elevation 184.7).

5.8.1 Topsoil

A 0.2 m thick layer of topsoil was encountered in Borehole BH-20-16 at ground surface. The topsoil consists of clayey silt, trace of sand and gravel.

5.8.2 Fill

A 0.7 m to 0.8 m thick layer of granular fill consisting of gravelly sand to sand and gravel was encountered at ground surface in Boreholes BH-20-15 and BH-21-06. The granular fill material is underlain by a layer of silty clay with sand fill material that extends to depths of 2.2 m and 2.3 m below ground surface (Elevation 193.7 m).

The SPT “N” values recorded within the granular fill were 9 blows and 15 blows per 0.3 m of penetration, suggesting a loose to compact compactness condition. The SPT “N” values recorded within the cohesive fill range from 3 blows to 14 blows per 0.3 m of penetration, suggesting a soft to stiff consistency.

Atterberg limits test were carried out on two samples of cohesive fill material and measured liquid limits of 32 per cent and 39 per cent, plastic limits of 15 per cent and 18 per cent, and plasticity indices of 13 per cent and 18 per cent, indicating a silty clay of medium plasticity. The results of the Atterberg limits test are shown on the plasticity chart on Figure C8-1 in Appendix C.

Grain size distribution tests carried out on two samples of granular fill material are shown on Figure C8-2 in Appendix C.

The water content measured on samples of the granular fill material were about 10 per cent and 12 per cent and the water content measured on samples of the cohesive fill material range from 12 per cent to 28 per cent.

5.8.3 Clayey Silt to Silty Clay (Till)

Underlying the fill material in Boreholes BH-20-15 and BH-21-06 and underlying the topsoil in Borehole BH-20-16 a cohesive till deposit consisting of clayey silt with sand to clayey silt, some sand, trace gravel was encountered at depths of between 0.2 m and 2.3 m below ground surface (between Elevations 194.2 m and 193.7 m). The cohesive till deposit in Borehole BH-20-16 contains granular till layers consisting of silt and sand, trace clay to silty sand, trace gravel, trace clay between depths of 2.1 m to 5.6 m below ground surface (between Elevations 192.5 m and 189.0 m). In Borehole BH-21-06 a granular till consisting of silty sand, trace to some gravel was encountered underlying the cohesive till at a depth of 9.1 m below ground surface (Elevation 186.9 m). Borehole BH-21-06 terminated within the granular till deposit at a depth of 11.3 m below ground surface (Elevation 184.7 m). Boreholes BH-20-15 and BH-20-16 terminated within the cohesive till deposit at a depth of 9.8 m below ground surface (between Elevation 186.1 m and 184.8 m). Silty sand lenses with thicknesses of less than 0.1 m were also detected through the cohesive till layer.

The SPT “N” values recorded within the cohesive till deposit range from 10 blows to 33 blows per 0.3 m of penetration, suggesting a stiff to hard consistency. The SPT “N” values recorded within the granular till deposit ranged from 15 blows to 29 blows per 0.3 m of penetration, suggesting a compact compactness condition.

Atterberg limits tests were carried out on five samples of cohesive till deposit and measured liquid limits between about 25 per cent and 33 per cent, plastic limits between about 13 per cent and 18 per cent, and plasticity indices between about 10 per cent and 15 per cent. The results of the Atterberg limits tests shown on the plasticity chart on Figure C8-3 in Appendix C indicate that the cohesive deposit consists of low to medium plasticity clayey silt.

Grain size distribution tests carried out on three samples of cohesive till deposit and the results are provided on Figure C8-4 in Appendix C. Grain size distribution tests carried out on three samples of the granular till deposit and the results are provided on Figure C8-5 in Appendix C.

The water content measured on samples of the cohesive till deposit range between about 12 per cent to 27 per cent and the water content measured on samples of the granular till deposit range between about 10 per cent to 66 per cent.

5.9 Groundwater

Groundwater observations and measurements were obtained from the open boreholes during and upon completion of drilling each borehole. A monitoring well was installed in Boreholes BH-21-01, BH-21-03 and BH-21-06 to monitor the groundwater levels at the borehole locations. The water levels measured in the open boreholes and the monitoring wells are summarized in Table 3 below.

Table 5 Summary of Groundwater Level Measurements

Culvert Number	Borehole Number	Water Level Depth (m)	Water Level Elevation (m)	Date of Observation (Measurement)	Remark
06X-0420/C0	BH-20-01	Dry	--	April 27, 2020	Upon completion of drilling
	BH-20-02	Dry	--	April 27, 2020	
06X-0421/C0	BH-20-03	2.2	193.1	April 28, 2020	
	BH-20-04	Dry	--	April 28, 2020	
06X-0422/C0	BH-20-05	Dry	--	April 28, 2020	
	BH-20-06	6.1	188.3	April 28, 2020	
06X-0423/C0	BH-20-07	Dry	--	April 30, 2020	

Culvert Number	Borehole Number	Water Level Depth (m)	Water Level Elevation (m)	Date of Observation (Measurement)	Remark
	BH-20-08	Dry	--	April 30, 2020	Monitoring well
	BH-21-01	Dry	--	April 10, 2021	
		0.9	193.9	November 24, 2021	
06X-0426/C0	BH-20-09	Dry	--	April 30, 2020	Upon completion of drilling
	BH-20-10	10.7	182.6	May 1, 2020	
	BH-21-02	Dry	--	November 10, 2021	
06X-0427/C0	BH-20-11	1.2	193.9	May 1, 2020	
	BH-20-12	4.9	189.7	May 1, 2020	
	BH-21-03	Dry	--	May 10, 2021	
		5.1	189.6	November 24, 2021	Monitoring well
06X-0429/C0	BH-20-13	0.8	194.5	May 4, 2020	Upon Completion of Drilling
	BH-20-14	6.1	188.6	May 4, 2020	
	BH-21-04	10.4	184.6	November 11, 2021	
	BH-21-05	11.5	183.8	November 10, 2021	
06X-0432/C0	BH-20-15	1.8	194.1	May 19, 2020	
	BH-20-16	2.4	192.2	May 19, 2020	
	BH-21-06	7.6	188.4	October 5, 2021	
		8.4	187.6	November 24, 2021	Monitoring well

It should be noted that the groundwater level at the site may be influenced by the water level in the culvert, and will fluctuate with seasonal changes, periods of precipitation, and temperature and should be expected to be higher during wet periods of the year.

5.10 Analytical Testing Results

Soil corrosivity chemical test consisting of pH, water soluble sulphate, sulphide, chloride and resistivity was conducted on a total of twelve samples. A summary of the test results is provided in Table 4. The test methods and test results are provided in Appendix D.

Table 6 Soil Corrosivity Test Results

Culvert Number	Borehole No.	Sample No.	Depth (Elevation) (m)	Sulphate (µg/g)	Sulphide (µg/g)	Chloride (µg/g)	pH	Resistivity (Ohm-cm)
06X-0420/C0	BH-20-02	SS-6	4.8 (189.5)	510	< 5	13	7.78	1870
06X-0421/C0	BH-20-03	SS-6	3.0 (191.3)	980	< 5	129	7.80	1240
06X-0422/C0	BH-20-05	SS-6	4.8 (189.7)	800	< 5	71	7.69	1410
06X-0423/C0	BH-20-08	SS-5	3.2 (192.3)	510	< 5	12	7.68	1880
	BH-21-01	SS-4	2.6 (192.3)	729	<0.2	80.3	7.48	1180
06X-0426/C0	BH-20-10	SS-6	4.9 (189.8)	580	< 5	16	7.70	1730
	BH-21-02	SS-5	3.3 (192.4)	166	0.23	133	7.89	2070
06X-0427/C0	BH-20-11	SS-5	3.3 (191.8)	130	< 5	230	7.75	2060

Culvert Number	Borehole No.	Sample No.	Depth (Elevation) (m)	Sulphate (µg/g)	Sulphide (µg/g)	Chloride (µg/g)	pH	Resistivity (Ohm-cm)
	BH-21-03	SS-4	2.6 (192.2)	840	<0.2	263	7.46	857
06X-0429/C0	BH-20-13	SS-5	3.3 (192.0)	30	< 5	171	7.71	2880
	BH-21-04	SS-5	3.5 (191.5)	84	<0.2	133	7.61	1600
06X-0432/C0	BH-20-16	SS-5	3.3 (191.3)	280	< 5	30	7.70	2420

6. Closure

The fieldwork was supervised by Mr. Moe Nasir, E.I.T. and Mr. Manvit Reddy Mettupalli, E.I.T. under the direction of Mr. Nirjar Vyas, M.Eng., P.Eng., and Ms. Sandra McGaghran M.Eng., P.Eng.

This report was prepared by Ms. Sahar Soleimani, Ph.D., P.Eng, a Senior Geotechnical Engineer with GHD. Ms. Sandra McGaghran, M.Eng., P.Eng., a Senior Geotechnical Engineer with GHD and MTO Foundations Designated Contact conducted an independent review of the report.

Sincerely,

GHD Limited




Sahar Soleimani, Ph.D., P.Eng.
Senior Geotechnical Engineer




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MTO Foundations Designated Contact, Senior Geotechnical Engineer



Part B

FOUNDATION DESIGN REPORT

**CULVERT EXTENSIONS AND REPLACEMENT, HIGHWAY 3 WIDENING AND
SAFETY ENHANCEMENTS – WINDSOR TO LEAMINGTON, ONTARIO
MTO, GWP 3021-18-00**

**SITE NOS: 06X-0420/C0, 06X-0421/C0, 06X-0422/C0, 06X-0423/C0
06X-0426/C0, 06X-0427/C0, 06X-0429/C0, 06X-0432/C0**

7. Discussion and Engineering Recommendations

This section of the report provides foundation design recommendations for the extension of the following six culverts located along Highway 3, from 1.2 km east of Essex Road 23 to 1.1 km east of Essex Road 34, Town of Kingsville, Essex County, Ontario.

- Culvert No. 06X-0421/C0 is located just west of the intersection between Highway 3 and Concession Road 8;
- Culvert No. 06X-0423/C0 is located approximately 220 m east of the intersection between Highway 3 and Concession Road 8;
- Culverts Nos. 06X-0426/C0, 06X-0427/C0 and 06X-0429/C0 are located between Essex Road 27 (Belle River Road) and Essex Road 29 (Division Road); and,
- Culvert No. 06X-0432/C0 is located about 600 m east of the intersection between Highway 3 and Essex Road 29 (Division Road).

The Project Specific details in the agreement for services identified a total of eight structural culverts that required extensions to the south of existing culverts. It is understood that access to Highway 3 from Cameron Side Road / Concession Road 9 and Marsh Road / Concession Road 8 will be closed as part of the Approved Plan for the project. Therefore Culvert No. 06X-0420/C0 and No. 06X-0422/C are not required to be extended and will be abandoned.

During the preliminary design phase two changes occurred for the remaining six structural culverts under review. At the location of Culvert No. 06X-0426/C0 a new replacement culvert was proposed at a location about 25 m east of the existing culvert. The second change included the extension of the Culvert Nos. 06X-0421/C0, 06X-0423/C0, 06X-0427/C0, 06X-0427/C0, and 06X-0432/C0 to the north to mitigate roadside hazards.

The discussion and engineering recommendations are based on the interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. These recommendations presented are intended to provide the designers with sufficient information to assess the feasible culvert foundation alternatives and carry out the design of the culvert foundations for the design-build ready assignment. This report is intended for the use of the Ministry of Transportation, Ontario (MTO) for the purpose of designing culvert extensions/replacement in the above-mentioned locations. It shall not be relied upon for any other purpose or by any other parties, including construction or design-build contractor used for any other purposes or locations, or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

7.1 Design Details

According to the original culvert drawings, the existing culverts are all open footings having a width of 0.76 m and about 1.2 m of cover above the underside of the footing. Based on the original culvert drawings and General Arrangement (GA) drawings of the proposed structures the following summarizes the details regarding the existing culvert:

Table 7 *Details of Existing Culvert Structures and Footings*

Culvert No.	Existing Structure Dimensions	Existing Culvert Invert (m)	Approximate Existing Maximum Embankment Height (m)
Culvert No. 06X-0421/C0	Span:4.2 m, Rise: 1.8 m, Length: 30.5 m	Upstream: 192.6 downstream: 192.6	0.5
Culvert No. 06X-0423/C0	Span:3.6 m, Rise: 1.8 m, Length: 28.7 m	Upstream: 192.7 Downstream:192.6	1.5
Culvert No. 06X-0426/C0	Span:3.1 m, Rise: 1.5 m, Length: 33.5 m	Upstream: 192.3 Downstream:192.3	1.0
Culvert No. 06X-0427/C0	Span:4.2 m, Rise: 1.8 m, Length: 33.3 m	Upstream: 192.7 Downstream:192.6	1.0
Culvert No. 06X-0429/C0	Span:3.6 m, Rise: 1.8 m, Length: 33.1 m	Upstream: 193.1 Downstream:193.0	1.0
Culvert No. 06X-0432/C0	Span:3.6 m, Rise: 1.5 m, Length: 24.9 m	Upstream: 194.5 Downstream:194.0	1.5

Based on the General Arrangement (GA) drawing of the proposed structure, the following details the proposed extension / replacement at the six culvert locations:

- **North Extension at Culvert No. 06X-0423/C0, No. 06X-0427/C0 No. 06X-0429/C0 No. 06X-0432/C0:** north of the existing culvert an extension of between 3.1 m and 4.3 m is proposed at these culvert locations. It is understood that an open footing culvert is proposed and that the existing invert elevations will be matched.
- **South Extension at Culverts No. 06X-0421/C0, 06X-0423/C0, No. 06X-0427/C0 No. 06X-0429/C0 No. 06X-0432/C0:** south of the existing culvert an extension of between 31.7 m and 38.5 m is proposed at these culvert locations. It is understood that a box culvert is proposed and that the existing invert elevations will be matched.
- **Replacement of Culvert No. 06X-0426/C0:** Culvert 06X-0426/C0 will be replaced with a new concrete box culvert at about 15 m east of the existing culvert. The thickness of the embankment fill above the culvert decks will be about 1.0 m and no significant grade raise will be considered along the new culvert.
- **Retaining Walls at Inlet and Outlet:** retaining walls are required at the proposed south and north culvert extension at Culvert Nos. 06X-0426/C0, 06X-0427/C0 and 06X-0429/C0, whereas retaining walls will only be required at the north culvert extension at Culvert Nos. 06X-0423/C0 and 06X-0432/C0.

Table 8 summarizes the proposed dimensions, culvert invert and the length that the culvert will be replaced.

Table 8 *Details of proposed Structures and Footings for North and South Extensions*

Culvert No.	Proposed Structure Dimensions	Proposed Culvert Invert (m)	Proposed Extension length (m)
06X-0421/C0	South Extension: Span:4.2 m, Rise: 3.0 m, Concrete Box	192.0	24.6
06X-0423/C0	South Extension: Span: 3.6 m, Rise: 2.9 m, Concrete Box	South: 192.2	South: 32.7

Culvert No.	Proposed Structure Dimensions	Proposed Culvert Invert (m)	Proposed Extension length (m)
	North Extension: Span: 3.6 m, Rise: 2.1 m, Open Footing Concrete	North:192.7	North: 3.4
06X-0426/C0 ¹	Replacement: Span: 3.6 m, Rise: 2.5 m, Concrete Box	Upstream: 192.8 Downstream:192.8	63.2
06X-0427/C0	South Extension: Span: 4.3 m, Rise: 3.0 m, Concrete Box North Extension: Span: 4.3 m, Rise: 2.1 m, Open Footing Concrete	South: 192.1 North:192.7	South: 33.0 North: 3.9
06X-0429/C0	South Extension: Span: 3.6 m, Rise: 2.9 m, Concrete Box North Extension: Span: 3.6 m, Rise: 2.1 m, Open Footing Concrete	South: 192.5 North:193.1	South: 38.5 North: 4.3
06X-0432/C0	South Extension: Span: 3.6 m, Rise: 2.5 m, Concrete Box North Extension: Span: 3.6 m, Rise: 1.8 m, Open Footing Concrete	South: Upstream: 193.6 Downstream:193.0 North:194.5	South: 31.7 North: 3.1

Note:

1. New culvert is approximately 25 m east of existing culvert.

7.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* and its *Commentary* (CHBDC, 2019), the proposed culvert extensions/new culverts and retaining walls foundations at the site are classified as having a “typical consequence level” associated with exceeding limits states design. In addition, given the level of foundation investigation completed to date at the site in comparison to the degree of site understanding in Section 6.5 of the CHBDC (2019), the level of confidence for foundation design of the culvert and retaining walls is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ULS and SLS consequence factors, ψ , from Table 6.1 and the geotechnical factors, Φ_{gu} and Φ_{gs} , from, Table 6.2 of the CHBDC (2019) have been used for design.

7.3 Seismic Design

7.3.1 Seismic Site Classification

The project site based on the location of culverts along Highway 3 for this assignment, (approximate Latitude: 42.120047 and Longitude: -82.756696), may be classified as Site Class D in accordance with Table 4.1 of the CHBDC (2019), wherein the Seismic Site Classification was determined by energy corrected average penetration resistance.

7.3.2 Spectral Response Values and Seismic Performance Category

In accordance with Section 7.5.8.1 of the CHBDC (2019), buried structures shall be designed to resist inertial forces associated with a seismic event having a 2% chance of being exceeded in 50 years. The vertical component of the earthquake acceleration ratio, A_v , shall be two-thirds of the horizontal ground

acceleration ratio, A_H (A_H shall be set equal to the peak ground acceleration, PGA) for the design of buried structures, in accordance with Section 7.8.5.4 of the CHBDC (2019).

Based on the location of culverts along Highway 3 (approximately Latitude: 42.120047; Longitude: -82.756696), the reference Site Class C spectral acceleration values were obtained based on the 5th generation seismic hazard maps published by the Geological Survey of Canada (GSC). The values are then adjusted to correspond to the local soil condition and seismic Site Class 'D' using the value of PGA(ref) for use with Tables 4.2 to 4.9 in Section 4.4.3.3 of the CHBDC (2019). As indicated in Section 4.4.3.3 of the CHBDC, the value of PGA(ref) shall be taken as 80 per cent of the PGA for Site Class C where $S_a(0.2)/PGA$ is less than 2.0. Based on this requirement, a PGA(ref) value of 0.052 for the 2,475-year return period was used. The corresponding site-specific PGA value and design spectral acceleration (S) values for Site Class D as given in Table 9 below can therefore be used for design of the culverts in accordance with Section 7.5.5.1 of the CHBDC.

Table 9 *Peak Ground Acceleration (PGA) and Speed (PGV) Values and Design Spectral Acceleration (S) Values for Site Class D*

Seismic Hazard Values	2% Exceedance in 50 years (2,475-year return period) Site Class D
PGA (g)	0.084
A_v (g)	0.056
PGV (m/s)	0.101
S (0.2) (g)	0.134
S (0.5) (g)	0.098
S (1.0) (g)	0.057
S (2.0) (g)	0.028
S (5.0) (g)	0.006
S (10.0) (g)	0.003

7.3.3 Liquefaction Potential Below Culvert

Liquefaction is a phenomenon whereby seismically induced shaking generates shear stresses within the soil under undrained conditions. These stresses tend to densify the soil (i.e., leading to potentially large surface deformations) and under undrained conditions generate excess pore water pressures. The excess pore water pressures can lead to sudden temporary losses in soil strength. Where existing static shear stresses are present, the loss of soil strength can lead to loss of bearing resistance, slope instability, lateral spreading of the ground, settlement of the ground and loss of lateral resistance.

7.3.3.1 Granular Deposit

The liquefaction susceptibility of granular soils was evaluated in accordance with Section 6.14.8.1.2 of CHBDC (2019) by evaluating the SPT $(N_1)_{60cs}$ for a 0.9 m thick layer of saturated sandy silt to silty sand till layer and gravelly sand encountered at the location of Culverts 06X-0429/C0 and 06X-0432/C0 in Boreholes BH-21-04, BH-21-05, BH-20-16 and BH-21-06 encountered at depths ranging from 2.1 m to 13.7 m below ground surface (Elevations 192.5 m to 181.3 m). The liquefaction analysis was carried out using in-situ testing data collected at the borehole locations. The parameter, $(N_1)_{60cs}$, that is based on the SPT "N" value obtained in the field and corrected for overburden stress, rod length during sampling, hammer energy efficiencies, and fines content. The design groundwater level was determined based on the highest measured groundwater level in the standpipe piezometer installed in Borehole BH-21-01 at about Elevation 193.9 m (measured on November 24, 2021). The results of the liquefaction assessment

indicate that the saturated silty sand sandy silt encountered at the site are not considered liquefiable during the 2,475-year design earthquake.

7.3.3.2 Cohesive Deposit

For fine soils (with more than 35% fine particles), the Canadian Manual of Foundation Engineering (MCIF 2006) recommends the use of Bray et al (2004)⁵, Bray et Sancio (2006)⁶ or Boulanger et Idriss (2006)⁷ procedure to evaluate the liquefaction potential. According to the criteria for qualitative evaluation of the liquefaction potential of these fine soils (clayey silt to silty clay), involving water content (w), Liquid Limit and plasticity index (PI), as plotted in Appendix C, these fine soils encountered at the site are not likely to liquify during a reference seismic event and therefore no settlement or associated significant loss of lateral strength is expected.

7.4 Culvert Extension Options

It is understood that construction staging can permit the culvert replacement structure to be installed using open cut excavations and that trenchless installation is not required. For the proposed structures as described in Section 7.1 **Error! Reference source not found.**, based on the information obtained from the boreholes advanced at the culverts, the subsurface conditions below the proposed inverts at various culvert locations (Elevations 194.5 m to 192.0 m) are anticipated to generally consist of a stiff cohesive till deposit. From a foundation perspective, the subsurface conditions are considered suitable to support the shallow foundations associated with the different type of culvert structure.

Either box culvert or “open footing” (shallow foundation) concrete culverts are feasible options for extension/replacement of all the existing structures. It is understood that precast concrete structure on a cast-in-place “open footing” or a precast box culvert are the preferred options. The advantages and disadvantages associated with both the pre-cast box culvert and cast-in place open footing that can be considered for the extension/replacement at all culvert locations are provided below:

- **Precast concrete culvert with cast-in-place open footings** - The advantages of precast concrete structures include speed of installation, quality control and ease of maintenance. The main problem with the use of open footing culverts, is the effect of scour around footings, especially in high velocity flows. Clause C1.9.11.1 of CHBDC (2014) suggests avoiding the use of open footing culverts on materials susceptible to scour (scourable inverts). At the project site the granular fill material (engineering fill) or silty clay to clayey silt till are both considered as materials that are prone to erosion and scour. This can be addressed with adequate scour/erosion protection. The cohesive till deposit is capable of providing adequate geotechnical resistance to support open footing precast concrete culverts. The disadvantage with these structures compared to box culverts, is the challenge with an increase in the depth of excavation, dewatering and shoring requirements.
- **Precast concrete box culvert** - Given the subsurface conditions at the structure location, the use of precast concrete box culvert is feasible and recommended. For, precast concrete box the segments can usually be installed more expeditiously than cast-in-place open footing culverts, resulting in shorter durations for dewatering, surface water pumping and traffic staging. In addition, pre-cast concrete box culvert segments are more tolerant of total and differential settlement, although this is not considered a significant concern at this site. The disadvantages of considering concrete box culvert is: potential sediment accumulation in the existing culvert section and upstream of the channel, the transportation to and on-site and lifting of large pre-cast sections and causing disturbance to natural stream bed.

⁵ Bray, J. D. and Sancio, R. B., Riemer, M.F. and Durgunoglu, T. 2004. “Liquefaction susceptibility of fine-grained soils.” in *Proceedings of the 11th International Conference on Soil Dynamics and Earthquake Engineering and 3rd International Conference on Earthquake Geotechnical Engineering*, Berkeley, CA, Jan. 7-9, pp. 655-662.

⁶ Bray, J. D. and Sancio, R. B. 2006. “Assessment of the liquefaction susceptibility of fine-grained soils.” *J. Geotech. Geoenviron. Eng.*, vol. 132, no. 9, pp. 1165–1177.

⁷ Boulanger, R. W. and Idriss, I. M. 2006. “Liquefaction susceptibility criteria for silts and clays.” *J. Geotech. Geoenviron. Eng.*, vol. 132, no. 11, pp. 1413–1426.

If the existing culverts are extended with open footing, cast-in-place or precast concrete structures, then it is recommended to construct the new footings at the elevation of the existing footings. Recommendations for both the open footing options and box culvert are provided in the following sections of this report. Table 20, following the text report, identifies and presents an assessment of the advantages, disadvantages, relative costs and risks/consequences of box culverts and open footing culvert options for culvert sites.

7.5 Foundation Frost Depth

The estimated depth of frost penetration at this site is 1.0 m, based on OPSD 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*). It is not necessary to found new box culverts at or below the depth of frost penetration as box structures segments are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. However, open footing precast culvert and other structures placed on cast-in-place footings must be founded at least 1.0 m below the lowest final grade adjacent surrounding grade to provide adequate protection against frost penetration.

7.6 Founding Elevations

7.6.1 Box Culverts Replacement or Extensions

As discussed in Section 7.9, box culverts should be provided with at least 300 mm of OPSS.PROV 1010 Granular A material for bedding purposes, or alternatively a 100 mm thick concrete working slab. The following table summarizes the underside of bedding elevation (based on the culvert invert less 0.3 m base slab thickness and less 0.3 m of bedding), subexcavation requirements and the expected subgrade stratum of the proposed underside of bedding elevations for the box culvert option.

Table 10 Proposed Underside of Bedding, Subexcavation, and Subgrade Stratum – Box Culverts

Culvert No.	Reference Boreholes	Proposed Underside of Culvert Upstream / Downstream Elevation (m) ⁽¹⁾	Sub-excavation Required?	Subgrade Stratum
06X-0421/C0	BH-20-03 (Hwy 3) BH-20-04 (Outlet)	191.6 / 191.6	No	Very stiff Clayey Silt (Till)
06X-0423/C0	BH-20-07 (Hwy 3) BH-20-08 (Outlet)	191.8 / 191.8	No	Very stiff Clayey Silt (Till)
06X-0426/C0	BH-21-02 (Hwy 3) BH-20-09 (Hwy 3) BH-20-10 (Outlet)	192.4 / 192.4	No	Very stiff Clayey Silt to Silty Clay (Till)
06X-0427/C0	BH-20-11 (Hwy 3) BH-20-12 (Hwy 3)	191.7 / 191.7	No	Very stiff Clayey Silt (Till)
06X-0429/C0	BH-20-13 (Hwy 3) BH-20-14 (Outlet)	192.1 / 192.1	No	Hard to stiff Clayey Silt (Till)
06X-0432/C0	BH-20-15 (Hwy 3) BH-20-16 (Outlet)	193.2 / 192.6	No	Very stiff Clayey Silt to Silty Clay (Till) / compact Silty Sand (Till)

NOTES:

1. Assumes a 100 mm working slab below underside of box structure.

As noted on Table 10, subexcavation is not expected to be required at any of the six culvert sites.

The excavation should be inspected by geotechnical engineer to ensure that all existing fill/softened zones, organics or other unsuitable material have been removed. Proof-rolling of the footing subgrade will be required to identify any soften/loosened zones. Following inspection, any subexcavated areas should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II, placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

The existing subgrade soils (clayey silt to silty clay, silty sand) are susceptible to loosening/softening and degradation on exposure to water and construction traffic. Therefore, it is recommended to place the bedding for the culvert within four hours of exposure of the founding level to protect the integrity of the subgrade; however, if the bedding is not placed within four hours after preparing the subgrade, a concrete working slab having a minimum thickness of 100 mm and a minimum 28-day compressive strength of 20 MPa, shall be placed in the excavation within four hours of exposure of the founding level to protect the integrity of the subgrade. A Non-Standard Special Provision (NSSP) to address this item is included in Appendix E.

7.6.2 Open Footing Culverts and Retaining Walls

Strip footings for open footing culvert replacements should be founded at a minimum depth of 1.0 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation, Frost Penetration Depths for Southern Ontario*). In addition, the footings should extend below any existing fill and surficial organic materials, where present. The following summarizes the recommended founding levels and subexcavation requirements for new open footing culverts, based on the inverts of the proposed culverts noted in Section 7.1.

Table 11 *Founding Elevations Open Footing Culverts, Sub-excavation Requirements and Subgrade Stratum*

Culvert No.	Reference Boreholes	Underside of Footing Elevation (m) ¹	Sub-excavation Required?	Subgrade Stratum
06X-0423/C0	BH-21-01 (Inlet) BH-20-07 (Hwy 3)	191.4	No	Very stiff Clayey Silt (Till)
06X-0427/C0	BH-21-03 (Inlet) BH-20-11 (Hwy 3)	191.4	No	Very stiff Clayey Silt (Till)
06X-0429/C0	BH-21-04 (Inlet) BH-21-05 (Inlet) BH-20-13 (Hwy 3)	191.8	No	Stiff to hard Clayey Silt (Till)
06X-0432/C0	BH-21-06 (Inlet) BH-20-15 (Hwy 3)	193.3	No	Very stiff to stiff Clayey Silt with Sand to Clayey Silt (Till)

NOTES:

1. Elevation based on 1.0 m below invert elevation and 100 mm working slab.

As noted on Table 11, subexcavation is not required at any of the culvert sites where the culvert is being extended to the north.

The base of the excavation should be inspected by geotechnical personal to ensure that all existing topsoil and fill/softened zones or other unsuitable material have been removed from the footing subgrade. Proof-rolling of the footing subgrade will be required to identify any soften/loosened zones. Where any soften/loosened zones are present subexcavations are required to remove any unsuitable material/soil. Following inspection, any subexcavated areas should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular A or Granular B Type II, placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22.

The existing subgrade soil (clayey silt) is susceptible to loosening/softening and degradation on exposure to water and construction traffic. If the footings are not constructed within four hours after preparing the subgrade a concrete working slab having a minimum thickness of 100 mm and a minimum 28-day compressive strength of 20 MPa, shall be placed in the excavation within four hours of exposure of the founding level to protect the integrity of the subgrade. A Non-Standard Special Provision (NSSP) to address this item is included in Appendix E.

7.7 Geotechnical Resistance

7.7.1 Box Culverts

The subsurface conditions along Hwy 3 are relatively consistent and consists of deposits of variable thickness of topsoil /fill which in turn is underlain by till deposits consisting of clayey silt to silty clay with interlayered sandy silt to sand and gravel till deposit. Table 12 provides the factored ultimate geotechnical resistance values and the factored Serviceability geotechnical reaction values (for 25 mm settlement) for the box culvert option based on the proposed culvert span as detailed in the General Arrangement drawings.

Table 12 *Geotechnical Resistances - Box Culverts*

Culvert No.	Culvert Span (m)	Proposed Underside of Culvert Upstream / Downstream Elevation (m) ⁽¹⁾	Subgrade Stratum	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance (25 mm of settlement) (kPa)
06X-0421/C0	4.2	191.6 / 191.6	Very stiff Clayey Silt (Till)	200	80
06X-0423/C0	3.6	191.8 / 191.8	Very stiff Clayey Silt (Till)	230	120
06X-0426/C0	3.6	192.4 / 192.4	Very stiff Clayey Silt to Silty Clay (Till)	190	90
06X-0427/C0	4.2	191.7 / 191.7	Very stiff Clayey Silt (Till)	190	120
06X-0429/C0	3.6	192.1/ 192.1	Hard to stiff Clayey Silt (Till)	190	110
06X-0432/C0	3.6	193.2 / 192.6	Very stiff Clayey Silt to Silty Clay (Till) / compact Silty Sand (Till)	200	150

NOTES:

1. Assumes a 100 mm thick concrete working slab as the culvert bedding below underside of box structure.

The geotechnical resistances and settlement are dependent on the box culvert span and must be reviewed if the culvert span/footing size or founding elevation differs significantly from that given in Table 12. The post construction total and differential settlements of footings sized using the above SLS net bearing resistance values should be less than about 25 mm and 15 mm, respectively, provided that the soil at or below founding level is not disturbed during construction.

The geotechnical resistances provided above are based on the loading applied perpendicular to the surface of the footings and where the load is not applied perpendicular to the surface of the footing, the

inclination of the load should be taken into account in accordance with Section 6.10.2 of the CHBDC (2019).

7.7.2 Open Footing Culverts and Retaining Walls

The subsurface conditions along Hwy 3 are relatively consistent and consists of deposits of variable thickness of topsoil /fill which in turn is underlain by till deposits consisting of clayey silt to silty clay with interlayered sandy silt to sand and gravel till deposit. Table 13 provides the factored ultimate geotechnical resistance values for the open footing option with the proposed foundation sizes at each culvert location. The factored geotechnical Serviceability geotechnical resistance (for 25 mm of settlement) is greater than the factored ultimate geotechnical resistance, therefore the factored ultimate geotechnical resistance governs the design.

Table 13 Geotechnical Resistance - Open Footing Culverts

Culvert No.	Underside of Footing Elevation ¹ (m)	Subgrade Stratum	Foundation Size B (m) x L (m)	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance (25 mm of settlement) (kPa)
06X-0423/C0	191.4	Very stiff Clayey Silt (Till)	0.76 x 3.40	240	— ²
06X-0427/C0	191.4	Very stiff Clayey Silt (Till)	0.76 x 3.86	240	200
06X-0429/C0	191.8	Stiff to hard Clayey Silt (Till)	0.76 x 4.28	240	200
06X-0432/C0	193.3	Very stiff to stiff Clayey Silt with Sand to Clayey Silt (Till)	0.76 x 3.11	300	250

NOTES:

1. Elevation based on 1.0 m frost depth below invert elevation plus 0.1 m working slab.
2. The factored geotechnical Serviceability geotechnical resistance (for 25 mm of settlement) is greater than the factored ultimate geotechnical resistance, therefore the factored ultimate geotechnical resistance governs the design.

The post construction total and differential settlements of footings sized using the above SLS net bearing resistance values should be less than about 25 mm and 15 mm, respectively, provided that the soil at or below founding level is not disturbed during construction.

The geotechnical resistances provided above are based on the loading applied perpendicular to the surface of the footings and where the load is not applied perpendicular to the surface of the footing, the inclination of the load should be taken into account in accordance with Section 6.10.2 of the CHBDC (2019).

7.8 Sliding Resistance

Resistance to lateral forces or sliding resistance between the precast box culverts or the cast-in-place open footings and the subgrade for the culvert extensions or replacement should be calculated in accordance with Clause 6.10.4 of CHBDC (2019), applying the appropriate consequence and degree of site understanding factors.

An unfactored coefficient of friction, $\tan \delta$ of 0.45 may be used to account for the sliding resistance at the interface between precast concrete box culvert and the granular bedding (leveling course) placed on the stiff to very stiff cohesive till deposit.

For cast-in-place concrete open footing culvert, an unfactored coefficient of friction ($\tan \delta$) of 0.45 may be used to account for the sliding resistance at the interface between the cast-in-place concrete and the stiff to very stiff cohesive till deposit.

An unfactored coefficient of friction, $\tan \delta$ of 0.50 may be used to account for the sliding resistance at the interface between the compacted granular and the stiff to very stiff cohesive till deposit.

In addition, a $\tan \phi'$ of 0.50 within the ground close to the ground-structure interface (cohesive material) can be considered and the effective cohesion, c' can be taken as zero.

7.9 Culvert Bedding, Cover and Backfill

In accordance with Section 7.5.7.3 of CHBDC (2019), structures constructed in embankment conditions shall have engineering fill extending beyond the buried structure's spring line as specified in Table 7.4 and Figure 7.2 of CHBDC (2019). For the replacement box culvert or extension, the levelling pad, bedding and backfill requirements should be in accordance with OPSS 422 (*Box Culverts and Box Sewers in Open Cut*) for pre-cast rigid frame culverts. New box culvert should be provided with at least 300 mm of OPSS.PROV 1010 Granular A material for bedding purposes, or alternatively a 100 mm thick concrete working slab. The levelling course may consist of OPSS.PROV 1010 Granular A or OPSS.PROV 1002 Fine Aggregate.

For the new open footing culverts, where the founding level is within the stiff to very stiff cohesive till, footings do not require granular bedding and footings can be placed directly on properly prepared subgrade, as described in Section 7.6.2.

Backfill to the culvert walls and cover for concrete culverts (either box culvert or open footing) should be completed in accordance with Section 7.5.6 and 7.5.7 of CHBDC (2019). In accordance with OPSS 422, backfill around the culvert should be placed simultaneously on both sides of the structure, maintaining the height of the backfill approximately the same. At no time should the difference in backfill elevation from one side to the other be greater than 400 mm. To minimize differential settlement, fill materials used to construct the new approach embankments should be similar to the fill materials used for the construction of the existing embankments.

Backfill and cover for concrete culverts (either box culvert or open footing) should be completed in accordance with OPSS 803.010 (*Backfill and Cover for Concrete Culverts*), including the placement of a 75 mm thick levelling course. Backfill to the culvert walls and cover should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular A or Granular B Type II. The backfill and cover should be placed and compacted in accordance with OPSS.PROV 501, as amended by SP 105S22. The new culverts should be designed for the full overburden and hydrostatic pressures, and live load, assuming that the embankment fill is designed in accordance with Section 7.5.6 and 7.5.7 of CHBDC (2019) and using a unit weight of 22 kN/m³ for OPSS.PROV Granular A, 21 kN/m³ for Granular B Type II and 19 kN/m³ for earth fill (Granular B Type I, Select Subgrade Material (SSM) or earth fill) meeting criteria required by 7.5.7.4 of CHBDC (2019) above the cover.

It is not recommended to reuse any excavated silty clay from the culvert sites for backfill material above the culvert or as part of the embankment reconstruction due to its high plasticity. A Notice to Contractor addressing this restriction is included in Appendix E.

Excavated granular fill material may be used to backfill above the culvert cover, as required in Section 7.5.6 of CHBDC (2019). Excavated granular fill material should meet the specifications for suitable earth borrow material as per OPSS.PROV 212 and in accordance with OPSS.PROV 206 and placed and compacted in accordance with OPSS.PROV 501, as amended by SP 105S22. The reuse of existing site soils from above the groundwater level would require verification. Depending on precipitation events these soils may require drying in order to reach the optimum water content for compacting. Granular deposits and the native silty clay and the fill material from below the groundwater will likely require drying in order to reach the optimum moisture content prior to placement and compaction. There may not be sufficient time in the construction schedule for drying of soils, particularly the cohesive soils, therefore consideration

should be given to use of granular fill material or imported fill meeting the requirements of Select Subgrade Material (SSM).

Further, to prevent erosion and material degradation, embankments composed of earth fill, meeting requirements 7.5.7.4 of CHBDC (2019), should be covered with topsoil or suitable excess earth material and seeded in accordance with OPSS.PROV 804 (*Construction Specification for Seed and Cover*) as soon as construction is completed.

7.10 Culvert Erosion Protection

Provision should be made for scour and erosion protection at the culvert inlets and outlets and in front of any wingwalls adjacent to the creek. A clay seal or concrete cut-off wall should be provided at the upstream and downstream end of each culvert to prevent surface water from flowing either beneath the culvert (i.e., in the case of box culverts), or potentially causing undermining and scouring, or around the culvert, thereby creating seepage through the embankment fill and potentially causing erosion and loss of fine soil particles. If a clay seal is adopted, the clay material should meet the requirements of OPSS.PROV 1205 and the seal should extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet openings, and a minimum vertical height equivalent to the high water level including treatment along the adjacent side slopes.

Scour protection in the form of rip-rap should be provided at the inlet and outlet of all culverts. At the outlet of the culverts the rip-rap treatment should be consistent with the requirements of OPSD 810.010. Erosion protection for the inlet of the culverts should also follow the standard presented in OPSD 810.010 similar to the outlet, but the rip-rap should be placed up to the toe of the slope level, in combination with the cut-off measures noted above. Further, outlet protection in accordance with OPSS 511 (*Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting*), and OPSS.PROV 1004 (*Material Specification for Aggregates*) is recommended to prevent erosion adjacent to the culvert as well as side scour.

7.11 Settlement and Global Stability

The height of the approach embankments for the new culvert extension will be similar to the existing. It is understood that widening of Highway 3 would require placement of embankment fill as high as 2.5 m with widening width of up to 38 m. The embankment widening will impose some settlement on the foundation soil beneath the culvert in the widened area.

The settlement analyses were carried out using the commercially available program Settle3 (Version 4.0), developed by Rocscience Inc., which is based on elastic stress distribution theory for a two-dimensional embankment loading. These analyses were carried out using the pre-consolidation pressure and parameters presented in **Error! Reference source not found.** below.

The sources of settlement are considered to include:

- Immediate settlement of the granular soils (short-term).
- Primary time-dependent consolidation of the cohesive deposits (using Terzaghi's one-dimensional consolidation theory – long-term).
- Secondary Consolidation of the cohesive deposits

The consolidation settlement of the cohesive deposits was assessed using the results of the laboratory consolidation test, and where appropriate, in-situ field vane tests to estimate the stress history and deformation parameters for the cohesive deposits. Below table summarizes the unit weight and associated deformation parameters employed for the assessment of the settlement at this site.

Table 14 summary of Deformation Parameters for Settlement Analysis

Soil Type	Stratum Bottom Depth (m)	γ_{bulk} (kN/m ³)	σ'_p (kPa)	e_0	C_r	C_c	C_v (m ² /year)	$C_{\alpha(\epsilon)}$ (%/log-cycle time)
Clayey Silt to Silty Clay (Till)	6.4	20	400	0.636	0.01	0.116	4.5	0.0004
	9.4		150					
	15		150 to 400					

The following correlation relating in situ undrained shear strength to preconsolidation stress (Mesri, 1975) was employed:

Where:

$$\sigma'_p = \frac{S_{u(mob)}}{0.22}$$

σ'_p = preconsolidation stress (kPa); and,

$$S_{u(mob)} = \mu S_{u(FV)} \text{ (after Bjerrum, 1973), where } S_{u(mob)} = \text{average mobilized undrained shear strength (kPa)}$$

$$S_{u(FV)} = \text{undrained strength from in-situ field vane test (kPa)}$$

$$\mu = \text{Bjerrum's correction factor based on Plasticity Index}$$

At all culvert locations except for Culvert No. 06X-0426/C0, where the maximum height of widening is less than 1.6 m, the settlement of the foundation soils is estimated to be less than 20 mm under the centre of widening area, decreasing to less than 5 mm under the shoulder of the existing embankment. At Culvert No. 06X-0426/C0, the calculated ultimate effective stress level in the clayey silt till will exceed the preconsolidation pressure. The consolidation settlements will therefore occur in the 'virgin' compression range and will take longer to occur. The estimated consolidation settlement is about 35 mm including about 10 mm of elastic recompression settlement and 20 mm of virgin consolidation settlement. Settlement mitigation option such as preloading maybe required at the location of Culvert No. 06X-0426/C0.

The height of the embankments at the culvert locations vary from 1.2 m to 2.5 m above the creek bed. Since there will be no significant increase in the profile grade of Highway 3 during road widening, and the existing side slopes in the vicinity of each culvert site appear to be in good condition, no instability problems are anticipated for the new approach embankment of the same height, constructed with side slopes at three horizontal to 1 vertical (3H:1V) or flatter. It is understood that the proposed embankment side slopes will be inclined at 6H:1V. Benching similar to OPSD 208.010 (*Benching of Earth Slopes*), is required to key new fills into existing slope and avoid any differential settlement between the existing and new approach embankments. The global stability of the embankment slopes is to be verified at detail design.

7.12 Lateral Earth Pressure

The lateral earth pressures acting on the walls will depend on the type and method of placement of backfill materials, the nature of soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure and the drainage conditions behind the walls. Seismic (earthquake) loading must also be taken into account in the design.

The following recommendations are made regarding the design of the walls:

- Free draining non-frost susceptible granular material such as Granular A or Granular B Type II, in accordance with Ontario Provincial Standards Specifications (OPSS) 1010 (and having maximum aggregate diameter of 100 mm) be provided as backfill to the walls. The backfill should be placed in lifts not exceeding 200 mm before compaction and compacted to 98 per cent of its Standard Proctor Maximum Dry Density (SPMDD).

- The effects of compaction surcharge should also be taken into account in the calculations of active and at rest earth pressures. The lateral pressure due to compaction should be taken as at least 12 kPa at the surface, and its magnitude should be assumed to diminish linearly with depth to zero at the depth where the active or at rest pressures are equal to 12 kPa. Lighter compaction equipment and smaller lifts should be used adjacent to walls to prevent overstressing. Heavy construction equipment should be maintained at a distance of at least 1 m away from the walls while the backfill soils are being placed.
- In addition to the above, hydrostatic forces must be taken into account in the design where the walls extend below the surface water/groundwater table. Additional surcharge loading that will influence the wall must also be taken into account in the wall design, as required.
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.0 m (equivalent to the depth of frost protection at this site), behind the back of the wall on Figure C6.31(a) of the *Commentary to the CHBDC* (2019). If the structure does not allow yielding (restrained system), at-rest horizontal earth pressures should be used.

7.12.1 Static Lateral Earth Pressure for Design of Walls

For design of walls, the unfactored parameters provided in Table 5 below are recommended, depending on the wall type. These unfactored lateral earth pressures assume that the ground above the wall will be flat (i.e., not sloping). If the inclination of the slope above the wall changes then new lateral earth pressures parameters will need to be calculated.

Table 15 *Parameters for Lateral Earth Pressure Design*

Material	Bulk Unit Weight (KN/m ³)	Coefficient of Earth Pressure	
		Active (Ka)	At-rest (Ko)
Granular A	22	0.27	0.43
Granular B, Type II	21	0.27	0.43

- If the walls allow for lateral displacement, active earth pressures may be used in the geotechnical design of the structure. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.12 of the *Commentary to the CHBDC* (2019).
- For restrained walls (i.e., retained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest pressures (plus any compaction surcharge and hydrostatic) should be assumed for geotechnical design.

7.12.2 Seismic Lateral Earth Pressures for Design

Seismic (earthquake) loading may also be taken into account in the design of the walls in accordance with Section 6.14 of the *CHBDC* (2019). In this regard, the following should be included in the assessment of the lateral earth pressures:

- Seismic loading will result in increased lateral earth pressure acting on the walls. The walls should be designed to withstand the combined lateral loading for the appropriate static pressured conditions given above, plus the earthquake dynamic earth pressure.
- In accordance with Sections 6.14.7 and C 6.14.7 of the *CHBDC* (2019) and its *Commentary*, for unrestrained wall, the horizontal seismic coefficient, k_h , used in the calculation of the seismic active pressure coefficient, is taken as 0.5 times the site-specific PGA. For restrained wall, k_h is taken as equal to the site-specific PGA. For both cases the value of the vertical seismic coefficient k_v is taken as zero.

- The following seismic active pressure coefficients (K_{AE}) may be used in design; these coefficients reflect the maximum K_{AE} obtained for each backfill condition and for required earthquake design period (2,475 years or 2% in 50 years) per Section 7.5.8 of the CHBDC (2019).
- It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the walls level and the friction angle at the interface wall/granular fill is neglected. Where sloping backfill is present above / beyond the top of the wall, the lateral earth pressures under seismic loading conditions should be calculated by treating the weight of the backfill located above the top of the wall as a surcharge.

Table 16 Seismic Parameters for Lateral Earth Pressure Design

Displacement state	Site PGA (g), Site Class D	Seismic Active Pressure Coefficients, K_{AE} for Class D for design earthquake period of 2,475 years	
		Granular A	Granular B Type II
Unrestrained Wall	0.084	0.29	0.29
Restrained Wall	0.084	0.32	0.32

The K_{AE} value for unrestrained wall is applicable provided that the wall is able to move a distance equal to $250k_h$ mm, where k_h is 0.5 times the site-specific PGA as given in the table above. As per Section C6.14.7.2, of the Commentary to the CHBDC (2019), referring to Elms and Martin (1979)⁽⁸⁾, the wall displacement-based design is estimated to 10 mm.

The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e., an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined per Section C6.14.7 of the Commentary to the CHBDC (2019).

7.13 Analytical Testing for Construction Materials

Representative soil samples of the cohesive till deposit from the six culvert locations were tested for parameters used to assess the potential corrosivity of the soil to steel and concrete. A summary of the chemical test results are provided in Table .

Table 17 Summary of Analytical Test Results at the Culvert Structure Locations

Culvert No.	Borehole No.	Depth (Elevation) (m)	Sulphate ($\mu\text{g/g}$)	Sulphide ($\mu\text{g/g}$)	Chloride ($\mu\text{g/g}$)	pH	Resistivity (Ohm-cm)
06X-0421/C0	BH-20-03	3.0 (191.3)	980	< 5	129	7.80	1240
06X-0423/C0	BH-20-08	3.2 (192.3)	510	< 5	12	7.68	1880
	BH-21-01	2.6 (192.3)	729	<0.2	80.3	7.48	1180
06X-0426/C0	BH-20-10	4.9 (189.8)	580	< 5	16	7.70	1730
	BH-21-02	3.3 (192.4)	166	0.23	133	7.89	2070
06X-0427/C0	BH-20-11	3.3 (191.8)	130	< 5	230	7.75	2060
	BH-21-03	2.6 (192.2)	840	<0.2	263	7.46	857
06X-0429/C0	BH-20-13	3.3 (192.0)	30	< 5	171	7.71	2880
	BH-21-04	3.5 (191.5)	84	<0.2	133	7.61	1600
06X-0432/C0	BH-20-16	3.3 (191.3)	280	< 5	30	7.70	2420

⁸ Elms, D.A., and Martin, G.R. 1979. *Factors Involved in the Seismic Design of Bridge Abutments, Proceedings, Workshop on Seismic Problems Related to Bridges, Applied Technology Council, San Diego, California, USA.*

As shown in this table, the sulphate contents range from 30 µg/g to 980 µg/g. According to Clause 4.1.1.6 of the Canadian Standards Association (CSA) A23.1-14/A23.2-14 Standard (2014), soluble sulphate concentrations less than 0.1% (1000 µg/g) generally indicate a low degree of sulphate attack when concrete is in contact with soil or groundwater. Hence, the potential for sulphate attack of concrete at all structure locations is considered to be low. Based on Table 1 of CSA A23.1-14, concrete made with general use (GU) type cement should be acceptable for buried concrete elements.

Based on MTO Gravity Pipe Design Guideline (April 2014), a soil with a resistivity of less than 2,000 Ohm-cm is considered very corrosive, a soil with a resistivity between 2,000 and 4,500 Ohm-cm is considered corrosive, and a soil with a resistivity between 4,500 and 6,000 Ohm-cm is considered moderately corrosive. For an environment to be corrosive to metal or steel, it is generally recognised that the chloride concentration in soils or water should be above 250 µg/g (250 ppm). As the culverts will also be located under the roadway and shoulders and will be exposed to de-icing salt, it is recommended to use the adequate exposure class type concrete according to CSA A23.1-14 Table 1.

The corrosion and sulphate attack potentials for each site are summarized in the table below and should be considered in the design of culverts.

Table 18 Sulphate Attack and Corrosion Potential

Culvert No.	Sulphate attack Potential	Corrosivity Potential
06X-0421/C0	low	Moderate to Severe
06X-0423/C0	low	Moderate
06X-0426/C0	low	Moderate
06X-0427/C0	low	Severe
06X-0429/C0	low	Moderate
06X-0432/C0	low	Moderate to Severe

It is expected that granular backfill will be used at structure locations for different purposes. Generally, no sulphate attack is expected from granular backfill materials. However, it may be advisable to test backfill material for corrosion potential if it is imported from unknown sources.

7.14 Construction Considerations

7.14.1 Excavation

All excavations should be carried out to the manner specified in Ontario Regulation 213/91 and the Occupational Health and Safety Act and Regulations (OHSA) for Construction Projects.

Based on the borehole records, the excavations for footings of the culvert extension at all structure locations will be advanced through the granular and cohesive fill material and a till deposit consisting of stiff to very stiff clayey silt to silty clay. The firm to stiff fill deposit is classified as Type 3 soil. The stiff to very stiff clayey silt till should be considered as Type 2 soil. Below the groundwater table the stiff to very stiff cohesive till deposit is classified as Type 3 soils. With the use of dewatering, the side slope geometry for excavations through multiple soil layers is governed by the soil type with the highest OHSA designation number (in this case Type 3 soils). Unsupported excavation walls in Type 2 and 3 soils must be inclined at a gradient of 1H:1V or flatter to the base of excavation.

Excavation of the soils at the six culvert locations should be feasible using conventional excavation equipment. All excavated surfaces should be kept free of frost and water during the period of construction. Runoff should be directed away from open excavations and should not be allowed to flow across slope

faces. Excavated material must be stockpiled at a distance away from the excavation equal to or greater than the depth of the open cut excavation.

7.14.2 Groundwater Control

Based on the monitoring wells installed in Borehole BH-21-01 the groundwater level will be 2.6 m and 2.4 m above the subgrade level for the box culvert and open footing options at Culvert Nos. 06X-0421/C0 and 06X-0423/C0, respectively. Perched groundwater conditions may also be present in the fill material overlying the cohesive till deposit. Excavations for the box culverts and open footings will extend through the fill material and into the cohesive till deposit and seepage through the cohesive till deposit is expected to be low due to the low permeability of the deposit; however, depending on the duration of time that the excavation is open for, and if there is groundwater seepage that cannot be handled by pumping from well filtered sumps located outside of the footprint of the excavation, then dewatering will be required to lower the groundwater table. If dewatering is required, the groundwater level should be lowered to 1 m below the subgrade level.

Based on the monitoring wells installed in Boreholes BH-21-03 and BH-21-06 it is expected that the groundwater level will be below the subgrade level for the box culvert and open footing options at Culvert Nos. 06X-0426/C0, 06X-0427/C0, 06X-0429/C0 and 06X-0432/C0. However perched groundwater conditions are to be expected in the fill material overlying the cohesive till deposit and it is expected that this groundwater seepage can be handled by pumping from well filtered sumps located outside of the footprint of the excavation.

In addition, to maintain a dry work environment, the creeks at all structure locations may have to be diverted by means of temporary by-passes or be pumped from behind cofferdams constructed across channels or the watercourses. A cofferdam may consist of sand bags, and dewatering may be carried out by pumping from sumps formed along its periphery. This is discussed further in Section 7.14.3. **Error! Reference source not found..**

Further, surface water and runoff should be directed away from the excavation areas to prevent the disturbance of footings. Pumping from within the excavation will also likely be required as water can flow into the excavation from below the base of the dewatering system (sheet pile) or the base of the excavation.

The dewatering system, if required, should be designed to conform to the requirements of OPSS.902 (Construction Specification for Excavating and Backfilling) as amended by NSP FOUN0003. The temporary flow passage system should be designed in accordance with OPSS .PROV 517 (*Construction Specification for Dewatering*) as amended by SP 517F01.

If pumping of groundwater at volumes greater than 50,000 L/day and less than 400,000 L/day is required during the construction stage, the Environmental Activity Sector Registry (EASR) must be completed. The EASR streamlines the process and water pumping may begin once the EASR registration is completed, the fee paid and supporting documents prepared. If water taking in excess of 400,000 litres/day is required, a Permit to Take Water (PTTW) must be obtained in advance. PTTW applications may take up to 90 working days for the Ministry of the Environment, Conservation, and Parks (MECP) to review and approve. The actual rate of groundwater taking will be a function of the final design, time of year, and the contractor's schedule, equipment, and techniques.

7.14.3 Temporary Cofferdam System

To facilitate the extensions of the existing culverts, the watercourse will be required to be diverted and a temporary cofferdam will be required at the inlet and outlet of the culvert to enable the construction of the open footings or the box culvert, or so that the work can be carried out in the dry. Based on the anticipated ground conditions at the inlet and outlet, a cofferdam consisting of a sheet pile cut-off wall installed to an appropriate depth is considered feasible although there is the potential that cobbles and or boulders may

be present in the till deposits, which may impede the advancement of the sheet pile wall to a sufficient depth that provides the necessary passive resistance. Consideration should be given to protecting the tips of the sheet piles prior to sheet pile installation, assuming a sheet pile system is adopted by the contractor. It may be possible to construct temporary cofferdams and divert the creek using one of the following methods:

- Small inflatable bladder cofferdams.
- Water dams consisting of industrial grade, impermeable, composite fabrics formed into flexible tubes containing one or more chambers.
- Multiple rows of large sand bags lined with an impermeable layer.

The viability and effectiveness of such systems will depend on the water level in the creek at the time of construction as well as the available space between where the diversion structures/temporary cofferdam will be located relative to the excavation for the new culvert and the proximity of any surrounding infrastructure/residents to the site.

If the water levels in the creek are high during construction, it may be necessary to install a more robust groundwater cut-off system (i.e., interlocking steel sheet piles driven to a suitable depth) to avoid excavation instability of the foundation subgrade.

The temporary cofferdams at the site should be designed and constructed in accordance with OPSS.PROV 539 for Performance Level 2. The design of the temporary cofferdam system should include an evaluation of the tolerable lateral movement, base stability and hydraulic uplift as defined in the Canadian Foundation Engineering Manual (CFEM, 2006). The contractor is responsible for the design and construction of the cofferdam system. An NSSP Dewatering Structures (i.e., cofferdams) is included in Appendix E.

7.14.4 Temporary Protection System

It is understood that staged construction will not be required for culvert extensions; however, where the extension connects to the existing culvert temporary protection systems may be required. Temporary protection systems could consist of either driven steel sheet piles or soldier piles and lagging. Based on the borehole information, the cohesive till deposit encountered at all structure locations should be favourable for driving sheet piles to an adequate depth of embedment. A temporary protection system shall be designed and constructed by the contractor and should meet the requirements of Performance Level 2, in accordance with OPSS.PROV 539 (*Construction Specification for Temporary Protection Systems*) and its amendment (SP 105S09).

While the selection and design of the temporary protection system will be the responsibility of the contractor, the following information is provided to MTO and its designers to aid in assessment of the approximate construction costs during detail design. Lateral support to the sheet pile wall or soldier pile wall could be provided in the form of rakers/struts or temporary anchors. The tiebacks or rakers/struts must be designed to accommodate the loads applied from the earth pressures, water pressure and surcharge pressures from area, line or point loads as well as the effects of slope ground behind the system. Passive toe restraint to the soldier piles may be determined using conventional passive earth pressure distribution acting over an equivalent width equal to three times the soldier pile socket diameter provided that the soldier piles are separated by more than three times the socket diameter. Design of the temporary protection system should include an evaluation of base stability and hydraulic uplift stability as defined in the CFEM (2006).

Table 19 Recommended Soil Parameters for Temporary Protection System

Material	Bulk Unit Weight (KN/m ³)	Submerged Unit Weight (KN/m ³)*	Angle of Internal Friction, θ	Cu (KPa)	Coefficient of Earth Pressure		
					Active (Ka)	At-rest (Ko)	Passive (Kp)
Existing Granular Fill	20	10.2	30	-	0.33	0.50	3.00
Silty Clay Fill	18	8.2	28	60	0.36	0.53	2.77
Clayey Silt to Silty Clay Till	19	9.2	27	150 to 50	0.37	0.55	2.70
Silty Sand Till	20	10.2	36	-	0.26	0.41	3.85
Note: * Submerged unit weight should be used below the groundwater table							

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly. The total passive resistance below the base of the excavation (i.e., adjacent to the temporary protection system) may be calculated based on the values of Kp indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It should be noted that the parameters given above are applicable to the ultimate stress condition; a stiffer design may be required than predicted by these parameters in order to maintain displacements within an acceptable range.

Depending on the time of year, there may be perched water in the fill materials. If groundwater is present, it would be necessary to control seepage or include measures to mitigate loss of soil particles through lagging boards if a soldier pile and lagging system is employed.

Consideration should be given to either partial or full removal of the protection system upon completion of construction. Where possible, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work. An NSSP is included in Appendix E which addressed the removal or cut-off of the protection system.

Cobbles and/or boulders were not inferred during drilling within the upper part of the till at all structure locations. However, wood fragments were observed in Borehole BH-21-05 (Culvert No. 06X-0429/C0) and there is the potential that cobbles and or boulders may be present in cohesive till deposit. An NSSP is provided in Appendix E.

7.14.5 Obstructions During Installation of Temporary Protection System and Cofferdams System

Wood fragments were encountered during advancement of the Borehole BH-21-05 and there is a potential that cobbles and/or boulders may be encountered within the till deposits in the vicinity of the culvert locations. The presence of these obstructions may affect the installation of the temporary protection and cofferdam system elements. It is recommended that the Contract Documents warn the contractor of the possible presence of wood, cobbles and/or boulders within the overburden soils; an NSSP is provided in Appendix E.

7.14.6 Subgrade Protection

The subgrade soils at the base level of the excavations for the culvert extensions will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that the subgrade for open footings culverts be protected within four hours of preparation, inspection, and approval of the subgrade for the footing. Following inspection and approval of the subgrade for box culverts granular bedding or a concrete working slab should be provided within four hours.

7.14.7 Winter Construction

The soils encountered at all project sites are frost-susceptible and freezing conditions could cause problems to culvert footings. Hence, during any winter construction, exposed surfaces intended to support the footings must be protected from freezing. In the event that construction is required during freezing temperatures, the soil below the footings should be protected immediately from freezing using straw, propane heaters and insulated tarpaulins, or other suitable means. Any excavation should be opened for as short a time as practicable and the excavations should be carried out only in lengths which allow all of the construction operations, including backfilling, to be fully completed in one working day. In addition, the granular backfill should be used without being disturbed by frost or mixed with snow or ice.

8. Closure

This report was prepared by Ms. Sahar Soleimani, Ph.D., P.Eng., a Senior Geotechnical Engineer with GHD. Sandra McGaghran, M.Eng., P.Eng., a Senior Geotechnical Engineer with GHD and MTO Foundations Designated Contact conducted an independent review of the report.

Sincerely,

GHD Limited



Sahar Soleimani, Ph.D., P.Eng.
Senior Geotechnical Engineer



Sandra McGaghran, M.Eng., P.Eng.
MTO Foundations Designated Contact, Senior Geotechnical Engineer

References

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

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.

Concrete materials and methods of concrete construction / Test methods and standard practices for concrete

(CSA A23.1-14/A23.2-14). Canadian Standard Association. (CSA) Group.

International Society for Rock Mechanics Commission on Test Methods. 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

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Mitchell, J.K. 1993. Fundamentals of Soil Behaviour. 2nd Edition, John Wiley and Sons Inc., New York.

Peck, R.B., Hanson, W.E., and Thornburn, T.H. 1974. Foundation Engineering, 2nd Edition, John Wiley and Sons, New York.

Unified Facilities Criteria, U.S. Navy. 1986. NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures. Alexandria, Virginia.

ASTM International:

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

ASTM D2573-15 Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils

ASTMD1587 Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes

Commercial Software:

Settle 3 (Version 4) Rocscience Inc.

Ontario Provisional Standard Drawing:

OPSD 208.010 Benching of Earth Slopes

OPSD 810.010 Rip-Rap Treatment for Sewer and Culvert Outlets

OPSD 803.010 Backfill and Cover for Concrete Culverts

OPSD 3090.101 Foundation Frost Penetration Depths for Southern Ontario

Ontario Provincial Standard Specification:

OPSS.PROV 206 Construction Specification for Grading

OPSS.PROV 212 Construction Specification for Earth Borrow

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specifications for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 802	Construction Specification for Topsoil
OPSS 803	Construction Specification for Sodding
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1002	Material Specifications for Aggregates – Concrete
OPSS.PROV 1004	Material Specification for Aggregates – Miscellaneous
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS.PROV 1205	Material Specifications for Clay Seal
SP 105S22	Special Provision – Amendment to OPSS 501, June 2016
SP 105S09	Special Provision – Amendment to OPSS 539, November 2014
SP 109S12	Special Provision – Amendment to OPSS 902, August 2018
SP 517F01	Special Provision - Amendment to OPSS 517, July

Ontario Water Resources Act:

Ontario Regulation 903 Wells (as amended)

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91 Construction Projects (as amended)

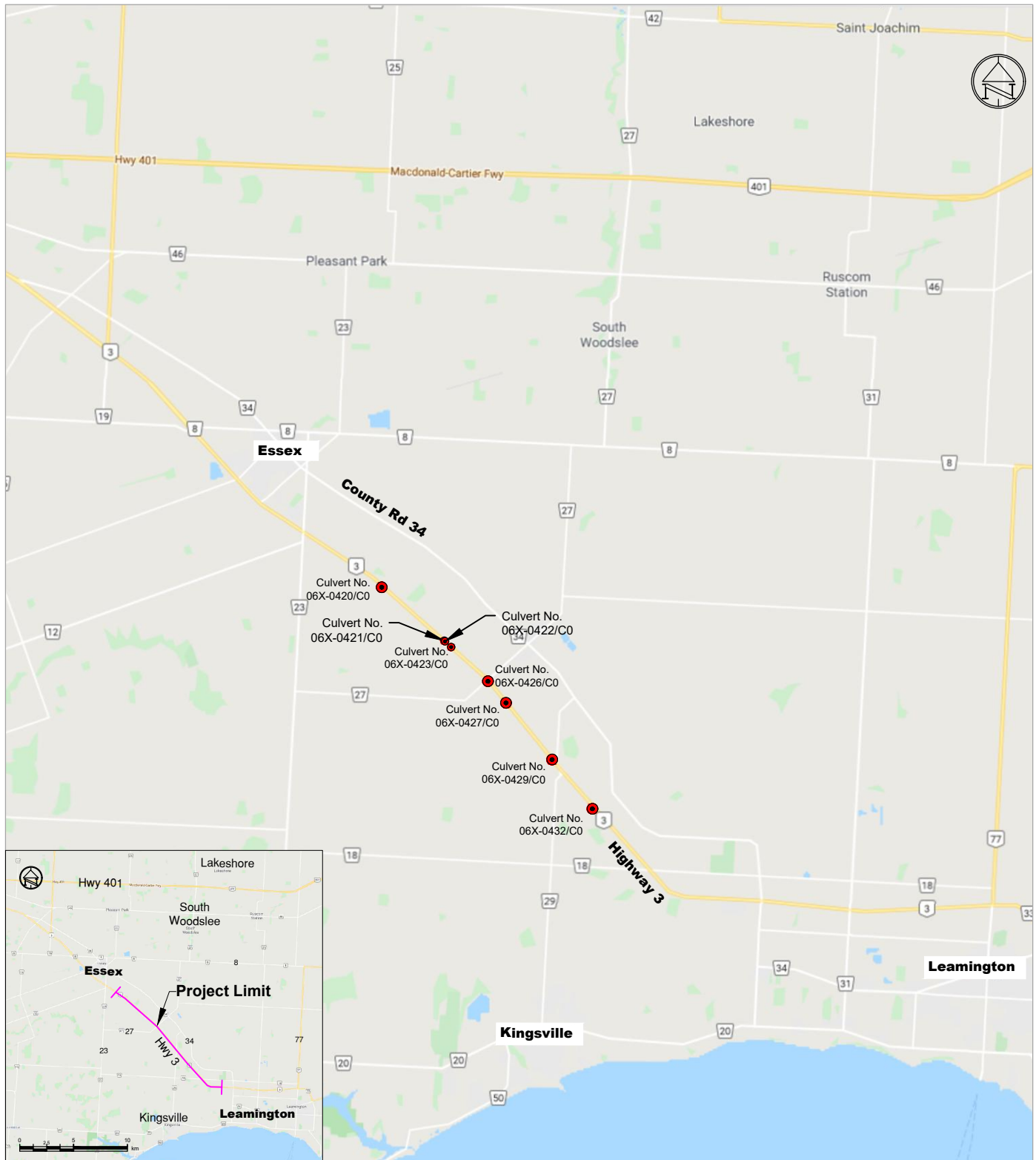
Ministry of Transportation, Ontario

Highway Drainage Design Standards, January 2008

Embankment Settlement Criteria for Design, July 2, 2010

Table 20 *Comparison of Alternatives for Culvert Extensions / Replacement*

Options	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Box Culvert	<ul style="list-style-type: none"> Minimizes depth of excavation, excavation support and potential dewatering requirements compared to open-footing option. Pre-cast box sections expected to allow faster construction than cast-in-place open footings, with shorter duration for dewatering (if required) and temporary flow passage systems. 	<ul style="list-style-type: none"> Will require excavation below the water table and potentially dewatering at Culvert No. 06X-0421/C0 and No. 06X-0423/C0 	<ul style="list-style-type: none"> Less overall cost relative to open footing culvert extensions because shorter period of excavation, temporary support, temporary flow passage systems and dewatering systems are required. 	<ul style="list-style-type: none"> Potential challenges connecting box culvert to existing open footing. If temporary protection systems are required cobbles and/ boulders may be encountered in the cohesive till deposit.
Open Footing	<ul style="list-style-type: none"> May be feasible to build culvert extensions on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering (if required) and temporary flow passage systems. 	<ul style="list-style-type: none"> Excavation depths are greater than box culvert option in order to found footings at/below depth of frost penetration, resulting in increased excavation support and dewatering (if required) requirements. Cast-in-place footings may require a longer duration for construction, including dewatering and temporary flow passage systems, as compared with pre-cast culvert segments or footing elements. 	<ul style="list-style-type: none"> Greater overall cost relative to box culvert option because deeper excavations are required which will also result in additional time period for temporary support systems, temporary flow passage systems and dewatering (if required). 	<ul style="list-style-type: none"> Longer construction time and deeper excavations introduce greater risk to the extension of the culvert. Where required groundwater levels will have to be lowered to greater depths. If temporary protection systems are required cobbles and/ boulders may be encountered in the cohesive till deposit.



LEGEND:  Culvert Location



REFERENCE: Google Map Data

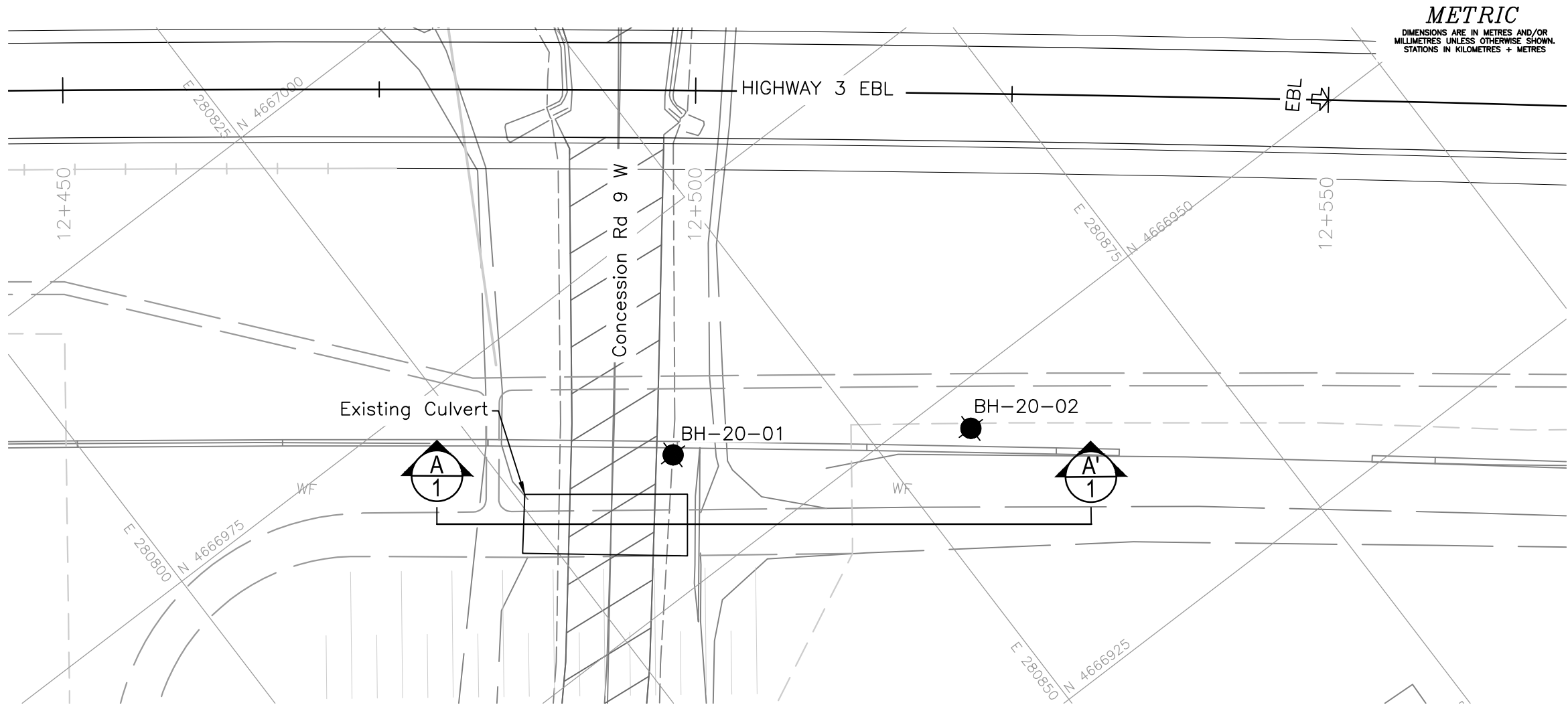
Assignment No.:	3017-E-0012	Geocres No.:	40J2-147
GWP:	3021-18-00	Hwy No.:	3
Township:	Gosfield North and Gosfield South		
District:	Chatham		
Drawn:	AW	Project No.:	11202866
Checked:	SS	Date:	1.10.2022
Reviewed:	SS	Revision:	
Approved:	SMM	Drawing:	1



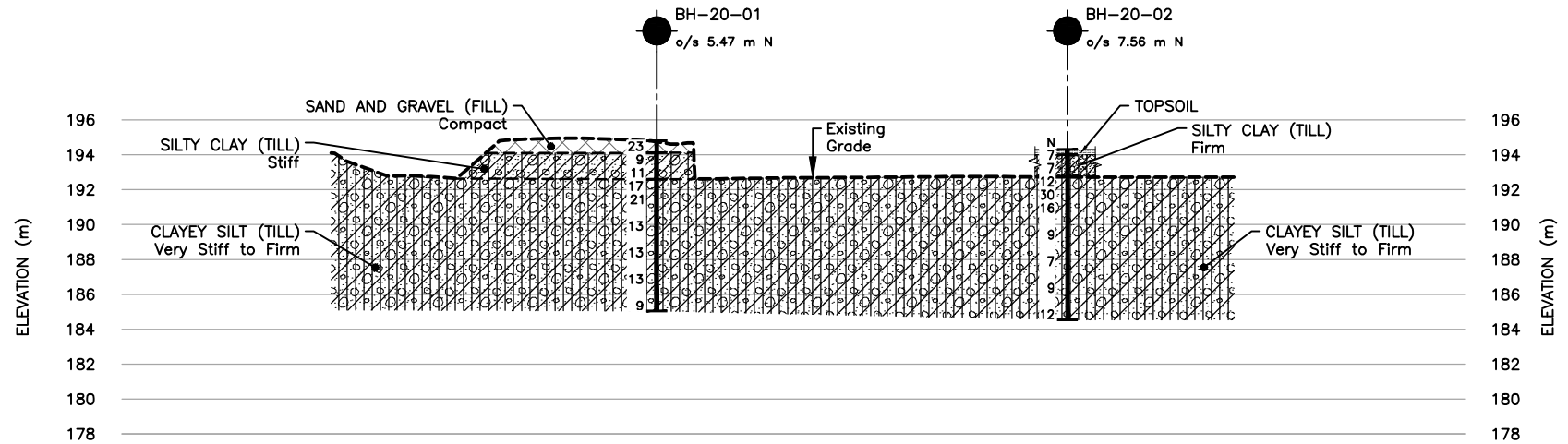
Key Plan

Foundation Investigation and Design

Hwy 3 Widening, Windsor to Leamington, Phase 3 - Contract 2



PLAN
SCALE 0 2.5 5 10 m



PROFILE A-A'

HORIZONTAL SCALE 0 2.5 5 10 m
VERTICAL SCALE 0 2.5 5 10 m



CONT No.
GWP No. 3021-18-00



CULVERT No. 06X-0420/C0
HIGHWAY 3
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEY PLAN
SCALE

0 2.5 5 10 km

LEGEND

- Borehole
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test. 475 j/blow)

BOREHOLE CO-ORDINATES (MTM ZONE 11)

NO	ELEVATION	NORTHING	EASTING
BH-20-01	194.8	4666959.4	280836.9
BH-20-02	194.3	4666946.7	280856.9

NOTES

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

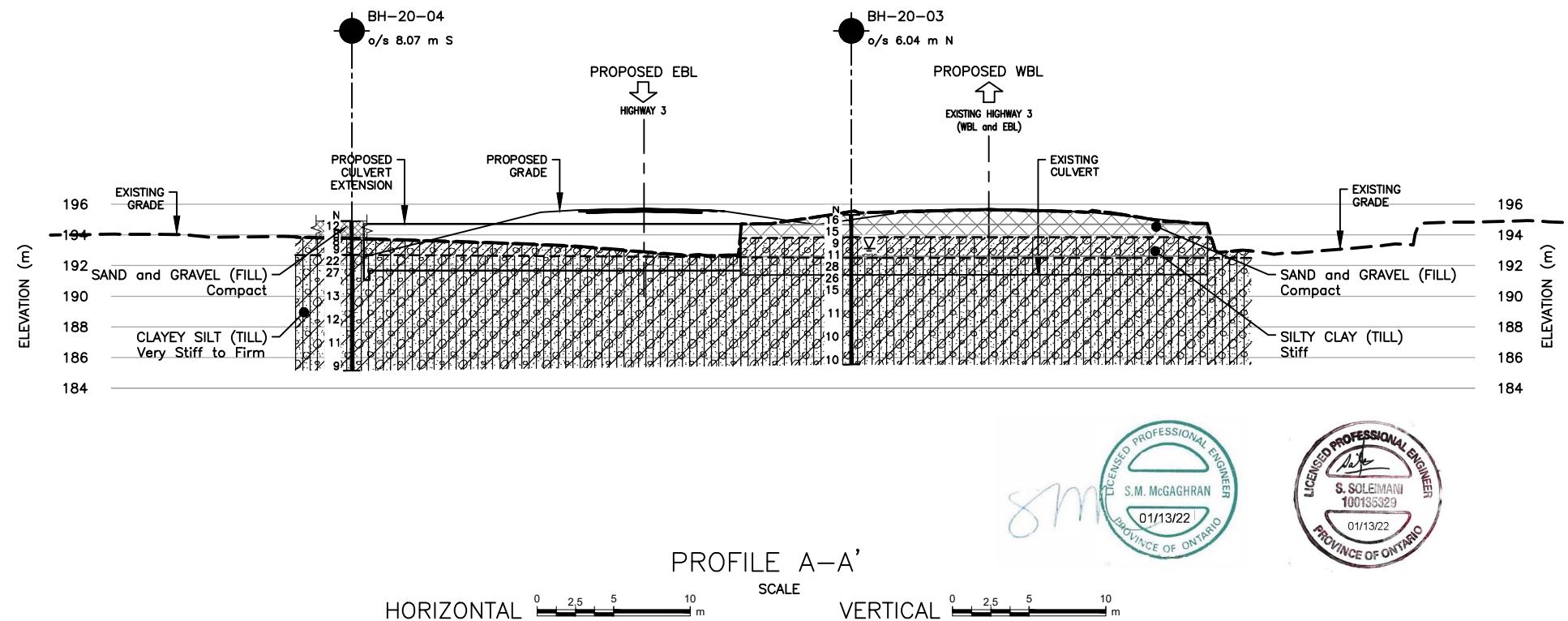
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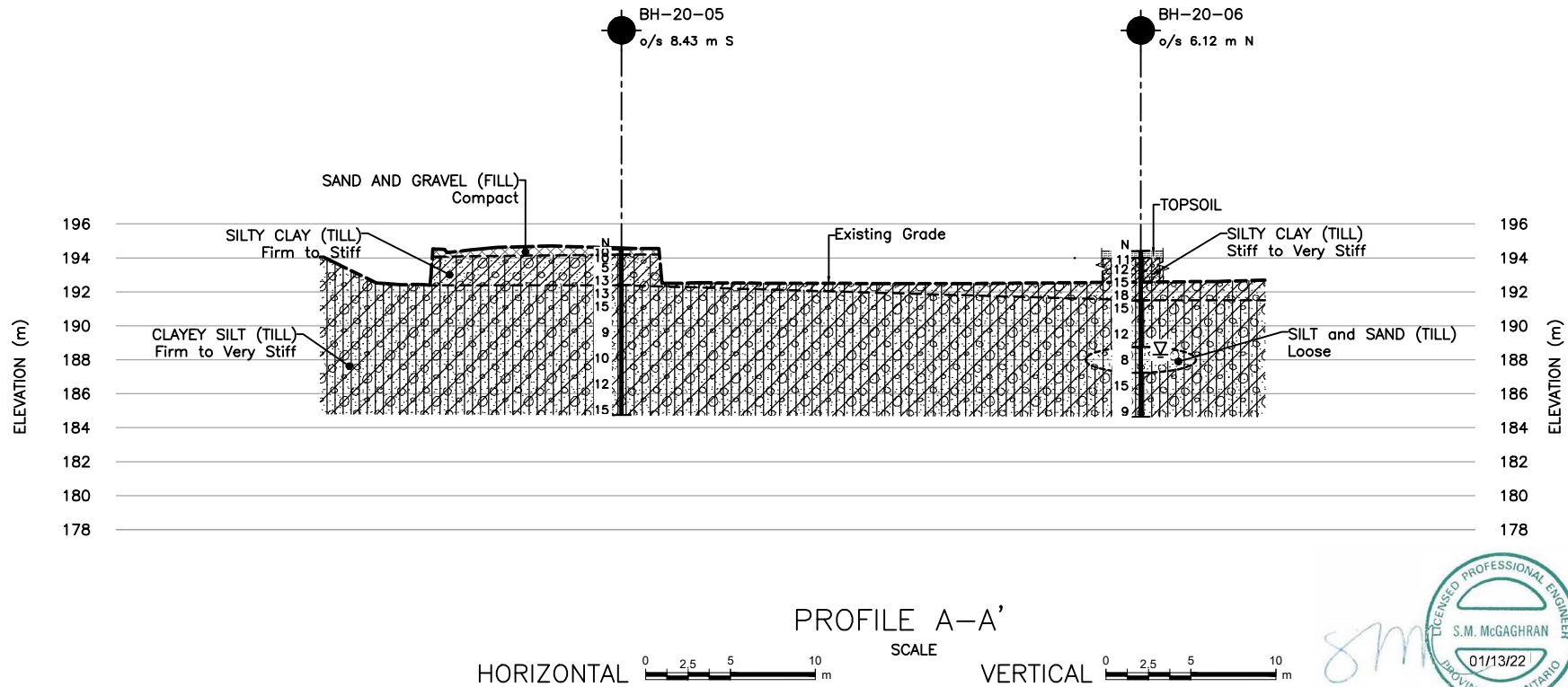
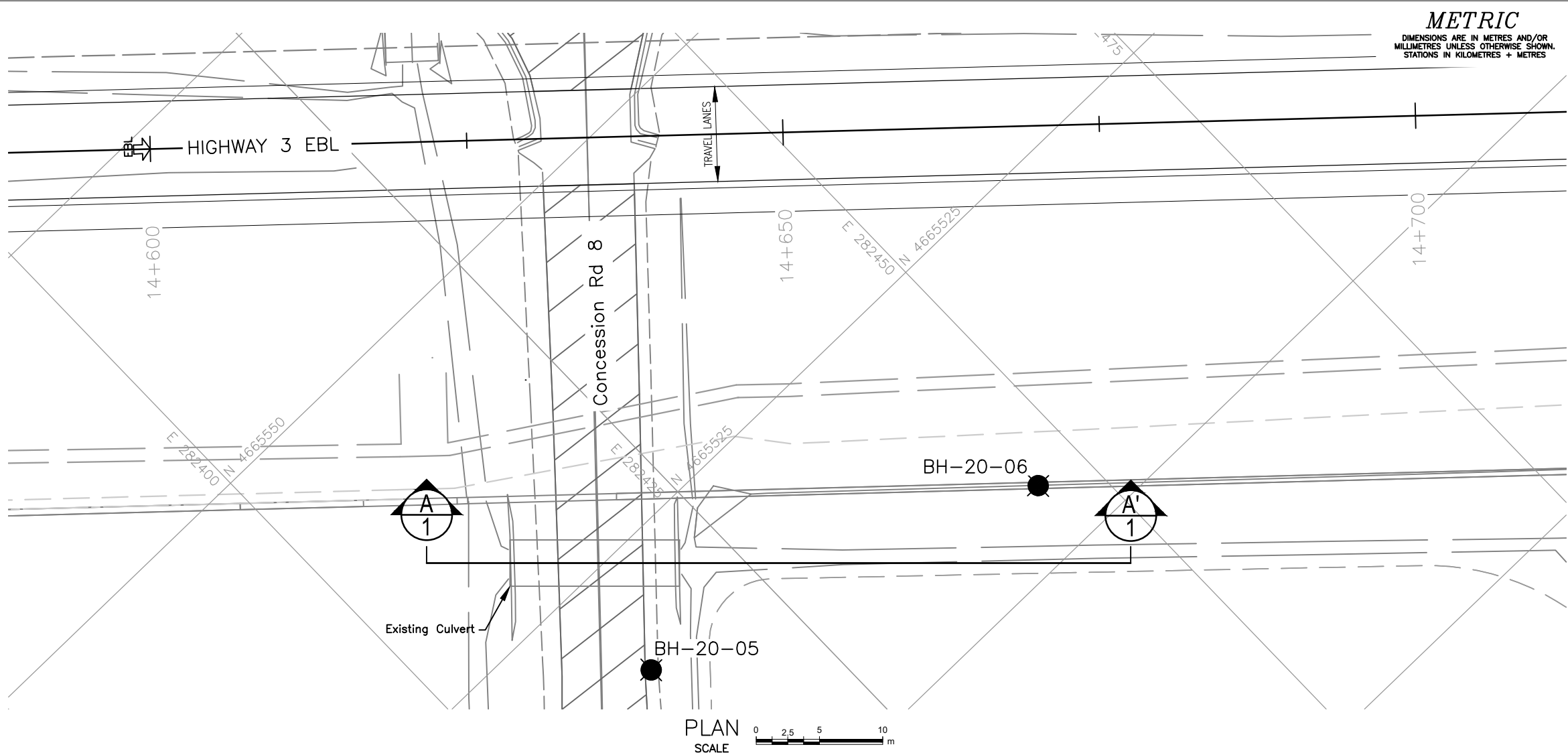
NO.	DATE	BY	REVISION

Geocres No.: 40J2-147

HWY. 3	PROJECT NO. 11202886	DIST. CHATHAM
SUBM'D. MN	CHKD. SS	DATE: 1.10.2022
DRAWN: AW	CHKD. SS	APPD. SMM
		SITE: 06X-0420/C0
		DWG. 2



NO.	DATE	BY	REVISION		
Geocres No.: 40J2-147					
HWY. 3		PROJECT NO. 11202886		DIST. CHATHAM	
SUBM'D. MN		CHKD. SS	DATE:1.10.2022	SITE: 06X-0421/CO	
DRAWN: AW		CHKD. SS	APPD. SMM	DWG. 3	



CONT No.
GWP No. 3021-18-00

CULVERT No. 06X-0422/CO
HIGHWAY 3
BOREHOLE LOCATIONS AND SOIL STRATA

GHD

KEY PLAN
SCALE 0 2.5 5 10 km

LEGEND

- Borehole
- N Standard Penetration Test Value
Blows/0.3m unless otherwise stated
(Std. Pen. Test. 475 j/blow)
- Water Level in open borehole upon completion of drilling

BOREHOLE CO-ORDINATES (MTM ZONE 11)			
NO	ELEVATION	NORTHING	EASTING
BH-20-05	194.5	4665516.3	282413.7
BH-20-06	194.4	4665505.6	282445.9

NOTES

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NO.	DATE	BY	REVISION

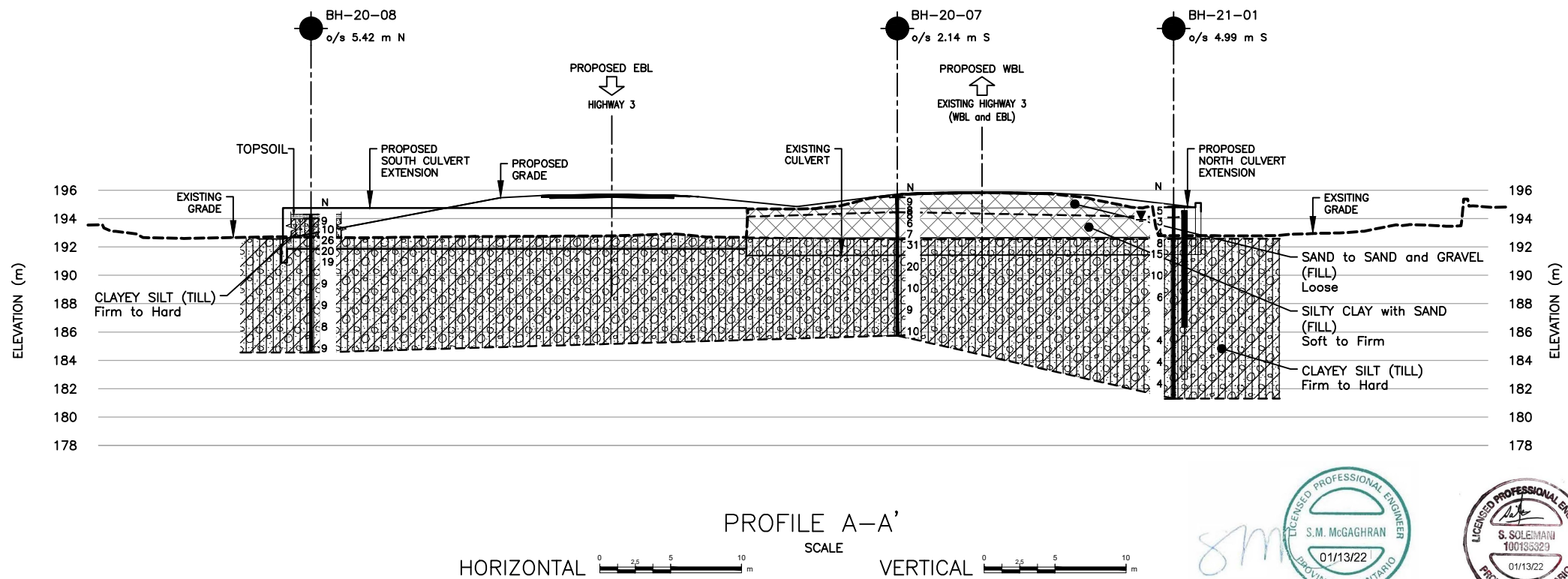
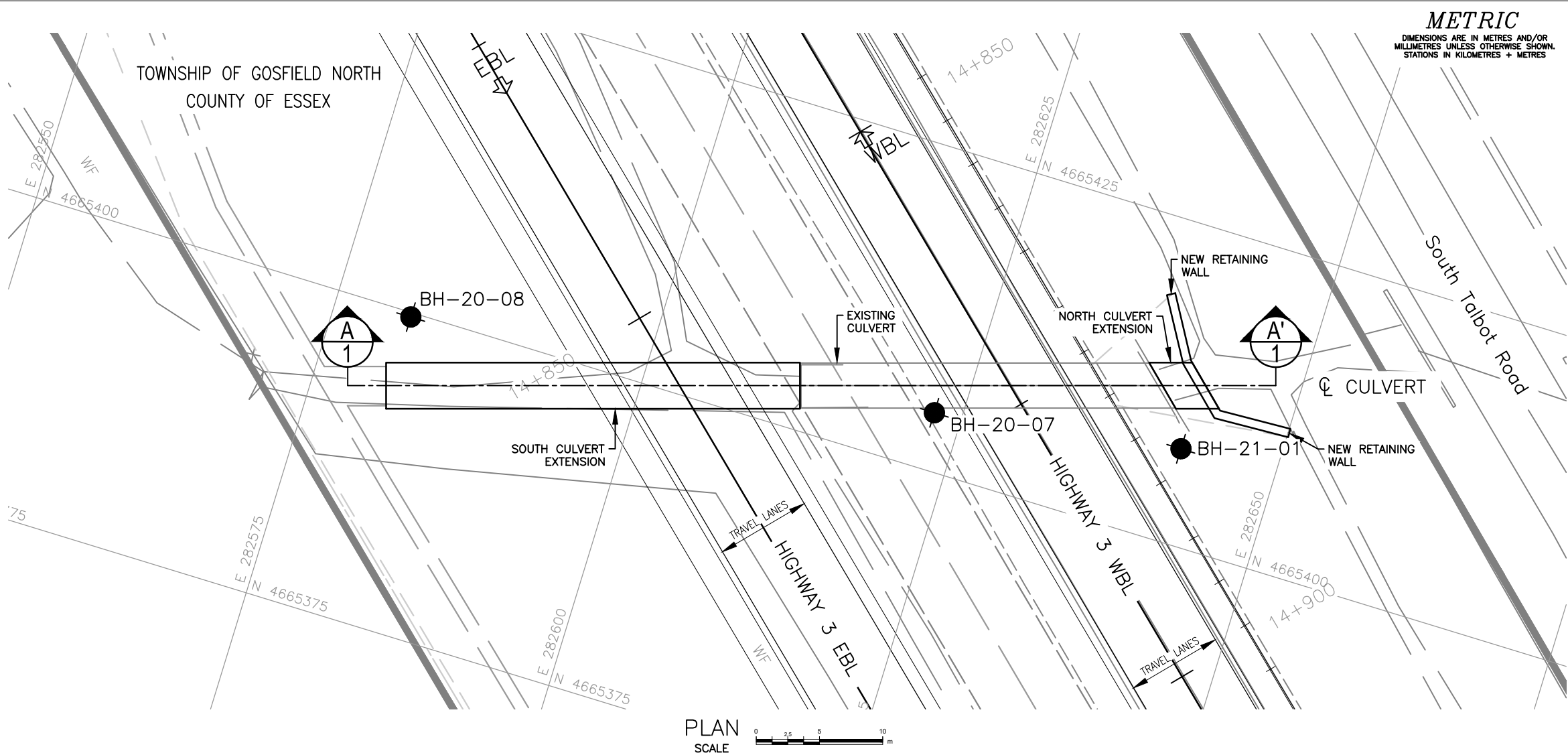
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HWY. 3	PROJECT NO. 11202886	DIST. CHATHAM
SUBM'D. MN	CHKD. SS	DATE: 1.10.2022
DRAWN: AW	CHKD. SS	APPD. SMM

SITE: 06X-0422/CO
DWG. 4

PROFESSIONAL ENGINEER
S.M. McGAGHRAN
100135329
01/13/22
PROVINCE OF ONTARIO

PROFESSIONAL ENGINEER
S. SOLEIMANI
180135329
01/13/22
PROVINCE OF ONTARIO



CONT No.
GWP No. 3021-18-00

CULVERT No. 06X-0423/C0
HIGHWAY 3
BOREHOLE LOCATIONS AND SOIL STRATA



KEY PLAN
SCALE

LEGEND

- Borehole
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test. 475 j/blow)
- Water Level in open borehole upon completion of drilling
- Water Level measured in piezometer (Nov. 24/2021)

BOREHOLE CO-ORDINATES (MTM ZONE 11)

NO	ELEVATION	NORTHING	EASTING
BH-20-07	195.5	4665404.5	282622.8
BH-20-08	194.3	4665399.6	282581.1
BH21-01	194.9	4665407.5	282642.3

NOTES

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REFERENCE

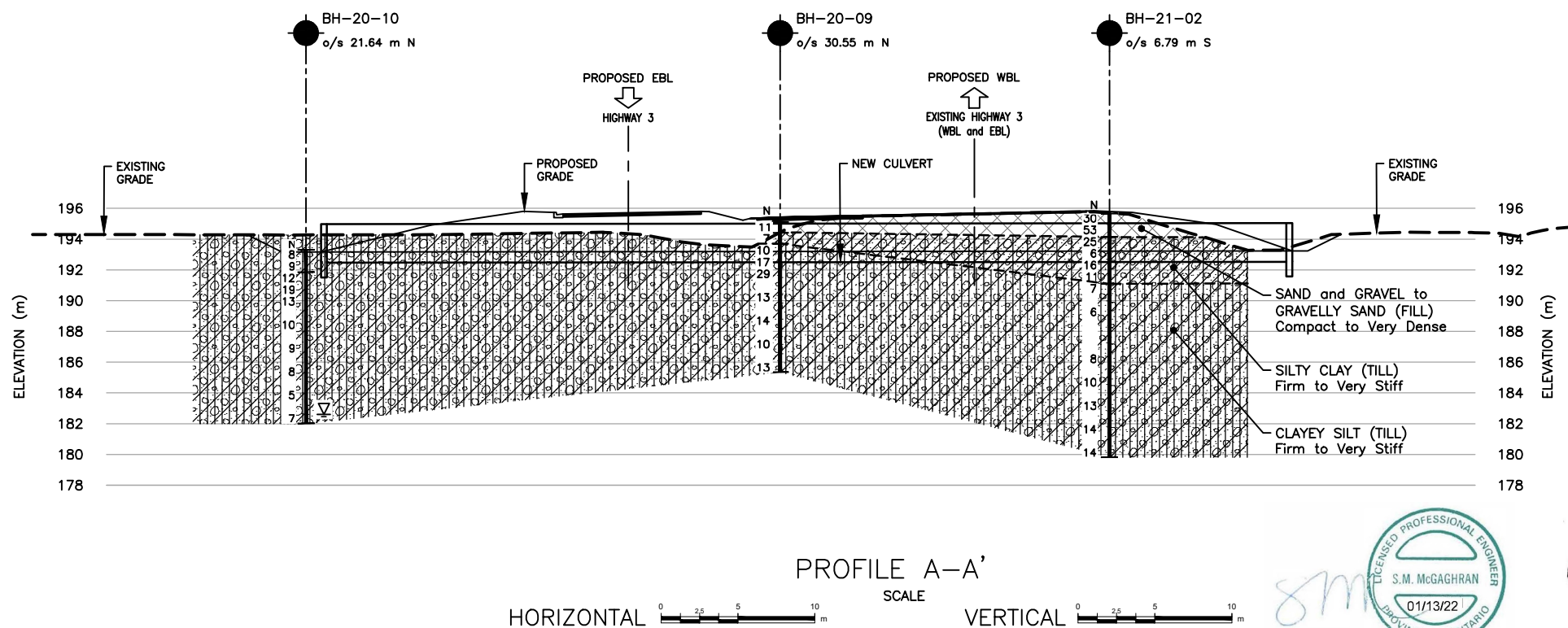
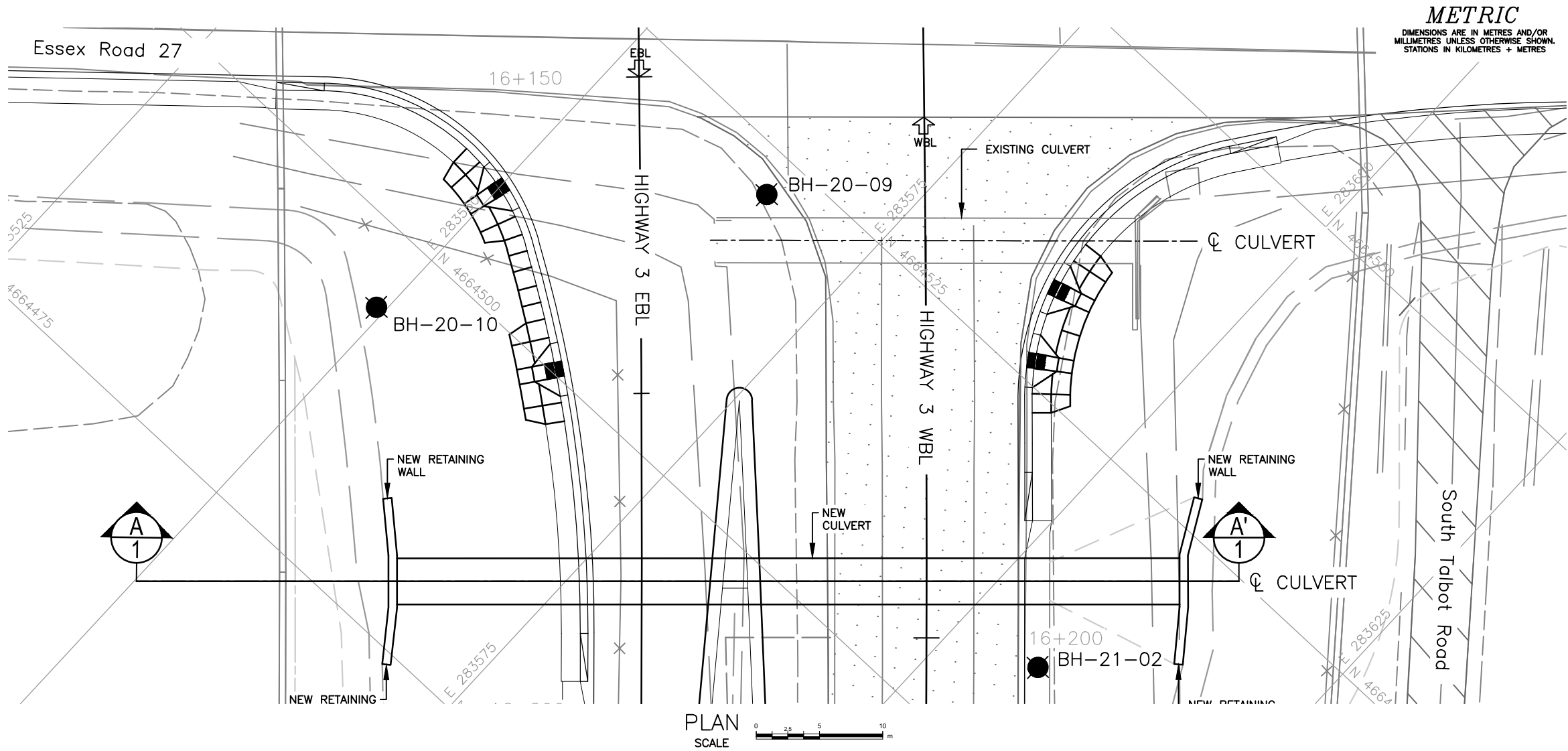
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NO.	DATE	BY	REVISION

Geocres No.: 40J2-147

HWY. 3	PROJECT NO. 11202886	DIST. CHATHAM
SUBM'D. MN/MRM	CHKD. SS	DATE: 1.10.2022
DRAWN: AW	CHKD. SS	APPD. SMM
		SITE: 06X-0423/C0
		DWG. 5





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

CONT No.
GWP No. 3021-18-00

CULVERT No. 06X-0426/C0
HIGHWAY 3
BOREHOLE LOCATIONS AND SOIL STRATA



LEGEND

- Borehole
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test. 475 j/blow)
- Water Level in open borehole upon completion of drilling

BOREHOLE CO-ORDINATES (MTM ZONE 11)

NO	ELEVATION	NORTHING	EASTING
BH-20-09	195.1	4664521.8	283565.9
BH-20-10	193.3	4664494.3	283549.3
BH21-02	195.7	4664509.0	283607.0

NOTES

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

REFERENCE

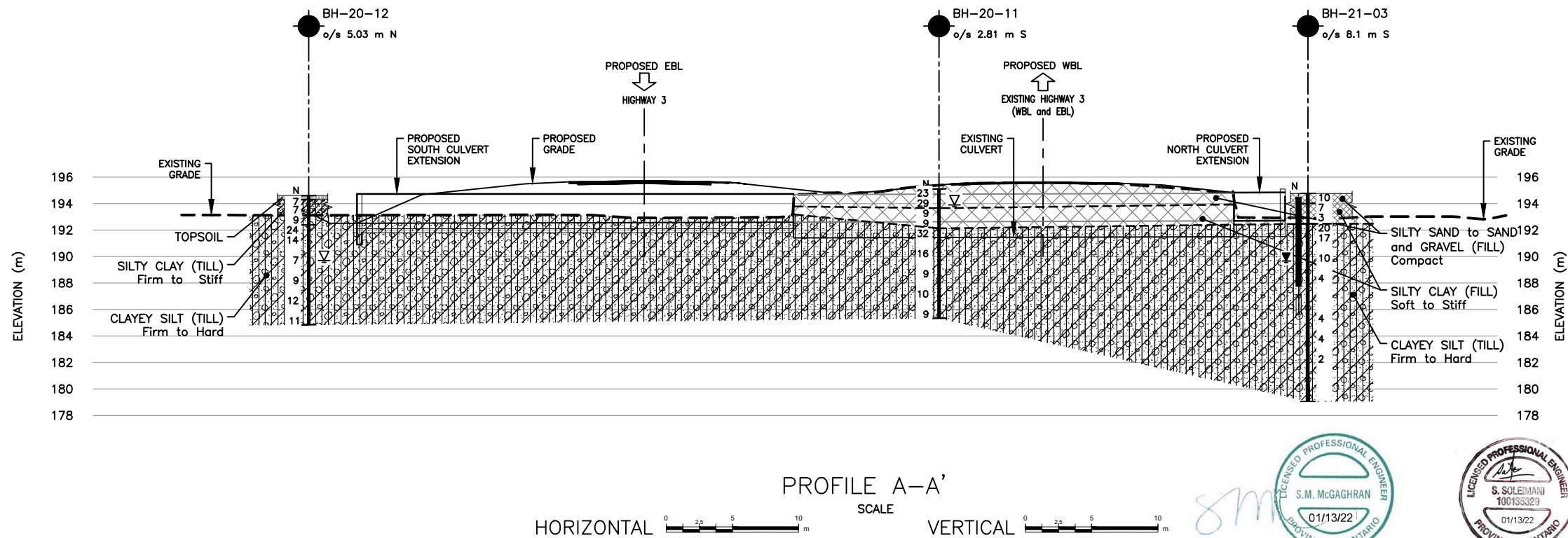
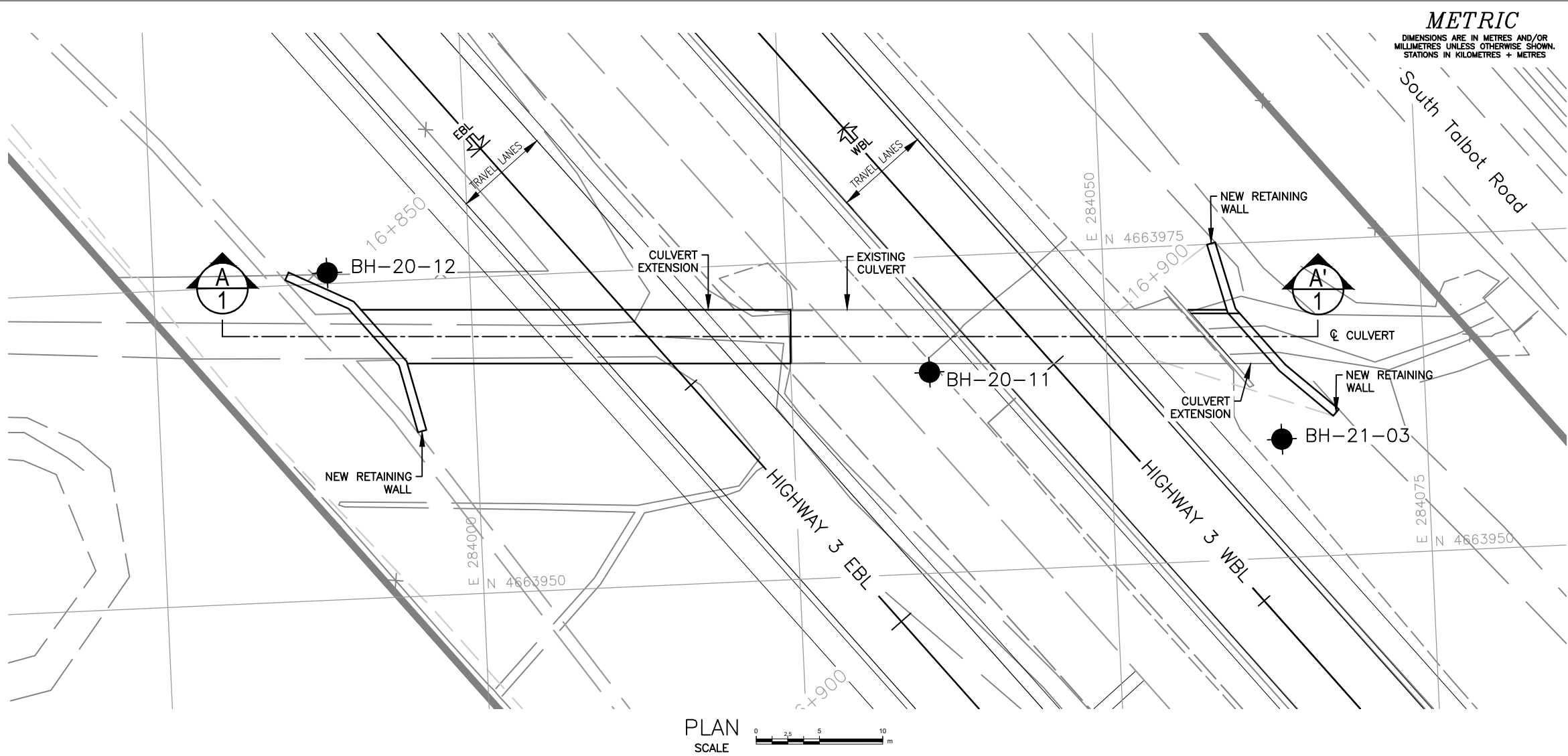
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NO.	DATE	BY	REVISION

Geocres No.: 40J2-147

HWY. 3	PROJECT NO. 11202886	DIST. CHATHAM
SUBM'D. MN/MRM	CHKD. SS	DATE: 1.10.2022
DRAWN: AW	CHKD. SS	APPD. SMM
		SITE: 06X-0426/C0
		DWG. 6





CONT No.
GWP No. 3021-18-00

CULVERT No. 06X-0427/C0
HIGHWAY 3
BOREHOLE LOCATIONS AND SOIL STRATA



KEY PLAN
SCALE

LEGEND

- Borehole
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test. 475 j/blow)
- Water Level in open borehole upon completion of drilling
- Water Level measured in piezometer (Nov. 24/2021)

BOREHOLE CO-ORDINATES (MTM ZONE 11)

NO	ELEVATION	NORTHING	EASTING
BH-20-11	195.1	4663965.9	284035.9
BH-20-12	194.6	4663975.9	283988.7
BH21-03	194.8	4663959.4	284063.5

NOTES

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REFERENCE

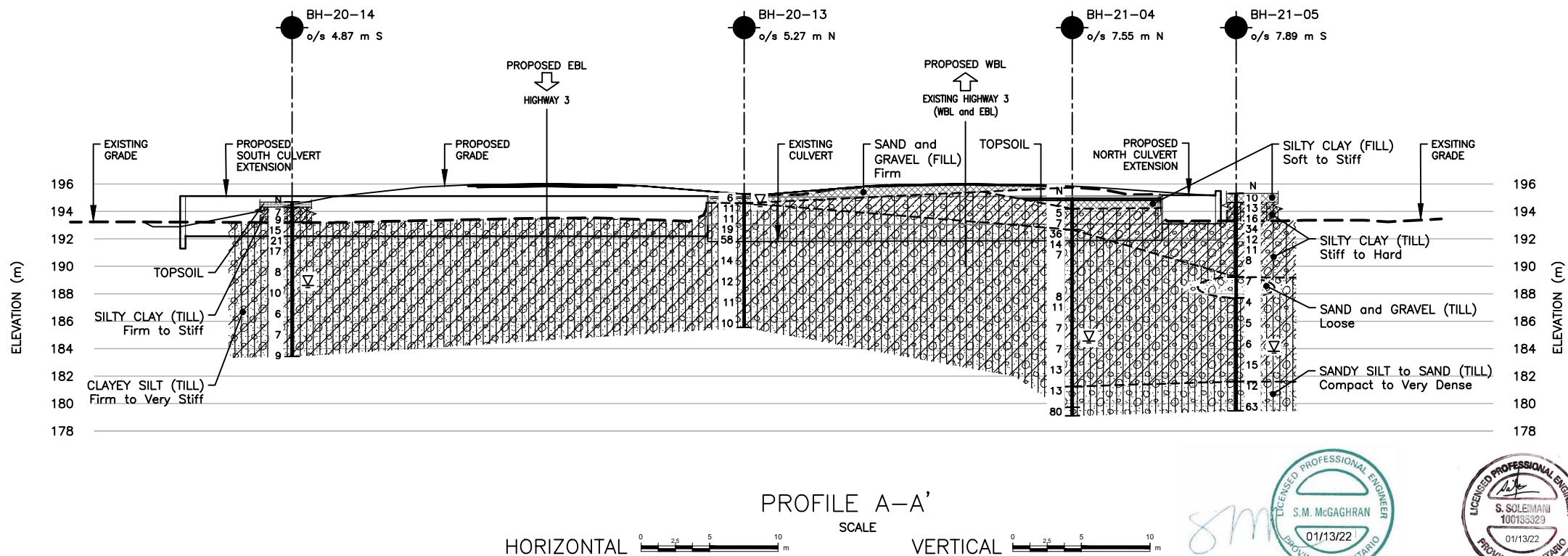
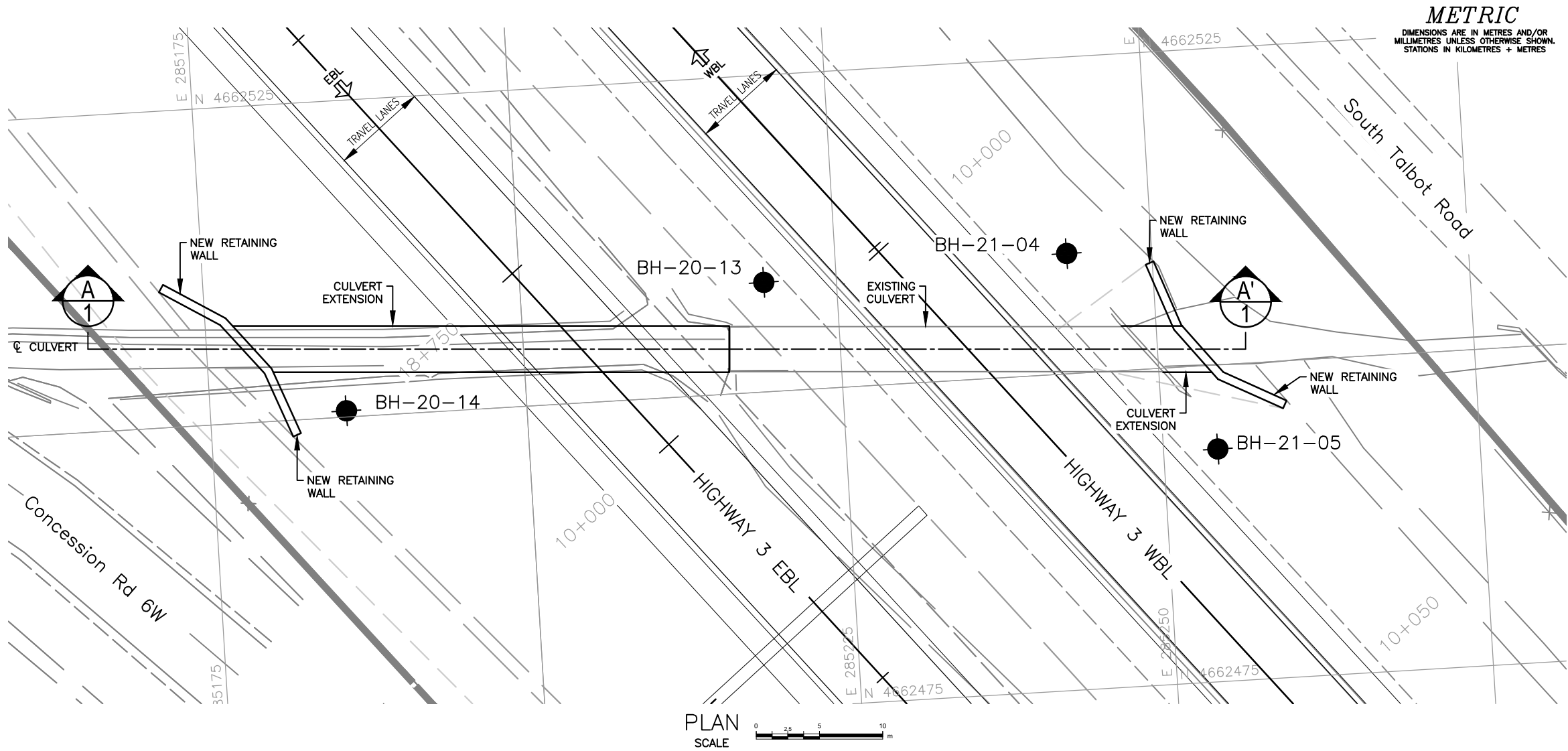
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NO.	DATE	BY	REVISION

Geocres No.: 40J2-147

HWY. 3	PROJECT NO. 11202886	DIST. CHATHAM
SUBM'D. MN/MRM	CHKD. SS	DATE: 1.10.2022
DRAWN: AW	CHKD. SS	APPD. SMM
		SITE: 06X-0427/C0
		DWG. 7





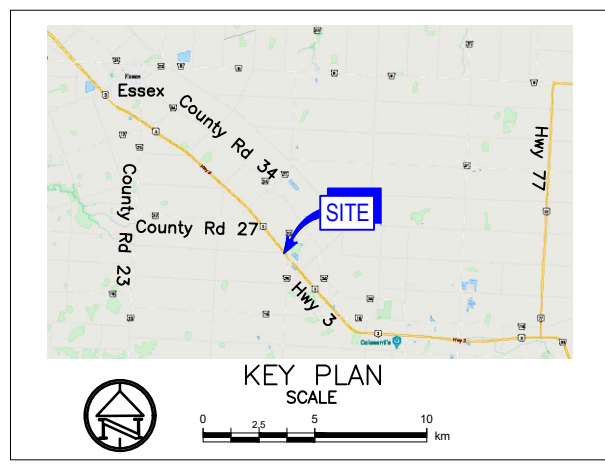
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES

CONT No.
GWP No. 3021-18-00

CULVERT No. 06X-0429/C0
HIGHWAY 3
BOREHOLE LOCATIONS AND SOIL STRATA

GHD

SHEET



LEGEND

- Borehole
- N Standard Penetration Test Value
- Blows/0.3m unless otherwise stated
(Std. Pen. Test. 475 j/blow)
- Water Level in open borehole upon completion of drilling

BOREHOLE CO-ORDINATES (MTM ZONE 11)			
NO	ELEVATION	NORTHING	EASTING
BH-20-13	195.3	4662508.6	285219.3
BH-20-14	194.7	4662500.5	285185.7
BH21-04	195.0	4662509.5	285243.3
BH21-05	195.3	4662493.4	285254.3

NOTES

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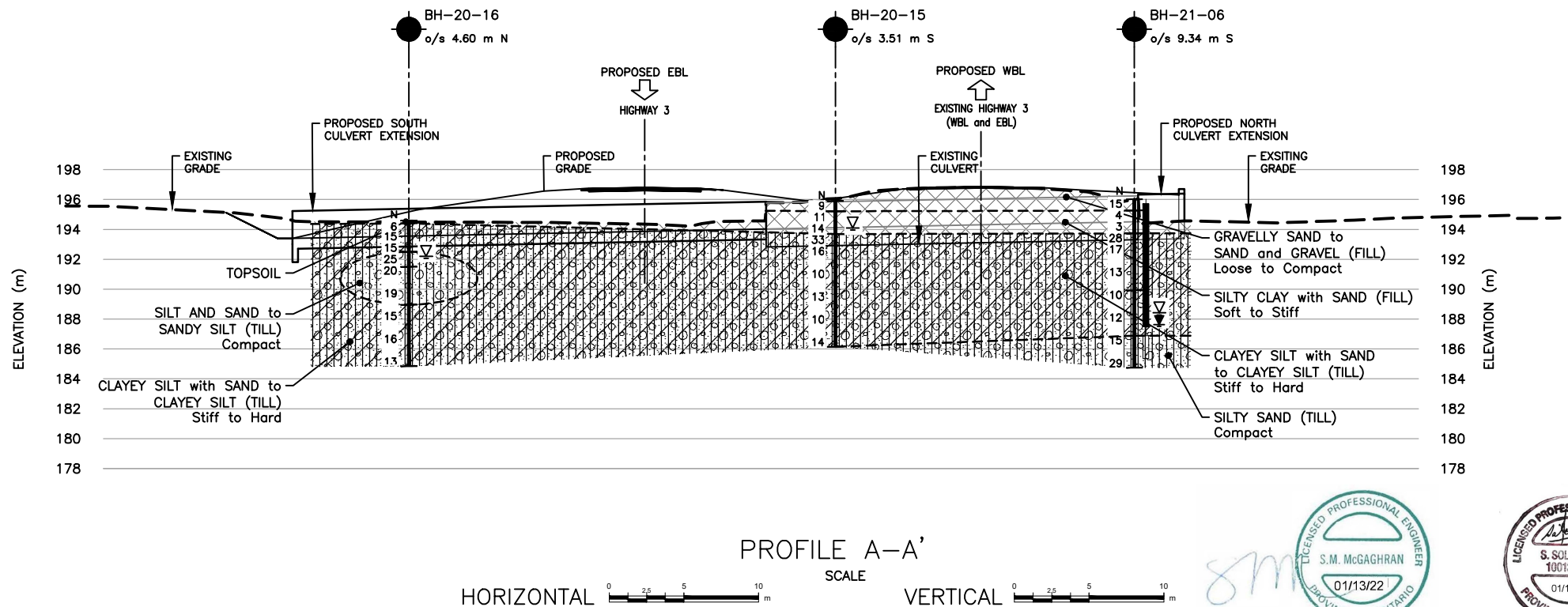
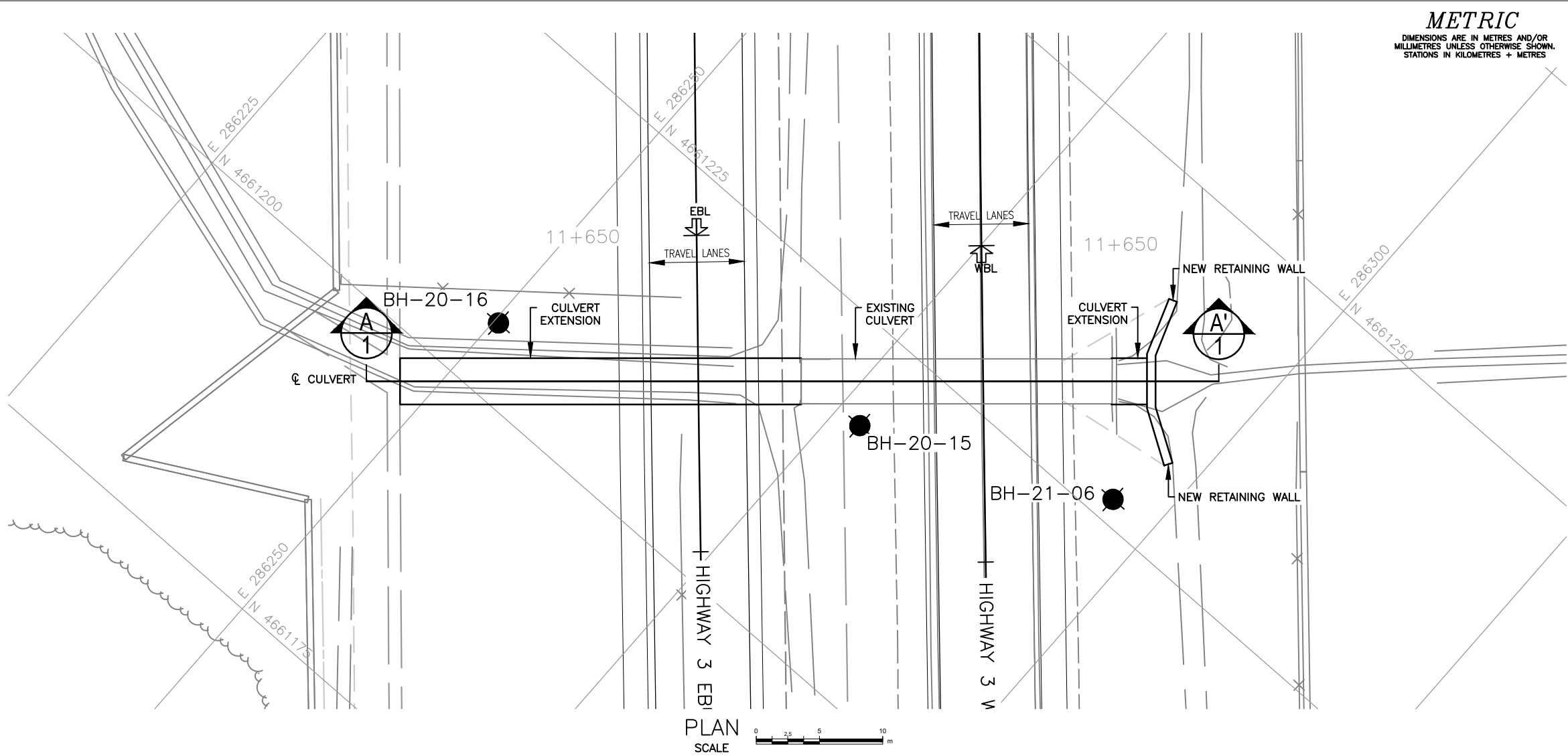
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REFERENCE

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NO.	DATE	BY	REVISION
Geocres No.: 40J2-147			
HWY. 3	PROJECT NO. 11202886		DIST. CHATHAM
SUBM'D. MN/MRM	CHKD. SS	DATE: 1.10.2022	SITE: 06X-0429/C0
DRAWN: AW	CHKD. SS	APPD. SMM	DWG. 8





CONT No.
GWP No. 3021-18-00



CULVERT No. 06X-0432/C0
HIGHWAY 3
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEY PLAN
SCALE

LEGEND

- Borehole
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test. 475 j/blow)
- Water Level in open borehole upon completion of drilling
- Water Level measured in piezometer (Nov. 24/2021)

BOREHOLE CO-ORDINATES (MTM ZONE 11)

NO	ELEVATION	NORTHING	EASTING
BH-20-15	195.9	4661218.0	286277.2
BH-20-16	194.6	4661205.3	286250.4
BH21-06	196.0	4661226.8	286296.1

NOTES

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REFERENCE

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NO.	DATE	BY	REVISION

Geocres No.: 40J2-147

HWY. 3	PROJECT NO. 11202886	DIST. CHATHAM
SUBM'D. MN/MRM	CHKD. SS	DATE: 1.10.2022
DRAWN: AW	CHKD. SS	APPD. SMM
		DWG. 9



Appendices

Appendix A

Site Photographs



Photo 1 – Culvert No. 06X-420/C0 – Concession Road 9



Photo 2 – A Sample of Silty Clay at BH-20-02 – Culvert No. 06X-420/C0



Photo 3 – Culvert No. 06X-421/C0 – Intersection between Hwy 3 and Concession Road 8



Photo 4 – Drilling at BH-20-03 – Culvert No. 06X-421/C0



Photo 5 – Culvert No. 06X-422/C0 – Concession Road 8



Photo 6 – Drilling at BH-20-06 – Culvert No. 06X-422/C0



Photo 7 – Drilling at BH-20-07 – Culvert No. 06X-423/C0 – Hwy 3, 220 m East of Concession Road 8



Photo 8 – Drilling at BH-20-08 – Culvert No. 06X-423/C0, Hwy 3, 220 m East of Concession Road 8



Photo 9- Culvert No. 06X-423/C0, North Extension- Location of BH-21-01



Photo 10 – Culvert No. 06X-426/C0 – Intersection between Hwy 3 and County Road 27



Photo 11 – Drilling Set up at BH-20-10 – Culvert No. 06X-426/C0 – Hwy 3 between County Road 27



Photo 12 – Drilling at BH-21-02 – Culvert No. 06X-426/C0 North Extension– Hwy 3 Shoulder



Photo 13 – Drilling at BH-20-11 – Culvert No. 06X-427/C0 – Hwy 3, 700 m east of County Road 27



Photo 14 – Drilling at BH-20-12 – Culvert No. 06X-427/C0 – Hwy 3, 700 m east of County Road 27



Photo 15 – BH-21-03– Culvert No. 06X-427/C0 North Extension – Hwy 3



Photo 16 – Culvert No. 06X-429/C0 – Hwy 3, 460 m west of Division Road



Photo 17 – Drilling at BH-20-13 – Culvert No. 06X-429/C0 – Hwy 3, 460 m West of Division Road



Photo 18– Drilling at BH-21-04 – Culvert No. 06X-429/C0, North Extension – Hwy 3 Shoulder



Photo 19—BH-21-05 Location – Culvert No. 06X-429/C0, North Extension – Hwy 3 Shoulder



Photo 20 – Culvert No. 06X-432/C0 – Hwy 3, 600 m East of County Road 34



Photo 21– Drilling at BH-20-16 - Culvert No. 06X-432/C0 – Hwy 3, 600 m East of County Road 34



Photo 22– Location of BH-21-016 with respect to Culvert No. 06X-432/C0 , North Extension– Hwy 3

Appendix B

Borehole Records



Notes on Borehole and Test Pit Reports

Soil description :

Each subsurface stratum is described using the following terminology. The relative density of granular soils is determined by the Standard Penetration Index ("N" value), while the consistency of clayey soils is measured by the value of undrained shear strength (S_u).



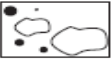





Classification (Unified system)			
Clay	< 0.002 mm		
Silt	0.002 to 0.075 mm		
Sand	0.075 to 4.75 mm	fine	0.075 to 4.25 mm
		medium	0.425 to 2.0 mm
		coarse	2.0 to 4.75 mm
Gravel	4.75 to 75 mm	fine	4.75 to 19 mm
		coarse	19 to 75 mm
Cobbles	75 to 300 mm		
Boulders	>300 mm		

Terminology	
"trace"	1-10%
"some"	10-20%
adjective (silty, sandy)	20-35%
"and"	35-50%

Relative density of granular soils	Standard penetration index "N" value (BLOWS/ft – 300 mm)
Very loose	0-4
Loose	4-10
Compact	10-30
Dense	30-50
Very dense	>50

Consistency of cohesive soils	Undrained shear strength (C_u)	
	(P.S.F)	(kPa)
Very soft	<250	<12
Soft	250-500	12-25
Firm	500-1000	25-50
Stiff	1000-2000	50-100
Very stiff	2000-4000	100-200
Hard	>4000	>200

Rock quality designation	
"RQD" (%) Value	Quality
<25	Very poor
25-50	Poor
50-75	Fair
75-90	Good
>90	Excellent

STRATIGRAPHIC LEGEND			
			
Sand	Gravel	Cobbles & boulders	Bedrock
			
Silt	Clay	Organic soil	Fill

Samples:

Type and Number

The type of sample recovered is shown on the log by the abbreviation listed hereafter. The numbering of samples is sequential for each type of sample.

SS: Split spoon

ST: Shelby tube

AG: Auger

SSE, GSE, AGE: Environmental sampling

PS: Piston sample (Osterberg)

RC: Rock core

NR: No Recovery

GS: Grab sample

Recovery

The recovery, shown as a percentage, is the ratio of length of the sample obtained to the distance the sampler was driven/pushed into the soil

RQD

The "Rock Quality Designation" or "RQD" value, expressed as percentage, is the ratio of the total length of all core fragments of 4 inches (10 cm) or more to the total length of the run.

IN-SITU TESTS:

N: Standard penetration index

N_c : Dynamic cone penetration index

k: Permeability

R: Refusal to penetration

S_u : Undrained Shear Strength

ABS: Absorption (Packer test)

Pr: Pressuremeter

LABORATORY TESTS:

I_p : Plasticity index

H: Hydrometer analysis

A: Atterberg limits

C: Consolidation

O.V.: Organic

W_L : Liquid limit

GSA: Grain size analysis

w: Water content

CS: Swedish fall cone

vapor

W_p : Plastic limit

NP: non-plastic

γ : Unit weight

CHEM: Chemical analysis

RECORD OF BOREHOLE No BH-21-01

1 OF 2

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0423/C0 (Northing: 4665407.5, Easting: 282642.3, MTM Zone 11, NAD 83) ORIGINATED BY Manvit.M
DIST Chatham HWY 3 BOREHOLE TYPE Hollow Stem Auger (4") DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2021.10.04 LATITUDE 42.127864 LONGITUDE -82.768005 CHECKED BY Sandra McGaghran

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED									WATER CONTENT (%)
194.9 0.0	FILL - SAND, trace clay Loose Brown Moist		1	SS	5		194									1 15 45 39 LL=34% PL=18% PI=16%	
194.1 0.8	FILL - SILTY CLAY, contains organics, trace sand, trace gravel Soft Brown to Grey Moist		2	SS	3												
			3	SS	4												
192.6 2.3	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to Very Stiff Grey Moist		4	SS	8		192									LL=33% PL=13% PI=20%	
			5	SS	15												
								191									
			6	SS	10			190									
								189									
			7	SS	6												
						188											
							187										
			8	TW	PH												

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1 15 45 39
LL=34% PL=18% PI=16%

LL=33% PL=13% PI=20%

RECORD OF BOREHOLE No BH-21-01

2 OF 2

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0423/C0 (Northing: 4665407.5, Easting: 282642.3, MTM Zone 11, NAD 83) ORIGINATED BY Manvit.M
 DIST Chatham HWY 3 BOREHOLE TYPE Hollow Stem Auger (4") DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2021.10.04 LATITUDE 42.127864 LONGITUDE -82.768005 CHECKED BY Sandra McGaghran

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × REMOULDED						
								20 40 60 80 100						

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RECORD OF BOREHOLE No BH-21-02

1 OF 2

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0426/C0 (Northing: 4664509.0, Easting: 283607.0, MTM Zone 11, NAD 83) ORIGINATED BY Manvit.M
 DIST Chatham HWY 3 BOREHOLE TYPE Hollow Stem Auger (4") DRILLING RIG TYPE Truck Mounted COMPILED BY Anne Wang
 DATUM Geodetic DATE 2021.11.10 LATITUDE 42.119801 LONGITUDE -82.756304 CHECKED BY Sandra McGaghran

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED	+ FIELD VANE							
						● QUICK TRIAXIAL	× REMOULDED	WATER CONTENT (%)								
195.7	0.0	FILL - GRAVELLY SAND, some silt Dense to Very Dense Brown Moist	1	SS	30								50			
			2	SS	53								90			
194.2	1.5	SILTY CLAY, trace gravel, trace to some sand (TILL) Very Stiff to Firm Greyish Brown Moist	3	SS	25								230			LL=46% PL=30% PI=16%
			4	SS	6								220			
			5	SS	16								190			
		becoming with SAND	6	SS	11								200			4 26 45 25 LL=40% PL=17% PI=23%
191.1	4.6	CLAYEY SILT, some sand, trace gravel (TILL) Very Stiff to Stiff Brown to Grey Moist	7	SS	7								180			2 12 53 33 LL=35% PL=18% PI=17%
													>100 kPa			
			8	SS	6								200			LL=34% PL=15% PI=19%
													1.8			
													>100 kPa			
			1	TW	PH											C

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METRIC

DATUM Geodetic DATE 2021.11.10 LATITUDE 42.119801 LONGITUDE -82.756304 CHECKED BY Sandra McGaghran

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RECORD OF BOREHOLE No BH-21-03

1 OF 2

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0427/C0 (Northing: 4663959.4, Easting: 284063.5, MTM Zone 11, NAD 83) ORIGINATED BY Manvit.M
 DIST Chatham HWY 3 BOREHOLE TYPE Hollow Stem Auger (4") DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2021.10.05 LATITUDE 42.114864 LONGITUDE -82.750763 CHECKED BY Sandra McGaghran

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
194.8 0.0	FILL - SILTY SAND, some gravel, some clay, contains rootlets Compact Dark Brown to Grey Moist		1	SS	10		194						24	
194.0 0.8	FILL - SILTY CLAY, trace sand, trace gravel, contains rootlets, Firm to Soft Greyish Brown to Grey Moist		2	SS	7		193						18	
			3	SS	3		193						30	
192.5 2.3	CLAYEY SILT, some sand (TILL) Very Stiff to Stiff Brown to Grey Moist		4	SS	20		192						17	
			5	SS	17		191						18	LL=34% PL=17% PI=17%
			6	SS	10		190						19	0 12 49 39
			7	SS	4		189						23	0 13 45 42
							188							LL=34% PL=19% PI=15%
							187							
			8	TW	PH									

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RECORD OF BOREHOLE No BH-21-03

2 OF 2

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0427/C0 (Northing: 4663959.4, Easting: 284063.5, MTM Zone 11, NAD 83) ORIGINATED BY Manvit.M
DIST Chatham HWY 3 BOREHOLE TYPE Hollow Stem Auger (4") DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2021.10.05 LATITUDE 42.114864 LONGITUDE -82.750763 CHECKED BY Sandra McGaghran

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W _p	W	W _L		WATER CONTENT (%)	GR	SA	SI	CL
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL									
							20	40	60	80	100	20	40	60					
179.1 <																			

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METRIC

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RECORD OF BOREHOLE No BH-21-05

1 OF 2

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0429/C0 (Northing: 4662493.4, Easting: 285254.3, MTM Zone 11, NAD 83) ORIGINATED BY Manvit.M
DIST Chatham HWY 3 BOREHOLE TYPE Hollow Stem Auger (4") DRILLING RIG TYPE Truck Mounted COMPILED BY Anne Wang
DATUM Geodetic DATE 2021.11.10 LATITUDE 42.101695 LONGITUDE -82.736315 CHECKED BY Sandra McGaghran

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED + FIELD VANE								
						● QUICK TRIAXIAL × REMOULDED										
195.3							20	40	60	80	100					
0.0	FILL - SILTY CLAY, some sand, trace gravel, contains rootlets Stiff Brown Moist		1	SS	10								22			
194.6																
0.7	SILTY CLAY, some sand, trace gravel (TILL) Stiff to Hard Grey Moist		2	SS	13								22			
			3	SS	16								24		LL=36% PL=17% PI=19%	
	becoming brown															
	0.15 m thick layer of sand and gravel		4	SS	34								22			
			5	SS	12								23		3 19 43 35 LL=45% PL=19% PI=26%	
			6	SS	11								19			
	0.1 m thick layer of sand		7	SS	8								19		LL=39% PL=18% PI=21%	

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RECORD OF BOREHOLE No BH-21-06

1 OF 2

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0432/C0 (Northing: 4661226.8, Easting: 286296.1, MTM Zone 11, NAD 83) ORIGINATED BY Manvit.M
 DIST Chatham HWY 3 BOREHOLE TYPE Hollow Stem Auger (4") DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2021.10.05 LATITUDE 42.090317 LONGITUDE -82.723679 CHECKED BY Sandra McGaghran

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
196.0	FILL - GRAVELLY SAND, trace silt, some organics (plants) Compact Brown Moist		1	SS	15									
195.2	FILL - SILTY CLAY with SAND, contains rootlets and organics Soft Brown to Grey Moist		2	SS	4		195							
0.8			3	SS	3		194							0 29 37 34 LL=39% PL=21% PI=18%
193.7	CLAYEY SILT with SAND (TILL) Stiff to Very Stiff Brown to Grey Moist		4	SS	28		193							LL=25% PL=15% PI=10%
2.3			5	SS	17		192							0 27 42 31 LL=26% PL=13% PI=13%
			6	SS	13		191							
189.9	CLAYEY SILT, some sand (TILL) Stiff Grey Moist to Wet		7	SS	10		190							LL=25% PL=14% PI=11%
6.1			8	SS	12		189							
							188							

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RECORD OF BOREHOLE No BH-21-06

2 OF 2

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0432/C0 (Northing: 4661226.8, Easting: 286296.1, MTM Zone 11, NAD 83) ORIGINATED BY Manvit.M
 DIST Chatham HWY 3 BOREHOLE TYPE Hollow Stem Auger (4") DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2021.10.05 LATITUDE 42.090317 LONGITUDE -82.723679 CHECKED BY Sandra McGaghran

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× REMOULDED							
							20	40	60	80	100							
186.9	CLAYEY SILT, some sand (TILL) Stiff Grey Moist to Wet						187											
9.1	SILTY SAND, trace to some gravel (TILL) Compact Grey Wet		9	SS	15							10						
							186											
			10	SS	29		185					10				7 60 (33)		
184.7	END OF BOREHOLE																	
11.3	Notes: 1. Groundwater level at a depth of 7.6 m below ground surface (Elev. 188.4 m) upon completion of drilling. 2. Groundwater level at a depth of 8.4 m (Elev. 187.6 m) on Nov 24, 2021.																	

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 Library File: 11202886 MTO LIBRARY V01.GLB Report: 11202886 SCOPE CHANGE Date: 19/12/21

RECORD OF BOREHOLE No BH-20-01

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0420/C0 (Northing: 4666959.4, Easting: 280836.9, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2020.04.27 LATITUDE 42.141783 LONGITUDE -82.789905 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
194.8 0.0	FILL - SAND and GRAVEL, some silt Compact Light Brown Moist		1	SS	23		194						9 0	
194.1 0.7	SILTY CLAY, some sand, trace gravel (TILL) Stiff Brown to Grey Moist to Wet		2	SS	9		193						21 0	1 15 39 45 LL=52% PL=21% PI=31%
192.6 2.2	CLAYEY SILT, some sand, trace gravel (TILL) Very Stiff to Stiff Grey Moist		3	SS	11		192						25 0	
			4	SS	17		191						18 0	
			5	SS	21		190						16 0	2 14 41 43 LL=34% PL=16% PI=18%
			6	SS	13		189						19 0	
			7	SS	13		188						20 0	
			8	SS	13		187						22 0	
			9	SS	9		186						22 0	
185.0 9.8	END OF BOREHOLE													
	Notes: 1. Borehole dry during and upon completion of drilling.													

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Library File: 11202886 MTO LIBRARY V01.GLB Report: 11202886 SCOPE CHANGE Date: 19/12/21

RECORD OF BOREHOLE No BH-20-02

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0420/C0 (Northing: 4666946.7, Easting: 280856.9, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2020.04.27 LATITUDE 42.141670 LONGITUDE -82.789663 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
194.3 0.0	TOPSOIL - Clayey Silt, trace sand and gravel, containing rootlets		1	SS	7		194						24	0 14 36 50 LL=46% PL=20% PI=26%
194.0 0.3	Dark Brown Moist Firm		2	SS	7		193						26	
	SILTY CLAY, some sand, trace gravel (TILL) Firm		3	SS	12		192						19	
192.8 1.5	Light Brown to Grey Moist		4	SS	30		191						15	0 12 41 47 LL=31% PL=18% PI=13%
	CLAYEY SILT, some sand, trace gravel (TILL) Firm to Hard Grey Moist		5	SS	16		190						18	
			6	SS	9		189						21	
			7	SS	7		188						22	0 14 41 45 LL=35% PL=18% PI=17%
			8	SS	9		187						23	
			9	SS	12		186						22	
184.5 9.8	END OF BOREHOLE						185							
Notes: 1. Borehole dry during and upon completion of drilling.														

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RECORD OF BOREHOLE No BH-20-03

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0421/C0 (Northing: 4665573.4, Easting: 282433.8, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2020.04.28 LATITUDE 42.129352 LONGITUDE -82.770533 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
195.3 0.0	FILL - SAND and GRAVEL, trace to some fines Compact Light Brown Moist		1	SS	16		195						2	
			2	SS	15		194						2	46 45 (9)
193.9 1.4	SILTY CLAY, some sand, trace gravel (TILL) Stiff Brown to Grey Moist to Wet		3	SS	9		193						24	
			4	SS	11								25	2 14 36 48 LL=38% PL=18% PI=20%
192.5 2.8	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to Very Stiff Grey Moist		5	SS	28		192						20	
			6	SS	26		191						17	
			7	SS	15		190						20	2 13 39 46 LL=34% PL=16% PI=18%
			8	SS	11		189						22	
			9	SS	10		188						23	
			10	SS	10		187						24	
185.5 9.8	END OF BOREHOLE						186							
	Notes: 1. Groundwater level at a depth of 2.2 m below ground surface (Elev. 193.1 m) upon completion of drilling.													

+ 3 Numbers refer to
Sensitivity






File: N:\CAWATERLOO\PROJECTS\662\11202886\TECH\12 FOUNDATIONS\04\FIELDWORK\06-FIELD NOTES AND LOGS\2020 GINT LOGS\11202886 HWY 3 WIDENING - WINDSOR TO LEAMINGTON BH LOGS V02.GPJ
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RECORD OF BOREHOLE No BH-20-04

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0421/C0 (Northing: 4665539.7, Easting: 282422.5, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
 DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2020.04.28 LATITUDE 42.129048 LONGITUDE -82.770669 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L			WATER CONTENT (%)	
								20 40 60 80 100								
								○ UNCONFINED + FIELD VANE								
								● QUICK TRIAXIAL × REMOULDED								
								20 40 60 80 100								
194.9																
0.0	FILL - SAND and GRAVEL, some silt Loose to Compact Light Brown Moist		1	SS	12							3 ○		1 15 45 39 LL=37% PL=19% PI=18%		
193.8			2A	SS	8							4 ○				
1.1	SILTY CLAY, some sand, trace gravel (TILL) Stiff Grey Wet		2B									25 ○				
			3	SS	9							20 ○				
192.7																
2.2	CLAYEY SILT, some sand, trace gravel (TILL) Very Stiff to Stiff Grey Moist		4	SS	22							17 ○				
			5	SS	27							17 ○				
			6	SS	13							19 ○			1 12 47 40 LL=34% PL=14% PI=20%	
			7	SS	12							22 ○				
			8	SS	11							21 ○				
			9	SS	9							22 ○				
185.1																
9.8	END OF BOREHOLE															
Notes: 1. Borehole dry during and upon completion of drilling.																

+ 3 Numbers refer to
Sensitivity

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RECORD OF BOREHOLE No BH-20-05

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0422/C0 (Northing: 4665516.3, Easting: 282413.7, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2020.04.28 LATITUDE 42.128837 LONGITUDE -82.770774 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED						
194.5							20 40 60 80 100								
0.0	FILL - SAND and GRAVEL, trace to some fines		1A	SS	10					6	20				
194.2															
0.3	Compact Brown Moist		1B								20				
	SILTY CLAY, some sand, trace gravel (TILL) Firm to Stiff Grey Moist		2	SS	5						22				
			3	SS	13						19			3 12 46 39 LL=40% PL=19% PI=21%	
192.4															
2.1	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to Very Stiff Grey Moist		4	SS	13						19				
			5	SS	15						18				
			6	SS	9						22				
			7	SS	10						23				
			8	SS	12						22			5 11 48 36 LL=35% PL=19% PI=16%	
			9	SS	15						22				
184.7															
9.8	END OF BOREHOLE														
	Notes: 1. Borehole dry during and upon completion of drilling.														

+ 3 Numbers refer to
Sensitivity

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RECORD OF BOREHOLE No BH-20-06

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0422/C0 (Northing: 4665505.6, Easting: 282445.9, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2020.04.28 LATITUDE 42.128742 LONGITUDE -82.770385 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								<div><div></div><div></div><div></div><div></div><div></div></div>						
194.4	TOPSOIL, Clayey Silt, trace sand, containing rootlets		1A											
0.0	Stiff		1B	SS	11									
194.0	Dark Brown to Black Moist													
0.4	SILTY CLAY, some sand, trace gravel, some organic (TILL)		2	SS	12									0 11 37 52 LL=51% PL=21% PI=30%
	Stiff to Very Stiff													
	Light Brown to Grey Moist		3	SS	15									
			4	SS	18									1 12 46 41 LL=37% PL=18% PI=19%
191.5	CLAYEY SILT, some sand, trace gravel (TILL)													
2.9	Stiff to Very Stiff		5	SS	15									
	Grey Moist													
			6	SS	12									
188.8	SILT and SAND, trace to some clay (TILL)													
5.6	Loose Grey Moist		7	SS	8									0 39 51 10
187.2	CLAYEY SILT, some sand, trace gravel (TILL)													
7.2	Stiff to Very Stiff		8	SS	15									
	Grey Moist													
			9	SS	9									
184.6	END OF BOREHOLE													
9.8	Notes: 1. Groundwater level at a depth of 6.1 m below ground surface (Elev. 188.3m) upon completion of drilling.													

+³ Numbers refer to Sensitivity




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RECORD OF BOREHOLE No BH-20-07

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0423/C0 (Northing: 4665404.5, Easting: 282622.8, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
 DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2020.04.30 LATITUDE 42.127837 LONGITUDE -82.768241 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							W _p W W _L				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED							WATER CONTENT (%)				
195.5								20	40	60	80	100							
0.0	FILL - SAND and GRAVEL, some fines Loose Brown Moist		1	SS	9		195							3 ○				38 49 (13)	
194.4			2A											4 ○					
1.1	FILL - SILTY CLAY with SAND, trace gravel Firm Grey Moist to Wet		2B	SS	8		194							16 ○					
														19 ○					
			3	SS	6														
			4	SS	7		193							24 ○				4 26 33 37 LL=45% PL=19% PI=26%	
192.5																			
3.0	CLAYEY SILT, some sand, trace gravel (TILL) Hard to Stiff Grey Moist		5	SS	31		192							18 ○					
			6	SS	20		191												
			7	SS	10		189							23 ○				0 13 47 40 LL=34% PL=18% PI=16%	
			8	SS	9		188							24 ○					

+ 3 Numbers refer to
Sensitivity

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RECORD OF BOREHOLE No BH-20-08

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0423/C0 (Northing: 4665399.6, Easting: 282581.1, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2020.04.30 LATITUDE 42.127792 LONGITUDE -82.768745 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p W W _L				
194.3								20	40	60	80	100					
0.0	TOPSOIL, Clayey Silt, trace sand, trace gravel, containing rootlets		1A				194									1 18 49 32 LL=32% PL=17% PI=15%	
194.0																	
0.3	Firm Dark Brown to Black Moist		1B	SS	9									20			
	CLAYEY SILT, some sand, trace gravel (TILL)		2	SS	10			193									
	Very Stiff to Stiff																
	Light Brown to Grey Moist		3	SS	26										14		
								192									
			4	SS	20										16		
			5	SS	19		191										
														18			
														9			
							190									0 12 46 42 LL=31% PL=18% PI=13%	
			6	SS	9										22		
							189										
			7	SS	9										23		
							188										
							187										
			8	SS	8		186								24		
							185										
			9	SS	9										24		
184.5																	
9.8	END OF BOREHOLE																
	Notes: 1. Borehole dry during and upon completion of drilling.																

+ 3 Numbers refer to
Sensitivity










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RECORD OF BOREHOLE No BH-20-09

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0426/C0 (Northing: 4664521.8, Easting: 283565.9, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2020.04.30 LATITUDE 42.119915 LONGITUDE -82.756802 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W _p	W	W _L		
195.1 0.0	FILL - SAND and GRAVEL, trace silt Compact Light Brown Moist		1	SS	11								8 ○		
194.4 0.7	SILTY CLAY, some sand, trace gravel (TILL) Firm Grey Moist		2	SS	7								21 ○	4 17 40 39 LL=40% PL=21% PI=19%	
193.7 1.4	CLAYEY SILT, some sand, trace gravel (TILL) Very Stiff to Stiff Grey Moist		3	SS	10								20 ○		
			4	SS	17								19 ○		
			5	SS	29								17 ○	0 12 49 39 LL=34% PL=18% PI=16%	
			6	SS	13								19 ○		
			7	SS	14								22 ○	1 12 48 39 LL=31% PL=18% PI=13%	
			8	SS	10								23 ○		
			9	SS	13								23 ○		
185.3 9.8	END OF BOREHOLE														
Notes: 1. Borehole dry during and upon completion of drilling.															

+ 3 Numbers refer to
Sensitivity

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RECORD OF BOREHOLE No BH-20-10

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0426/C0 (Northing: 4664494.3, Easting: 283549.3, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
 DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2020.05.01 LATITUDE 42.119667 LONGITUDE -82.757001 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED							Wp W WL				
193.3							20	40	60	80	100	20	40	60	GR	SA	SI	CL	
0.0	CLAYEY SILT, some sand, trace gravel, some organics (TILL) Firm to Very Stiff Light Brown to Grey Moist to Wet		1	SS	8	193							25						
			2	SS	9	192								19					
			3	SS	12	191								20					
			4	SS	19	190								17					
			5	SS	13	189								18					
			6	SS	10	188								20					
			7	SS	9	187								23					
			8	SS	8	186								23					
			9	SS	5	184								25					
			10	SS	7	183								27					
182.0	END OF BOREHOLE																		
11.3	Note: 1. Groundwater level at a depth of 10.7 m below ground surface (Elev. 182.6 m) upon completion of drilling.																		

+ 3 Numbers refer to
Sensitivity





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RECORD OF BOREHOLE No BH-20-11

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0427/C0 (Northing: 4663965.9, Easting: 284035.9, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
 DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2020.05.01 LATITUDE 42.114922 LONGITUDE -82.751097 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× REMOULDED						
195.1							20	40	60	80	100						
0.0	FILL - SAND and GRAVEL, trace fines Compact Brown Moist		1	SS	23		195							7 ○		35 57 (8)	
							194								11 ○		
193.7			2	SS	29												
1.4	FILL - SILTY CLAY, some sand, trace gravel, some organics Stiff Light Brown to Grey Moist to Wet		3	SS	9		193								28 ○		1 19 36 44 LL=55% PL=22% PI=33%
			4	SS	9										22 ○		
192.1							192								18 ○		
3.0	CLAYEY SILT, some sand, trace gravel (TILL) Hard to Stiff Brown to Grey Moist		5	SS	32		191										
			6	SS	16	190								20 ○	1 17 48 34 LL=29% PL=17% PI=12%		
			7	SS	9	189								22 ○			
			8	SS	10	188								22 ○			
						187											
						186								23 ○			
185.3			9	SS	9												
9.8	END OF BOREHOLE																
	Note: 1. Groundwater level at a depth of 1.2 m below ground surface (Elev. 193.9 m) upon completion of drilling.																

+ 3 Numbers refer to
Sensitivity

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RECORD OF BOREHOLE No BH-20-12

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0427/C0 (Northing: 4663975.9, Easting: 283988.7, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 2020.05.01 LATITUDE 42.115011 LONGITUDE -82.751668 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							W _p W W _L			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED							WATER CONTENT (%)			
194.6								20	40	60	80	100						
0.0	TOPSOIL, Clayey Silt, trace sand and gravel, containing rootlets		1A				▽											
194.3																		
0.3	Firm Dark Brown to Black Moist		1B	SS	7									25				
	SILTY CLAY, some sand, trace gravel, some organics (TILL) Firm to Stiff Light Brown to Grey Moist		2	SS	7									21				1 14 43 42 LL=41% PL=20% PI=21%
			3	SS	9									18				
192.4																		
2.2	CLAYEY SILT, some sand, trace gravel (TILL) Firm to Very Stiff Brown to Grey Moist		4	SS	24									18				
			5	SS	14									18				0 14 49 37 LL=31% PL=17% PI=14%
			6	SS	7									20				

+ 3 Numbers refer to
Sensitivity

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RECORD OF BOREHOLE No BH-20-13

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0429/C0 (Northing: 4662508.6, Easting: 285219.3, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
 DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2020.05.04 LATITUDE 42.101832 LONGITUDE -82.736739 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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195.3							20	40	60	80	100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						

+ 3 Numbers refer to
Sensitivity

File: N:\CAWATERLOO\PROJECTS\662\11202886\TECH\12 FOUNDATIONS\04-FIELDWORK\06-FIELD NOTES AND LOGS\2020 GINT LOGS\11202886 HWY 3 WIDENING - WINDSOR TO LEAMINGTON BH LOGS V02.GPJ
 Library File: 11202886 MTO LIBRARY V01.GLB Report: 11202886 SCOPE CHANGE Date: 19/12/21

RECORD OF BOREHOLE No BH-20-14

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0429/C0 (Northing: 4662500.5, Easting: 285185.7, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
 DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
 DATUM Geodetic DATE 2020.05.04 LATITUDE 42.101758 LONGITUDE -82.737144 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED							W _p W W _L		
194.7							20	40	60	80	100	20	40	60			
0.0	TOPSOIL, Clayey Silt, trace sand, trace gravel, containing rootlets		1A														
194.3	Firm		1B	SS	7								26				
0.4	Dark Brown to Black																
	Moist		2	SS	9								21			0 12 43 45 LL=43% PL=20% PI=23%	
	SILTY CLAY, some sand, some organic (TILL)																
193.2	Firm to Stiff												18				
1.5	Brown		3	SS	15												
	Moist																
	CLAYEY SILT, some sand, trace gravel (TILL)												18			0 14 46 40 LL=34% PL=18% PI=16%	
	Very Stiff to Firm		4	SS	21												
	Grey																
	Moist		5	SS	17								19				
			6	SS	8								23				
			7	SS	10								26			0 11 48 41 LL=34% PL=19% PI=15%	
			8	SS	6								24				
			9	SS	7								26				

+ 3 Numbers refer to
Sensitivity

File: N:\CAWATERLOO\PROJECTS\662\11202886\TECH\12 FOUNDATIONS\04\FIELDWORK\06-FIELD NOTES AND LOGS\2020 GINT LOGS\11202886 HWY 3 WIDENING - WINDSOR TO LEAMINGTON BH LOGS V02.GPJ
 Library File: 11202886 MTO LIBRARY V01.GLB Report: 11202886 SCOPE CHANGE Date: 19/12/21

RECORD OF BOREHOLE No BH-20-15

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0432/C0 (Northing: 4661218.0, Easting: 286277.2, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 0202.05.19 LATITUDE 42.090237 LONGITUDE -82.723907 CHECKED BY Sahar Soleimani

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L			WATER CONTENT (%)					
195.9 0.0	FILL - SAND and GRAVEL, trace silt, trace clay Loose Brown		1	SS	9		195	20	40	60	80	100	20	40	60	8 29 39 24 LL=32% PL=16% PI=14%				
195.2 0.7	Moist		2	SS	11			12												
	FILL - CLAYEY SILT with SAND, trace to some gravel Stiff Grey Moist		3	SS	14			12												
193.7 2.2	CLAYEY SILT, some sand (TILL) Stiff to Hard Grey Moist		4	SS	33			194	193	15									0 19 49 32 LL=29% PL=16% PI=13%	
			5	SS	16					18										
			6	SS	10					18										
			7	SS	13					15										
		8	SS	10	27															
						189	188													
						187		15												
								12												
186.1 9.8	END OF BOREHOLE																			
<p>Note: 1. Groundwater level at a depth of 1.8 m below ground surface (Elev. 194.1 m) upon completion of drilling.</p>																				

+ 3 Numbers refer to
Sensitivity

File: N:\CAWATERLOO\PROJECTS\662\11202886\TECH\12 FOUNDATIONS\04-FIELDWORK\06-FIELD NOTES AND LOGS\11202886 HWY 3 WIDENING - WINDSOR TO LEAMINGTON BH LOGS V02.GPJ
Library File: 11202886 MTO LIBRARY V01.GLB Report: 11202886 SCOPE CHANGE Date: 19/12/21

RECORD OF BOREHOLE No BH-20-16

1 OF 1

METRIC

G.W.P. NO. 3021-18-00 LOCATION Culvert No. 06X-0432/C0 (Northing: 4661205.3, Easting: 286250.4, MTM Zone 11, NAD 83) ORIGINATED BY Moe Nasir
DIST Chatham HWY 3 BOREHOLE TYPE Solid Stem Auger DRILLING RIG TYPE Diedrich D-50 Track COMPILED BY Anne Wang
DATUM Geodetic DATE 0202.05.19 LATITUDE 42.090123 LONGITUDE -82.724231 CHECKED BY Sahar Soleimani

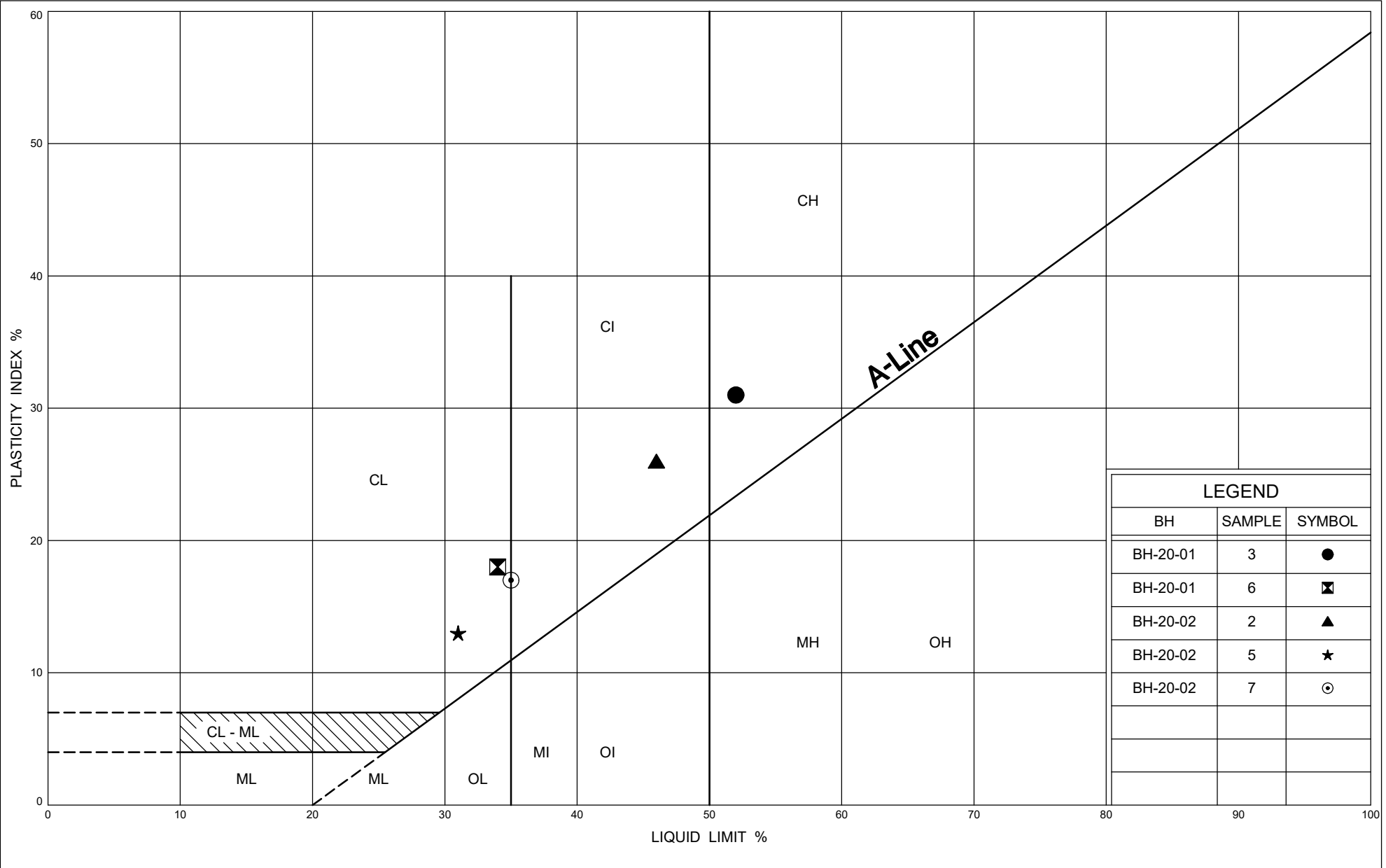
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
194.6 0.0	TOPSOIL, Clayey Silt, trace sand, trace gravel, containing rootlets		1A				194							
194.2 0.2	Firm Dark Brown Moist		1B	SS	6		194						26	
	CLAYEY SILT, some sand, trace gravel (TILL)		2	SS	15		193						21	
	Stiff Grey Moist		3	SS	15		193						17	
192.5 2.1	SILTY SAND, trace gravel, trace clay (TILL)		4	SS	25		192						13	7 57 29 7
	Compact Grey Moist		5	SS	20		191						16	
191.5 3.1	SILT and SAND, trace clay (TILL)		6	SS	19		190						15	0 55 42 3
	Compact Grey Moist		7	SS	15		189						24	3 16 47 34
189.0 5.6	CLAYEY SILT, some sand, trace gravel (TILL)		8	SS	16		188						17	LL=33% PL=18% PI=15%
	Stiff to Very Stiff Grey Moist		9	SS	13		187						26	
184.8 9.8	END OF BOREHOLE						185							
	Note: 1. Groundwater level at a depth of 2.4 m below ground surface (Elev. 192.2 m) upon completion of drilling.													

+ 3 Numbers refer to
Sensitivity

File: N:\CAWATERLOO\PROJECTS\662\11202886\TECH\12 FOUNDATIONS\04-FIELDWORK\06-FIELD NOTES AND LOGS\2020 GINT LOGS\11202886 HWY 3 WIDENING - WINDSOR TO LEAMINGTON BH LOGS V02.GPJ
Library File: 11202886 MTO LIBRARY V01.GLB Report: 11202886 SCOPE CHANGE Date: 19/12/21

Appendix C

Geotechnical Laboratory Test



Ministry of
Transportation

PLASTICITY CHART

Culvert No. 06X-0420/C0 - Clayey Silt to Silty Clay (Till)

Figure:

C1-1

Assignment No.:

3017-E-0012

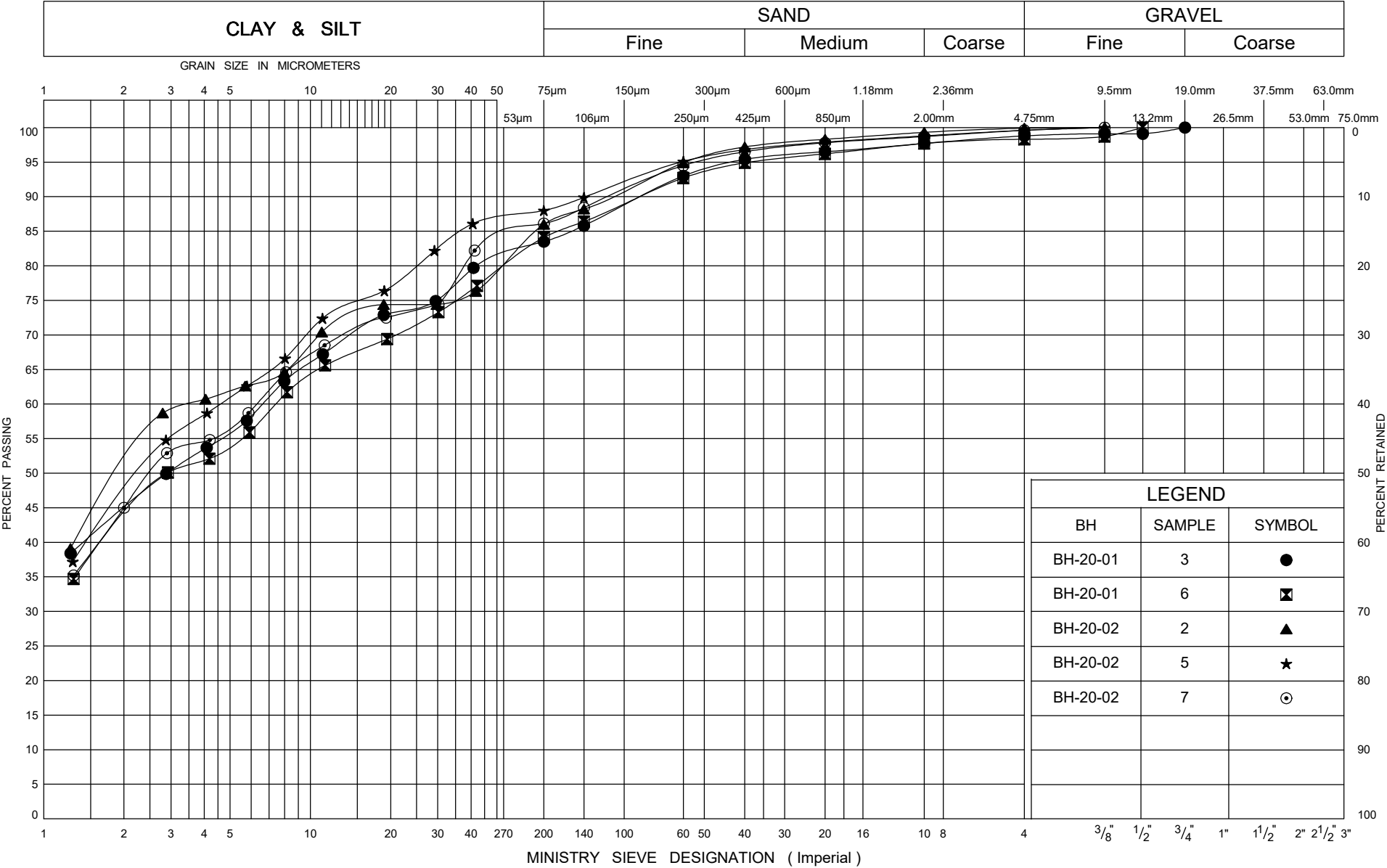
G.W.P. No.:

3021-18-00

GHD Project No.:

11202886

UNIFIED SOIL CLASSIFICATION SYSTEM



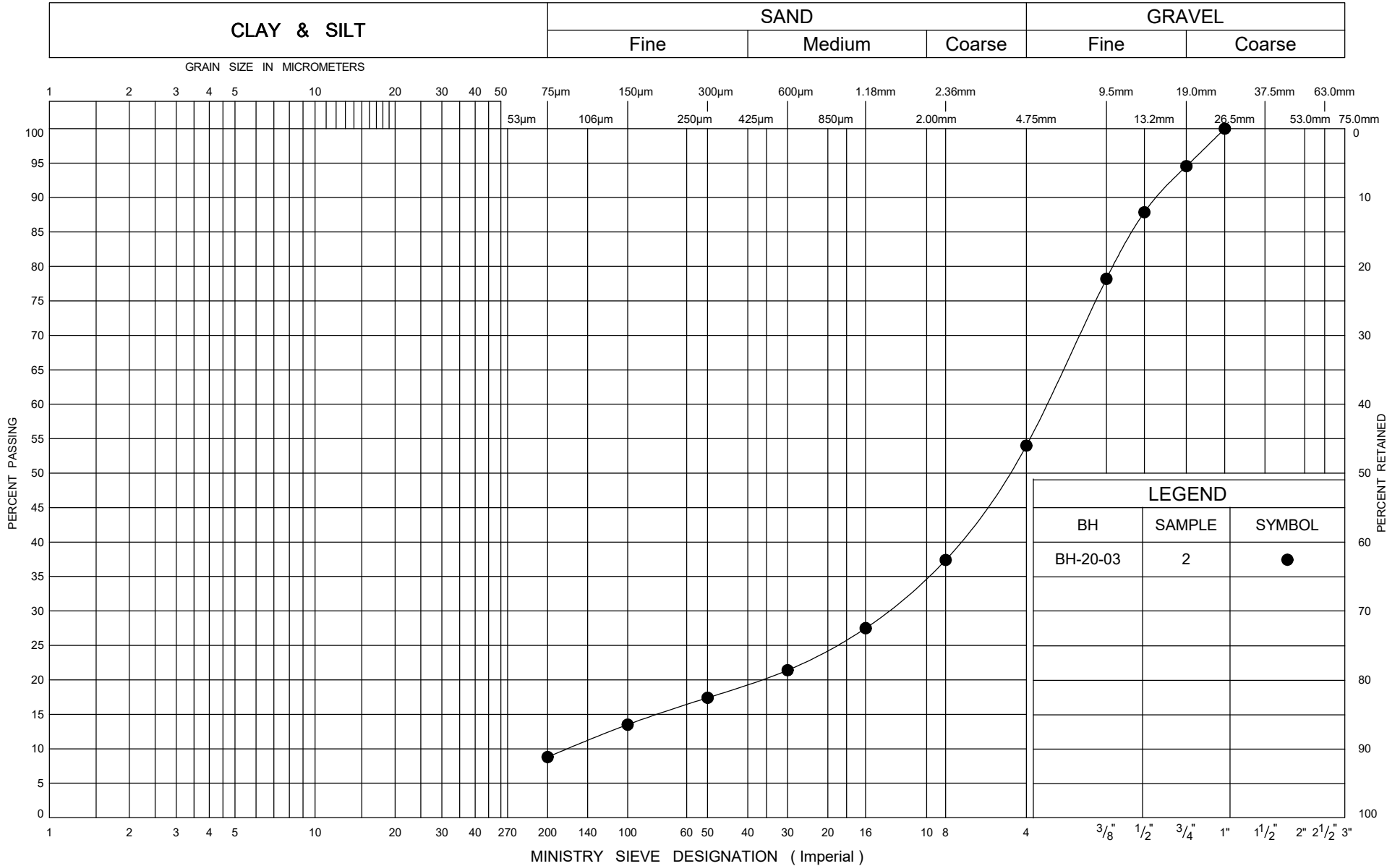
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

Culvert No. 06X-0420/C0 - Clayey Silt to Silty Clay (Till)

Figure:	C1-2
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

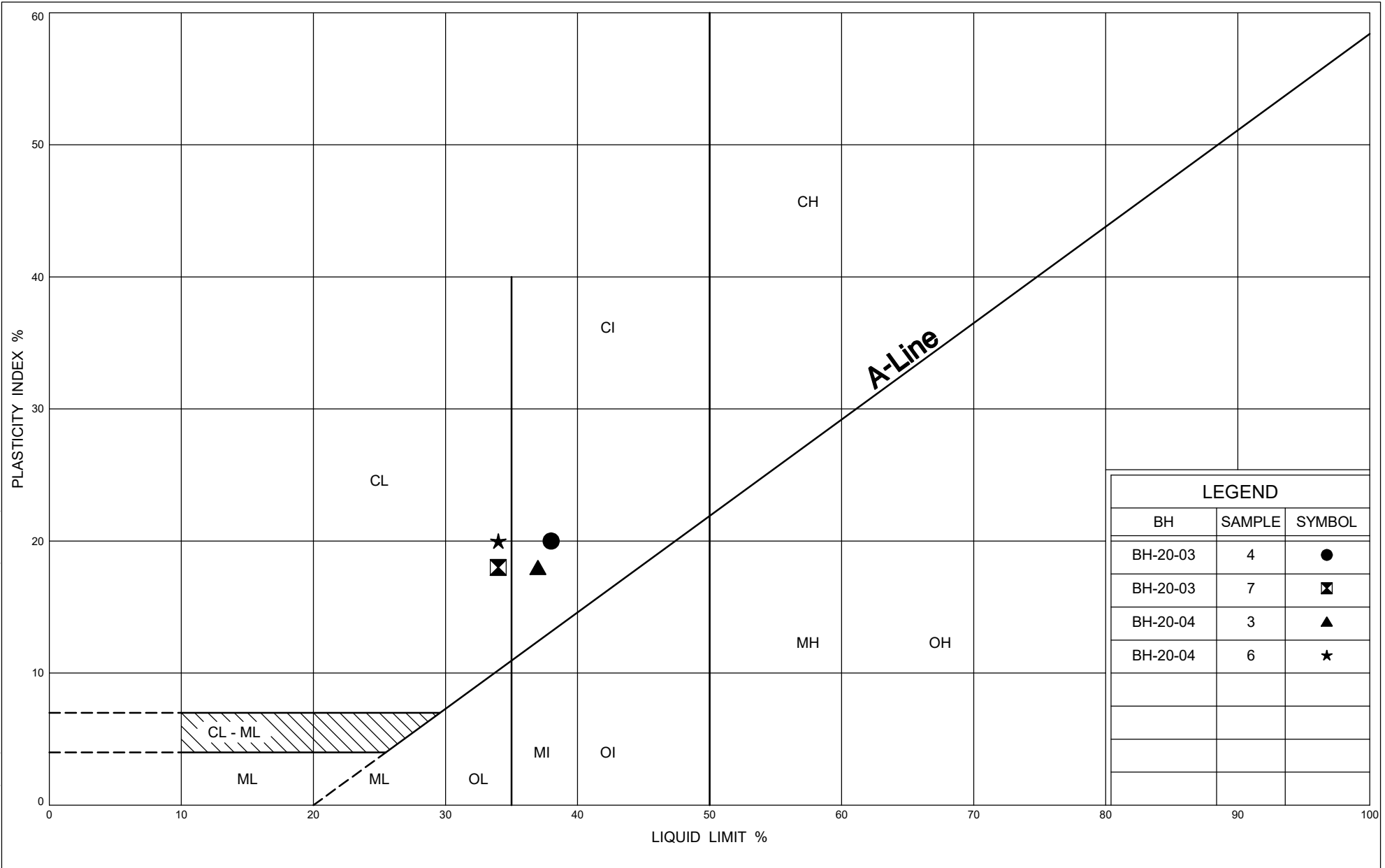
UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
Culvert No. 06X-0421/C0 - Fill - Sand and Gravel

Figure:	C2-1
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886



Ministry of
Transportation

PLASTICITY CHART

Culvert No. 06X-0421/C0 - Clayey Silt to Silty Clay (Till)

Figure:

C2-2

Assignment No.:

3017-E-0012

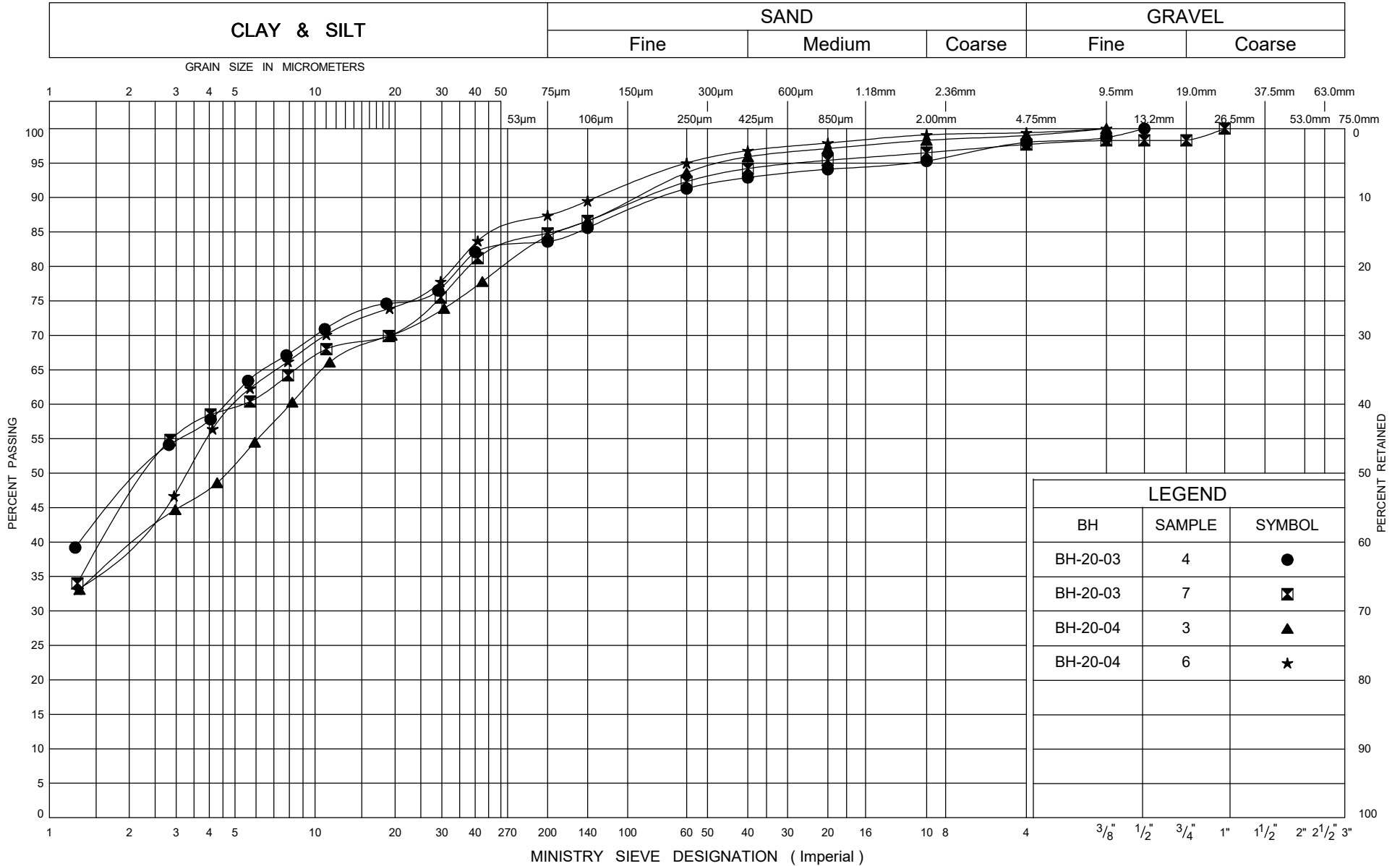
G.W.P. No.:

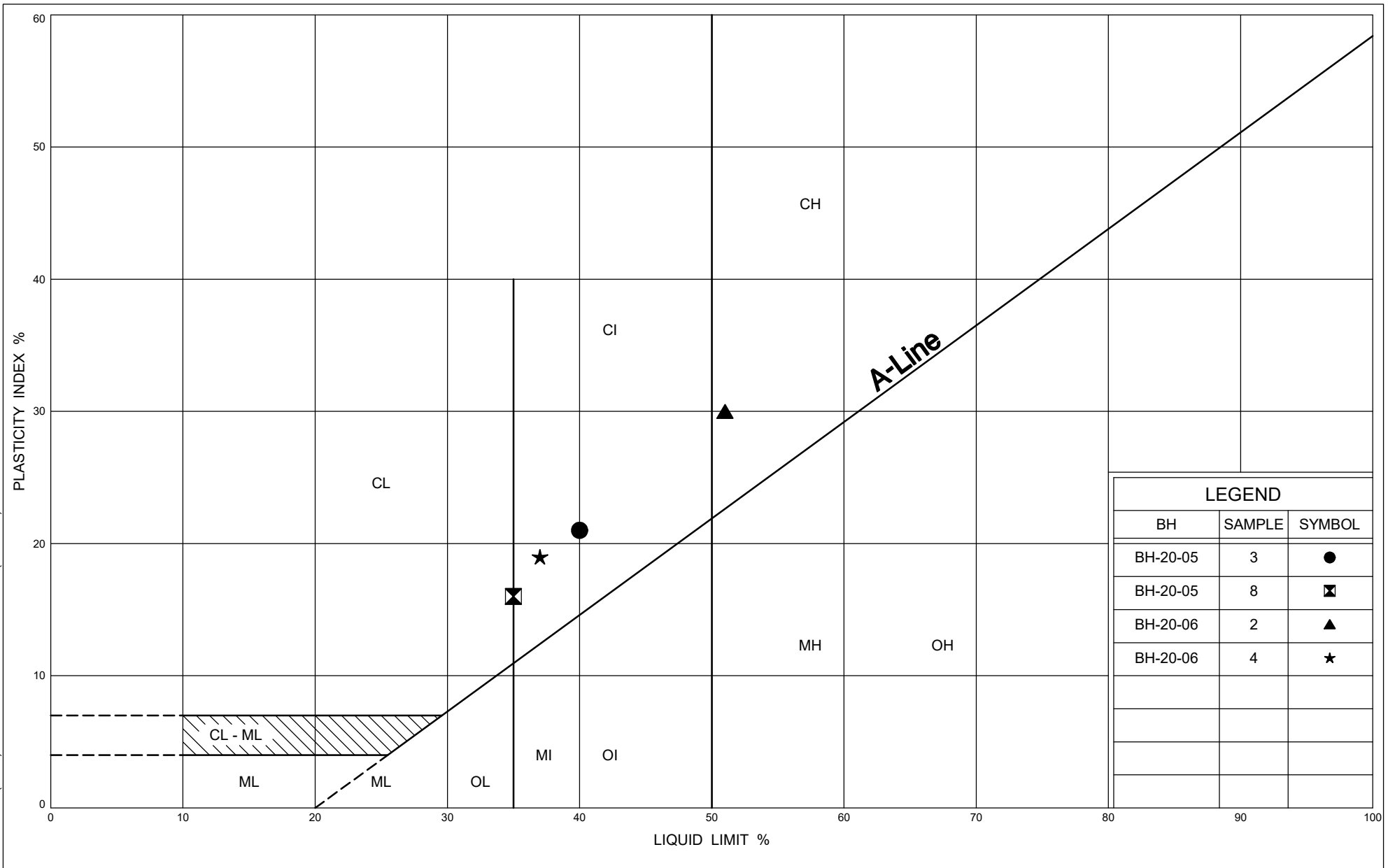
3021-18-00

GHD Project No.:

11202886

UNIFIED SOIL CLASSIFICATION SYSTEM

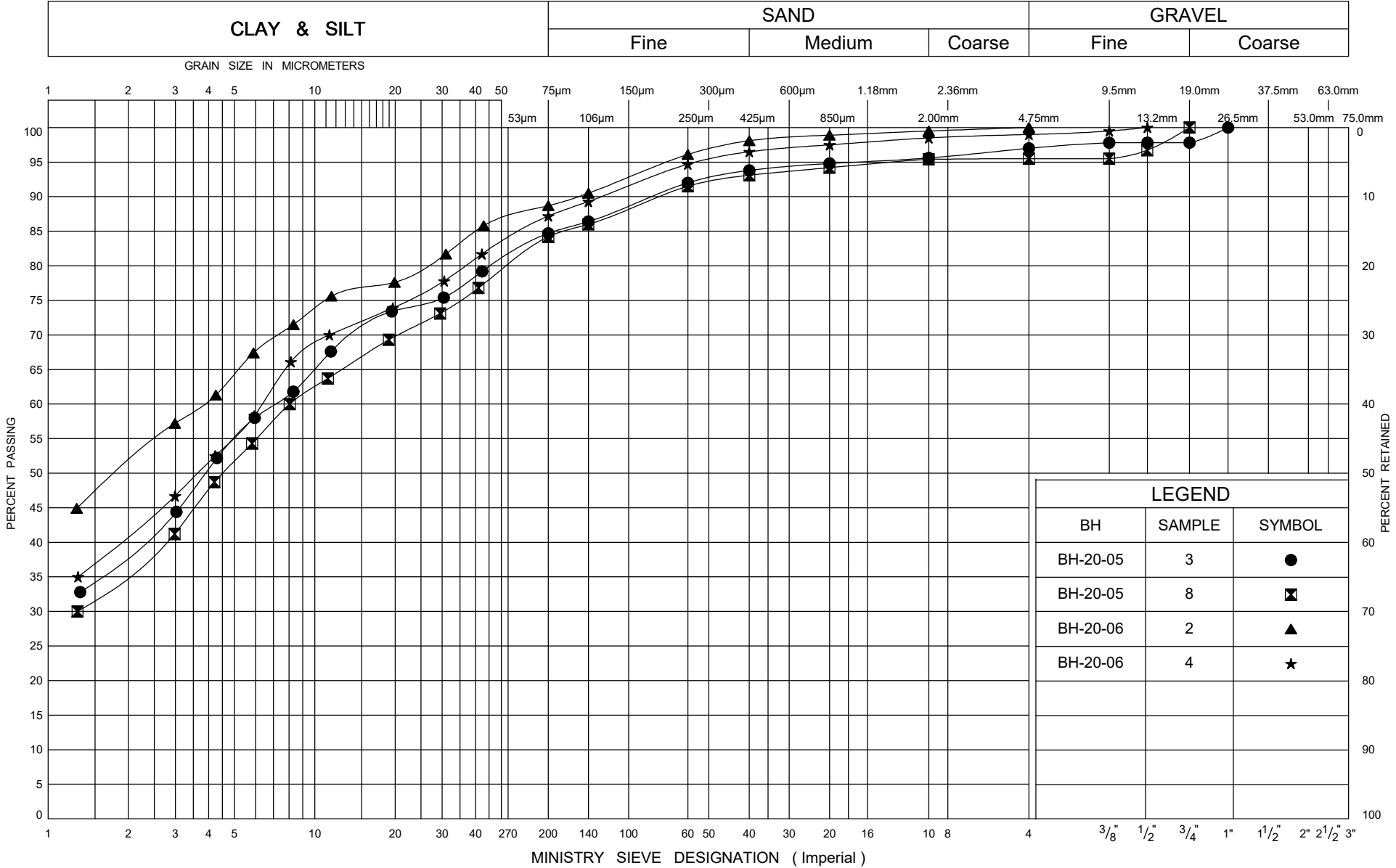




PLASTICITY CHART
Culvert No. 06X-0422/C0 - Clayey Silt to Silty Clay (Till)

Figure:	C3-1
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

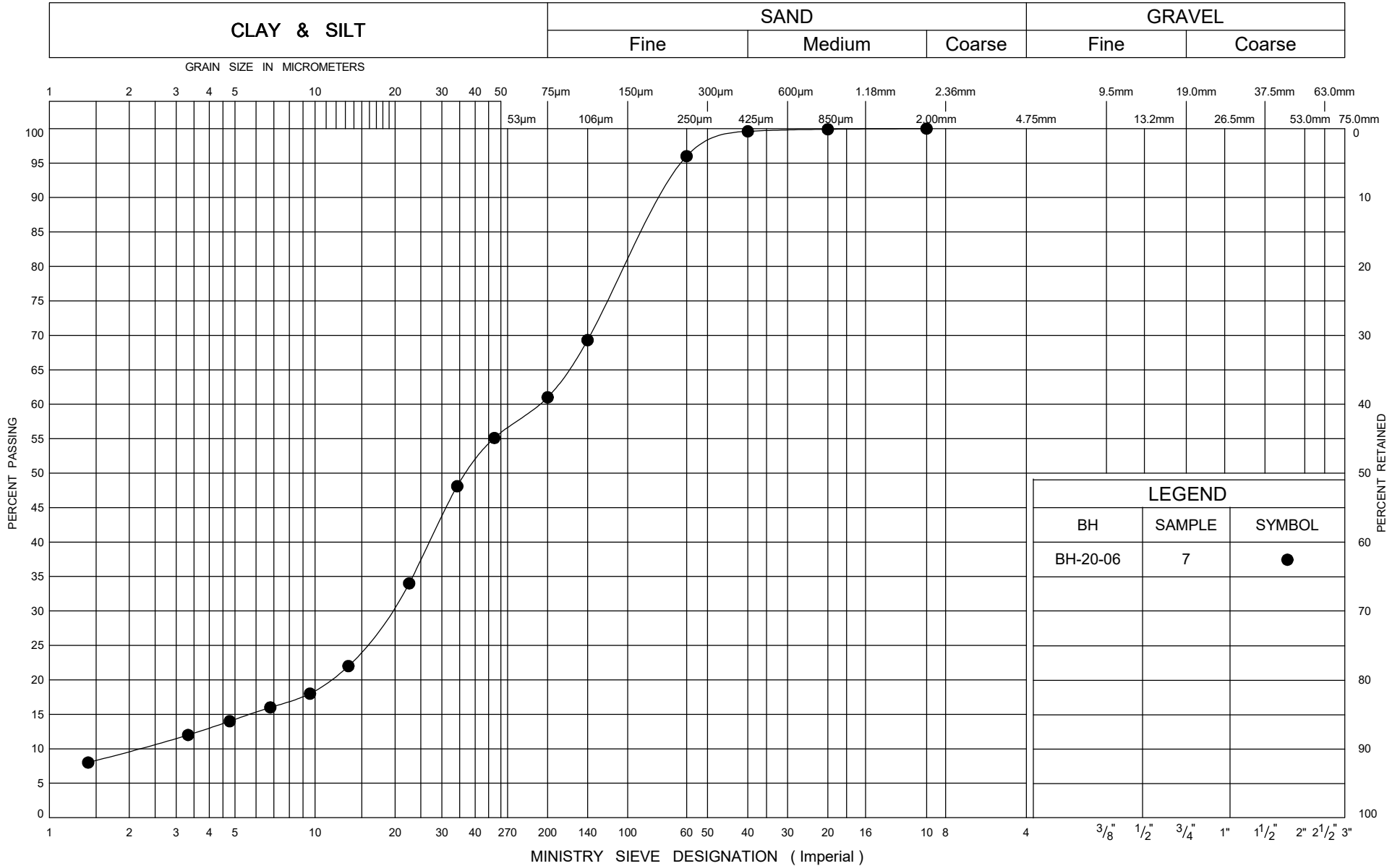
UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
Culvert No. 06X-0422/C0 - Clayey Silt to Silty Clay (Till)

Figure:	C3-2
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

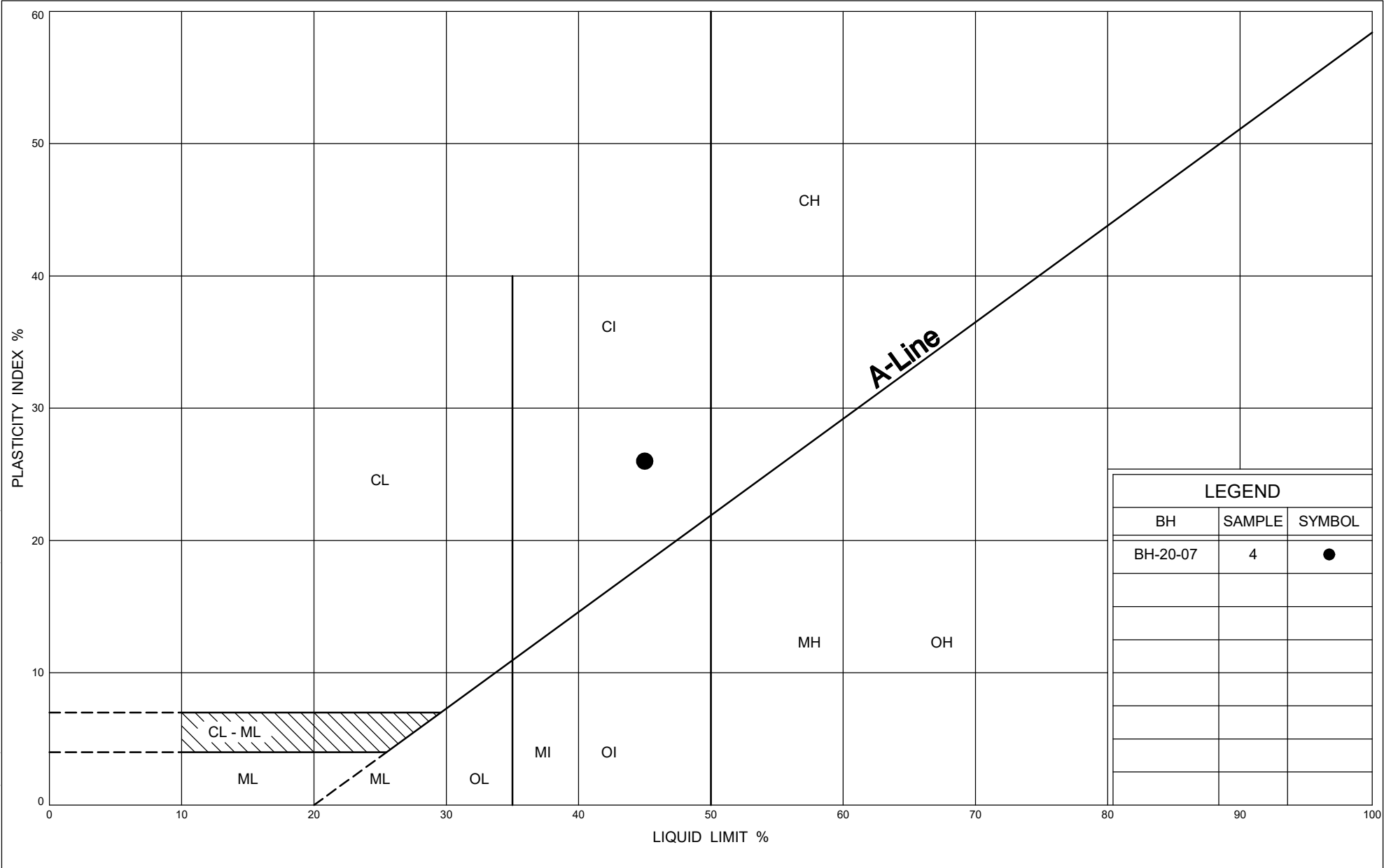
UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
Culvert No. 06X-0422/C0 - Silt and Sand (Till)

Figure:	C3-3
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

ONTARIO MOT PLASTICITY CHART (TITLE) 11202886 COMBINE FOR FIGURE(20211217)-1.GPJ ONTARIO MOT.GDT 17/12/21

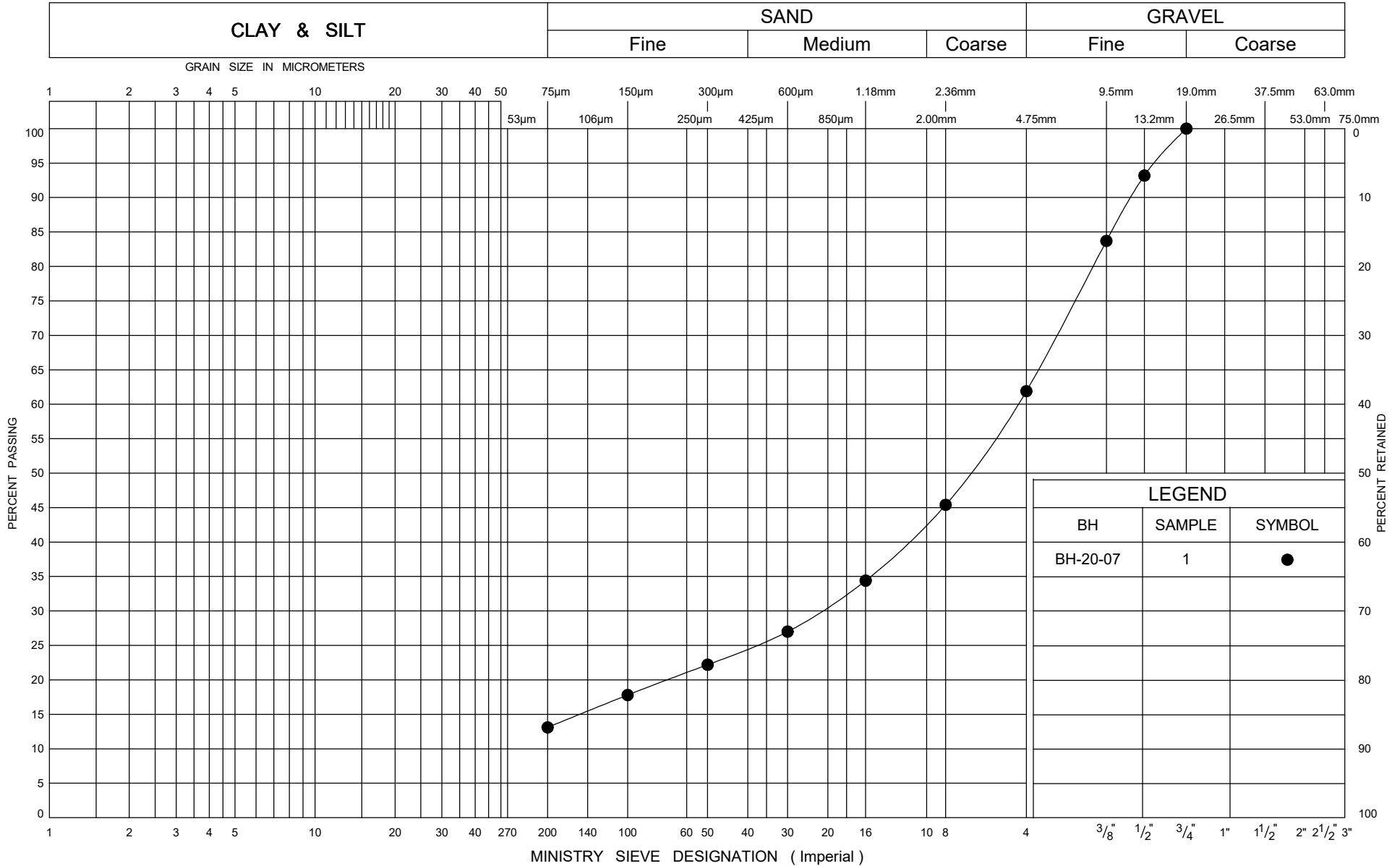


PLASTICITY CHART

Culvert No. 06X-0423/C0 - Silty Clay Fill

Figure:	C4-1
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

UNIFIED SOIL CLASSIFICATION SYSTEM



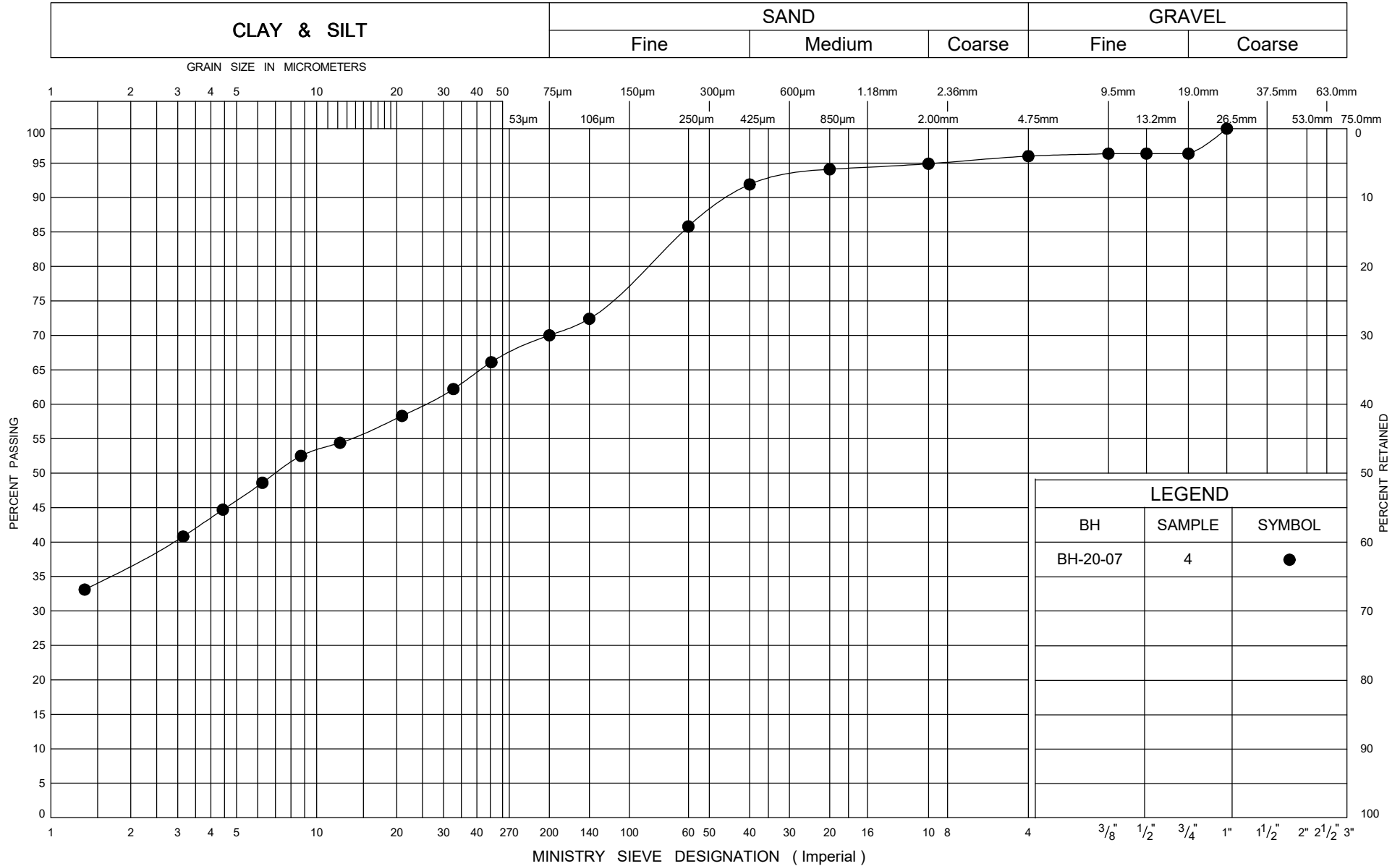
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

Culvert No. 06X-0423/C0 - Sand and Gravel Fill

Figure:	C4-2
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

UNIFIED SOIL CLASSIFICATION SYSTEM

Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

Culvert No. 06X-0423/C0 - Silty Clay Fill

Figure:

C4-3

Assignment No.:

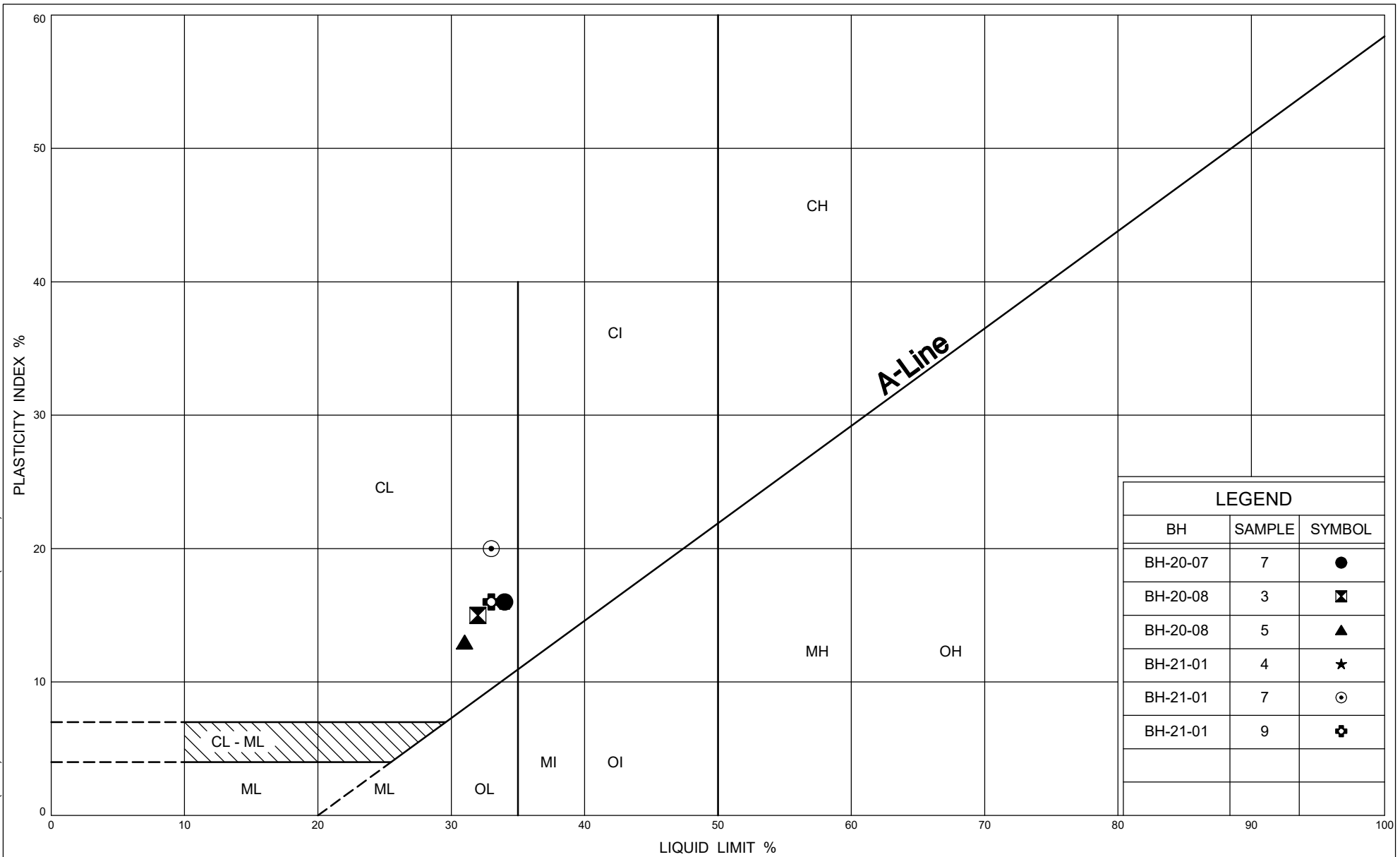
3017-E-0012

G.W.P. No.:

3021-18-00

GHD Project No.:

11202886



Ministry of
Transportation

PLASTICITY CHART

Culvert No. 06X-0423/C0 - Clayey Silt (Till)

Figure:

C4-4

Assignment No.:

3017-E-0012

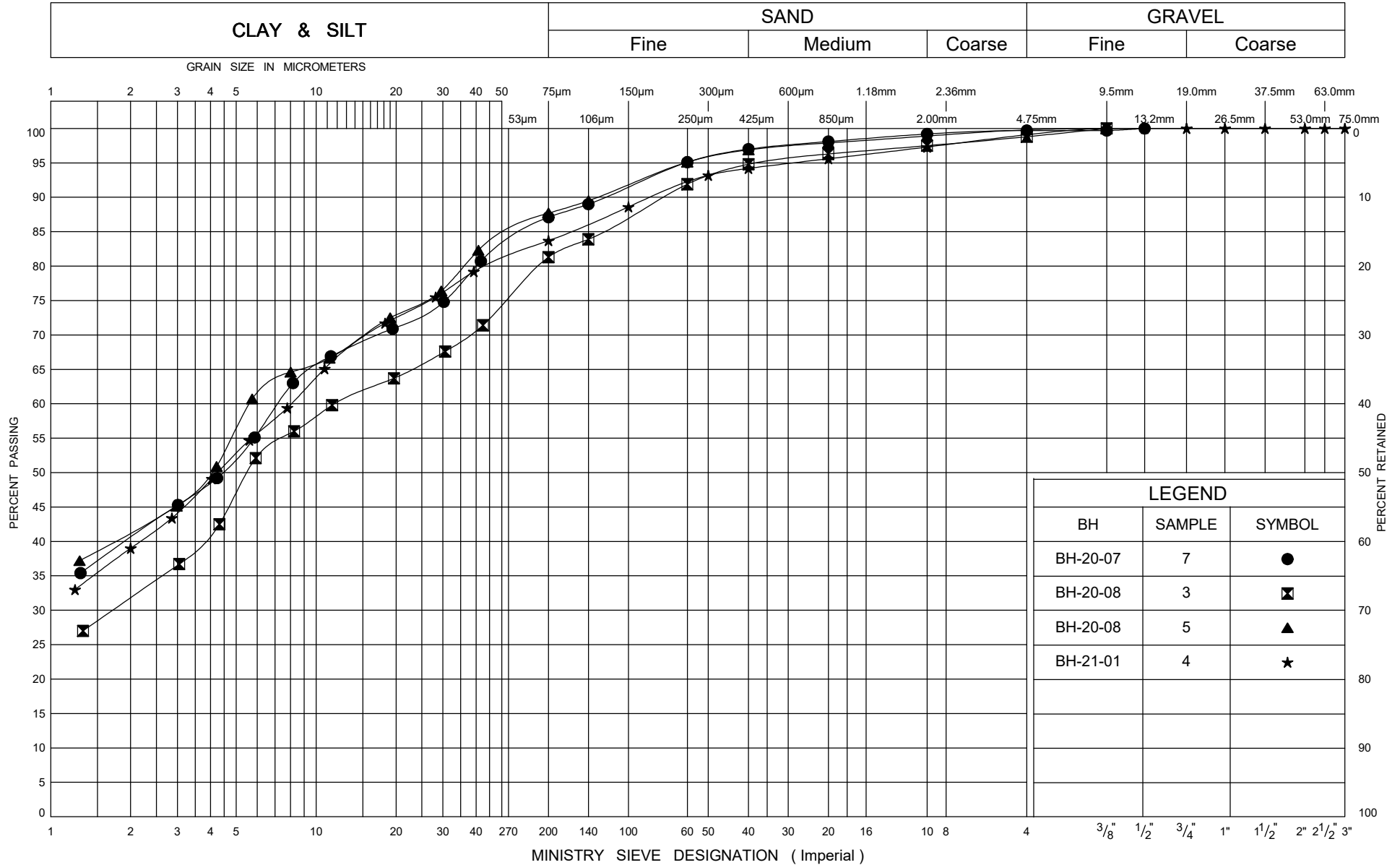
G.W.P. No.:

3021-18-00

GHD Project No.:

11202886

UNIFIED SOIL CLASSIFICATION SYSTEM

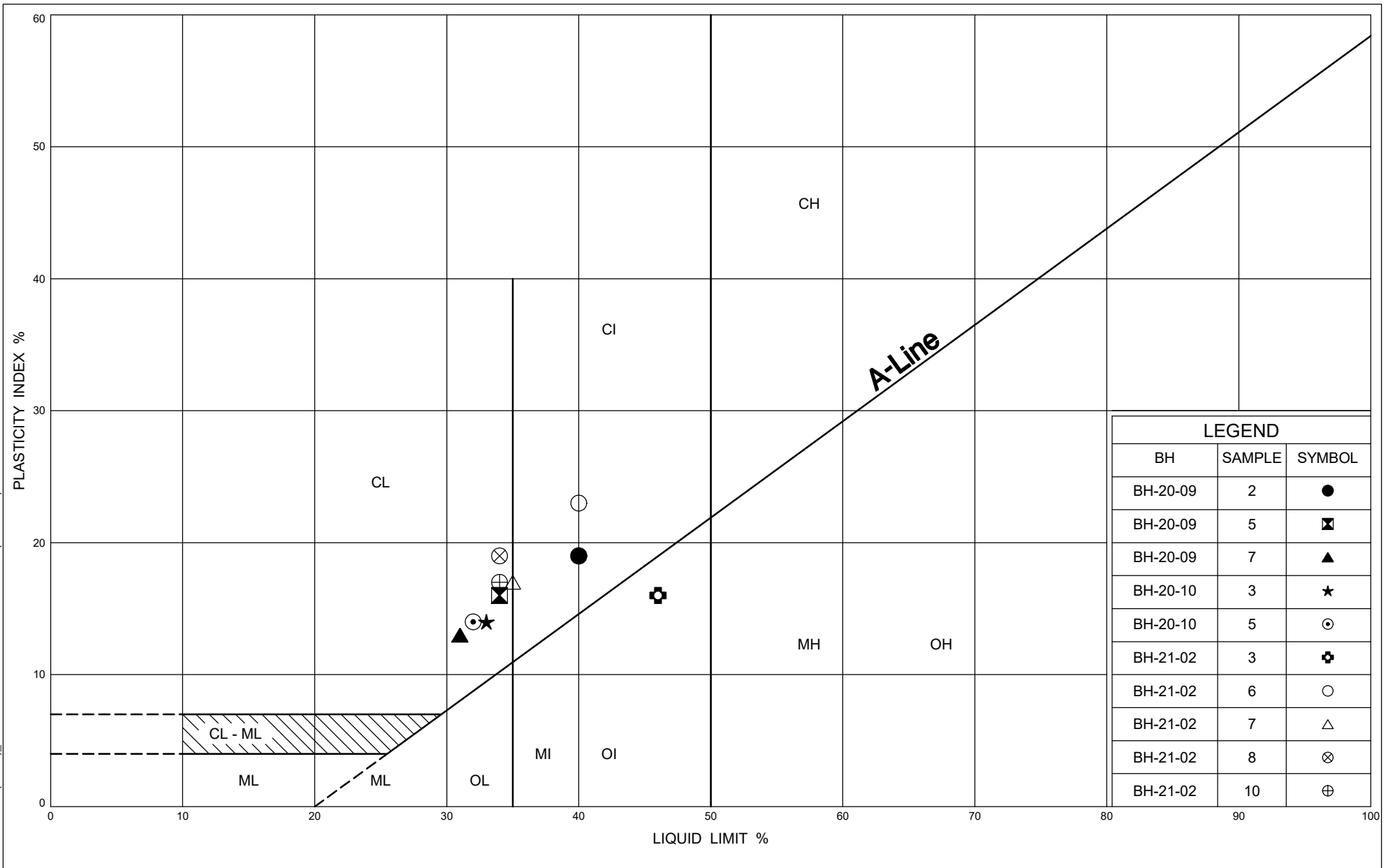


Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

Culvert No. 06X-0423/C0 - Clayey Silt (Till)

Figure:	C4-5
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886



UNIFIED SOIL CLASSIFICATION SYSTEM

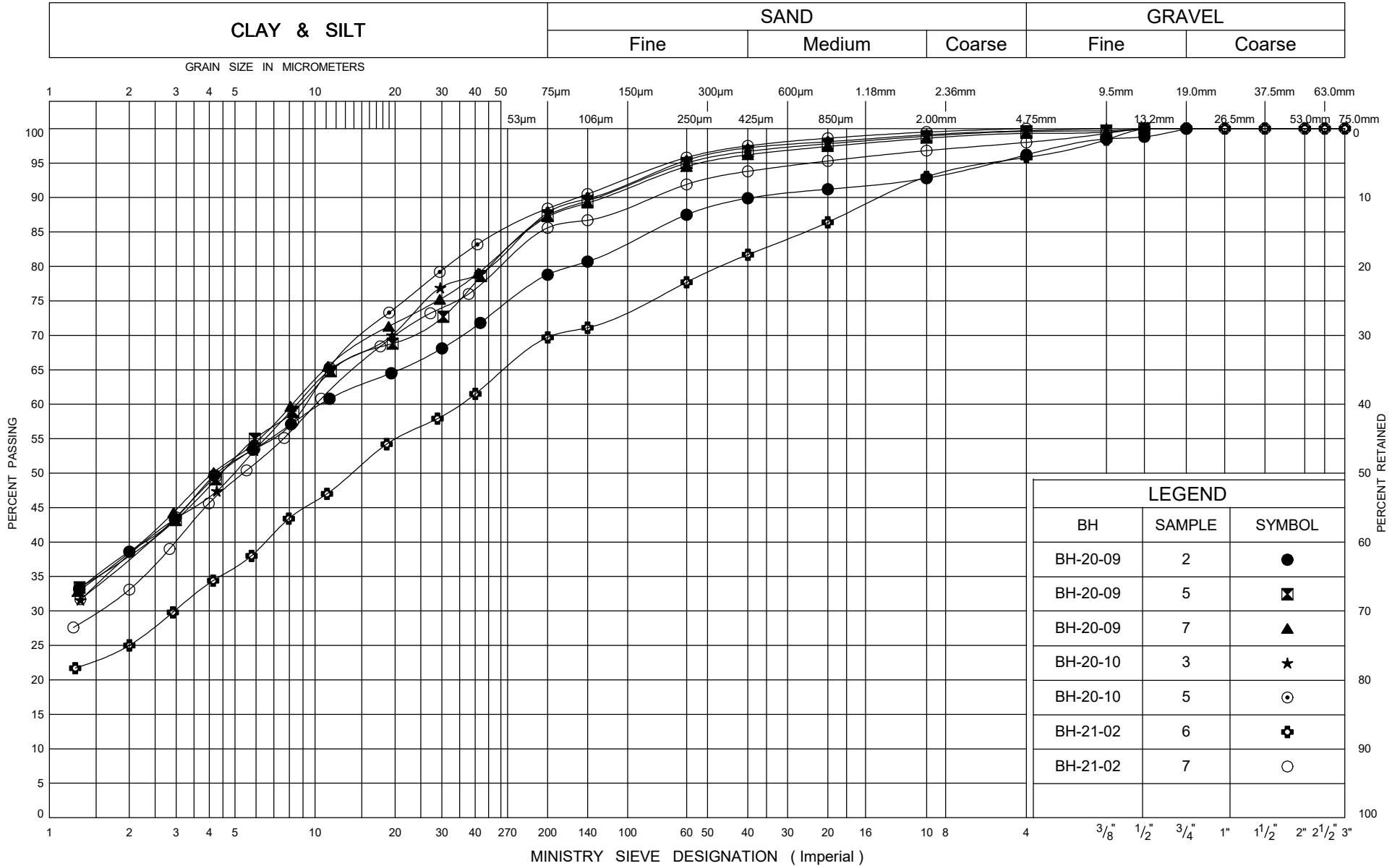




Figure C5-3 Consolidation Test Results

CLIENT:	Ministry of Transportation of Ontario	PROJECT No:	11202886
PROJECT:	GWP 3021-18.00 Highway 3 Widening, Windsor to Leamington, Phase 3, Contract 2	LAB No:	WLT 710-1
BOREHOLE No:	BH21-02	SAMPLE No:	TW1
DEPTH:	7.6 - 8.2 m (25'0" - 27'0")		
DESCRIPTION OF MATERIAL:	Culvert No. 06X-0426/C0 - Clayey Silt (Till)		

Axial Stress kPa	Specimen Height mm	Axial Strain %	Void Ratio e	c_v $m^2/year$
Initial	19.910	0.00	0.565	
6	19.887	0.12	0.563	
12	19.852	0.29	0.560	
25	19.777	0.67	0.554	2.3
50	19.619	1.46	0.542	3.3
100	19.414	2.49	0.526	2.6
25	19.478	2.17	0.531	
6	19.557	1.77	0.537	
12	19.557	1.77	0.537	
25	19.526	1.93	0.534	
50	19.471	2.21	0.530	
100	19.397	2.58	0.524	
200	19.149	3.82	0.505	4.5
400	18.786	5.64	0.476	4.5
800	18.336	7.91	0.441	4.6
200	18.446	7.36	0.449	
50	18.663	6.26	0.467	
12	18.851	5.32	0.481	

Test Summary			
σ'_p Preconsolidation pressure, kPa	153.0	e_0 Initial Void Ratio	0.565
σ'_0 Effective vertical pressure, kPa	141.7	e_f Final Void Ratio	0.481
$\sigma'_p - \sigma'_0$ Overconsolidation, kPa	11.3	Initial Degree of Saturation	0.97
Overconsolidation ratio ("OCR")	1.1	Final Degree of Saturation	1.00
C_c Compression Index	0.116	C_R Recompression Index	0.010

Sample dry density, g/cm^3		Moisture content (W) %	
Initial state	1.757	Initial state	20.0
Final state	1.855	Final state	17.5

REMARKS:

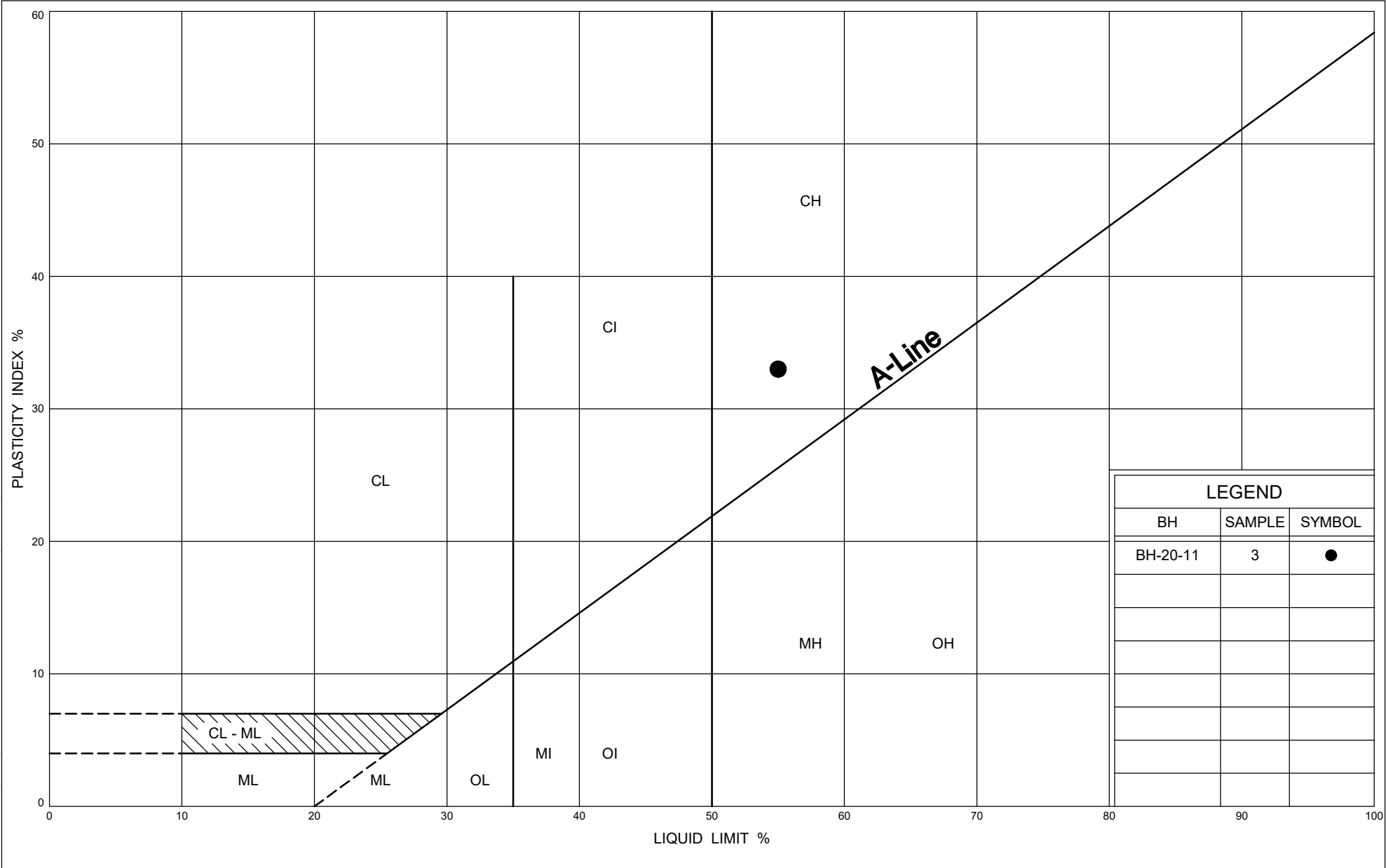
PERFORMED BY: Melanie Mitchell

DATE: Nov 12 - Nov 28, 2021

VERIFIED BY: Michael Braverman

DATE: November 30, 2021

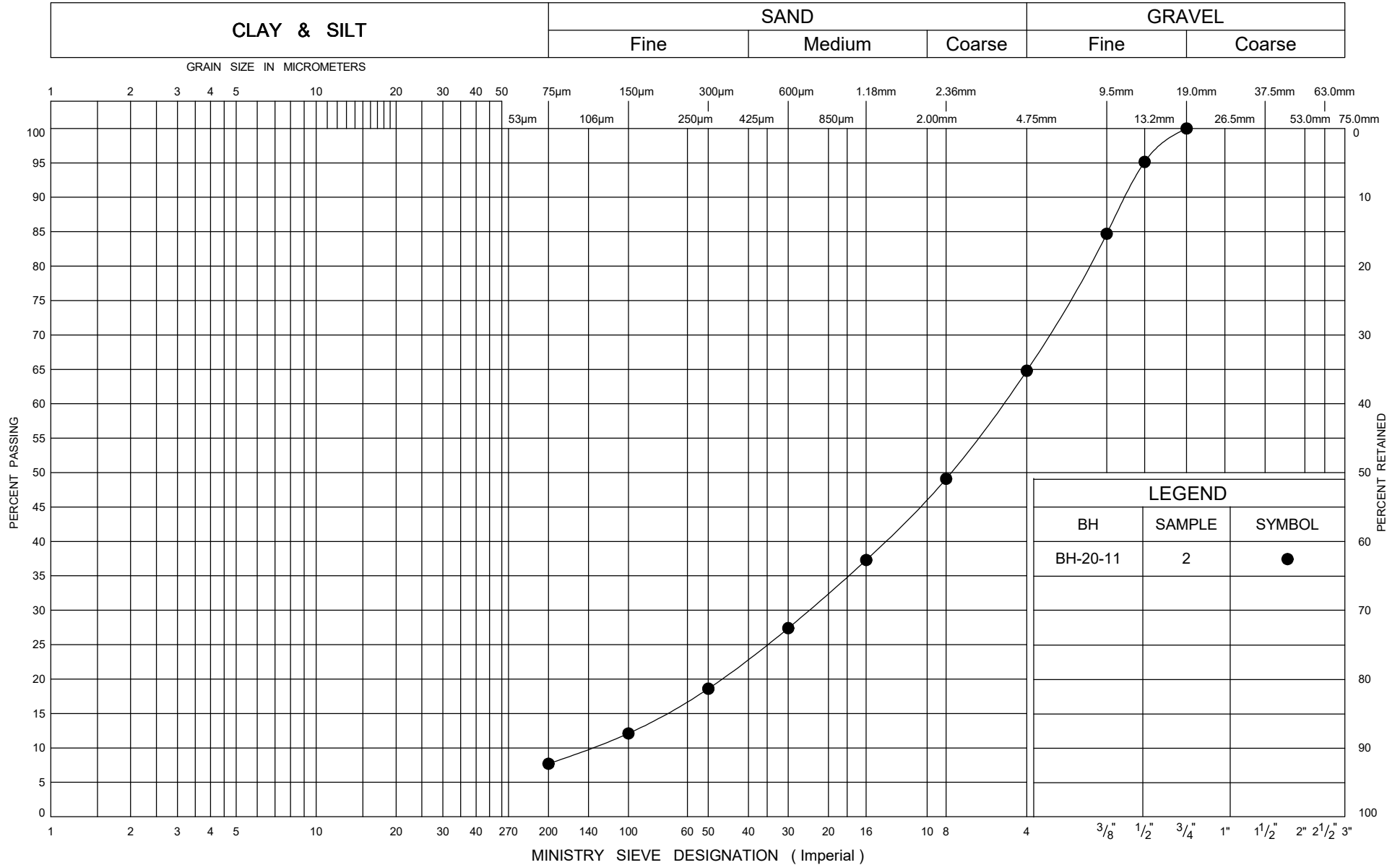
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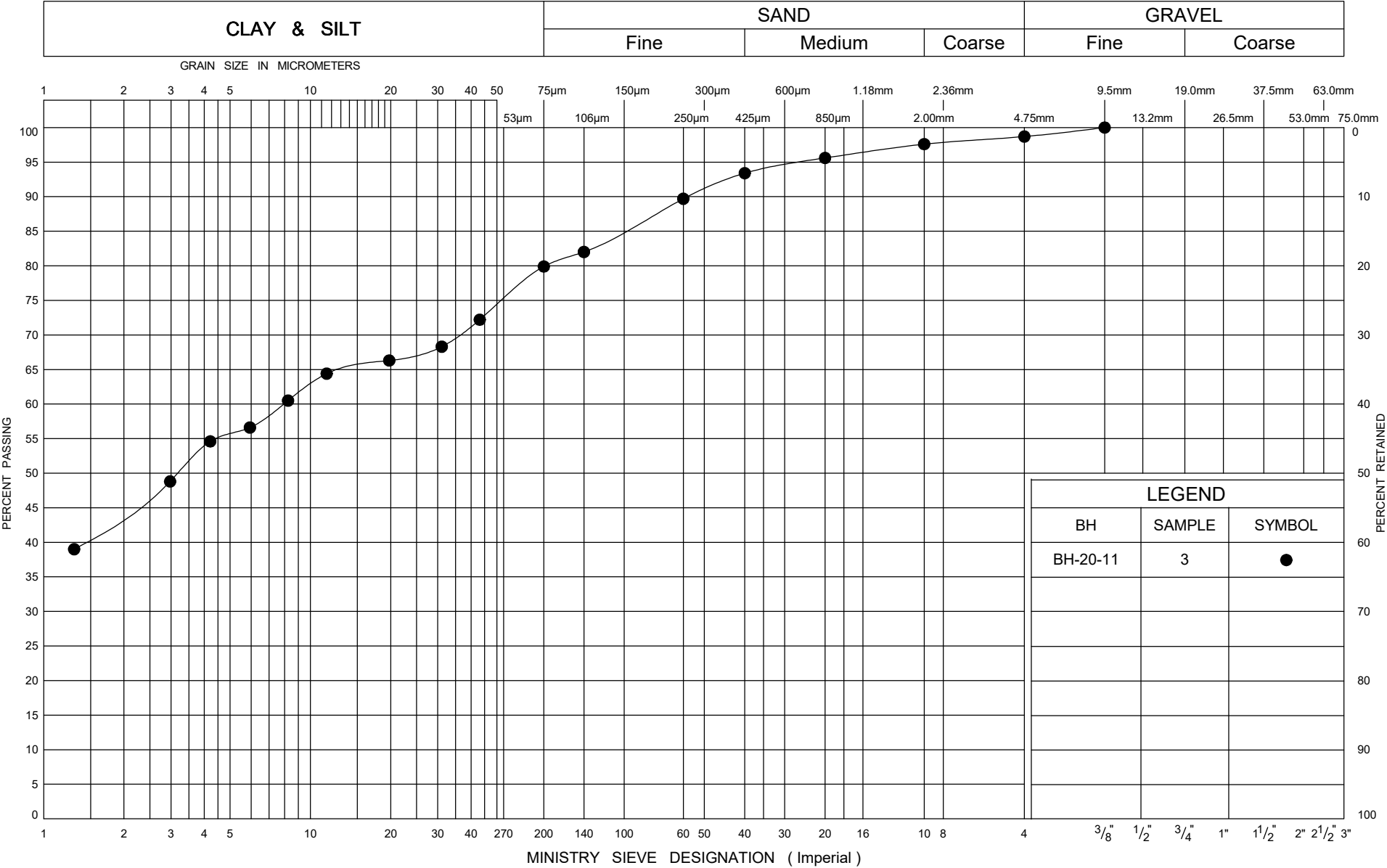
PLASTICITY CHART
Culvert No. 06X-0427/C0 - Silty Clay Fill

Figure:	C6-1
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

UNIFIED SOIL CLASSIFICATION SYSTEM



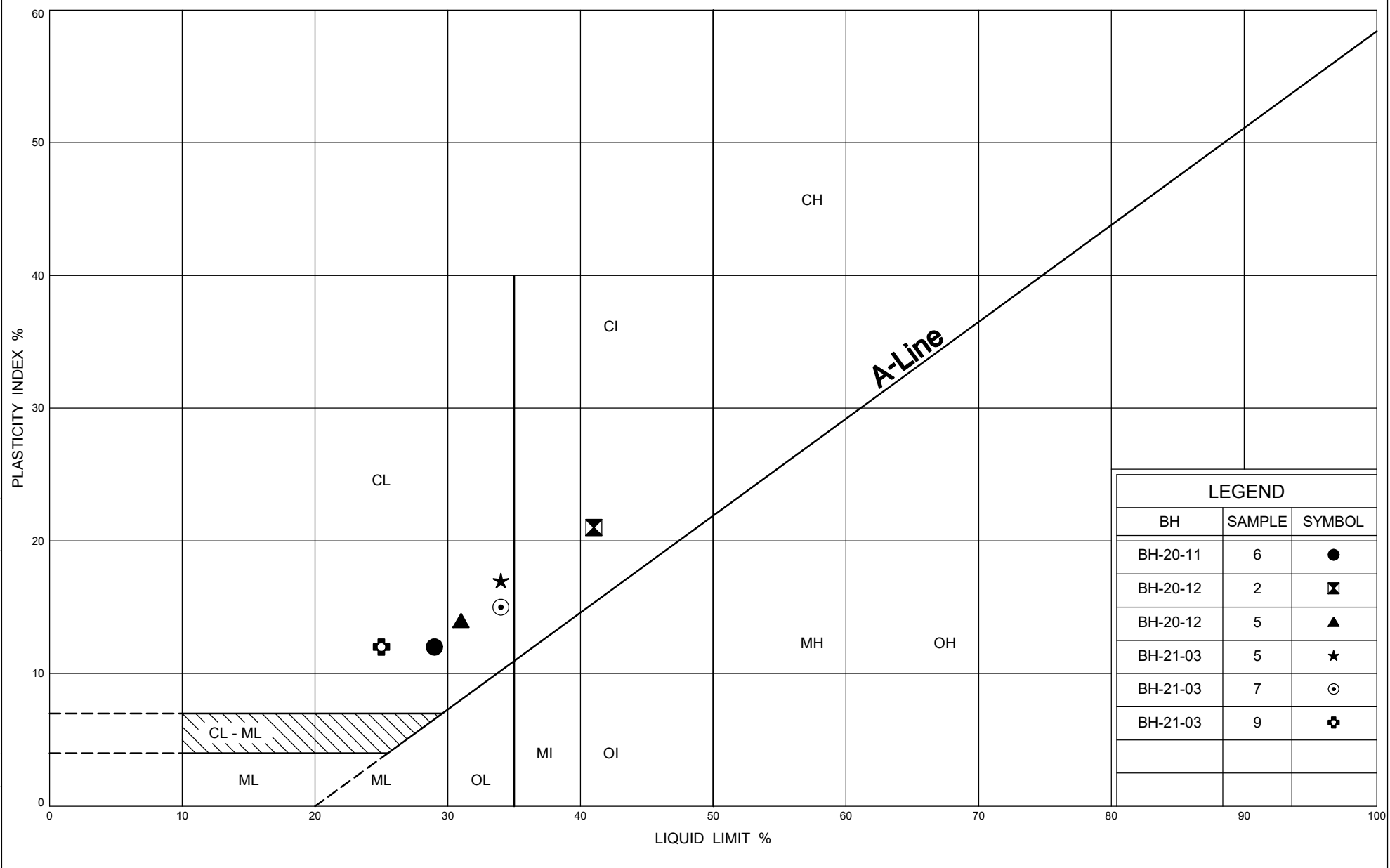
UNIFIED SOIL CLASSIFICATION SYSTEM



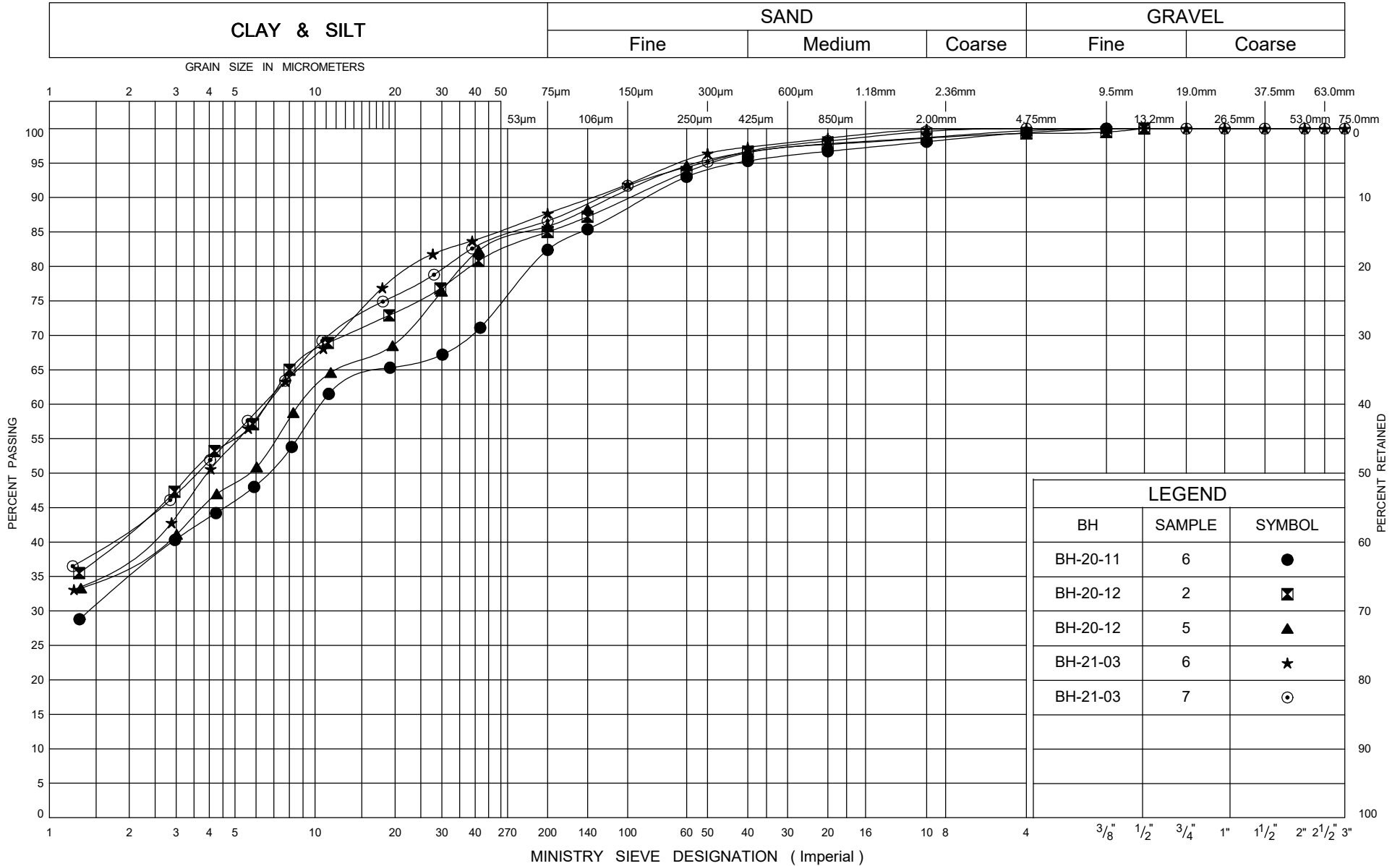
Ministry of
Transportation

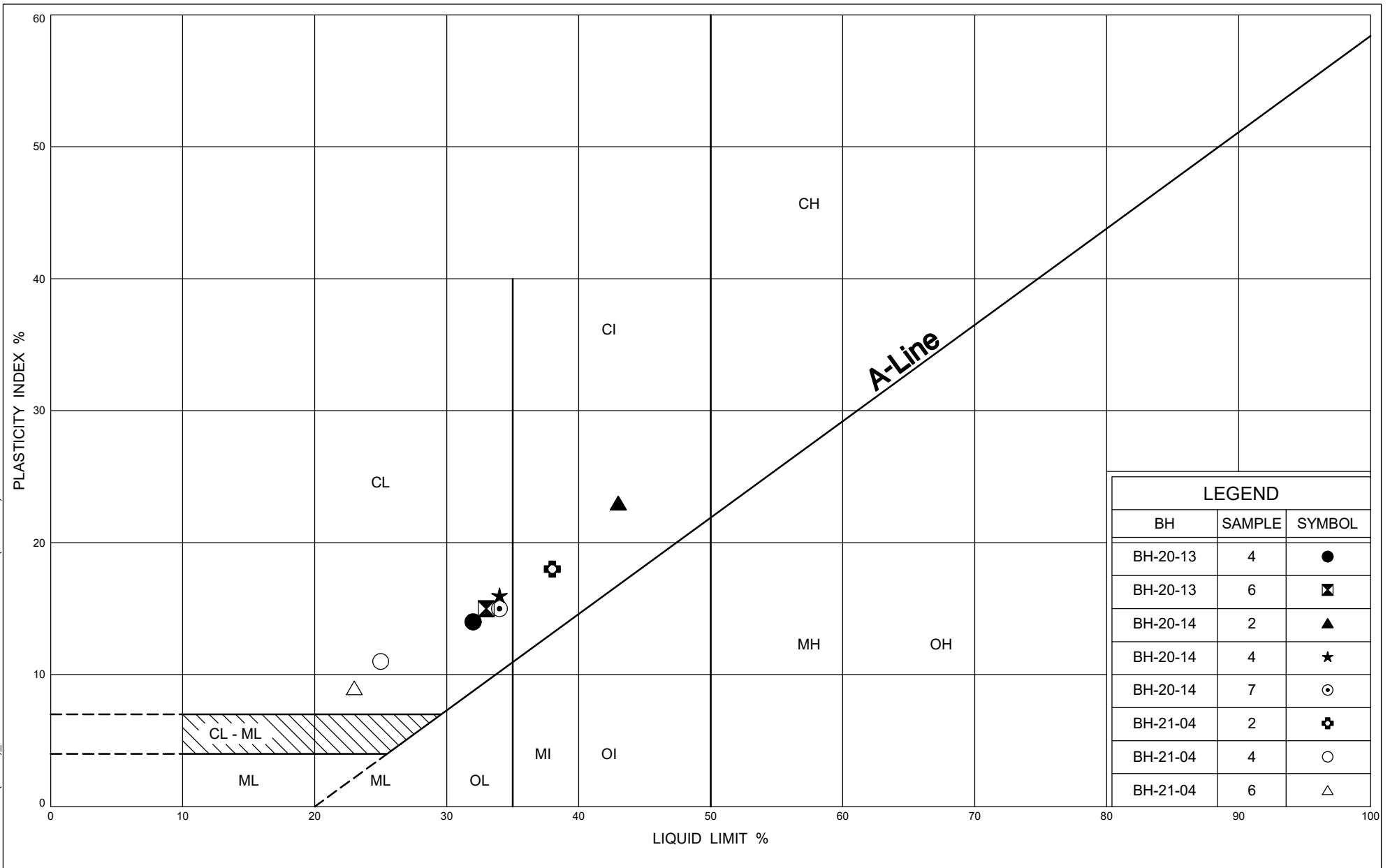
GRAIN SIZE DISTRIBUTION
Culvert No. 06X-0427/C0 - Silty Clay Fill

Figure:	C6-3
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886



UNIFIED SOIL CLASSIFICATION SYSTEM



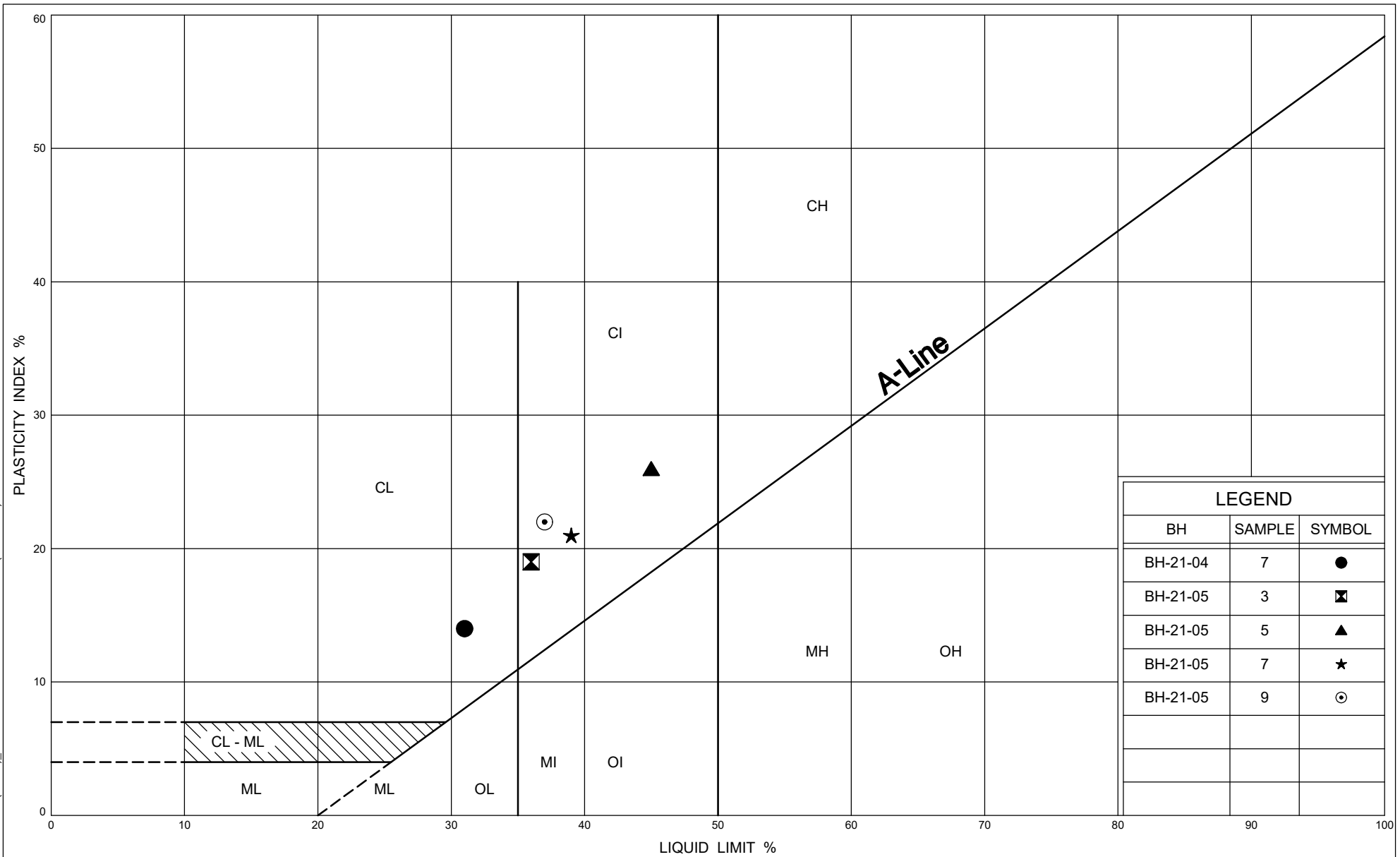


Ministry of
Transportation

PLASTICITY CHART

Culvert No. 06X-0429/C0 - Clayey Silt and Sand to Silty Clay (Till)

Figure:	C7-1A
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886



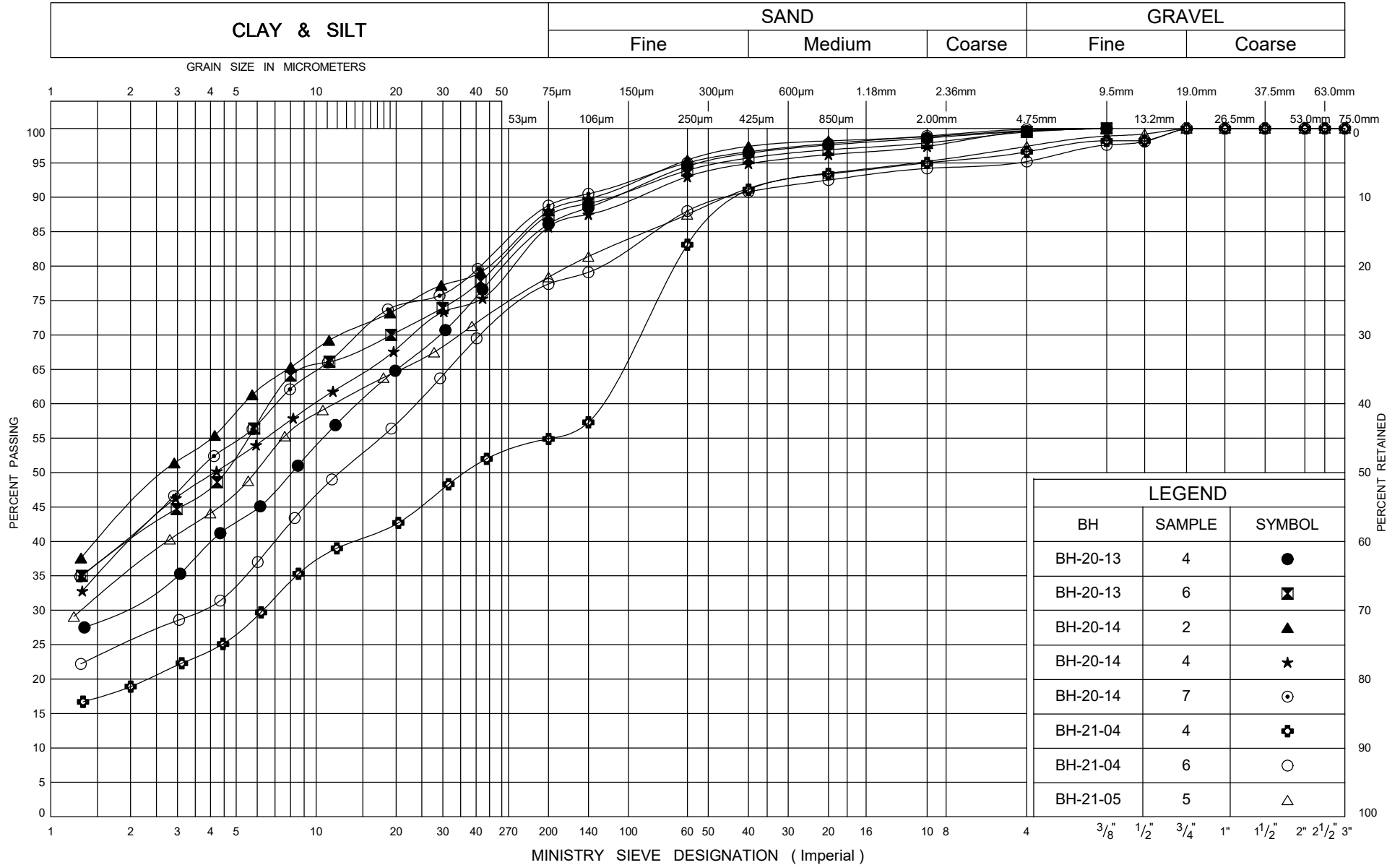
Ministry of
Transportation

PLASTICITY CHART

Culvert No. 06X-0429/C0 - Clayey Silt and Sand to Silty Clay (Till)

Figure:	C7-1B
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
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GRAIN SIZE DISTRIBUTION

Culvert No. 06X-0429/C0 - Clayey Silt and Sand to Silty Clay (Till)

Figure:	C7-2
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

UNIFIED SOIL CLASSIFICATION SYSTEM

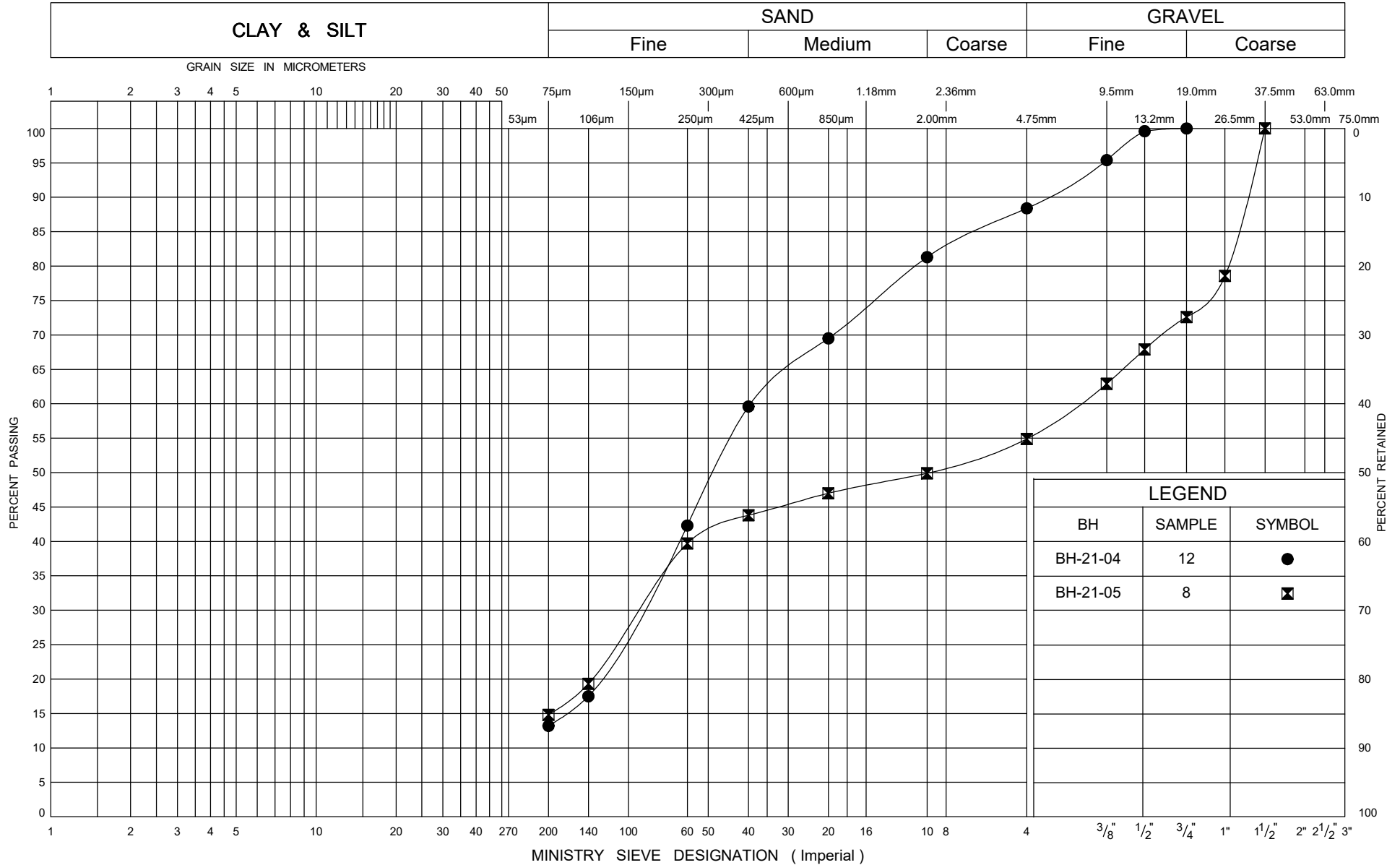




Figure C7-4 Consolidation Test Results

CLIENT:	Ministry of Transportation of Ontario	PROJECT No:	11202886
PROJECT:	GWP 3021-18.00 Highway 3 Widening, Windsor to Leamington, Phase 3, Contract 2	LAB No:	WLT 710-2
BOREHOLE No:	BH21-04	SAMPLE No:	TW2
DEPTH:	6.1 - 6.7 m (20'0" - 22'0")		
DESCRIPTION OF MATERIAL:	Culvert No. 06X-0429/C0 - Clayey Silt (Till)		

Axial Stress kPa	Specimen Height mm	Axial Strain %	Void Ratio e	c_v m²/year
Initial	19.590	0.00	0.636	
6	19.563	0.14	0.633	
12	19.510	0.41	0.629	
25	19.462	0.66	0.625	2.0
50	19.365	1.15	0.617	3.5
100	19.143	2.28	0.598	2.7
25	19.198	2.00	0.603	
6	19.299	1.49	0.611	
12	19.295	1.50	0.611	
25	19.261	1.68	0.608	
50	19.210	1.94	0.604	
100	19.099	2.51	0.595	
200	18.841	3.83	0.573	3.4
400	18.464	5.75	0.541	4.0
800	17.940	8.42	0.498	3.7
200	18.074	7.74	0.509	
50	18.328	6.44	0.530	
12	18.553	5.30	0.549	

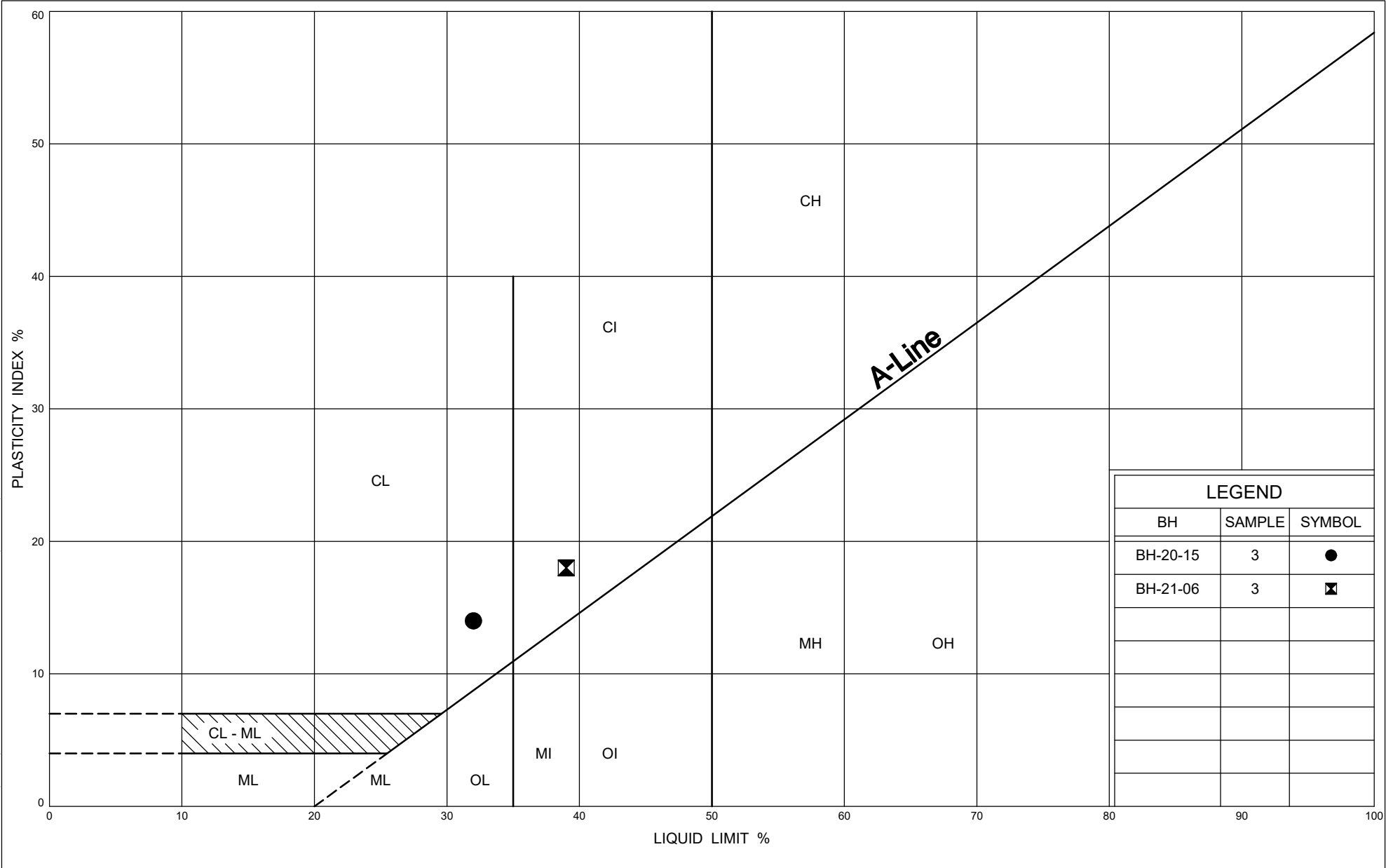
Test Summary			
σ'_p Preconsolidation pressure, kPa	145.0	e_0 Initial Void Ratio	0.636
σ'_0 Effective vertical pressure, kPa	125.5	e_f Final Void Ratio	0.549
$\sigma'_p - \sigma'_0$ Overconsolidation, kPa	19.5	Initial Degree of Saturation	0.97
Overconsolidation ratio ("OCR")	1.16	Final Degree of Saturation	1.00
C_c Compression Index	0.116	C_R Recompression Index	0.010

Sample dry density, g/cm³	Moisture content (W) %
Initial state 1.681 Final state 1.775	Initial state 22.3 Final state 19.9

REMARKS:

PERFORMED BY: Melanie Mitchell VERIFIED BY: Michael Braverman	DATE: Nov 12 - Nov 28, 2021 DATE: November 30, 2021
--	--

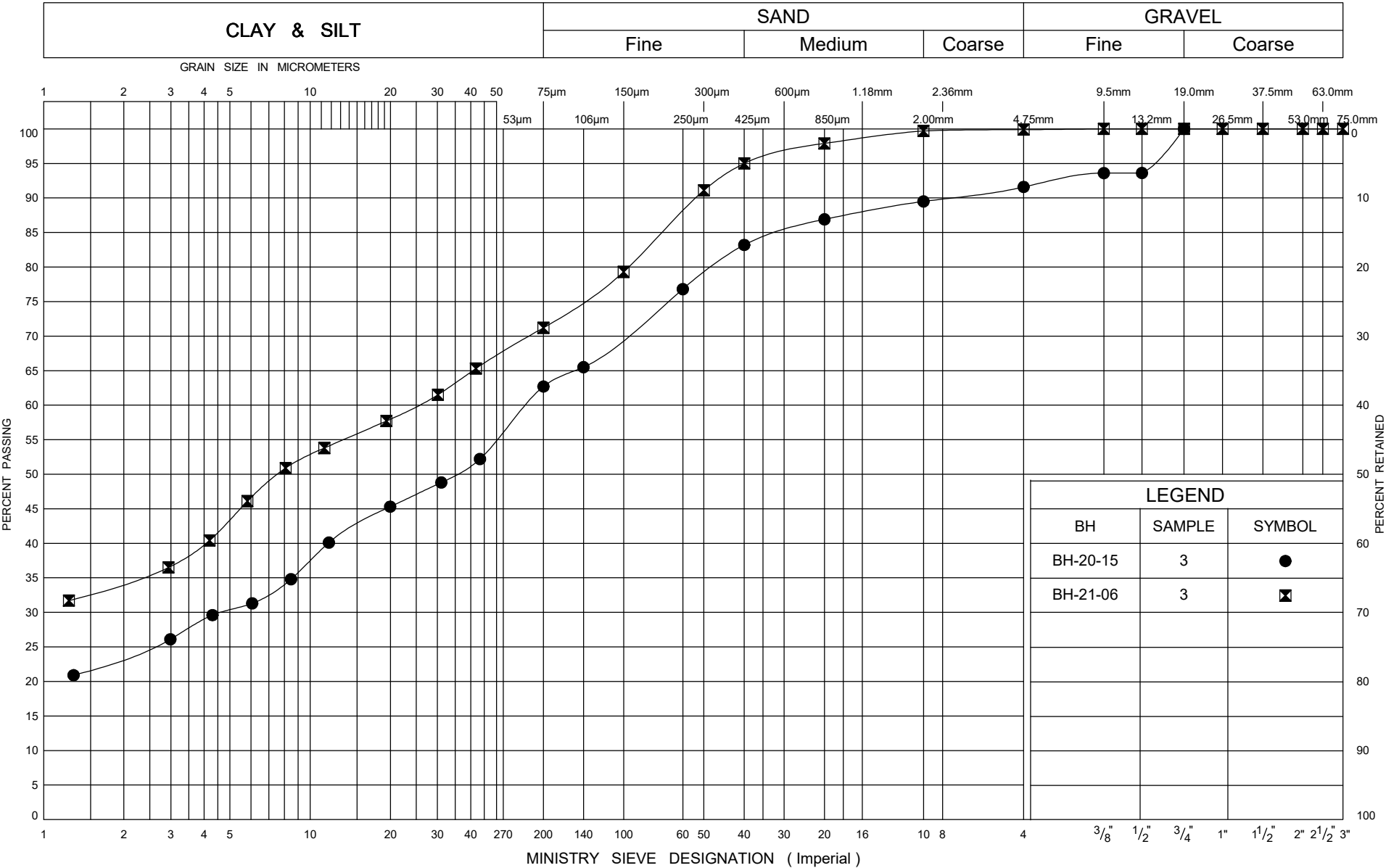
ONTARIO MOT PLASTICITY CHART (TITLE)_8_11202886 COMBINE FOR FIGURE(20211217)-1.GPJ ONTARIO MOT.GDT 17/12/21



PLASTICITY CHART
Culvert No. 06X-0432/C0 - Silty Clay with Sand Fill

Figure:	C8-1
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886

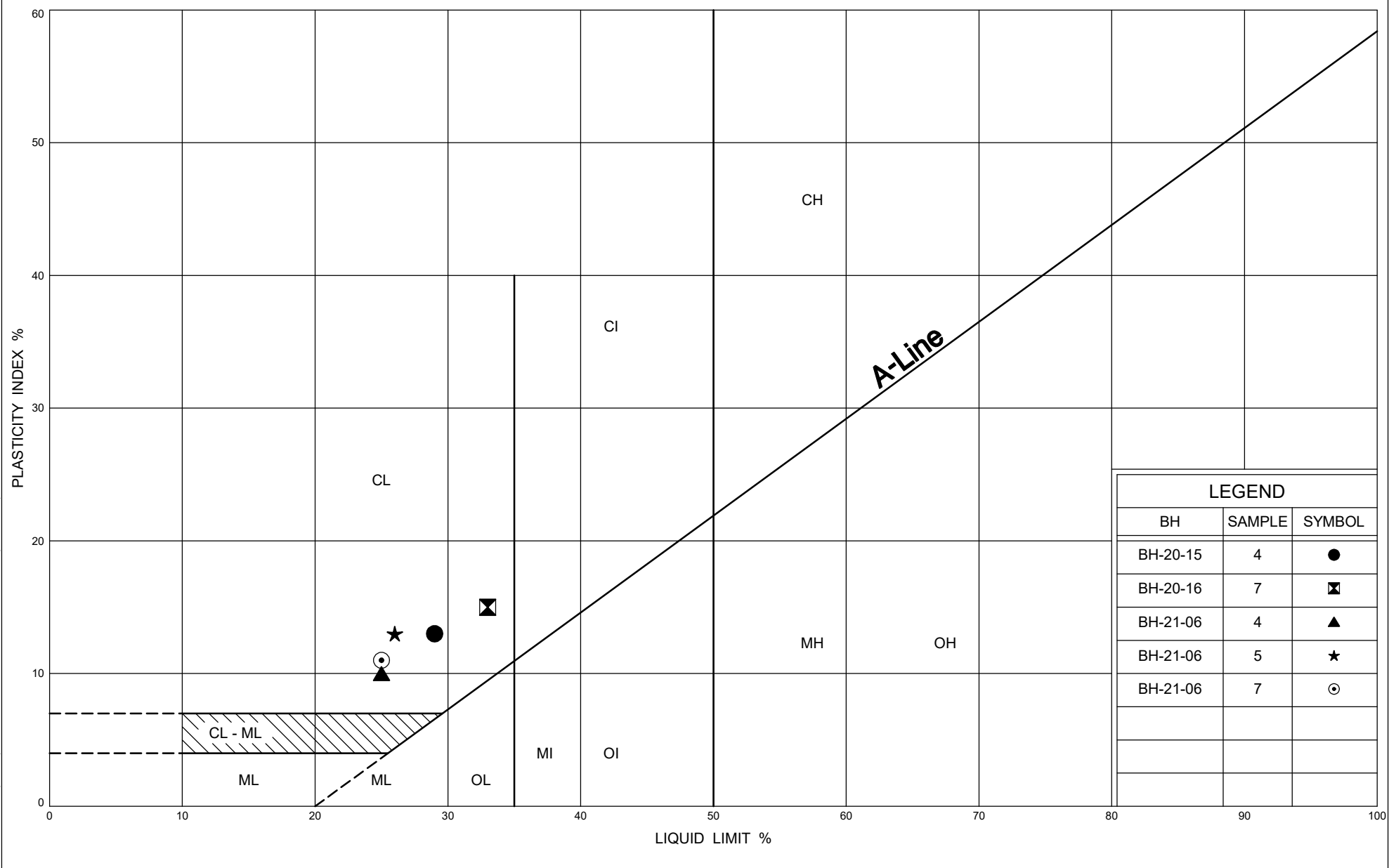
UNIFIED SOIL CLASSIFICATION SYSTEM



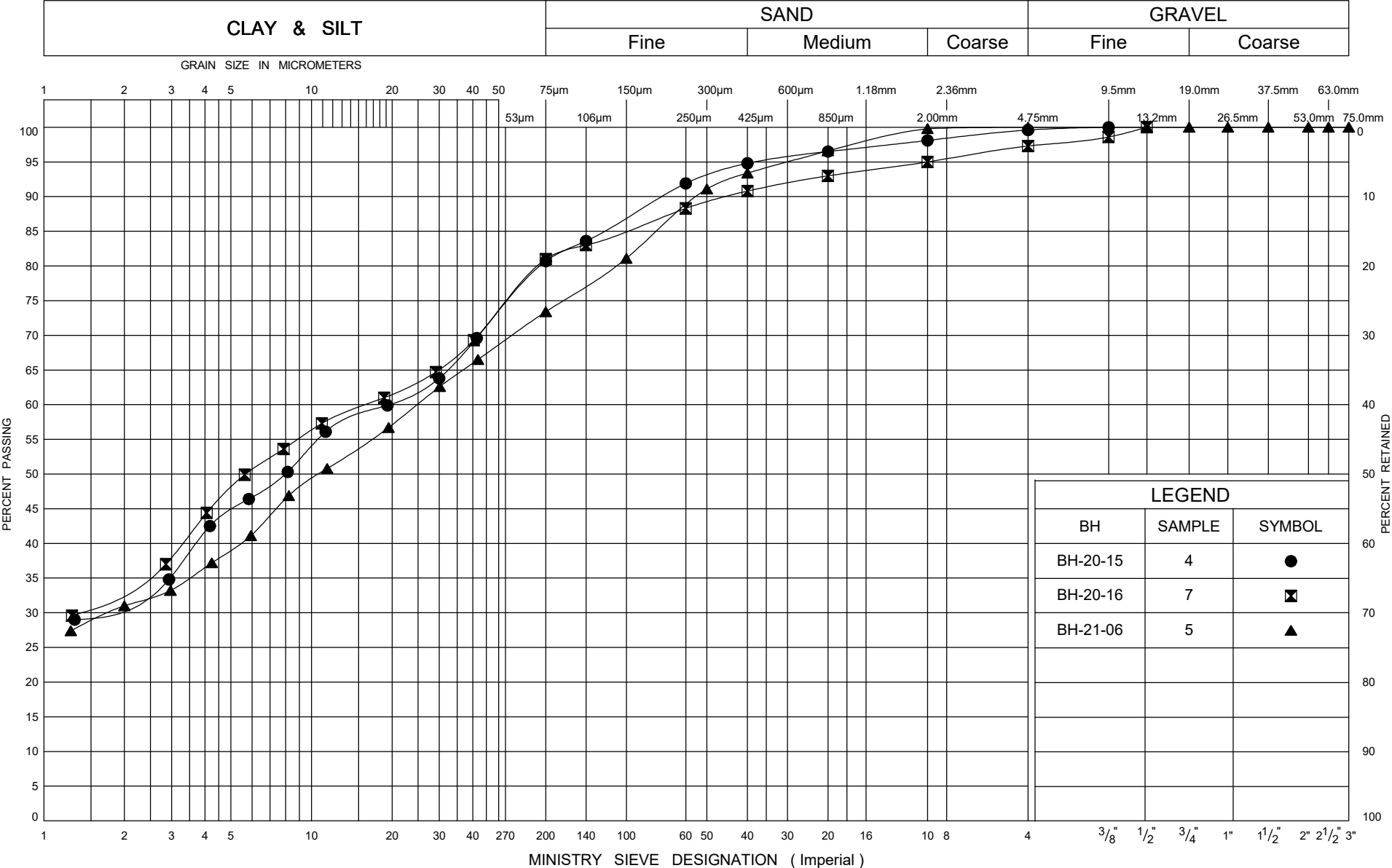
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
Culvert No. 06X-0432/C0 - Silty Clay with Sand Fill

Figure:	C8-2
Assignment No.:	3017-E-0012
G.W.P. No.:	3021-18-00
GHD Project No.:	11202886



UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

Culvert No. 06X-0432/C0 - Clayey Silt (Till)

Figure:

C8-4

Assignment No.:

3017-E-0012

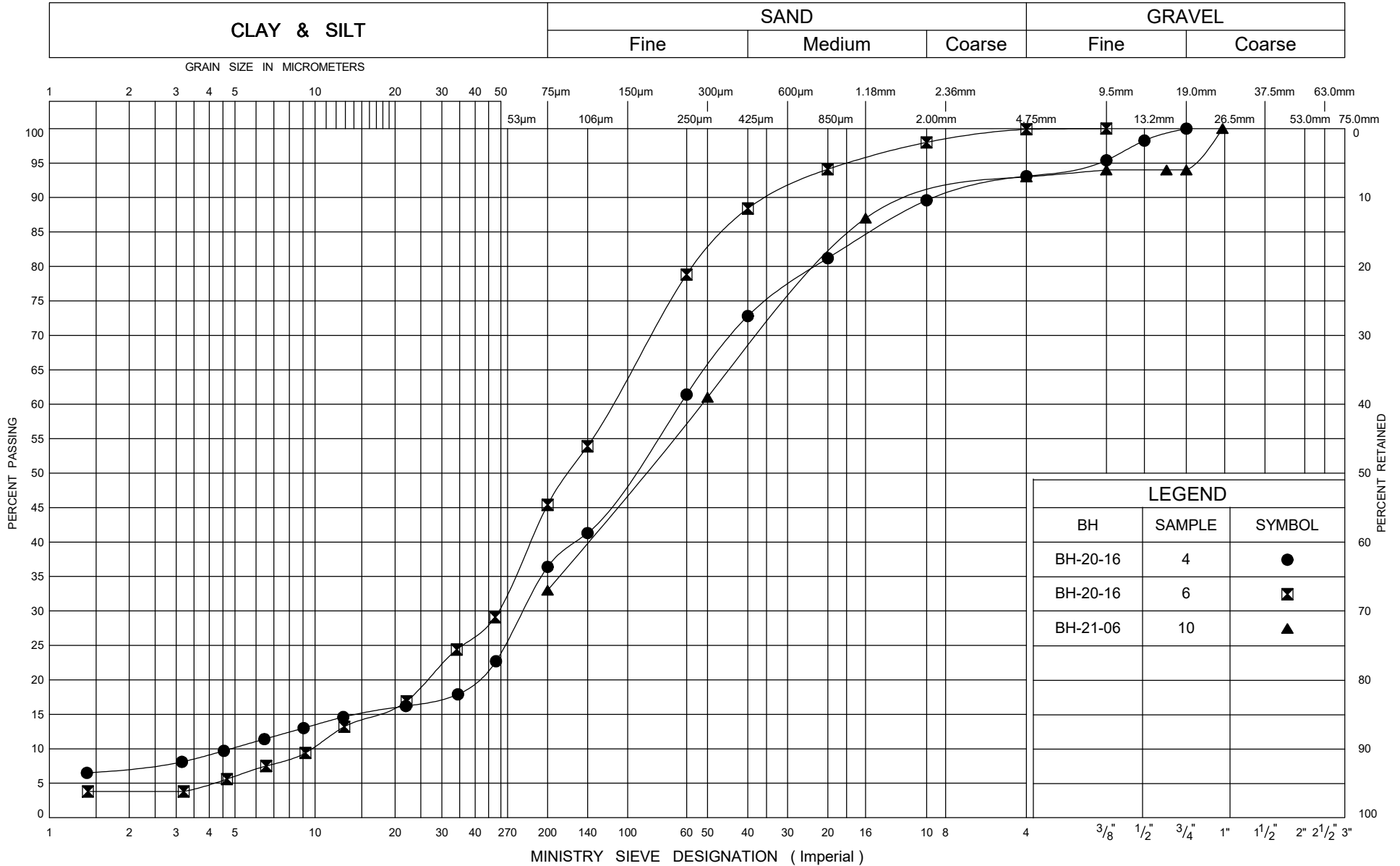
G.W.P. No.:

3021-18-00

GHD Project No.:

11202886

UNIFIED SOIL CLASSIFICATION SYSTEM



Appendix D

Analytical Test Results

C.O.C.: G93264

REPORT No. B20-13601

Report To:

GHD Limited

455 Phillip Street,
Waterloo Ontario N2L 3X2 Canada

Attention: Vincent Zappia

Caduceon Environmental Laboratories

110 West Beaver Creek Rd Unit 14
Richmond Hill ON L4B 1J9

Tel: 289-475-5442

Fax: 289-562-1963

DATE RECEIVED: 20-May-20

JOB/PROJECT NO.: Hwy 3 Widening

DATE REPORTED: 27-May-20

P.O. NUMBER:

SAMPLE MATRIX: Soil

WATERWORKS NO.

			Client I.D.		BH-20-02; SS-6	BH-20-03; SS-6	BH-20-05; SS-6	BH-20-08; SS-5
			Sample I.D.		B20-13601-1	B20-13601-2	B20-13601-3	B20-13601-4
			Date Collected		19-May-20	19-May-20	19-May-20	19-May-20
Parameter	Units	R.L.	Reference Method	Date/Site Analyzed				
pH @25°C	pH Units		MOEE3530	21-May-20/R	7.78	7.80	7.69	7.68
Resistivity	ohms-cm		SM 2510B	26-May-20/O	1870	1240	1410	1880
REDOX potential	mV		In-House	22-May-20/R	161	189	173	172
Chloride	µg/g	5	SM4110C	26-May-20/O	13	129	71	12
Sulphate	µg/g	10	SM4110C	26-May-20/O	510	980	800	510
Sulfide	µg/g	5	In-House	26-May-20	< 5 ¹	< 5 ¹	< 5 ¹	< 5 ¹

¹ Subcontracted to Testmark Labs



Christine Burke
Lab Manager

R.L. = Reporting Limit

Test methods may be modified from specified reference method unless indicated by an *

Site Analyzed=K-Kingston,W-Windsor,O-Ottawa,R-Richmond Hill,B-Barrie

The analytical results reported herein refer to the samples as received. Reproduction of this analytical report in full or in part is prohibited without prior consent from Caduceon Environmental Laboratories.

C.O.C.: G93264

REPORT No. B20-13601

Report To:

GHD Limited

455 Phillip Street,
Waterloo Ontario N2L 3X2 Canada

Attention: Vincent Zappia

Caduceon Environmental Laboratories

110 West Beaver Creek Rd Unit 14
Richmond Hill ON L4B 1J9

Tel: 289-475-5442

Fax: 289-562-1963

DATE RECEIVED: 20-May-20

JOB/PROJECT NO.: Hwy 3 Widening

DATE REPORTED: 27-May-20

P.O. NUMBER:

SAMPLE MATRIX: Soil

WATERWORKS NO.

			Client I.D.		BH-20-10; SS-6	BH-20-11; SS-5	BH-20-13; SS-5A	BH-20-16; SS-5
			Sample I.D.		B20-13601-5	B20-13601-6	B20-13601-7	B20-13601-8
			Date Collected		19-May-20	19-May-20	19-May-20	19-May-20
Parameter	Units	R.L.	Reference Method	Date/Site Analyzed				
pH @25°C	pH Units		MOEE3530	21-May-20/R	7.70	7.75	7.71	7.70
Resistivity	ohms-cm		SM 2510B	26-May-20/O	1730	2060	2880	2420
REDOX potential	mV		In-House	22-May-20/R	163	208	222	167
Chloride	µg/g	5	SM4110C	26-May-20/O	16	230	171	30
Sulphate	µg/g	10	SM4110C	26-May-20/O	580	130	30	280
Sulfide	µg/g	5	In-House	26-May-20	< 5 ¹	< 5 ¹	< 5 ¹	< 5 ¹

¹ Subcontracted to Testmark Labs



Christine Burke
Lab Manager

R.L. = Reporting Limit

Test methods may be modified from specified reference method unless indicated by an *

Site Analyzed=K-Kingston,W-Windsor,O-Ottawa,R-Richmond Hill,B-Barrie

The analytical results reported herein refer to the samples as received. Reproduction of this analytical report in full or in part is prohibited without prior consent from Caduceon Environmental Laboratories.



GHD Limited (Waterloo)
ATTN: JENNIFER BALKWILL
455 PHILLIP STREET
WATERLOO ON N2L 3X2

Date Received: 19-OCT-21
Report Date: 29-OCT-21 14:46 (MT)
Version: FINAL

Client Phone: 519-884-0510

Certificate of Analysis

Lab Work Order #: L2652975
Project P.O. #: 735-001026
Job Reference: 11202886
C of C Numbers:
Legal Site Desc:

Rick Hawthorne
Account Manager

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ADDRESS: 60 Northland Road, Unit 1, Waterloo, ON N2V 2B8 Canada | Phone: +1 519 886 6910 | Fax: +1 519 886 9047
ALS CANADA LTD Part of the ALS Group An ALS Limited Company

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2652975-1 BH21-01-SS4 Sampled By: CLIENT on 18-OCT-21 @ 16:00 Matrix: WATER Physical Tests Conductivity 0.845 % Moisture 18.7 pH 7.48 Redox Potential 263 Resistivity 1180 Leachable Anions & Nutrients Chloride 80.3 Anions and Nutrients Sulphate 729 Inorganic Parameters Acid Volatile Sulphides <0.20							
L2652975-2 BH21-03-SS4 Sampled By: CLIENT on 18-OCT-21 @ 16:00 Matrix: WATER Physical Tests Conductivity 1.17 % Moisture 15.1 pH 7.46 Redox Potential 297 Resistivity 857 Leachable Anions & Nutrients Chloride 263 Anions and Nutrients Sulphate 840 Inorganic Parameters Acid Volatile Sulphides <0.20							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
CL-R511-WT	Soil	Chloride-O.Reg 153/04 (July 2011)	EPA 300.0
5 grams of dried soil is mixed with 10 grams of distilled water for a minimum of 30 minutes. The extract is filtered and analyzed by ion chromatography.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011 and as of November 30, 2020), unless a subset of the Analytical Test Group (ATG) has been requested (the Protocol states that all analytes in an ATG must be reported).			
EC-WT	Soil	Conductivity (EC)	MOEE E3138
A representative subsample is tumbled with de-ionized (DI) water. The ratio of water to soil is 2:1 v/w. After tumbling the sample is then analyzed by a conductivity meter.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).			
MOISTURE-WT	Soil	% Moisture	CCME PHC in Soil - Tier 1 (mod)
PH-WT	Soil	pH	MOEE E3137A
A minimum 10g portion of the sample is extracted with 20mL of 0.01M calcium chloride solution by shaking for at least 30 minutes. The aqueous layer is separated from the soil and then analyzed using a pH meter and electrode.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).			
REDOX-POTENTIAL-WT	Soil	Redox Potential	APHA 2580
This analysis is carried out in accordance with the procedure described in the "APHA" method 2580 "Oxidation-Reduction Potential" 2012. Samples are extracted at a fixed ratio with DI water. Results are reported as observed oxidation-reduction potential of the platinum metal-reference electrode employed, in mV.			
RESISTIVITY-CALC-WT	Soil	Resistivity Calculation	APHA 2510 B
"Soil Resistivity (calculated)" is determined as the inverse of the conductivity of a 2:1 water:soil leachate (dry weight). This method is intended as a rapid approximation for Soil Resistivity. Where high accuracy results are required, direct measurement of Soil Resistivity by the Wenner Four-Electrode Method (ASTM G57) is recommended.			
SO4-WT	Soil	Sulphate	EPA 300.0
5 grams of soil is mixed with 50 mL of distilled water for a minimum of 30 minutes. The extract is filtered and analyzed by ion chromatography.			
SULPHIDE-WT	Soil	Sulphide, Acid Volatile	APHA 4500S2J
This analysis is carried out in accordance with the method described in APHA 4500 S2-J. Hydrochloric acid is added to sediment samples within a purge and trap system. The evolved hydrogen sulphide (H2S) is carried into a basic solution by inert gas. The acid volatile sulfide is then determined colourimetrically.			

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA

Chain of Custody Numbers:

Reference Information

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.

mg/kg - milligrams per kilogram based on dry weight of sample

mg/kg ww - milligrams per kilogram based on wet weight of sample

mg/kg lwt - milligrams per kilogram based on lipid weight of sample

mg/L - unit of concentration based on volume, parts per million.

< - Less than.

D.L. - The reporting limit.

N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.

UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.

Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.



Environmental

Quality Control Report

Workorder: L2652975

Report Date: 29-OCT-21

Page 1 of 3

Client: GHD Limited (Waterloo)
455 PHILLIP STREET
WATERLOO ON N2L 3X2
Contact: JENNIFER BALKWILL

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
CL-R511-WT		Soil						
Batch	R5630777							
WG3645863-3	CRM	AN-CRM-WT						
Chloride			93.3		%		70-130	27-OCT-21
WG3645863-4	DUP	WG3645863-5						
Chloride		80.1	79.5		ug/g	0.7	30	27-OCT-21
WG3645863-2	LCS							
Chloride			99.9		%		80-120	27-OCT-21
WG3645863-1	MB							
Chloride			<5.0		ug/g		5	27-OCT-21
EC-WT		Soil						
Batch	R5632792							
WG3645937-6	DUP	WG3645937-3						
Conductivity		0.400	0.394		mS/cm	1.5	20	29-OCT-21
WG3645937-2	IRM	WT SAR4						
Conductivity			112.1		%		70-130	29-OCT-21
WG3648689-1	LCS							
Conductivity			96.8		%		90-110	29-OCT-21
WG3645937-1	MB							
Conductivity			<0.0040		mS/cm		0.004	29-OCT-21
MOISTURE-WT		Soil						
Batch	R5626550							
WG3642699-3	DUP	L2647897-28						
% Moisture		79.2	82.7		%	4.3	20	22-OCT-21
WG3642699-2	LCS							
% Moisture			99.5		%		90-110	22-OCT-21
WG3642699-1	MB							
% Moisture			<0.25		%		0.25	22-OCT-21
PH-WT		Soil						
Batch	R5628935							
WG3643896-1	DUP	L2653172-6						
pH		8.11	8.09	J	pH units	0.02	0.3	26-OCT-21
WG3646007-1	LCS							
pH			6.95		pH units		6.9-7.1	26-OCT-21
REDOX-POTENTIAL-WT		Soil						
Batch	R5627178							
WG3643513-1	CRM	WT-REDOX						
Redox Potential			99.4		%		80-120	22-OCT-21
WG3641736-1	DUP	L2651880-1						



Environmental

Quality Control Report

Workorder: L2652975

Report Date: 29-OCT-21

Page 2 of 3

Client: GHD Limited (Waterloo)
455 PHILLIP STREET
WATERLOO ON N2L 3X2
Contact: JENNIFER BALKWILL

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
REDOX-POTENTIAL-WT								
Soil								
Batch	R5627178							
WG3641736-1	DUP	L2651880-1						
Redox Potential		277	252		mV	9.5	25	22-OCT-21
SO4-WT								
Soil								
Batch	R5630777							
WG3645863-3	CRM	AN-CRM-WT						
Sulphate			101.3		%		60-140	27-OCT-21
WG3645863-4	DUP	WG3645863-5						
Sulphate		729	683		ug/g	6.5	25	27-OCT-21
WG3645863-2	LCS							
Sulphate			100.1		%		70-130	27-OCT-21
WG3645863-1	MB							
Sulphate			<20		ug/g		20	27-OCT-21
SULPHIDE-WT								
Soil								
Batch	R5629101							
WG3646000-3	DUP	L2653158-1						
Acid Volatile Sulphides		<0.20	<0.20	RPD-NA	mg/kg	N/A	45	26-OCT-21
WG3646000-2	LCS							
Acid Volatile Sulphides			71.9		%		70-130	26-OCT-21
WG3646000-1	MB							
Acid Volatile Sulphides			<0.20		mg/kg		0.2	26-OCT-21

Quality Control Report

Workorder: L2652975

Report Date: 29-OCT-21

Client: GHD Limited (Waterloo)
455 PHILLIP STREET
WATERLOO ON N2L 3X2
Contact: JENNIFER BALKWILL

Page 3 of 3

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.



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Chain of Cust



L2652975-COFC

COC Number: 21 -

Page of

Report To Contact and company name below will appear on the final report		Reports / Recipients		Turnaround Time (TAT) Requested		AFFIX ALS BARCODE LABEL HERE (ALS use only)													
Company:	GHD LIMITED - ACCT# 13791	Select Report Format: <input type="checkbox"/> PDF <input type="checkbox"/> EXCEL <input type="checkbox"/> EDD (DIGITAL)		<input checked="" type="checkbox"/> Routine [R] if received by 3pm M-F - no surcharges apply															
Contact:	Jennifer Balkwill	Merge QC/QCI Reports with COA <input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> N/A		<input type="checkbox"/> 4 day [P4] if received by 3pm M-F - 20% rush surcharge minimum															
Phone:	519 884 0510	<input type="checkbox"/> Compare Results to Criteria on Report - provide details below if box checked		<input type="checkbox"/> 3 day [P3] if received by 3pm M-F - 25% rush surcharge minimum															
Company address below will appear on the final report		Select Distribution: <input type="checkbox"/> EMAIL <input type="checkbox"/> MAIL <input type="checkbox"/> FAX		<input type="checkbox"/> 2 day [P2] if received by 3pm M-F - 50% rush surcharge minimum															
Street:	111 Brunel Road Suite 200	Email 1 or Fax Sandra.McGaghran@ghd.com		<input type="checkbox"/> 1 day [E] if received by 3pm M-F - 100% rush surcharge minimum															
City/Province:	Mississauga/Ontario	Email 2 Nirjar.Vyas@ghd.com		<input type="checkbox"/> Same day [E2] if received by 10am M-S - 200% rush surcharge.															
Postal Code:	L4Z 1X3	Email 3 Puneet.Verma@ghd.com		Additional fees may apply to rush requests on weekends, statutory holidays and for non-routine tests.															
Invoice To	Same as Report To <input type="checkbox"/> YES <input type="checkbox"/> NO	Invoice Recipients		Date and Time Required for all E&P TATs:															
	Copy of Invoice with Report <input type="checkbox"/> YES <input type="checkbox"/> NO	Select Invoice Distribution: <input type="checkbox"/> EMAIL <input type="checkbox"/> MAIL <input type="checkbox"/> FAX		For all tests with rush TATs requested, please contact your AM to confirm availability.															
Company:	GHD LIMITED	Email 1 or Fax		Analysis Request															
Contact:	Jennifer Balkwill	Email 2		Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below															
Project Information		Oil and Gas Required Fields (client use)		NUMBER OF CONTAINERS													SAMPLES ON HOLD	EXTENDED STORAGE REQUIRED	SUSPECTED HAZARD (see notes)
ALS Account # / Quote #:		AFE/Cost Center:																	
Job #:		Major/Minor Code:																	
PO / AFE:		Routing Code:																	
LSD:		Requisitioner:																	
ALS Lab Work Order # (ALS use only):		ALS Contact:		Sampler:															
ALS Sample # (ALS use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type															
	BH21-01-SS4	18-Oct-21	4:00 PM	soil															
	BH21-03-SS4	18-Oct-21	4:00 PM	soil															
Drinking Water (DW) Samples¹ (client use)		Notes / Specify Limits for result evaluation by selecting from drop-down below (Excel COC only)		SAMPLE RECEIPT DETAILS (ALS use only)															
Are samples taken from a Regulated DW System? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		Ontario Regulation 153/04 - April 15, 2011 Standards		Cooling Method: <input type="checkbox"/> NONE <input checked="" type="checkbox"/> ICE <input type="checkbox"/> ICE PACKS <input type="checkbox"/> FROZEN <input type="checkbox"/> COOLING INITIATED															
Are samples for human consumption/ use? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO				Submission Comments identified on Sample Receipt Notification: <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO															
				Cooler Custody Seals Intact: <input type="checkbox"/> YES <input type="checkbox"/> N/A Sample Custody Seals Intact: <input type="checkbox"/> YES <input type="checkbox"/> N/A															
				INITIAL COOLER TEMPERATURES °C: 1.3 FINAL COOLER TEMPERATURES °C: 2.0															
SHIPMENT RELEASE (client use)		INITIAL SHIPMENT RECEPTION (ALS use only)		FINAL SHIPMENT RECEPTION (ALS use only)															
Released by: Satbir Guram	Date: Oct 18, 2021	Time: 6pm	Received by: Karan	Date: 10/18/2021	Time: 8:57	Received by: [Signature]	Date: 10/19/21	Time: 5:01											

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY

YELLOW - CLIENT COPY

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a Regulated Drinking Water (DW) System, please submit using an Authorized DW COC form.

195 (KS)



GHD Limited (Waterloo)
ATTN: JENNIFER BALKWILL
455 PHILLIP STREET
WATERLOO ON N2L 3X2

Date Received: 15-NOV-21
Report Date: 23-NOV-21 11:12 (MT)
Version: FINAL

Client Phone: 519-884-0510

Certificate of Analysis

Lab Work Order #: L2662811
Project P.O. #: 735-001026
Job Reference: 11202886
C of C Numbers:
Legal Site Desc:

Rick Hawthorne
Account Manager

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ADDRESS: 60 Northland Road, Unit 1, Waterloo, ON N2V 2B8 Canada | Phone: +1 519 886 6910 | Fax: +1 519 886 9047
ALS CANADA LTD Part of the ALS Group An ALS Limited Company

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters		Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2662811-1 11202886-BH-21-02, SS5 Sampled By: CLIENT on 10-NOV-21 @ 12:00 Matrix: SOIL								
Physical Tests								
Conductivity		0.484		0.0040	mS/cm		22-NOV-21	R5655044
% Moisture		15.6		0.25	%	16-NOV-21	17-NOV-21	R5650566
pH		7.89		0.10	pH units		18-NOV-21	R5653879
Redox Potential		319		-1000	mV		17-NOV-21	R5652635
Resistivity		2070		1.0	ohm*cm		22-NOV-21	
Leachable Anions & Nutrients								
Chloride		133		5.0	ug/g	19-NOV-21	22-NOV-21	R5655790
Anions and Nutrients								
Sulphate		166		20	ug/g	19-NOV-21	22-NOV-21	R5655790
Inorganic Parameters								
Acid Volatile Sulphides		0.23		0.20	mg/kg	22-NOV-21	22-NOV-21	R5655518
L2662811-2 11202886-BH-21-04, SS5 Sampled By: CLIENT on 11-NOV-21 @ 12:00 Matrix: SOIL								
Physical Tests								
Conductivity		0.626		0.0040	mS/cm		22-NOV-21	R5655044
% Moisture		18.2		0.25	%	16-NOV-21	17-NOV-21	R5650566
pH		7.61		0.10	pH units		18-NOV-21	R5653879
Redox Potential		288		-1000	mV		17-NOV-21	R5652635
Resistivity		1600		1.0	ohm*cm		22-NOV-21	
Leachable Anions & Nutrients								
Chloride		133		5.0	ug/g	19-NOV-21	22-NOV-21	R5655790
Anions and Nutrients								
Sulphate		84		20	ug/g	19-NOV-21	22-NOV-21	R5655790
Inorganic Parameters								
Acid Volatile Sulphides		<0.20		0.20	mg/kg	22-NOV-21	22-NOV-21	R5655518

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
CL-R511-WT	Soil	Chloride-O.Reg 153/04 (July 2011)	EPA 300.0
5 grams of dried soil is mixed with 10 grams of distilled water for a minimum of 30 minutes. The extract is filtered and analyzed by ion chromatography.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011 and as of November 30, 2020), unless a subset of the Analytical Test Group (ATG) has been requested (the Protocol states that all analytes in an ATG must be reported).			
EC-WT	Soil	Conductivity (EC)	MOEE E3138
A representative subsample is tumbled with de-ionized (DI) water. The ratio of water to soil is 2:1 v/w. After tumbling the sample is then analyzed by a conductivity meter.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).			
MOISTURE-WT	Soil	% Moisture	CCME PHC in Soil - Tier 1 (mod)
PH-WT	Soil	pH	MOEE E3137A
A minimum 10g portion of the sample is extracted with 20mL of 0.01M calcium chloride solution by shaking for at least 30 minutes. The aqueous layer is separated from the soil and then analyzed using a pH meter and electrode.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).			
REDOX-POTENTIAL-WT	Soil	Redox Potential	APHA 2580
This analysis is carried out in accordance with the procedure described in the "APHA" method 2580 "Oxidation-Reduction Potential" 2012. Samples are extracted at a fixed ratio with DI water. Results are reported as observed oxidation-reduction potential of the platinum metal-reference electrode employed, in mV.			
RESISTIVITY-CALC-WT	Soil	Resistivity Calculation	APHA 2510 B
"Soil Resistivity (calculated)" is determined as the inverse of the conductivity of a 2:1 water:soil leachate (dry weight). This method is intended as a rapid approximation for Soil Resistivity. Where high accuracy results are required, direct measurement of Soil Resistivity by the Wenner Four-Electrode Method (ASTM G57) is recommended.			
SO4-WT	Soil	Sulphate	EPA 300.0
5 grams of soil is mixed with 50 mL of distilled water for a minimum of 30 minutes. The extract is filtered and analyzed by ion chromatography.			
SULPHIDE-WT	Soil	Sulphide, Acid Volatile	APHA 4500S2J
This analysis is carried out in accordance with the method described in APHA 4500 S2-J. Hydrochloric acid is added to sediment samples within a purge and trap system. The evolved hydrogen sulphide (H2S) is carried into a basic solution by inert gas. The acid volatile sulfide is then determined colourimetrically.			

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA

Chain of Custody Numbers:

Reference Information

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.

mg/kg - milligrams per kilogram based on dry weight of sample

mg/kg ww - milligrams per kilogram based on wet weight of sample

mg/kg lwt - milligrams per kilogram based on lipid weight of sample

mg/L - unit of concentration based on volume, parts per million.

< - Less than.

D.L. - The reporting limit.

N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.

UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.

Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.



Environmental

Quality Control Report

Workorder: L2662811

Report Date: 23-NOV-21

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Client: GHD Limited (Waterloo)
455 PHILLIP STREET
WATERLOO ON N2L 3X2
Contact: JENNIFER BALKWILL

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
CL-R511-WT		Soil						
Batch	R5655790							
WG3661697-7	CRM	AN-CRM-WT						
Chloride			104.4		%		70-130	22-NOV-21
WG3661697-8	DUP	WG3661697-9						
Chloride		6.0	5.8		ug/g	4.4	30	22-NOV-21
WG3661697-6	LCS							
Chloride			101.2		%		80-120	22-NOV-21
WG3661697-5	MB							
Chloride			<5.0		ug/g		5	22-NOV-21
EC-WT		Soil						
Batch	R5655044							
WG3661808-3	DUP	L2662751-4						
Conductivity		0.187	0.186		mS/cm	0.2	20	22-NOV-21
WG3661808-2	IRM	WT SAR4						
Conductivity			112.5		%		70-130	22-NOV-21
WG3662461-1	LCS							
Conductivity			98.3		%		90-110	22-NOV-21
WG3661808-1	MB							
Conductivity			<0.0040		mS/cm		0.004	22-NOV-21
MOISTURE-WT		Soil						
Batch	R5650566							
WG3659023-3	DUP	L2662161-1						
% Moisture		13.3	13.5		%	2.0	20	17-NOV-21
WG3659023-2	LCS							
% Moisture			101.3		%		90-110	17-NOV-21
WG3659023-1	MB							
% Moisture			<0.25		%		0.25	17-NOV-21
PH-WT		Soil						
Batch	R5653879							
WG3658893-1	DUP	L2662156-8						
pH		7.20	7.17	J	pH units	0.03	0.3	18-NOV-21
WG3660796-1	LCS							
pH			6.98		pH units		6.9-7.1	18-NOV-21
REDOX-POTENTIAL-WT		Soil						
Batch	R5652635							
WG3659997-1	CRM	WT-REDOX						
Redox Potential			100.4		%		80-120	17-NOV-21
WG3659748-1	DUP	L2663014-9						



Environmental

Quality Control Report

Workorder: L2662811

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Page 2 of 3

Client: GHD Limited (Waterloo)
455 PHILLIP STREET
WATERLOO ON N2L 3X2
Contact: JENNIFER BALKWILL

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
REDOX-POTENTIAL-WT	Soil							
Batch	R5652635							
WG3659748-1	DUP	L2663014-9						
Redox Potential		272	256		mV	6.1	25	17-NOV-21
SO4-WT	Soil							
Batch	R5655790							
WG3661697-7	CRM	AN-CRM-WT						
Sulphate			110.3		%		60-140	22-NOV-21
WG3661697-8	DUP	WG3661697-9						
Sulphate		<20	<20	RPD-NA	ug/g	N/A	25	22-NOV-21
WG3661697-6	LCS							
Sulphate			100.2		%		70-130	22-NOV-21
WG3661697-5	MB							
Sulphate			<20		ug/g		20	22-NOV-21
SULPHIDE-WT	Soil							
Batch	R5655518							
WG3662900-3	DUP	L2662794-1						
Acid Volatile Sulphides		<0.20	<0.20	RPD-NA	mg/kg	N/A	45	22-NOV-21
WG3662900-2	LCS							
Acid Volatile Sulphides			90.8		%		70-130	22-NOV-21
WG3662900-1	MB							
Acid Volatile Sulphides			<0.20		mg/kg		0.2	22-NOV-21

Quality Control Report

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Contact: JENNIFER BALKWILL

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Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

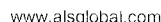
Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.


ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.



12662811-COFC

Report To		Contact and company name below will appear on the final report				L2662811-COFC		Turnaround Time (TAT) Requested		AFFIX ALS BARCODE LABEL HERE (ALS use only)			
Company:		GHD LIMITED - ACCT# 13791		Select Report For		Merge QC/QCI R		Received by 3pm M-F - no surcharges apply					
Contact:		Jennifer Balkwill		Compare Results to Criteria on Report - provide details below if box checked		<input type="checkbox"/> 4 day [P4] if received by 3pm M-F - 20% rush surcharge minimum		<input type="checkbox"/> 3 day [P3] if received by 3pm M-F - 25% rush surcharge minimum					
Phone:		519 884 0510		Select Distribution: <input checked="" type="checkbox"/> EMAIL <input type="checkbox"/> MAIL <input type="checkbox"/> FAX				<input type="checkbox"/> 2 day [P2] if received by 3pm M-F - 50% rush surcharge minimum					
Company address below will appear on the final report				Email 1 or Fax Sandra.McGaghran@ghd.com				<input type="checkbox"/> 1 day [E] if received by 3pm M-F - 100% rush surcharge minimum					
Street:		111 Brunel Road Suite 200		Email 2 Nirjar.Vyas@ghd.com				<input type="checkbox"/> Same day [E2] if received by 10am M-S - 200% rush surcharge.					
City/Province:		Mississauga/Ontario		Email 3 Puneet.Verma@ghd.com				Additional fees may apply to rush requests on weekends, statutory holidays and for non-routine tests.					
Postal Code:		L4Z 1X3						Date and Time Required for all E&P TATs:					
Invoice To		Same as Report To <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		Invoice Recipients				For all tests with rush TATs requested, please contact your AM to confirm availability.					
		Copy of Invoice with Report <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		Select Invoice Distribution: <input type="checkbox"/> EMAIL <input type="checkbox"/> MAIL <input type="checkbox"/> FAX				Analysis Request					
Company:		GHD LIMITED		Email 1 or Fax				Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below					
Contact:		Jennifer Balkwill		Email 2									
Project Information				Oil and Gas Required Fields (client use)				NUMBER OF CONTAINERS Corrosivity package					
ALS Account # / Quote #:				AFE/Cost Center:		PO#							
Job #:				Major/Minor Code:		Routing Code:							
PO / AFE:				Requisitioner:									
LSD:				Location:									
ALS Lab Work Order # (ALS use only): L2662811 JD				ALS Contact:		Sampler:		SAMPLES ON HOLD EXTENDED STORAGE REQUIRED SUSPECTED HAZARD (see notes)					
ALS Sample # (ALS use only)		Sample Identification and/or Coordinates (This description will appear on the report)		Date (dd-mmm-yy)		Time (hh:mm)						Sample Type	
		11202886 - BH-21-02, SS5		10-Nov-21		12:00						soil	
		11202886 - BH-21-04, SS5		11-Nov-21		12:00						soil	
Drinking Water (DW) Samples¹ (client use)				Notes / Specify Limits for result evaluation by selecting from drop-down below (Excel COC only)				SAMPLE RECEIPT DETAILS (ALS use only)					
Are samples taken from a Regulated DW System? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO				Ontario Regulation 153/04 - April 15, 2011 Standards				Cooling Method: <input type="checkbox"/> NONE <input checked="" type="checkbox"/> ICE <input type="checkbox"/> ICE PACKS <input type="checkbox"/> FROZEN <input type="checkbox"/> COOLING INITIATED					
Are samples for human consumption/ use? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO								Submission Comments identified on Sample Receipt Notification: <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO					
								Cooler Custody Seals Intact: <input type="checkbox"/> YES <input checked="" type="checkbox"/> N/A Sample Custody Seals Intact: <input type="checkbox"/> YES <input checked="" type="checkbox"/> N/A					
								INITIAL COOLER TEMPERATURES °C		FINAL COOLER TEMPERATURES °C			
								0.4		4.8			
SHIPMENT RELEASE (client use)				INITIAL SHIPMENT RECEPTION (ALS use only)				FINAL SHIPMENT RECEPTION (ALS use only)					
Released by:		Date:		Time:		Received by:		Date:		Time:			
Sathya Guram		Nov 15, 21		1 pm		H.K		11/15/21		1:30			

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY

YELLOW - CLIENT COPY

AUG 2020 FROM

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

Appendix E

Non-Standard Special Provisions (NSSP), Special Provisions and Notice to Contractor

NOTICE TO CONTRACTOR – Subsurface Obstructions

Special Provision

The Contactor is advised of the potential presence of cobbles or boulders in the fill material and till deposits at the culvert sites that may be encountered during the installation of roadway protection system (shoring) elements. The presence of the above-noted near surface conditions shall be considered by the Contractor in the selection of appropriate equipment and procedures for various activities, including but not limited to excavation, grading, installation of the culvert foundations and installation of cofferdams/protection systems.

EARTH BORROW – Item No.

Non-Standard Special Provision

Amendment to OPSS.PROV 212, November 2013

212.05.01 Earth Borrow

Subsection 212.05.01 of OPSS.PROV 212 is amended by the addition of the following:

Earth borrow shall have a plasticity index less than 15 per cent and a liquid limit less than 35 per cent.

PROTECTION SYSTEM – Item No.

Special Provision

Amendment to OPSS 539, November 2014

593.07.02 Removal of Protection Systems

Subsection 539.07.02 of OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top(s) shall be removed to at least 1.0 m below the finished grade or ground level or ditch bottom.

The method and sequence of removal shall be such that there shall be no damage to the new work, and existing work being protected.

All disturbed areas shall be restored to an equivalent or better condition than existing prior to the commencement of construction.

WORKING SLAB – Item No.

Special Provision

1.0 Scope

This Special Provision covers the requirements for the supply and placement of a concrete working slab under foundations and box culverts where necessary for the culvert extensions at Culvert No. 06X-0421/C0, No. 06X-0423/C0, No. 06X-0426/C0, No. 06X-0427/C0, No. 06X-0429/C0, and No. 06X-0432/C0.

2.0 References

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

Ontario Provincial Standard Specifications, Construction

OPSS 902 Excavating and Backfilling – Structures

3.0 Definitions – Not Used

4.0 Design and Submission Requirements – Not Used

5.0 Materials

Concrete for working slabs shall have a minimum thickness of 100 mm and a minimum of 28 day compressive strength of 20 MPa.

6.0 Equipment – Not Used

7.0 Construction

7.01 Excavation

Excavation for the working slab shall be according to OPSS 902.

7.02 Protection of Founding Soil

Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents.

7.04 Dewatering

Dewatering shall be carried out according to OPSS 902.

8.0 Quality Assurance - Not Used

9.0 Measurement for Payment - Not Used

10.0 Basis of Payment

10.01 Working Slab – Item

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

END OF SECTION

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision No. FOUN0003

Amendment to OPSS 902, November 2010

OPSS 902, November 2010, Construction Specification for Excavating and Backfilling – Structures, is amended as follows:

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517	Dewatering
OPSS 805	Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517. Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517. Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517. Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517. Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a 10 year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, utilities, and structures, at a distance from the groundwater control system that is assessed by the Design Build to be impacted by. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

Clause 902.04.02.03 of OPSS 902 is deleted in its entirety.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

DEWATERING STRUCTURE EXCAVATIONS – Item No.

Non-Standard Special Provision

1.0 Scope

As part of the work under this item, the Contractor shall design, supply, and install cofferdams where necessary to construct the culvert extensions at Culvert Nos. 06X-0421/C0, 06X-0423/C0, 06X-0426/C0, 06X-0427/C0, 06X-0429/C0, and 06X-0432/C0

All work as shown on the Contract Drawings.

2.0 REFERENCES – Not Used

3.0 DEFINITIONS

Stamped means drawings or details that have been reviewed and stamped “Conforms With Contract Documents”. The stamp shall include the date and signature of the Contractor’s Engineer.

Contractor’s Engineer means an Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of cofferdams. The Contractor shall retain the Contractor’s Engineer to ensure conformance with the contract document.

Cofferdam Design Engineer means an Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of bridges. In addition, the Cofferdam Design Engineer shall have had responsible experience in the design of at least 5 other cofferdams. The Contractor shall retain the Cofferdam Design Engineer to ensure conformance with the contract documents and issue certificate(s) of conformance for the design.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

The design of cofferdams shall be in accordance with the Canadian Highway Bridge Design Code CAN/CSA-S6-14.

Submission of Shop Drawings

All shop drawings submissions shall bear the seal and signature of the Cofferdam Design Engineer.

The Contractor shall submit to the Contractor’s Engineer shop drawings for review and stamping.

At least two weeks prior to the commencement of cofferdam construction, the Contractor shall submit to the Contract Administrator, for information purposes only, four (4) sets of stamped drawings and calculations of the cofferdam system.

The Contractor shall, at least three (3) weeks prior to the commencement of the cofferdam installation, submit to the Contractor’s Engineer for review, four (4) sets of drawings and calculations indicating:

- the cofferdam design;
- the location, type and dimensions of each cofferdam to be used;
- a schematic showing the configuration of all cofferdams;
- the thickness of the tremie plug to ensure stability of the design excavation and cofferdam and the pour sequence of the tremie concrete for which the cofferdam was designed to accommodate unbalanced loading from staged placement and variable heights of the tremie concrete.

The Contractor’s Engineer shall review all calculations, construction details, shop drawings and procedures. All submissions shall bear the seal and signature of the Cofferdam Design Engineer and Contractor’s Engineer.

5.0 MATERIALS – Not Used

6.0 EQUIPMENT – Not Used

7.0 CONSTRUCTION

Footing or box culvert construction must be carried out in dry conditions. The excavation shall be kept stable during the work.

8.0 QUALITY ASSURANCE

Certificates of Conformance

The Cofferdam Design Engineer shall inspect the installation of each cofferdam prior to the placing of the tremie concrete in that cofferdam. After the installation of each of the cofferdam has been completed, but before placing the tremie concrete, the Contractor shall submit a Certificate of Conformance for each cofferdam to the Contract Administrator, sealed and signed by the Cofferdam Design Engineer. The Certificates of Conformance shall state that the cofferdam is in place, and has been installed in conformance with the stamped shop drawings and the Contract Drawings.

9.0 MEASUREMENT FOR PAYMENT

Measurement for cofferdams shall be by length in metres of cofferdam installed.

10.0 BASIS OF PAYMENT

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Materials to carry out the work.



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