Foundation Investigation and Design Report

CONSOR Engineers

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Trenchless Culverts:
Highway 403, East Oxford Township and Burford Township
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1.4 km east of West Quarter Townline Road

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Part I: Foundation Investigation Report

Rehabilitation of Highway 403 - Culverts – Trenchless Method

1 Introduction

EXP Services Inc. (EXP) was retained by CONSOR Engineers to provide a detailed geotechnical evaluation for the replacement of 5 culverts via trenchless method as part of the rehabilitation of the H403 project. The foundation investigation services (field and laboratory work) for this project were performed by other entities; the results of which were reviewed and analysed by EXP. Based on reviewed geotechnical data, this report provides an assessment of the geotechnical issues, geotechnical design parameters and geotechnical foundation design recommendations for the proposed structure. Geotechnical related construction recommendations are also provided. The findings, analyses and recommendations are presented in a Geotechnical Design Report created for each structure along the proposed highway.

The scope of this report is specifically limited to the 5 culverts requiring replacement by trenchless method located along the alignment of Highway 403. The General Arrangement drawings (GA) for the culvert structure was provided to EXP by CONSOR Engineers.

2 Structure Description

General arrangement drawings prepared by CONSOR shows the proposed configuration of the trenchless culverts.

A summary of the proposed culverts are as follows:

- Culvert SR3 will be a newly constructed HDPE Pipe Culvert with Beveled End Treatment, approximately 42.12 m in length and 1.05 m in diameter located at Station 15+615 along Hwy 403 under Oxford Road 14. The culvert invert level is proposed to be at an approximate elevation of 287.82 m at the inlet and 287.59 m at the outlet.
- Culvert SR5 will be a newly constructed HDPE Pipe Culvert with Beveled End Treatment, approximately 82.31 m in length and 1.2 m in diameter located at Station 16+750 along Hwy 403 under County Road 55. The culvert invert level is proposed to be at an approximate elevation of 286.87 m at the inlet and 286.79 m at the outlet.
- Culvert SR6 will be a newly constructed 0.61 m HDPE Closed Profile Pipe Culvert/0.60 m Steel Pipe Culvert (Spiral Rib 19 x 19 x 190 with 1.6 mm thick wall) approximately 45.75 m in length located at Station 19+240 along Hwy 403 under Muir Road. The culvert invert level is proposed to be at an approximate elevation of 286.76 m at the inlet and 286.63 m at the outlet.
- Culvert SR7 will be a newly constructed 0.76 m HDPE Closed Profile Pipe Culvert/0.75 m Steel Pipe Culvert (Spiral Rib 19 x 19 x 190 with 1.6 mm thick wall) approximately 46.13 m in length located at Station 19+240 along Hwy 403. The culvert invert level is proposed to be at an approximate elevation of 286.64 m at the inlet and 286.40 m at the outlet.
- Culvert SR8 will be a newly constructed 1.22 m HDPE Closed Profile Pipe Culvert/1.20 m Steel Pipe Culvert (Spiral Rib 19 x19 x 190 with 2.0 mm thick wall) approximately 41.12 m in length located at Station 13+575 along Hwy 403. The culvert invert level is proposed to be at an approximate elevation of 277.152 m at the inlet and 276.845 m at the outlet.

The GA drawings included as a part of this report are used for initial context to address the nature and scope of the investigation and are shown in Appendix B. It is understood that some changes might occur because of normal refinement or the findings of the geotechnical report.

The details of the proposed culverts are also summarized in Table 1 below.

Table 1: Summary of Trenchless Culverts

Culvert ID.	Municipality	Station	Location	Diameter (m) / Height x Span (m)	Material
SR3	East Oxford	15+615	Oxford Road 14	1.05	HDPE
SR5	East Oxford	16+750	Country Road 55	1.20	HDPE
SR6	East Oxford	19+240	Country Road 55	0.60	HDPE/Steel
SR7	East Oxford	19+240	Muir Road North	0.75	HDPE/Steel
SR8	Burford	13+575	West Quarter Townline Road	1.10	HDPE/Steel

The GA drawings included as a part of this report are used for initial context to address the nature and scope of the investigation and are shown in Appendix B. It is understood that some changes might occur because of normal refinement or the findings of the geotechnical report.

3 Site Description and Geological Setting

All proposed culverts are located within the Port Stanley Till, which is a pleistocene deposition typically composed of silt to sandy silt matrix, becoming silt to silty clay near Lake Erie, strongly calcareous, moderate to low clast content decreasing southward. The sites where the culverts are proposed are generally flat and lightly vegetated except for the embankments which are part of the individual road structures (i.e., Oxford Road 14, Country Road 55, Muir Road North and West Quarter Townline Road) where the proposed culverts will be advanced.

4 Field Investigation and Labortory Analyses

During the tender design for the project, two previous reports were issued which contained relevant information to the proposed culverts, as follows:

- Geotechnical Investigation Report, Highway 403, East Oxford Township and Burford Township, Project No. 13211.201, MTO DB Contract No. 2021-3006, AME Materials Engineering, dated August 2022.
- Preliminary Pavement Design Memorandum – Highway 403 from Highway 401 to 1.4km East of West Quarter Townline Road, Agreement No. 3019-E-0007 – Assignment No.3, Golder, dated August 2021.

The information as presented in the Geotechnical Investigation Report (prepared by AME) was based on field investigations executed during a period between June 20 to July 12, 2022. Of interest to this project, twelve (12) boreholes, one (1) taken at each end of the culverts while one (1) was taken at the mid-span of two culverts, all of which are proposed to be replaced by trenchless methods. All boreholes were reported to be advanced below the invert level of the culvert to the minimum required depth (3x tunnel diameter). It was further noted from the report that continuous flight hollow stem augers were used to advance the boreholes. Moreover, Standard Penetration Tests (SPT's) were conducted at frequent intervals of depth while soil samples were recovered using spilt spoon samplers. Observations for groundwater were reported to be made both during drilling and prior to backfilling.

The information as presented in the Preliminary Pavement Design Memorandum (prepared by Golder) was based on field investigations conducted in June 2021. Of interest to this project, four (4) boreholes, all of which were taken (one (1) each per one (1) culvert) from the various road surfaces overlaying the proposed culverts set to be replaced by trenchless methods were drilled.

The details of the boreholes completed by both AME and Golder are outlined in Table 2 below.

Both reports indicated that laboratory tests were conducted on selected soil samples obtained from the field. These tests include Natural moisture content tests, sieve and hydrometer tests, Atterberg Limits tests and Corrosivity tests.

The AME and Golder borehole logs are presented in Appendix D while the laboratory tests are presented in Appendix E in this report.

Table 2: Summary of boreholes

Borehole No.	Northing	Easting	Borehole Elevation (m)	Borehole Depth (m)	Monitoring Well Installed (Yes/No)
BH22-01	4774908.7	528794.8	288.3	5.17	No
BH22-02 (MW)	4774916.8	528840.5	288.8	4.40	Yes
BH22-03	4775115.2	529898.5	287.9	5.17	No
BH22-04 (MW)	4775115.1	529964.8	295.2	12.8	Yes
BH22-05	4775133.9	529984.2	287.9	5.17	No
BH22-06 (MW)	4775667.3	532332.8	287.4	3.65	Yes
BH22-07	4775680.1	532377.7	287.6	3.65	No
BH22-08	4775604.4	532353.2	287.4	3.65	No
BH22-09 (MW)	4775613.6	532398.3	287.6	4.40	Yes
BH22-10	4776073.7	535865.5	277.8	5.17	No
BH22-11	4776076.8	535892.5	284.6	12.65	No
BH22-12 (MW)	4776055.5	535920.3	277.8	5.17	Yes
BH601*	4774901.2	528819.2	295.2	11.13	No
BH602*	4775117.1	529932.7	295.5	11.13	No
BH603*	4775605.8	532378.7	294.4	9.60	No
BH604*	4775672.3	532354.0	294.5	9.60	No

*Northings and Eastings are approximate locations

5 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix D. The "Explanation of Terms Used in Report" preceding the borehole logs in Appendix D forms an integral part of and should be read in conjunction with this report.

A borehole location plan and stratigraphic sections are provided in Appendix C. It should be noted that the stratigraphic boundaries indicated on the borehole log and stratigraphic section are inferred from semi-continuous sampling, observations of drilling progress and results of Standard Penetration Tests. These boundaries typically represent transitions from one soil type to another and should not be interpreted as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

A detailed description of the stratigraphy encountered is discussed further in subsequent sections. It should be noted that the following sections are based on the geotechnical investigation conducted by AME and Golder.

5.1 Culvert SR3

5.1.1 Soil

5.1.1.1 Topsoil

A topsoil layer was encountered at the ground surface in boreholes BH22-01 and BH22-02MW. The thickness of topsoil ranged from approximately 80 mm to 120 mm.

5.1.1.2 Asphalt

An asphalt layer was encountered at the ground surface in borehole BH601. The thickness of the layer was 150 mm.

5.1.1.3 Fill (Non-Cohesive)

A cohesionless fill layer was encountered in boreholes BH22-01, BH22-02MW and BH601. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 3 below.

Table 3: Summary of Non-Cohesive Fill Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-01	288.2	287.5	0.10	0.70	Sandy Silt	11
BH22-02MW	288.7	288.1	0.10	0.60	Sandy Silt	16
BH601	295.03	294.71	0.15	0.32	Sand and Gravel	-
	294.71	294.23	0.47	0.48	Sand	-

Traces of clay, gravel and rootlets were encountered in boreholes BH22-01 and BH22-02MW while traces of silt and gravel were encountered in the sand layer. The color of the material ranged from dark brown to brown.The SPT “N” value within this layer ranged from 11 to 16 blows per 300 mm penetration, corresponding to compact in condition. Moisture content tests conducted from samples from BH22-01 and BH22-02MW revealed values ranging between 8.6% and 11.4%.

5.1.1.4 Fill (Cohesive)

A cohesive fill layer was encountered in borehole BH601. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 4 below.

Table 4: Summary of Cohesive Fill Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT “N” Value Range
	Top	Bottom				
BH601	294.23	289.24	0.95	4.99	Clayey Silt	4-14
	289.24	288.47	5.94	0.77	Clayey Silt and Gravel	25

Sand was encountered in both layers along with traces of gravel in the clayey silt layer and fragments of asphaltic concrete in the clayey silt and gravel layer. The color of the material in general ranged from brown to grey. The SPT “N” value within this layer ranged from 4 to 25 blows per 300 mm penetration, corresponding to firm to very stiff but generally firm to stiff in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 6.9% to 15.9%

Grain Size Distribution:

- 1% gravel;
- 18% to 22% sand;
- 55% to 58% silt;
- 19% to 26%clay;

Atterberg Limits:

- Liquid Limit: 24% to 28%
- Plastic Limit: 13% to 14%
- Plasticity Index: 11% to 14%

5.1.1.5 Clayey Silt Till

A clayey silt till layer was encountered in boreholes BH22-01, BH22-02MW and BH601. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 5 below.

Table 5: Summary of Clayey Silt Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-01	287.50	283.10	0.80	4.40	Clayey Silt	10-25
BH22-02MW	288.10	284.40	0.80	3.70	Clayey Silt	6-21
BH601	288.47	285.05	6.71	3.42	Clayey Silt	17-26

Sand and traces of gravel were encountered in all layers. The color of the material in general was brown to grey with the SPT "N" value within this layer ranged from 6 to 26 blows per 300 mm penetration, corresponding to firm to very stiff but generally stiff to very stiff in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 11.0% to 20.9%

Grain Size Distribution:

- 0% to 7% gravel;
- 1% to 31% sand;
- 34% to 73% silt;
- 15% to 29%clay;

Atterberg Limits:

- Liquid Limit: 16.9% to 23.0%
- Plastic Limit: 11.7% to 14.0%
- Plasticity Index: 5.2% to 9.0%

5.1.1.6 Silt

A silt layer was encountered underlying the clayey silt stratum in borehole BH601. The explored thickness of the layer was 1 m extending from an elevation of 285.05 m. The material was grey in color and wet with a moisture content of 16.8%. The SPT "N" value within this layer was recorded at 10 blows per 300 mm penetration, corresponding to compact condition.

5.1.2 Groundwater Conditions

No groundwater level was encountered in boreholes during or upon completion of drilling.

5.2 Culvert SR5

5.2.1 Soil

5.2.1.1 Topsoil

A topsoil layer was encountered at the ground surface in boreholes BH22-03 and BH22-05. The thickness of topsoil ranged from approximately 120 mm to 200 mm.

5.2.1.2 Asphalt

An asphalt layer was encountered at the ground surface in boreholes BH22-04MW and BH602. The thickness of the layer ranged from 125 mm to 180 mm.

5.2.1.3 Fill (Non-Cohesive)

A cohesionless fill layer was encountered in boreholes BH22-03, BH22-04MW, BH22-05 and BH602. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 6 below.

Table 6: Summary of Non-Cohesive Fill Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-03	287.78	287.10	0.12	0.68	Sandy Silt	7
BH22-04MW	295.08	294.50	0.13	0.58	Granular Fill	23
	288.4	287.6	6.90	0.80	Sandy Silt	14
BH22-05	287.7	287.1	0.20	0.60	Sandy Silt	7
BH602	295.31	295.11	0.18	0.20	Sand and Gravel	-
	295.11	294.74	0.38	0.37	Sand	-

Traces of gravel, clay and rootlets were encountered in the sandy silt layer in boreholes BH22-03 and BH22-05 while traces of gravel were encountered in the sandy silt of BH22-04MW and traces of silt and gravel in the sand layer of borehole BH602. The material was brown in colour. Recorded moisture content from samples ranged between 3.7% to 20.9%. The SPT "N" value within this layer was 7 to 23 blows per 300 mm penetration, corresponding to loose to compact condition.

5.2.1.4 Fill (Cohesive)

A cohesive fill layer was encountered in borehole BH22-04MW and BH602. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 7 below.

Table 7: Summary of Cohesive Fill Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-04MW	294.50	288.4	0.80	6.10	Clayey Silt	3-20
BH602	294.74	288.02	0.75	6.72	Clayey Silt	4-76

Sand along with traces of gravel was observed in both boreholes while organic matter as well as asphaltic concrete was encountered in BH602. The material's color ranged from brown to dark brown though a greenish grey color was observed at a lower depth in borehole BH22-04MW. The SPT "N" value within this layer ranged from 3 to 76 blows per 300 mm penetration, corresponding to soft to hard but generally stiff to very stiff in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 3.2% to 21.7%

Grain Size Distribution:

- 0% to 4%% gravel;
- 25% to 47% sand;
- 31% to 55% silt;
- 17% to 25% clay;

Atterberg Limits:

- Liquid Limit: 22.0% to 26.2%
- Plastic Limit: 13.0% to 20.7%
- Plasticity Index: 5.5% to 9.7%

5.2.1.5 Silty Clay Till

A silty clay till layer was encountered in boreholes BH22-03, BH22-04MW and BH22-05. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 8 below.

Table 8: Summary of Silty Clay Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-03	287.1	282.7	0.80	4.40	Silty Clay	13-23
BH22-04MW	283.0	282.4	12.20	0.60	Silty Clay	30
BH22-05	287.1	282.7	0.80	4.40	Silty Clay	19-37

Sand along with traces of gravel was encountered in all boreholes. The color of the material ranged from brown to grey with the SPT "N" value within this layer ranging from 13 to 37 blows per 300 mm penetration, corresponding to stiff to hard but generally stiff to very stiff in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 7.3% to 21.2%

Grain Size Distribution:

- 1% to 6% gravel;
- 4% to 30% sand;
- 35% to 42% silt;
- 27% to 56% clay;

Atterberg Limits:

- Liquid Limit: 22.8% to 33.0%
- Plastic Limit: 14.0% to 16.8%
- Plasticity Index: 8.8% to 16.6%

5.2.1.6 Clayey Silt Till

A clayey silt till layer was encountered in boreholes BH22-04MW and BH602. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 9 below.

Table 9: Summary of Clayey Silt Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-04MW	287.60	283.00	7.60	4.60	Clayey Silt	12-30
BH602	288.02	284.36	7.47	3.66	Clayey Silt	20-35

Sand and traces of gravel was encountered in both layers. The color of the material ranged from brown to grey with plasticity ranging from moist to dry. The SPT "N" value within this layer ranged from 12 to 35 blows per 300 mm penetration, corresponding to stiff to hard but generally very stiff in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 11.0% to 14.3%

Grain Size Distribution:

- 3% gravel;
- 4% to 31% sand;
- 33% to 51% silt;
- 16% to 56% clay;

Atterberg Limits:

- Liquid Limit: 19.0% to 19.4%
- Plastic Limit: 12.0% to 12.2%
- Plasticity Index: 7.0% to 7.2%

5.2.2 Groundwater Conditions

Groundwater level was encountered in borehole BH22-04MW. A summary of the short-term groundwater level observed in the monitoring well is recorded on the attached borehole logs in Appendix D and is as summarized in Table 10 below.

Table 10: Summary of Groundwater Conditions

Borehole	Ground Surface Elevation (m)	Water Level Depth/Elevation (m)	Date
BH22-04MW	295.2	6.8/288.4	July 06, 2022

5.3 Culvert SR6

5.3.1 Soil

5.3.1.1 Topsoil

A topsoil layer was encountered at the ground surface in boreholes BH22-06 and BH22-07. The thickness of the topsoil ranged from approximately 190 mm to 200 mm.

5.3.1.2 Fill (Non-Cohesive)

A cohesionless fill layer was encountered in boreholes BH22-06MW, BH22-07 and BH604. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 11 below.

Table 11: Summary of Non-Cohesive Fill Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-06MW	287.2	286.7	0.20	0.50	Sandy Silt	16
BH22-07	287.4	286.9	0.20	0.50	Sandy Silt	12
BH604	294.34	294.13	0.13	0.21	Sand and Gravel	-
	294.13	293.27	0.34	0.86	Sand	-

Some clay and traces of gravel and rootlets were encountered in the sandy silt fill layer in boreholes BH22-06MW and BH22-07 while traces of silt and gravel were found in the sand fill layer of BH604. The color of the material was brown with the SPT "N" value within this layer ranging from 12 to 16 blows per 300 mm penetration, corresponding to compact condition. Moisture content results based on samples taken from BH22-06MW and BH22-07 showed values ranging between 10.1% to 10.3%.

5.3.1.3 Fill (Cohesive)

A clayey silt fill layer with some sand and traces to gravel was encountered underlying the cohesionless fill layers in borehole BH604. The material was brown in color with plasticity ranging from moist to dry. The SPT "N" value within this layer ranged from 4 to 14 blows per 300 mm penetration, corresponding to firm to stiff but generally firm in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 11.9% to 18.8%

Grain Size Distribution:

- 7% gravel;
- 20% sand;
- 53% silt;
- 20% clay;

Atterberg Limits:

- Liquid Limit: 26%
- Plastic Limit: 15%
- Plasticity Index: 11%

5.3.1.4 Clayey Silt Till

A clayey silt till layer was encountered in boreholes BH22-06MW, BH22-07 and BH604. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 12 below.

Table 12: Summary of Clayey Silt Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-06MW	286.70	285.90	0.80	0.80	Clayey Silt	37
BH22-07	286.90	286.10	0.80	0.80	Clayey Silt	43
BH604	286.24	284.87	8.23	1.37	Clayey Silt	28

Some sand and traces of gravel were encounetered in the clayey silt layers in all boreholes. The color of the material ranged from brown to grey with the SPT "N" value within this layer rangeing from 28 to 43 blows per 300 mm penetration, corresponding to very stiff to hard in consistency.

Available laboratory testing of samples from the layer comprised of moisture content tests. The results of the tests are as follows:

Moisture Content:

- 11% to 12.3%.

Grain Size Distribution:

- 1% gravel;
- 10% sand;
- 55% silt;
- 34% clay;

Atterberg Limits:

- Liquid Limit: 30.0%
- Plastic Limit: 15.0%
- Plasticity Index: 15.0%

5.3.1.5 Silty Clay Till

A silty clay till layer with some sand and traces of gravel was encountered in boreholes BH22-06MW and BH22-07. The material was grey in colour with the SPT "N" value within this layer ranged from 19 to 32 blows per 300 mm penetration, corresponding to very stiff to hard but generally very stiff in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 12.2% to 14.9%

Grain Size Distribution:

- 1% to 4% gravel;
- 9% to 11% sand;
- 39% to 41% silt;
- 45% to 51% clay;

Atterberg Limits:

- Liquid Limit: 28.3% to 28.5%
- Plastic Limit: 15.1% to 15.2%
- Plasticity Index: 13.1% to 13.4%

5.3.2 Groundwater Conditions

Groundwater level was encountered in borehole BH604. A summary of the short-term groundwater level observed in the monitoring well is recorded on the attached borehole logs in Appendix D and is as summarized in Table 13 below.

Table 13: Summary of Groundwater Conditions

Borehole	Ground Surface Elevation (m)	Water Level Depth/Elevation (m)	Date
BH604	294.47	8.53/285.94	June 16, 2022

5.4 Culvert SR7

5.4.1 Soil

5.4.1.1 Topsoil

A topsoil layer was encountered at the ground surface in boreholes BH22-08 and BH22-09MW. The thickness of the topsoil ranged from approximately 75 mm to 150 mm.

5.4.1.2 Asphalt

An asphalt layer was encountered at the ground surface in borehole BH603. The thickness of the layer was 120 mm.

5.4.1.3 Fill (Non-Cohesive)

A cohesionless fill layer was encountered in borehole BH603. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the borehole is summarized in Table 14 below.

Table 14: Summary of Non-Cohesive Fill Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH603	294.28	294.02	0.12	0.26	Sand and Gravel	-
	294.02	293.39	0.38	0.63	Sand	-

Traces of silt and gravel were encountered in the sand fill layer. The material in both layers was brown in color.

5.4.1.4 Fill (Cohesive)

A cohesive fill layer was encountered in boreholes BH22-08, BH22-09MW and BH603. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the borehole is summarized in Table 15 below.

Table 15: Summary of Cohesive Fill Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-08	287.25	286.80	0.15	0.45	Clayey Silt	9
BH22-09MW	287.53	287.00	0.08	0.53	Clayey Silt	12
BH603	293.39	287.69	1.01	5.70	Clayey Silt	7-14

Some sand and traces to gravel, rootlets and some organics was encountered within the layers. The color of the material ranged from dark brown to brown with the SPT "N" value within this layer ranging from 9 to 14 blows per 300 mm penetration, corresponding to stiff in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 10.9% to 16.9%

Grain Size Distribution:

- 3% gravel;
- 25% sand;
- 50% silt;
- 22% clay;

Atterberg Limits:

- Liquid Limit: 28.0%
- Plastic Limit: 15.0%
- Plasticity Index: 13.0%

5.4.1.5 Silty Clay Till

A silty clay till layer was encountered in boreholes BH22-08 and BH22-09MW. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the borehole is summarized in Table 16 below.

Table 16: Summary of Silty Clay Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-08	286.80	283.80	0.60	3.00	Silty Clay	30-39
BH22-09MW	287.00	283.20	0.60	3.80	Silty Clay	25-39

Some sand and traces of gravel was encountered in the layers. The color of the material was brown with the SPT "N" value within this layer ranging from 25 to 39 blows per 300 mm penetration, corresponding to very stiff to hard but generally hard in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 10.8% to 13.4%

Grain Size Distribution:

- 1% to 3% gravel;
- 12% to 21% sand;
- 35% to 41% silt;
- 41% to 49% clay;

Atterberg Limits:

- Liquid Limit: 28.7% to 30.4%
- Plastic Limit: 13.3% to 16.0%
- Plasticity Index: 14.4% to 15.4%

5.4.1.6 Clayey Silt Till

A clayey silt till layer with some sand and traces of gravel was encountered in boreholes BH603. The material was brown in colour and dry. The SPT "N" value within this layer ranged from 25 to 54 blows per 300 mm penetration, corresponding to very stiff to hard in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 11.0% to 14.9%

Grain Size Distribution:

- 1% gravel;
- 18% sand;
- 56% silt;
- 25% clay;

Atterberg Limits:

- Liquid Limit: 30.0%
- Plastic Limit: 15.0%
- Plasticity Index: 15.0%

5.4.2 Groundwater Conditions

No groundwater level was encountered in boreholes during or upon completion of drilling.

5.5 Culvert SR8

5.5.1 Soil

5.5.1.1 Topsoil

A topsoil layer was encountered at the ground surface in boreholes BH22-10 and BH22-12MW. The thickness of the topsoil ranged from approximately 100 mm to 200 mm.

5.5.1.2 Asphalt

An asphalt layer was encountered at the ground surface in borehole BH22-11. The thickness of the layer was approximately 75 mm.

5.5.1.3 Granular Fill

A granular fill layer was encountered underlying the asphalt in borehole BH22-11. The thickness of the layer was 685 mm. The SPT "N" value within this layer was 17 blows per 300 mm penetration, corresponding to compact condition.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 4.7%

5.5.1.4 Fill (Non-Cohesive)

A non-cohesive fill layer layer was encountered in boreholes BH22-08 and BH22-09MW. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the borehole is summarized in Table 17 below.

Table 17: Summary of Non-Cohesive Fill Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-10	277.60	277.10	0.20	0.50	Sandy Silt	6
BH22-11	284.53	283.90	0.08	0.63	Granular Fill	17
	283.90	281.60	0.80	2.30	Silty Sand	29-31
	278.50	277.30	6.10	1.20	Silty Sand	8-14
BH22-012MW	277.70	277.10	0.10	0.60	Sandy Silt	13

Some clay and traces to gravel and rootlets was encountered in the layers. The material was brown in color with the SPT "N" value within this layer ranged from 6 to 31 blows per 300 mm penetration, corresponding to loose to dense but generally loose to compact condition.

Available laboratory testing of samples from the layer comprised of moisture content and grain size distribution tests. The results of the tests are as follows:

Moisture Content:

- 4.9% to 28.9%

Grain Size Distribution:

- 0% gravel;
- 48% sand;
- 40% silt;
- 12% clay;

5.5.1.5 Fill (Cohesive)

A sandy clayey silt fill layer with traces of gravel was encountered in borehole BH22-11. The material was brown in color and moist. The thickness of the layer was 3.0 m extending from an elevation of 281.6 m. The SPT "N" value within this layer ranged from 10 to 17 blows per 300 mm penetration, corresponding to stiff to very stiff in consistency.

Available laboratory testing of samples from the layer comprised of moisture content tests. The results of the tests are as follows:

Moisture Content:

- 9.2% to 14.0%

Grain Size Distribution:

- 6% gravel;
- 31% sand;
- 30% silt;
- 33% clay;

Atterberg Limits:

- Liquid Limit: 23.0%
- Plastic Limit: 13.3%
- Plasticity Index: 9.7%

5.5.1.6 Silty Clay Till

A silty clay till layer was encountered in boreholes BH22-10, BH22-11 and BH22-12MW. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in the borehole is summarized in Table 18 below.

Table 18: Summary of Silty Clay Layers

Borehole	Elevations (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH22-10	273.30	272.70	4.60	0.60	Silty Clay	30
BH22-11	277.30	272.0	7.30	5.30	Silty Clay	14-46
BH22-12MW	277.10	272.70	0.80	4.40	Silty Clay	10-30

Traces of sand and gravel was encountered in the layers. The material was grey in colour and moist. The SPT "N" value within this layer ranged from 10 to 46 blows per 300 mm penetration, corresponding to stiff to hard but generally very stiff to hard in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 10.2% to 18.3%

Grain Size Distribution:

- 0% to 4% gravel;

- 3% to 27% sand;
- 31% to 38% silt;
- 31% to 66% clay;

Atterberg Limits:

- Liquid Limit: 19.0% to 34.5%
- Plastic Limit: 11.7% to 17.1%
- Plasticity Index: 7.3% to 17.4%

5.5.1.7 Clayey Silt Till

A clayey silt till layer with some sand and traces of gravel was encountered in borehole BH22-10. The material was grey in colour and moist. The SPT "N" value within this layer ranged from 13 to 26 blows per 300 mm penetration, corresponding to stiff to very stiff but generally very stiff in consistency.

Available laboratory testing results reviewed consisted of moisture content, grain size distributions and Atterberg limits tests. The test results are as follows:

Moisture Content:

- 9.7% to 14.0%

Grain Size Distribution:

- 7% gravel;
- 20% sand;
- 38% silt;
- 35% clay;

Atterberg Limits:

- Liquid Limit: 23.4%
- Plastic Limit: 13.7%
- Plasticity Index: 9.7%

5.5.2 Groundwater Conditions

No groundwater level was encountered in boreholes during or upon completion of drilling.

Part II: Foundation Design Report

Discussion and Engineering Recommendations for Culverts – Trenchless Methods

6 Discussion and Recommendations

6.1 Installation of Culverts SR3

6.1.1 General

Trenchless (Tunneling) Method is preferred by CONSOR for the installation of culvert SR3. Based on the GA drawings, Culvert SR3 will be a newly constructed HDPE Pipe Culvert with Beveled End Treatment, approximately 42.12 m in length and 1.05 m in diameter located at Station 15+615 along Hwy 403 under Oxford Road 14. The culvert invert level is proposed to be at an approximate elevation of 287.82 m at the inlet and 287.59 m at the outlet. A summary of the proposed culvert specification for SR3 is presented in Table 2.1 below.

Table 2.1 Summary of Culvert SR3 Specifications

Culvert ID.	Station	Invert Elevation		Approximate Length (m)	Diameter (m) / Height x Span (m)	Material
		Inlet	Outlet			
SR3	15+615	287.82	287.59	42.1	1.05	HDPE

For trenchless installation methods, the procedures should conform to all relevant Ontario Provincial Standard Specifications (OPSS), Non-Standard Special Provisions (NSSP) such as Pipe Installation by Trenchless Method (Appendix F), and CMO-Guidelines for Tunneling????.

Considering the requirements noted in the above documents, drilled boreholes in the vicinity of the proposed culvert SR3 (BH22-01, BH22-02MW and BH601) meet the requirements for the trenchless installation (i.e. the boreholes shall be located outside but within 2 m of the tunnel's excavated footprint; spacing between the boreholes shall not exceed 50 m; and boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert). Boreholes BH22-01 and BH22-02 were drilled outside the road at the vicinity of the proposed exit and entry shafts respectively, while Borehole BH601 was drilled between these two boreholes from the surface of oxford road 14 (ground surface Elev. 295.18 m). The location of these boreholes along the proposed culvert are shown in the drawings provided in Appendix C. The drawing also shows the soil profile along the culvert alignment. Based on this drawing, it is anticipated that the subsurface at the location of the proposed culvert (tunnel) generally consists of compact sand and gravel fills, compact sandy silt fill, firm to very stiff clayey silt fills, very stiff to hard native clayey silts and stiff silts. No groundwater levels were observed in any boreholes during exploration. A summary of the drilled borehole locations for culvert SR3 is presented in Table 2.2 below.

Table 2.2: Summary of SR3 Borehole Locations

Borehole No.	Borehole Elevation (m)	Borehole Depth/Elevation (m)	Borehole Location
BH22-01	288.3	5.17/283.1	Outlet
BH22-02 (MW)	288.8	4.40/284.4	Inlet
BH601	295.2	11.13/284.1	Mid-section

The attached drawing also shows the proposed locations of the entry and exit shafts, suggesting that the tunneling portion of the new culvert will be approximately 41.0 m long. The subsurface at the location of the entry shaft consists of a compact sandy silt fill underlaying the topsoil which is further underlaid by a firm to very stiff clayey silt till layer. At the exit shaft, the subsurface consist of a compact sandy silt fill underlaying the topsoil which is further underlaid by a stiff to very stiff clayey silt till layer.

The fill soils are generally considered to be "firm" as classified in Terzaghi's Tunnelman's Ground Classification. At this site, it is expected that the groundwater level is well below the pipe invert (since no groundwater was observed in boreholes during and after drilling) at both the inlet and outlet. However, the fill material behavior should be anticipated to vary. The native soil at the site consisted of firm to very stiff clayey silt till and loose silt and are classified as "firm" soil. The possibility of encountering potential cobbles and boulders in the till layers should be anticipated. It is the contractor's responsibility to select means and method appropriate for the soil and groundwater conditions. Detailed discussions on trenchless installation options are provided below.

6.1.2 Culvert Installation Options

Based on the site conditions and characteristics of methods available, the following options for the culvert construction at the proposed new alignment are discussed in the following sections:

- Jack and bore technique;
- Pipe ramming;
- Micro-tunneling; and
- Horizontal Directional Drilling (HDD) Technique.

The following table summarizes some of the possible alternatives for the culvert installation using trenchless technology and the following sections provide a discussion for some of the options for the proposed trenchless culvert installation.

Table 2.3A: Installation methods comparison

Installation Method	Advantages	Disadvantages
Jack and Bore	• Handles wide variety of ground conditions • Minimal surface disruption • Very accurate (slope of 0.2% easily achieved) • Relatively simple operation • Common use in Ontario • Short mobilization time • Suitable for tunnels up to 1.5 m in diameter and 150 m long	• Requires large area for jacking shaft and support equipment • Relatively high construction costs • Obstructions problematic • Short- and long-term settlement • Fluid to support annular space • Pipe can be difficult to steer/direct • Dewatering required along route, if the GWL is high
Pipe Ramming	• Not very sensitive to ground condition • Suitable for steel pipes up to 1.8 m in diameter and best up to 50 m long • Accommodates obstructions well • Little surface settlement • Soil removed after pipe in place	• Pipe can be difficult to steer/direct • Large entry pit size • Possible ground heave • Excavation and shoring required to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment

Installation Method	Advantages	Disadvantages
		• Vibrations could potentially impact the stability of the existing slope and neighbouring structures • Slower than other trenchless methods • More expensive than cut and cover methods and jack and bore method
Microtunneling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Suitable for tunneling under groundwater table • Alignment can be adjusted to avoid obstructions • Suitable for tunnels with 250 – 3000 mm in diameter and up to 300 m in length with Intermediate Jacking Stations (IJS) every 75 m • Local skilled contractor is available in the area	• High construction costs • Requires large area for jacking shaft and support equipment. • Short- and long-term settlement • Require sophisticated equipment
Directional Drilling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Does not require staging pits • Alignment can be adjusted to avoid obstructions • Local contractors are available in the area • Short mobilization time • Rapid drilling • Minor settlement if fluid well controlled • Less expensive than microtunneling	• Potential for inadvertent drilling returns • Requires drilling fluid to maintain the bore which could allow subsidence • Annular space filling (i.e., fluid or grouting) • Suitable for installation of pipes up to 1.0 m in diameter and up to 475 m in length

Table 2.3B: General comparison of technical issues associated with trenchless methods

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
Typical limitations: Length of drive & Diameter	• Drive lengths to 150m • Diameters up to 1.5m are feasible	• Generally best suited to short watercourse crossings where risks imposed by ground surface heave are low • 30 to 60m drives are typical	• Drive lengths of 300m are typical, provided that Intermediate Jacking Stations (IJS) are launched every 75m • Micro tunnels up to 1500mm dia. can be readily constructed in Ontario; 3000mm	• Drive pullback lengths of several hundred meters are feasible • In Southern Ontario, HDD diameters less than 750mm are fairly commonplace but larger bores add risk,

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
		• Diameters of 1800mm are technically feasible with a large hammer, however, the stability / integrity of the soil plug in the lead pipe segment is less certain with larger diameters	dia. may be feasible by specialists	complexity and considerable cost
Ability to control line & grade	• Average control of line and grade • Limited ability to steer and to correct grade	• Relatively Poor	• Good • Line and grade control to within ±40mm is feasible over 300m drive	• Specialized tracker system is needed to control line and grade • Fair to Good
Ability to control ground surface displacement	• Poor • No ability to retain running ground	• Poor • Risk of ground heave is moderate to high • If soil plug in lead pipe segment washes out or is breached, then excessive ground loss and settlement will occur	• Good • Slurry shield MTBM can balance earth pressures in the shield to a variety of ground and groundwater conditions • Full and immediate ground support by means of jacking pipe	• Fair • Ground heave and hydro fracturing may result from excessive rates of pullback • Bore stability relies on good quality control and circulation of drilling mud
Ability to deal with Mixed face ground Conditions	• Mixed face conditions will likely cause line and grade deviations to occur • Overmining may result when augering is labored due to hard ground • Augers may jam on rock slabs	• Mixed face conditions will likely deviate the line and grade	• Good • High pressure water jets are necessary to breakdown cohesive clays	• Mixed ground may interfere with line and grade control
Ability to deal with Flowing / unstable face Conditions	• No ability to deal with flowing / unstable face conditions • Flowing soils may result in total collapse / excessive ground loss • Method is unsuitable in cohesionless soils below the water table	• The ability to retain flowing ground depends entirely on maintaining a soil plug in the lead pipe segment. If the plug breaches, then the bore may fail	• Slurry shield MTBMs are better suited to flowing ground conditions than any other trenchless method	• Bore wall stability can be maintained with suitably viscous drilling fluid and filter cake buildup on bore wall • Risk of pipe jamming during pullback if stones / cobbles become dislodged from crown of bore
Ability to deal with Cobbles & boulders and other obstructions	• For bores >900mm, auger removal and personnel entry are needed to break up	• Typically better than Jack & Bore • May require removal of soil plug	• Combination of disk and pick cutters is needed	• Cobbles and rock slabs may jam pipe in bore during pullback

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
	boulders, however the tunnel face must be cohesive for this to be safely conducted	to remove / breakup boulder which could possibly compromise tunnel stability	• Person entry not practical • Wood troublesome	• Boulders will result in a failed bore
Option feasibility for this site	• Feasible	• Feasible	• Feasible	• Might not be feasible; too big pipe diameter

6.1.2.1 Jack and Bore

The jack and bore method involve drilling a borehole from a jacking pit (entry pit) with a rotary cutter head within the confines of a steel casing or liner jacked ahead for support. The casing is pushed through the soil with a hydraulic ram, and soil is removed with an auger. A cutting head is fixed to the leading edge of the culvert. The auger transports spoils from the cutting head back to the jacking pit. The procedures must conform to all relevant OPSS standards and industrial standards.

Based on the information from the boreholes drilled in the vicinity of new culvert, it is expected that the tunnel boring will be carried out in mostly stiff clayey silt and compact sandy silt fills and the groundwater level will be below the culvert invert. Considering these conditions as well as the proposed culvert diameter of 1.05 m, pipe jacking using mechanical means is feasible for the proposed installation.

To reduce loss of ground and groundwater ingress (if any), consideration may be given to jacking the casing across the alignment as far as possible, prior to auguring. Lubricant selected based on the characteristics of the surrounding soil, may be provided to reduce the friction between the casing and the borehole walls. However, obstacles such as deleterious debris, e.g., wood, which should be anticipated in the fill could make this difficult or impractical. EXP recommends the lead auger be kept at least one casing diameter behind the lead end of the casing to minimize the potential for ground losses. Furthermore, any significant voids between the casing and the surrounding soil should be filled with pressurized cementitious grout to prevent / minimize ground loss. In addition, the installation of the proposed culvert must not interfere with existing utilities. Therefore, driving of the pipe must be fairly accurate noting that there is only limited steering ability, where minor adjustments can be made should it be necessary or to address obstructions. Generally, utility tunneling using pipe jacking method is a relatively slow and labor-intensive process. The actual tunnel advance rate is a function of soil conditions encountered, method of soil excavation, spoil removal, pipe liners materials, and field conditions.

To minimize possible negative impact on the stability of the existing embankment slope due to excavations required for the bore/jacking pits and installation of the pipe using the pipe jack and auger bore method, a protection system might be required for the existing roadway. Excavation shoring for the pits will be addressed in the following sections of this report.

6.1.2.2 Pipe Ramming

The pipe ramming is a trenchless method for installation of steel pipes over distances typically up to 50 m long and up to 1.8 m in diameter. The method uses pneumatic percussive blows to drive the pipe into ground. Spoil removal from the pipe can be done by auger. It typically requires excavation of two pits, but the ramming can be launched without an insertion pit if the ram is designed to start at the side of a slope. It should be noted that installation is very noisy and difficult to steer, and its vibration could destabilize the embankment slope with potential impact on adjacent existing structures.

Considering the length of the proposed culvert, the pipe ramming method is a potential option for the installation of culvert SR3. However, the potential for vibration induced issues and steerability impacts it priority in ranking.

6.1.2.3 Microtunneling

Microtunneling should be feasible to install the proposed culvert. Microtunneling method is a non-entry, remotely controlled, guided 2-stage process, which provides continuous support to the excavation face. In this method a Micro Tunneling Boring Machine (MTBM) is used for soil cutting, while a pipe is jacked into place behind the cutting head with hydraulics. The MTBM is equipped with a slurry spoil removal system to control the groundwater inflow and counterbalance the earth and hydrostatic pressure while tunneling through the mixed face conditions. The cutting tool and the drilling fluid must be able to handle the different materials and the “mixed face” condition. To minimize the resistance along the pipe exterior, a bentonite grout lubricant can be injected behind the cutting face. Steel, concrete, or fibreglass pipes can be installed with this method.

The major advantage of microtunneling method is that its performance is not affected by high groundwater levels, so the dewatering is not required; which is not a case for this project. Major disadvantage of microtunneling for this project is the relatively high cost. This option may become more attractive if potential bidders have available equipment in house.

Considering the length of the proposed culvert, no Intermediate Jacking Stations (IJS) will be required. For excavation of the launching pit, a protection system might be required to minimize possible negative impact on the stability of the existing embankment slope. Based on the length and size of the culvert, microtunneling is an acceptable alternative for the installation of culvert SR3.

6.1.2.4 Horizontal Directional Drilling (HDD)

Horizontal Directional Drill installation should follow the requirements of OPSS.PROV 450. If there is enough space to achieve entry and exit angles as recommended in ASTM F1962-11 (12° to 15° for bore entry and 10° for bore exit), horizontal directional drilling (HDD) should be considered for the culvert installation, provided the drill hole is at all times supported with a properly designed drilling fluid. Given that the proposed culvert installation will be within the slope of the embankment, installation via HDD may require significant build up at the entry and exit points to allow for construction to follow best practices. HDD is also typically a more expensive option. Based on the required set-up work and the the size of the proposed culvert diameter (D~1.05 m) this method is an unacceptable alternative for the installation of culvert SR3.

6.1.2.5 Discussion of Drilling Methods

The jack and bore or pipe ramming method for installation is suitable at this site since the culvert is shorter than 50 m. The HDD method is not recommended due to the culvert size and required set-up.

The microtunneling method is a feasible method and local, experienced contractors have successfully installed pipes using this method. If a qualified and experienced contractor is used for construction, the required alignment/slope can be achieved with minimal risk for short- and long-term settlements. However, the initial installation cost is anticipated to be higher than the alternatives.

Although difficulty in directing the drill head should be anticipated, the jack and bore method of installation is considered the preferred option from a feasibility and cost perspective. A summary of the recommendation based on the various methods is presented in Table 2 below.

Table 2.4: Summary of Recommendations

Installation Method	Recommendation
Jack and Bore	Preferred
Pipe Ramming	Acceptable
Microtunneling	Acceptable
Directional Drilling	Not Recommended

6.1.3 Entry and Exit Shafts

6.1.3.1 Excavation of Shafts

All excavations for entry (launching) and exit (receiving) shafts must be completed in accordance with the most recent regulations of the Ontario Occupation Health and Safety Act (OHSA). The encountered fill and native soils may generally be classified as Type 2 and Type 3 soils above the groundwater level and Type 4 soils below the groundwater level in conformance with the OHSA.

Temporary excavation side slopes in Type 2 and Type 3 soils should remain stable at a slope of 1H:1V. Excavation side slopes in Type 4 soils should remain stable at a slope of 3H:1V. The need to excavate flatter side slopes if excessively wet or soft/loose materials, or concentrated seepage zones are encountered, should not be overlooked. Water (i.e., surface water runoff) should not be permitted to enter and/or pond within the construction area.

To limit the extents of the excavation and protect the existing embankment, temporary shoring may be required for this project. Note that in accordance with the OHSA pre-engineered excavation support methods are not suitable for use in Type 4 soils and a temporary support method must be designed by a professional engineer.

Excavations for the proposed culvert construction is expected to extend to depths greater than 1.5 m below existing grades at the inlet and outlet. As such, the construction excavation bases are expected to consist of native clayey silt material and sandy silt fills. Basal instability is not anticipated in excavations since the groundwater level is significantly below the base of excavation.

6.1.3.2 Backfilling of Shafts

It is anticipated that backfilling work will be required at the entry and exit shafts to return site condition to pre-construction grades. The following comments and recommendations are provided for backfilling such excavations.

All excavations should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted to at least 95% of the Standard Proctor Maximum Dry Density (SPMDD). Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials.

All backfill and compaction operations should be monitored by qualified geotechnical personnel to approve materials, to evaluate placement operations, and to verify that the specified degree of compaction is being achieved throughout the fill.

6.1.4 Dewatering

Surface water should be always directed away from the excavation area(s). Based on an assessment of the water levels observed in the adjacent borings/piezometers, groundwater at the site is interpreted to be non-existent. The soils encountered within potential excavation depths will consist of sandy silt fills and native clayey silts. These materials (particularly the deposits with high silt content) are susceptible to disturbance from groundwater and mobilized equipment. As such, the groundwater level needs to be controlled below the excavation level to avoid disturbance. Given the conditions at this site, it is anticipated that control of seepage can be accomplished by conventional pumping from sumps in oversize excavations. This dewatering can likely be achieved by gravity drainage and pumping from strategically placed sumps with side ditches. Confirmation of control should be verified before general excavation to final levels.

At this site, it is not expected to require registry on EASR or need to obtain PTTW. However, it is noted that dewatering operations more than 50,000 L/day will require a Permit to Take Water (PTTW); EXP can be contacted to provide additional hydrogeological services, if required.

All collected water should be discharged a sufficient distance away from the excavated area to prevent the water from re-entering the excavation. Sediment control measures such as silt fences should be provided at the discharge point of the dewatering system. Caution should also be taken to avoid any adverse impact to the environment.

Dewatering shall be carried out in accordance with OPSS.PROV 517, SP 517F01 and SP FOUN0003. As noted in the SP FOUN0003 working drawings, discharge of water, monitoring and removal of the dewatering system should be according to OPSS 517. The method used should not undermine the adjacent existing footings and utilities. Alternatively, and in accordance with SP 5017F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5 year experience.

6.1.5 Temporary Shoring

The temporary shoring that may be required for tunneling should be designed to resist lateral earth pressure. The lateral earth pressure acting on supported walls may be computed using the following equation, assuming a rectangular pressure distribution and that appropriate dewatering will be carried out:

$P = K(\gamma h + q)$ for non-braced cut, or $K(0.65\gamma H + q)$ for braced support

Where:
P = earth pressure intensity at depth h, kPa
K = earth pressure coefficient
γ = unit weight of retained soil, kN/m^3
q = surcharge near wall, kPa
h = depth to point of interest, m
H= total depth of excavation, m

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation (rotation of 0,002 about the base of vertical walls (horizontal displacement divided by wall height) or translation of 0.001 times wall height or combination of these). Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design. For design purposes, the unfactored static earth pressure parameters are given in Table 2.5 of this report.

Table 2.5: Material types and unfactored earth pressure properties under static conditions

Material	Unfactored Friction Angle ϕ′ (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)	Unit Weight γ (kN/m³)
Compacted Granular A or Granular B Type II	35	0.27	3.69	0.43	22
Compacted Granular B Type I	32	0.31	3.25	0.47	21
Compact sandy silt fill	29	0.35	2.88	0.52	19
Compact sand fill	30	0.33	3	0.5	20
Firm to very stiff clayey silt fill (1)	29	0.35	2.88	0.52	19
Firm to very stiff clayey silt till(1)	30	0.33	3	0.5	20

Notes:

1 Assumes long term conditions. In short term conditions K_a = K_p = 1.

2 Values given for horizontal earth pressures are for horizontal backfill. For sloping backfill, the design requirements outlined in CHBDC clause 6.12.2.2 should be used.

Temporary shoring system should be designed and constructed in accordance with OPSS.PROV 539 as amended by SP105S09. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

It is considered that a sheet pile of sufficiently robust cross section could be driven through the native layers encountered at this site location. Difficulties with installation may occur where occasional boulders are encountered in the native layers (i.e., boulders not encountered in the boreholes drilled during this investigation), requiring their removal before further driving. Alternatively, an H-pile with lagging wall can be used as a vertical temporary shoring system. The H-piles are installed, and lagging is inserted between installed H-piles during excavation. Space between the excavation and lagging must be suitably backfilled and drained. Lagging wall material can be selected as wood (timber), steel or concrete.

For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided if the center-to-center spacing of the soldier piles does not exceed 2.5 m. Soldier piles should extend a minimum depth of 3.0 m below the planned excavation depth. The actual depth of embedment should be determined by balancing moments about the pile tip. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours. Any loose zones from behind the shoring should be prevented during installation of the protection system. If required, backfill Granular A should be placed and compacted behind the shoring wall.

For the relatively shallow depth of excavation anticipated, cantilevered systems may be adequate. However, depending on the actual excavation depth and shoring system used, additional anchorage or tiebacks may be required. This must be confirmed by the shoring designer. Conventional practice is to incorporate either buried deadman anchors, rakers or grouted soil anchors. Deadman anchors can be designed based on the earth pressure coefficients and soil parameters provided in Table 2.5. For this project, either continuous or individual concrete block anchors would likely be appropriate. The anchor resistance is provided by a combination of the dead weight and passive resistance. For the full passive resistance to be realized with no load transfer to the wall, the anchor needs to be fully beyond the active wedge acting on the wall. Pressure grouted soil anchors can be designed in a preliminary fashion in accordance with Section 26 of the CFEM (2006). Based on the generally stiff to very stiff clayey silt to silty clay till at this site, the estimated factored (α=0.4) ULS resistance of grouted anchors would be approximately 50 kN/m length. Detailed design should be completed following the conception of the wall and when the associated loads have been established. Normally, such anchors are supplied and installed/tested by specialist vendors/contractors.

6.1.6 Ground Movement Monitoring

Following the CMO- Guidelines for Tunneling it is recommended that ground movement monitoring be carried out for this site to identify potential movements which could result in damage to existing utilities or structures along the culvert alignment. Monitoring details are provided in Appendix F – NSSP for Culvert Installation by Trenchless Method.

A condition survey should be carried out before the construction takes place, and after the completion of the proposed bore. The survey should document the pavement surface conditions (i.e., cracks, distortion and deviations, heaves, and depressions).

An average of at least two readings should be taken prior to construction to establish the initial conditions. Provided these readings are consistent within 2 mm of eachother, the average of the two may be used as the Baseline Readings. If the difference in values are greater than 2 mm, then the process shall be repeated until the desired accuracy is achieved.

A procedure should be established to ensure that the monitoring data will reach all parties as soon as possible. The consultant and the contractor should interpret monitoring data as needed. The Foundation Engineer will be contacted for technical support in the interpretation of the ground movements and review of the contractor response when review and alert levels are reached.

6.1.7 Scour/Erosion

Scour/erosion protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist Hydraulic engineer (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions, considering that the boreholes indicate that below some surficial deposits, the main soil type consists as a combination with silt and/or sand.

The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented, and remain effective for the design life of the culvert. The potential for scour below foundations must be incorporated into the design. The proposed foundation design for non-structural culverts incorporates shallow foundations and requires such assessment and/or protection.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope which for the subsoils materials should be no steeper than 2H:1V for stability reasons.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts the following are typical options for seepage cutoff approaches: typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, cutoff wall incorporated in the apron slab (if one is used) of the culvert, cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert.

Open footing foundations can be protected against structural undermining by locating the foundations at an appropriate depth, by provided rock protection and/or by using sheet piling. Sheet piling used for this purpose should be designed to accommodate the assessed scour depths. In some cases, it may be possible to incorporate sheeting in temporary dewatering schemes. Typically, the inlet and outlet of a culvert require protection.

A clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS 1205.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic design engineer experienced in this field. Pertinent geotechnical parameters to support this design have been provided in this report. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters are determined based on the soils encountered at the site during this investigation and are presented on the borehole logs performed by EXP attached in Appendix D and the graphs included in Appendix E and borehole logs and graphs prepared by others attached in Appendix H. All tested soils were classified using the Unified Soil Classification System which can be used for evaluation. EXP will review the scour analysis technical memorandum from the Hydraulic design engineer to check that the interpretation of the geotechnical soil types and thickness are in good agreement with the borehole information provided in this report.

Scour design is a multi-disciplinary exercise that involves the structural and hydrology designer as well as the geotechnical designer working as a team.

6.2 Installation of Culvert SR5

6.2.1 General

Trenchless (Tunneling) Method is preferred by CONSOR for the installation of culvert SR5. Based on the GA drawings, Culvert SR5 will be a newly constructed HDPE Pipe Culvert with Beveled End Treatment, approximately 82.31 m in length and 1.20 m in diameter located at Station 16+750 along Hwy 403 under County Road 55. The culvert invert level is proposed to be at an approximate elevation of 286.87 m at the inlet and 286.79 m at the outlet. A summary of the proposed culvert specification for SR5 is presented in Table 2.6 below.

Table 2.6: Summary of Culvert Specifications

Culvert ID.	Station	Invert Elevation		Approximate Length (m)	Diameter (m) / Height x Span (m)	Material
		Inlet	Outlet			
SR5	16+750	286.87	286.79	82.31	1.20	HDPE

For trenchless installation methods, the procedures should conform to all relevant Ontario Provincial Standard Specifications (OPSS), Non-Standard Special Provisions (NSSP) such as Pipe Installation by Trenchless Method, CMO- Guidelines for Tunneling and all other industrial standards.

Considering the requirements noted in the above documents, drilled boreholes in the vicinity of the proposed culvert SR5 (BH22-03, BH22-04MW, BH22-05 and BH602) meet the requirements for the trenchless installation (i.e. the boreholes shall be located outside but within 2 m of the tunnel's excavated footprint; spacing between the boreholes shall not exceed 50 m; and boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert). Boreholes BH22-05 and BH22-03 were drilled outside the road at the vicinity of the proposed entry and exit shafts, respectively, while boreholes BH22-04MW and BH602 were drilled between these two boreholes from the surface of County Road (ground Elev. 295.18 m and Elev.295.49 m at BH22-04MW and BH602 respectively). The location of these boreholes along the proposed culvert are shown in the drawings provided in Appendix C. The drawing also shows the soil profile along the culvert alignment. Based on this drawing it is anticipated that the subsurface at the location of the proposed culvert (tunnel) generally consists of compact sand and gravel fills, loose to compact sandy silt fills, soft to very stiff clayey silt fills, stiff to hard silty clays and stiff to hard clayey silt. However, the tunnel is expected to be driven predominantly through a stiff to very stiff clayey silt layer. Some loose to compact sandy silt fill along with some stiff to very stiff silty clay is also expected along the tunnel's alignment. Groundwater levels were observed in BH22-04(MW) at 288.44 m. A summary of the drilled boreholes in relation to invert elevations for culvert SR5 is presented in Table 2.7 below.

Table 2.7: Summary of SR5 Borehole Locations

Borehole No.	Borehole Elevation (m)	Borehole Depth/Elevation (m)	Borehole Location
BH22-03	287.9	5.17/282.7	Outlet
BH22-04 (MW)	295.2	12.8/282.4	County Road 55 Edge
BH22-05	287.9	5.17/282.7	Inlet
BH602	295.5	11.13/284.4	County Road 55

The attached drawing also shows the proposed locations of the entry and exit shafts, suggesting that the tunneling portion of the new culvert will be approximately 82.31 m long. The subsurface at the location of the entry shaft consists of a loose sandy silt fill underlaying the topsoil which is further underlain by a very stiff to hard silty clay till layer. At the exit shaft, the subsurface consist of a loose sandy silt fill underlaying the topsoil which is further underlain by a stiff to very stiff silty clay till layer.

The fill soils are generally considered to be "squeezing" to "running" and becoming "flowing" below the groundwater level as classified in Terzaghi's Tunnelman's Ground Classification. At this site, it is expected that the groundwater level will be above the pipes invert and obvert at both inlet and outlet locations. The native soil at the site consisted of stiff to very stiff clayey silt tills and and very stiff clayey silt tills and are classified as "firm" soil. The possibility of encountering potential cobbles and boulders in the till layers should be anticipated. It is the contractor's responsibility to select means and method appropriate for the soil and groundwater conditions. Detailed discussions on trenchless installation options are provided below.

6.2.2 Culvert Installation Options

Based on the site conditions and characteristics of methods available, the following options for the culvert construction at the proposed new alignment are discussed in the following sections:

- Jack and bore technique;
- Pipe ramming;

- Micro-tunneling; and
- Horizontal Directional Drilling (HDD) Technique.

The following table summarizes some of the possible alternatives for the culvert installation using trenchless technology and the following sections provide a discussion for some of the options for the proposed trenchless culvert installation.

Table 2.8A: Installation methods comparison

Installation Method	Advantages	Disadvantages
Jack and Bore	• Handles wide variety of ground conditions • Minimal surface disruption • Very accurate (slope of 0.2% easily achieved) • Relatively simple operation • Common use in Ontario • Short mobilization time • Suitable for tunnels up to 1.5 m in diameter and 150 m long	• Requires large area for jacking shaft and support equipment • Relatively high construction costs • Obstructions problematic • Short- and long-term settlement • Fluid to support annular space • Pipe can be difficult to steer/direct • Dewatering required along route, if the GWL is high
Pipe Ramming	• Not very sensitive to ground condition • Suitable for steel pipes up to 1.8 m in diameter and best up to 50 m long • Accommodates obstructions well • Little surface settlement • Soil removed after pipe in place	• Pipe can be difficult to steer/direct • Large entry pit size • Possible ground heave • Excavation and shoring required to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment • Vibrations could potentially impact the stability of the existing slope and neighbouring structures • Slower than other trenchless methods • More expensive than cut and cover methods and jack and bore method
Microtunneling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Suitable for tunneling under groundwater table • Alignment can be adjusted to avoid obstructions • Suitable for tunnels with 250 – 3000 mm in diameter and up to 300 m in length with Intermediate Jacking Stations (IJS) every 75 m	• High construction costs • Requires large area for jacking shaft and support equipment. • Short- and long-term settlement • Require sophisticated equipment

Installation Method	Advantages	Disadvantages
	• Local skilled contractor is available in the area	
Directional Drilling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Does not require staging pits • Alignment can be adjusted to avoid obstructions • Local contractors are available in the area • Short mobilization time • Rapid drilling • Minor settlement if fluid well controlled • Less expensive than microtunneling	• Potential for inadvertent drilling returns • Requires drilling fluid to maintain the bore which could allow subsidence • Annular space filling (i.e. fluid or grouting) • Suitable for installation of pipes up to 1.0 m in diameter and up to 475 m in length

Table 2.8B: General comparison of technical issues associated with trenchless methods

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
Typical limitations: Length of drive & Diameter	• Drive lengths to 150m • Diameters up to 1.5m are feasible	• Generally best suited to short watercourse crossings where risks imposed by ground surface heave are low • 30 to 60m drives are typical • Diameters of 1800mm are technically feasible with a large hammer, however, the stability / integrity of the soil plug in the lead pipe segment is less certain with larger diameters	• Drive lengths of 300m are typical, provided that Intermediate Jacking Stations (IJS) are launched every 75m • Micro tunnels up to 1500mm dia. can be readily constructed in Ontario; 3000mm dia. may be feasible by specialists	• Drive pullback lengths of several hundred meters are feasible • In Southern Ontario, HDD diameters less than 750mm are fairly common place but larger bores add risk, complexity and considerable cost
Ability to control line & grade	• Average control of line and grade • Limited ability to steer and to correct grade	• Relatively Poor	• Good • Line and grade control to within ±40mm is feasible over 300m drive	• Specialized tracker system is needed to control line and grade • Fair to Good
Ability to control ground surface displacement	• Poor • No ability to retain running ground	• Poor • Risk of ground heave is moderate to high • If soil plug in lead pipe segment washes out or is breached, then excessive ground loss and settlement will occur	• Good • Slurry shield MTBM can balance earth pressures in the shield to a variety of ground and groundwater conditions	• Fair • Ground heave and hydro fracturing may result from excessive rates of pullback • Bore stability relies on good quality control and circulation of drilling mud

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
			• Full and immediate ground support by means of jacking pipe	
Ability to deal with Mixed face ground Conditions	• Mixed face conditions will likely cause line and grade deviations to occur • Overmining may result when augering is labored due to hard ground • Augers may jam on rock slabs	• Mixed face conditions will likely deviate the line and grade	• Good • High pressure water jets are necessary to breakdown cohesive clays	• Mixed ground may interfere with line and grade control
Ability to deal with Flowing / unstable face Conditions	• No ability to deal with flowing / unstable face conditions • Flowing soils may result in total collapse / excessive ground loss • Method is unsuitable in cohesionless soils below the water table	• The ability to retain flowing ground depends entirely on maintaining a soil plug in the lead pipe segment. If the plug breaches, then the bore may fail	• Slurry shield MTBMs are better suited to flowing ground conditions than any other trenchless method	• Bore wall stability can be maintained with suitably viscous drilling fluid and filter cake buildup on bore wall • Risk of pipe jamming during pullback if stones / cobbles become dislodged from crown of bore
Ability to deal with Cobbles & boulders and other obstructions	• For bores >900mm, auger removal and personnel entry are needed to break up boulders, however the tunnel face must be cohesive for this to be safely conducted	• Typically better than Jack & Bore • May require removal of soil plug to remove / breakup boulder which could possibly compromise tunnel stability	• Combination of disk and pick cutters is needed • Person entry not practical • Wood troublesome	• Cobbles and rock slabs may jam pipe in bore during pullback • Boulders will result in a failed bore
Option feasibility for this site	• Feasible	• Might not be feasible; too long pipe	• Feasible	• Might not be feasible; too big pipe diameter

6.2.2.1 Jack and Bore

The jack and bore method involve drilling a borehole from a jacking pit (entry pit) with a rotary cutter head within the confines of a steel casing or liner jacked ahead for support. The casing is pushed through the soil with a hydraulic ram, and soil is removed with an auger. A cutting head is fixed to the leading edge of the culvert. The auger transports spoils from the cutting head back to the jacking pit. The procedures must conform to all relevant OPSS standards and industrial standards.

Based on the information from the boreholes drilled in the vicinity of the new culvert, it is expected that the tunnel boring will be carried out in mostly a combination of native stiff to very stiff clayey silt. Some loose to compact sandy silt fill along with some stiff to very stiff silty clay is also expected along the tunnel's alignment and the groundwater level will be higher than the culvert's elevation. Noting the height of the groundwater elevation, dewatering will be required along the route of the culvert if this method is employed. Considering these conditions as well as the proposed culvert diameter of 1.20 m, pipe jacking using mechanical means is feasible for the proposed installation.

To reduce loss of ground and groundwater ingress (if any), consideration may be given to jacking the casing across the alignment as far as possible, prior to auguring. Lubricant selected based on the characteristics of the surrounding soil, may be provided to reduce the friction between the casing and the borehole walls. However, obstacles such as deleterious debris, e.g., wood, which should be anticipated in the fill could make this difficult or impractical. EXP recommends the lead auger be kept at least one casing diameter behind the lead end of the casing to minimize the potential for ground losses. Furthermore, any significant voids between the casing and the surrounding soil should be filled with pressurized cementitious grout to prevent / minimize ground loss. In addition, the installation of the proposed culvert must not interfere with existing utilities. Therefore, driving of the pipe must be fairly accurate noting that there is only limited steering ability, where minor adjustments can be made should it be necessary or to address obstructions. Generally, utility tunneling using pipe jacking method is a relatively slow and labor-intensive process. The actual tunnel advance rate is a function of soil conditions encountered, method of soil excavation, spoil removal, pipe liners materials, and field conditions.

To minimize possible negative impact on the stability of the existing embankment slope due to excavations required for the bore/jacking pits and installation of the pipe using the pipe jack and auger bore method, a protection system might be required for the existing roadway. Excavation shoring for the pits will be addressed in the following sections of this report.

6.2.2.2 Pipe Ramming

The pipe ramming is a trenchless method for installation of steel pipes over distances typically up to 50 m long and up to 1.8 m in diameter. The method uses pneumatic percussive blows to drive the pipe into ground. Spoil removal from the pipe can be done by auger. It typically requires excavation of two pits, but the ramming can be launched without an insertion pit if the ram is designed to start at the side of a slope. It should be noted that installation is very noisy and difficult to steer, and its vibration could destabilize the embankment slope with potential impact on adjacent existing structures.

Considering the length of the proposed culvert (82.31 m), the pipe ramming method is an unacceptable option for the installation of culvert SR5. If pipe ramming is a desired option, the tunneling contractor must provide a Work Plan detailing the methodology to control the ram orientation. Potential options include drilling pilot holes or telescoping pipe diameters.

6.2.2.3 Microtunneling

Microtunneling should be feasible to install the proposed culvert. Microtunneling method is a non-entry, remotely controlled, guided 2-stage process, which provides continuous support to the excavation face. In this method a Micro Tunneling Boring Machine (MTBM) is used for soil cutting, while a pipe is jacked into place behind the cutting head with hydraulics. The MTBM is equipped with a slurry spoil removal system to control the groundwater inflow and counterbalance the earth and hydrostatic pressure while tunneling through the mixed face conditions. The cutting tool and the drilling fluid must be able to handle the different materials and the “mixed face” condition. To minimize the resistance along the pipe exterior, a bentonite grout lubricant can be injected behind the cutting face. Steel, concrete or fibreglass pipes can be installed with this method.

The major advantage of microtunneling method is that its performance is not affected by high groundwater levels, so the dewatering is not required; which is not a case for this project. Major disadvantage of microtunneling for this project is the relatively high cost. This option may become more attractive if potential bidders have available equipment in house.

Considering the length of the proposed culvert, no Intermediate Jacking Stations (IJS) will be required. For excavation of the launching pit, a protection system might be required to minimize possible negative impact on the stability of the existing embankment slope. Based on the length and size of the culvert, microtunneling is an acceptable alternative for the installation of culvert SR5.

6.2.2.4 Horizontal Directional Drilling (HDD)

Horizontal Directional Drill installation should follow the requirements of OPSS.PROV 450. If there is enough space to achieve entry and exit angles as recommended in ASTM F1962-11 (12° to 15° for bore entry and 10° for bore exit), horizontal directional drilling (HDD) should be considered for the culvert installation, provided the drill hole is at all times supported with a properly designed drilling fluid. Given that the proposed culvert installation will be within the slope of the embankment, installation via HDD may require significant build up at the entry and exit points to allow for construction to follow best practices. HDD is also typically a more expensive option. Based on the required set-up work and the the size of the proposed culvert diameter (D~1.20 m) this method is an unacceptable alternative for the installation of culvert SR5.

6.2.2.5 Discussion of Drilling Methods

The pipe ramming method for installation is unsuitable at this site since the culvert is longer than 50 m. The HDD method is also unsuitable as well since the proposed culvert diameter is greater than 1.0 m.

The microtunneling method is a feasible method and local, experienced contractors have successfully installed pipes using this method. If a qualified and experienced contractor is used for construction, the required alignment/slope can be achieved with minimal risk for short- and long-term settlements. However, the initial installation cost is anticipated to be higher than the alternatives.

Although difficulty in directing the drill head should be anticipated, the jack and bore method of installation is considered the preferred option from a feasibility and cost perspective. A summary of the recommendation based on the various methods is presented in Table 2.9 below.

Table 2.9: Summary of Recommendations

Installation Method	Recommendation
Jack and Bore	Preferred
Pipe Ramming	Not Recommended
Microtunneling	Acceptable
Directional Drilling	Not Recommended

6.2.3 Entry and Exit Shafts

6.2.3.1 Excavation of Shafts

All excavations for entry (launching) and exit (receiving) shafts must be completed in accordance with the most recent regulations of the Ontario Occupation Health and Safety Act (OHSA). The encountered fill and native soils may generally be classified as Type 2 and Type 3 soils above the groundwater level and Type 4 soils below the groundwater level in conformance with the OHSA.

Temporary excavation side slopes in Type 2 and Type 3 soils should remain stable at a slope of 1H:1V. Excavation side slopes in Type 4 soils should remain stable at a slope of 3H:1V. The need to excavate flatter side slopes if excessively wet or soft/loose materials, or concentrated seepage zones are encountered, should not be overlooked. Water (i.e., surface water runoff) should not be permitted to enter and/or pond within the construction area.

To limit the extents of the excavation and protect the existing embankment, temporary shoring may be required for this project. Note that in accordance with the OHSA pre-engineered excavation support methods are not suitable for use in Type 4 soils and a temporary support method must be designed by a professional engineer.

Excavations for the proposed culvert construction is expected to extend to depths greater than 1.5 m below existing grades at the inlet and outlet. As such, the construction excavation bases will consist of materials such as native silty clay material and sandy silt fills. Basal instability should be anticipated in excavations since the groundwater level is above the base of excavation.

6.2.3.2 Backfilling of Shafts

It is anticipated that backfilling work will be required at the entry and exit shafts to return site condition to pre-construction grades. The following comments and recommendations are provided for backfilling such excavations.

All excavations should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted to at least 95% of the Standard Proctor Maximum Dry Density (SPMDD). Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials.

All backfill and compaction operations should be monitored by qualified geotechnical personnel to approve materials, to evaluate placement operations, and to verify that the specified degree of compaction is being achieved throughout the fill.

6.2.4 Dewatering

Surface water should be always directed away from the excavation area(s). Based on an assessment of the water levels observed in the adjacent borings/piezometers, groundwater at the site is interpreted to be present, with a groundwater level near 288.4 m. The soils encountered within potential excavation depths will consist of sandy silt fills and both native clayey silts and native silty clays. These materials (particularly the deposits with high silt content) are susceptible to disturbance from groundwater and mobilized equipment. As such, the groundwater level needs to be controlled below the excavation level to avoid disturbance. Given the conditions at this site, it is anticipated that control of seepage can be accomplished by conventional pumping from sumps in oversize excavations. This dewatering can likely be achieved by gravity drainage and pumping from strategically placed sumps with side ditches. Confirmation of control should be verified before general excavation to final levels. However, given the conditions at this site, conventional sump pumping may not be effective for deeper excavations below the groundwater table and those conditions will require more positive dewatering systems. Positive dewatering programs may also be required if certain tunneling options are selected, such as Jack and Bore or Pipe Ramming.

At this site, the requirement for an EASR or need to obtain PTTW should be evaluated based on the proposed dewatering and tunnelling methodology. It is noted that dewatering operations more than 50,000 L/day will require a Permit to Take Water (PTTW); EXP can be contacted to provide additional hydrogeological services, if required.

All collected water should be discharged a sufficient distance away from the excavated area to prevent the water from re-entering the excavation. Sediment control measures such as silt fences should be provided at the discharge point of the dewatering system. Caution should also be taken to avoid any adverse impact to the environment.

Dewatering shall be carried out in accordance with OPSS.PROV 517, SP 517F01 and SP FOUN0003. As noted in the SP FOUN0003 working drawings, discharge of water, monitoring and removal of the dewatering system should be according to OPSS 517. The method used should not undermine the adjacent existing footings and utilities. Alternatively, and in accordance with SP 5017F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5 year experience.

6.2.5 Temporary Shoring

The temporary shoring that may be required for tunneling should be designed to resist lateral earth pressure. The lateral earth pressure acting on supported walls may be computed using the following equation, assuming a rectangular pressure distribution and that appropriate dewatering will be carried out:

$P = K(\gamma h + q)$ for non-braced cut, or $K(0.65\gamma H + q)$ for braced support

where
P = earth pressure intensity at depth h, kPa
K = earth pressure coefficient
γ = unit weight of retained soil, kN/m^3
q = surcharge near wall, kPa
h = depth to point of interest, m
H= total depth of excavation, m

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation (rotation of 0,002 about the base of vertical walls (horizontal displacement divided by wall height) or translation of 0.001 times wall height or combination of these). Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design. For design purposes, the unfactored static earth pressure parameters are given in Table 2.10 of this report.

Table 2.10: Material types and unfactored earth pressure properties under static conditions

Material	Unfactored Friction Angle ϕ' (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)	Unit Weight γ (kN/m^3)
Compacted Granular A or Granular B Type II	35	0.27	3.69	0.43	22
Compacted Granular B Type I	32	0.31	3.25	0.47	21
Loose to compact sandy silt fill	28	0.36	2.77	0.53	18
Compact sand and gravel fill	30	0.33	3.00	0.5	20
Soft to stiff clayey silt fill (1)	28	0.36	2.77	0.53	18
Stiff to very stiff clayey silt fill (1)	30	0.33	3.00	0.50	19
Stiff to hard silty clay till(1)	30	0.33	3.00	0.50	19
Stiff to hard clayey silt till(1)	31	0.32	3.12	0.48	20

Notes:
1 Assumes long term conditions. In short term conditions $K_a = K_p = 1$.

2 Values given for horizontal earth pressures are for horizontal backfill. For sloping backfill, the design requirements outlined in CHBDC clause 6.12.2.2 should be used.

Temporary shoring system should be designed and constructed in accordance with OPSS.PROV 539 as amended by SP105S09. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

It is considered that a sheet pile of sufficiently robust cross section could be driven through the native layers encountered at this site location. Difficulties with installation may occur where occasional boulders are encountered in the native layers (i.e., boulders not encountered in the boreholes drilled during this investigation), requiring their removal before further driving. Alternatively, an H-pile with lagging wall can be used as a vertical temporary shoring system. The H-piles are installed, and lagging is inserted between installed H-piles during excavation. Space between the excavation and lagging must be suitably backfilled and drained. Lagging wall material can be selected as wood (timber), steel or concrete.

For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided if the center-to-center spacing of the soldier piles does not exceed 2.5 m. Soldier piles should extend a minimum depth of 3.0 m below the planned excavation depth. The actual depth of embedment should be determined by balancing moments about the pile tip. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours. Any loose zones from behind the shoring should be prevented during installation of the protection system. If required, backfill Granular A should be placed and compacted behind the shoring wall.

For the relatively shallow depth of excavation anticipated, cantilevered systems may be adequate. However, depending on the actual excavation depth and shoring system used, additional anchorage or tiebacks may be required. This must be confirmed by the shoring designer. Conventional practice is to incorporate either buried deadman anchors, rakers or grouted soil anchors. Deadman anchors can be designed based on the earth pressure coefficients and soil parameters provided in Table 2.10. For this project, either continuous or individual concrete block anchors would likely be appropriate. The anchor resistance is provided by a combination of the dead weight and passive resistance. For the full passive resistance to be realized with no load transfer to the wall, the anchor needs to be fully beyond the active wedge acting on the wall. Pressure grouted soil anchors can be designed in a preliminary fashion in accordance with Section 26 of the CFEM (2006). Based on the generally stiff to very stiff clayey silt to silty clay till at this site, the estimated factored (α=0.4) ULS resistance of grouted anchors would be approximately 24 kN/m length. Detailed design should be completed following the conception of the wall and when the associated loads have been established. Normally, such anchors are supplied and installed/tested by specialist vendors/contractors.

6.2.6 Ground Movement Monitoring

Following the CMO- Guidelines for Tunneling it is recommended that ground movement monitoring be carried out for this site to identify potential movements which could result in damage to existing utilities or structures along the culvert alignment. Monitoring details are provided in Appendix F – NSSP for Culvert Installation by Trenchless Method.

A condition survey should be carried out before the construction takes place, and after the completion of the proposed bore. The survey should document the pavement surface conditions (i.e., cracks, distortion and deviations, heaves, and depressions).

An average of at least two readings should be taken prior to construction to establish the initial conditions. Provided these readings are consistent within 2 mm of eachother, the average of the two may be used as the Baseline Readings. If the difference in values are greater than 2 mm, then the process shall be repeated until the desired accuracy is achieved.

A procedure should be established to ensure that the monitoring data will reach all parties as soon as possible. The consultant and the contractor should interpret monitoring data as needed. The Foundation Engineer will be contacted for technical support in the interpretation of the ground movements and review of the contractor response when review and alert levels are reached.

6.2.7 Scour/Erosion

Scour/erosion protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist Hydraulic engineer (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions, considering that the boreholes indicate that below some surficial deposits, the main soil type consists as a combination with silt and/or sand.

The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented and remain effective for the design life of the culvert. The potential for scour below foundations must be incorporated into the design. The proposed foundation design for non-structural culverts incorporates shallow foundations and requires such assessment and/or protection.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope which for the subsoils materials should be no steeper than 2H:1V for stability reasons.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts the following are typical options for seepage cutoff approaches: typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, cutoff wall incorporated in the apron slab (if one is used) of the culvert, cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert.

Open footing foundations can be protected against structural undermining by locating the foundations at an appropriate depth, by provided rock protection and/or by using sheet piling. Sheet piling used for this purpose should be designed to accommodate the assessed scour depths. In some cases, it may be possible to incorporate sheeting in temporary dewatering schemes. Typically, the inlet and outlet of a culvert require protection.

A clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS 1205.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic design engineer experienced in this field. Pertinent geotechnical parameters to support this design have been provided in this report. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters are determined based on the soils encountered at the site during this investigation and are presented on the borehole logs performed by EXP attached in Appendix D and the graphs included in Appendix E and borehole logs and graphs prepared by others attached in Appendix H. All tested soils were classified using the Unified Soil Classification System which can be used for evaluation. EXP will review the scour analysis technical memorandum from the Hydraulic design engineer to check that the interpretation of the geotechnical soil types and thickness are in good agreement with the borehole information provided in this report.

Scour design is a multi-disciplinary exercise that involves the structural and hydrology designer as well as the geotechnical designer working as a team.

6.3 Installation of Culvert SR6

6.3.1 General

Trenchless (Tunneling) Method is preferred by CONSOR for the installation of culvert SR6. Based on the GA drawings, Culvert SR6 will be a newly constructed 0.61 m HDPE Closed Profile Pipe Culvert/0.60 m Steel Pipe Culvert (Spiral Rib 19 x 19 x 190 with 1.6 mm thick wall) approximately 45.75 m in length located at Station 19+240 along Hwy 403 under Muir Road. The culvert invert level is proposed to be at an approximate elevation of 286.76 m at the inlet and 286.63 m at the outlet. A summary of the proposed culvert specification for SR6 is presented in Table 2.11 below.

Table 2.11: Summary of Culvert Specifications

Culvert ID.	Station	Invert Elevation		Approximate Length (m)	Diameter (m) / Height x Span (m)	Material
		Inlet	Outlet			
SR6	19+240	286.76	286.63	45.75	0.61/0.60	HDPE/Steel

For trenchless installation methods, the procedures should conform to all relevant Ontario Provincial Standard Specifications (OPSS), Non-Standard Special Provisions (NSSP) such as Pipe Installation by Trenchless Method, CMO- Guidelines for Tunneling and all other industrial standards.

Considering the requirements noted in the above documents, drilled boreholes in the vicinity of the proposed culvert SR6 (BH22-06MW, BH22-07, BH604) meet the requirements for the trenchless installation (i.e. the boreholes shall be located outside but within 2 m of the tunnel's excavated footprint; spacing between the boreholes shall not exceed 50 m; and boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert). Boreholes BH22-06MW and BH22-07 were drilled outside the road at the vicinity of the proposed exit and entry shafts respectively, while Borehole BH604 was drilled between these two boreholes from the surface of Muir Road (the surface ground Elev. 294.47 m). The location of these boreholes along the proposed culvert are shown on the drawings provided in Appendix C. The drawing also shows the soil profile along the culvert alignment.

Based on this drawing, it is anticipated that the subsurface at the location of the proposed culvert (tunnel) generally consists of compact sand and gravel fills, compact sandy silt fills, firm to stiff clayey silt fills and native very stiff to hard silty clay tills and very stiff to hard clayey silt tills. However, the tunnel is expected to be driven predominantly through a combination of native very stiff to hard clayey silt tills, compact sandy silt fills and firm clayey silt fills. Groundwater levels were observed in BH604 at 285.94 m.

A summary of the drilled boreholes in relation to invert elevations for culvert SR6 is presented in Table 2.12 below.

Table 2.12 Summary of SR6 Borehole Locations

Borehole No.	Borehole Elevation (m)	Borehole Depth/Elevation (m)	Borehole Location
BH22-06(MW)	287.4	3.65/283.8	Outlet
BH22-07	287.6	3.65/284.0	Inlet
BH604	294.5	9.60/284.9	Muir Road North

The attached drawing also shows the proposed locations of the entry and exit shafts, suggesting that the tunneling portion of the new culvert will be approximately 45.75 m long. Review of the existing bridge structure indicates that the proposed location may be within the zone of influence of the bridge foundation elements. The existing abutment spread footing foundation is at

Elevation 289.8 m, with an approximately 1.8 m thick compacted Granular 'A' foundation pad. Consideration should be given to moving the proposed location to the north to avoid any potential impacts on the granular pad and structure.

The subsurface at the location of the entry shaft consists of a compact sandy silt fill underlaying the topsoil which is further underlain by a hard native clayey silt till material. A very stiff to hard silty clay till material is further found underlying the native clayey silt. At the exit shaft, the subsurface consist of a compact sandy silt fill underlaying the topsoil which is further underlain by a hard native clayey silt till layer material. A very stiff to hard silty clay till material is also found underlying the native clayey silt.

The fill soils are generally considered to be "squeezing" to "running" and becoming "flowing" below the groundwater level as classified in Terzaghi's Tunnelman's Ground Classification. At this site, it is expected that the groundwater level will be below the pipes invert (measured groundwater Elev. 285.94 m vs. invert at outlet, 286.63 m). However, the fill material behavior should be anticipated to vary. In general, the native soil at the site consists of very stiff to hard silty clay tills and hard clayey silt tills. Both native soil types are also classified as "firm" soils. The possibility of encountering potential cobbles and boulders in the till layers should be anticipated. It is the contractor's responsibility to select means and method appropriate for the soil and groundwater conditions. Detailed discussions on trenchless installation options are provided below.

6.3.2 Culvert Installation Options

Based on the site conditions and characteristics of methods available, the following options for the culvert construction at the proposed new alignment are discussed in the following sections:

- Jack and bore technique;
- Pipe ramming;
- Micro-tunneling; and
- Horizontal Directional Drilling (HDD) Technique.

The following table summarizes some of the possible alternatives for the culvert installation using trenchless technology and the following sections provide a discussion for some of the options for the proposed trenchless culvert installation.

Table 2.13A: Installation methods comparison

Installation Method	Advantages	Disadvantages
Jack and Bore	• Handles wide variety of ground conditions • Minimal surface disruption • Very accurate (slope of 0.2% easily achieved) • Relatively simple operation • Common use in Ontario • Short mobilization time • Suitable for tunnels up to 1.5 m in diameter and 150 m long	• Requires large area for jacking shaft and support equipment • Relatively high construction costs • Obstructions problematic • Short- and long-term settlement • Fluid to support annular space • Pipe can be difficult to steer/direct • Dewatering required along route, if the GWL is high
Pipe Ramming	• Not very sensitive to ground condition • Suitable for steel pipes up to 1.8 m in diameter and best up to 50 m long	• Pipe can be difficult to steer/direct • Large entry pit size • Possible ground heave

Installation Method	Advantages	Disadvantages
	• Accommodates obstructions well • Little surface settlement • Soil removed after pipe in place	• Excavation and shoring required to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment • Vibrations could potentially impact the stability of the existing slope and neighbouring structures • Slower than other trenchless methods • More expensive than cut and cover methods and jack and bore method
Microtunneling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Suitable for tunneling under groundwater table • Alignment can be adjusted to avoid obstructions • Suitable for tunnels with 250 – 3000 mm in diameter and up to 300 m in length with Intermediate Jacking Stations (IJS) every 75 m • Local skilled contractor is available in the area	• High construction costs • Requires large area for jacking shaft and support equipment. • Short- and long-term settlement • Require sophisticated equipment
Directional Drilling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Does not require staging pits • Alignment can be adjusted to avoid obstructions • Local contractors are available in the area • Short mobilization time • Rapid drilling • Minor settlement if fluid well controlled • Less expensive than microtunneling	• Potential for inadvertent drilling returns • Requires drilling fluid to maintain the bore which could allow subsidence • Annular space filling (i.e. fluid or grouting) • Suitable for installation of pipes up to 1.0 m in diameter and up to 475 m in length

Table 2.13B: General comparison of technical issues associated with trenchless methods

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
Typical limitations: Length of drive & Diameter	• Drive lengths to 150m • Diameters up to 1.5m are feasible	• Generally best suited to short watercourse crossings where risks imposed by ground surface heave are low • 30 to 60m drives are typical • Diameters of 1800mm are technically feasible with a large hammer, however, the stability / integrity of the soil plug in the lead pipe segment is less certain with larger diameters	• Drive lengths of 300m are typical, provided that Intermediate Jacking Stations (IJS) are launched every 75m • Micro tunnels up to 1500mm dia. can be readily constructed in Ontario; 3000mm dia. may be feasible by specialists	• Drive pullback lengths of several hundred meters are feasible • In Southern Ontario, HDD diameters less than 750mm are fairly common place but larger bores add risk, complexity and considerable cost
Ability to control line & grade	• Average control of line and grade • Limited ability to steer and to correct grade	• Relatively Poor	• Good • Line and grade control to within ±40mm is feasible over 300m drive	• Specialized tracker system is needed to control line and grade • Fair to Good
Ability to control ground surface displacement	• Poor • No ability to retain running ground	• Poor • Risk of ground heave is moderate to high • If soil plug in lead pipe segment washes out or is breached, then excessive ground loss and settlement will occur	• Good • Slurry shield MTBM can balance earth pressures in the shield to a variety of ground and groundwater conditions • Full and immediate ground support by means of jacking pipe	• Fair • Ground heave and hydro fracturing may result from excessive rates of pullback • Bore stability relies on good quality control and circulation of drilling mud
Ability to deal with Mixed face ground Conditions	• Mixed face conditions will likely cause line and grade deviations to occur • Overmining may result when augering is labored due to hard ground • Augers may jam on rock slabs	• Mixed face conditions will likely deviate the line and grade	• Good • High pressure water jets are necessary to breakdown cohesive clays	• Mixed ground may interfere with line and grade control
Ability to deal with Flowing / unstable face Conditions	• No ability to deal with flowing / unstable face conditions • Flowing soils may result in total collapse / excessive ground loss • Method is unsuitable in cohesionless soils below the water table	• The ability to retain flowing ground depends entirely on maintaining a soil plug in the lead pipe segment. If the plug breaches, then the bore may fail	• Slurry shield MTBMs are better suited to flowing ground conditions than any other trenchless method	• Bore wall stability can be maintained with suitably viscous drilling fluid and filter cake buildup on bore wall • Risk of pipe jamming during pullback if stones / cobbles become dislodged from crown of bore
Ability to deal with	• For bores >900mm, auger removal and personnel entry are needed to break up	• Typically better than Jack & Bore • May require removal of soil plug to remove /	• Combination of disk and pick cutters is needed	• Cobbles and rock slabs may jam pipe in bore during pullback

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
Cobbles & boulders and other obstructions	boulders, however the tunnel face must be cohesive for this to be safely conducted	breakup boulder which could possibly compromise tunnel stability	• Person entry not practical • Wood troublesome	• Boulders will result in a failed bore
Option feasibility for this site	• Feasible	• Feasible	• Feasible	• Feasible

6.3.2.1 Jack and Bore

The jack and bore method involve drilling a borehole from a jacking pit (entry pit) with a rotary cutter head within the confines of a steel casing or liner jacked ahead for support. The casing is pushed through the soil with a hydraulic ram, and soil is removed with an auger. A cutting head is fixed to the leading edge of the culvert. The auger transports spoils from the cutting head back to the jacking pit. The procedures must conform to all relevant OPSS standards and industrial standards.

Based on the information from the boreholes drilled in the vicinity of the new culvert, it is expected that the tunnel is expected to be driven predominantly through a combination of native very stiff to hard clayey silts, compact sandy silt fills and firm clayey silt fills and the groundwater level will be below the culvert invert (measured groundwater Elev. 285.94 m vs. invert at outlet, 286.63 m). Considering these conditions as well as the proposed culvert diameter of 0.61/0.60 m, pipe jacking using mechanical means is an acceptable option for the installation of culvert SR6.

To reduce loss of ground and groundwater ingress (if any), consideration may be given to jacking the casing across the alignment as far as possible, prior to auguring. Lubricant selected based on the characteristics of the surrounding soil, may be provided to reduce the friction between the casing and the borehole walls. However, obstacles such as deleterious debris, e.g., wood, which should be anticipated in the fill could make this difficult or impractical. EXP recommends the lead auger be kept at least one casing diameter behind the lead end of the casing to minimize the potential for ground losses. Furthermore, any significant voids between the casing and the surrounding soil should be filled with pressurized cementitious grout to prevent / minimize ground loss. In addition, the installation of the proposed culvert must not interfere with existing utilities. Therefore, driving of the pipe must be fairly accurate noting that there is only limited steering ability, where minor adjustments can be made should it be necessary or to address obstructions. Generally, utility tunneling using pipe jacking method is a relatively slow and labor-intensive process. The actual tunnel advance rate is a function of soil conditions encountered, method of soil excavation, spoil removal, pipe liners materials, and field conditions.

To minimize possible negative impact on the stability of the existing embankment slope due to excavations required for the bore/jacking pits and installation of the pipe using the pipe jack and auger bore method, a protection system might be required for the existing roadway. Excavation shoring for the pits will be addressed in the following sections of this report.

6.3.2.2 Pipe Ramming

The pipe ramming is a trenchless method for installation of steel pipes over distances typically up to 50 m long and up to 1.8 m in diameter. The method uses pneumatic percussive blows to drive the pipe into ground. Spoil removal from the pipe can be done by auger. It typically requires excavation of two pits, but the ramming can be launched without an insertion pit if the ram is designed to start at the side of a slope. It should be noted that installation is very noisy and difficult to steer, and its vibration could destabilize the embankment slope with potential impact on adjacent existing structures.

Considering the length of the proposed culvert, the pipe ramming method is feasible for the proposed installation. However, the potential for vibration induced issues and steerability impacts it priority in ranking.

6.3.2.3 Microtunneling

Microtunneling should be feasible to install the proposed culvert. Microtunneling method is a non-entry, remotely controlled, guided 2-stage process, which provides continuous support to the excavation face. In this method a Micro Tunneling Boring Machine (MTBM) is used for soil cutting, while a pipe is jacked into place behind the cutting head with hydraulics. The MTBM is equipped with a slurry spoil removal system to control the groundwater inflow and counterbalance the earth and hydrostatic pressure while tunneling through the mixed face conditions. The cutting tool and the drilling fluid must be able to handle the different materials and the "mixed face" condition. To minimize the resistance along the pipe exterior, a bentonite grout lubricant can be injected behind the cutting face. Steel, concrete or fibreglass pipes can be installed with this method.

The major advantage of microtunneling method is that its performance is not affected by high groundwater levels, so the dewatering is not required; which is not a case for this project. Major disadvantage of microtunneling for this project is the relatively high cost. This option may become more attractive if potential bidders have available equipment in house.

Considering the length of the proposed culvert, no Intermediate Jacking Stations (IJS) will be required. For excavation of the launching pit, a protection system might be required to minimize possible negative impact on the stability of the existing embankment slope. Based on the length and size of the culvert, microtunneling is an acceptable alternative for the installation of culvert SR6.

6.3.2.4 Horizontal Directional Drilling (HDD)

Horizontal Directional Drill installation should follow the requirements of OPSS.PROV 450. If there is enough space to achieve entry and exit angles as recommended in ASTM F1962-11 (12° to 15° for bore entry and 10° for bore exit), horizontal directional drilling (HDD) should be considered for the culvert installation, provided the drill hole is at all times supported with a properly designed drilling fluid. Given that the proposed culvert installation will be within the slope of the embankment, installation via HDD may require significant build up at the entry and exit points to allow for construction to follow best practices. HDD is also typically a more expensive option. Based on the size of the proposed culvert diameter (D~0.61/0.60 m) this method is an acceptable alternative for the installation of culvert SR6, noting the construction related issues discussed above.

6.3.2.5 Discussion of Drilling Methods

The pipe ramming method for installation is a suitable method at this site since the culvert is shorter than 50 m. The HDD method is also a suitable method as well since the proposed culvert diameter is less than 1.0 m.

The microtunneling method is a feasible method and local, experienced contractors have successfully installed pipes using this method. If a qualified and experienced contractor is used for construction, the required alignment/slope can be achieved with minimal risk for short- and long-term settlements. However, the initial installation cost is anticipated to be higher than the alternatives.

Although difficulty in directing the drill head should be anticipated, the jack and bore method of installation is considered the preferred option from a feasibility and cost perspective. A summary of the recommendation based on the various methods is presented in Table 2.14 below.

Table 2.14: Summary of Recommendations

Installation Method	Recommendation
Jack and Bore	Preferred
Pipe Ramming	Acceptable
Microtunneling	Acceptable
Directional Drilling	Acceptable

6.3.3 Entry and Exit Shafts

6.3.3.1 Excavation of Shafts

All excavations for entry (launching) and exit (receiving) shafts must be completed in accordance with the most recent regulations of the Ontario Occupation Health and Safety Act (OHSA). The encountered fill and native soils may generally be classified as Type 2 and Type 3 soils above the groundwater level and Type 4 soils below the groundwater level in conformance with the OHSA.

Temporary excavation side slopes in Type 2 and Type 3 soils should remain stable at a slope of 1H:1V. Excavation side slopes in Type 4 soils should remain stable at a slope of 3H:1V. The need to excavate flatter side slopes if excessively wet or soft/loose materials, or concentrated seepage zones are encountered, should not be overlooked. Water (i.e., surface water runoff) should not be permitted to enter and/or pond within the construction area.

To limit the extents of the excavation and protect the existing embankment, temporary shoring may be required for this project. Note that in accordance with the OHSA pre-engineered excavation support methods are not suitable for use in Type 4 soils and a temporary support method must be designed by a professional engineer.

Excavations for the proposed culvert construction is expected to extend to depths greater than 1.5 m below existing grades at the inlet and outlet. As such, the construction excavation bases may consist of materials such as sandy silt fills and both native silty clays and clayey silts. The groundwater level is below the inverts of both the inlet and outlet of culvert SR6, however, basal instability should be evaluated in excavations at depths lower than the groundwater level.

6.3.3.2 Backfilling of Shafts

It is anticipated that backfilling work will be required at the entry and exit shafts to return site condition to pre-construction grades. The following comments and recommendations are provided for backfilling such excavations.

All excavations should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted to at least 95% of the Standard Proctor Maximum Dry Density (SPMDD). Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials.

All backfill and compaction operations should be monitored by qualified geotechnical personnel to approve materials, to evaluate placement operations, and to verify that the specified degree of compaction is being achieved throughout the fill.

6.3.4 Dewatering

Surface water should be always directed away from the excavation area(s). Based on an assessment of the water levels observed in the adjacent borings/piezometers, groundwater at the site is interpreted to be below the invert level of culvert SR 6 at both inlet and outlet. The soils encountered within potential excavation depths will consist of sandy silt fills and native clayey silts. These materials (particularly the deposits with high silt content) are susceptible to disturbance from groundwater and mobilized equipment. As such, the groundwater level needs to be controlled below the excavation level to avoid disturbance. Given the conditions at this site, it is anticipated that control of seepage can be accomplished by conventional pumping from sumps in oversize excavations. This dewatering can likely be achieved by gravity drainage and pumping from strategically placed sumps with side ditches. Confirmation of control should be verified before general excavation to final levels

At this site, it is not expected to require registry on EASR or need to obtain PTTW. However, it is noted that dewatering operations more than 50,000 L/day will require a Permit to Take Water (PTTW); EXP can be contacted to provide additional hydrogeological services, if required.

All collected water should be discharged a sufficient distance away from the excavated area to prevent the water from re-entering the excavation. Sediment control measures such as silt fences should be provided at the discharge point of the dewatering system. Caution should also be taken to avoid any adverse impact to the environment.

Dewatering shall be carried out in accordance with OPSS.PROV 517, SP 517F01 and SP FOUN0003. As noted in the SP FOUN0003 working drawings, discharge of water, monitoring and removal of the dewatering system should be according to OPSS 517. The method used should not undermine the adjacent existing footings and utilities. Alternatively, and in accordance with SP 5017F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5 year experience.

6.3.5 Temporary Shoring

The temporary shoring that may be required for tunneling should be designed to resist lateral earth pressure. The lateral earth pressure acting on supported walls may be computed using the following equation, assuming a rectangular pressure distribution and that appropriate dewatering will be carried out:

$P = K(\gamma h + q)$ for non-braced cut, or $K(0.65\gamma H + q)$ for braced support

where
P = earth pressure intensity at depth h, kPa
K = earth pressure coefficient
γ = unit weight of retained soil, kN/m^3
q = surcharge near wall, kPa
h = depth to point of interest, m
H= total depth of excavation, m

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation (rotation of 0,002 about the base of vertical walls (horizontal displacement divided by wall height) or translation of 0.001 times wall height or combination of these). Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design. For design purposes, the unfactored static earth pressure parameters are given in Table 2.15 of this report.

Table 2.15: Material types and unfactored earth pressure properties under static conditions

Material	Unfactored Friction Angle ϕ' (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)	Unit Weight γ (kN/m^3)
Compacted Granular A or Granular B Type II	35	0.27	3.69	0.43	22
Compacted Granular B Type I	32	0.31	3.25	0.47	21
Compact sandy silt fill	29	0.35	2.88	0.52	19
Compact sand and gravel fill	30	0.33	3.00	0.50	20
Firm to stiff clayey silt fill (1)	28	0.36	2.77	0.53	18
Very stiff to hard clayey silt till (1)	31	0.32	3.12	0.48	20

Material	Unfactored Friction Angle ϕ' (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)	Unit Weight γ (kN/m³)
Very stiff to hard silty clay till(1)	30	0.33	3.00	0.50	19

Notes:

1 Assumes long term conditions. In short term conditions $K_a = K_p = 1$.

2 Values given for horizontal earth pressures are for horizontal backfill. For sloping backfill, the design requirements outlined in CHBDC clause 6.12.2.2 should be used.

Temporary shoring system should be designed and constructed in accordance with OPSS.PROV 539 as amended by SP105S09. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

It is considered that a sheet pile of sufficiently robust cross section could be driven through the native layers encountered at this site location. Difficulties with installation may occur where occasional boulders are encountered in the native layers (i.e., boulders not encountered in the boreholes drilled during this investigation), requiring their removal before further driving. Alternatively, an H-pile with lagging wall can be used as a vertical temporary shoring system. The H-piles are installed, and lagging is inserted between installed H-piles during excavation. Space between the excavation and lagging must be suitably backfilled and drained. Lagging wall material can be selected as wood (timber), steel or concrete.

For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided if the center-to-center spacing of the soldier piles does not exceed 2.5 m. Soldier piles should extend a minimum depth of 3.0 m below the planned excavation depth. The actual depth of embedment should be determined by balancing moments about the pile tip. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours. Any loose zones from behind the shoring should be prevented during installation of the protection system. If required, backfill Granular A should be placed and compacted behind the shoring wall.

For the relatively shallow depth of excavation anticipated, cantilevered systems may be adequate. However, depending on the actual excavation depth and shoring system used, additional anchorage or tiebacks may be required. This must be confirmed by the shoring designer. Conventional practice is to incorporate either buried deadman anchors, rakers or grouted soil anchors. Deadman anchors can be designed based on the earth pressure coefficients and soil parameters provided in Table 2.15. For this project, either continuous or individual concrete block anchors would likely be appropriate. The anchor resistance is provided by a combination of the dead weight and passive resistance. For the full passive resistance to be realized with no load transfer to the wall, the anchor needs to be fully beyond the active wedge acting on the wall. Pressure grouted soil anchors can be designed in a preliminary fashion in accordance with Section 26 of the CFEM (2006). Based on the generally stiff to very stiff clayey silt to silty clay till at this site, the estimated factored (α=0.4) ULS resistance of grouted anchors would be approximately 24 kN/m length. Detailed design should be completed following the conception of the wall and when the associated loads have been established. Normally, such anchors are supplied and installed/tested by specialist vendors/contractors.

6.3.6 Ground Movement Monitoring

Following the CMO- Guidelines for Tunneling it is recommended that ground movement monitoring be carried out for this site to identify potential movements which could result in damage to existing utilities or structures along the culvert alignment. Monitoring details are provided in Appendix F – NSSP for Culvert Installation by Trenchless Method.

A condition survey should be carried out before the construction takes place, and after the completion of the proposed bore. The survey should document the pavement surface conditions (i.e., cracks, distortion and deviations, heaves, and depressions).

An average of at least two readings should be taken prior to construction to establish the initial conditions. Provided these readings are consistent within 2 mm of eachother, the average of the two may be used as the Baseline Readings. If the difference in values are greater than 2 mm, then the process shall be repeated until the desired accuracy is achieved.

A procedure should be established to ensure that the monitoring data will reach all parties as soon as possible. The consultant and the contractor should interpret monitoring data as needed. The Foundation Engineer will be contacted for technical support in the interpretation of the ground movements and review of the contractor response when review and alert levels are reached.

6.3.7 Scour/Erosion

Scour/erosion protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist Hydraulic engineer (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions, considering that the boreholes indicate that below some surficial deposits, the main soil type consists as a combination with silt and/or sand.

The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented and remain effective for the design life of the culvert. The potential for scour below foundations must be incorporated into the design. The proposed foundation design for non-structural culverts incorporates shallow foundations and requires such assessment and/or protection.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope which for the subsoils materials should be no steeper than 2H:1V for stability reasons.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts the following are typical options for seepage cutoff approaches: typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, cutoff wall incorporated in the apron slab (if one is used) of the culvert, cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert.

Open footing foundations can be protected against structural undermining by locating the foundations at an appropriate depth, by provided rock protection and/or by using sheet piling. Sheet piling used for this purpose should be designed to accommodate the assessed scour depths. In some cases, it may be possible to incorporate sheeting in temporary dewatering schemes. Typically, the inlet and outlet of a culvert require protection.

A clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS 1205.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic design engineer experienced in this field. Pertinent geotechnical parameters to support this design have been provided in this report. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters are determined based on the soils encountered at the site during this investigation and are presented on the borehole logs performed by EXP attached in Appendix D and the graphs included in Appendix E and borehole logs and graphs prepared by others attached in Appendix H. All tested soils were classified using the Unified Soil Classification System which can be used for evaluation. EXP will review the scour analysis technical memorandum from the Hydraulic design engineer to check that the interpretation of the geotechnical soil types and thickness are in good agreement with the borehole information provided in this report.

Scour design is a multi-disciplinary exercise that involves the structural and hydrology designer as well as the geotechnical designer working as a team.

6.4 Installation of Culvert SR7

6.4.1 General

Trenchless (Tunneling) Method is preferred by CONSOR for the installation of culvert SR7. Based on the GA drawings, Culvert SR7 will be a newly constructed 0.76 m HDPE Closed Profile Pipe Culvert/0.75 m Steel Pipe Culvert (Spiral Rib 19 x 19 x 190 with 1.6 mm thick wall) approximately 46.13 m in length located at Station 19+240 along Hwy 403. The culvert invert level is proposed to be at an approximate elevation of 286.64 m at the inlet and 286.40 m at the outlet. A summary of the proposed culvert specification for SR7 is presented in 2.16 below.

Table 2.16: Summary of Culvert Specifications

Culvert ID.	Station	Invert Elevation		Approximate Length (m)	Diameter (m) / Height x Span (m)	Material
		Inlet	Outlet			
SR7	19+240	286.64	286.40	46.13	0.76/0.75	HDPE/Steel

For trenchless installation methods, the procedures should conform to all relevant Ontario Provincial Standard Specifications (OPSS), Non-Standard Special Provisions (NSSP) such as Pipe Installation by Trenchless Method, CMO- Guidelines for Tunneling and all other industrial standards.

Considering the requirements noted in the above documents, drilled boreholes in the vicinity of the proposed culvert SR7 (BH22-08, BH22-09MW, BH603) meet the requirements for the trenchless installation (i.e. the boreholes shall be located outside but within 2 m of the tunnel's excavated footprint; spacing between the boreholes shall not exceed 50 m; and boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert). Boreholes BH22-08 and BH22-09 were drilled outside the road at the vicinity of the proposed exit and entry shafts respectively, while Borehole BH603 was drilled between these two boreholes from the surface of Muir Road North (Elev. 294.40 m). The location of these boreholes along the proposed culvert are shown on the drawing provided in Appendix C. The drawing also shows the soil profile along the culvert alignment.

Based on this drawing, it is anticipated that the subsurface at the location of the proposed culvert (tunnel) generally consists of compact sand and gravel fills, stiff clayey silt fills and native very stiff to hard silty clays and very stiff to hard clayey silts. However, the tunnel is expected to be driven predominantly through a combination of native very stiff to hard silty clays, very stiff clayey silts and stiff to very stiff clayey silt fills. No groundwater level was observed in boreholes during nor after drilling.

The attached drawing also shows the proposed locations of the entry and exit shafts, suggesting that the tunneling portion of the new culvert will be approximately 46.13 m long. . Review of the existing bridge structure indicates that the proposed location may be within the zone of influence of the bridge foundation elements. The existing abutment spread footing foundation is at Elevation 289.85 m, with an approximately 2.65 m thick compacted Granular 'A' foundation pad. Consideration should be given to moving the proposed location to the south to avoid any potential impacts on the granular pad and structure.

The subsurface condition at the location of both the entry and exit shafts consists of a stiff clayey silt fill underlaying the topsoil layer which is further underlain by a very stiff to hard but predominantly hard silty clay till layer.

A summary of the drilled boreholes in relation to invert elevations for culvert SR7 is presented in Table 2.17 below.

Table 2.17: Summary of SR7 Borehole Locations

Borehole No.	Borehole Elevation (m)	Borehole Depth/Elevation (m)	Borehole Location
BH22-08	287.4	3.65/283.8	Outlet
BH22-09(MW)	287.6	4.40/283.2	Inlet
BH603	294.4	9.60/284.8	Muir Road North

The fill soils are generally considered to be “squeezing” to “running” and becoming “flowing” below the groundwater level as classified in Terzaghi’s Tunnelman’s Ground Classification. At this site, it is expected that the groundwater level will be well below the pipes invert since no groundwater was encountered both during and after drilling. However, the fill material behavior should be anticipated to vary. Moreover, minimal tunneling is expected within the fill layer since the tunnel will be advanced predominantly through the native silty clay till and clayey silt till layers. Both native soil types are also classified as “firm” soils. The possibility of encountering potential cobbles and boulders in the till layers should be anticipated. It is the contractor’s responsibility to select means and method appropriate for the soil and groundwater conditions. Detailed discussions on trenchless installation options are provided below.

6.4.2 Culvert Installation Options

Based on the site conditions and characteristics of methods available, the following options for the culvert construction at the proposed new alignment are discussed in the following sections:

- Jack and bore technique;
- Pipe ramming;
- Micro-tunneling; and
- Horizontal Directional Drilling (HDD) Technique.

The following table summarizes some of the possible alternatives for the culvert installation using trenchless technology and the following sections provide a discussion for some of the options for the proposed trenchless culvert installation.

Table 2.18A: Installation methods comparison

Installation Method	Advantages	Disadvantages
Jack and Bore	• Handles wide variety of ground conditions • Minimal surface disruption • Very accurate (slope of 0.2% easily achieved) • Relatively simple operation • Common use in Ontario • Short mobilization time • Suitable for tunnels up to 1.5 m in diameter and 150 m long	• Requires large area for jacking shaft and support equipment • Relatively high construction costs • Obstructions problematic • Short- and long-term settlement • Fluid to support annular space • Pipe can be difficult to steer/direct • Dewatering required along route, if the GWL is high
Pipe Ramming	• Not very sensitive to ground condition	• Pipe can be difficult to steer/direct • Large entry pit size

Installation Method	Advantages	Disadvantages
	• Suitable for steel pipes up to 1.8 m in diameter and best up to 50 m long • Accommodates obstructions well • Little surface settlement • Soil removed after pipe in place	• Possible ground heave • Excavation and shoring required to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment • Vibrations could potentially impact the stability of the existing slope and neighbouring structures • Slower than other trenchless methods • More expensive than cut and cover methods and jack and bore method
Microtunneling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Suitable for tunneling under groundwater table • Alignment can be adjusted to avoid obstructions • Suitable for tunnels with 250 – 3000 mm in diameter and up to 300 m in length with Intermediate Jacking Stations (IJS) every 75 m • Local skilled contractor is available in the area	• High construction costs • Requires large area for jacking shaft and support equipment. • Short- and long-term settlement • Require sophisticated equipment
Directional Drilling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Does not require staging pits • Alignment can be adjusted to avoid obstructions • Local contractors are available in the area • Short mobilization time • Rapid drilling • Minor settlement if fluid well controlled • Less expensive than microtunneling	• Potential for inadvertent drilling returns • Requires drilling fluid to maintain the bore which could allow subsidence • Annular space filling (i.e. fluid or grouting) • Suitable for installation of pipes up to 1.0 m in diameter and up to 475 m in length

Table 2.18B: General comparison of technical issues associated with trenchless methods

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
Typical limitations: Length of drive & Diameter	• Drive lengths to 150m • Diameters up to 1.5m are feasible	• Generally best suited to short watercourse crossings where risks imposed by ground surface heave are low • 30 to 60m drives are typical • Diameters of 1800mm are technically feasible with a large hammer, however, the stability / integrity of the soil plug in the lead pipe segment is less certain with larger diameters	• Drive lengths of 300m are typical, provided that Intermediate Jacking Stations (IJS) are launched every 75m • Micro tunnels up to 1500mm dia. can be readily constructed in Ontario; 3000mm dia. may be feasible by specialists	• Drive pullback lengths of several hundred meters are feasible • In Southern Ontario, HDD diameters less than 750mm are fairly common place but larger bores add risk, complexity and considerable cost
Ability to control line & grade	• Average control of line and grade • Limited ability to steer and to correct grade	• Relatively Poor	• Good • Line and grade control to within ±40mm is feasible over 300m drive	• Specialized tracker system is needed to control line and grade • Fair to Good
Ability to control ground surface displacement	• Poor • No ability to retain running ground	• Poor • Risk of ground heave is moderate to high • If soil plug in lead pipe segment washes out or is breached, then excessive ground loss and settlement will occur	• Good • Slurry shield MTBM can balance earth pressures in the shield to a variety of ground and groundwater conditions • Full and immediate ground support by means of jacking pipe	• Fair • Ground heave and hydro fracturing may result from excessive rates of pullback • Bore stability relies on good quality control and circulation of drilling mud
Ability to deal with Mixed face ground Conditions	• Mixed face conditions will likely cause line and grade deviations to occur • Overmining may result when augering is labored due to hard ground • Augers may jam on rock slabs	• Mixed face conditions will likely deviate the line and grade	• Good • High pressure water jets are necessary to breakdown cohesive clays	• Mixed ground may interfere with line and grade control
Ability to deal with Flowing / unstable face Conditions	• No ability to deal with flowing / unstable face conditions • Flowing soils may result in total collapse / excessive ground loss • Method is unsuitable in cohesionless soils below the water table	• The ability to retain flowing ground depends entirely on maintaining a soil plug in the lead pipe segment. If the plug breaches, then the bore may fail	• Slurry shield MTBMs are better suited to flowing ground conditions than any other trenchless method	• Bore wall stability can be maintained with suitably viscous drilling fluid and filter cake buildup on bore wall • Risk of pipe jamming during pullback if stones / cobbles become dislodged from crown of bore
Ability to deal with	• For bores >900mm, auger removal and personnel entry are needed to break up	• Typically better than Jack & Bore • May require removal of soil plug to remove /	• Combination of disk and pick cutters is needed	• Cobbles and rock slabs may jam pipe in bore during pullback

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
Cobbles & boulders and other obstructions	boulders, however the tunnel face must be cohesive for this to be safely conducted	breakup boulder which could possibly compromise tunnel stability	• Person entry not practical • Wood troublesome	• Boulders will result in a failed bore
Option feasibility for this site	• Feasible	• Feasible	• Feasible	• Feasible

6.4.2.1 Jack and Bore

The jack and bore method involve drilling a borehole from a jacking pit (entry pit) with a rotary cutter head within the confines of a steel casing or liner jacked ahead for support. The casing is pushed through the soil with a hydraulic ram, and soil is removed with an auger. A cutting head is fixed to the leading edge of the culvert. The auger transports spoils from the cutting head back to the jacking pit. The procedures must conform to all relevant OPSS standards and industrial standards.

Based on the information from the boreholes drilled in the vicinity of new culvert, it is expected that the tunnel boring is expected to be driven predominantly through a combination of native very stiff to hard silty clays, very stiff clayey silts and stiff to very stiff clayey silt fills and the groundwater level will be below the culvert invert elevations at the inlet and outlet (~Elev. 286.64 m and 286.40 m). Considering these conditions as well as the proposed culvert diameter of 0.76/0.75 m, pipe jacking using mechanical means is an acceptable alternative for the installation of culvert SR7.

To reduce loss of ground and groundwater ingress (if any), consideration may be given to jacking the casing across the alignment as far as possible, prior to auguring. Lubricant selected based on the characteristics of the surrounding soil, may be provided to reduce the friction between the casing and the borehole walls. However, obstacles such as deleterious debris, e.g., wood, which should be anticipated in the fill could make this difficult or impractical. EXP recommends the lead auger be kept at least one casing diameter behind the lead end of the casing to minimize the potential for ground losses. Furthermore, any significant voids between the casing and the surrounding soil should be filled with pressurized cementitious grout to prevent / minimize ground loss. In addition, the installation of the proposed culvert must not interfere with existing utilities. Therefore, driving of the pipe must be fairly accurate noting that there is only limited steering ability, where minor adjustments can be made should it be necessary or to address obstructions. Generally, utility tunneling using pipe jacking method is a relatively slow and labor-intensive process. The actual tunnel advance rate is a function of soil conditions encountered, method of soil excavation, spoil removal, pipe liners materials, and field conditions.

To minimize possible negative impact on the stability of the existing embankment slope due to excavations required for the bore/jacking pits and installation of the pipe using the pipe jack and auger bore method, a protection system might be required for the existing roadway. Excavation shoring for the pits will be addressed in the following sections of this report.

6.4.2.2 Pipe Ramming

The pipe ramming is a trenchless method for installation of steel pipes over distances typically up to 50 m long and up to 1.8 m in diameter. The method uses pneumatic percussive blows to drive the pipe into ground. Spoil removal from the pipe can be done by auger. It typically requires excavation of two pits, but the ramming can be launched without an insertion pit if the ram is designed to start at the side of a slope. It should be noted that installation is very noisy and difficult to steer, and its vibration could destabilize the embankment slope with potential impact on adjacent existing structures.

Considering the length of the proposed culvert, the pipe ramming method is feasible for the proposed installation. However, the potential for vibration induced issues and steerability impacts it priority in ranking.

6.4.2.3 Microtunneling

Microtunneling should be feasible to install the proposed culvert. Microtunneling method is a non-entry, remotely controlled, guided 2-stage process, which provides continuous support to the excavation face. In this method a Micro Tunneling Boring Machine (MTBM) is used for soil cutting, while a pipe is jacked into place behind the cutting head with hydraulics. The MTBM is equipped with a slurry spoil removal system to control the groundwater inflow and counterbalance the earth and hydrostatic pressure while tunneling through the mixed face conditions. The cutting tool and the drilling fluid must be able to handle the different materials and the "mixed face" condition. To minimize the resistance along the pipe exterior, a bentonite grout lubricant can be injected behind the cutting face. Steel, concrete or fibreglass pipes can be installed with this method.

The major advantage of microtunneling method is that its performance is not affected by high groundwater levels, so the dewatering is not required; which is not a case for this project. Major disadvantage of microtunneling for this project is the relatively high cost. This option may become more attractive if potential bidders have available equipment in house.

Considering the length of the proposed culvert, no Intermediate Jacking Stations (IJS) will be required. For excavation of the launching pit, a protection system might be required to minimize possible negative impact on the stability of the existing embankment slope. Based on the length and size of the culvert, microtunneling is an acceptable alternative for the installation of culvert SR7.

6.4.2.4 Horizontal Directional Drilling (HDD)

Horizontal Directional Drill installation should follow the requirements of OPSS.PROV 450. If there is enough space to achieve entry and exit angles as recommended in ASTM F1962-11 (12° to 15° for bore entry and 10° for bore exit), horizontal directional drilling (HDD) should be considered for the culvert installation, provided the drill hole is at all times supported with a properly designed drilling fluid. Given that the proposed culvert installation will be within the slope of the embankment, installation via HDD may require significant build up at the entry and exit points to allow for construction to follow best practices. HDD is also typically a more expensive option. Based on the size of the proposed culvert diameter (D~0.76/0.75 m) this method is an acceptable alternative for the installation of culvert SR7, noting the construction related issues discussed above.

6.4.2.5 Discussion of Drilling Methods

The pipe ramming method for installation is suitable at this site since the culvert is shorter than 50 m. In addition, the HDD method is also suitable as well since the proposed culvert diameter is less than 1.0 m.

The microtunneling method is a feasible method and local, experienced contractors have successfully installed pipes using this method. If a qualified and experienced contractor is used for construction, the required alignment/slope can be achieved with minimal risk for short- and long-term settlements. However, the initial installation cost is anticipated to be higher than the alternatives.

Although difficulty in directing the drill head should be anticipated, the jack and bore method of installation is considered the preferred option from a feasibility and cost perspective. A summary of the recommendation based on the various methods is presented in Table 2.19 below.

Table 2.19: Summary of Recommendations

Installation Method	Recommendation
Jack and Bore	Preferred
Pipe Ramming	Acceptable
Microtunneling	Acceptable
Directional Drilling	Acceptable

6.4.3 Entry and Exit Shafts

6.4.3.1 Excavation of Shafts

All excavations for entry (launching) and exit (receiving) shafts must be completed in accordance with the most recent regulations of the Ontario Occupation Health and Safety Act (OHSA). The encountered fill and native soils may generally be classified as Type 2 and Type 3 soils above the groundwater level and Type 4 soils below the groundwater level in conformance with the OHSA.

Temporary excavation side slopes in Type 2 and Type 3 soils should remain stable at a slope of 1H:1V. Excavation side slopes in Type 4 soils should remain stable at a slope of 3H:1V. The need to excavate flatter side slopes if excessively wet or soft/loose materials, or concentrated seepage zones are encountered, should not be overlooked. Water (i.e., surface water runoff) should not be permitted to enter and/or pond within the construction area.

To limit the extents of the excavation and protect the existing embankment, temporary shoring may be required for this project. Note that in accordance with the OHSA pre-engineered excavation support methods are not suitable for use in Type 4 soils and a temporary support method must be designed by a professional engineer.

Excavations for the proposed culvert construction is expected to extend to depths greater than 1.5 m below existing grades at the inlet and outlet. As such, the construction excavation bases may consist of materials such as silty sand/sandy silt fill and native sandy silt. Basal instability is not anticipated in excavations since the groundwater level is significantly below the base of excavation.

6.4.3.2 Backfilling of Shafts

It is anticipated that backfilling work will be required at the entry and exit shafts to return site condition to pre-construction grades. The following comments and recommendations are provided for backfilling such excavations.

All excavations should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted to at least 95% of the Standard Proctor Maximum Dry Density (SPMDD). Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials.

All backfill and compaction operations should be monitored by qualified geotechnical personnel to approve materials, to evaluate placement operations, and to verify that the specified degree of compaction is being achieved throughout the fill.

6.4.4 Dewatering

Surface water should be always directed away from the excavation area(s) at all times. Based on an assessment of the water levels observed in the adjacent borings/piezometers, groundwater at the site is interpreted to be non-existent. The soils encountered within potential excavation depths will consist of clayey silts and silty clays. These materials (particularly the deposits with high silt content) are susceptible to disturbance from groundwater and mobilized equipment. As such, the groundwater level needs to be controlled below the excavation level to avoid disturbance. Given the conditions at this site, it is anticipated that control of seepage can be accomplished by conventional pumping from sumps in oversize excavations. This dewatering can likely be achieved by gravity drainage and pumping from strategically placed sumps with side ditches. Confirmation of control should be verified before general excavation to final levels.

At this site, it is not expected to require registry on EASR or need to obtain PTTW. However, it is noted that dewatering operations more than 50,000 L/day will require a Permit to Take Water (PTTW); EXP can be contacted to provide additional hydrogeological services, if required.

All collected water should be discharged a sufficient distance away from the excavated area to prevent the water from re-entering the excavation. Sediment control measures such as silt fences should be provided at the discharge point of the dewatering system. Caution should also be taken to avoid any adverse impact to the environment.

Dewatering shall be carried out in accordance with OPSS.PROV 517, SP 517F01 and SP FOUN0003. As noted in the SP FOUN0003 working drawings, discharge of water, monitoring and removal of the dewatering system should be according to OPSS 517. The method used should not undermine the adjacent existing footings and utilities. Alternatively, and in accordance with SP 5017F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5 year experience.

6.4.5 Temporary Shoring

The temporary shoring that may be required for tunneling should be designed to resist lateral earth pressure. The lateral earth pressure acting on supported walls may be computed using the following equation, assuming a rectangular pressure distribution and that appropriate dewatering will be carried out:

$P = K(\gamma h + q)$ for non-braced cut, or $K(0.65\gamma H + q)$ for braced support

where
P = earth pressure intensity at depth h, kPa
K = earth pressure coefficient
γ = unit weight of retained soil, kN/m^3
q = surcharge near wall, kPa
h = depth to point of interest, m
H= total depth of excavation, m

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation (rotation of 0,002 about the base of vertical walls (horizontal displacement divided by wall height) or translation of 0.001 times wall height or combination of these). Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design. For design purposes, the unfactored static earth pressure parameters are given in Table 2.20 of this report.

Table 2.20: Material types and unfactored earth pressure properties under static conditions

Material	Unfactored Friction Angle ϕ' (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)	Unit Weight γ (kN/m^3)
Compacted Granular A or Granular B Type II	35	0.27	3.69	0.43	22
Compacted Granular B Type I	32	0.31	3.25	0.47	21
Compact sand and gravel fill	30	0.33	3.00	0.50	20
Firm to stiff clayey silt fill	28	0.36	2.77	0.53	19
Very stiff to hard silty clay till(1)	30	0.33	3.00	0.50	19

Material	Unfactored Friction Angle ϕ' (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)	Unit Weight γ (kN/m³)
Very stiff to hard clayey silt till(1)	31	0.32	3.12	0.48	20

Notes:

1 Assumes long term conditions. In short term conditions K_a = K_p = 1.

2 Values given for horizontal earth pressures are for horizontal backfill. For sloping backfill, the design requirements outlined in CHBDC clause 6.12.2.2 should be used.

Temporary shoring system should be designed and constructed in accordance with OPSS.PROV 539 as amended by SP105S09. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

It is considered that a sheet pile of sufficiently robust cross section could be driven through the native layers encountered at this site location. Difficulties with installation may occur where occasional boulders are encountered in the native layers (i.e., boulders not encountered in the boreholes drilled during this investigation), requiring their removal before further driving. Alternatively, an H-pile with lagging wall can be used as a vertical temporary shoring system. The H-piles are installed, and lagging is inserted between installed H-piles during excavation. Space between the excavation and lagging must be suitably backfilled and drained. Lagging wall material can be selected as wood (timber), steel or concrete.

For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided if the center-to-center spacing of the soldier piles does not exceed 2.5 m. Soldier piles should extend a minimum depth of 3.0 m below the planned excavation depth. The actual depth of embedment should be determined by balancing moments about the pile tip. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours. Any loose zones from behind the shoring should be prevented during installation of the protection system. If required, backfill Granular A should be placed and compacted behind the shoring wall.

For the relatively shallow depth of excavation anticipated, cantilevered systems may be adequate. However, depending on the actual excavation depth and shoring system used, additional anchorage or tiebacks may be required. This must be confirmed by the shoring designer. Conventional practice is to incorporate either buried deadman anchors, rakers or grouted soil anchors. Deadman anchors can be designed based on the earth pressure coefficients and soil parameters provided in Table 2.20. For this project, either continuous or individual concrete block anchors would likely be appropriate. The anchor resistance is provided by a combination of the dead weight and passive resistance. For the full passive resistance to be realized with no load transfer to the wall, the anchor needs to be fully beyond the active wedge acting on the wall. Pressure grouted soil anchors can be designed in a preliminary fashion in accordance with Section 26 of the CFEM (2006). Based on the generally stiff to very stiff clayey silt to silty clay till at this site, the estimated factored (α=0.4) ULS resistance of grouted anchors would be approximately 24 kN/m length. Detailed design should be completed following the conception of the wall and when the associated loads have been established. Normally, such anchors are supplied and installed/tested by specialist vendors/contractors.

6.4.6 Ground Movement Monitoring

Following the CMO- Guidelines for Tunneling it is recommended that ground movement monitoring be carried out for this site To identify potential movements which could result in damage to existing utilities or structures along the culvert alignment. Monitoring details are provided in Appendix F – NSSP for Culvert Installation by Trenchless Method.

A condition survey should be carried out before the construction takes place, and after the completion of the proposed bore. The survey should document the pavement surface conditions (i.e., cracks, distortion and deviations, heaves, and depressions).

An average of at least two readings should be taken prior to construction to establish the initial conditions. Provided these readings are consistent within 2 mm of eachother, the average of the two may be used as the Baseline Readings. If the difference in values are greater than 2 mm, then the process shall be repeated until the desired accuracy is achieved.

A procedure should be established to ensure that the monitoring data will reach all parties as soon as possible. The consultant and the contractor should interpret monitoring data as needed. The Foundation Engineer will be contacted for technical support in the interpretation of the ground movements and review of the contractor response when review and alert levels are reached.

6.4.7 Scour/Erosion

Scour/erosion protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist Hydraulic engineer (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions, considering that the boreholes indicate that below some surficial deposits, the main soil type consists as a combination with silt and/or sand.

The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented and remain effective for the design life of the culvert. The potential for scour below foundations must be incorporated into the design. The proposed foundation design for non-structural culverts incorporates shallow foundations and requires such assessment and/or protection.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope which for the subsoils materials should be no steeper than 2H:1V for stability reasons.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts the following are typical options for seepage cutoff approaches: typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, cutoff wall incorporated in the apron slab (if one is used) of the culvert, cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert.

Open footing foundations can be protected against structural undermining by locating the foundations at an appropriate depth, by provided rock protection and/or by using sheet piling. Sheet piling used for this purpose should be designed to accommodate the assessed scour depths. In some cases, it may be possible to incorporate sheeting in temporary dewatering schemes. Typically, the inlet and outlet of a culvert require protection.

A clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS 1205.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic design engineer experienced in this field. Pertinent geotechnical parameters to support this design have been provided in this report. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters are determined based on the soils encountered at the site during this investigation and are presented on the borehole logs performed by EXP attached in Appendix D and the graphs included in Appendix E and borehole logs and graphs prepared by others attached in Appendix H. All tested soils were classified using the Unified Soil Classification System which can be used for evaluation. EXP will review the scour analysis technical memorandum from the Hydraulic design engineer to check that the interpretation of the geotechnical soil types and thickness are in good agreement with the borehole information provided in this report.

Scour design is a multi-disciplinary exercise that involves the structural and hydrology designer as well as the geotechnical designer working as a team.

6.5 Installation of Culvert SR8

6.5.1 General

Trenchless (Tunneling) Method is preferred by CONSOR for the installation of culvert SR8. Based on the GA drawings, Culvert SR8 will be a newly constructed 1.22 m HDPE Closed Profile Pipe Culvert/1.20 m Steel Pipe Culvert (Spiral Rib 19 x 19 x 190 with 2.0 mm thick wall) approximately 41.12 m in length located at Station 13+575 along Hwy 403. The culvert invert level is proposed to be at an approximate elevation of 277.152 m at the inlet and 276.845 m at the outlet. A summary of the proposed culvert specification for SR7 is presented in Table 2.21 below.

Table 2.21: Summary of Culvert Specifications

Culvert ID.	Station	Invert Elevation		Approximate Length (m)	Diameter (m) / Height x Span (m)	Material
		Inlet	Outlet			
SR8	13+575	277.152	276.845	41.12	1.22/1.20	HDPE/Steel

For trenchless installation methods, the procedures should conform to all relevant Ontario Provincial Standard Specifications (OPSS), Non-Standard Special Provisions (NSSP) such as Pipe Installation by Trenchless Method, CMO- Guidelines for Tunneling and all other industrial standards.

Considering the requirements noted in the above documents, drilled boreholes in the vicinity of the proposed culvert SR8 (BH22-10, BH22-11, BH22-12MW) meet the requirements for the trenchless installation (i.e. the boreholes shall be located outside but within 2 m of the tunnel's excavated footprint; spacing between the boreholes shall not exceed 50 m; and boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert). Boreholes BH22-10 and BH22-12MW were drilled outside to the left and right of West Quarter Townline Road at the vicinity of the proposed entry and exit shafts respectively, while Borehole BH22-11 was drilled between these two boreholes from the surface of West Quarter Townline Road (the surface ground Elev. 284.62 m). The location of these boreholes along the proposed culvert are shown on the drawing attached in Appendix C. The drawing also shows the soil profile along the culvert alignment.

Based on this drawing, it is anticipated that the subsurface at the location of the proposed culvert (tunnel) generally consists of granular fills, loose to compact sandy silt fills, loose to dense silty sand fills, stiff to very stiff sandy clayey silt fills, and both native stiff to hard silty clay till and stiff to very stiff clayey silt till. However, the tunnel is expected to be driven predominantly through a combination of loose to compact sandy silts, compact silty sands, and both native stiff silty clays and stiff clayey silts. No groundwater level was observed in boreholes during nor after drilling.

A summary of the drilled boreholes in relation to invert elevations for culvert SR8 is presented in Table 2.22 below.

Table 2.22: Summary of SR8 Borehole Locations

Borehole No.	Borehole Elevation (m)	Borehole Depth/Elevation (m)	Borehole Location
BH22-10	277.8	5.17/272.7	Inlet
BH22-11	284.6	12.65/272.0	West Quarter Townline Road
BH22-12(MW)	277.8	5.17/272.7	Outlet

The attached drawing also shows the proposed locations of the entry and exit shafts, suggesting that the tunneling portion of the new culvert will be approximately 41.12 m long. . Review of the existing bridge structure indicates that the proposed location may be within the zone of influence of the bridge foundation elements. The existing abutment spread footing foundation is at Elevation 279.6 m, with an approximately 2.5 m thick compacted Granular 'A' foundation pad. Consideration should be given to moving the proposed location to the north to avoid any potential impacts on the granular pad and structure.

The subsurface at the location of the entry shaft consists of a loose sandy silt fill underlaying the topsoil which is further underlain by a stiff to very stiff clayey silt till layer. A very stiff silty clay layer till was further encountered under the clayey silt layer. At the exit shaft, the subsurface consist of a compact sandy silt fill underlaying the topsoil which is further underlain by a stiff to very stiff silty clay till layer.

The fill soils are generally considered to be "squeezing" to "running" and becoming "flowing" below the groundwater level as classified in Terzaghi's Tunnelman's Ground Classification. At this site, no groundwater interference is expected since no observations were made during nor after completion of boreholes. However, the fill material behavior should be anticipated to vary. In general, the native soil at the site consists of silty clay till that is generally stiff to hard in nature and clayey silt till that is generally stiff to very stiff in nature. Both native soil types are classified as "stiff" soil. The possibility of encountering potential cobbles and boulders in the till layers should be anticipated. It is the contractor's responsibility to select means and method appropriate for the soil and groundwater conditions. Detailed discussions on trenchless installation options are provided below.

6.5.2 Culvert Installation Options

Based on the site conditions and characteristics of methods available, the following options for the culvert construction at the proposed new alignment are discussed in the following sections:

- Jack and bore technique;
- Pipe ramming;
- Micro-tunneling; and
- Horizontal Directional Drilling (HDD) Technique.

The following table summarizes some of the possible alternatives for the culvert installation using trenchless technology and the following sections provide a discussion for some of the options for the proposed trenchless culvert installation.

Table 2.23A: Installation methods comparison

Installation Method	Advantages	Disadvantages
Jack and Bore	• Handles wide variety of ground conditions • Minimal surface disruption • Very accurate (slope of 0.2% easily achieved) • Relatively simple operation • Common use in Ontario • Short mobilization time • Suitable for tunnels up to 1.5 m in diameter and 150 m long	• Requires large area for jacking shaft and support equipment • Relatively high construction costs • Obstructions problematic • Short- and long-term settlement • Fluid to support annular space • Pipe can be difficult to steer/direct • Dewatering required along route, if the GWL is high
Pipe Ramming	• Not very sensitive to ground condition • Suitable for steel pipes up to 1.8 m in diameter and best up to 50 m long • Accommodates obstructions well • Little surface settlement • Soil removed after pipe in place	• Pipe can be difficult to steer/direct • Large entry pit size • Possible ground heave • Excavation and shoring required to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment • Vibrations could potentially impact the stability of the existing slope and neighbouring structures • Slower than other trenchless methods • More expensive than cut and cover methods and jack and bore method
Microtunneling	• Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Suitable for tunneling under groundwater table • Alignment can be adjusted to avoid obstructions • Suitable for tunnels with 250 – 3000 mm in diameter and up to 300 m in length with Intermediate Jacking Stations (IJS) every 75 m • Local skilled contractor is available in the area	• High construction costs • Requires large area for jacking shaft and support equipment. • Short- and long-term settlement • Require sophisticated equipment
Directional Drilling	• Handles wide variety of ground conditions	• Potential for inadvertent drilling returns

Installation Method	Advantages	Disadvantages
	• Steerable both horizontally and vertically to maintain and adjust alignment • Does not require staging pits • Alignment can be adjusted to avoid obstructions • Local contractors are available in the area • Short mobilization time • Rapid drilling • Minor settlement if fluid well controlled • Less expensive than microtunneling	• Requires drilling fluid to maintain the bore which could allow subsidence • Annular space filling (i.e. fluid or grouting) • Suitable for installation of pipes up to 1.0 m in diameter and up to 475 m in length

Table 2.23B: General comparison of technical issues associated with trenchless methods

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
Typical limitations: Length of drive & Diameter	• Drive lengths to 150m • Diameters up to 1.5m are feasible	• Generally best suited to short watercourse crossings where risks imposed by ground surface heave are low • 30 to 60m drives are typical • Diameters of 1800mm are technically feasible with a large hammer, however, the stability / integrity of the soil plug in the lead pipe segment is less certain with larger diameters	• Drive lengths of 300m are typical, provided that Intermediate Jacking Stations (IJS) are launched every 75m • Micro tunnels up to 1500mm dia. can be readily constructed in Ontario; 3000mm dia. may be feasible by specialists	• Drive pullback lengths of several hundred meters are feasible • In Southern Ontario, HDD diameters less than 750mm are fairly common place but larger bores add risk, complexity and considerable cost
Ability to control line & grade	• Average control of line and grade • Limited ability to steer and to correct grade	• Relatively Poor	• Good • Line and grade control to within ±40mm is feasible over 300m drive	• Specialized tracker system is needed to control line and grade • Fair to Good
Ability to control ground surface displacement	• Poor • No ability to retain running ground	• Poor • Risk of ground heave is moderate to high • If soil plug in lead pipe segment washes out or is breached, then excessive ground loss and settlement will occur	• Good • Slurry shield MTBM can balance earth pressures in the shield to a variety of ground and groundwater conditions • Full and immediate ground support by means of jacking pipe	• Fair • Ground heave and hydro fracturing may result from excessive rates of pullback • Bore stability relies on good quality control and circulation of drilling mud
Ability to deal with	• Mixed face conditions will likely cause line and grade deviations to occur	• Mixed face conditions will likely deviate the line and grade	• Good • High pressure water jets are necessary to	• Mixed ground may interfere with line and grade control

	Jack & Boring	Pipe ramming	Microtunneling	Horizontal Directional drilling (HDD)
Mixed face ground Conditions	• Overmining may result when augering is labored due to hard ground • Augers may jam on rock slabs		breakdown cohesive clays	
Ability to deal with Flowing / unstable face Conditions	• No ability to deal with flowing / unstable face conditions • Flowing soils may result in total collapse / excessive ground loss • Method is unsuitable in cohesionless soils below the water table	• The ability to retain flowing ground depends entirely on maintaining a soil plug in the lead pipe segment. If the plug breaches, then the bore may fail	• Slurry shield MTBMs are better suited to flowing ground conditions than any other trenchless method	• Bore wall stability can be maintained with suitably viscous drilling fluid and filter cake buildup on bore wall • Risk of pipe jamming during pullback if stones / cobbles become dislodged from crown of bore
Ability to deal with Cobbles & boulders and other obstructions	• For bores >900mm, auger removal and personnel entry are needed to break up boulders, however the tunnel face must be cohesive for this to be safely conducted	• Typically better than Jack & Bore • May require removal of soil plug to remove / breakup boulder which could possibly compromise tunnel stability	• Combination of disk and pick cutters is needed • Person entry not practical • Wood troublesome	• Cobbles and rock slabs may jam pipe in bore during pullback • Boulders will result in a failed bore
Option feasibility for this site	• Feasible	• Feasible	• Feasible	• Might not be feasible; too big pipe diameter

6.5.2.1 Jack and Bore

The jack and bore method involve drilling a borehole from a jacking pit (entry pit) with a rotary cutter head within the confines of a steel casing or liner jacked ahead for support. The casing is pushed through the soil with a hydraulic ram, and soil is removed with an auger. A cutting head is fixed to the leading edge of the culvert. The auger transports spoils from the cutting head back to the jacking pit. The procedures must conform to all relevant OPSS standards and industrial standards.

Based on the information from the boreholes drilled in the vicinity of the new culvert, it is expected that the tunnel boring will be driven predominantly through a combination of loose to compact sandy silts, compact silty sands, and both native stiff silty clays and stiff clayey silts. The groundwater level is expected to be below the culvert invert (~Elev. 277.152 m at inlet and 276.845 at outlet). Considering these conditions as well as the proposed culvert diameter of 1.22/1.20 m, pipe jacking using mechanical means is an acceptable option for the installation of culvert SR8.

To reduce loss of ground and groundwater ingress (if any), consideration may be given to jacking the casing across the alignment as far as possible, prior to auguring. Lubricant selected based on the characteristics of the surrounding soil, may be provided to reduce the friction between the casing and the borehole walls. However, obstacles such as deleterious debris, e.g., wood, which should be anticipated in the fill could make this difficult or impractical. EXP recommends the lead auger be kept at least one casing diameter behind the lead end of the casing to minimize the potential for ground losses. Furthermore, any significant voids between the casing and the surrounding soil should be filled with pressurized cementitious grout to prevent / minimize ground loss. In addition, the installation of the proposed culvert must not interfere with existing utilities. Therefore, driving of the pipe must be fairly accurate noting that there is only limited steering ability, where minor adjustments can be made should it be necessary or to address obstructions. Generally, utility tunneling using pipe jacking method is a relatively slow and labor-intensive process. The actual tunnel advance rate is a function of soil conditions encountered, method of soil excavation, spoil removal, pipe liners materials, and field conditions.

To minimize possible negative impact on the stability of the existing embankment slope due to excavations required for the bore/jacking pits and installation of the pipe using the pipe jack and auger bore method, a protection system might be required for the existing roadway. Excavation shoring for the pits will be addressed in the following sections of this report.

6.5.2.2 Pipe Ramming

The pipe ramming is a trenchless method for installation of steel pipes over distances typically up to 50 m long and up to 1.8 m in diameter. The method uses pneumatic percussive blows to drive the pipe into ground. Spoil removal from the pipe can be done by auger. It typically requires excavation of two pits, but the ramming can be launched without an insertion pit if the ram is designed to start at the side of a slope. It should be noted that installation is very noisy and difficult to steer, and its vibration could destabilize the embankment slope with potential impact on adjacent existing structures.

Considering both the length and diameter of the proposed culvert, the pipe ramming method is feasible for the proposed installation. However, the potential for vibration induced issues and steerability impacts it priority in ranking.

6.5.2.3 Microtunneling

Microtunneling should be feasible to install the proposed culvert. Microtunneling method is a non-entry, remotely controlled, guided 2-stage process, which provides continuous support to the excavation face. In this method a Micro Tunneling Boring Machine (MTBM) is used for soil cutting, while a pipe is jacked into place behind the cutting head with hydraulics. The MTBM is equipped with a slurry spoil removal system to control the groundwater inflow and counterbalance the earth and hydrostatic pressure while tunneling through the mixed face conditions. The cutting tool and the drilling fluid must be able to handle the different materials and the “mixed face” condition. To minimize the resistance along the pipe exterior, a bentonite grout lubricant can be injected behind the cutting face. Steel, concrete or fibreglass pipes can be installed with this method.

The major advantage of microtunneling method is that its performance is not affected by high groundwater levels, so the dewatering is not required; which is not a case for this project. Major disadvantage of microtunneling for this project is the relatively high cost. This option may become more attractive if potential bidders have available equipment in house.

Considering the length of the proposed culvert, no Intermediate Jacking Stations (IJS) will be required. For excavation of the launching pit, a protection system might be required to minimize possible negative impact on the stability of the existing embankment slope. Based on the length and size of the culvert, microtunneling is an acceptable alternative for the installation of culvert SR8.

6.5.2.4 Horizontal Directional Drilling (HDD)

Horizontal Directional Drill installation should follow the requirements of OPSS.PROV 450. If there is enough space to achieve entry and exit angles as recommended in ASTM F1962-11 (12° to 15° for bore entry and 10° for bore exit), horizontal directional drilling (HDD) should be considered for the culvert installation, provided the drill hole is at all times supported with a properly designed drilling fluid. Given that the proposed culvert installation will be within the slope of the embankment, installation via HDD may require significant build up at the entry and exit points to allow for construction to follow best practices. HDD is also typically a more expensive option. Based on the required set-up work and the the size of the proposed culvert diameter (D~1.22/1.20 m) this method is an unacceptable alternative for the installation of culvert SR8.

6.5.2.5 Discussion of Drilling Methods

The pipe ramming method for installation is suitable at this site since the culvert is shorter than 50 m. To the contrary, the HDD method is an unsuitable method since the proposed culvert diameter is greater than 1.0 m.

The microtunneling method is a feasible method and local, experienced contractors have successfully installed pipes using this method. If a qualified and experienced contractor is used for construction, the required alignment/slope can be achieved with minimal risk for short- and long-term settlements. However, the initial installation cost is anticipated to be higher than the alternatives.

Although difficulty in directing the drill head should be anticipated, the jack and bore method of installation is considered the preferred option from a feasibility and cost perspective. A summary of the recommendation based on the various methods is presented in Table 2.24 below.

Table 2.24: Summary of Recommendations

Installation Method	Recommendation
Jack and Bore	Preferred
Pipe Ramming	Acceptable
Microtunneling	Acceptable
Directional Drilling	Not Recommended

6.5.3 Entry and Exit Shafts

6.5.3.1 Excavation of Shafts

All excavations for entry (launching) and exit (receiving) shafts must be completed in accordance with the most recent regulations of the Ontario Occupation Health and Safety Act (OHSA). The encountered fill and native soils may generally be classified as Type 3 soils above the groundwater level and Type 4 soils below the groundwater level in conformance with the OHSA.

Temporary excavation side slopes in Type 3 soils should remain stable at a slope of 1H:1V. Excavation side slopes in Type 4 soils should remain stable at a slope of 3H:1V. The need to excavate flatter side slopes if excessively wet or soft/loose materials, or concentrated seepage zones are encountered, should not be overlooked. Water (i.e., surface water runoff) should not be permitted to enter and/or pond within the construction area.

To limit the extents of the excavation and protect the existing embankment, temporary shoring may be required for this project. Note that in accordance with the OHSA pre-engineered excavation support methods are not suitable for use in Type 4 soils and a temporary support method must be designed by a professional engineer.

Excavations for the proposed culvert construction is expected to extend to depths greater than 1.5 m below existing grades at the inlet and outlet. As such, the construction excavation bases may consist of materials such as silty sand/sandy silt fill and native sandy silt. Basal instability is not anticipated in excavations since the groundwater level is significantly below the base of excavation.

6.5.3.2 Backfilling of Shafts

It is anticipated that backfilling work will be required at the entry and exit shafts to return site condition to pre-construction grades. The following comments and recommendations are provided for backfilling such excavations.

All excavations should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted to at least 95% of the Standard Proctor Maximum Dry Density (SPMDD). Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials.

All backfill and compaction operations should be monitored by qualified geotechnical personnel to approve materials, to evaluate placement operations, and to verify that the specified degree of compaction is being achieved throughout the fill.

6.5.4 Dewatering

Surface water should be always directed away from the excavation area(s) at all times. Based on an assessment of the water levels observed in the adjacent borings/piezometers, groundwater at the site is interpreted to be non-existent. The soils encountered within potential excavation depths will consist of sandy silt fills, silty sand fills, silty clay and clayey silts. These materials (particularly the deposits with high silt content) are susceptible to disturbance from groundwater and mobilized equipment. As such, the groundwater level needs to be controlled below the excavation level to avoid disturbance. Given the conditions at this site, it is anticipated that control of seepage can be accomplished by conventional pumping from sumps in oversize excavations. This dewatering can likely be achieved by gravity drainage and pumping from strategically placed sumps with side ditches. Confirmation of control should be verified before general excavation to final levels

At this site, it is not expected to require registry on EASR or need to obtain PTTW. However, it is noted that dewatering operations more than 50,000 L/day will require a Permit to Take Water (PTTW); EXP can be contacted to provide additional hydrogeological services, if required.

All collected water should be discharged a sufficient distance away from the excavated area to prevent the water from re-entering the excavation. Sediment control measures such as silt fences should be provided at the discharge point of the dewatering system. Caution should also be taken to avoid any adverse impact to the environment.

Dewatering shall be carried out in accordance with OPSS.PROV 517, SP 517F01 and SP FOUN0003. As noted in the SP FOUN0003 working drawings, discharge of water, monitoring and removal of the dewatering system should be according to OPSS 517. The method used should not undermine the adjacent existing footings and utilities. Alternatively, and in accordance with SP 5017F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5 year experience.

6.5.5 Temporary Shoring

The temporary shoring that may be required for tunneling should be designed to resist lateral earth pressure. The lateral earth pressure acting on supported walls may be computed using the following equation, assuming a rectangular pressure distribution and that appropriate dewatering will be carried out:

$P = K(\gamma h + q)$ for non-braced cut, or $K (0.65\gamma H + q)$ for braced support

where
P = earth pressure intensity at depth h, kPa
K = earth pressure coefficient
γ = unit weight of retained soil, kN/m^3
q = surcharge near wall, kPa
h = depth to point of interest, m
H= total depth of excavation, m

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation (rotation of 0,002 about the base of vertical walls (horizontal displacement divided by wall height) or translation of 0.001 times wall height or combination of these). Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design. For design purposes, the unfactored static earth pressure parameters are given in Table 2.25 of this report.

Table 2.25: Material types and unfactored earth pressure properties under static conditions

Material	Unfactored Friction Angle ϕ' (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)	Unit Weight γ (kN/m³)
Compacted Granular A or Granular B Type II	35	0.27	3.69	0.43	22
Compacted Granular B Type I	32	0.31	3.25	0.47	21
Loose to compact sandy silt fill	28	0.36	2.77	0.53	18
Loose to dense silty sand	30	0.33	3.00	0.50	19
Stiff to very stiff sandy clayey silt fill(1)	29	0.35	2.88	0.52	19
Stiff to very stiff silty clay till(1)	29	0.35	2.88	0.52	19
Hard silty clay(1)	30	0.33	3.00	0.50	19
Stiff to very stiff clayey silt till(1)	30	0.33	3.00	0.50	19

Notes:

1 *Assumes long term conditions. In short term conditions K_a = K_p = 1.*

2 *Values given for horizontal earth pressures are for horizontal backfill. For sloping backfill, the design requirements outlined in CHBDC clause 6.12.2.2 should be used.*

Temporary shoring system should be designed and constructed in accordance with OPSS.PROV 539 as amended by SP105S09. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

It is considered that a sheet pile of sufficiently robust cross section could be driven through the native layers encountered at this site location. Difficulties with installation may occur where occasional boulders are encountered in the native layers (i.e., boulders not encountered in the boreholes drilled during this investigation), requiring their removal before further driving. Alternatively, an H-pile with lagging wall can be used as a vertical temporary shoring system. The H-piles are installed, and lagging is inserted between installed H-piles during excavation. Space between the excavation and lagging must be suitably backfilled and drained. Lagging wall material can be selected as wood (timber), steel or concrete.

For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided if the center-to-center spacing of the soldier piles does not exceed 2.5 m. Soldier piles should extend a minimum depth of 3.0 m below the planned excavation depth. The actual depth of embedment should be determined by balancing moments about the pile tip. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours. Any loose zones from behind the shoring should be prevented during installation of the protection system. If required, backfill Granular A should be placed and compacted behind the shoring wall.

For the relatively shallow depth of excavation anticipated, cantilevered systems may be adequate. However, depending on the actual excavation depth and shoring system used, additional anchorage or tiebacks may be required. This must be confirmed by the shoring designer. Conventional practice is to incorporate either buried deadman anchors, rakers or grouted soil anchors. Deadman anchors can be designed based on the earth pressure coefficients and soil parameters provided in Table 2.26. For this project, either continuous or individual concrete block anchors would likely be appropriate. The anchor resistance is provided by a combination of the dead weight and passive resistance. For the full passive resistance to be realized with no load transfer to the wall, the anchor needs to be fully beyond the active wedge acting on the wall. Pressure grouted soil anchors can be designed in a preliminary fashion in accordance with Section 26 of the CFEM (2006). Based on the generally stiff to very stiff clayey silt to silty clay till at this site, the estimated factored (α=0.4) ULS resistance of grouted anchors would be approximately 24 kN/m length. Detailed design should be completed following the conception of the wall and when the associated loads have been established. Normally, such anchors are supplied and installed/tested by specialist vendors/contractors.

6.5.6 Ground Movement Monitoring

Following the CMO- Guidelines for Tunneling it is recommended that ground movement monitoring be carried out for this site to identify potential movements which could result in damage to existing utilities or structures along the culvert alignment. Monitoring details are provided in Appendix F – NSSP for Culvert Installation by Trenchless Method.

A condition survey should be carried out before the construction takes place, and after the completion of the proposed bore. The survey should document the pavement surface conditions (i.e., cracks, distortion and deviations, heaves, and depressions).

An average of at least two readings should be taken prior to construction to establish the initial conditions. Provided these readings are consistent within 2 mm of eachother, the average of the two may be used as the Baseline Readings. If the difference in values are greater than 2 mm, then the process shall be repeated until the desired accuracy is achieved.

A procedure should be established to ensure that the monitoring data will reach all parties as soon as possible. The consultant and the contractor should interpret monitoring data as needed. The Foundation Engineer will be contacted for technical support in the interpretation of the ground movements and review of the contractor response when review and alert levels are reached.

6.5.7 Scour/Erosion

Scour/erosion protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist Hydraulic engineer (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions, considering that the boreholes indicate that below some surficial deposits, the main soil type consists as a combination with silt and/or sand.

The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented and remain effective for the design life of the culvert. The potential for scour below foundations must be incorporated into the design. The proposed foundation design for non-structural culverts incorporates shallow foundations and requires such assessment and/or protection.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope which for the subsoils materials should be no steeper than 2H:1V for stability reasons.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts the following are typical options for seepage cutoff approaches: typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, cutoff wall incorporated in the apron slab (if one is used) of the culvert, cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert.

Open footing foundations can be protected against structural undermining by locating the foundations at an appropriate depth, by provided rock protection and/or by using sheet piling. Sheet piling used for this purpose should be designed to accommodate the assessed scour depths. In some cases, it may be possible to incorporate sheeting in temporary dewatering schemes. Typically, the inlet and outlet of a culvert require protection.

A clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS 1205.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic design engineer experienced in this field. Pertinent geotechnical parameters to support this design have been provided in this report. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters are determined based on the soils encountered at the site during this investigation and are presented on the borehole logs performed by EXP attached in Appendix D and the graphs included in Appendix E and borehole logs and graphs prepared by others attached in Appendix H. All tested soils were classified using the Unified Soil Classification System which can be used for evaluation. EXP will review the scour analysis technical memorandum from the Hydraulic design engineer to check that the interpretation of the geotechnical soil types and thickness are in good agreement with the borehole information provided in this report.

Scour design is a multi-disciplinary exercise that involves the structural and hydrology designer as well as the geotechnical designer working as a team.

7 Closure

The recommendations made in this report are in accordance with our present understanding of the project and are provided solely for the team responsible for the design of the works described herein.

A subsurface investigation is a limited sampling of a site; the subsurface conditions have been established only at the test hole locations. Should conditions at the site be encountered which differ from those reported at the test locations, we require that we be notified immediately to assess this additional information and our recommendations, as appropriate. It may then be necessary to perform an additional investigation and analysis.

Details of the limitations of this report are presented as Appendix A, "Limitations and Use of Report".

This Geotechnical Design Report has been prepared by Stephen Fredericks, M.Eng, P.Eng. It was reviewed by Thomas Lardner, PhD., P.Eng and Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact.

Yours truly,

EXP Services Inc.

Stephen Fredericks, M.Eng., P.Eng
Project Engineer

Thomas Lardner, PhD., P.Eng.
Senior Geotechnical Engineer

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Stan E. Gonsalves, M.Eng., P.Eng.
Executive Vice-President
Designated MTO Foundation Contact

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FEB. 02, 2023
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Encl.

References

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Appendix A – Limitations and Use of Report

LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of exp may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by exp. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and exp's recommendations. Any reduction in the level of services recommended will result in exp providing qualified opinions regarding the adequacy of the work. exp can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to exp to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to exp by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. exp has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to exp.

STANDARD OF CARE

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to exp by its client ("Client"), communications between exp and the Client, other reports, proposals or documents prepared by exp for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. exp is not responsible for use by any party of portions of the Report.

USE OF REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. No other party may use or rely upon the Report in whole or in part without the written consent of exp. Any use of the Report, or any portion of the Report, by a third party are the sole responsibility of such third party. exp is not responsible for damages suffered by any third party resulting from unauthorised use of the Report.

REPORT FORMAT

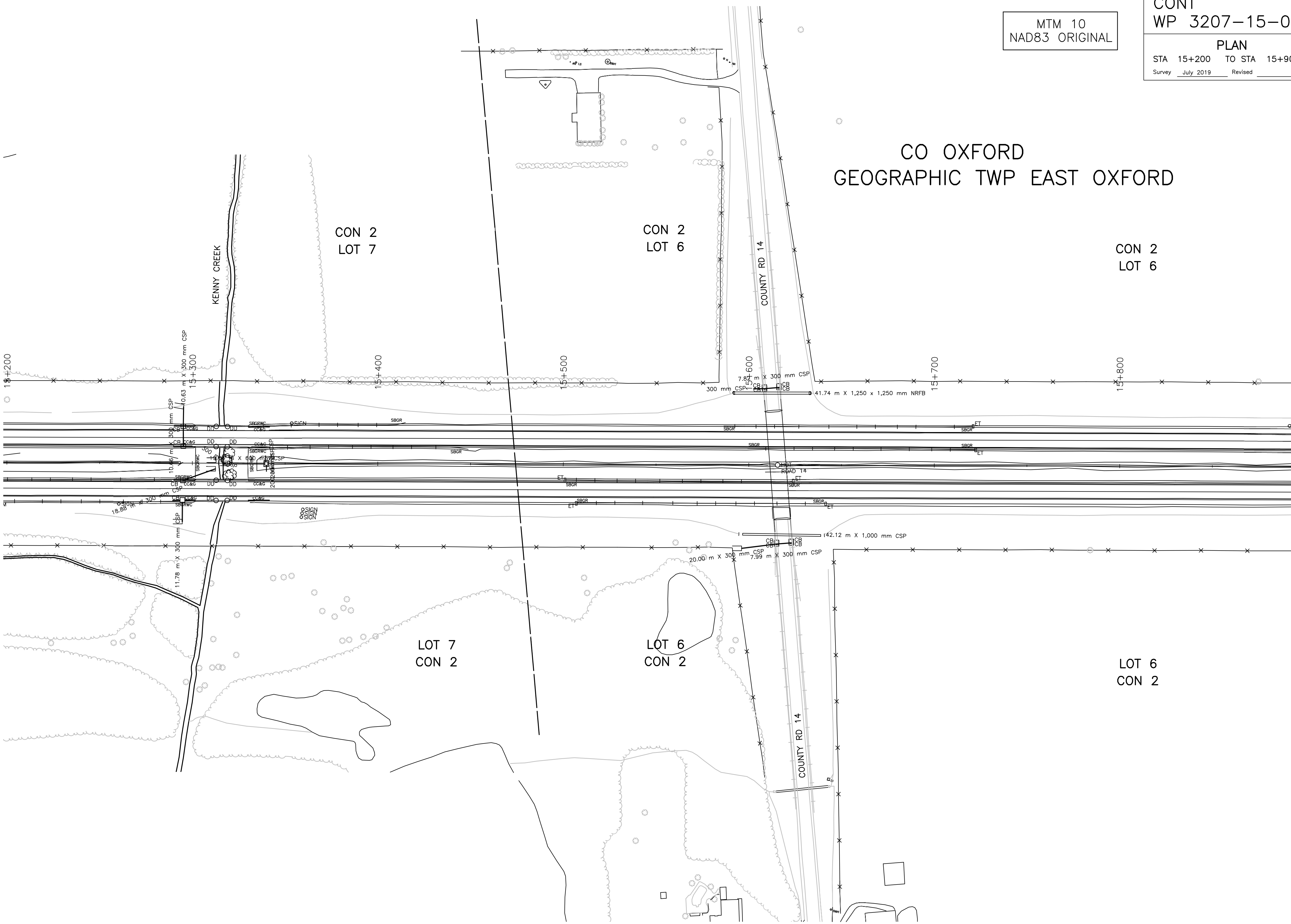
Where exp has submitted both electronic file and a hard copy of the Report, or any document forming part of the Report, only the signed and sealed hard copy shall be the original documents for record and working purposes. In the event of a dispute or discrepancy, the hard copy shall govern. Electronic files transmitted by exp have utilize specific software and hardware systems. exp makes no representation about the compatibility of these files with the Client's current or future software and hardware systems. Regardless of format, the documents described herein are exp's instruments of professional service and shall not be altered without the written consent of exp.

Appendix B – Culvert Plans and Details

METRIC

MTM 10
NAD83 ORIGINAL

PLATE No 89-403/21-0	
CONT WP 3207-15-00	
PLAN	SHEET
STA 15+200 TO STA 15+900	
Survey July 2019 Revised	



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METRIC

MTM 10
NAD83 ORIGINAL

PLATE No 89-403/25-0	
CONT WP 3207-15-00	
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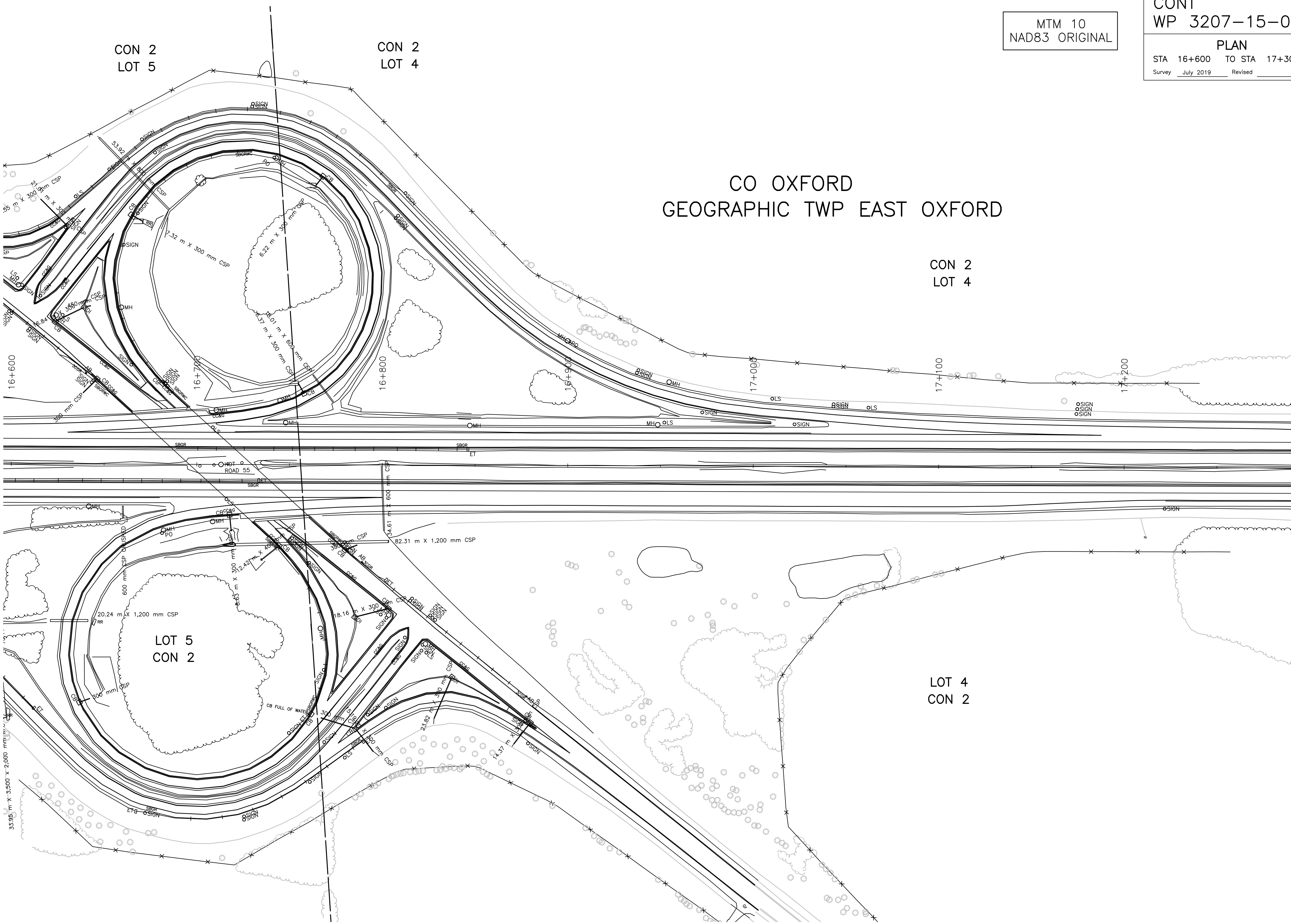
STA 16+600 TO STA 17+300	
Survey July 2019 Revised	



SCALE

MINISTRY OF TRANSPORTATION, ONTARIO PR-D-707 88-05

METRIC

MTM 10
NAD83 ORIGINAL

PLATE No 89-403/31-0	
CONT WP 3207-15-00	
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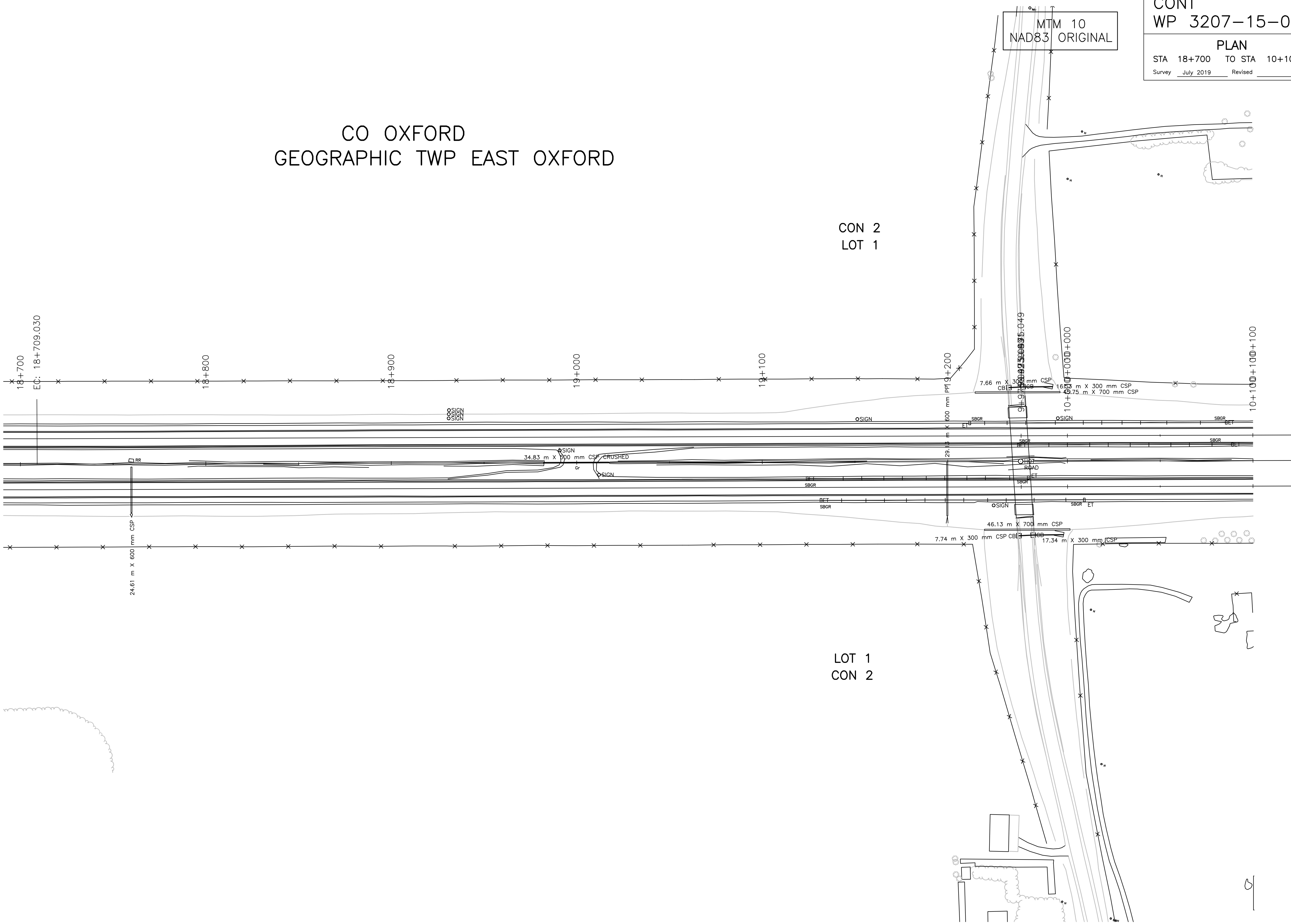
STA 18+700 TO STA 10+100	
Survey July 2019 Revised	

CO OXFORD
GEOGRAPHIC TWP EAST OXFORD



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Horizontal

METRIC

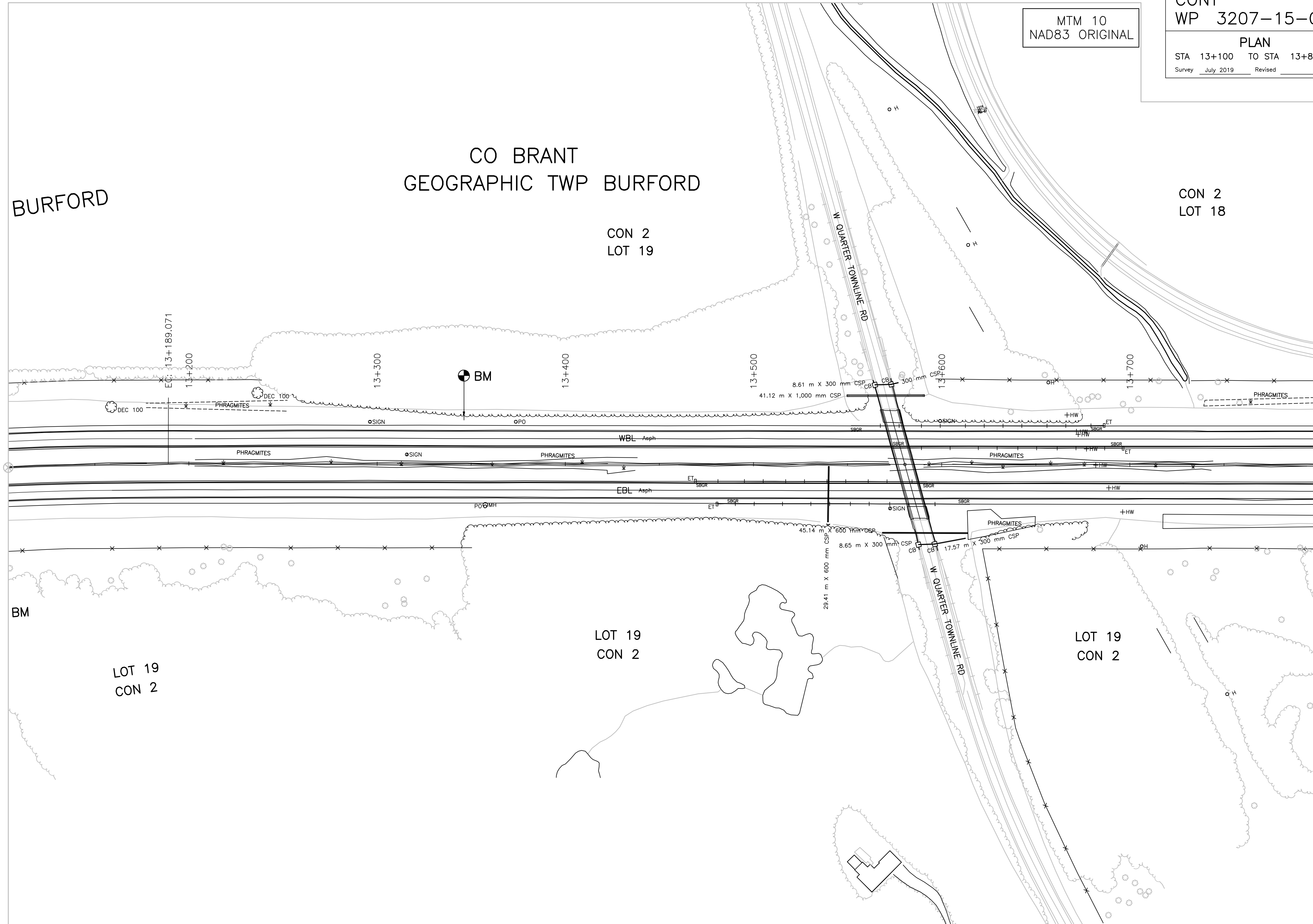
MTM 10
NAD83 ORIGINAL

PLATE No 88-403/15-0

CONT
WP 3207-15-00

PLAN
STA 13+100 TO STA 13+800
Survey July 2019 Revised

SHEET



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MINISTRY OF TRANSPORTATION, ONTARIO PR-D-707 88-05

MODIFIED:

DRAWING NAME:
CREATED:

Appendix C – Borehole Location Plan and Stratigraphic Profile

CONT No. 2021-3006
GWP No. 3207-15-00

Rehabilitation of Hwy 403 from Hwy 401 easterly to 1.4 Km East of West Quarter Townline Road
SR3 Culvert Oxford Road 14

SHEET 1

EXP SERVICES INC.

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

CO OXFORD
GEOGRAPHIC TWP EAST OXFORD

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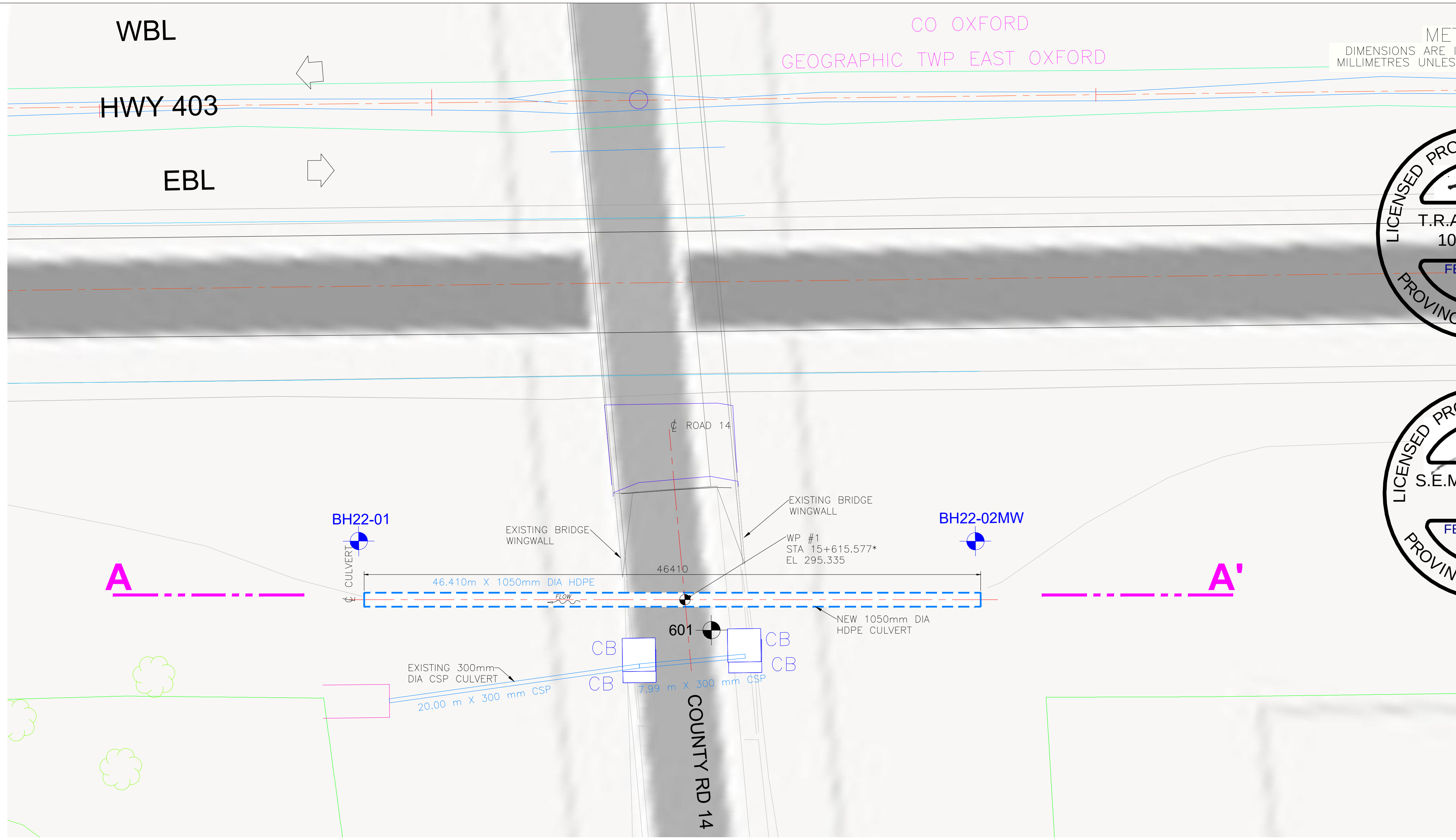
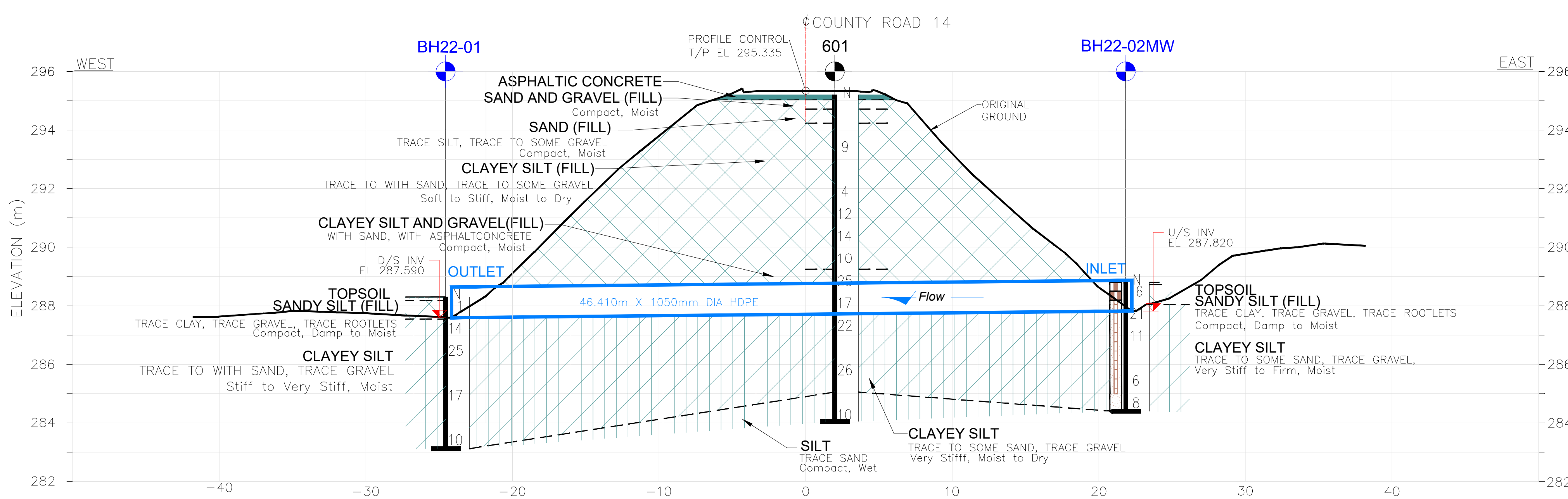


PLAN



SECTION A-A'

HOR 0 5 10 m
VERT 0 2.5 5 m
SCALE

KEY PLAN

LEGEND

- Proposed Borehole Location
- Existing Borehole Location
- Water Level Upon Completion of Drilling (W. L. NOT STABILIZED)
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer

SOIL STRATA SYMBOLS

TOPSOIL
ASPHALTIC CONCRETE
GRANULAR FILL
SILTY CLAY
CLAYEY SILT
SILT

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON 10

BH No.	ELEV.	NORTHING	EASTING
BH22-01	288.3	4776918.4	211554.7
BH22-02MW	288.8	4776925.8	211600.6
601	295.2	4776916.0	211582.0

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.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

REVISIONS

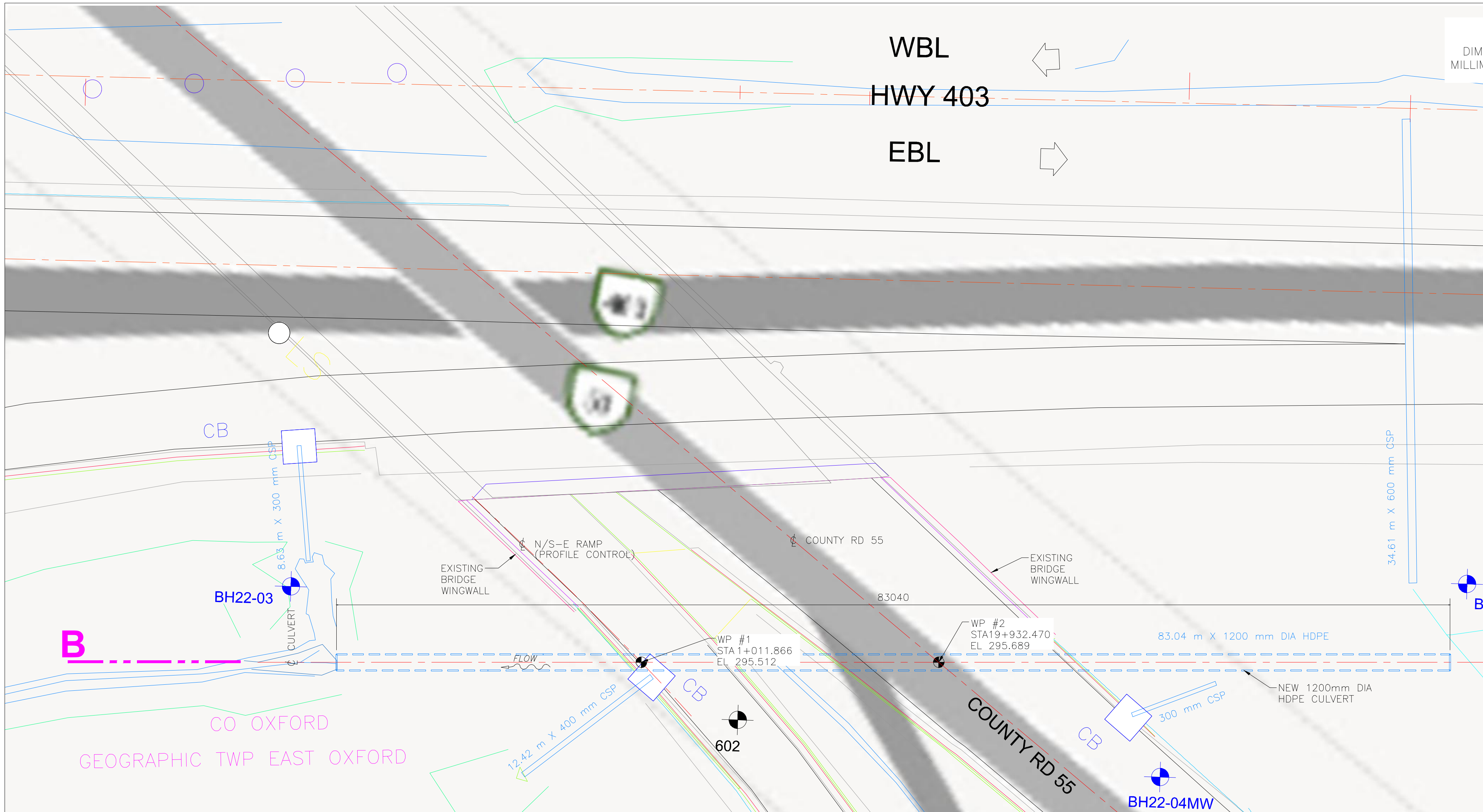
NO	DATE	BY	DESCRIPTION
			SUBMISSION FOR MTO REVIEW
1	Jan 27, 2023	TL	REV FOR MTO COMMENTS
0	Dec 02, 2022	TL	ISSUED FOR CONSTRUCTION

PROJECT No.	ADM-21019451-A0	GEOCRES No.	40P2-89
SUBM'D SH	CHKD. TL	DATE Jan 27, 2023	SITE
DRAWN SH	CHKD. TL	APPD SG	DWG 01

CONT No. 2021-3006		
GWP No. 3207-15-00		
Rehabilitation of Hwy 403 from Hwy 401 easterly to 1.4 Km East of West Quarter Townline Road SR 5 COUNTY RD 55	SHEET	2

EXP SERVICES INC.

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



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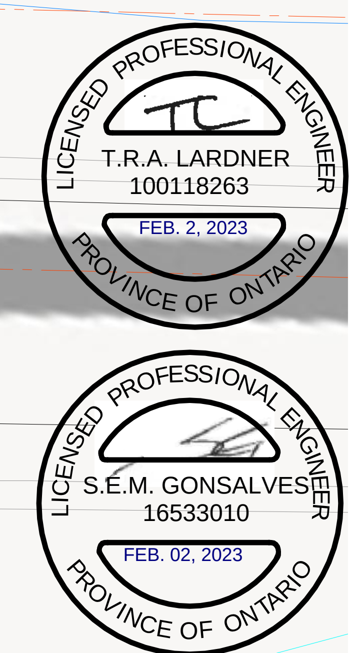

KEY PLAN

LEGEND

- Proposed Borehole Location
- Existing Borehole Location
- Water Level Upon Completion of Drilling (W. L. NOT STABILIZED)
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer

SOIL STRATA SYMBOLS

- TOPSOIL
- ASPHALTIC CONCRETE
- GRANULAR FILL
- SILTY CLAY
- CLAYEY SILT
- SILT

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON 10

BH No.	ELEV.	NORTHING	EASTING
BH22-03	287.9	4777105.3	212662.4
BH22-04MW	295.2	4777103.9	212728.7
BH22-05	287.9	4777122.4	212748.4
602	295.5	4777102.0	212697.0

NOTES

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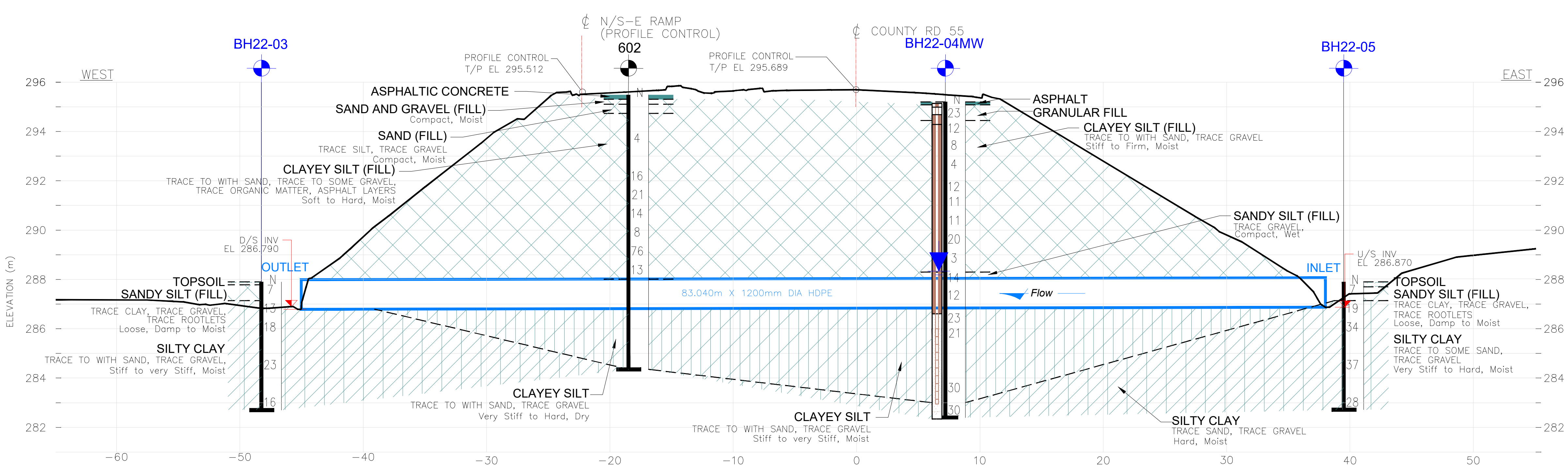

SECTION B-B'

SCALE: HOR 0 – 5 – 10 m; VERT 0 – 2.5 – 5 m

REVISIONS NO	DATE	BY	DESCRIPTION
			SUBMISSION FOR MTO REVIEW
1	Jan 27, 2023	TL	REV FOR MTO COMMENTS
0	Dec 02, 2022	TL	ISSUED FOR CONSTRUCTION

PROJECT No.	ADM-21019451-A0	GEOCRES No.			40P2-89
SUBM'D SH	CHKD. TL	DATE	Jan 27, 2023	SITE	
DRAWN SH	CHKD. TL	APPD	SG	DWG	02

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

CONT No. 2021-3006
GWP No. 3207-15-00

Rehabilitation of Hwy 403 from Hwy 401 easterly to 1.4 Km East of West Quarter Townline Road
SR 6 MUIR RD NORTH

SHEET 3

EXP SERVICES INC.

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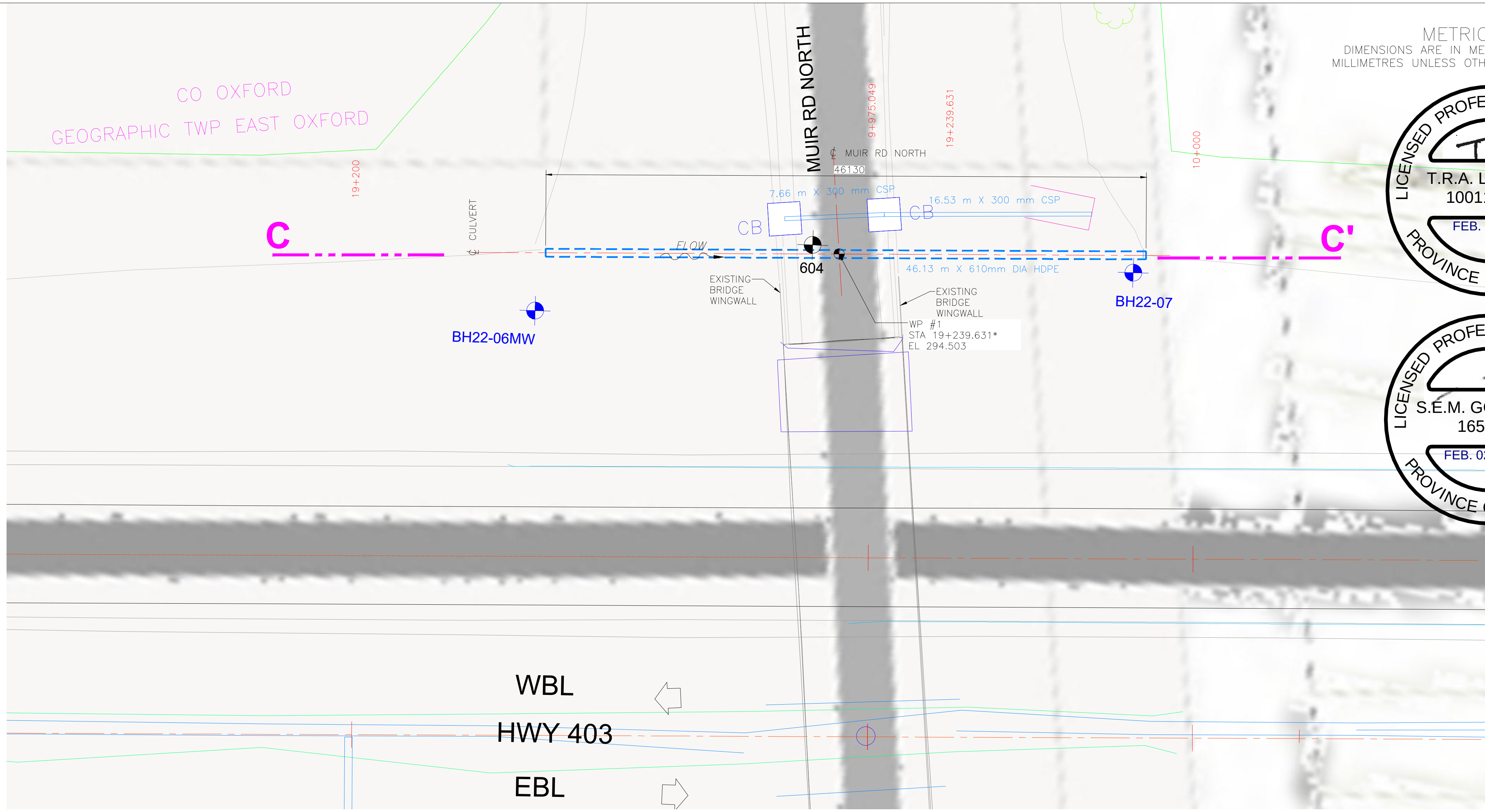
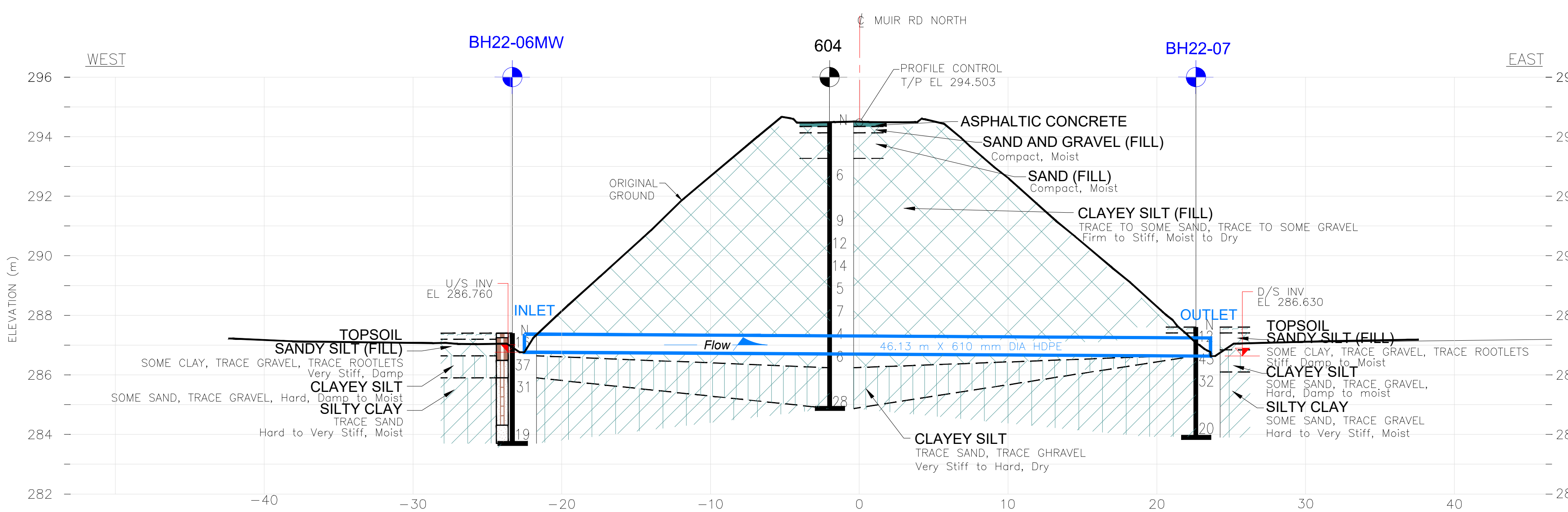
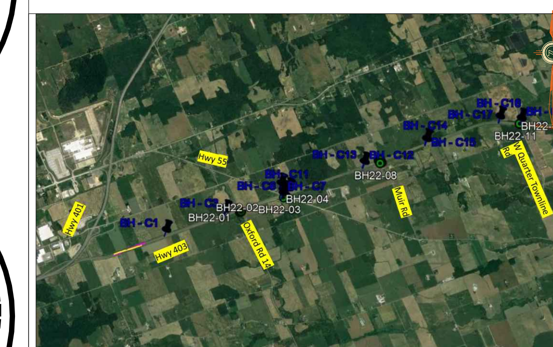


PLAN



SECTION C-C'

HOR 0 5 10 m
VERT 0 2.5 5 m
SCALE



KEY PLAN

LEGEND

- Proposed Borehole Location
- Existing Borehole Location
- Water Level Upon Completion of Drilling (W. L. NOT STABILIZED)
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer

SOIL STRATA SYMBOLS

TOPSOIL
ASPHALTIC CONCRETE
GRANULAR FILL
SILTY CLAY
CLAYEY SILT
SILT

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON 10

BH No.	ELEV.	NORTHING	EASTING
BH22-06MW	287.4	4777613.8	215107.1
BH22-07	287.6	4777625.8	215151.6
604	294.5	4777623.0	215127.0

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.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

REVISIONS NO	DATE	BY	DESCRIPTION
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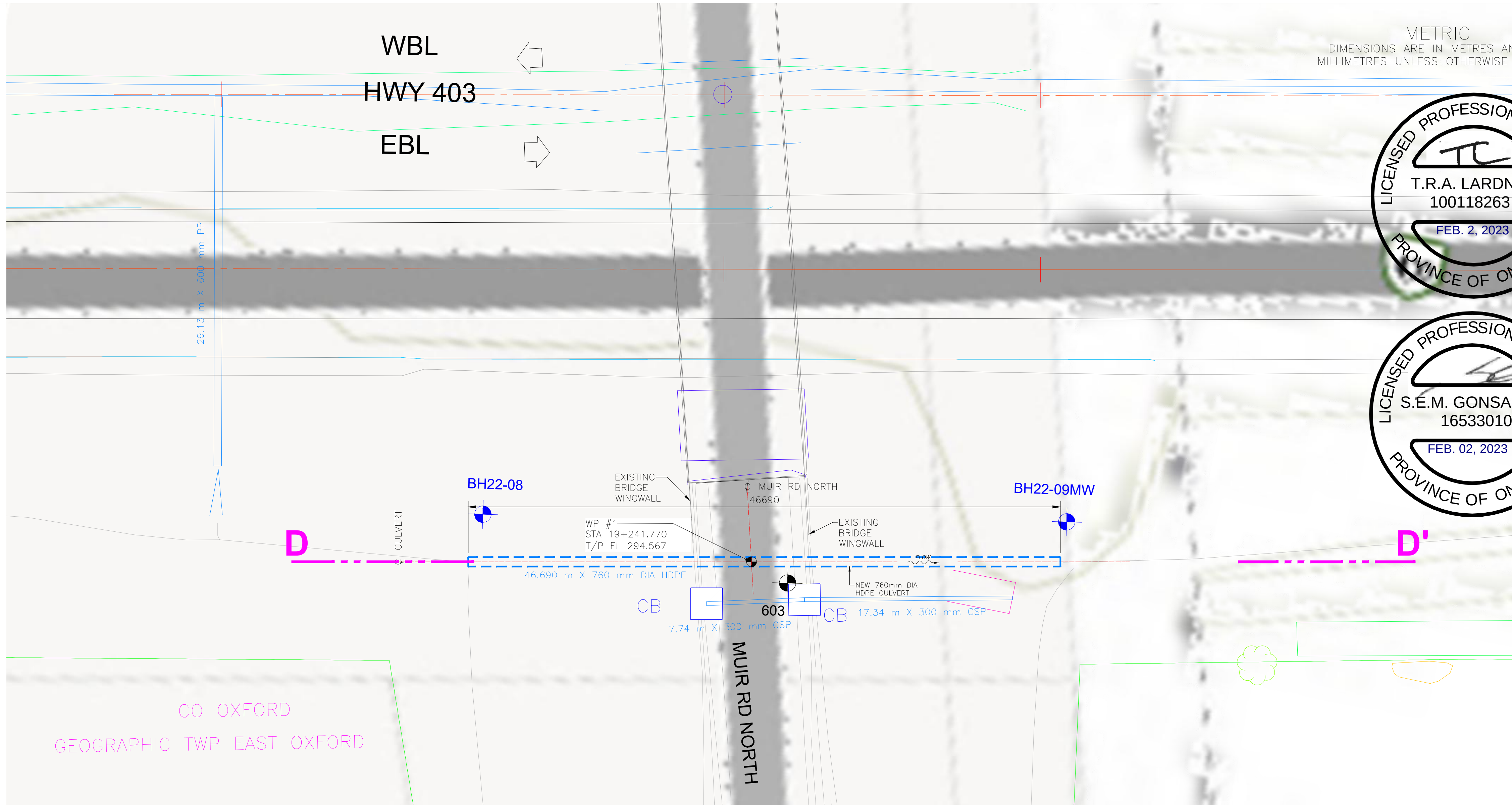
1	Jan 27, 2023	TL	REV FOR MTO COMMENTS
0	Dec 02, 2022	TL	ISSUED FOR CONSTRUCTION

PROJECT No.	ADM-21019451-A0	GEOCRES No.	40P2-89
SUBM'D SH	CHKD. TL	DATE Jan 27, 2023	SITE
DRAWN SH	CHKD. TL	APPD SG	DWG 03

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



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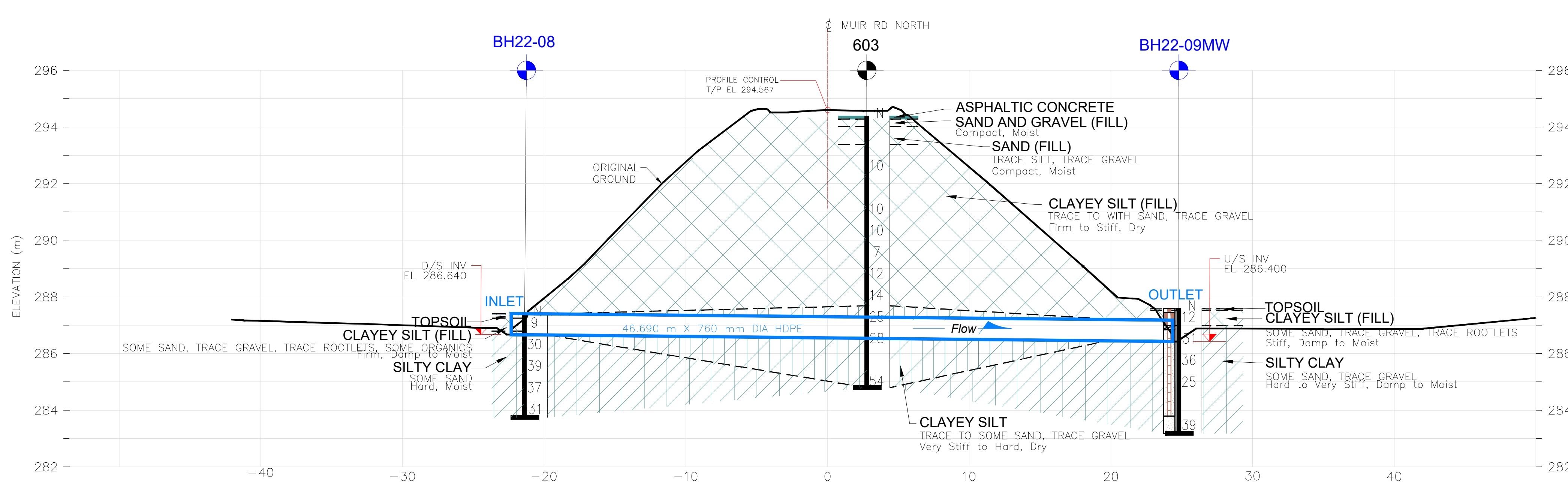
PROVINCE OF ONTARIO

PLAN



SECTION D-D'

HOR 0 5 10 m

VERT 0 2.5 5 m

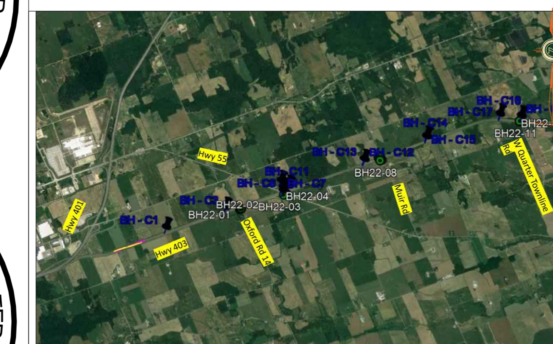
SCALE

CONT No. 2021-3006
GWP No. 3207-15-00

Rehabilitation of Hwy 403 from Hwy 401 easterly to 1.4 Km East of West Quarter Townline Road
SR 7 MUIR RD NORTH

SHEET 4

exp. EXP SERVICES INC.



KEY PLAN

LEGEND

- Proposed Borehole Location
- Existing Borehole Location
- Water Level Upon Completion of Drilling (W. L. NOT STABILIZED)
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer

SOIL STRATA SYMBOLS

- TOPSOIL
- ASPHALTIC CONCRETE
- GRANULAR FILL
- SILTY CLAY
- CLAYEY SILT
- SILT

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON 10

BH No.	ELEV.	NORTHING	EASTING
BH22-08	287.4	4777550.6	215126.4
BH22-09MW	287.6	4777559.0	215171.7
603	294.4	4777550.0	215151.0

NOTES

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

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

REVISIONS NO	DATE	BY	DESCRIPTION
			SUBMISSION FOR MTO REVIEW
1	Jan 27, 2023		REV FOR MTO COMMENTS
0	Dec 02, 2022	TL	ISSUED FOR CONSTRUCTION

PROJECT No. ADM-21019451-A0		GEOCRES No. 40P2-89	
SUBM'D SH	CHKD. TL	DATE Jan 27, 2023	SITE
DRAWN SH	CHKD. TL	APPD SG	DWG 04

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

CONT No. 2021-3006
GWP No. 3207-15-00

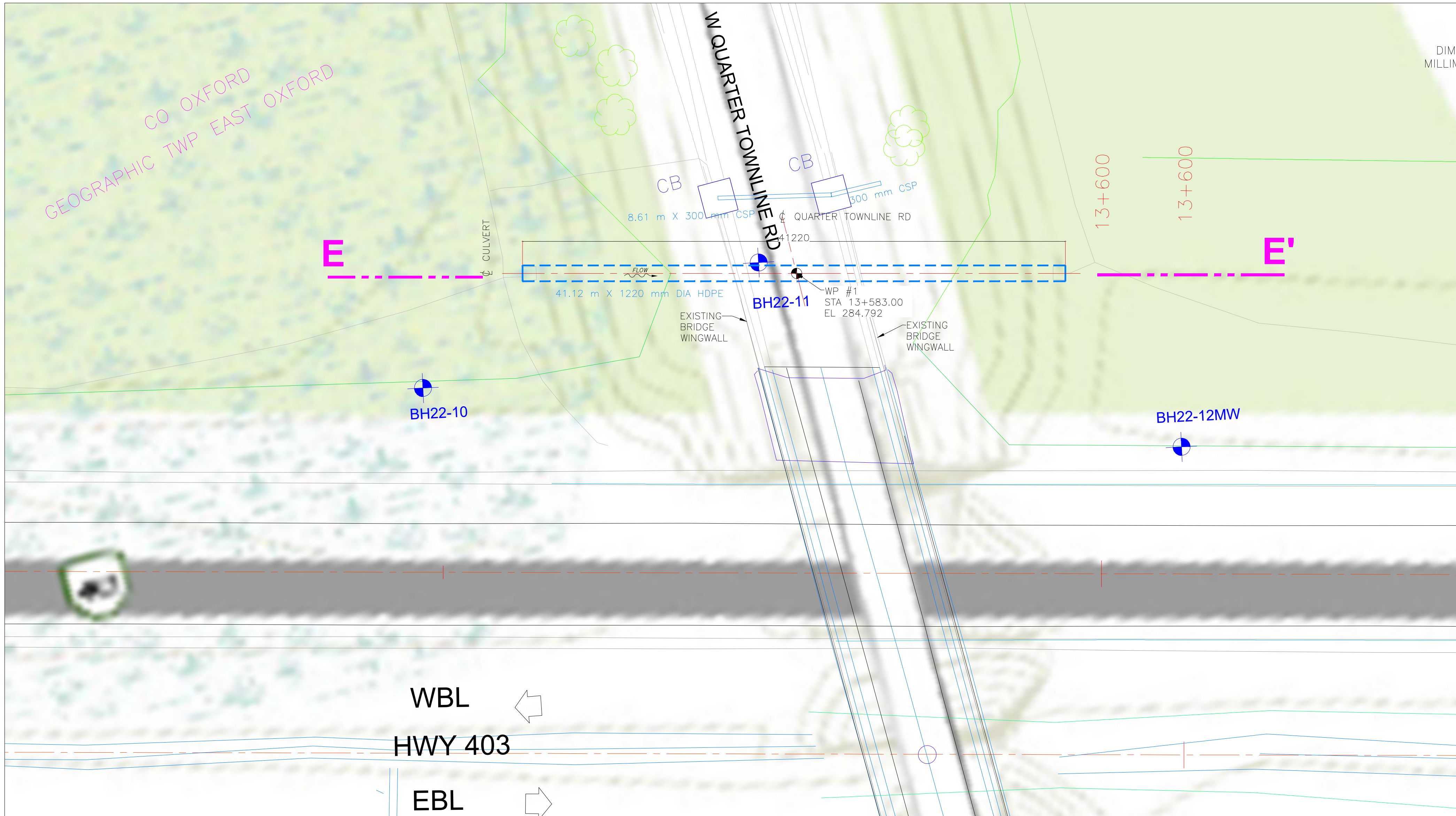
SHEET 5

Rehabilitation of Hwy 403 from Hwy 401 easterly to 1.4 Km East of West Quarter Townline Road
SR 8 QUARTER TOWNLINE RD

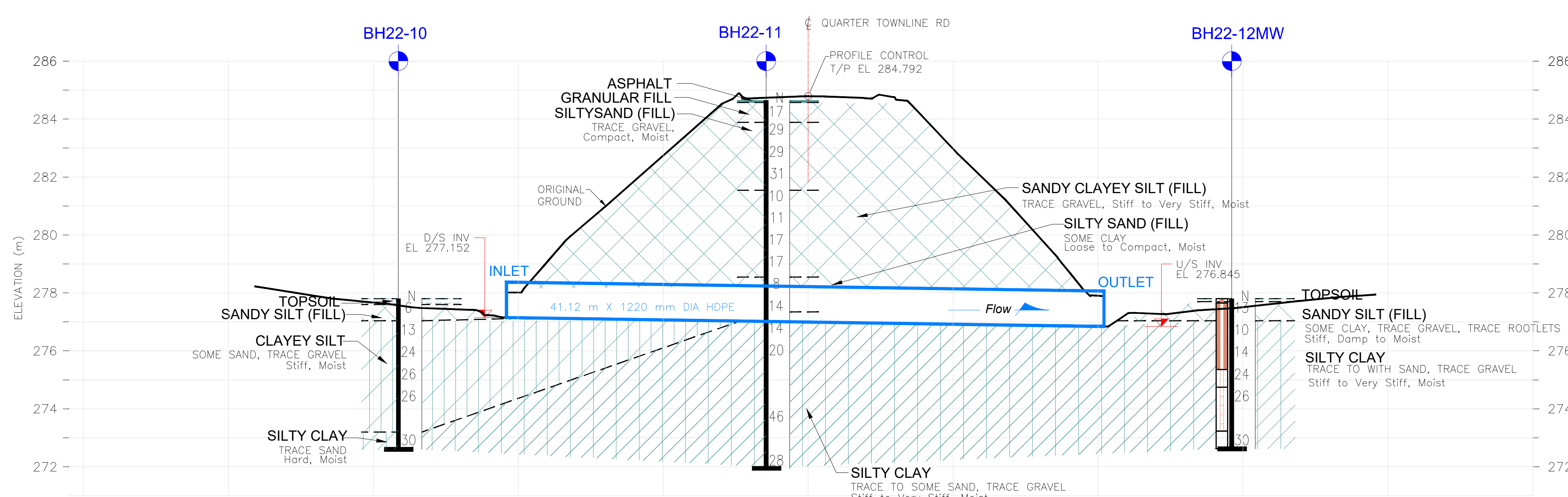
exp.
EXP SERVICES INC.

LICENSED PROFESSIONAL ENGINEER
T.R.A. LARDNER
100118263
FEB. 2, 2023
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
S.E.M. GONSALVES
16533010
FEB. 02, 2023
PROVINCE OF ONTARIO

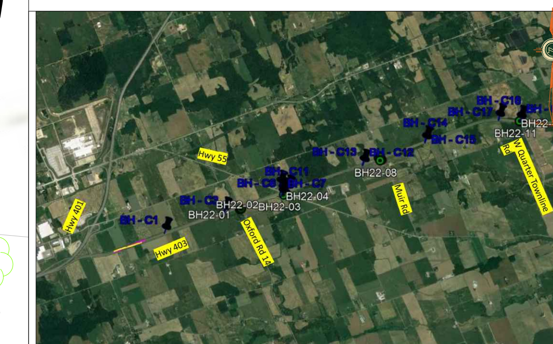


PLAN



SECTION E-E'

HOR 0 5 10 m
VERT 0 2.5 5 m
SCALE



KEY PLAN

LEGEND

- Proposed Borehole Location
- Existing Borehole Location
- Water Level Upon Completion of Drilling (W. L. NOT STABILIZED)
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level in Piezometer (most recent) (W. L. STABILIZED)
- Piezometer

SOIL STRATA SYMBOLS

- TOPSOIL
- ASPHALTIC CONCRETE
- GRANULAR FILL
- SILTY CLAY
- CLAYEY SILT
- SILT

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON 10

BH No.	ELEV.	NORTHING	EASTING
BH22-10	277.8	4777957.1	218647.8
BH22-11	284.6	4777959.7	218674.9
BH22-12MW	277.8	4777937.9	218702.4

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.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

SUBMISSION FOR MTO REVIEW

REVISIONS NO	DATE	BY	DESCRIPTION
1	Jan 27, 2023	TL	REV FOR MTO COMMENTS
0	Dec 02, 2022	TL	ISSUED FOR CONSTRUCTION

PROJECT No. ADM-21019451-A0		GEOCRES No. 40P2-89	
SUBM'D SH	CHKD. TL	DATE Jan 27, 2023	SITE
DRAWN SH	CHKD. TL	APPD SG	DWG 05

Appendix D – Borehole Logs

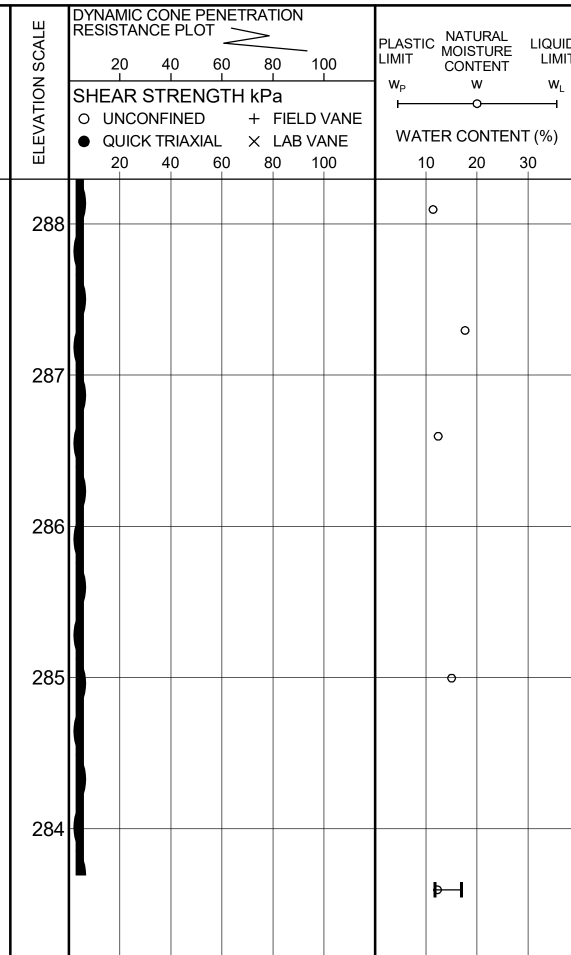
RECORD OF BOREHOLE No BH22-01

METRIC

W.P.		ORIGINATED BY	Rahul Anand
LOCATION	Oxford Rd 14, West Approach Culvert, Coords: 4774908.684,528794.8		
DIST	West	HWY	403
BOREHOLE TYPE	Conitnuous Flight Hollow Stem Augers	COMPILED BY	Rahul Anand
DATUM	Geodetic	DATE	22.7.5 - 22.7.5
CHECKED BY	Behrouz Ohadi		

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
288.3 / 0.0	~120 mm **TOPSOIL**				
288.2 / 0.1	**FILL**,sandy silt, trace clay, trace gravel, trace rootlets, compact, dark brown to brown, damp to moist	1	SS	11	
287.5 / 0.8	**CLAYEY SILT**, trace to with sand, trace gravel, stiff to very stiff, brown, moist	2	SS	14	
		3	SS	25	
		4	SS	17	
	... grey below 3.5 mbgs				
		5	SS	10	7 31 34 28
283.1 / 5.2	**End of Borehole**				

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of hollow stem augers.



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

RECORD OF BOREHOLE No BH22-02MW

METRIC

W.P. ______ LOCATION Oxford Rd 14, East Approach Culvert, Coords: 4774916.844,528840.483 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.5 - 22.7.5 CHECKED BY Behrouz Ohadi

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
288.8							
288.7 / 0.1	~80 mm **TOPSOIL**						
	FILL, sandy silt, trace clay, trace gravel, trace rootlets , compact, dark brown to brown, damp to moist	1	SS	16			
288.1 / 0.8	**CLAYEY SILT**, trace to some sand, trace gravel, v.stiff, brown, moist	2	SS	21	288		2 21 49 29
	...grey, stiff at 1.52 mbgs	3	SS	11	287		
					286		
	..firm below 3.05 mbgs	4	SS	6			
		5	SS	8	285		0 1 73 26
284.4 / 4.4	**End of Borehole**						

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of Hollow stem augers.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

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

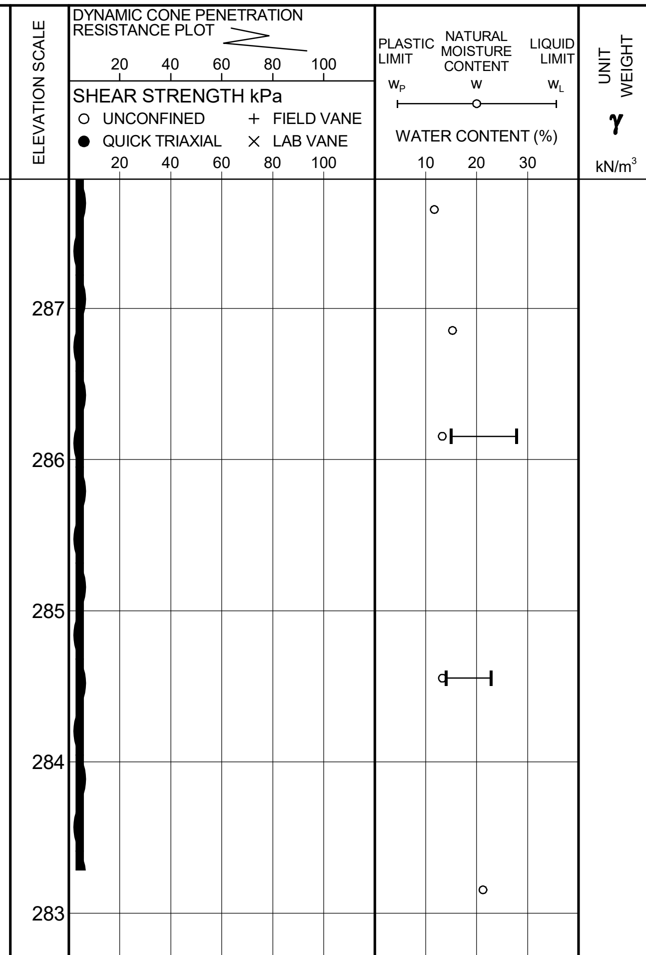
Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH22-03

METRIC

W.P.		ORIGINATED BY	Rahul Anand
LOCATION	Hwy 55, West Approach Culvert, Coords:4775115.223,529898.513	COMPILED BY	Rahul Anand
DIST	West	HWY	403
BOREHOLE TYPE	Conitnuous Flight Solid Stem Augers	CHECKED BY	Behrouz Ohadi
DATUM	Geodetic	DATE	22.7.5 - 22.7.5

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.9 / 0.0	~120 mm **TOPSOIL**					
287.8 / 0.1	**FILL**, sandy silt, trace clay, trace gravel, trace rootlets, loose, dark brown to brown, damp to moist	1	SS	7		
287.1 / 0.8	**SILTY CLAY**, trace to with sand, trace gravel, stiff to very stiff,brown, moist	2	SS	13		
		3	SS	18		2 10 42 47
		4	SS	23		6 30 37 27
		5	SS	16		
282.7 / 5.2	**End of Borehole**					



Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of solid stem augers.

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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No BH22-04MW

METRIC

W.P. ______ LOCATION Hwy 55, North Approach Culvert, Coords: 4775115.051,529964.848 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.6 - 22.7.6 CHECKED BY Behrouz Ohadi

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
295.2 / 0.0	~125 mm **ASPHALT**
295.1 / 0.1	~600 mm **GRANULAR FILL**
294.5 / 0.8	**FILL**, clayey silt, trace to with sand, trace gravel, stiff, brown, moist ...firm below 1.5 mbgs ...stiff below 3.05 mbgs ...greenish grey, soft at 6.09 mbgs
288.4 / 6.9	**FILL**, sandy silt, trace gravel, compact, brown, wet
287.6 / 7.6	**CLAYEY SILT**, trace to with sand, trace gravel, stiff to very stiff, grey, moist

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	23				
2	SS	12				
3	SS	8	4	33	38	25
4	SS	4				
5	SS	12				
6	SS	11				
7	SS	11				
8	SS	20				
9	SS	3	0	47	31	23
10	SS	14				
11	SS	12	3	31	33	33
12	SS	23				
13	SS	21				

ELEVATION SCALE: 295, 294, 293, 292, 291, 290, 289, 288, 287, 286

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m^3

Continued Next Page

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

RECORD OF BOREHOLE No BH22-04MW

METRIC

W.P. ______ LOCATION Hwy 55, North Approach Culvert, Coords: 4775115.051,529964.848 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.6 - 22.7.6 CHECKED BY Behrouz Ohadi

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT / PLASTIC LIMIT / LIQUID LIMIT	GR	SA	SI	CL
	CLAYEY SILT, trace to with sand, trace gravel, stiff to very stiff, grey, moist *(continued)*				285					
	...hard below 10.67 mbgs	14	SS	30		w ≈ 19				
					284					
283.0 / 12.2	**SILTY CLAY**, trace sand, trace gravel, hard, grey, moist	15	SS	30	283	wP ≈ 17, wL ≈ 31	3	4	37	56
282.4 / 12.8	**End of Borehole**									

Notes:
1. Groundwater level was measured at 6.8 m below ground surface upon completion of drilling.
2. No Cave-in was noted upon extraction of Hollow stem augers.

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

RECORD OF BOREHOLE No BH22-05

METRIC

W.P.		LOCATION	Hwy 55, East Approach Culvert, Coords:4775133.912,529984.173
DIST	West	HWY 403	ORIGINATED BY: Rahul Anand
BOREHOLE TYPE	Conitnuous Flight Hollow Stem Augers	COMPILED BY	Rahul Anand
DATUM	Geodetic	DATE	22.7.5 - 22.7.5
CHECKED BY	Behrouz Ohadi		

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.9 / 0.0	~200 mm **TOPSOIL**							
287.7 / 0.2	**FILL**, sandy silt, trace clay, trace gravel, trace rootlets, loose, dark brown to brown, damp to moist		1	SS	7			
287.1 / 0.8	**SILTY CLAY**, trace to some sand, trace gravel, very stiff, brown, moist		2	SS	19		287	1 11 36 53
	...grey, hard below 1.56 mbgs		3	SS	34		286	
							285	
			4	SS	37		284	2 8 35 55
			5	SS	28		283	
282.7 / 5.2	**End of Borehole**							

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of Hollow stem augers.

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100)

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100)

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No BH22-06MW

METRIC

W.P. LOCATION Muir Rd, North/West Approach Culvert, Coords: 4775667.267,532332.773 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.7 - 22.7.7 CHECKED BY Behrouz Ohadi

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.4 / 0.0	~200 mm **TOPSOIL**				
287.2 / 0.2	**FILL**, sandy silt, some clay, trace gravel, trace rootlets, v.stiff, brown, damp	1	SS	16	
286.7 / 0.8	**CLAYEY SILT**,some sand, trace gravel, hard, grey, damp to moist	2	SS	37	
285.9 / 1.5	**SILTY CLAY**, trace sand, hard, grey, moist	3	SS	31	
	...very stiff at 3.05 mbgs	4	SS	19	1 9 39 51
283.8 / 3.7	**End of Borehole**				

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of Hollow stem augers.

Elevation scale: 287, 286, 285, 284

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m^3

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

RECORD OF BOREHOLE No BH22-07

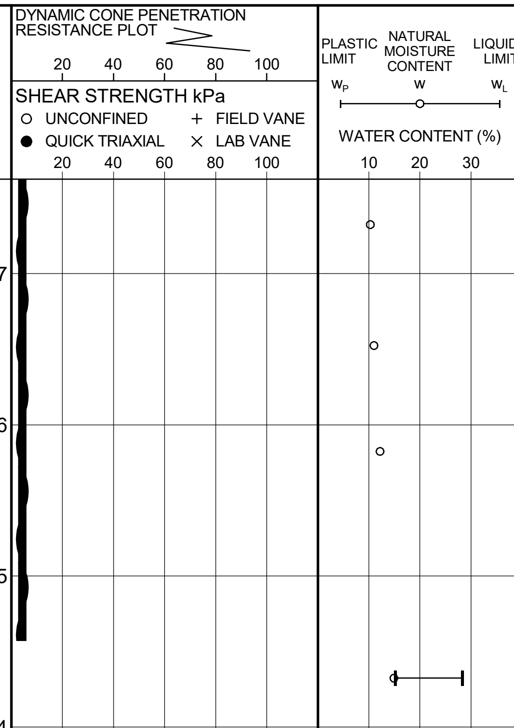
METRIC

W.P. ______ LOCATION Muir Rd, North/East Approach Culvert, Coords: 4775680,532377 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.7 - 22.7.7 CHECKED BY Behrouz Ohadi

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.6					
287.4 / 0.0	~190 mm **TOPSOIL**				
0.2	**FILL**, sandy silt, some clay, trace gravel, trace rootlets, stiff, brown, damp to moist	1	SS	12	
286.9 / 0.8	**CLAYEY SILT**,some sand, trace gravel, hard, grey, damp to moist	2	SS	43	
286.1 / 1.5	**SILTY CLAY**, some sand, trace gravel, hard, grey, moist	3	SS	32	
	...very stiff at 3.05 mbgs	4	SS	20	4 11 41 45
284.0 / 3.7	**End of Borehole**				



Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of Hollow stem augers.

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

RECORD OF BOREHOLE No BH22-08

METRIC

W.P. ______ LOCATION Muir Rd, South/West Approach Culvert, Coords:4775604.446,532353.178 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.6 - 22.7.6 CHECKED BY Behrouz Ohadi

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.4							
287.3 / 0.0	~150 mm **TOPSOIL**						
0.2	**FILL**, clayey silt, some sand, trace gravel, trace rootlets, some organics, firm ,dark brown to brown, damp to moist	1	SS	9	287		
286.8 / 0.6	**SILTY CLAY**, some sand, hard,brown, moist	2	SS	30			1 12 41 47
					286		
	... grey below 1.6 mbgs	3	SS	39			
		4	SS	37	285		
		5	SS	31	284		1 14 36 49
283.8 / 3.7	**End of Borehole**						

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of Hollow stem augers.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

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

RECORD OF BOREHOLE No BH22-09MW

METRIC

W.P. ______ LOCATION Muir Rd, South/East Approach Culvert, Coords:4775613.643,532398.287 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.6 - 22.7.6 CHECKED BY Behrouz Ohadi

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)	GR	SA	SI	CL
287.6 / 0.0	~75 mm **TOPSOIL**											
287.5 / 0.1	**FILL**, clayey silt, some sand, trace gravel, trace rootlets, stiff, dark brown to brown, damp to moist		1	SS	12			o				
287.0 / 0.6	**SILTY CLAY**, some sand, trace gravel, hard, brown, damp to moist		2	SS	31		287	o ├─┤	2	15	37	46
	...grey at 1.52 mbgs		3	SS	36		286	o				
	...very stiff at 2.28 mbgs		4	SS	25		285	o				
	...hard below 3.8 mbgs		5	SS	39		284	o ├─┤	3	21	35	41
283.2 / 4.4	**End of Borehole**											

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of Hollow stem augers.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m^3
REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No BH22-10

METRIC

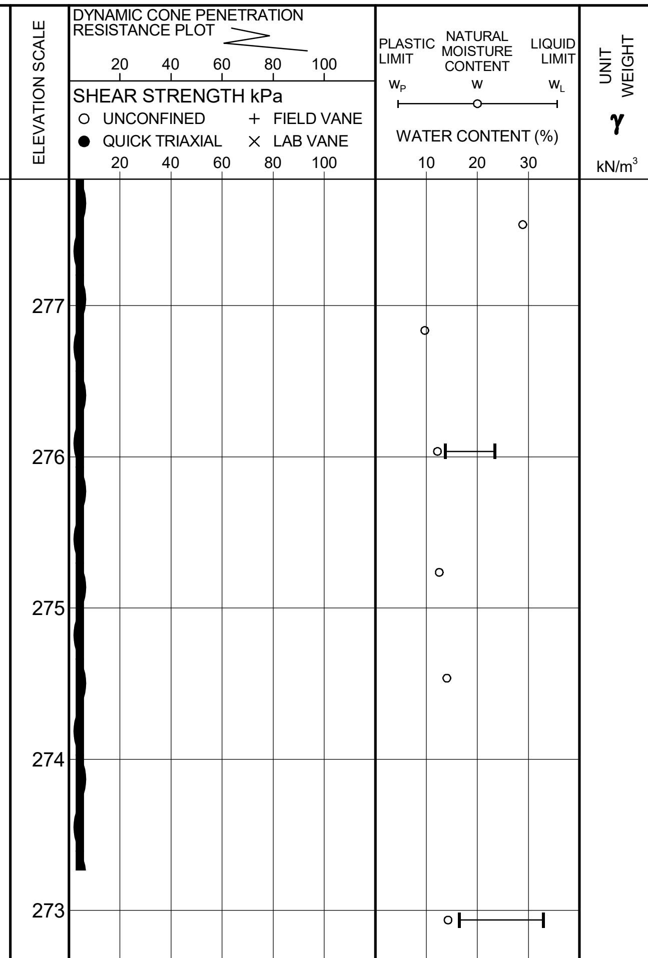
W.P.		LOCATION	W Quarter Townline Rd, West Approach Culvert, Coords: 4776073.663,535865.469
DIST West	HWY 403	BOREHOLE TYPE	Conitnuous Flight Hollow Stem Augers
DATUM Geodetic		DATE	22.7.7 - 22.7.7

ORIGINATED BY Rahul Anand

COMPILED BY Rahul Anand

CHECKED BY Behrouz Ohadi

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
277.8 / 0.0	~200 mm **TOPSOIL**								
277.6 / 0.2	**FILL**, sandy silt, trace gravel, trace clay, trace rootlets, loose, brown, moist	1	SS	6					
277.1 / 0.8	**CLAYEY SILT**, some sand, trace gravel, stiff, grey, moist	2	SS	13					
	...very stiff below 1.52 mbgs	3	SS	24		7	20	38	35
		4	SS	26					
		5	SS	26					
273.3 / 4.6	**SILTY CLAY**, trace sand, hard, grey, moist	6	SS	30		0	3	31	66
272.7 / 5.2	**End of Borehole**								



Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of Hollow stem augers.

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

RECORD OF BOREHOLE No BH22-11

METRIC

W.P. ______ LOCATION W Quarter Townline Rd, South Approach Culvert, Coords: 4776076.792,535892.499 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.7 - 22.7.7 CHECKED BY Behrouz Ohadi

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
284.6					
284.5 / 0.1	~75 mm **ASPHALT** ~685 mm **GRANUAL FILL**	1	SS	17	
283.9 / 0.8	**FILL**, silty sand, trace gravel, compact, brown, moist	2	SS	29	
		3	SS	29	
		4	SS	31	
281.6 / 3.1	**FILL**, sandy clayey silt, trace gravel, stiff to very stiff, brown, moist	5	SS	10	6 31 30 33
	...greenish grey at 3.8 mbgs	6	SS	11	
		7	SS	17	
		8	SS	17	
278.5 / 6.1	**FILL**, silty sand, some clay, loose to compact, brown, moist	9	SS	8	0 48 40 12
		10	SS	14	
277.3 / 7.3	**SILTY CLAY**, trace to some sand, trace gravel, grey, stiff to very stiff, moist	11	SS	14	
		12	SS	14	
		13	SS	20	

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (284, 283, 282, 281, 280, 279, 278, 277, 276, 275); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

Continued Next Page

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH22-11

METRIC

W.P. ______ LOCATION W Quarter Townline Rd, South Approach Culvert, Coords: 4776076.792,535892.499 ORIGINATED BY Rahul Anand

DIST West HWY 403 BOREHOLE TYPE Conitnuous Flight Hollow Stem Augers COMPILED BY Rahul Anand

DATUM Geodetic DATE 22.7.7 - 22.7.7 CHECKED BY Behrouz Ohadi

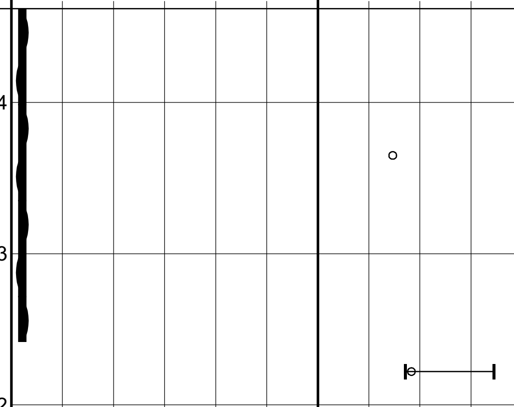
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY, trace to some sand, trace gravel, grey, stiff to very stiff, moist *(continued)*							
	...hard below 10.67 mgs						274	
			14	SS	46			
							273	
272.0 / 12.7			15	SS	28		272	3 5 36 56
	End of Borehole Notes: 1. Groundwater level was not encountered during or upon completion of drilling. 2. No Cave-in was noted upon extraction of Hollow stem augers.							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m³



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

RECORD OF BOREHOLE No BH22-12MW

METRIC

W.P.		ORIGINATED BY	Rahul Anand
LOCATION	W Quarter Townline Rd, East Approach Culvert, Coords: 4776055.48,535920.3	COMPILED BY	Rahul Anand
DIST	West	HWY	403
BOREHOLE TYPE	Conitnuous Flight Solid Stem Augers	CHECKED BY	Behrouz Ohadi
DATUM	Geodetic	DATE	22.7.13 - 22.7.13

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
277.8	
277.7 / 0.0 / 0.1	~100 mm **TOPSOIL**
	FILL, sandy silt, some clay, trace gravel, trace rootlets,stiff, brown, damp to moist,
277.1 / 0.8	**SILTY CLAY**, trace to with sand, trace gravel, stiff to very stiff, grey, moist
	...hard below 4.57 mbgs
272.7 / 5.2	**End of Borehole**

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No Cave-in was noted upon extraction of solid stem augers.

SAMPLES

NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	13					
2	SS	10	277				
3	SS	14	276	4	27	38	31
4	SS	24	275				
5	SS	26	274				
6	SS	30	273	1	3	36	61

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 601

METRIC

W.P. GWP 3207-15-00	LOCATION Oxford Road 14, South Approach Culvert, Coords: 4776916 N; 211582 E		ORIGINATED BY Joe Lin
DIST West HWY 403	BOREHOLE TYPE Continuous Flight Hollow Stem Augers		COMPILED BY Joe Lin
DATUM Geodetic	DATE 2021.06.16 - 2021.06.16	LATITUDE 43.1263 LONGITUDE -80.6457	CHECKED BY Brian Squire

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
295.182 / 0.000	150 mm **ASPHALTIC CONCRETE**
295.032 / 0.150	**FILL**, sand and gravel, compact, brown, moist
294.712 / 0.470	**FILL**, sand, trace silt, trace to some gravel, compact, brown, moist
294.232 / 0.950	**FILL**, clayey silt, trace to with sand, trace to some gravel, soft to stiff, brown to grey, moist to dry
289.242 / 5.940	**FILL**, clayey silt and gravel, with sand, with asphalt concrete, compact, brown / dark brown, moist
288.472 / 6.710	**CLAYEY SILT**, trace to some sand, trace gravel, very stiff, brown, moist to dry
285.052 / 10.130	**SILT**, trace sand, compact, grey, wet
284.052 / 11.130	**END OF BOREHOLE**

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No cave-in was noted upon extraction of hollow stem augers.

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	9				
2	SS	4	1	22	58	19
3	SS	12				
4	SS	14				
5	SS	10	1	18	55	26
6	SS	25				
7	SS	17	1	15	69	15
8	SS	22				
9	SS	26				
10	SS	10				

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (295 – 285); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

ONTARIO MTO 20137516 GINT.GPJ ONTARIO MTO.GDT 8/23/21

RECORD OF BOREHOLE No 602

METRIC

W.P. GWP 3207-15-00	LOCATION Oxford Road 55, South Approach Culvert, Coords: 4777102 N; 212697 E		ORIGINATED BY Joe Lin
DIST West HWY 403	BOREHOLE TYPE Continuous Flight Hollow Stem Augers		COMPILED BY Joe Lin
DATUM Geodetic	DATE 2021.06.17 - 2021.06.17	LATITUDE 43.1282 LONGITUDE -80.6320	CHECKED BY Brian Squire

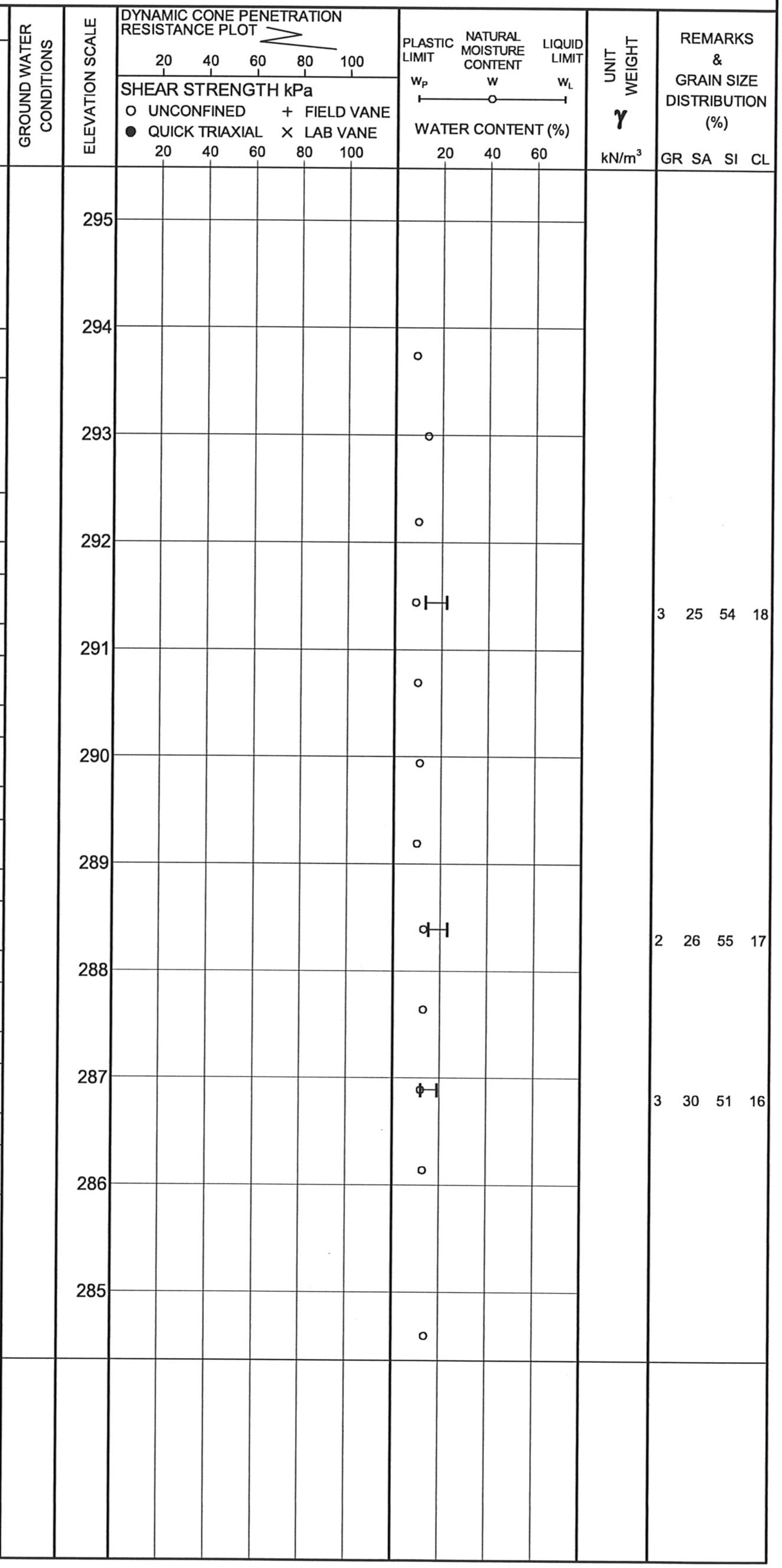
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION	STRAT PLOT
295.490		
295.310 / 0.000	180 mm **ASPHALTIC CONCRETE**	
295.110 / 0.180	**FILL**, sand and gravel, compact, brown, moist	
0.380	**FILL**, sand, trace silt, trace gravel, compact, brown, moist	
294.740 / 0.750	**FILL**, clayey silt, trace to with sand, trace to some gravel, trace organic matter, asphalt layers at 6.32 to 6.45 mbgs, soft to hard, brown to dark brown, moist	
288.020 / 7.470	**CLAYEY SILT**, trace to with sand, trace gravel, very stiff to hard, brown to grey, dry	
284.360 / 11.130	**END OF BOREHOLE**	

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No cave-in was noted upon extraction of hollow stem augers.

SAMPLES

NUMBER	TYPE	"N" VALUES	GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	4				
2	SS	16				
3	SS	21	3	25	54	18
4	SS	14				
5	SS	8				
6	SS	76				
7	SS	13	2	26	55	17
8	SS	20				
9	SS	22	3	30	51	16
10	SS	28				
11	SS	35				



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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 603

METRIC

W.P. GWP 3207-15-00	LOCATION Muir Road, South Approach Culvert, Coords: 4777550 N; 215151 E		ORIGINATED BY Joe Lin
DIST West HWY 403	BOREHOLE TYPE Continuous Flight Hollow Stem Augers		COMPILED BY Joe Lin
DATUM Geodetic	DATE 2021.06.16 - 2021.06.16	LATITUDE 43.1325 LONGITUDE -80.6019	CHECKED BY Brian Squire

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
294.397 / 0.000	120 mm **ASPHALTIC CONCRETE**
294.277 / 0.120	**FILL**, sand and gravel, compact, brown, moist
294.017 / 0.380	**FILL**, sand, trace silt, trace gravel, compact, brown, moist
293.387 / 1.010	**FILL**, clayey silt, trace to with sand, trace gravel, firm to stiff, brown, dry
287.687 / 6.710	**CLAYEY SILT**, trace to some sand, trace gravel, very stiff to hard, brown, dry
284.797 / 9.600	**END OF BOREHOLE**

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	10				
2	SS	10				
3	SS	10				
4	SS	7				
5	SS	12				
6	SS	14	3	25	50	22
7	SS	25				
8	SS	28	1	18	56	25
9	SS	54				

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (294 to 285); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

Notes:
1. Groundwater level was not encountered during or upon completion of drilling.
2. No cave-in was noted upon extraction of hollow stem augers.

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

RECORD OF BOREHOLE No 604

METRIC

W.P. GWP 3207-15-00	LOCATION Muir Road, North Approach Culvert, Coords: 4777623 N; 215127 E		ORIGINATED BY Joe Lin
DIST West HWY 403	BOREHOLE TYPE Continuous Flight Hollow Stem Augers		COMPILED BY Joe Lin
DATUM Geodetic	DATE 2021.06.16 - 2021.06.16	LATITUDE 43.1331 LONGITUDE -80.6022	CHECKED BY Brian Squire

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
294.471 / 0.000	130 mm **ASPHALTIC CONCRETE**
294.341 / 0.130	**FILL**, sand and gravel, compact, brown, moist
294.131 / 0.340	**FILL**, sand, trace silt, trace gravel, compact, brown, moist
293.271 / 1.200	**FILL**, clayey silt, trace to some sand, trace to some gravel, firm to stiff, brown, moist to dry
286.241 / 8.230	**CLAYEY SILT**, trace sand, trace gravel, very stiff to hard, brown to grey, dry
284.871 / 9.600	**END OF BOREHOLE**

Notes:
1. Groundwater level was measured at 8.53 m below ground surface upon completion of drilling.
2. No cave-in was noted upon extraction of hollow stem augers.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	6	
2	SS	9	
3	SS	12	
4	SS	14	
5	SS	5	
6	SS	7	
7	SS	4	
8	SS	6	7 20 53 20
9	SS	28	1 10 55 34

GROUND WATER CONDITIONS: water level symbol (▽) at elevation approx. 286.

ELEVATION SCALE: 294, 293, 292, 291, 290, 289, 288, 287, 286, 285

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

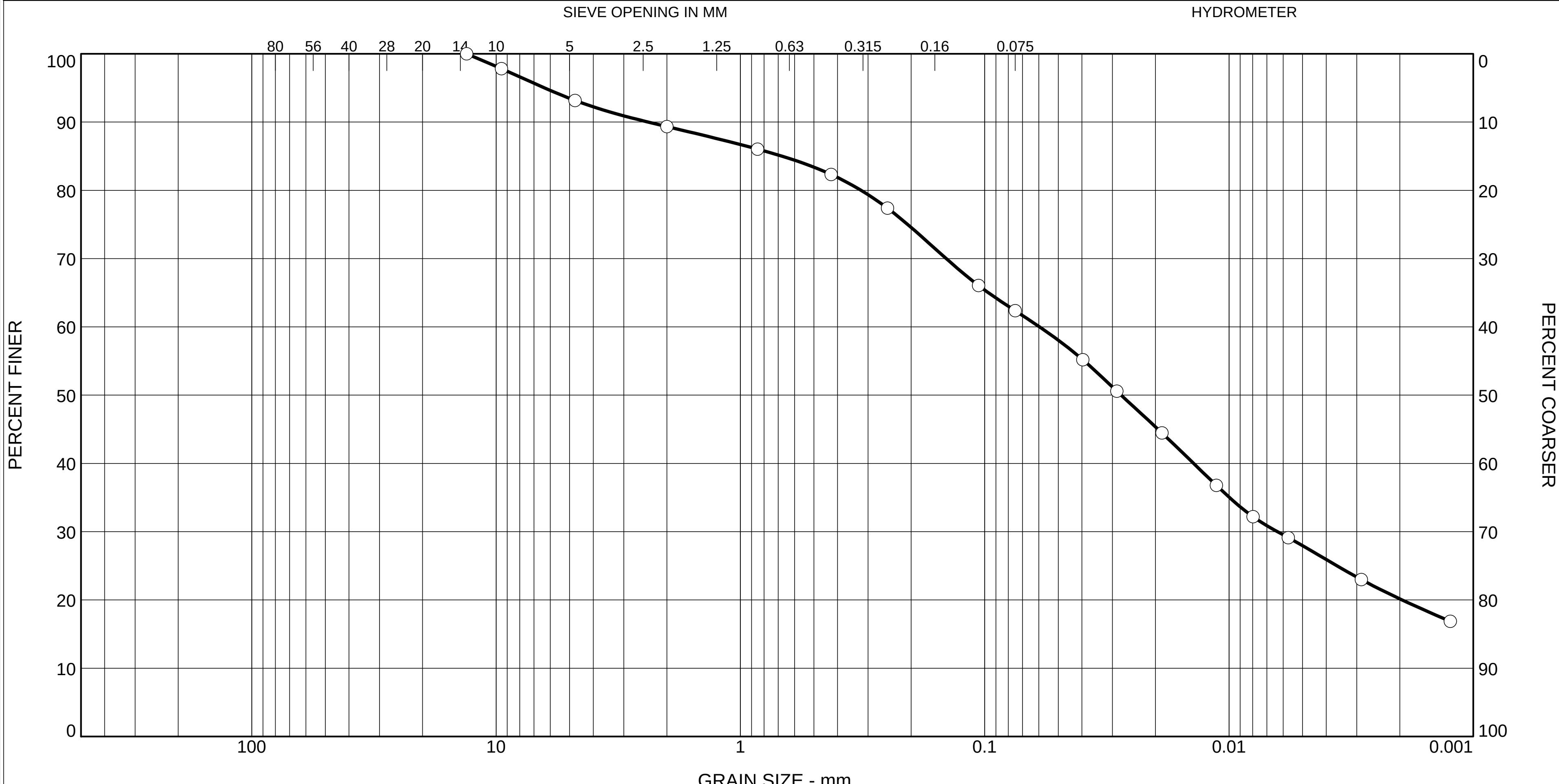
WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

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

Appendix E – Laboratory Data

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	6.8	3.9	7.0	19.9	34.4	28.0

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-01 SS5 Sample Number: MG-37207		Jul 20, 2022	Jul 28, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

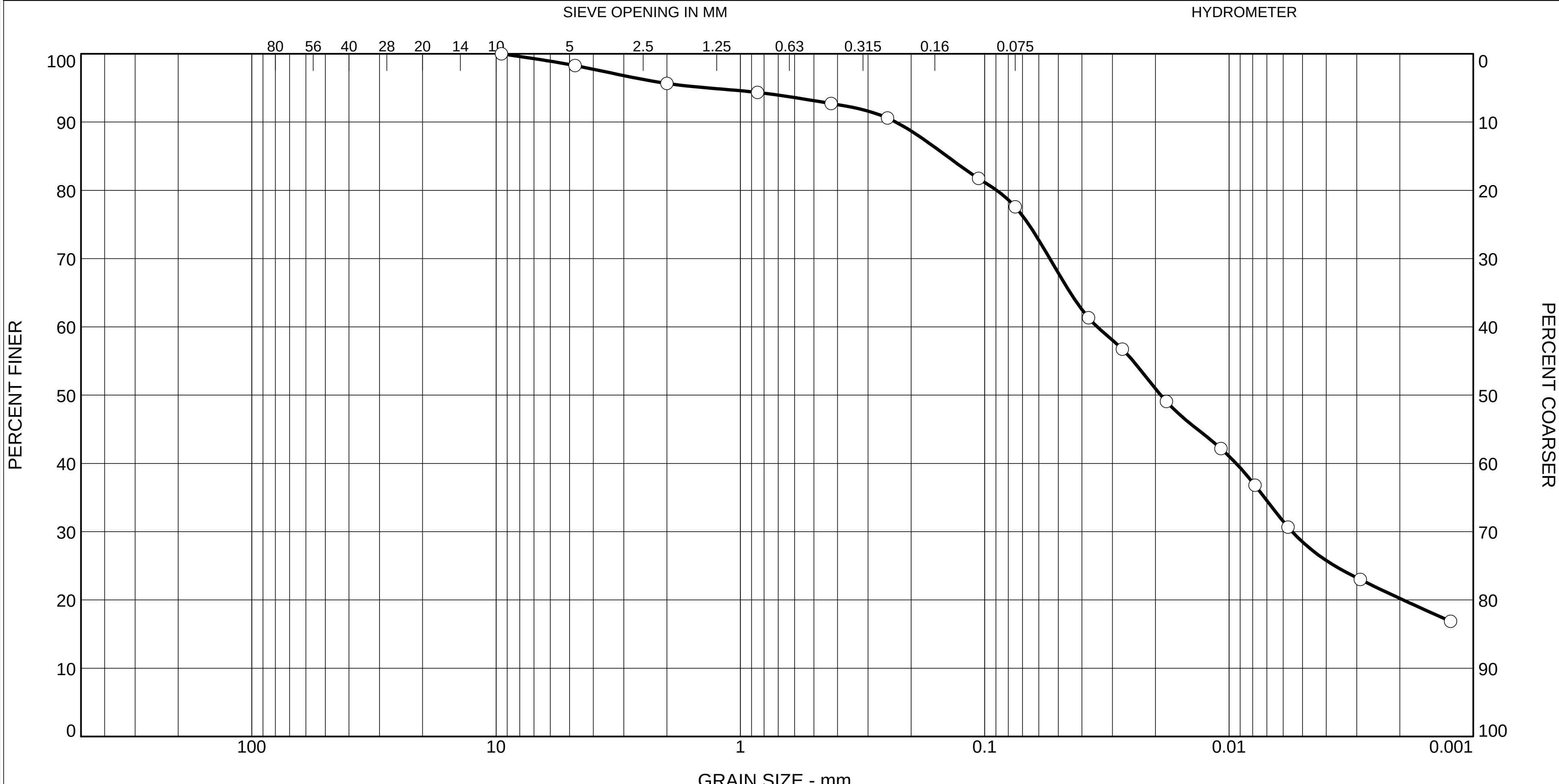
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sandy Clayey Silt

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	1.7	2.6	3.0	15.1	49.1	28.5

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-02 SS2 Sample Number: MG-37096A		Jul 13, 2022	Jul 18, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

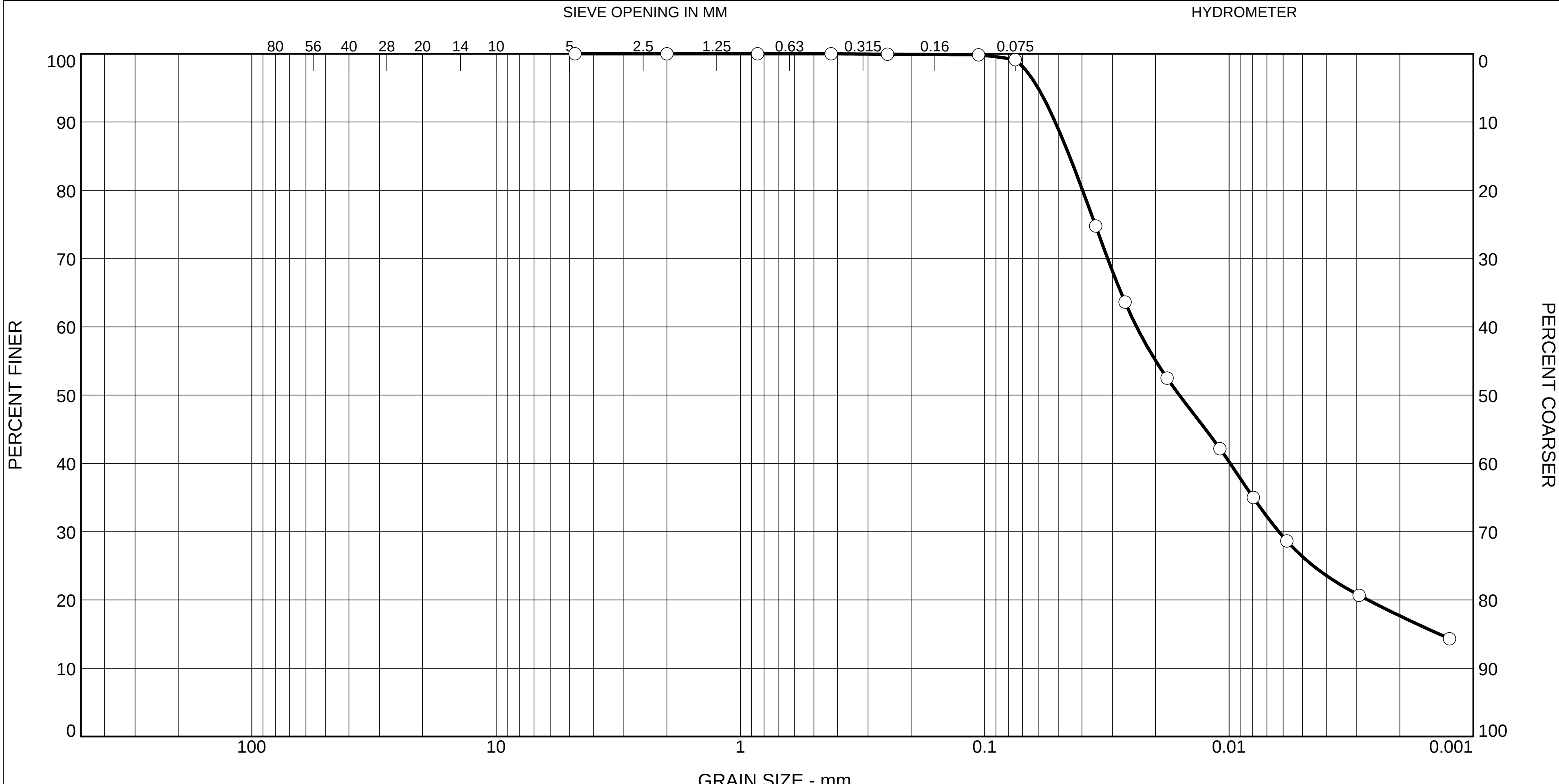
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sandy Silty Clay

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	0.0	0.0	0.0	0.9	72.8	26.3

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-02 SS5 Sample Number: MG-37096B		Jul 13, 2022	Jul 15, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

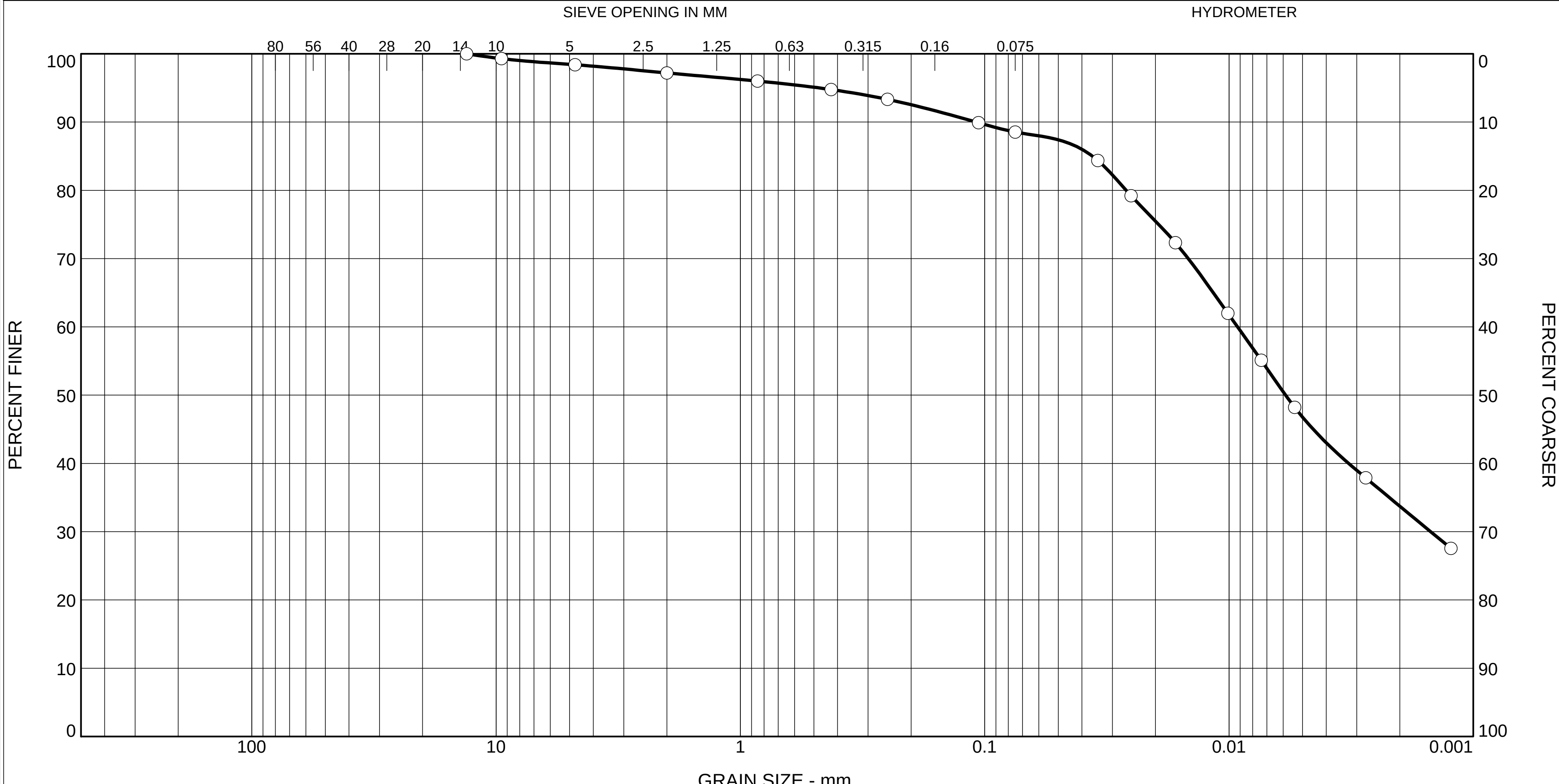
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Clayey Silt

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.6	1.2	2.4	6.3	41.7	46.8

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-03 SS3 Sample Number: MG-37210A		Jul 20, 2022	Jul 29, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

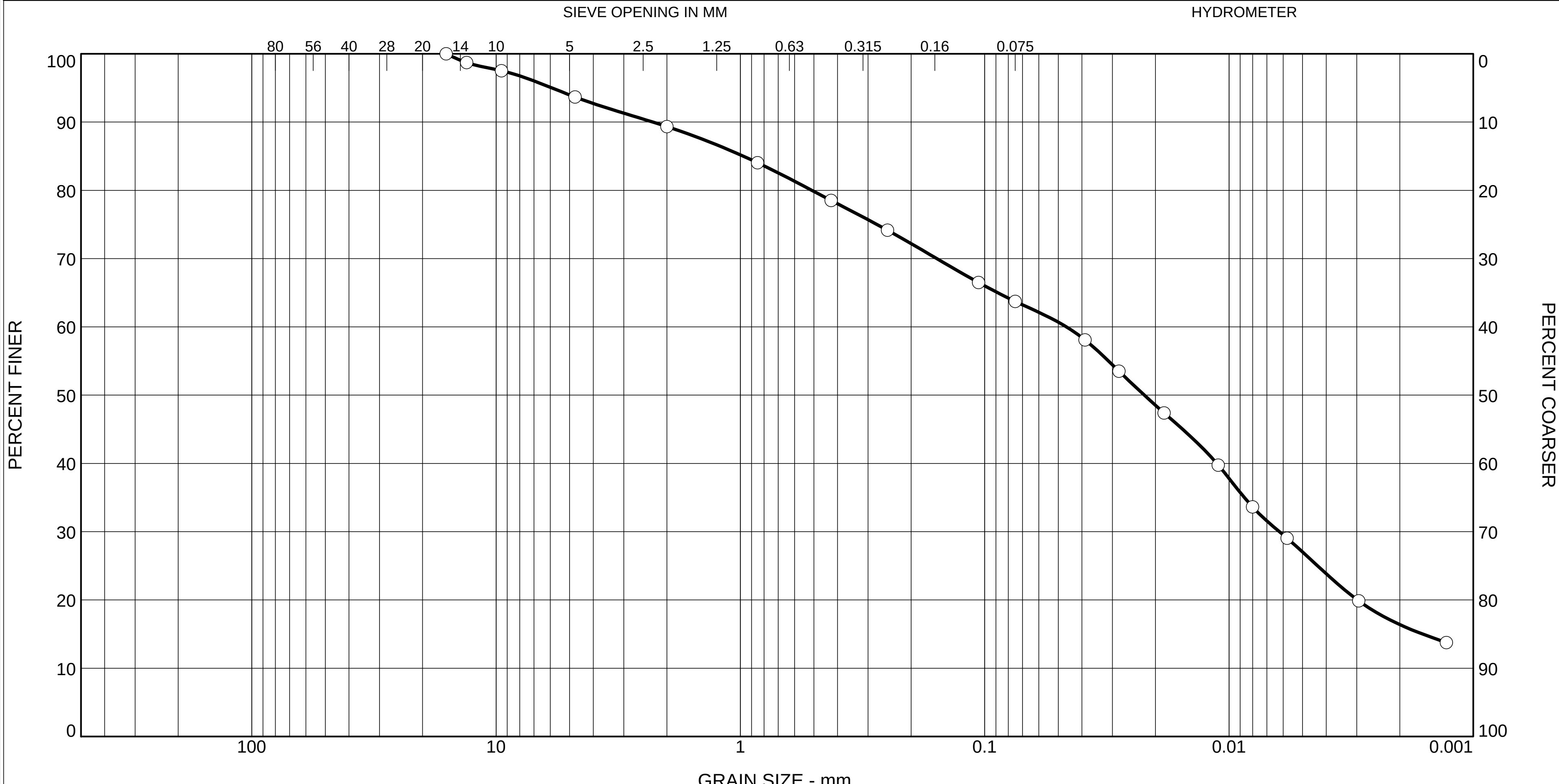
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, some Sand

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	6.3	4.4	10.8	14.8	36.7	27.0

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-03 SS4 Sample Number: MG-37210B		Jul 20, 2022	Jul 29, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

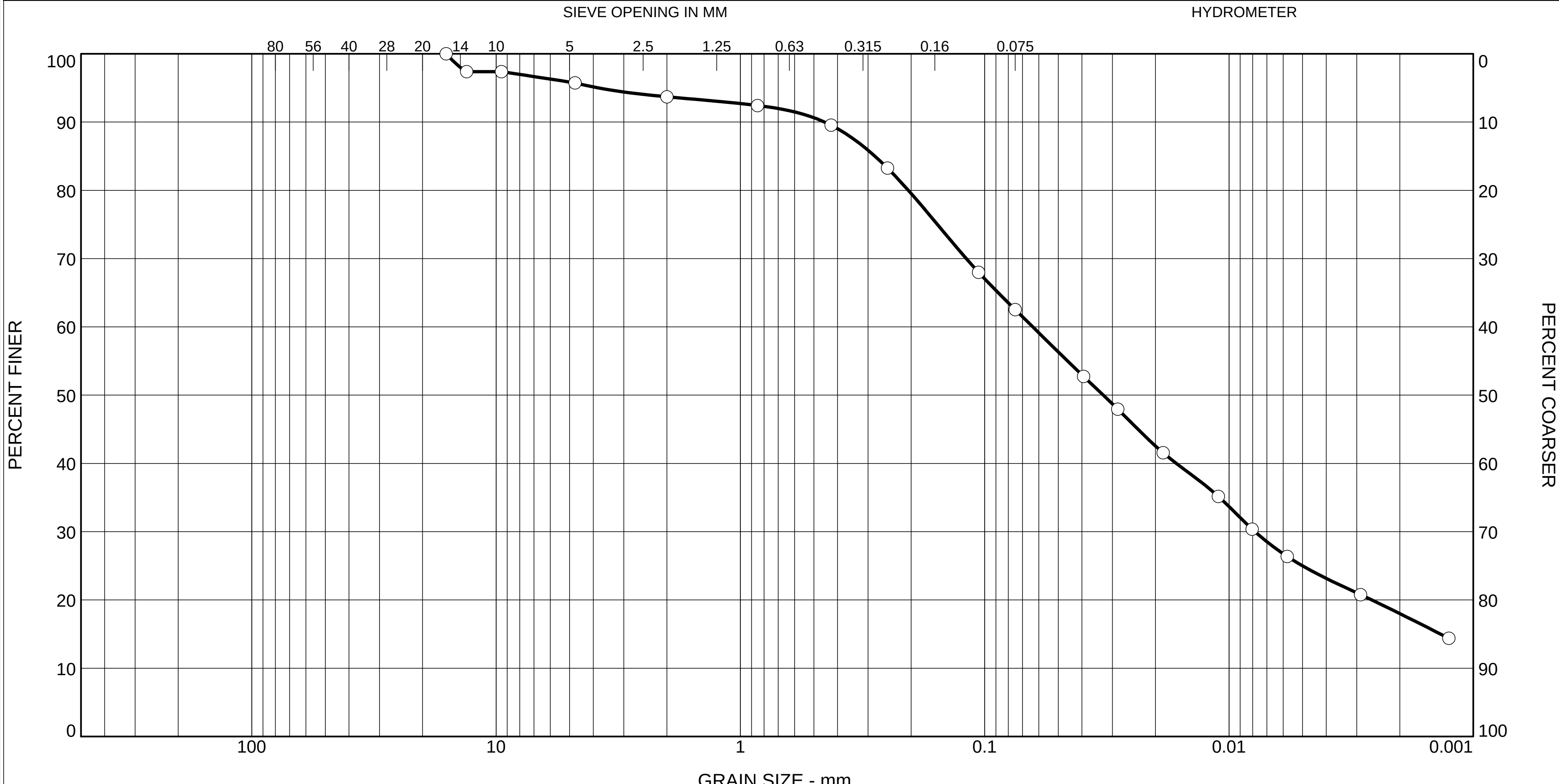
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sandy Silty Clay

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	4.3	2.0	4.2	27.0	37.5	25.0

Identification		Date Sampled	Date Received	Date Tested
Location: BH22-04 SS3	Sample Number: MG-37161A		Jul 18, 2022	Jul 21, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

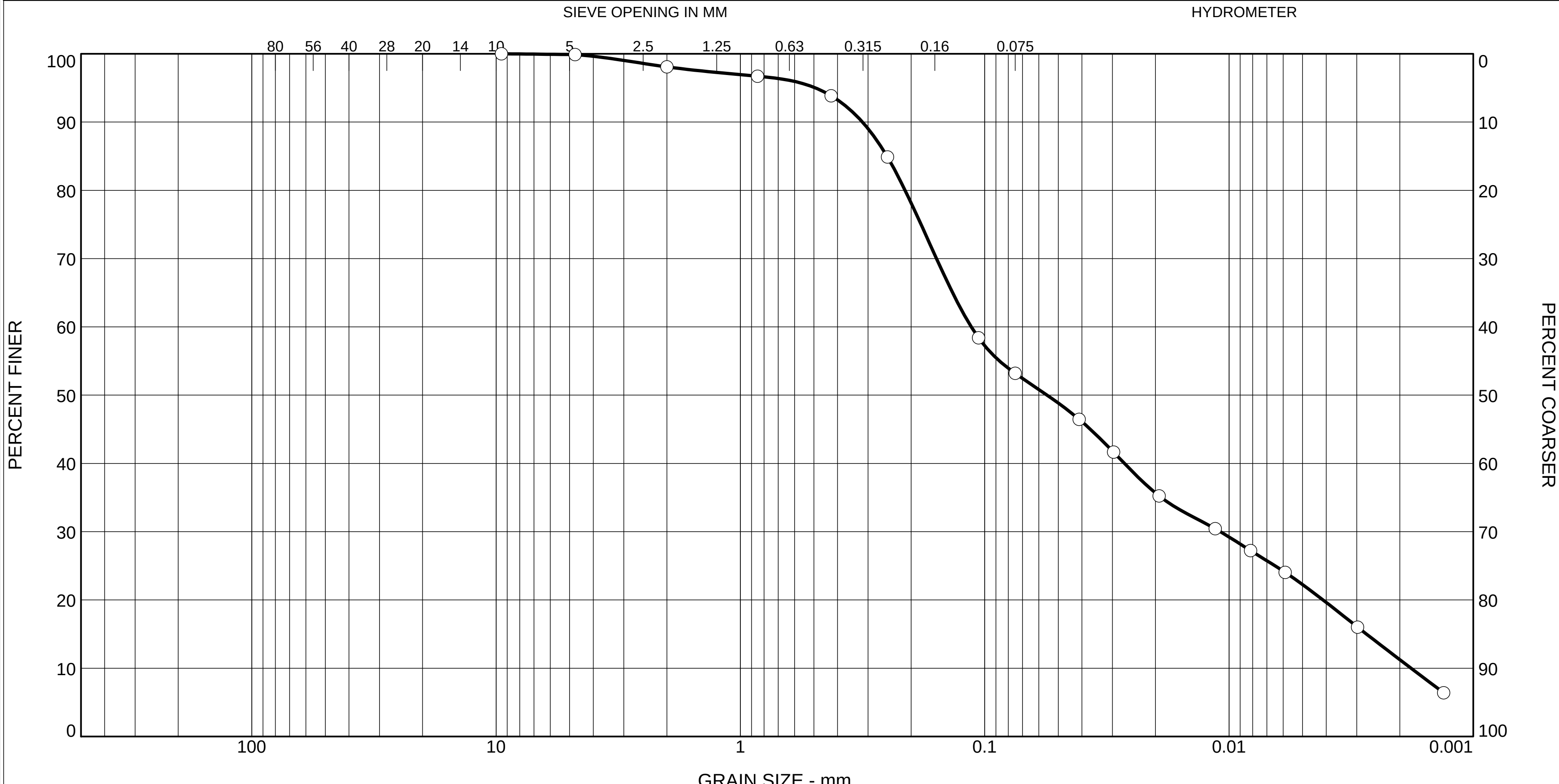
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sandy Silty Clay, trace Gravel

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	0.1	1.8	4.2	40.7	30.9	22.3

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-04 SS9 Sample Number: MG-37161B		Jul 18, 2022	Jul 20, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

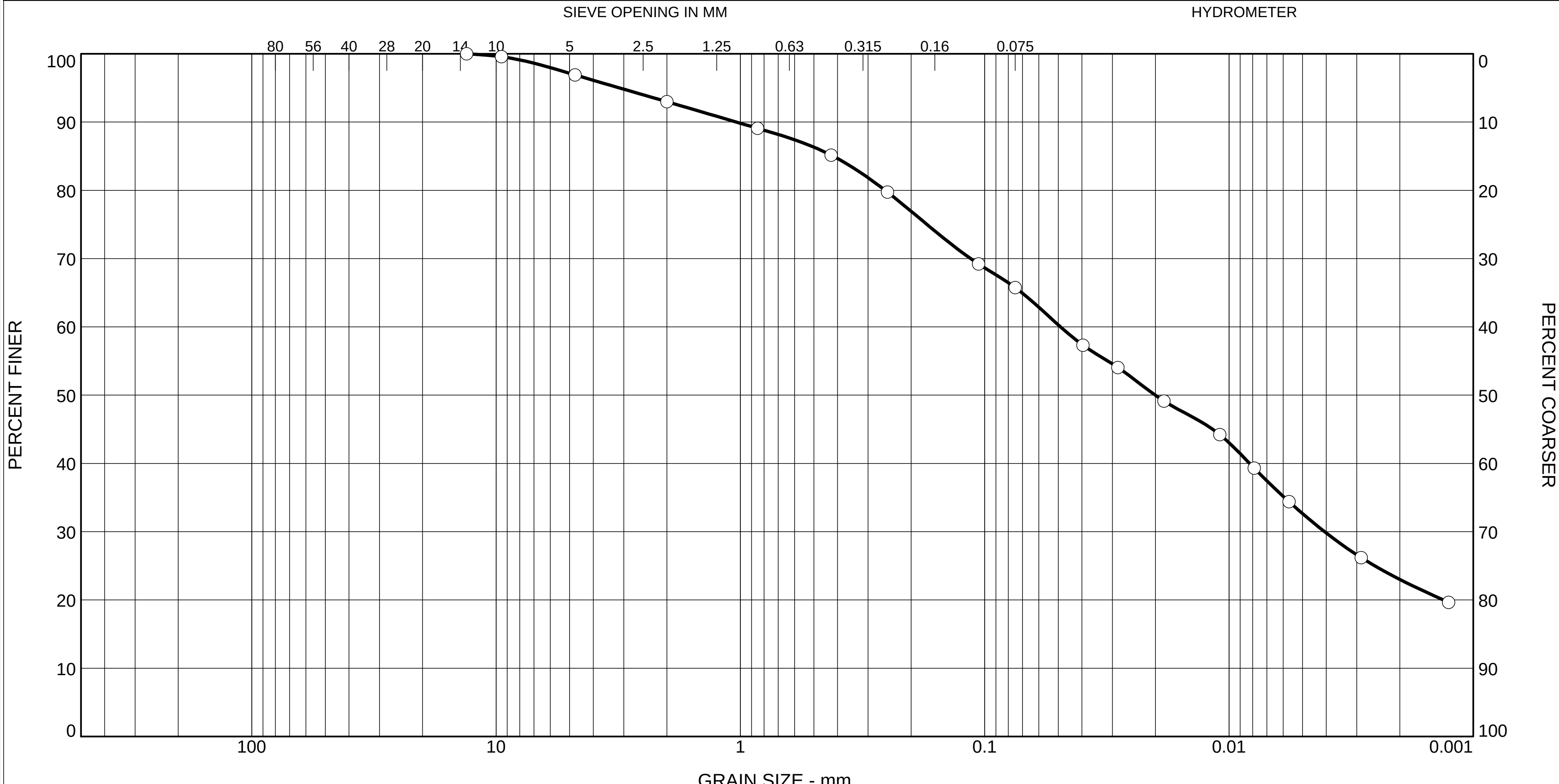
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sandy Clayey Silt

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	3.1	3.9	7.8	19.4	33.2	32.6

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-04 SS11 Sample Number: MG-37161C		Jul 18, 2022	Jul 20, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

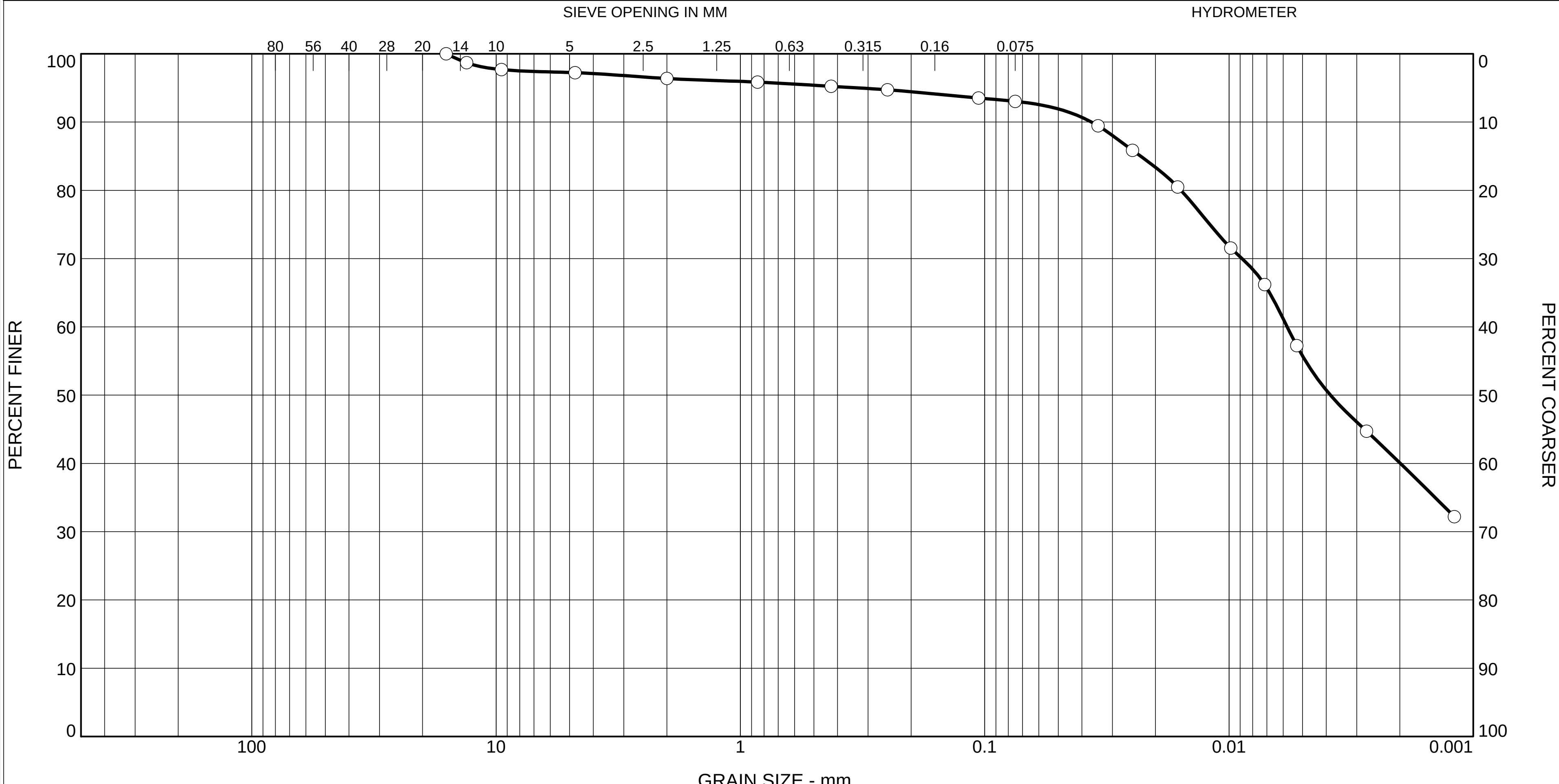
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sandy Clayey Silt, trace Gravel

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.8	0.8	1.2	2.2	37.3	55.7

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-04 SS15 Sample Number: MG-37161D		Jul 18, 2022	Jul 25, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

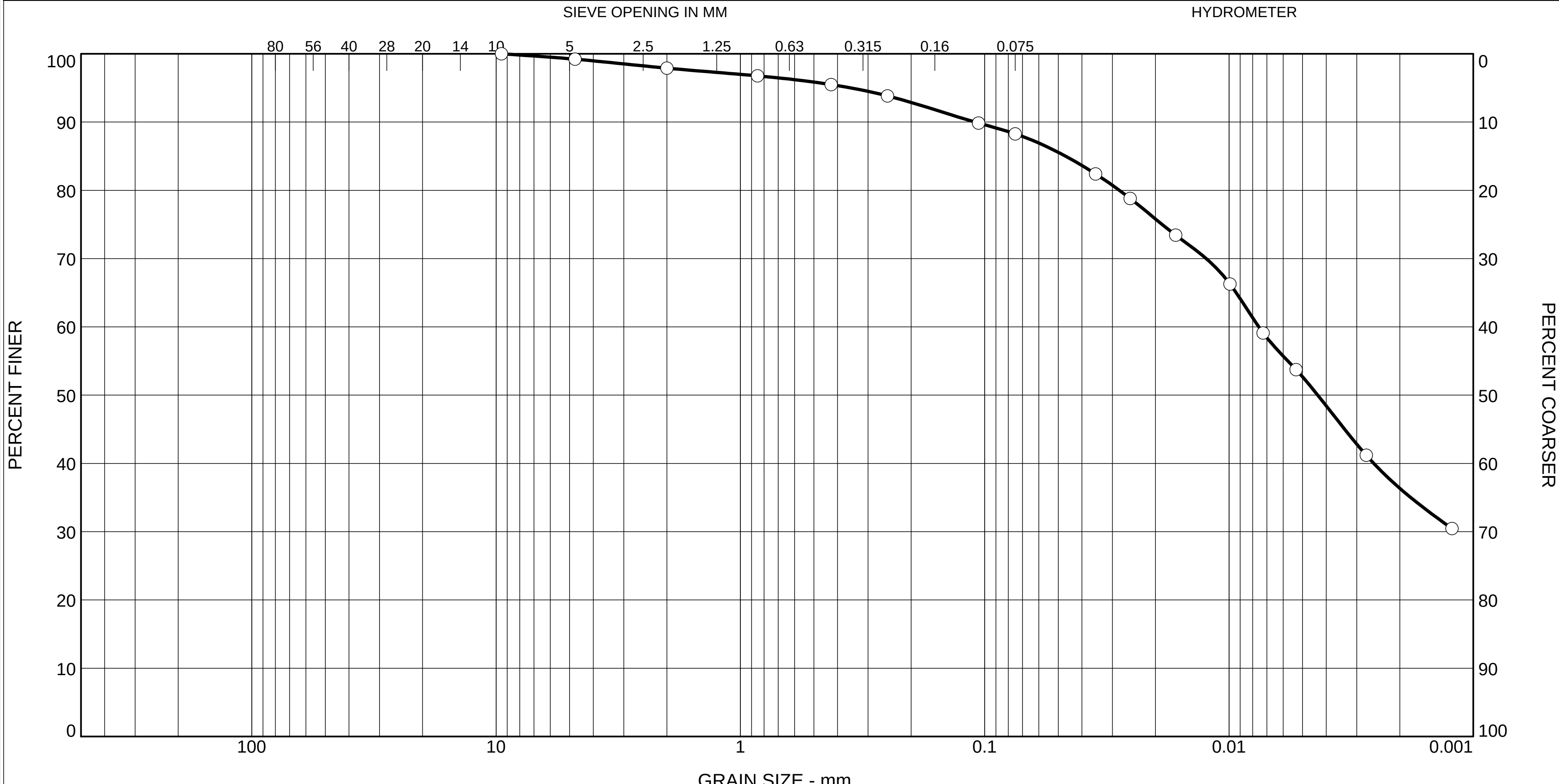
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, trace Sand

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	0.8	1.3	2.4	7.2	35.6	52.7

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-05 SS2 Sample Number: MG-37159A		Jul 18, 2022	Jul 20, 2022

Client ACML

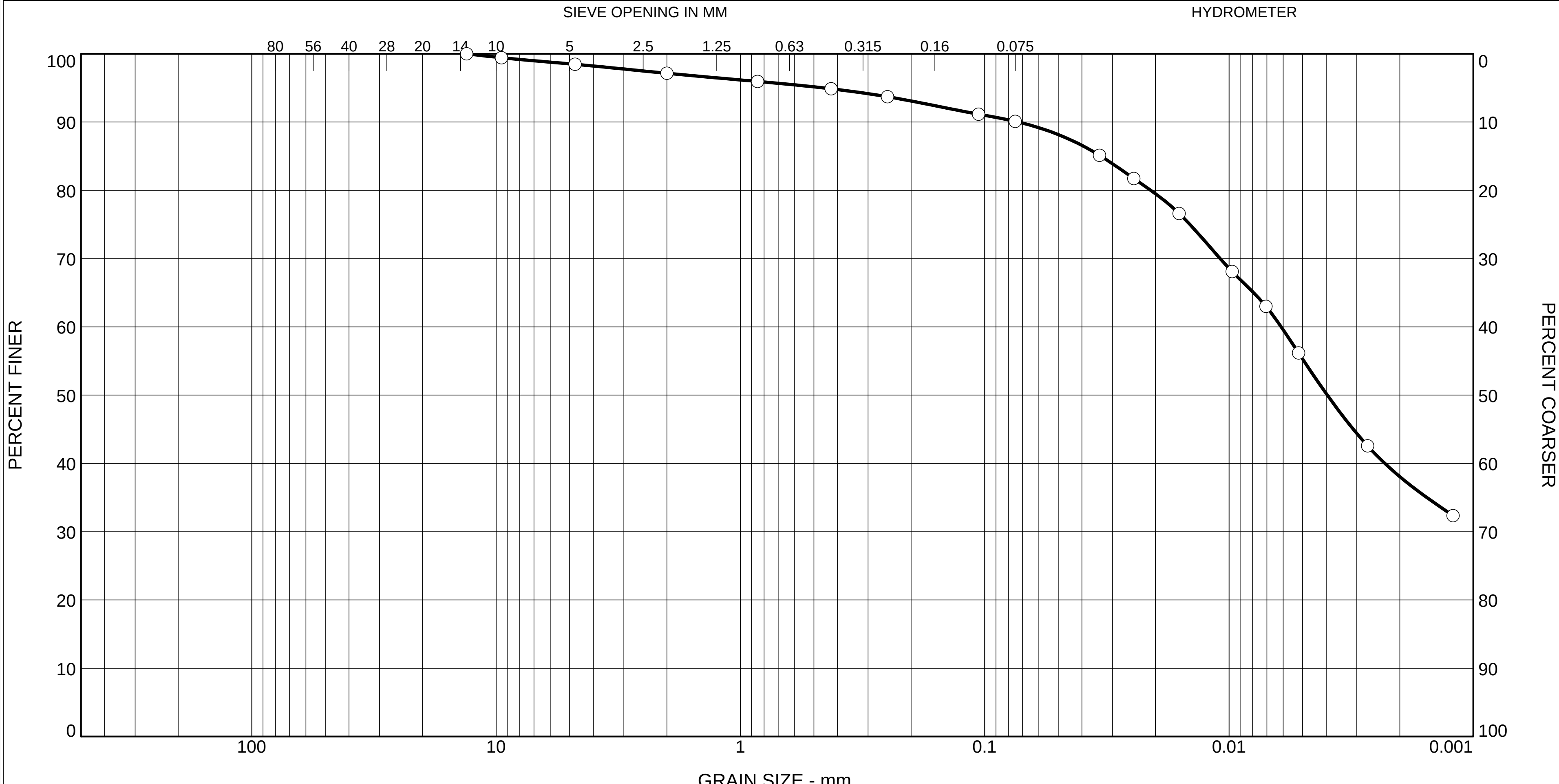
Project MTO 2021-3006 Hwy 403, Woodstock

Project No. 13211.201 Figure

○ Description: Silty Clay, some Sand

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	1.5	1.4	2.2	4.8	34.8	55.3

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-05 SS4 Sample Number: MG-37213A		Jul 20, 2022	Jul 29, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

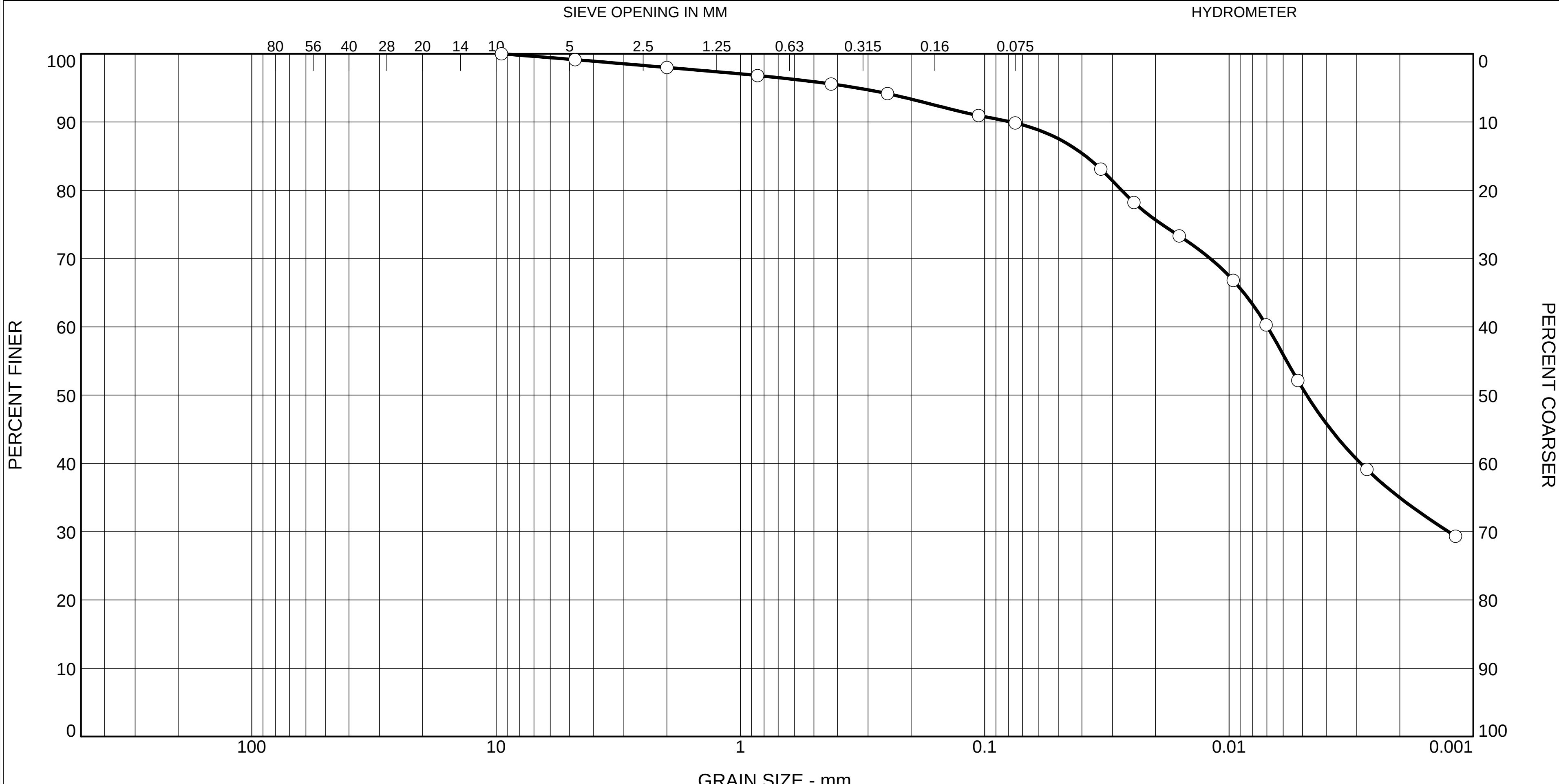
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, trace Sand

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.9	1.1	2.4	5.7	38.9	51.0

Identification		Date Sampled	Date Received	Date Tested
Location: BH22-06 SS4	Sample Number: MG-37100		Jul 13, 2022	Jul 15, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

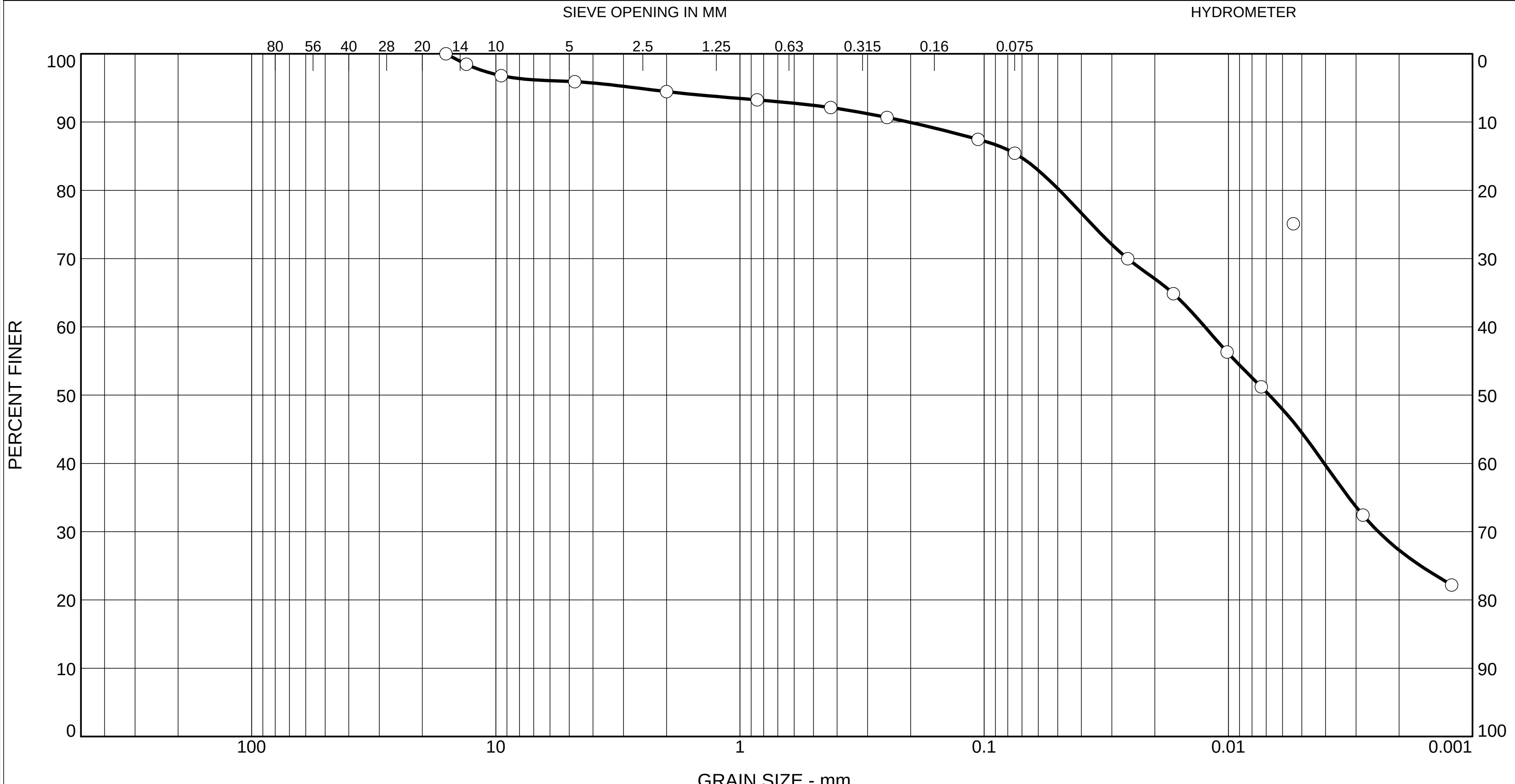
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, trace Sand

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	4.1	1.4	2.4	6.7	40.9	44.5

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-07 SS4 Sample Number: MG-37095		Jul 13, 2022	Jul 15, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

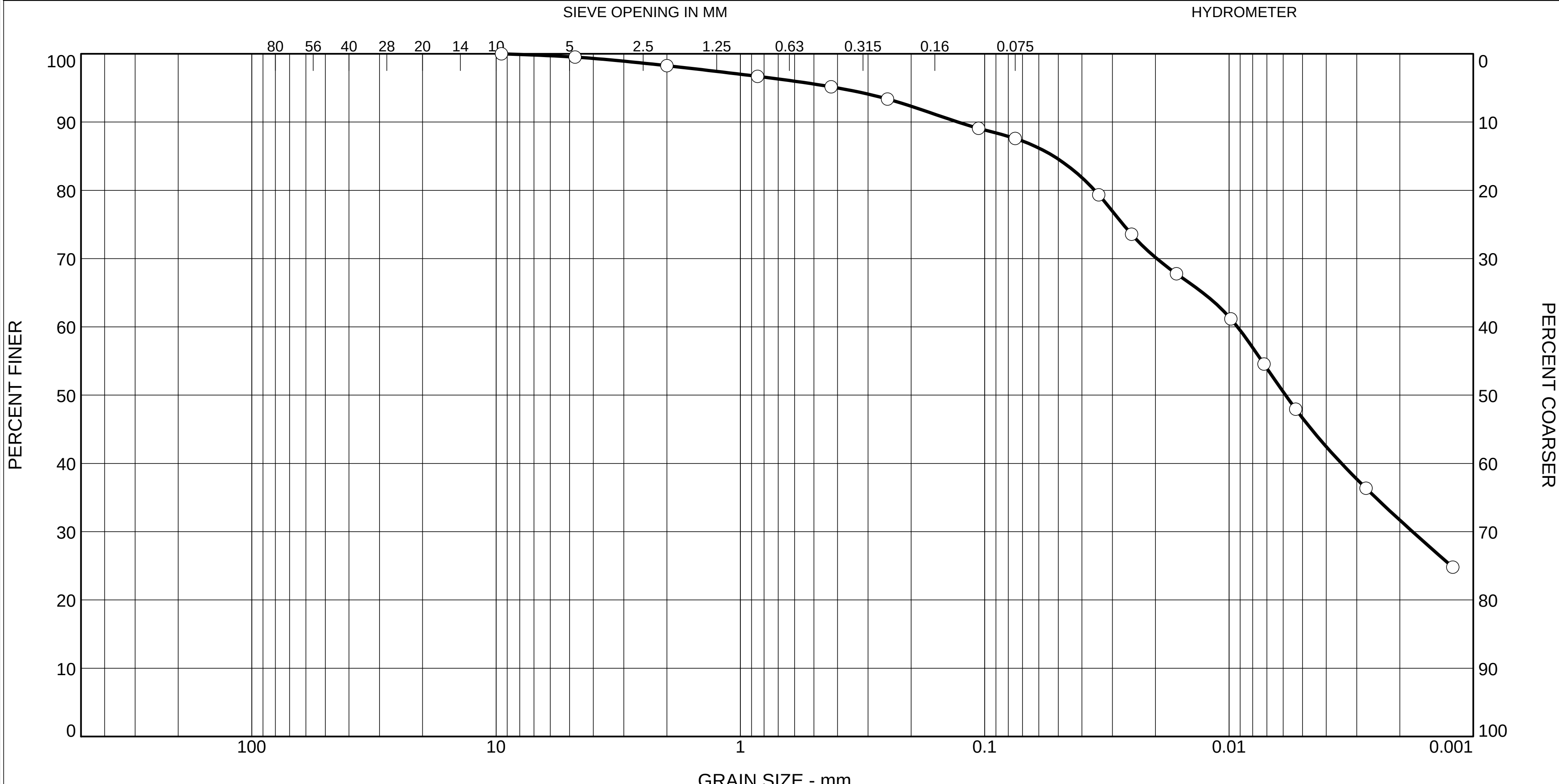
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, some Sand, trace Gravel

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.5	1.2	3.1	7.6	41.0	46.6

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-08 SS2 Sample Number: MG-37167A		Jul 18, 2022	Jul 21, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

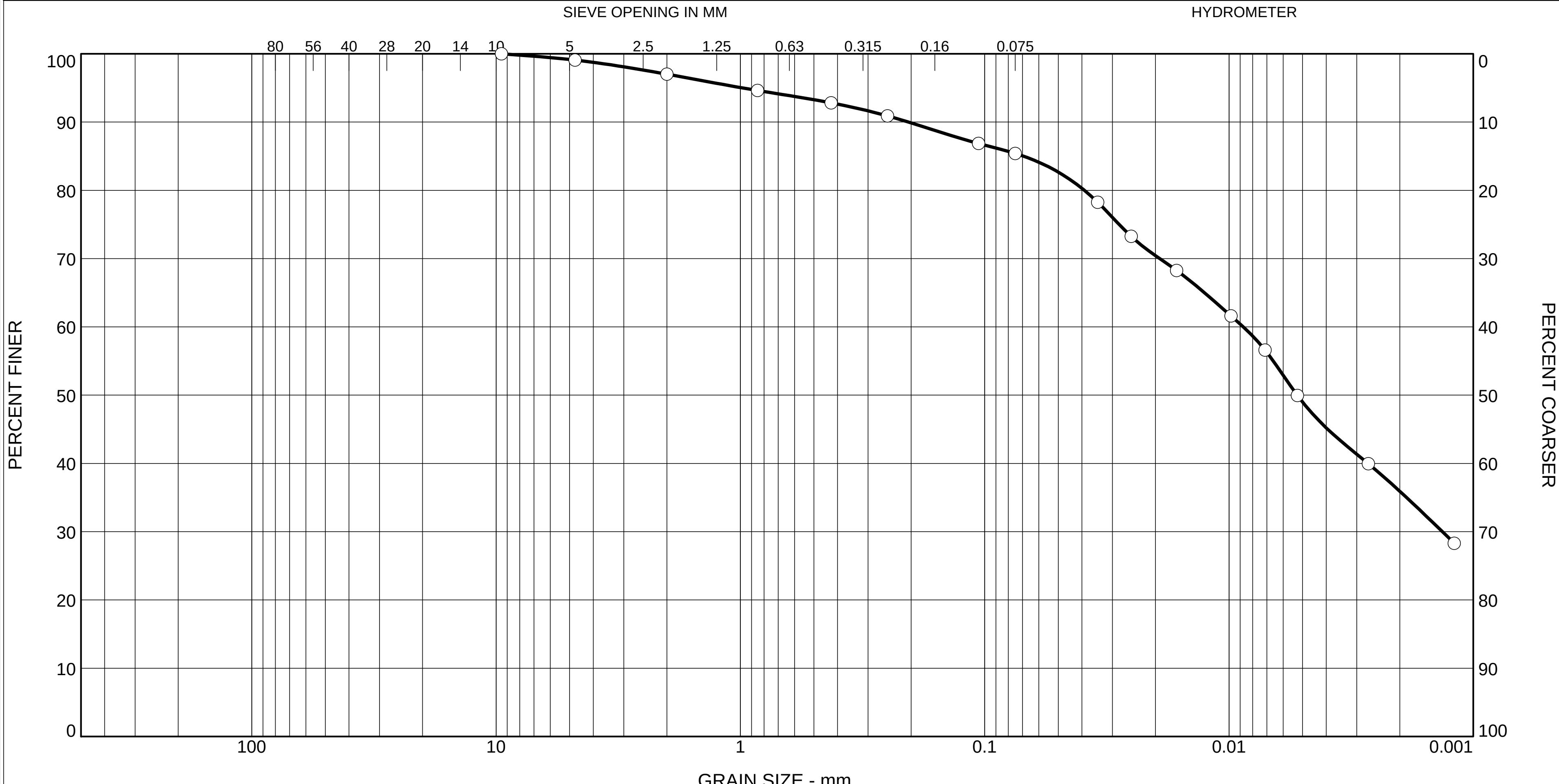
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, some Sand

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.9	2.1	4.2	7.4	36.4	49.0

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-08 SS5 Sample Number: MG-37167B		Jul 18, 2022	Jul 21, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

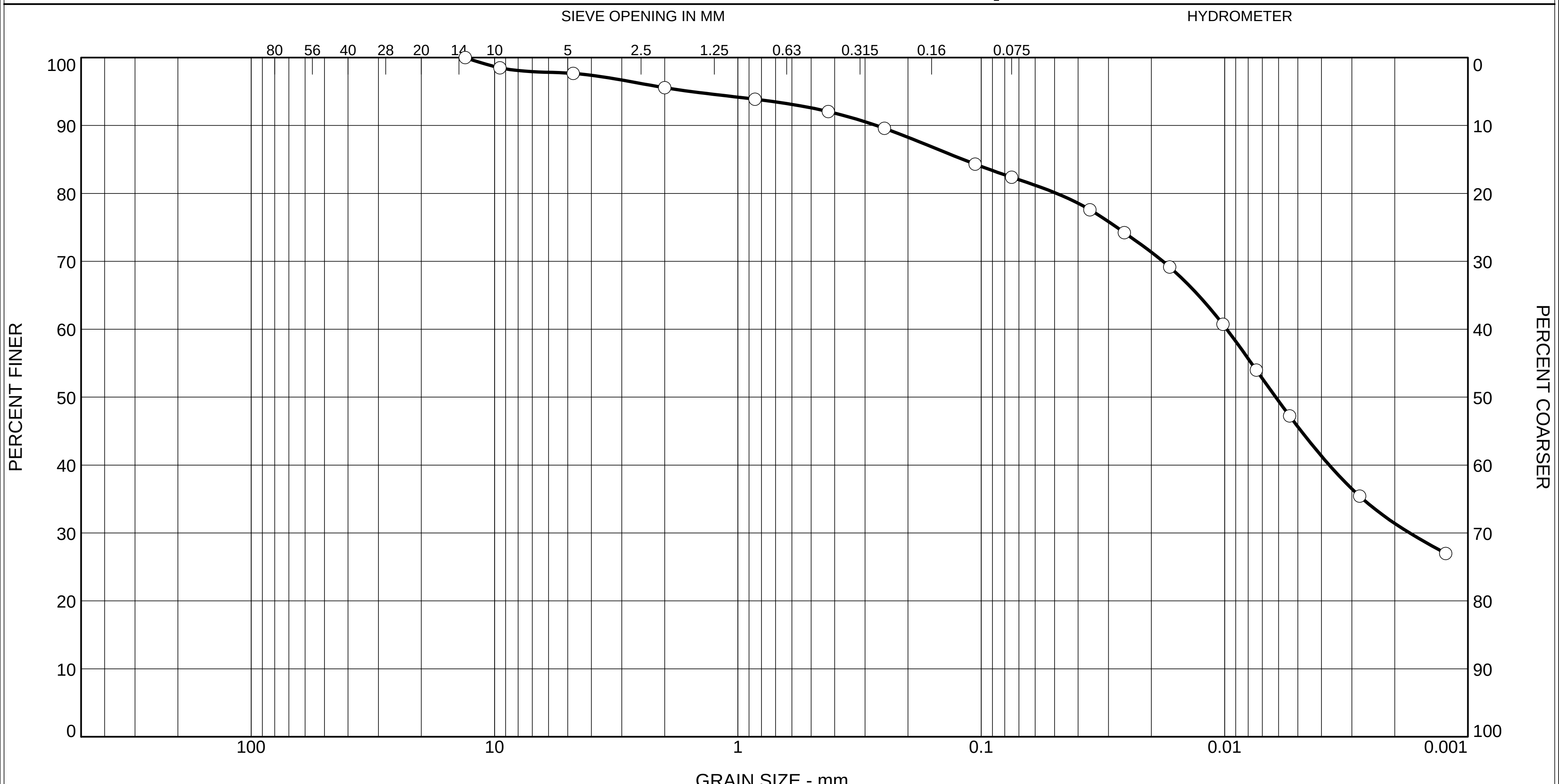
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, some Sand

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.3	2.1	3.5	9.7	36.8	45.6

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-09 SS2 Sample Number: MG-37211A		Jul 20, 2022	Jul 29, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

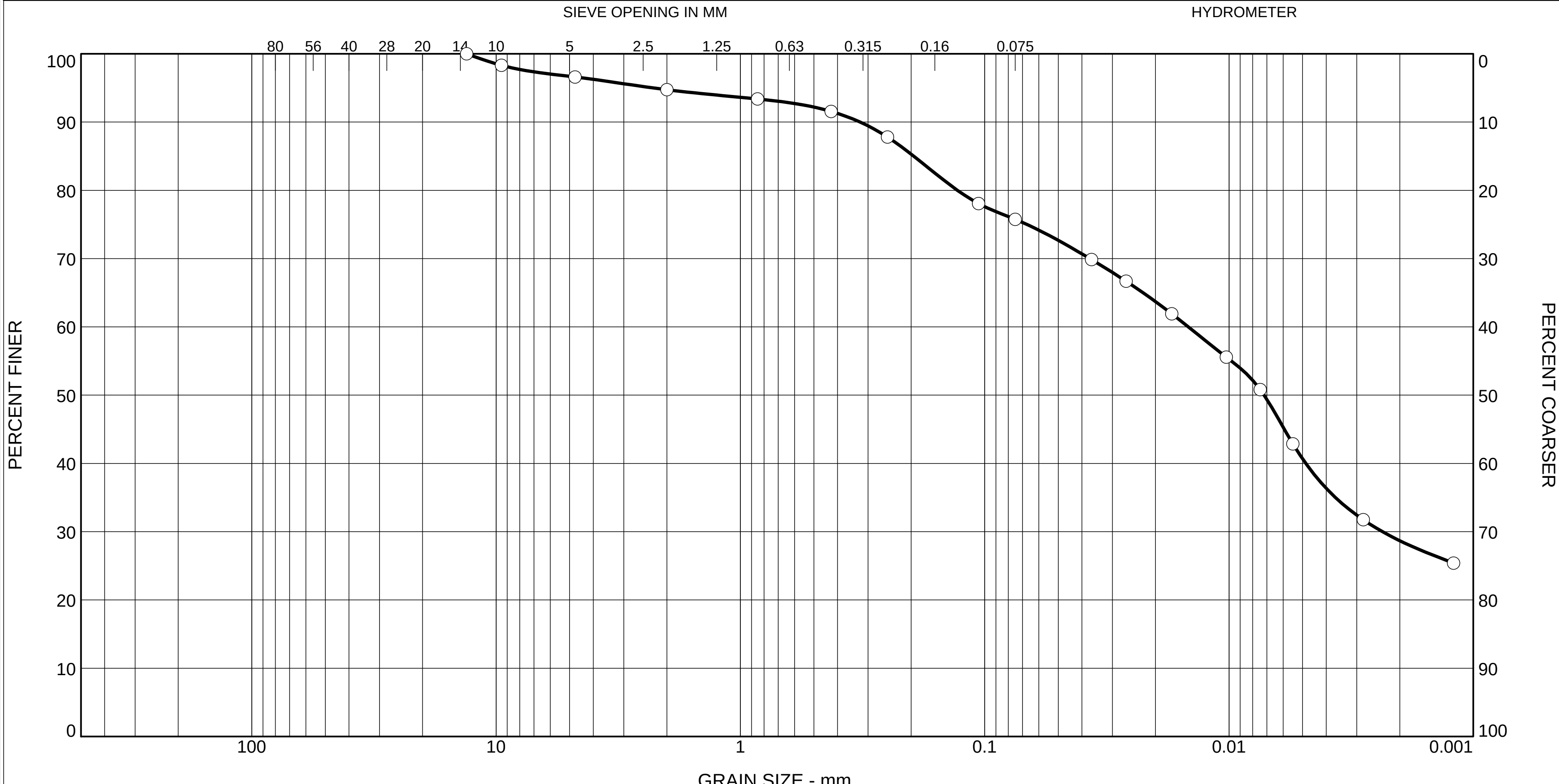
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, some Sand

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	3.4	1.9	3.1	15.8	35.1	40.7

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-09 SS5 Sample Number: MG-37211B		Jul 20, 2022	Jul 29, 2022

Client ACML

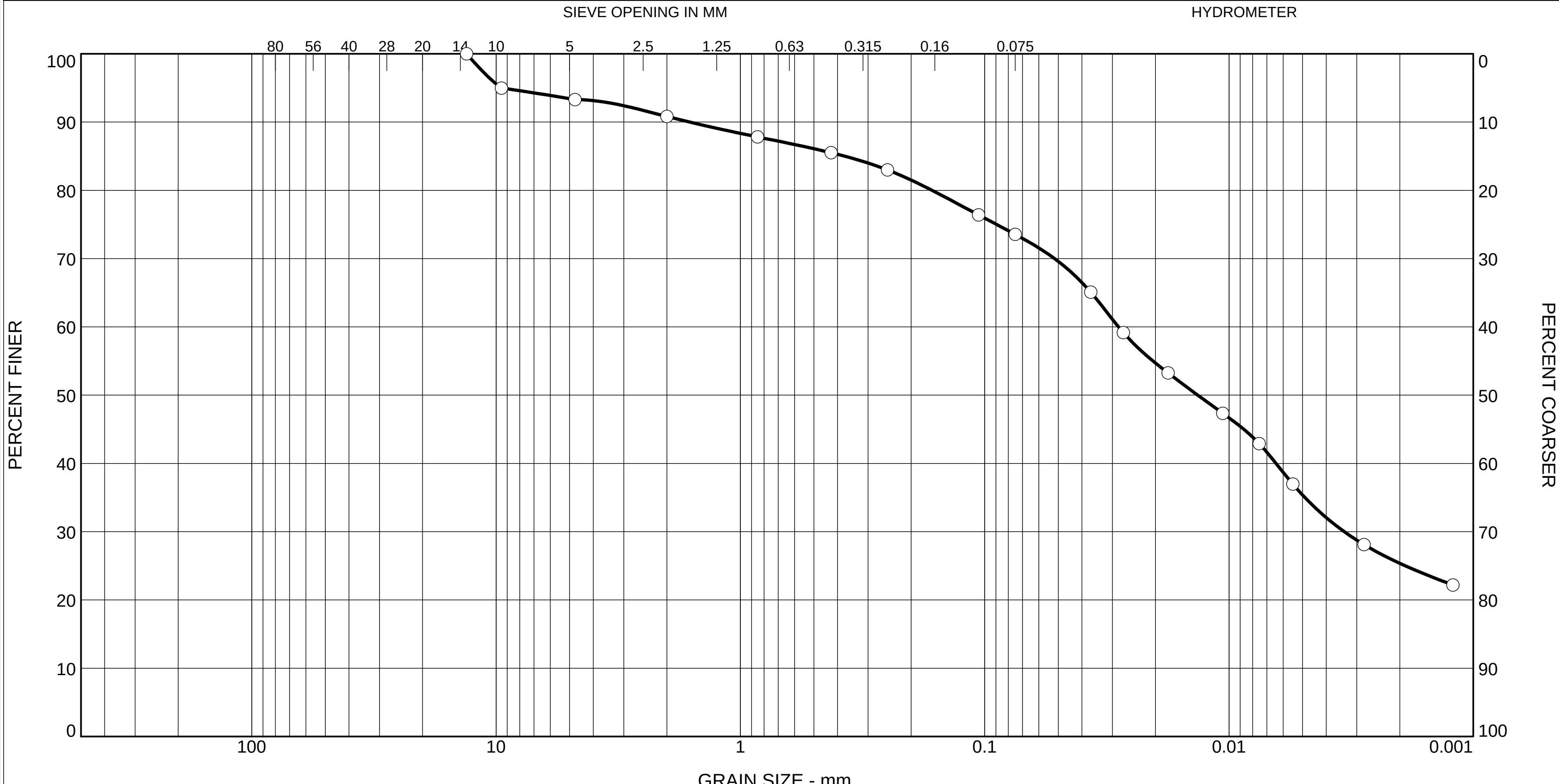
Project MTO 2021-3006 Hwy 403, Woodstock

Project No. 13211.201 Figure

○ Description: Sandy Silty Clay, trace Gravel

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○ 0.0	0.0	6.7	2.5	5.3	11.9	38.2	35.4

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-10 SS3 Sample Number: MG-37208A		Jul 20, 2022	Jul 29, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

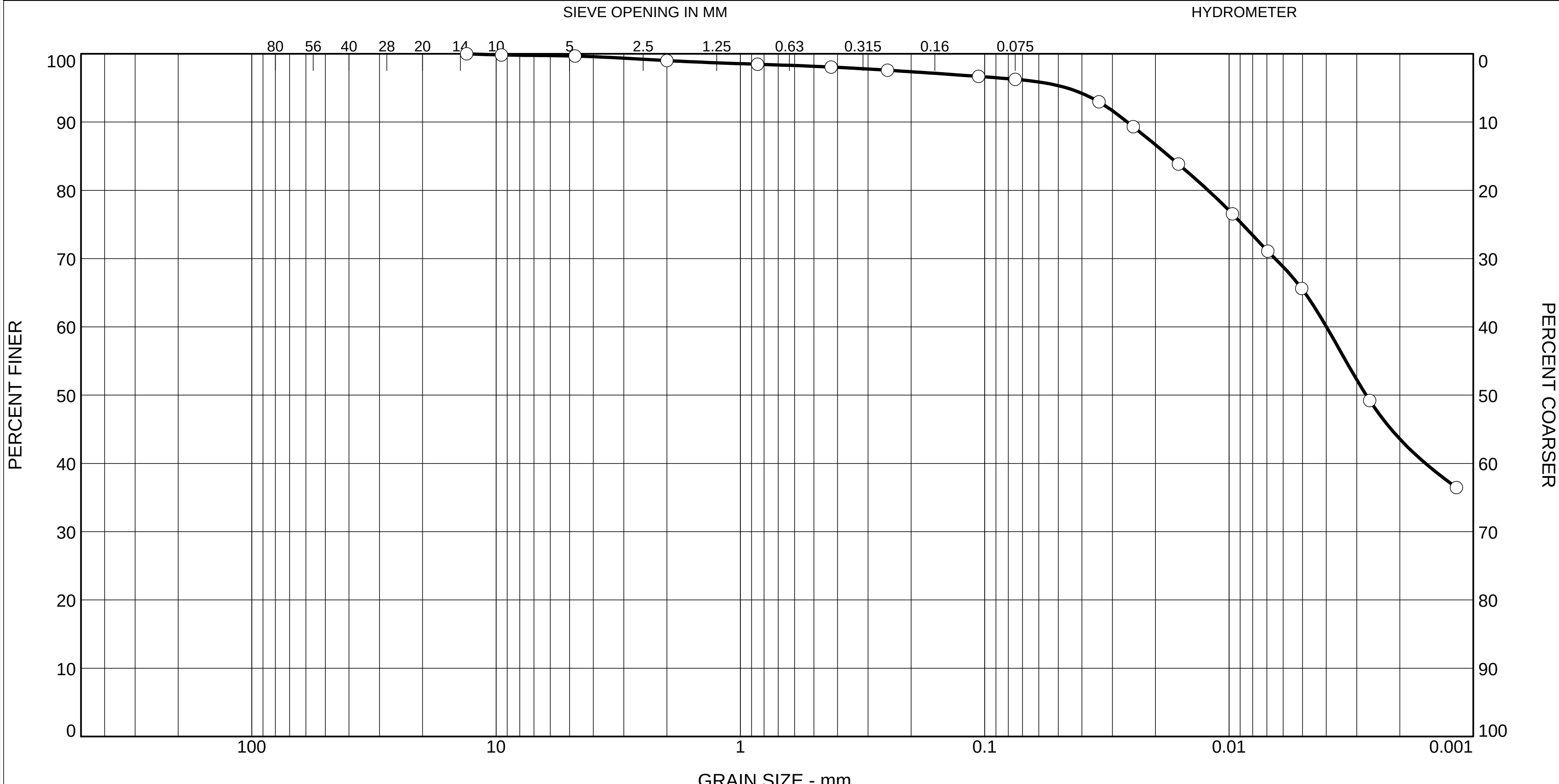
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, some Sand, trace Gravel

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.3	0.7	0.9	1.8	30.8	65.5

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-10 SS6 Sample Number: MG-37208B		Jul 20, 2022	Jul 29, 2022

Client ACML

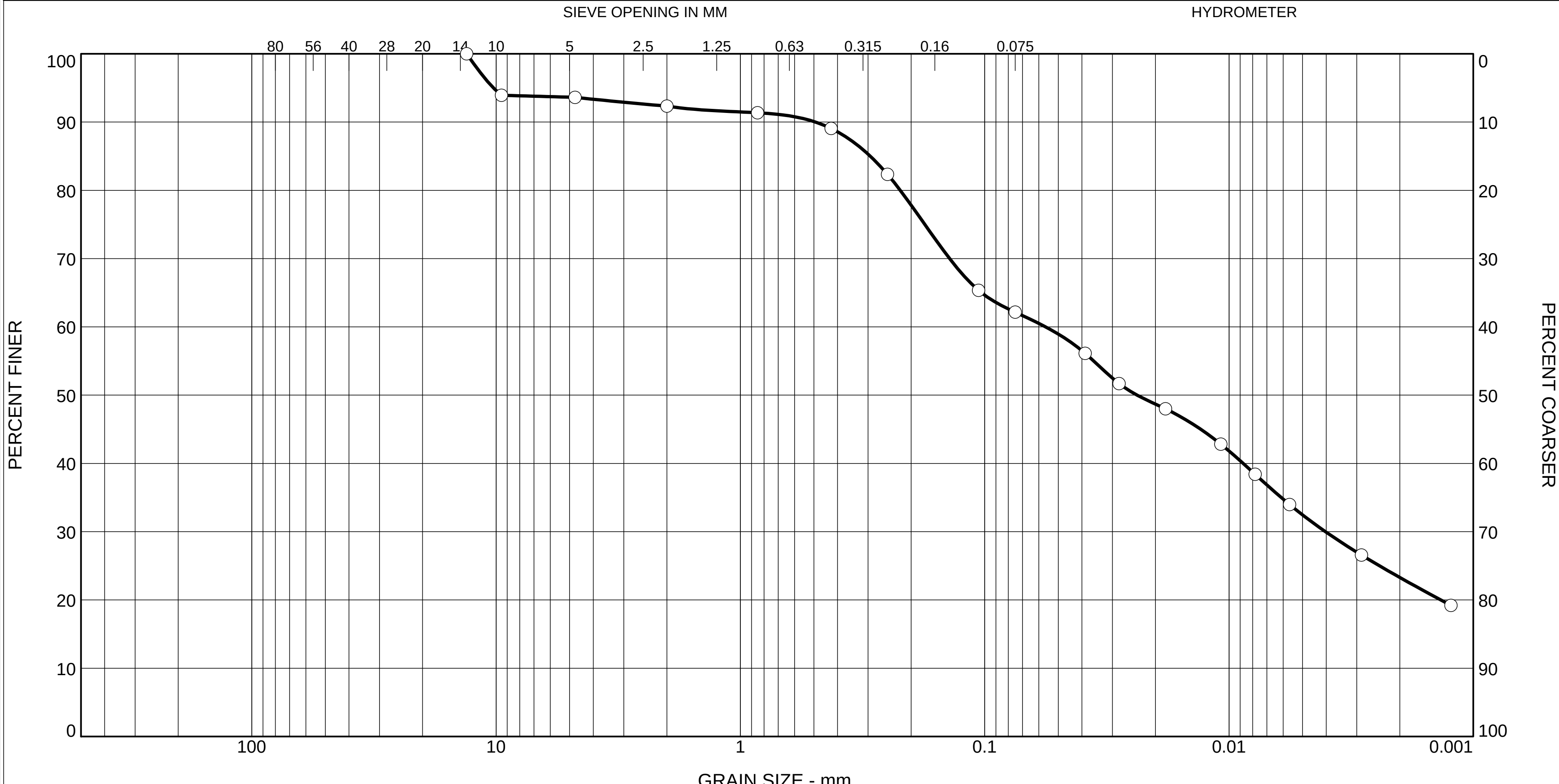
Project MTO 2021-3006 Hwy 403, Woodstock

Project No. 13211.201 Figure

○ Description: Silty Clay, trace Sand

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	6.4	1.3	3.2	26.9	29.7	32.5

Identification		Date Sampled	Date Received	Date Tested
Location: BH22-11 SS5	Sample Number: MG-37164A		Jul 18, 2022	Jul 25, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

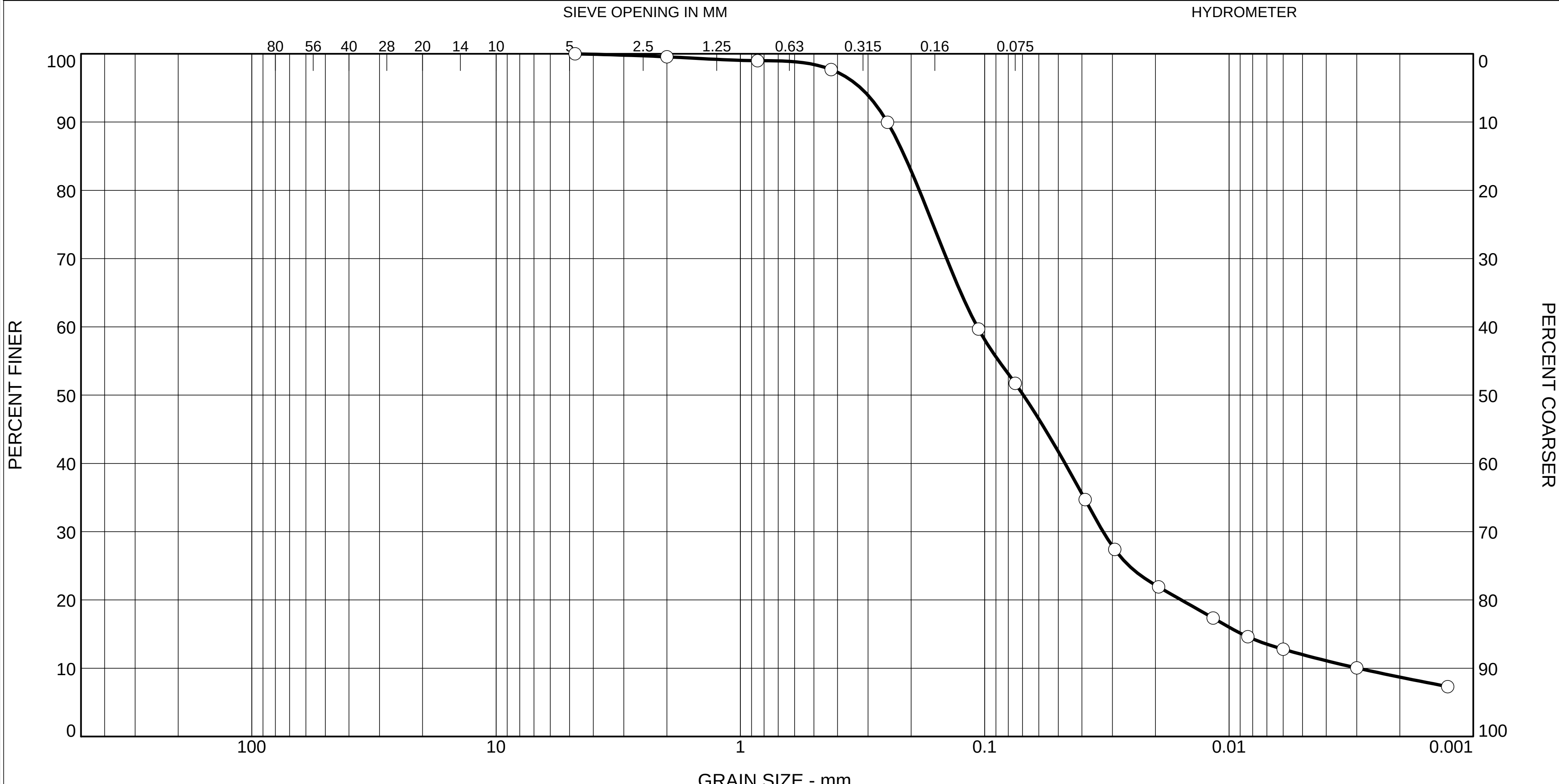
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sandy Silty Clay, trace Gravel

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.4	1.9	46.0	39.7	12.0

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-11 SS9 Sample Number: MG-37164B		Jul 18, 2022	Jul 25, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

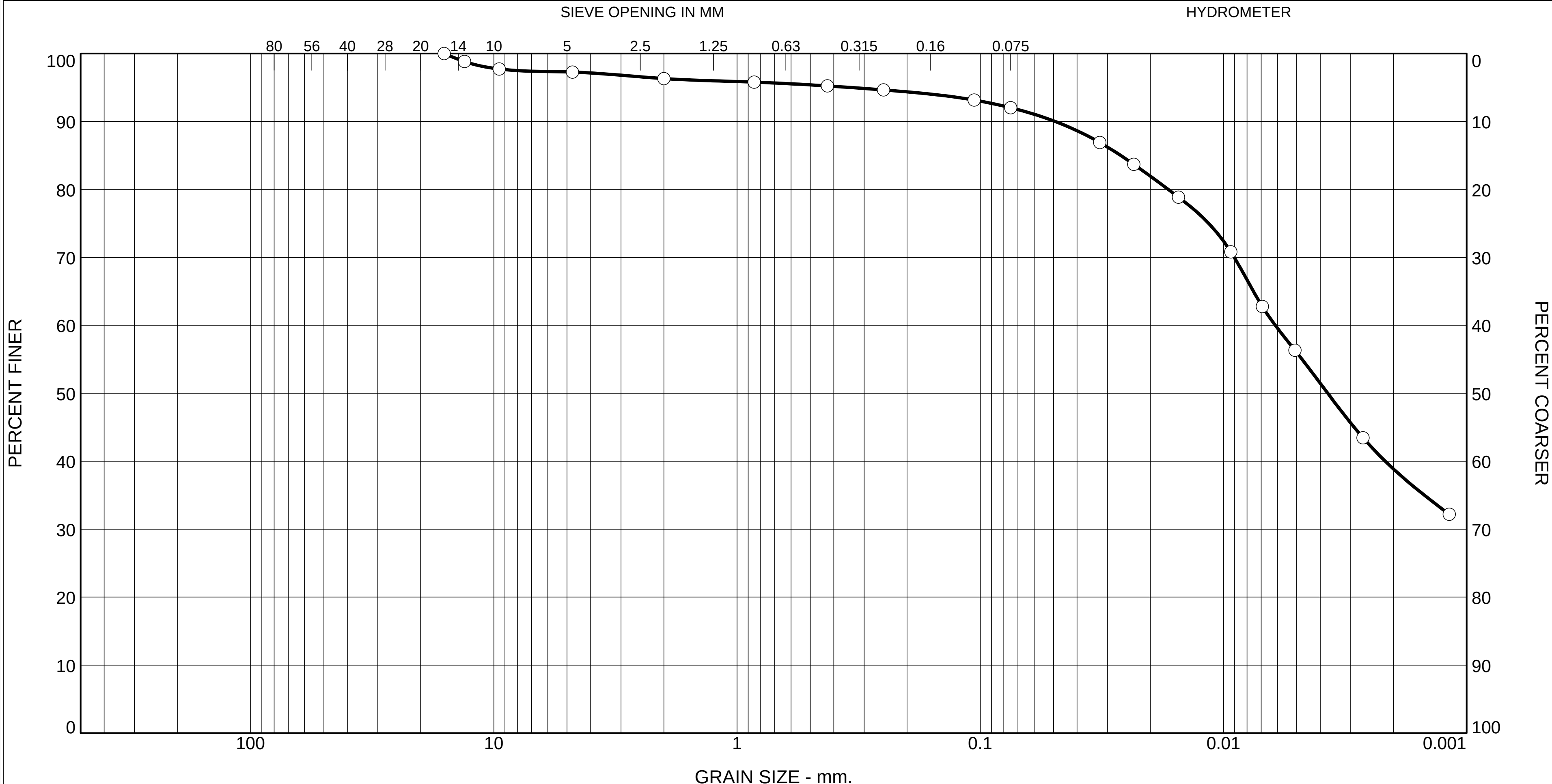
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sand and Silt, some Clay

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.7	1.0	1.1	3.2	36.0	56.0

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-11 SS15 Sample Number: MG-37164C		Jul 18, 2022	Jul 22, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

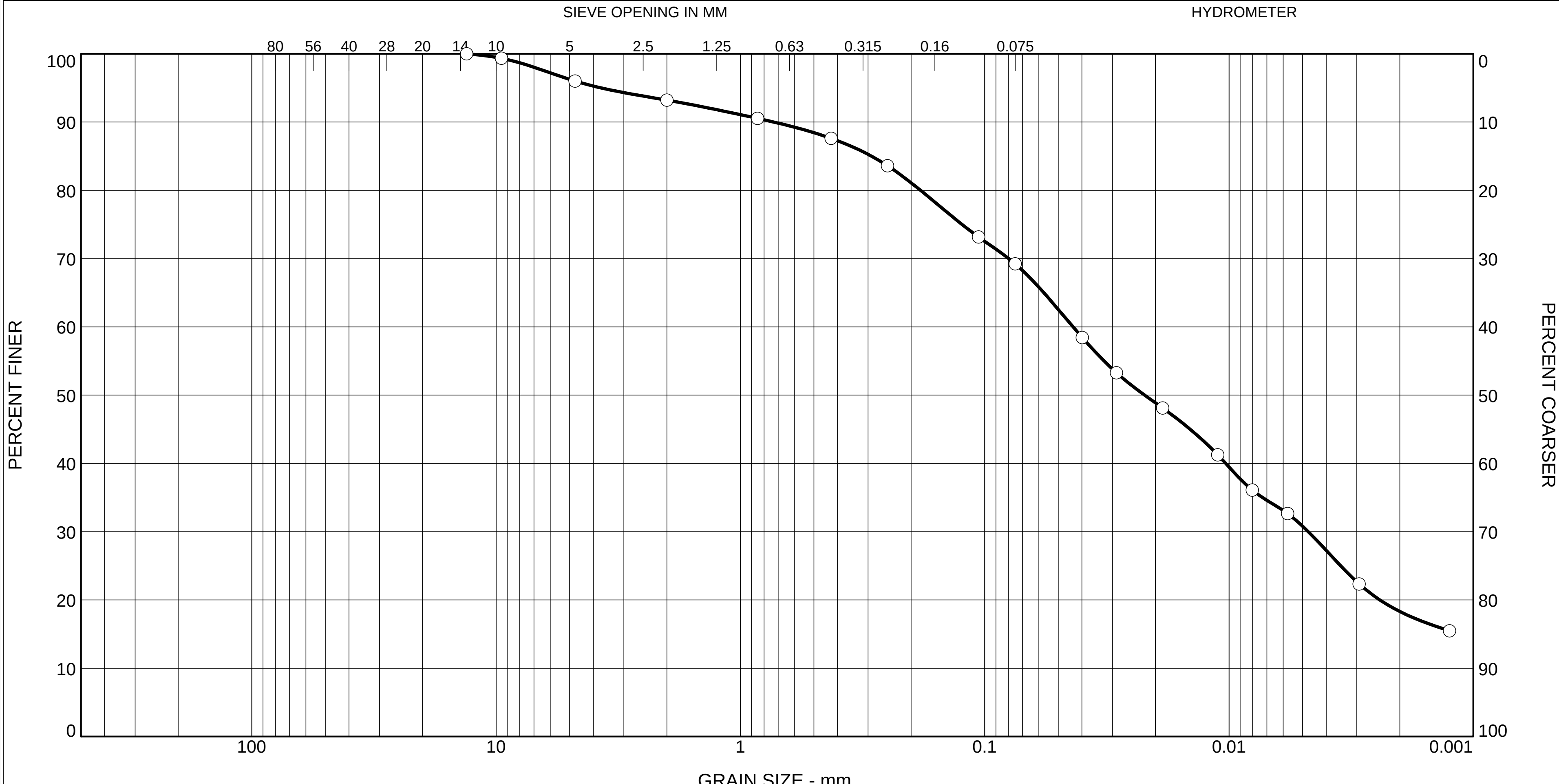
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, trace Sand

Tested By: TZ **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	4.0	2.8	5.6	18.4	38.4	30.8

Identification	Date Sampled	Date Received	Date Tested
Location: BH22-12 SS3 Sample Number: MG-37094A		Jul 13, 2022	Jul 15, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

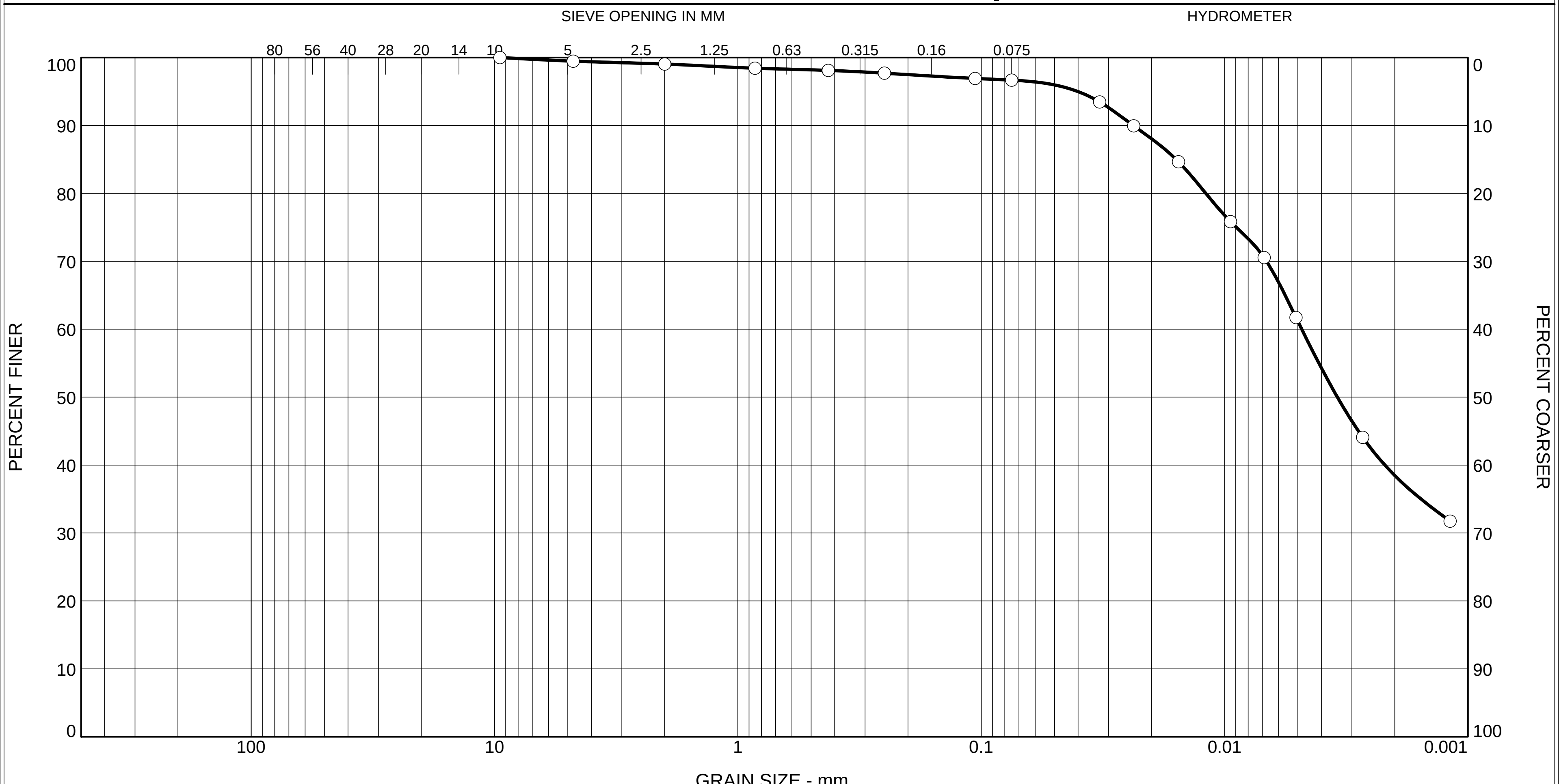
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Sandy Clayey Silt, trace Gravel

Tested By: SH **Checked By:** JY

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.5	0.5	0.9	1.4	35.5	61.2

Identification		Date Sampled	Date Received	Date Tested
Location: BH22-12 SS6	Sample Number: MG-37094B		Jul 13, 2022	Jul 18, 2022

Client ACML

Project MTO 2021-3006 Hwy 403, Woodstock

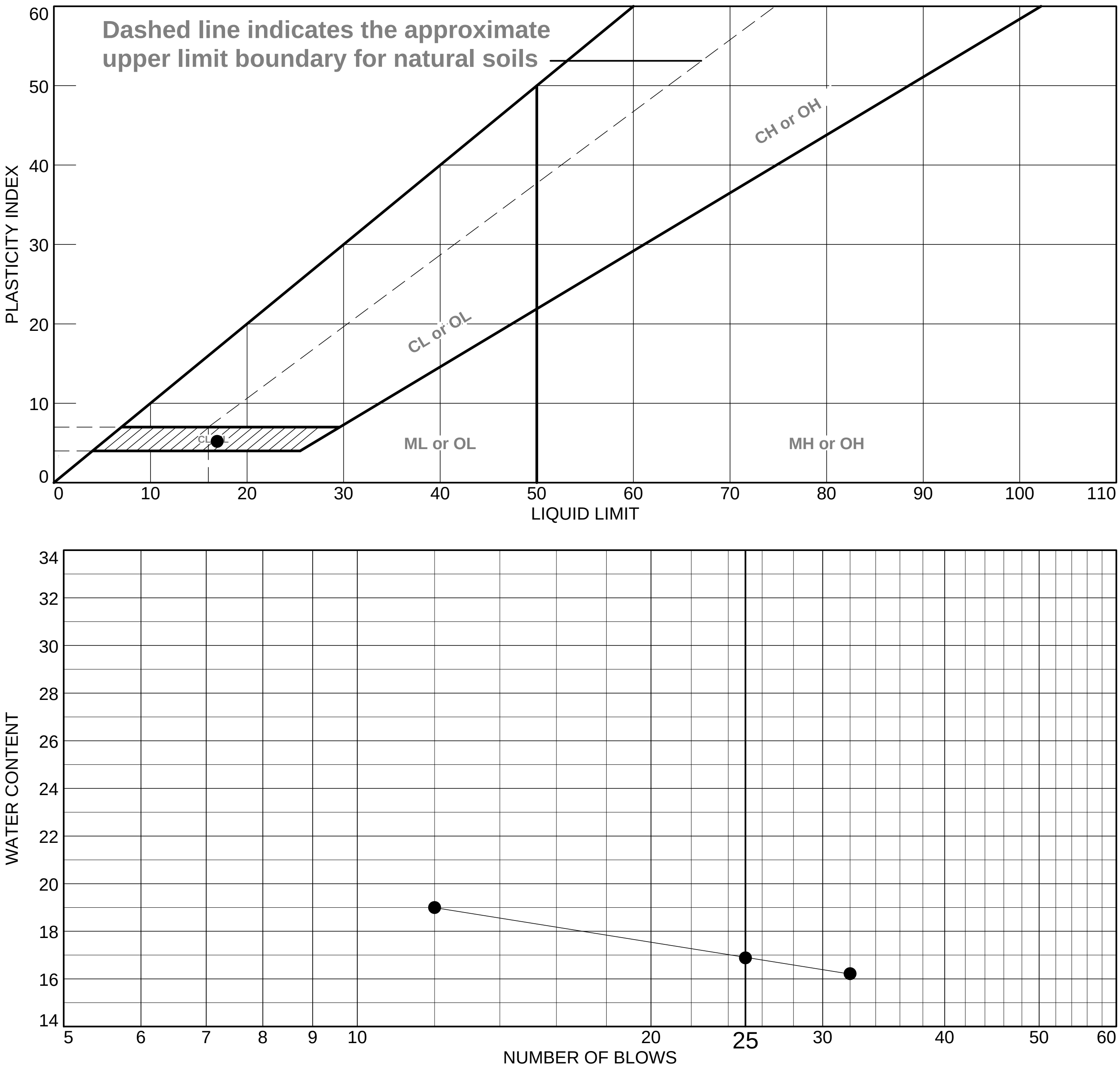
Project No. 13211.201 Figure

AME Materials Engineering

○ Description: Silty Clay, trace Sand

Tested By: SH **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Clayey Silt	16.9	11.7	5.2	82.3	62.4	CL-ML

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-01 SS5
Sample Number: MG-37207

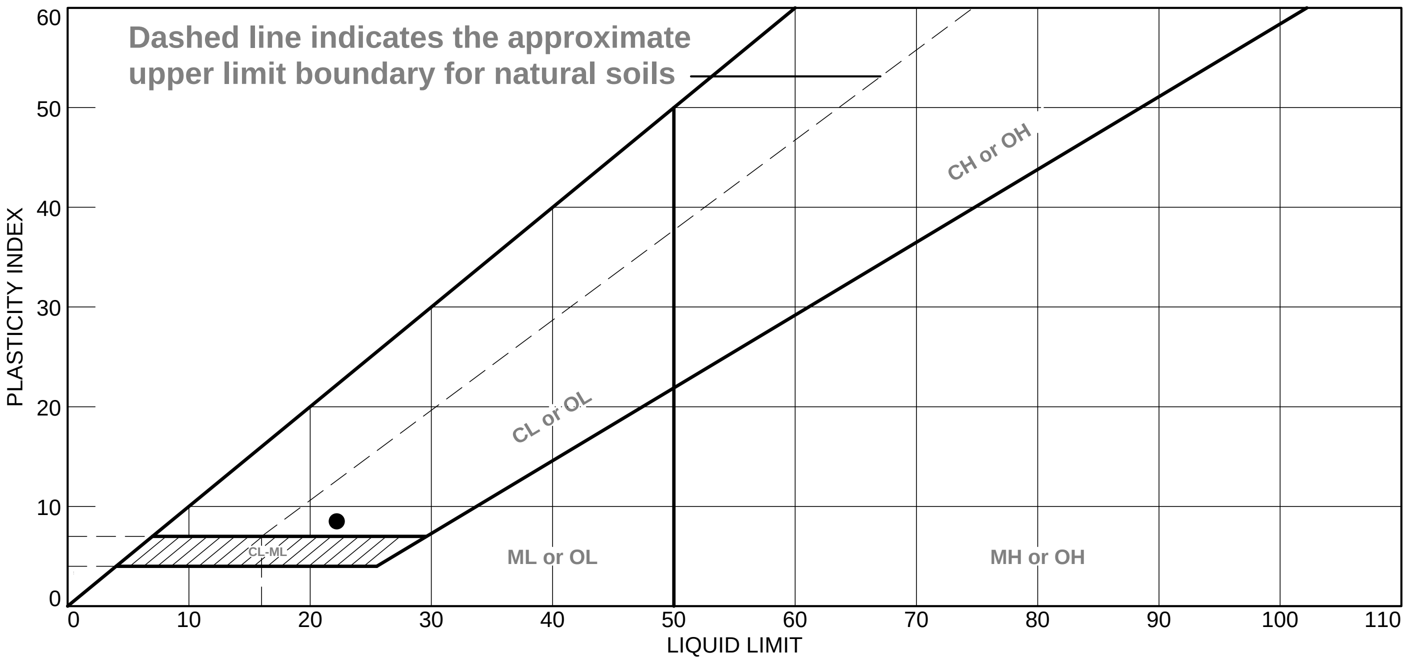
Remarks:

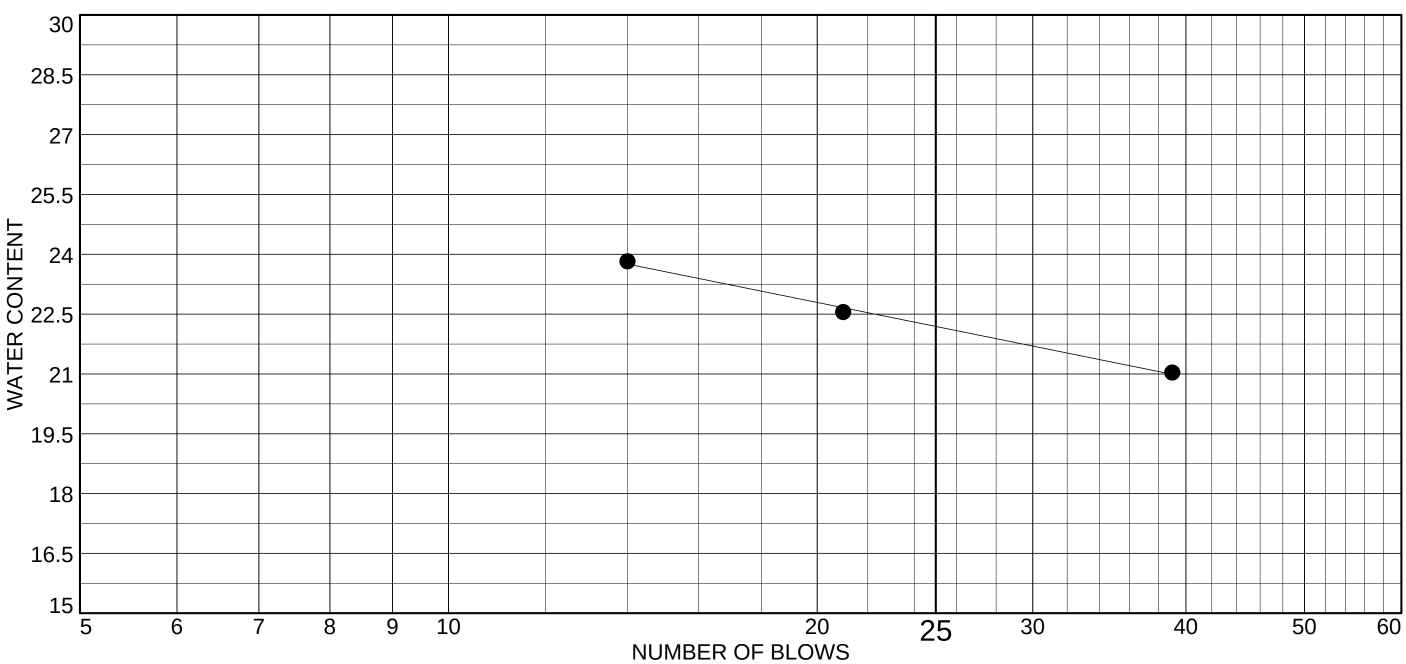
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Silty Clay	22.2	13.7	8.5	92.7	77.6	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-02 SS2
Sample Number: MG-37096A

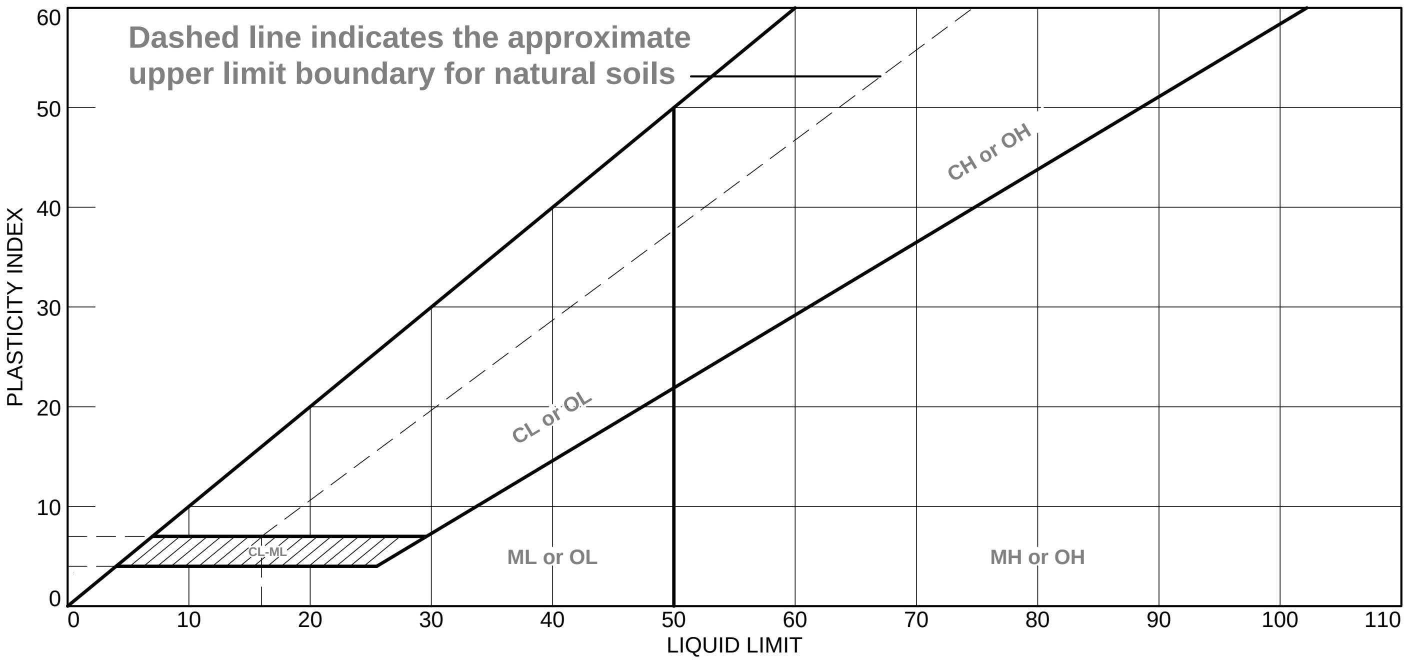
Remarks:

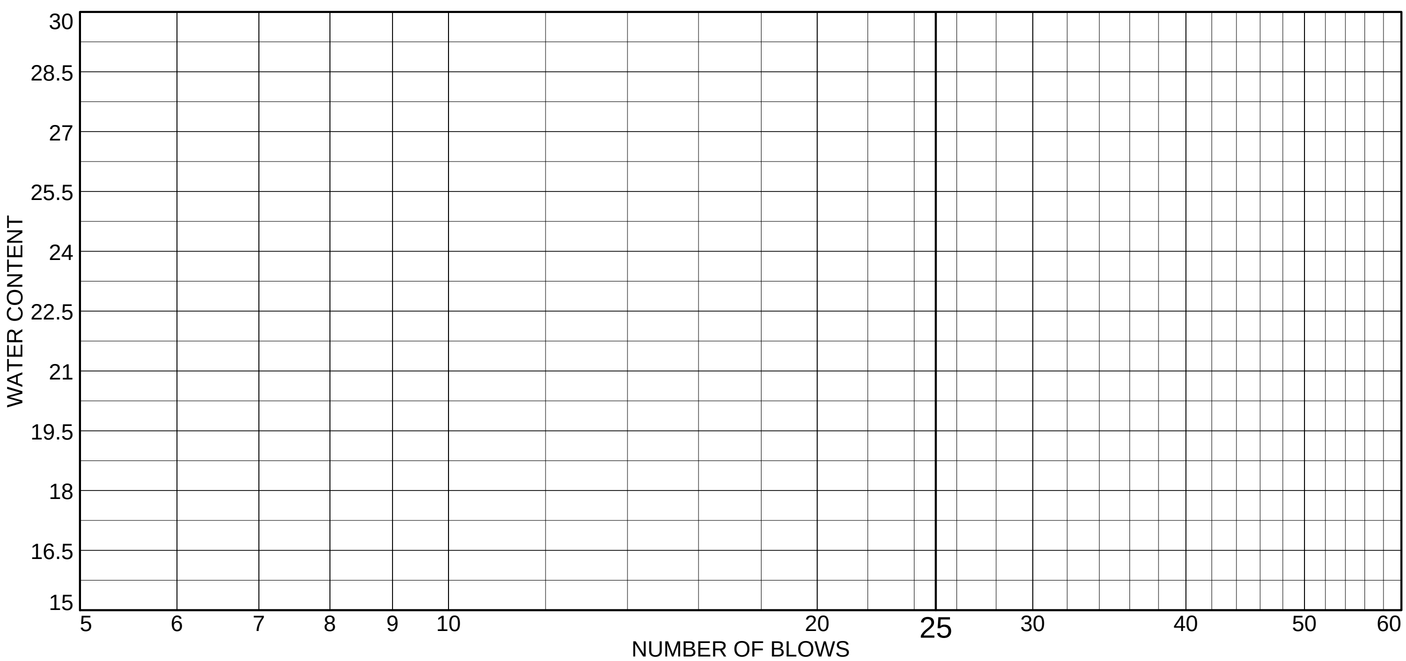
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Clayey Silt			NP	100.0	99.1	

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-02 SS5

Sample Number: MG-37096B

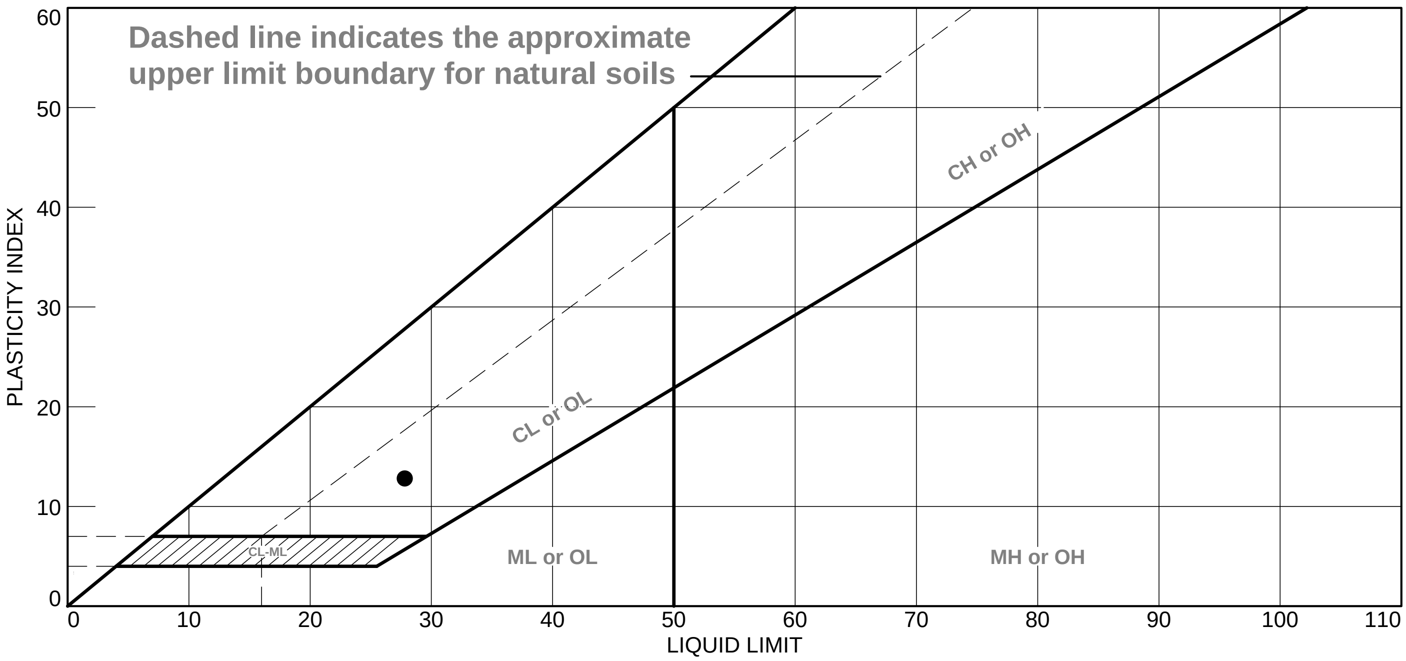
Remarks:

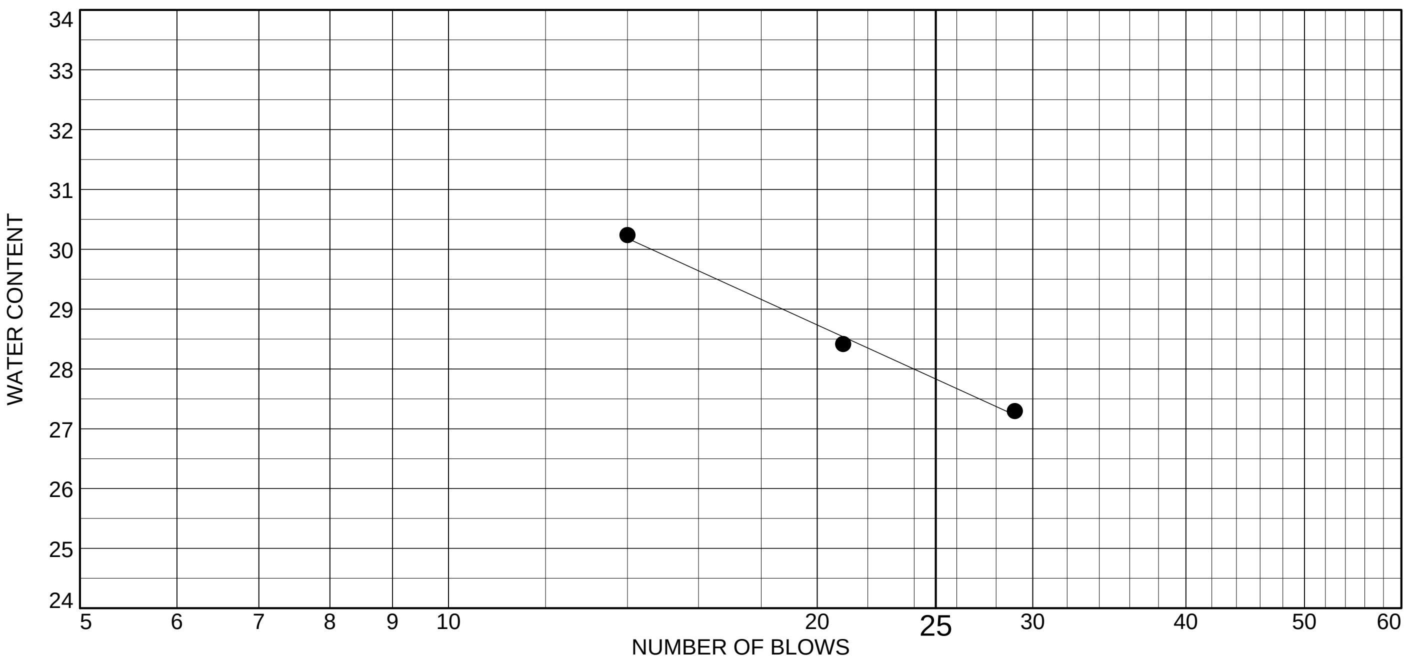
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, some Sand	27.8	15.0	12.8	94.8	88.5	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-03 SS3
Sample Number: MG-37210A

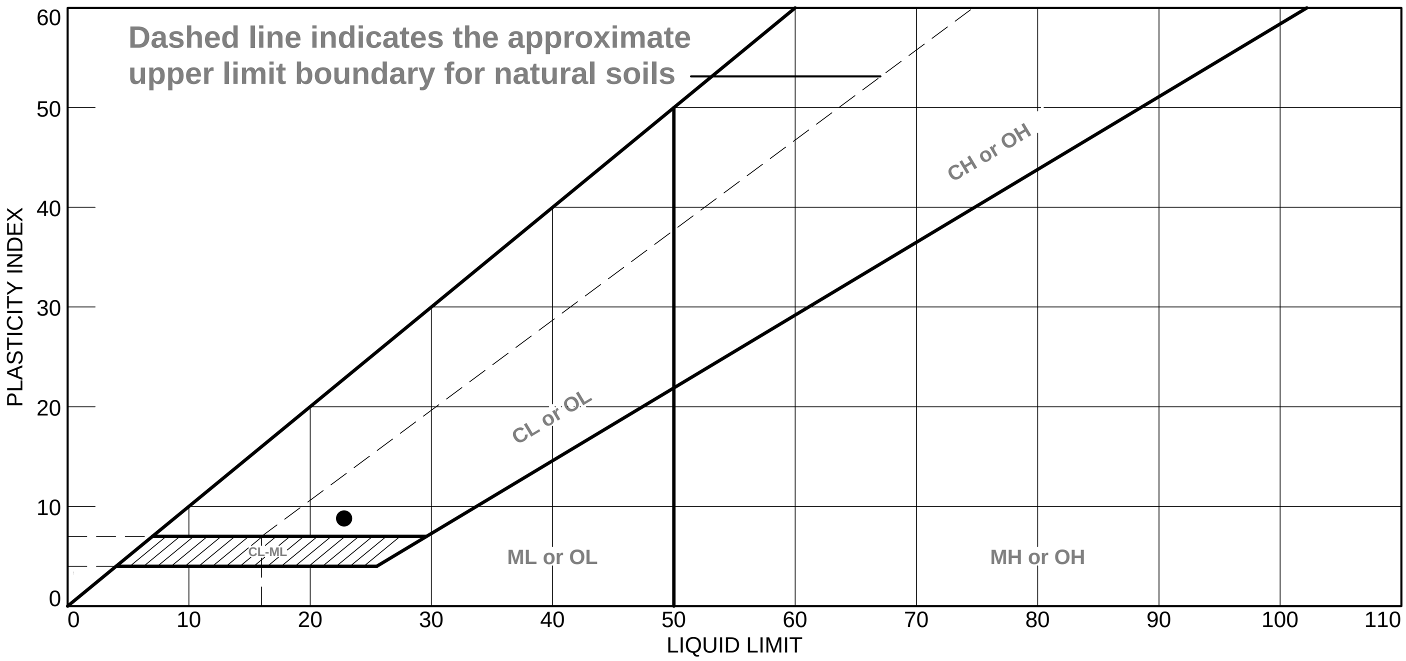
Remarks:

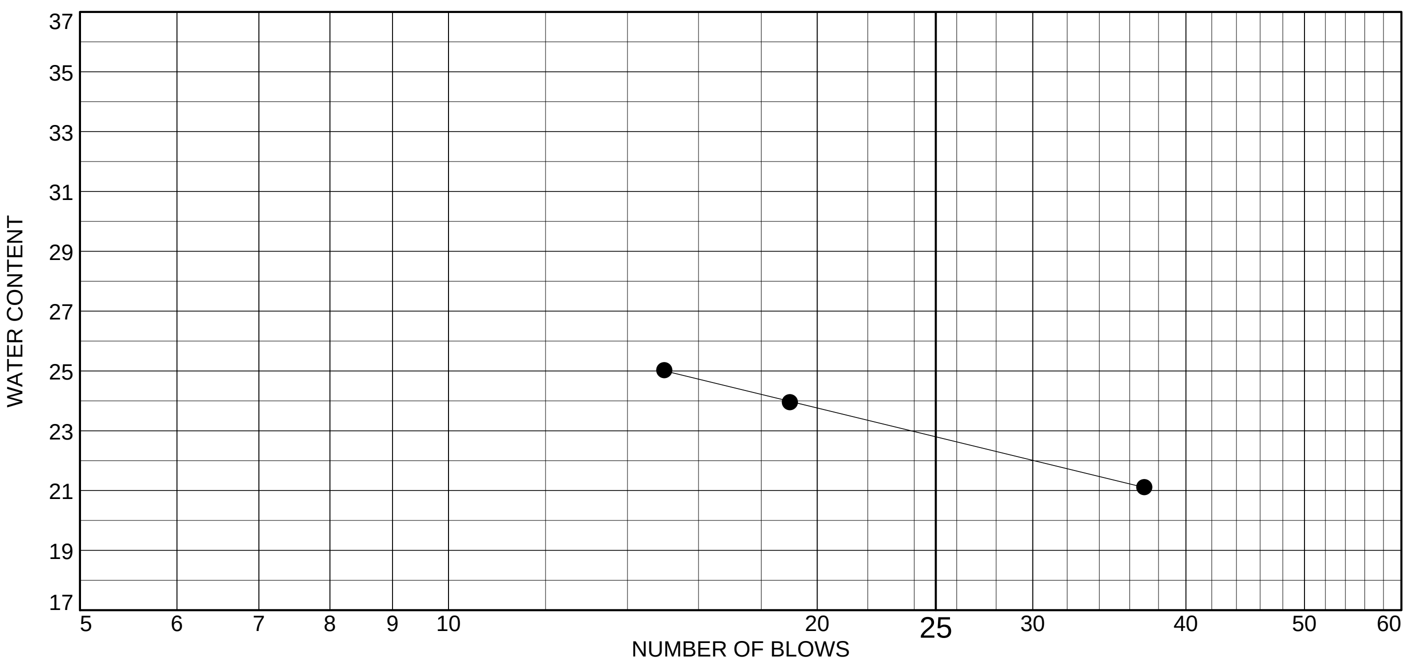
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Silty Clay	22.8	14.0	8.8	78.5	63.7	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-03 SS4
Sample Number: MG-37210B

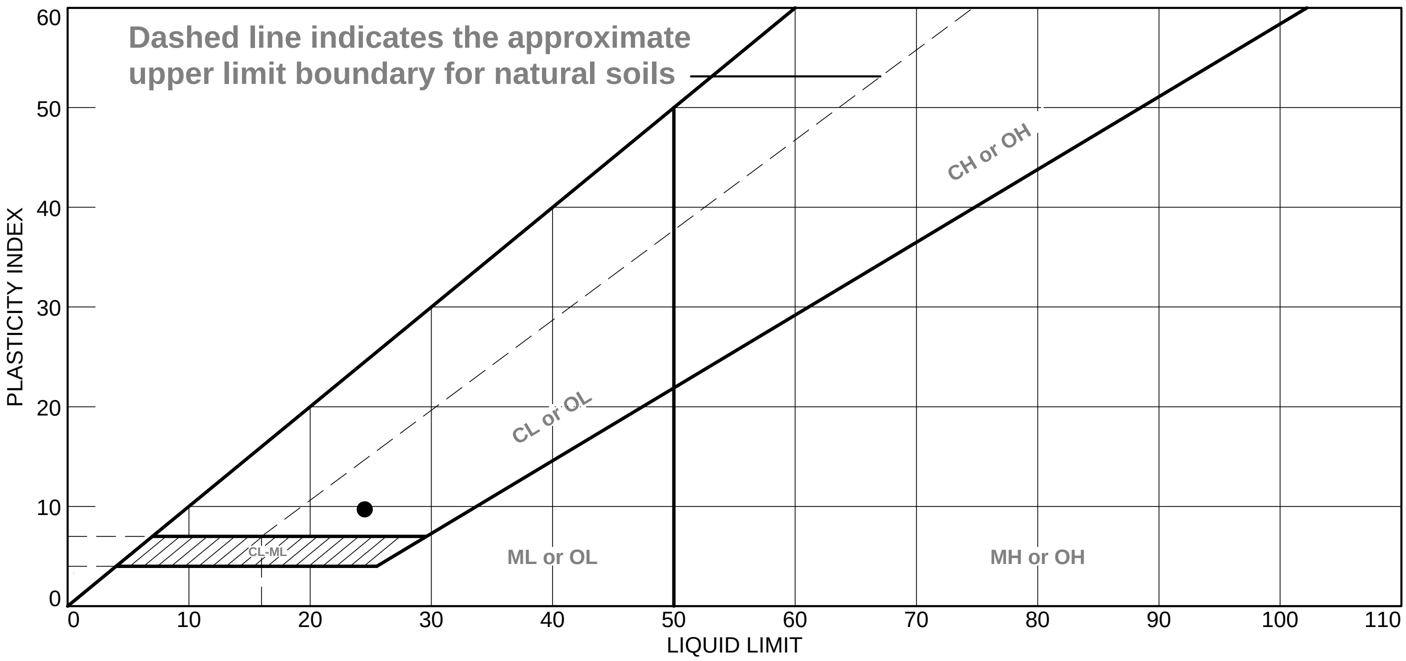
Remarks:

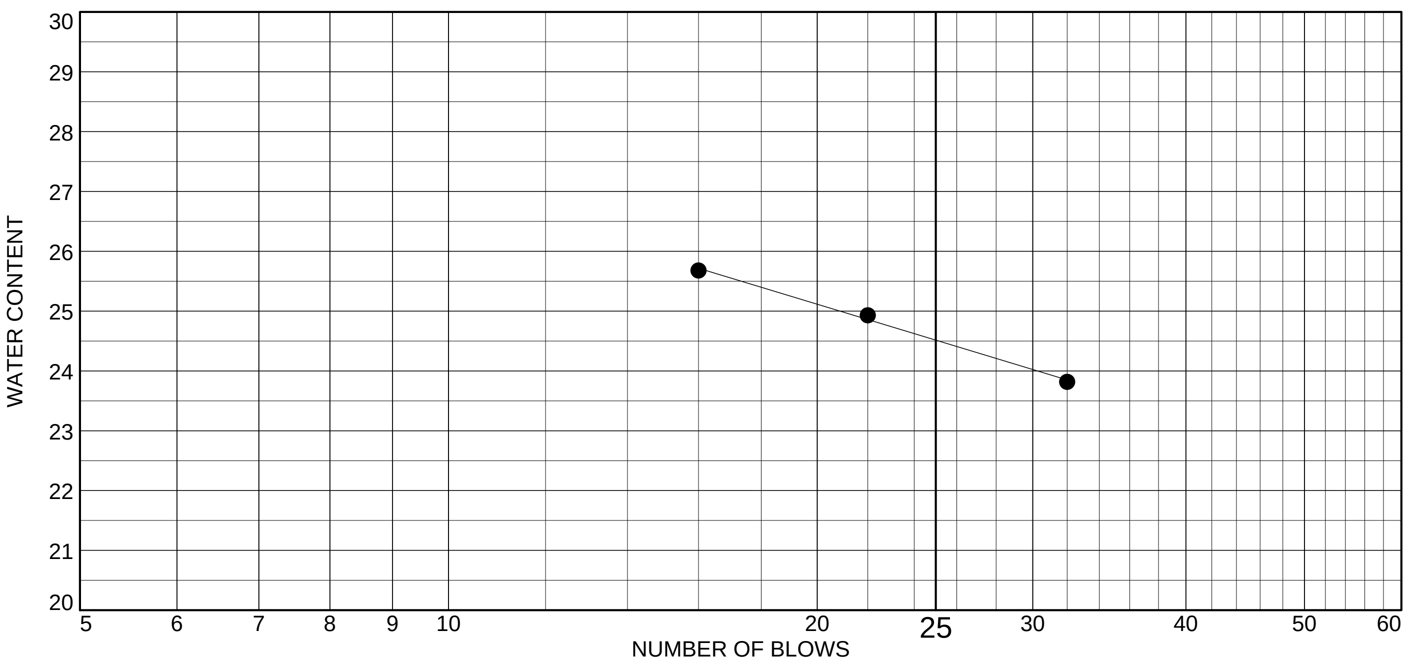
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Silty Clay, trace Gravel	24.5	14.8	9.7	89.5	62.5	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-04 SS3

Sample Number: MG-37161A

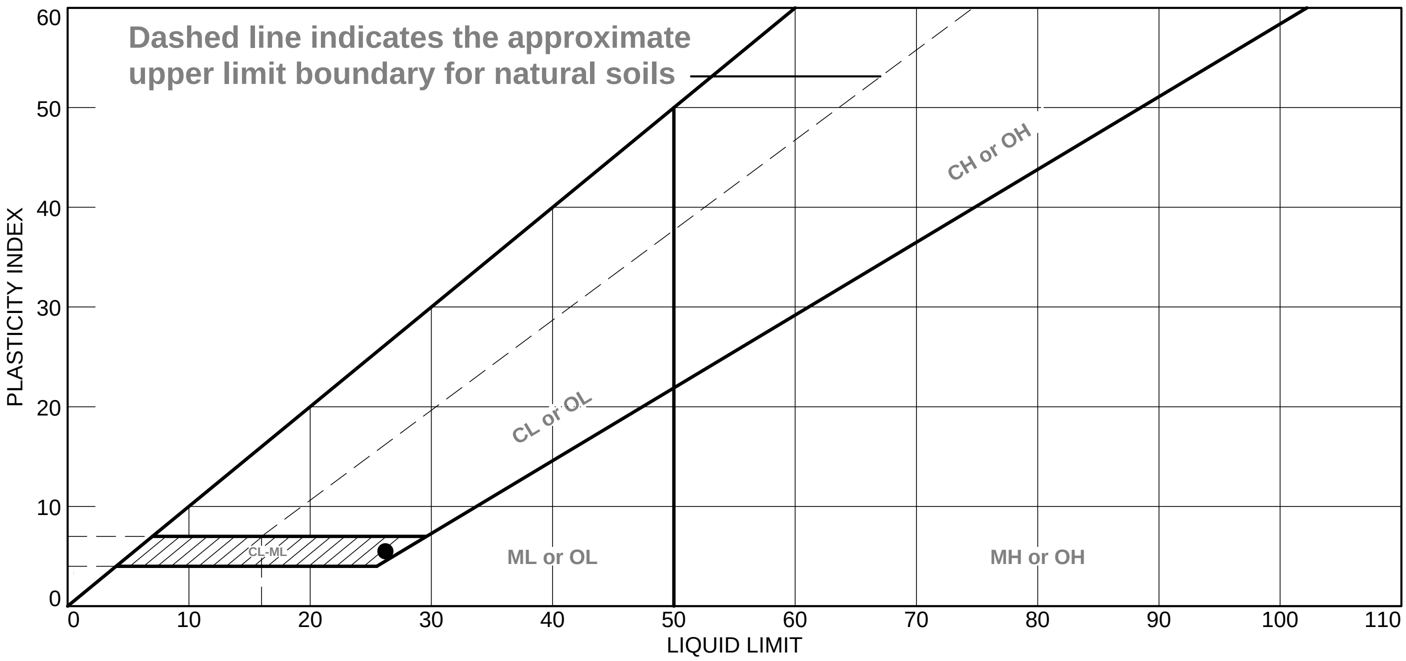
AME Materials Engineering

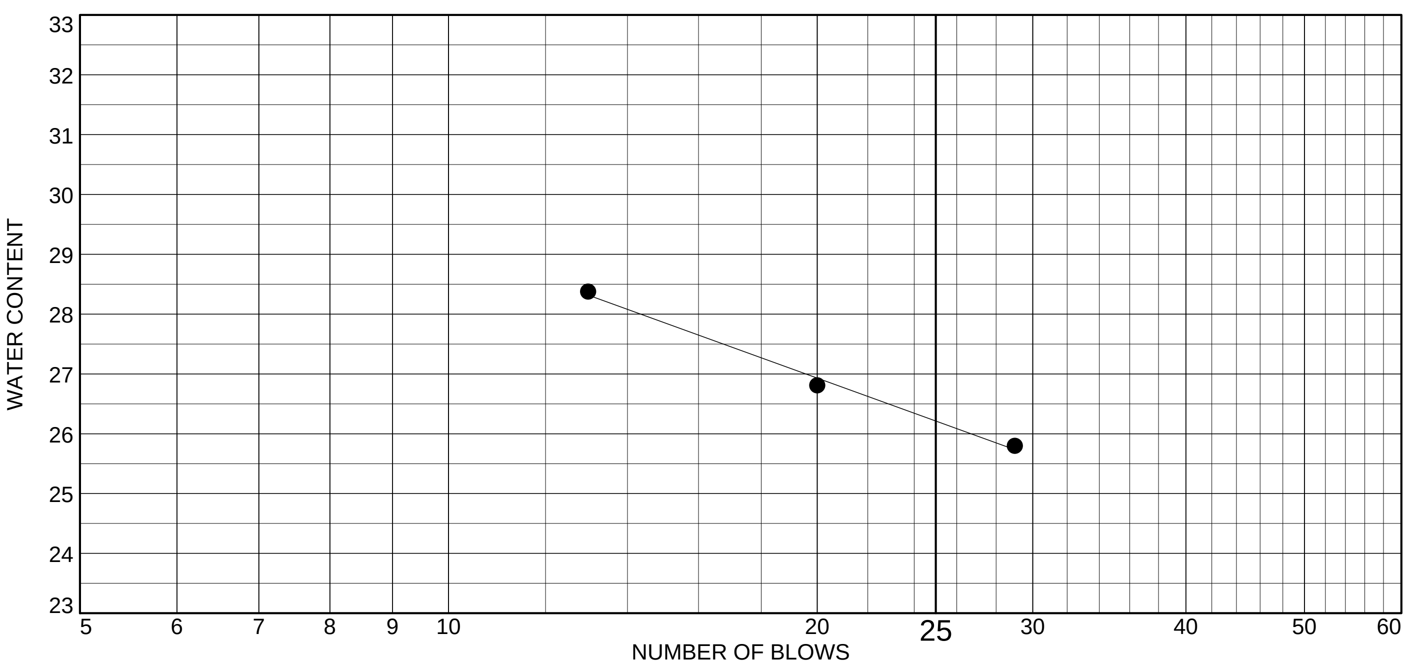
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Clayey Silt	26.2	20.7	5.5	93.9	53.2	CL-ML

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-04 SS9
Sample Number: MG-37161B

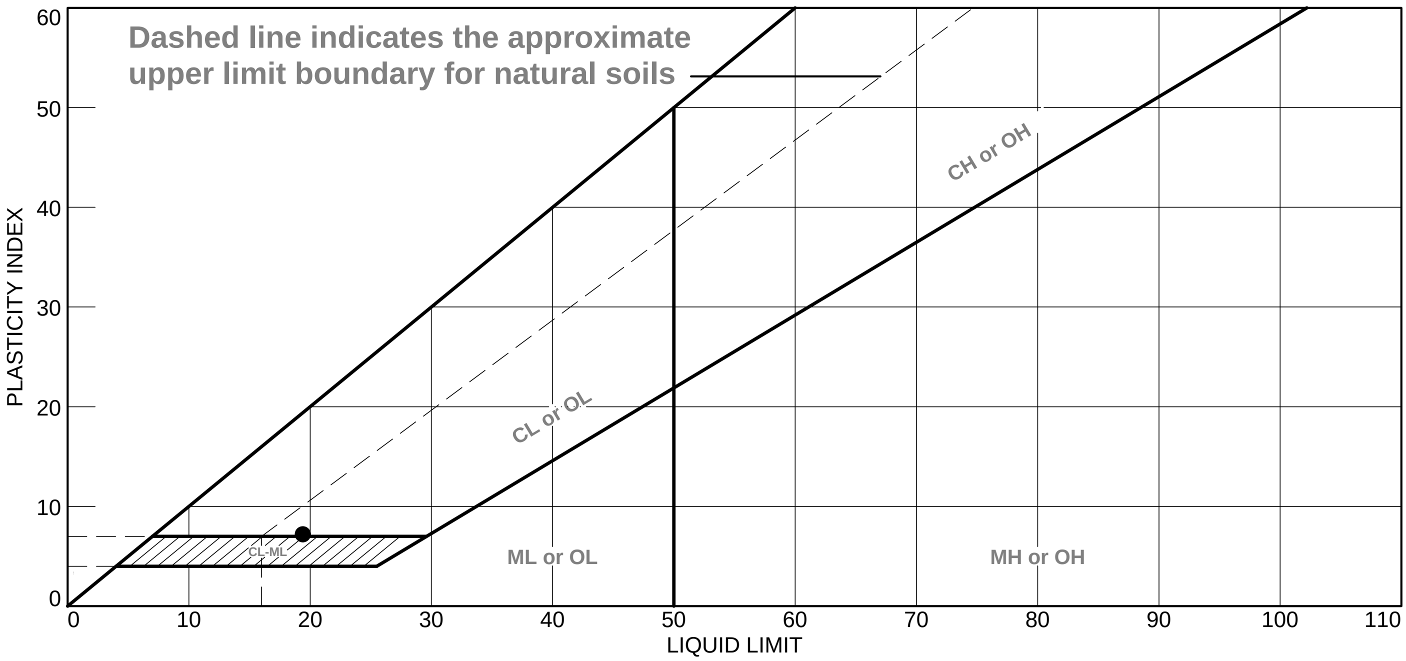
Remarks:

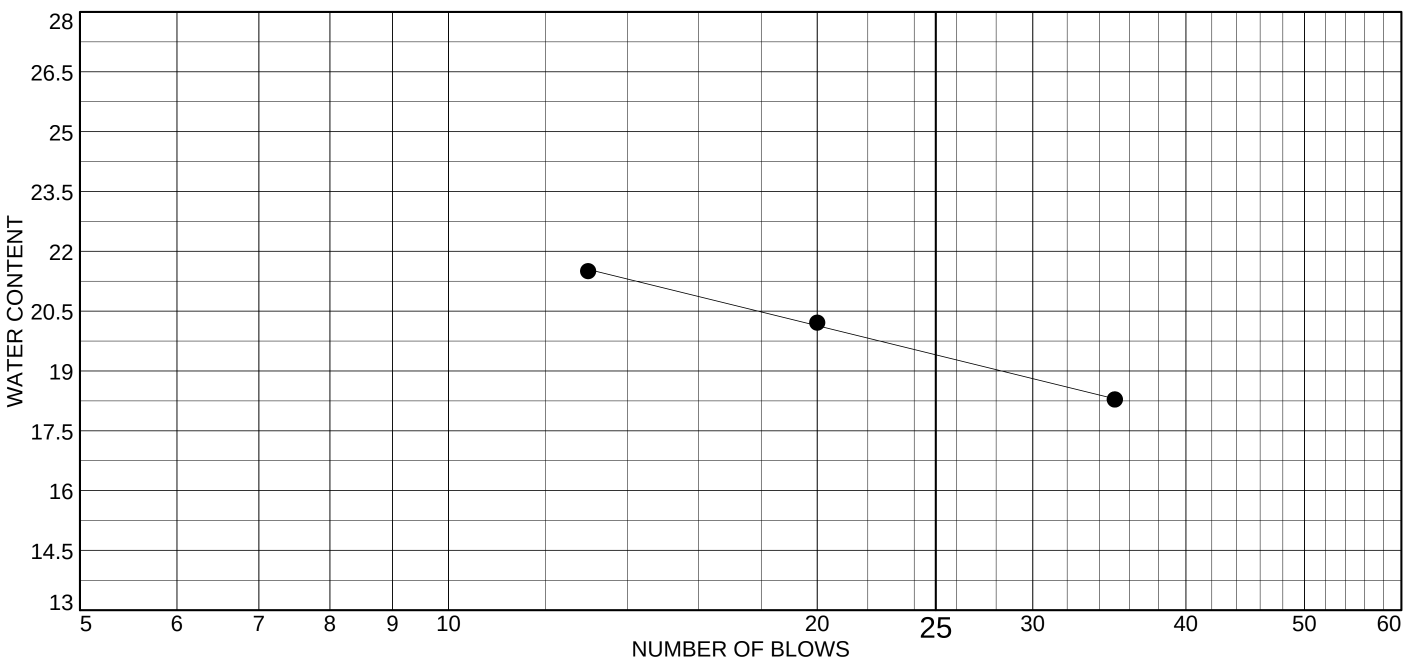
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Clayey Silt, trace Gravel	19.4	12.2	7.2	85.2	65.8	CL-ML

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-04 SS11
Sample Number: MG-37161C

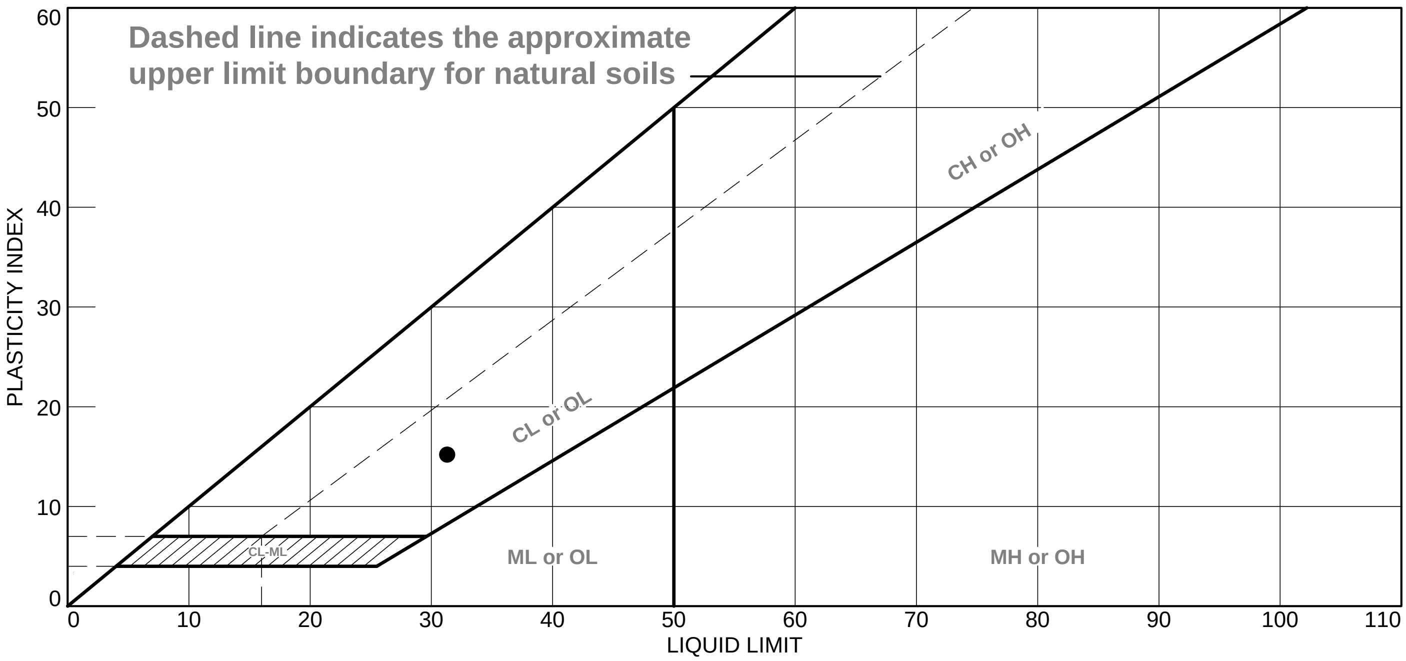
Remarks:

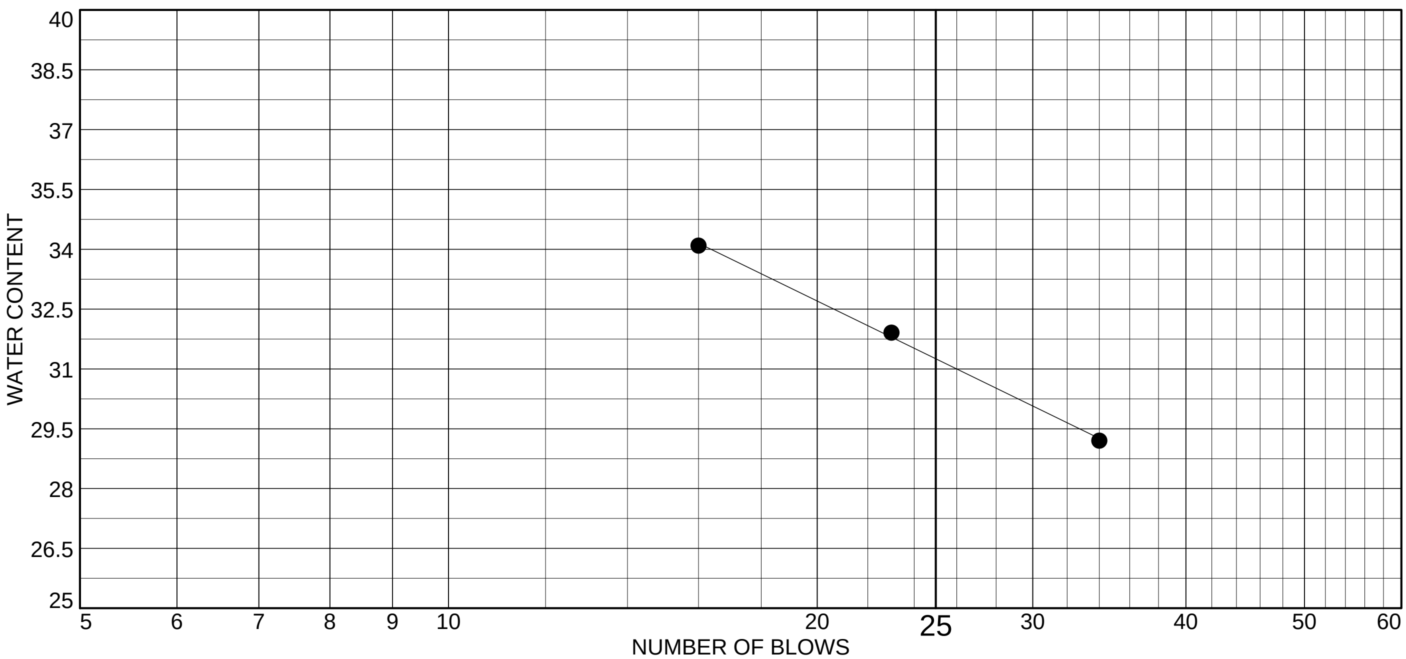
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, trace Sand	31.3	16.1	15.2	95.2	93.0	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

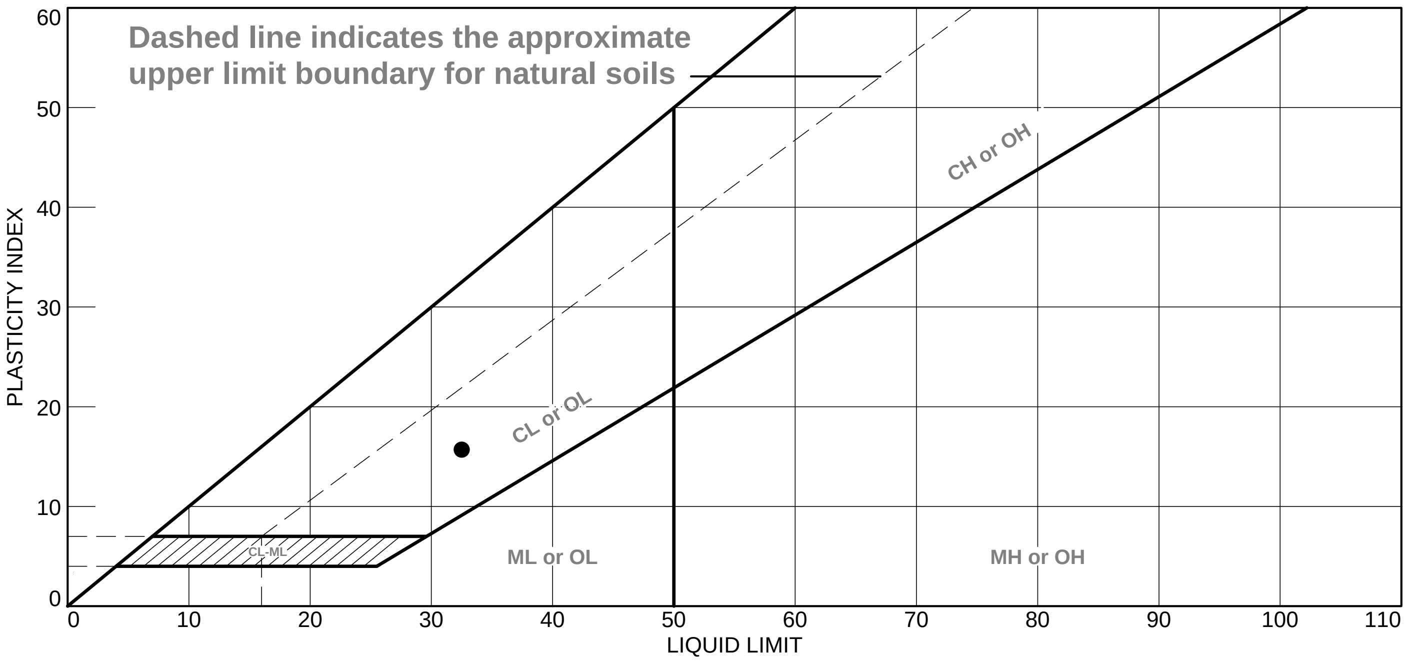
Location: BH22-04 SS15
Sample Number: MG-37161D

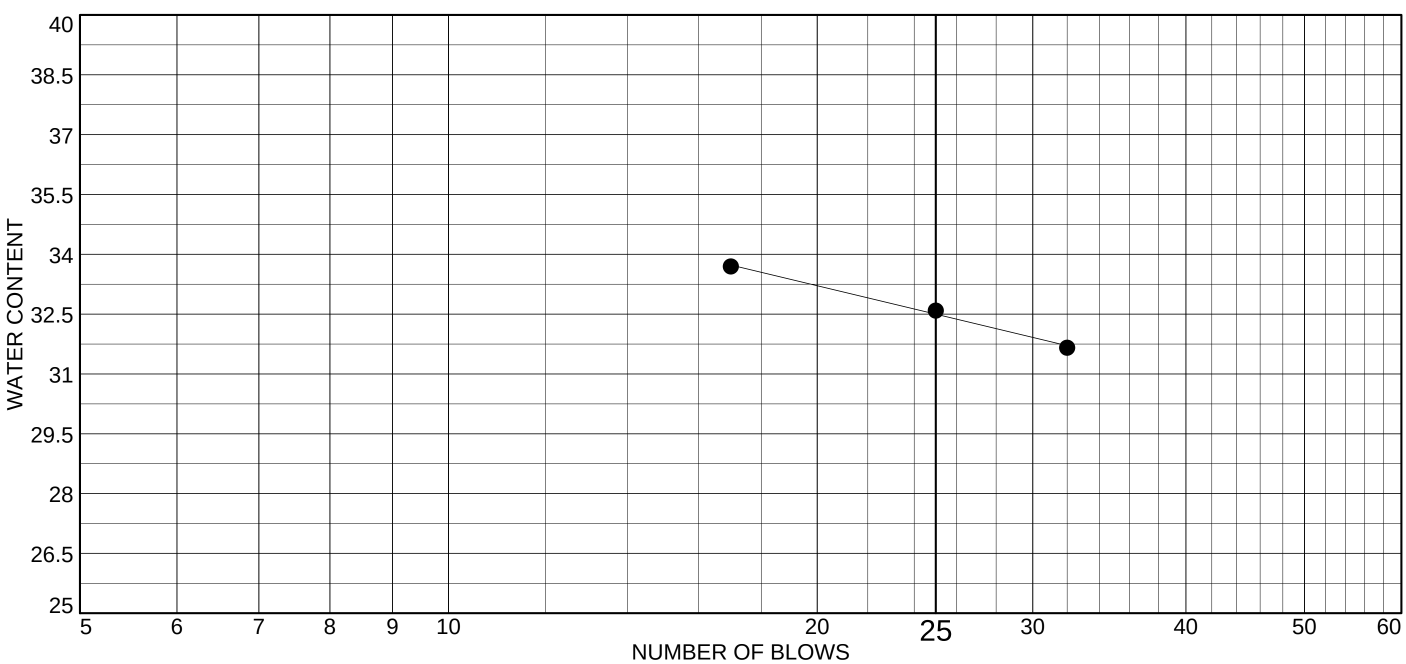
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, some Sand	32.5	16.8	15.7	95.5	88.3	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

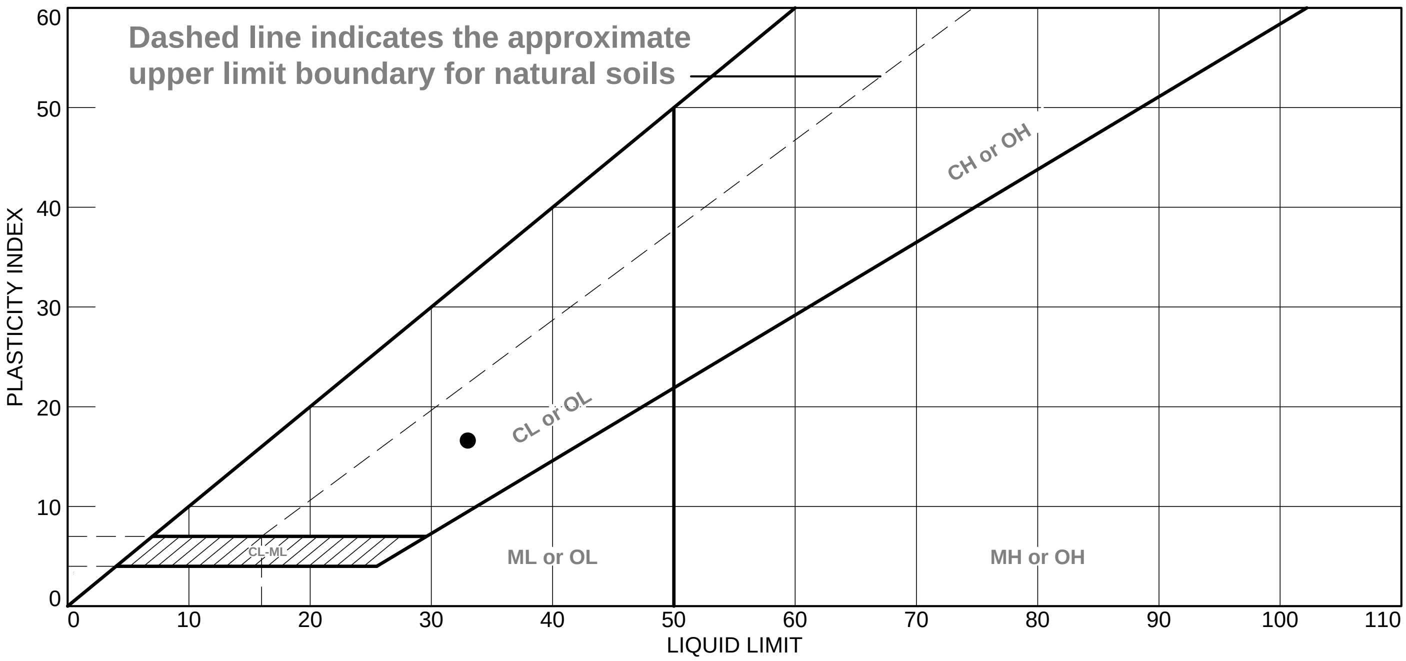
Location: BH22-05 SS2
Sample Number: MG-37159A

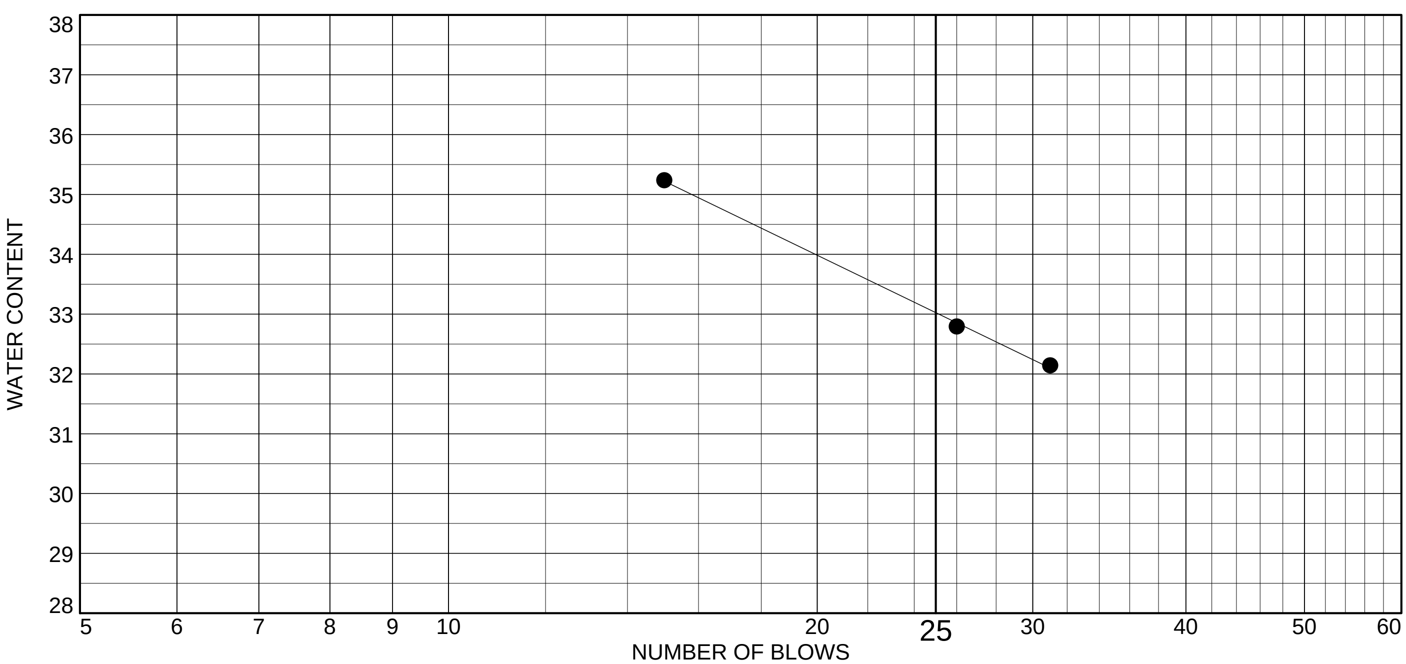
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, trace Sand	33.0	16.4	16.6	94.9	90.1	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-05 SS4
Sample Number: MG-37213A

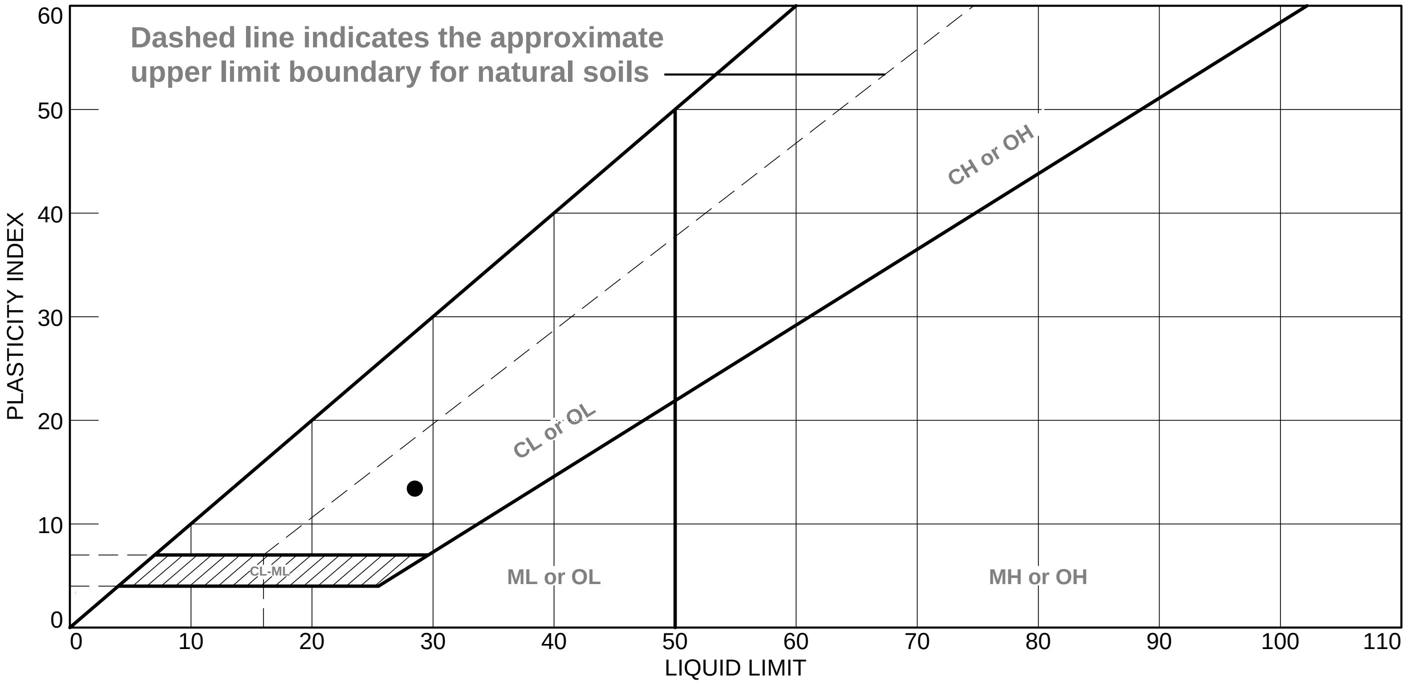
Remarks:

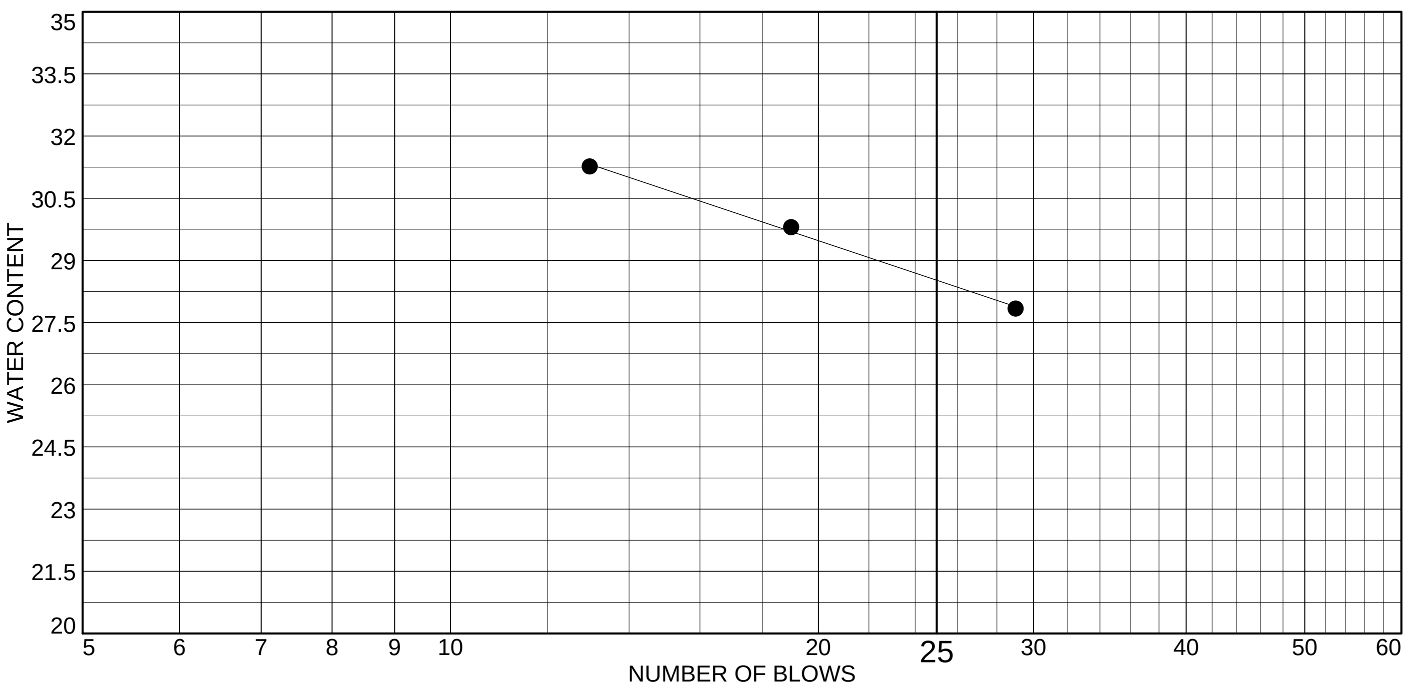
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, trace Sand	28.5	15.1	13.4	95.6	89.9	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

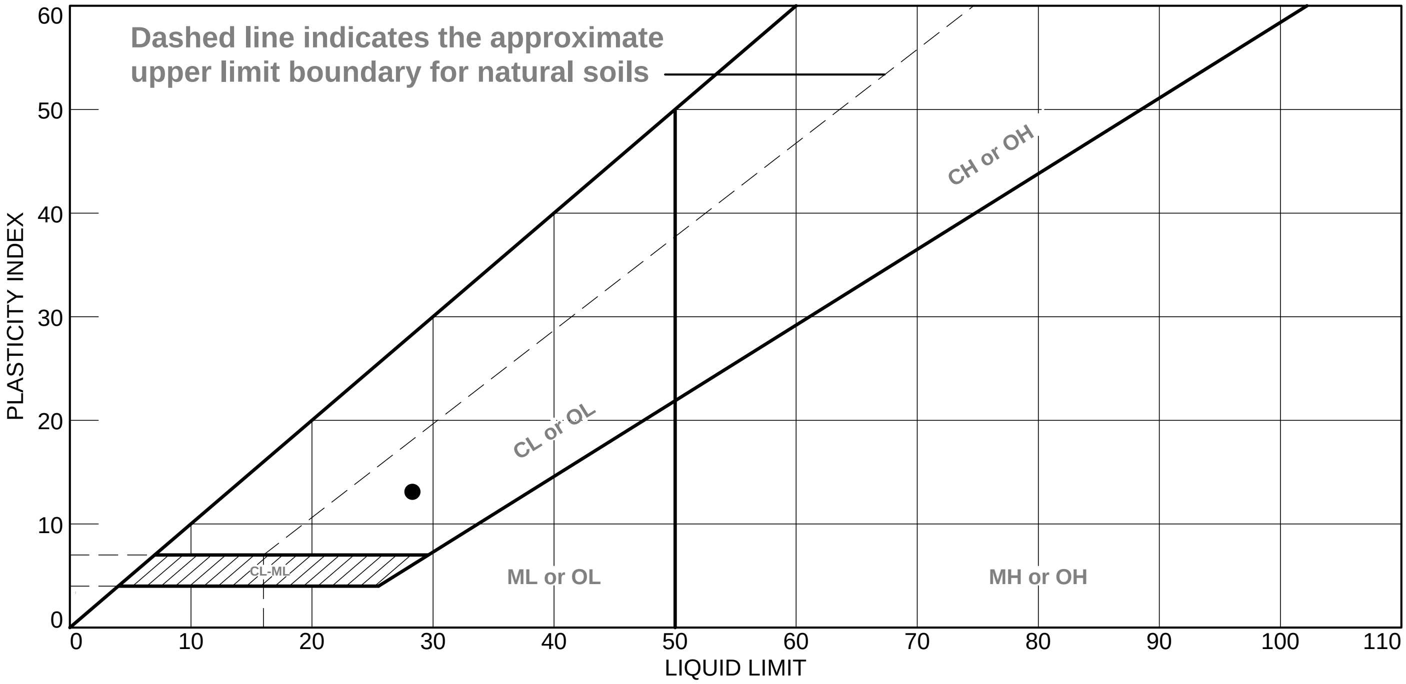
Location: BH22-06 SS4
Sample Number: MG-37100

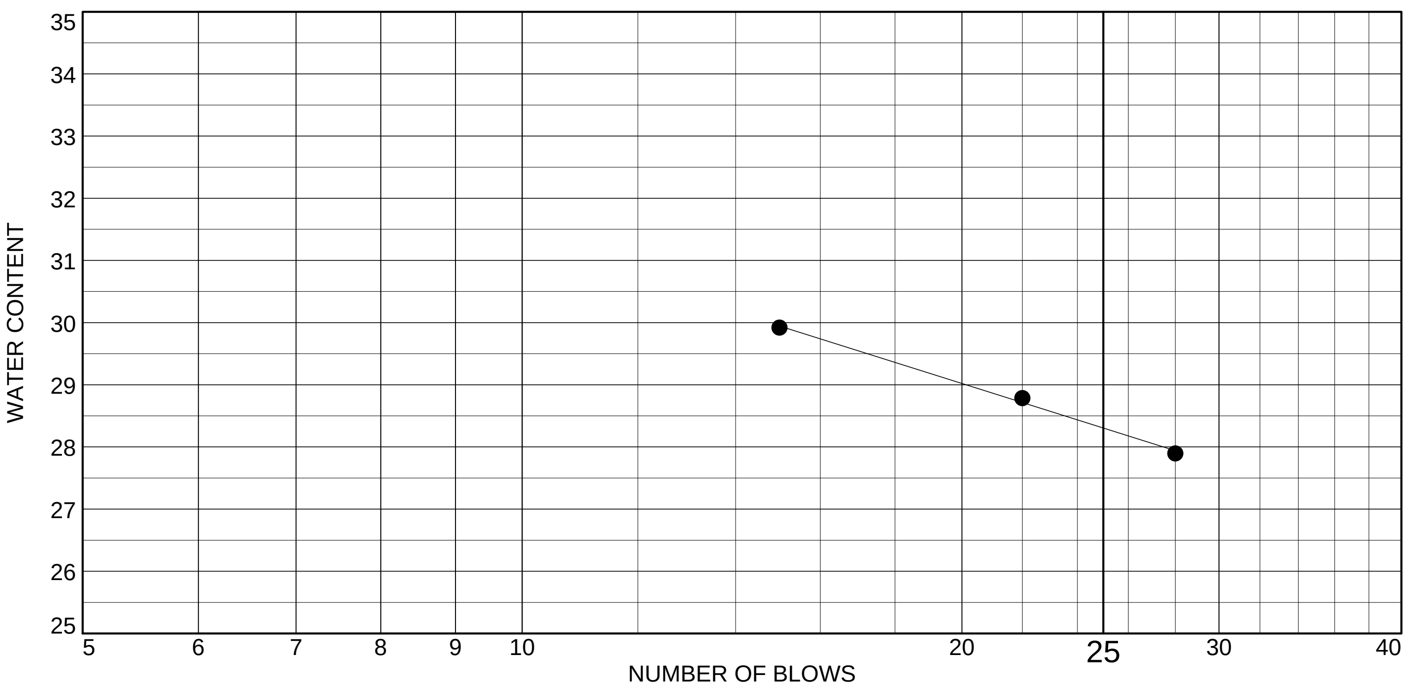
Remarks:

AME Materials Engineering

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, some Sand, trace Gravel	28.3	15.2	13.1	92.1	85.4	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

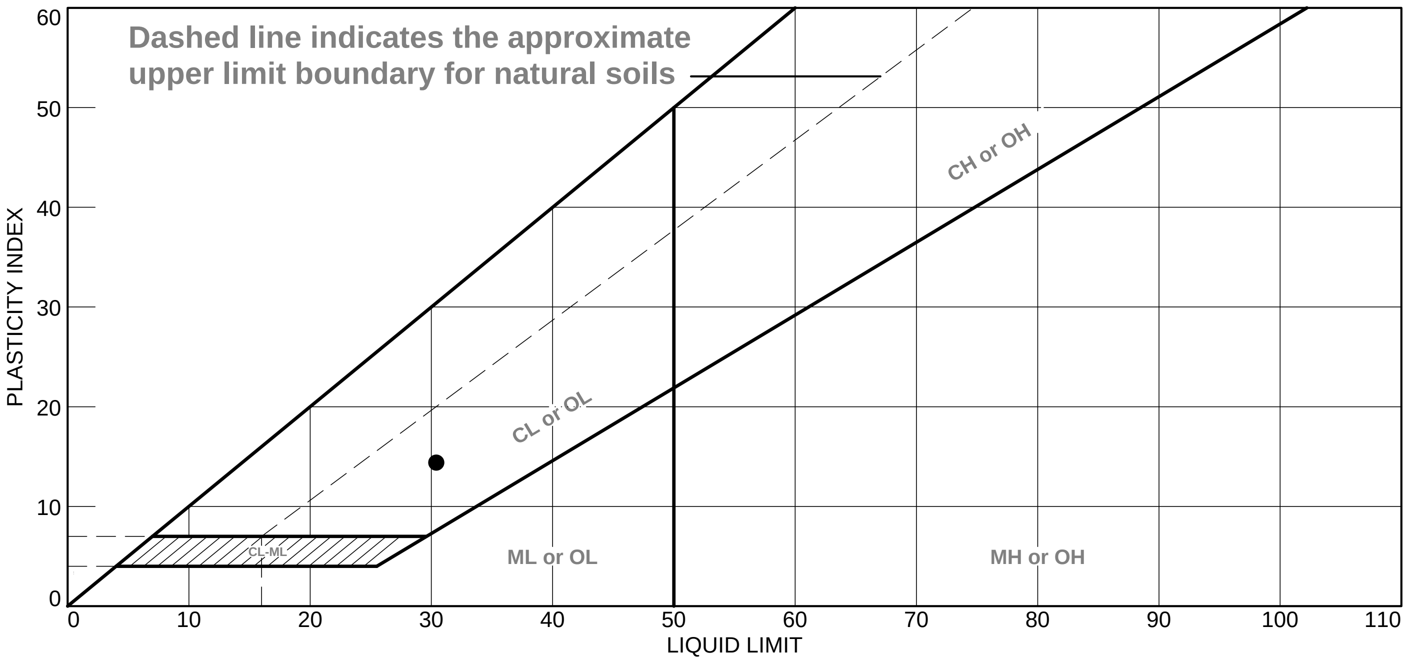
Location: BH22-07 SS4
Sample Number: MG-37095

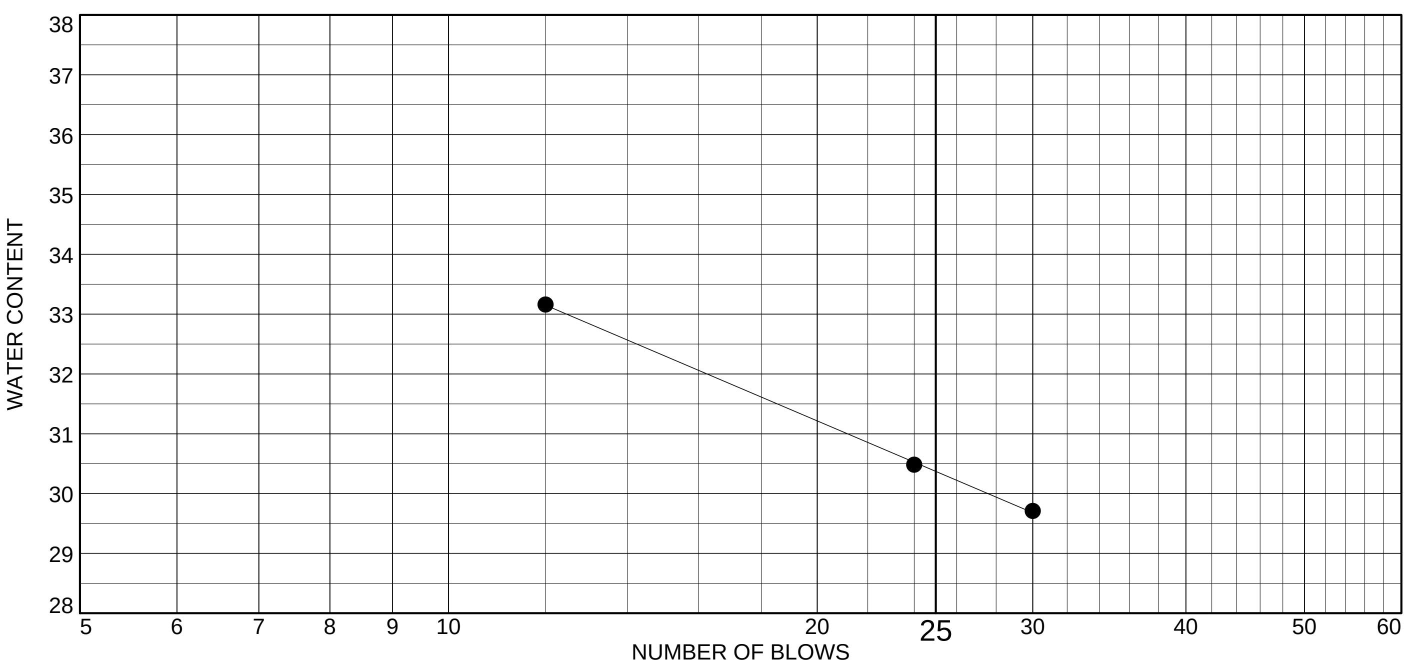
AME Materials Engineering

Remarks:

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, some Sand	30.4	16.0	14.4	95.2	87.6	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-08 SS2
Sample Number: MG-37167A

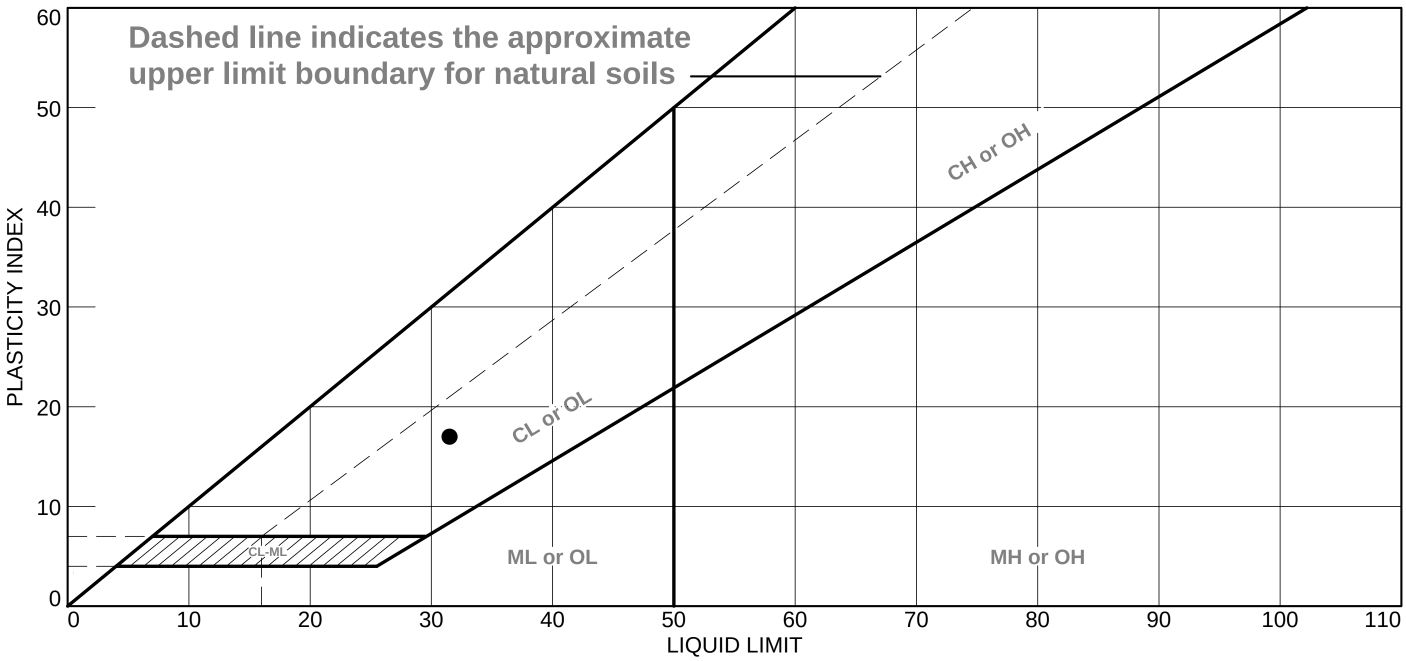
AME Materials Engineering

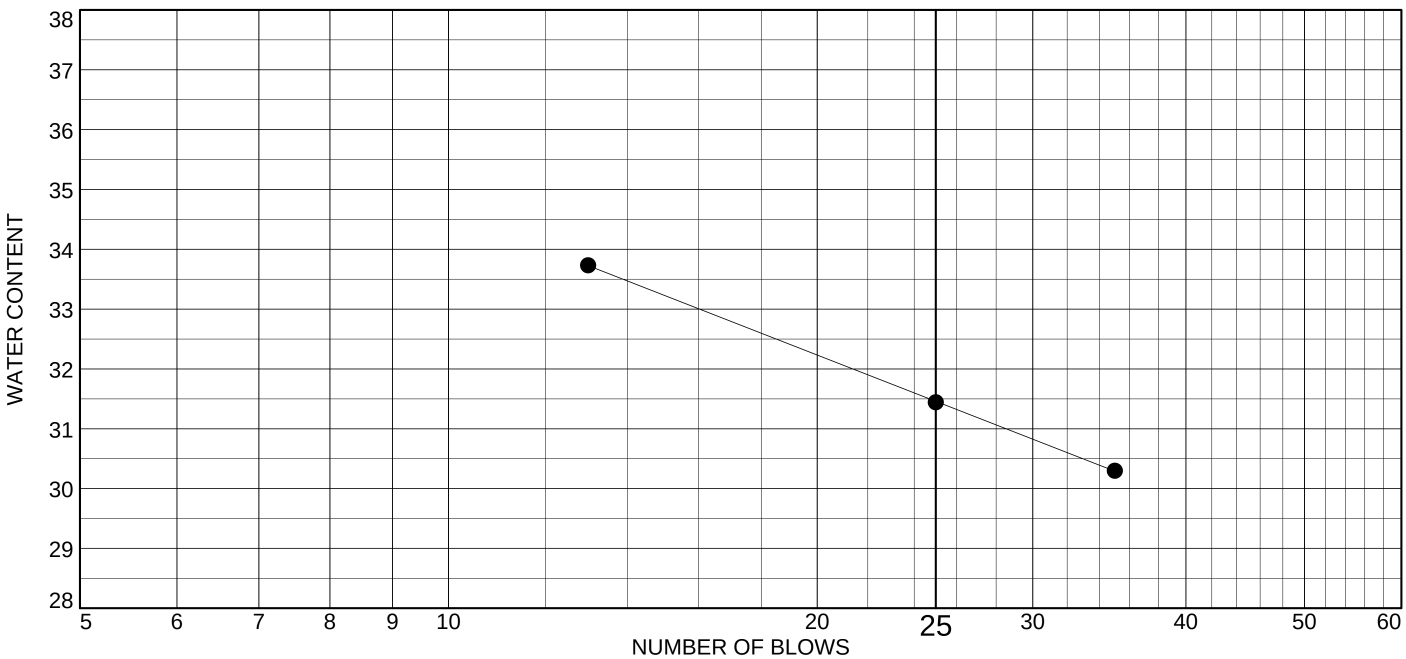
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, some Sand	31.5	14.5	17.0	92.8	85.4	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-08 SS5
Sample Number: MG-37167B

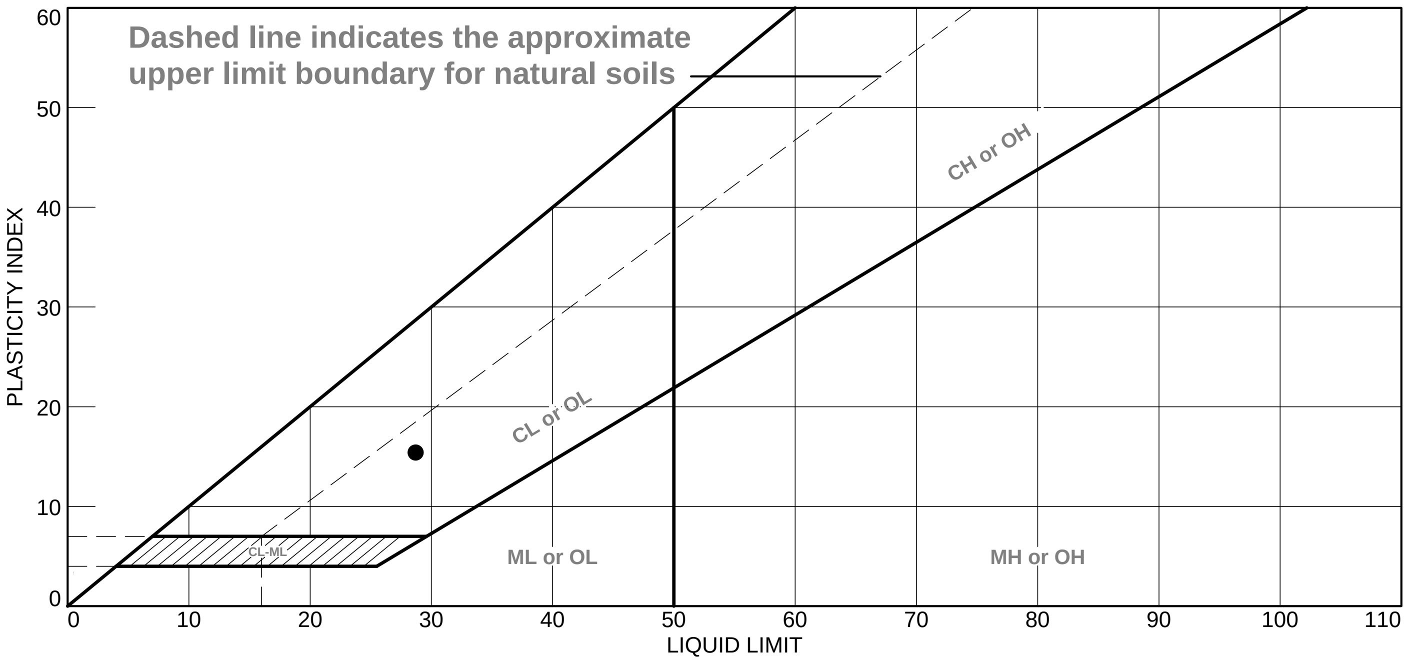
AME Materials Engineering

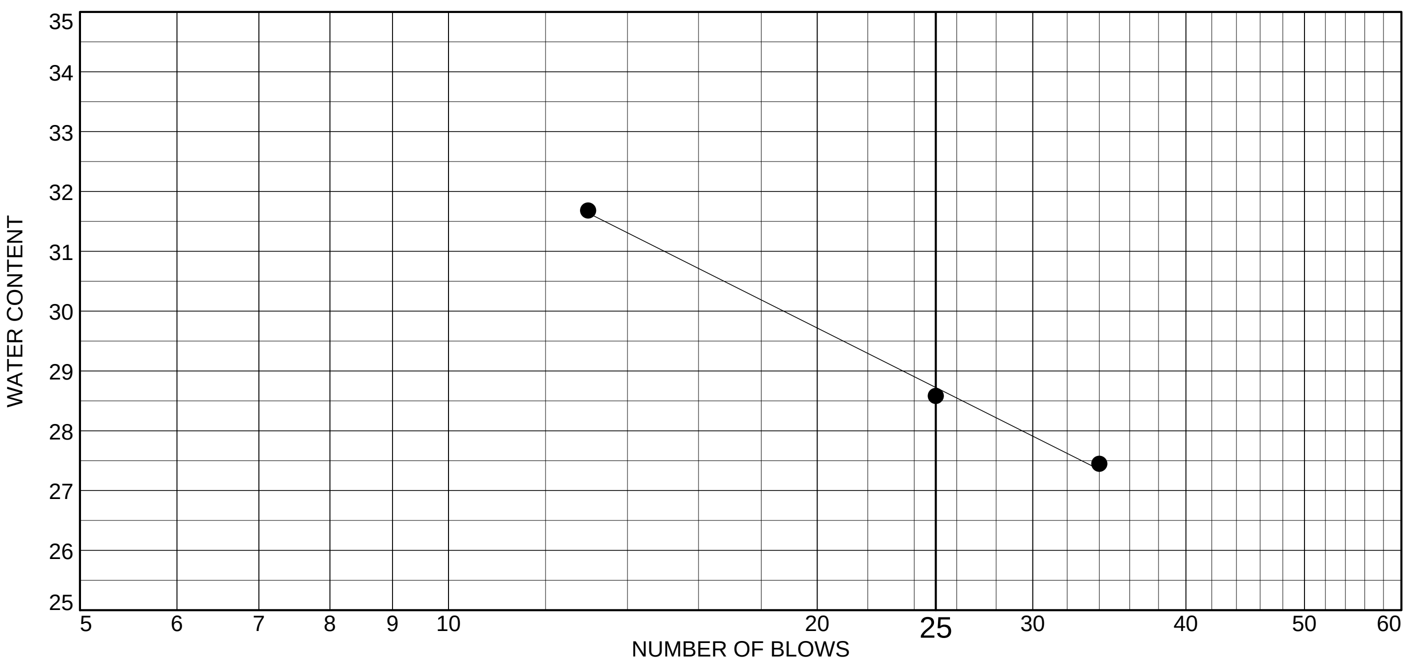
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, some Sand	28.7	13.3	15.4	92.1	82.4	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-09 SS2
Sample Number: MG-37211A

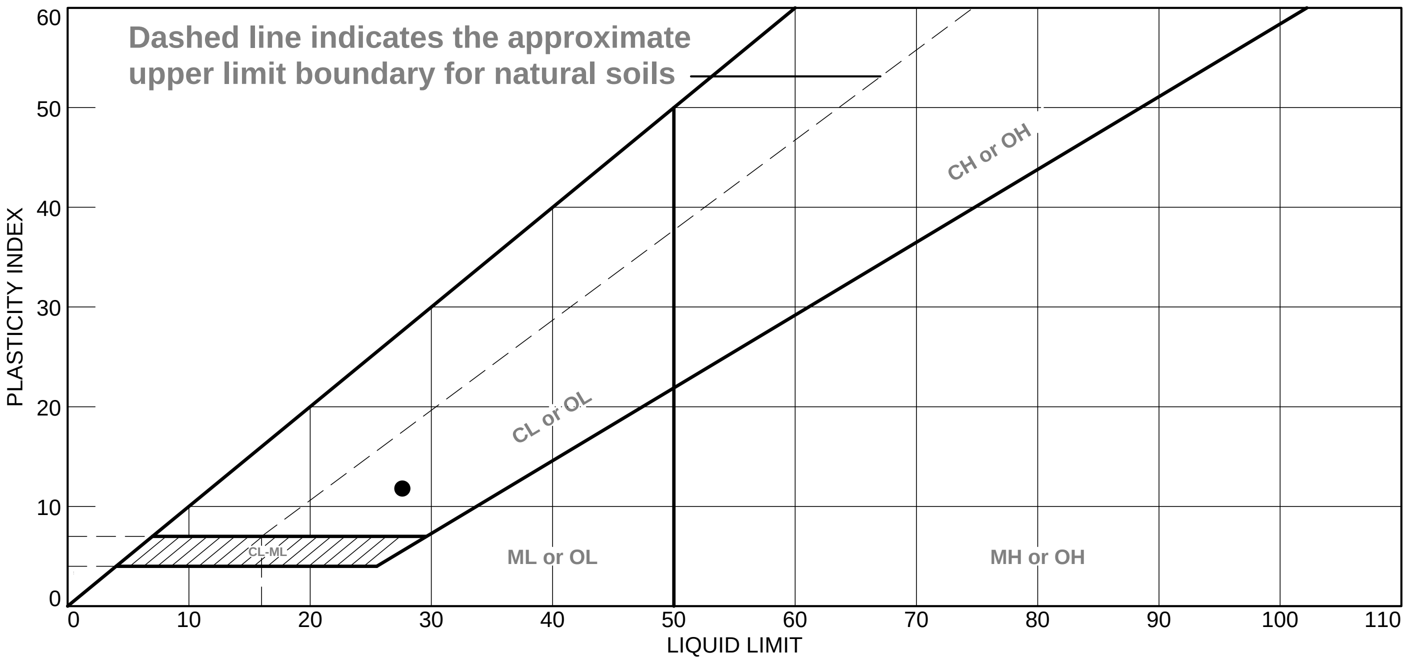
AME Materials Engineering

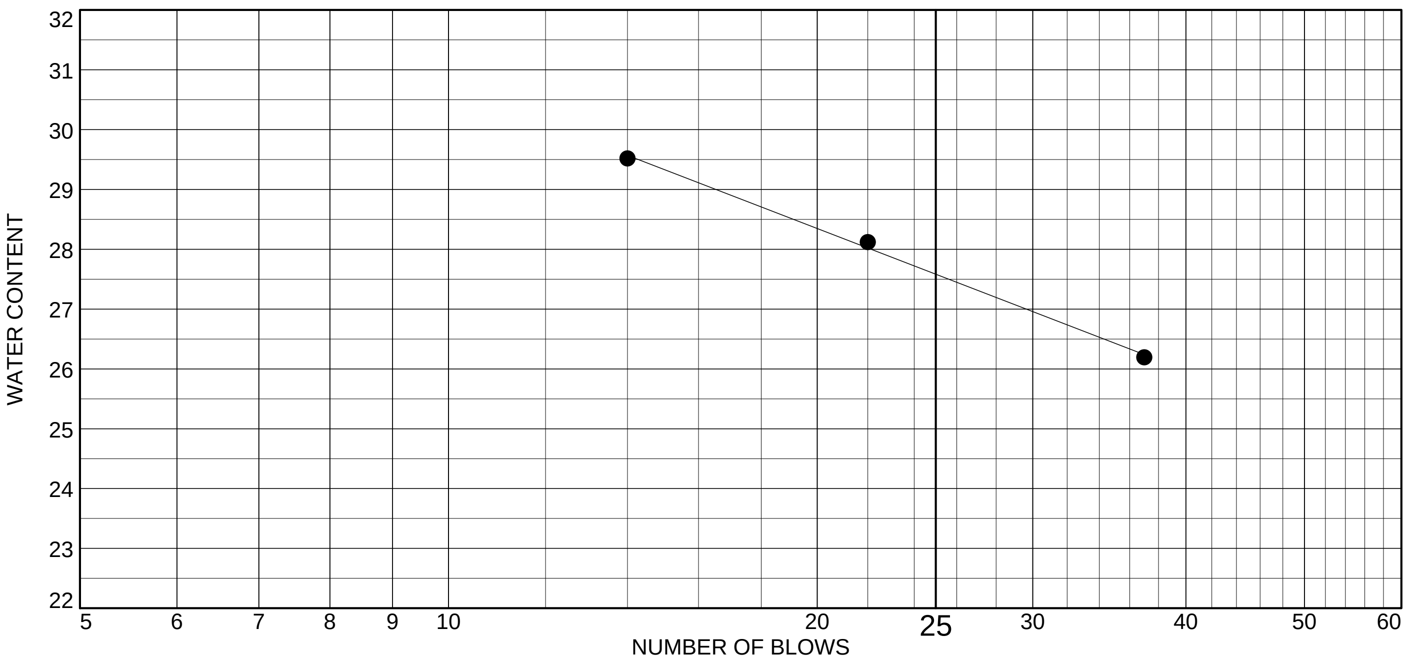
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Silty Clay, trace Gravel	27.6	15.8	11.8	91.6	75.8	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-09 SS5
Sample Number: MG-37211B

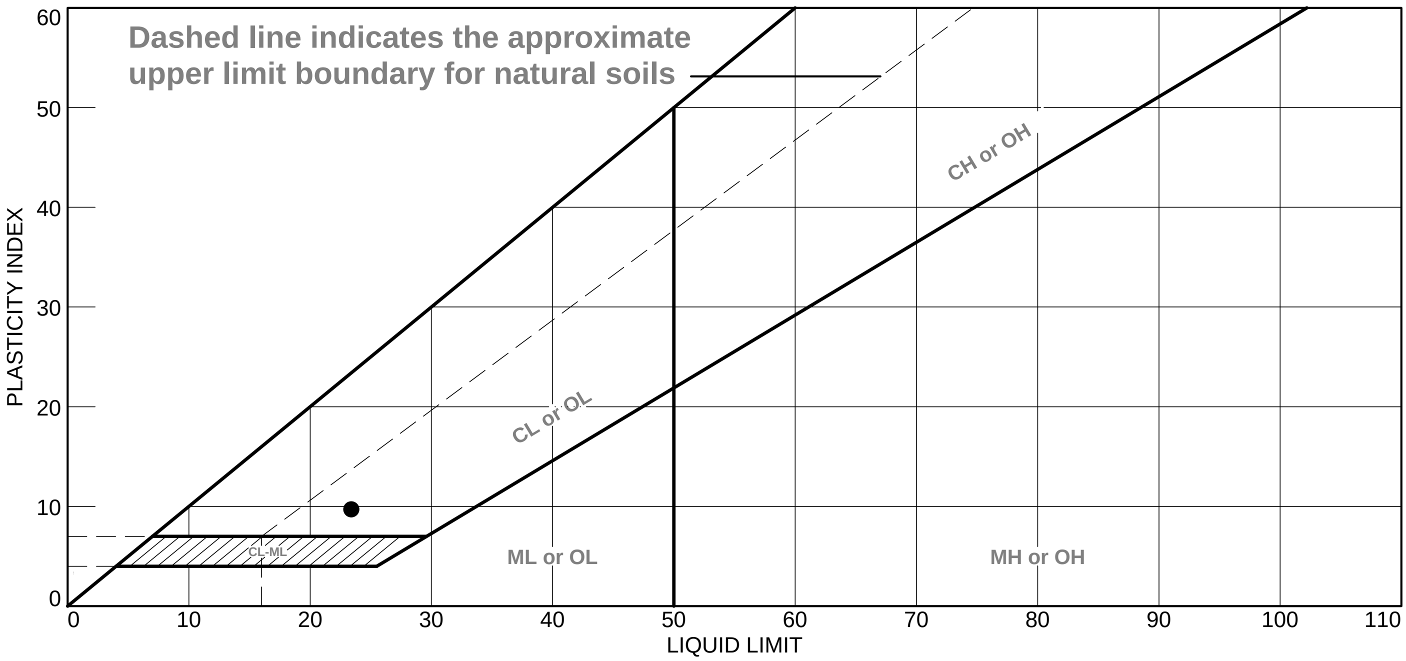
AME Materials Engineering

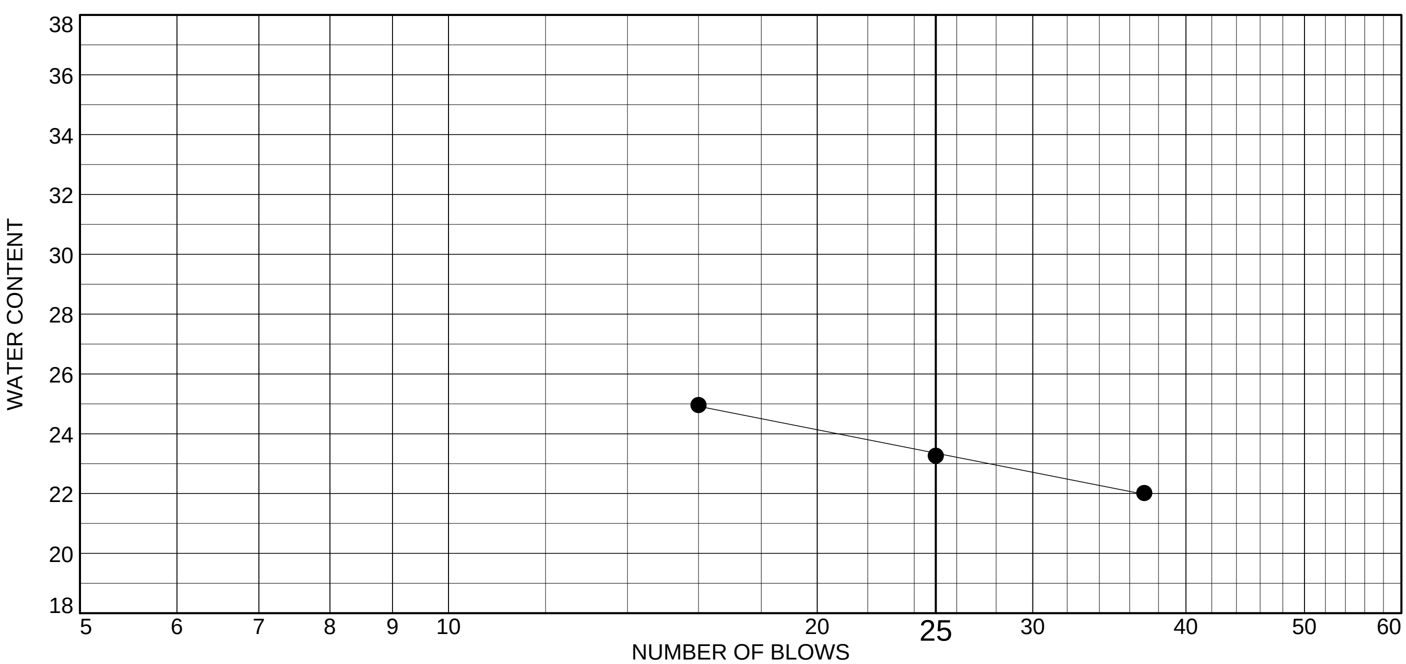
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, some Sand, trace Gravel	23.4	13.7	9.7	85.5	73.6	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-10 SS3
Sample Number: MG-37208A

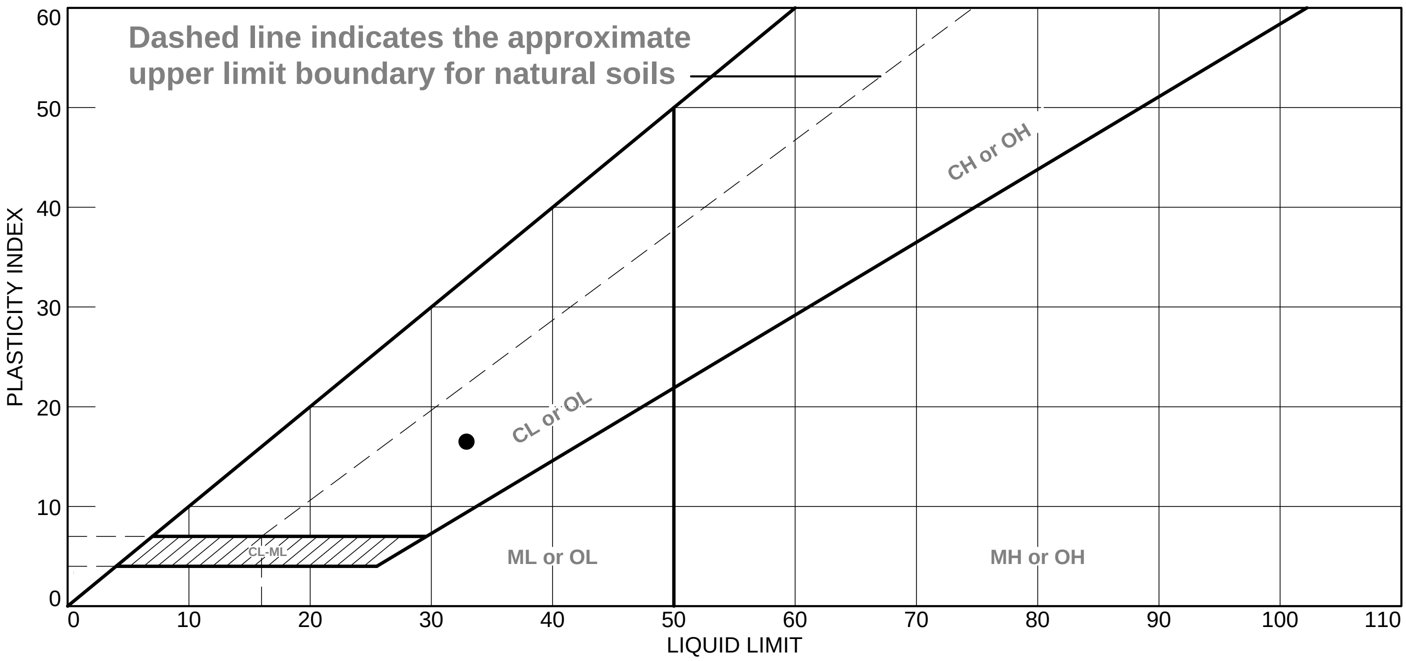
AME Materials Engineering

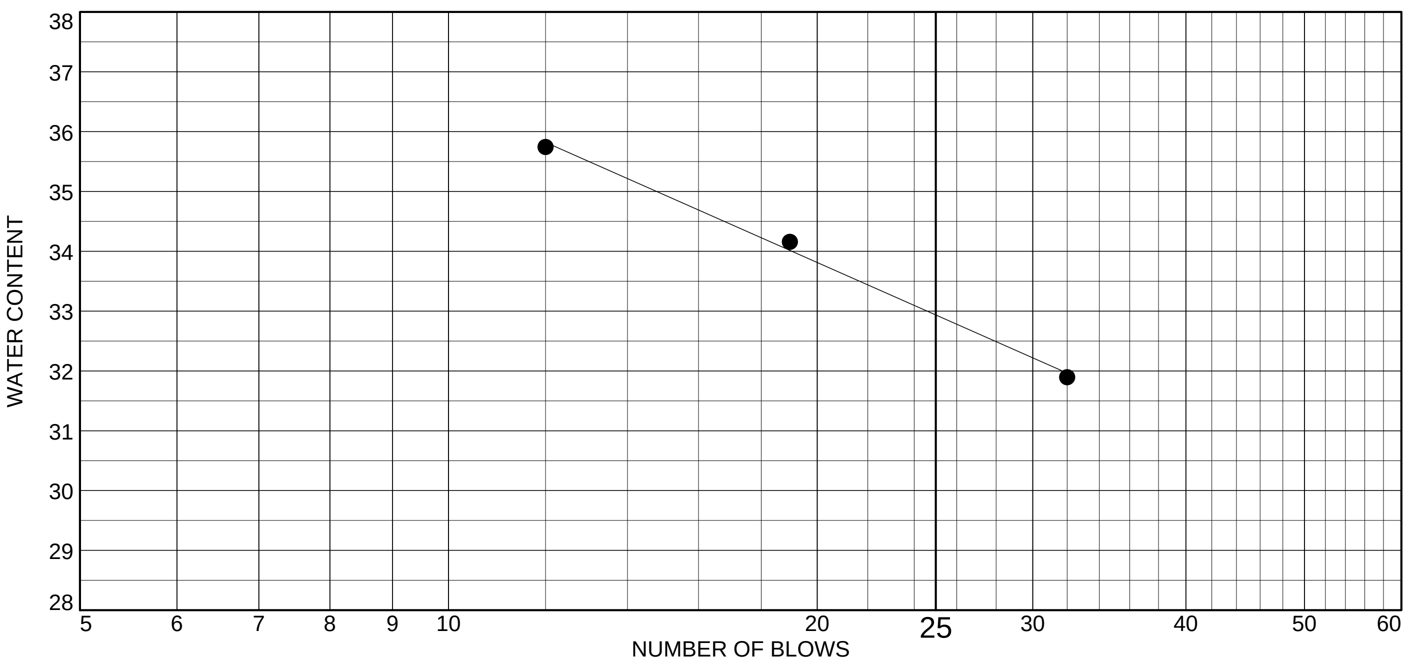
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, trace Sand	32.9	16.4	16.5	98.1	96.3	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-10 SS6
Sample Number: MG-37208B

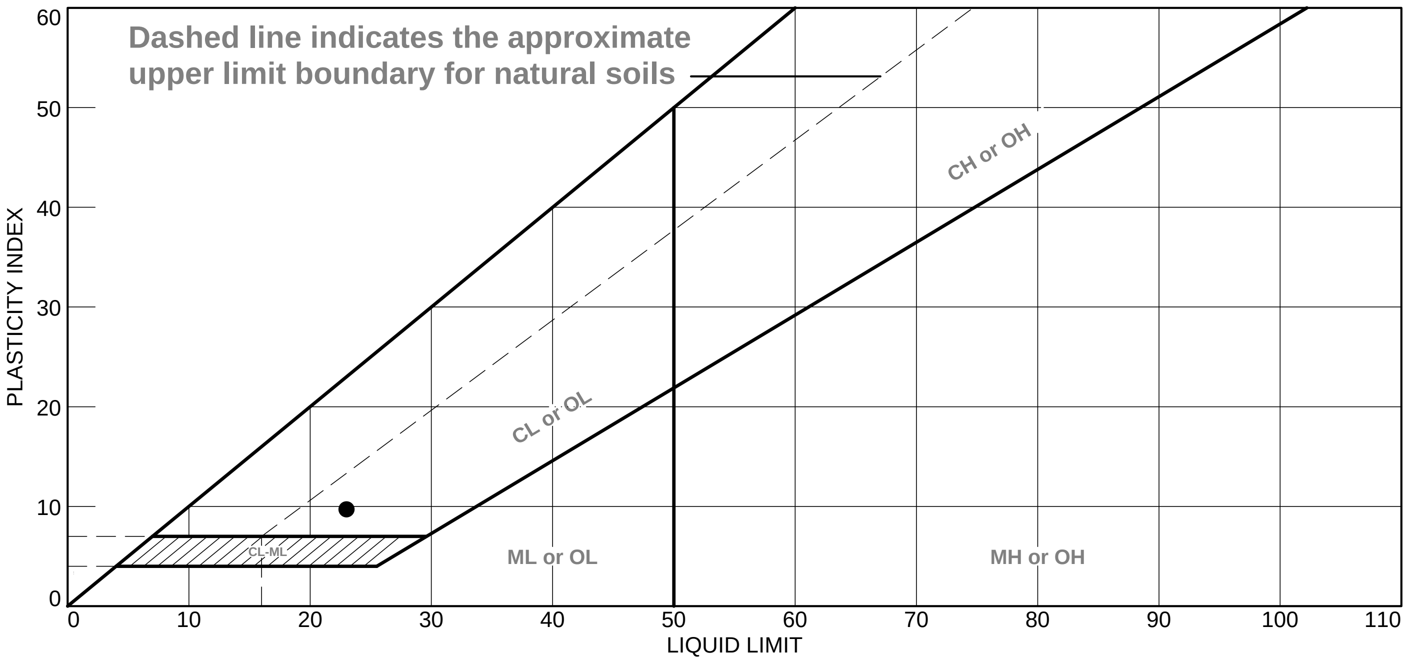
AME Materials Engineering

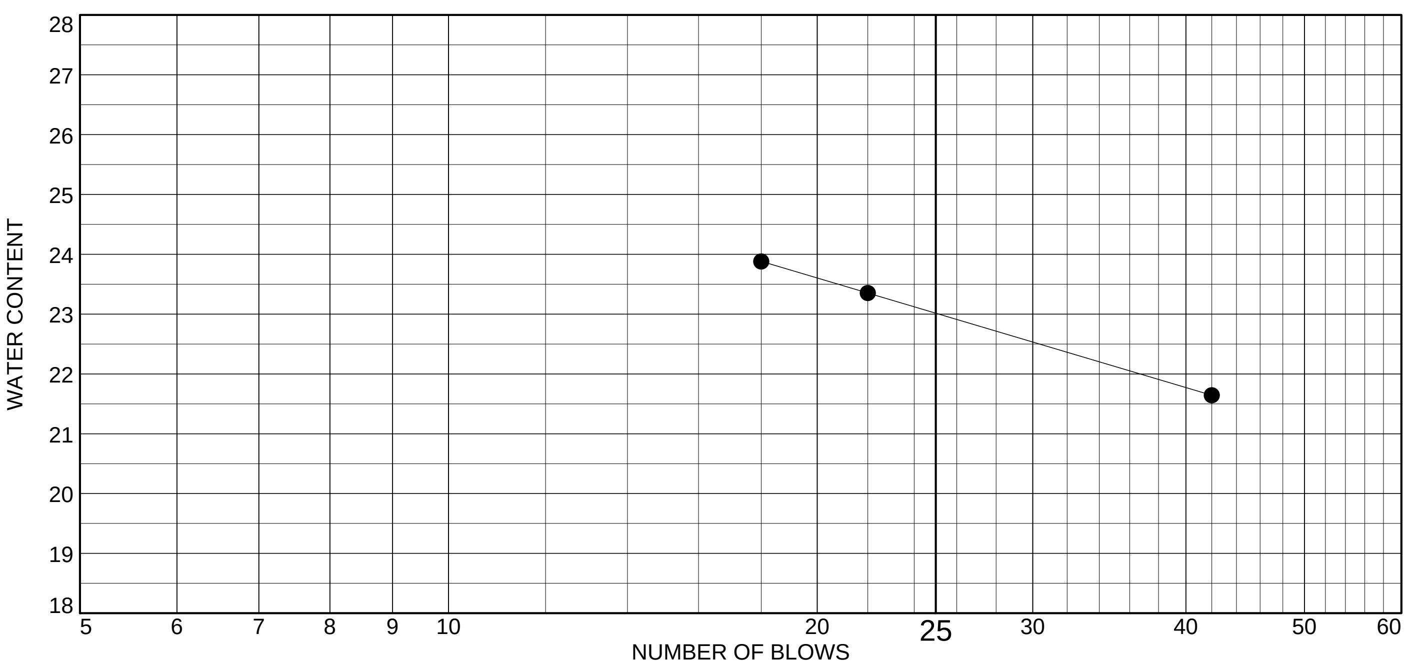
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Silty Clay, trace Gravel	23.0	13.3	9.7	89.1	62.2	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-11 SS5
Sample Number: MG-37164A

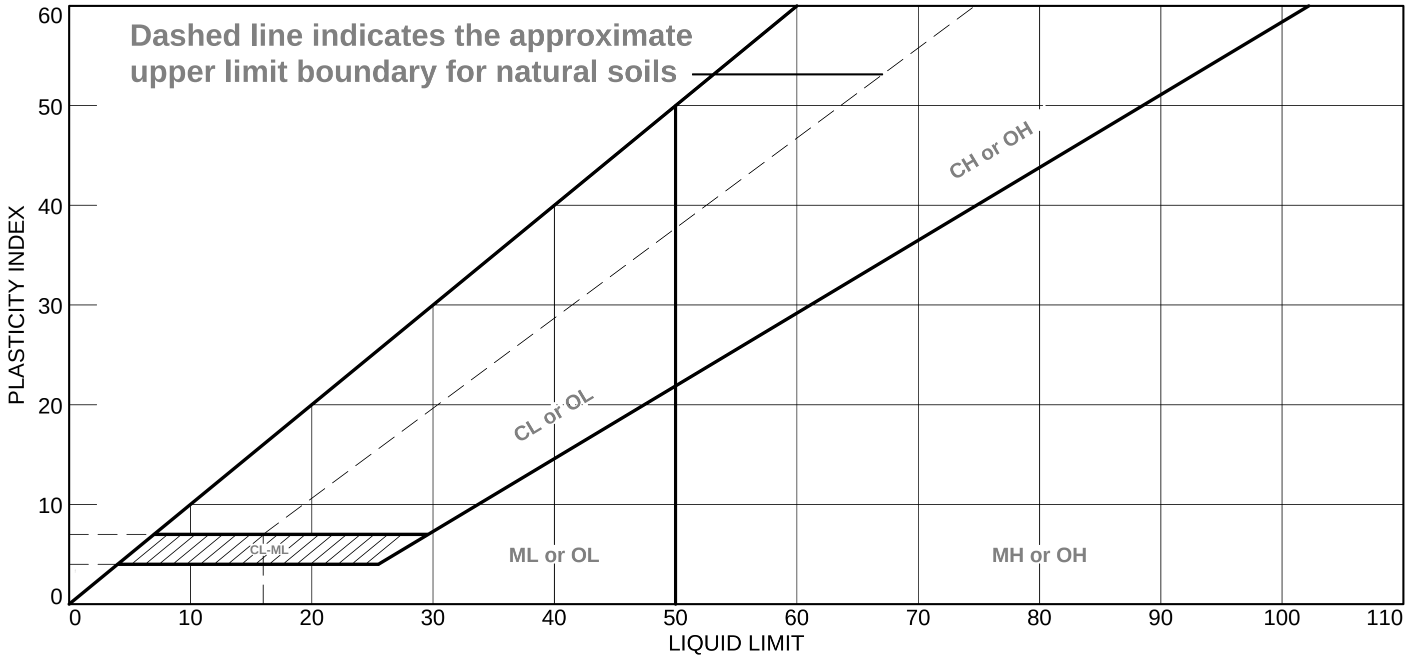
Remarks:

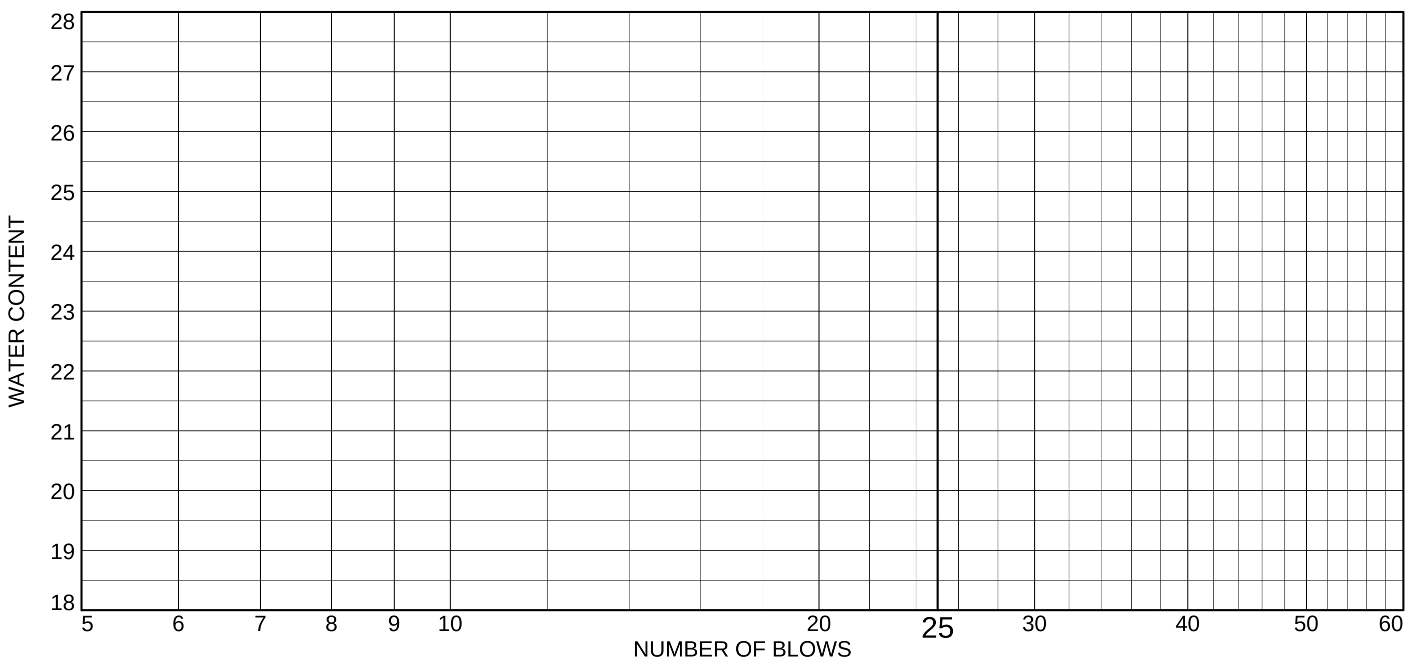
AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sand and Silt, some Clay			NP	97.7	51.7	

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-11 SS9
Sample Number: MG-37164B

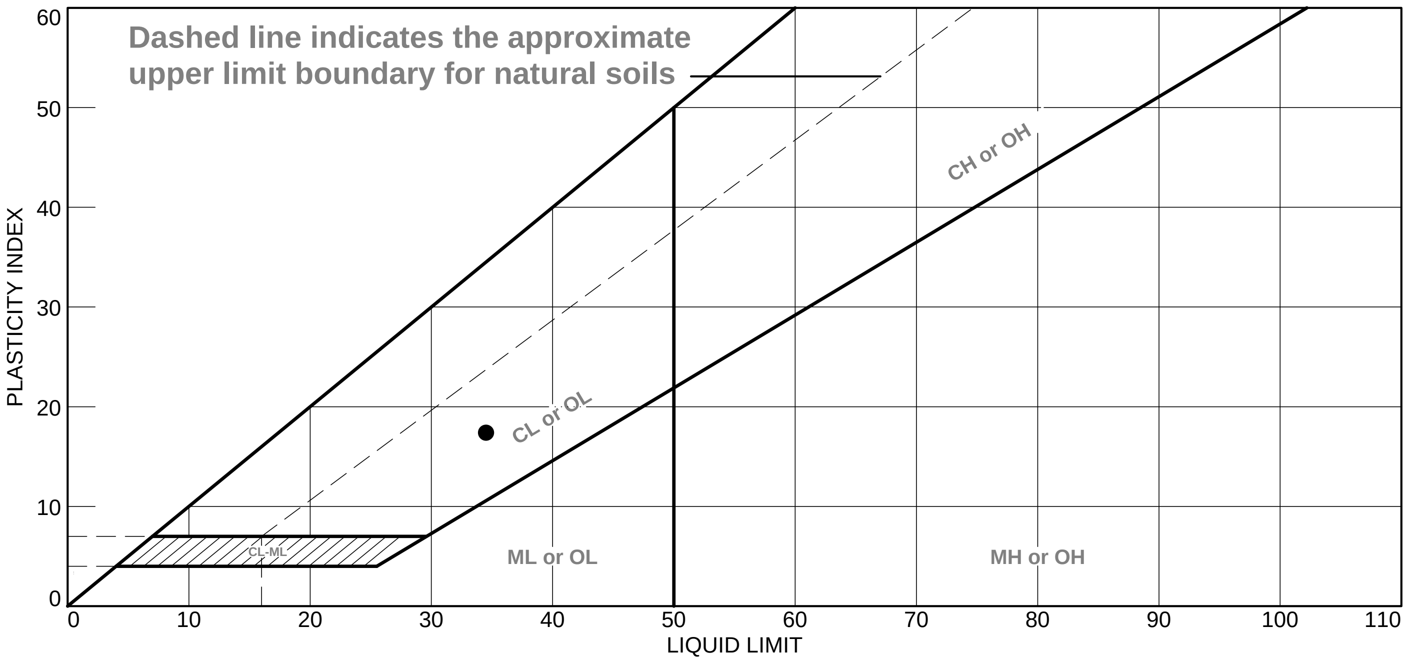
AME Materials Engineering

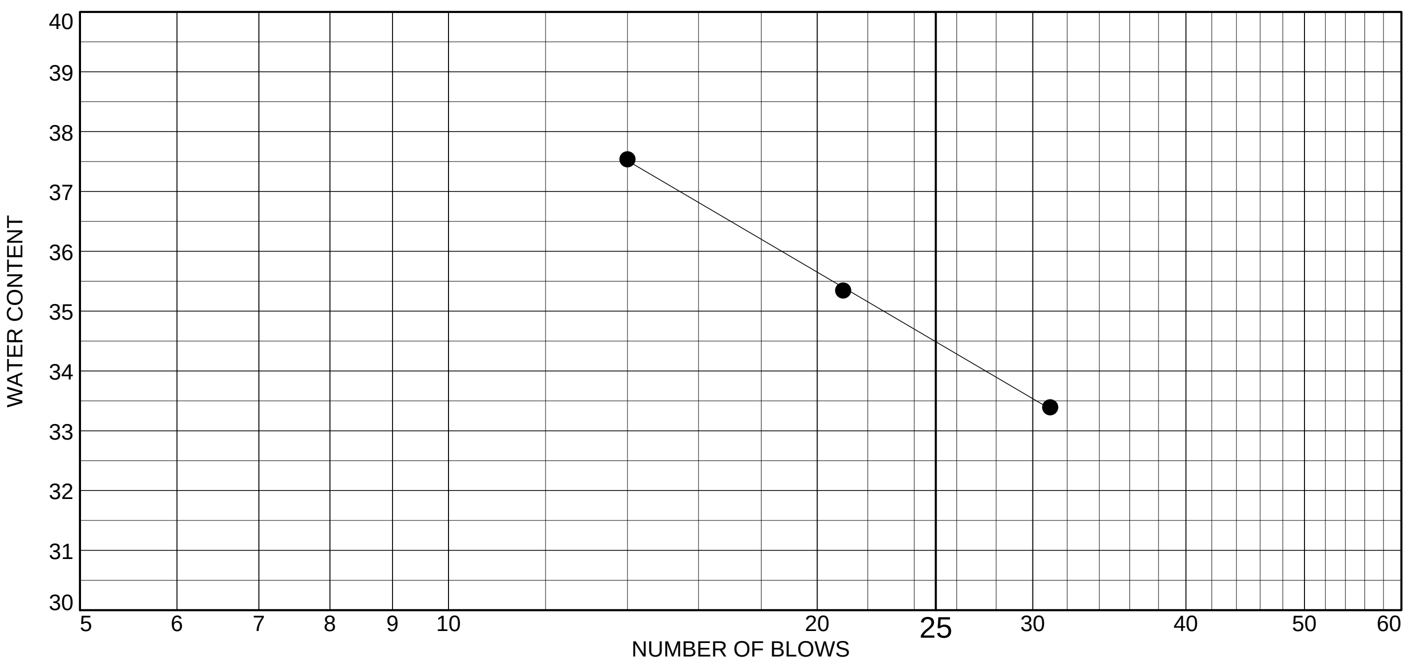
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, trace Sand	34.5	17.1	17.4	95.2	92.0	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

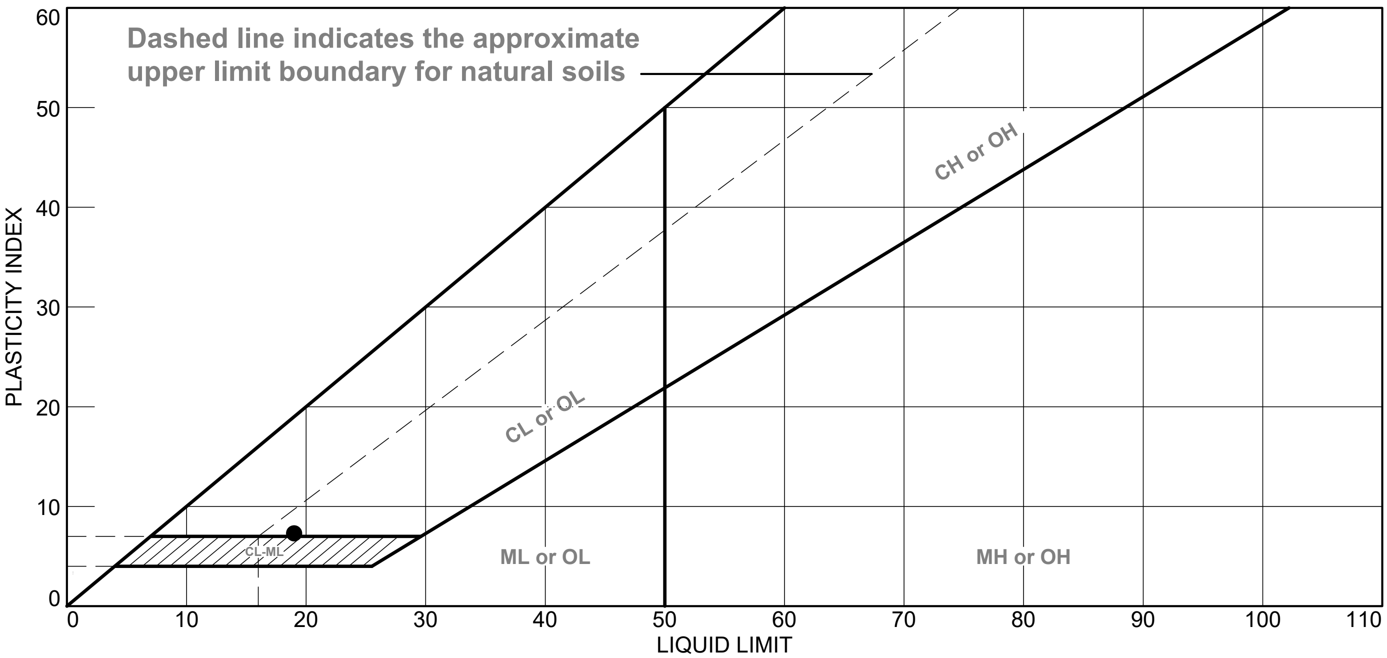
Location: BH22-11 SS15
Sample Number: MG-37164C

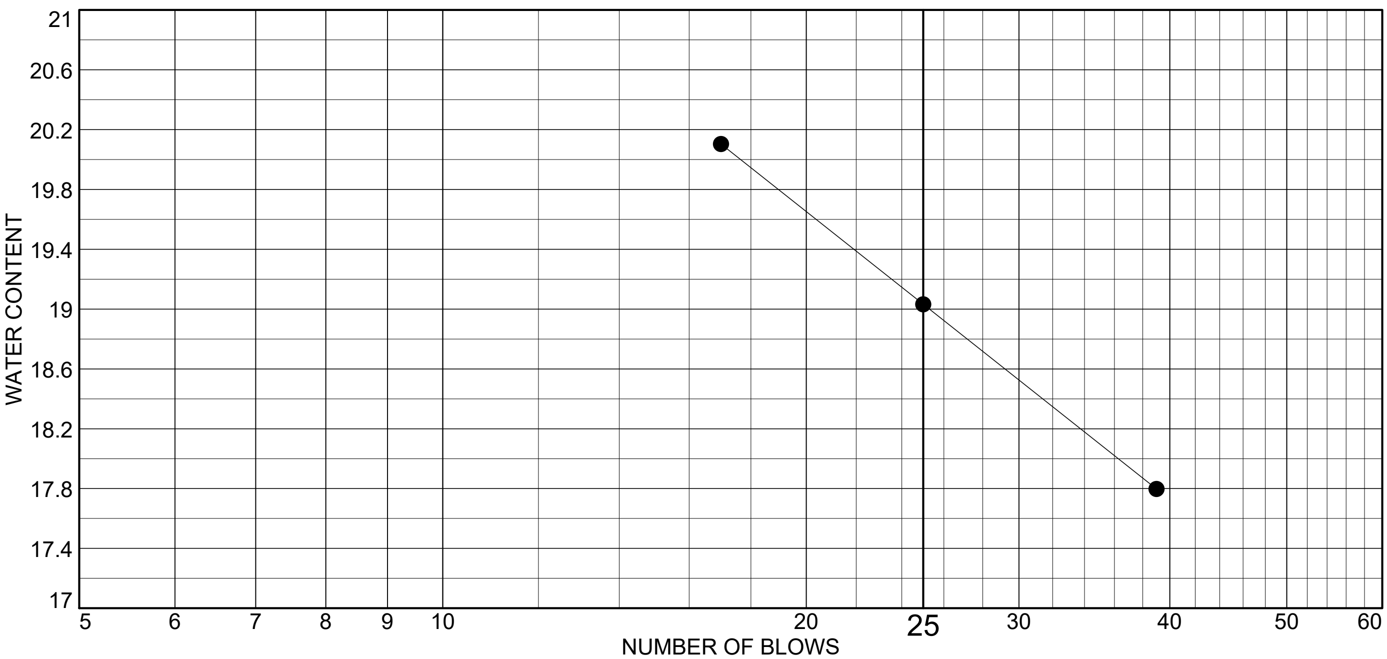
Remarks:

Figure

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Silty Clay, trace Gravel	19.0	11.7	7.3	87.6	69.2	CL-ML

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

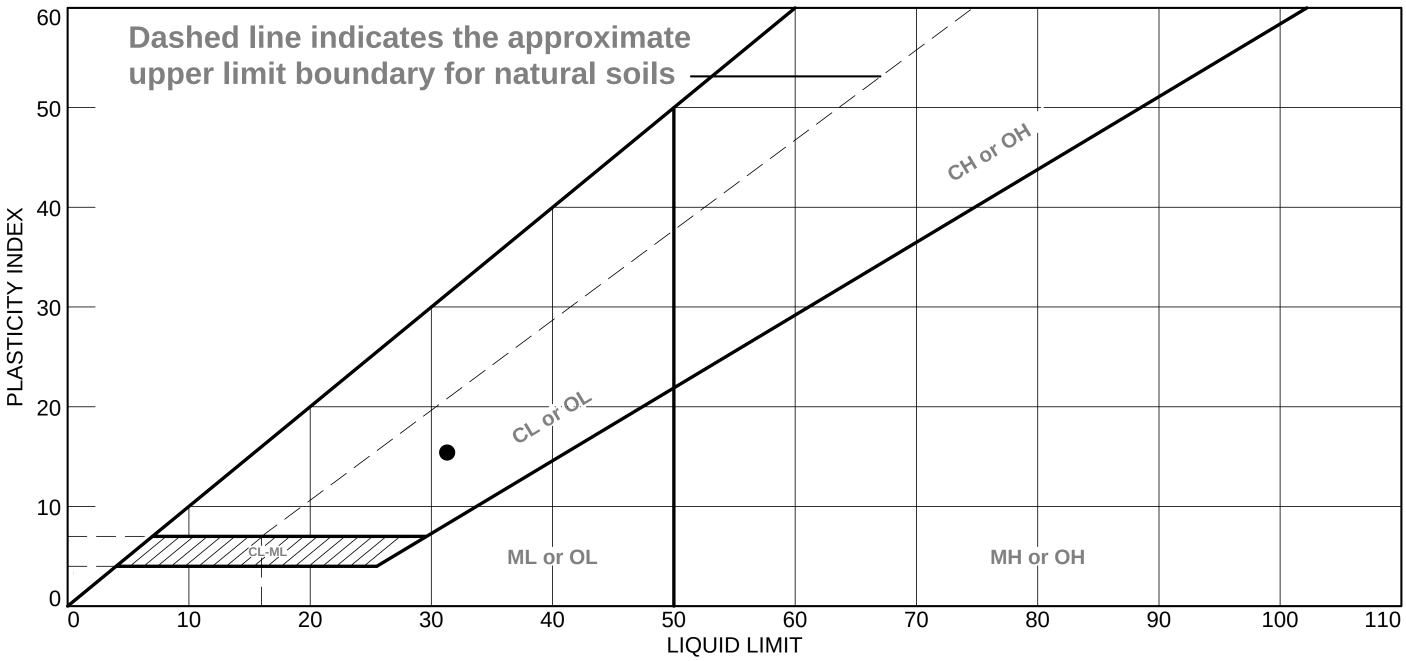
Location: BH22-12 SS3
Sample Number: MG-37094A

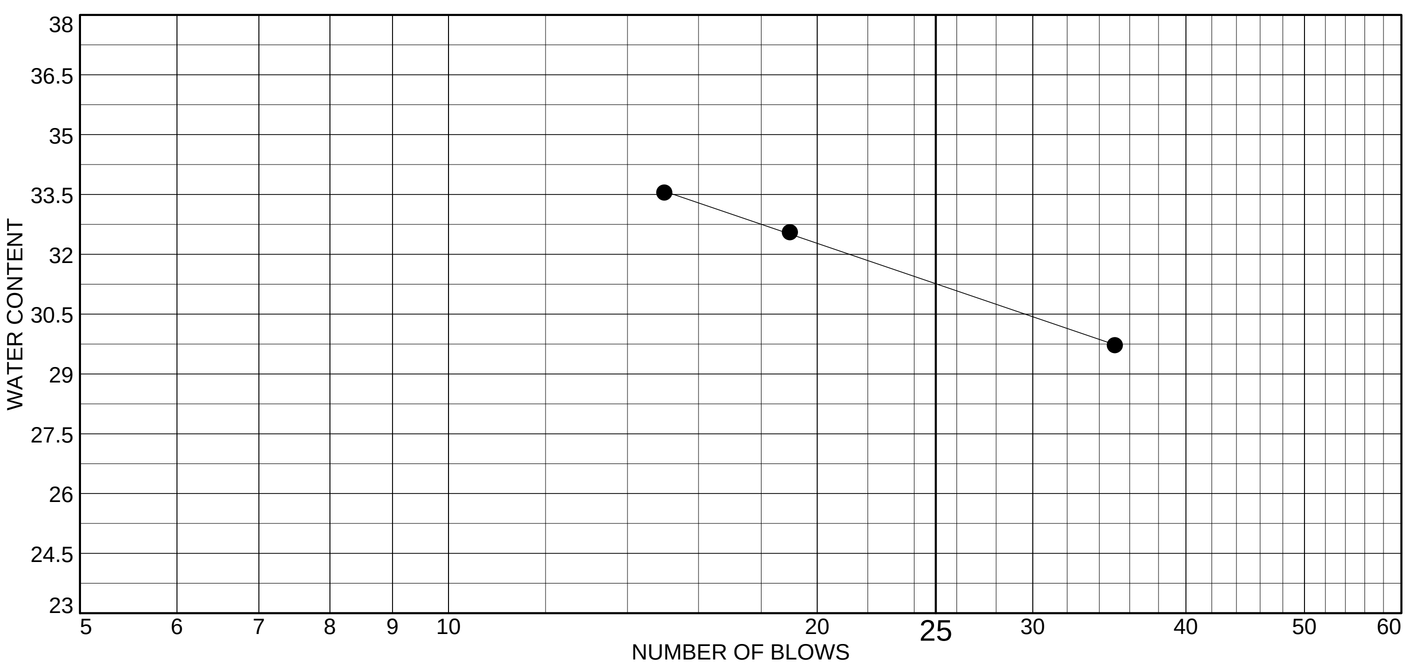
Remarks:

AMe Materials Engineering

Tested By: TZ **Checked By:** JY

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Silty Clay, trace Sand	31.3	15.9	15.4	98.1	96.7	CL

Project No. 13211.201 **Client:** ACML

Project: MTO 2021-3006 Hwy 403, Woodstock

Location: BH22-12 SS6
Sample Number: MG-37094B

Remarks:

AME Materials Engineering

Figure

Tested By: TZ **Checked By:** JY

AME Materials Engineering

AME - Materials Engineering

Borehole / Soil Sample Moisture Content (LS-700)

Sample No.:	MG-37090 to MG-37101	**Date Sampled:**	
Job No.:	13211.201	**Date Tested:**	13-Jul-22
Job Name:	MTO 2021-3006 Hwy 403, Woodstock	**Tested By:**	SH
Source:	Borehole	**Reviewed By:**	JY
Material Type:	SS	**Results To:**	Behrouz

Borehole No.	Tin No.:	Depth Sample Taken	Wet Sample + Tare (A)	Dry Sample + Tare (B)	Tare (C)	Mass of Sample (D) (B-C)	% Moisture (A-B)/D x100
BH22-02		SS1	133.13	125.71	38.99	86.72	8.56
		SS2	388.83	361.56	158.68	202.88	13.44
		SS3	181.11	165.17	39.07	126.10	12.64
		SS4	166.11	146.61	41.57	105.04	18.56
		SS5	415.75	370.56	153.95	216.61	20.86
BH22-04		SS1	170.17	165.51	38.37	127.14	3.67
		SS2	148.13	144.74	38.84	105.90	3.20
		SS3	311.03	291.41	151.69	139.72	14.04
		SS4	125.41	116.32	41.76	74.56	12.19
		SS5	124.37	114.41	38.16	76.25	13.06
		SS6	132.7	122.61	38.26	84.35	11.96
		SS7	118.02	108.82	38.63	70.19	13.11
		SS8	113.77	105.35	37.86	67.49	12.48
		SS9	475.44	437.95	264.82	173.13	21.65
		SS10	143.33	125.15	38.11	87.04	20.89
		SS11	519.06	485.79	251.58	234.21	14.21
		SS12	140.79	130.64	38.26	92.38	10.99
		SS13	135.79	125.30	38.22	87.08	12.05
		SS14	121.53	111.11	38.24	72.87	14.30
		SS15	484.2	450.30	250.80	199.50	16.99
BH22-06		SS1	172.54	160.29	38.55	121.74	10.06
		SS2	189.32	172.77	38.26	134.51	12.30
		SS3	138.52	127.38	38.27	89.11	12.50
		SS4	500.09	468.26	252.54	215.72	14.76
BH22-07		SS1	172.26	159.74	37.91	121.83	10.28
		SS2	174.93	161.37	37.93	123.44	10.99
		SS3	196.36	179.17	38.02	141.15	12.18
		SS4	488.76	445.10	152.06	293.04	14.90
BH22-12		SS1	197.34	180.63	37.82	142.81	11.70
		SS2	214.89	194.87	38.02	156.85	12.76
		SS3	568.98	526.06	151.61	374.45	11.46
		SS4	176.22	158.39	38.33	120.06	14.85
		SS5	174.82	157.21	37.96	119.25	14.77
		SS6	603.17	544.49	152.41	392.08	14.97

AME - Materials Engineering

AME Materials Engineering

Borehole / Soil Sample Moisture Content (LS-700)

Sample No.:	MG-37090 to MG-37101	**Date Sampled:**	
Job No.:	13211.201	**Date Tested:**	13-Jul-22
Job Name:	MTO 2021-3006 Hwy 403, Woodstock	**Tested By:**	SH
Source:	Borehole	**Reviewed By:**	JY
Material Type:	SS	**Results To:**	Behrouz

Borehole No.	Tin No.:	Depth Sample Taken	Wet Sample + Tare (A)	Dry Sample + Tare (B)	Tare (C)	Mass of Sample (D) (B-C)	% Moisture (A-B)/D x100
BH22-05		SS1	135.32	121.99	38.43	83.56	15.95
		SS2	519.12	485.86	272.92	212.94	15.62
		SS3	153.86	146.15	41.00	105.15	7.33
		SS4	125.44	115.62	38.02	77.60	12.65
		SS5	126.95	117.62	37.84	79.78	11.69
		SS6	489.74	454.07	252.53	201.54	17.70
		SS7	140.74	125.89	39.95	85.94	17.28
BH22-08		SS1	167.14	152.64	37.98	114.66	12.13
		SS2	400.25	373.20	160.92	212.28	12.74
		SS3	105.1	97.82	37.81	60.01	12.13
		SS4	132.09	121.73	37.79	83.94	12.34
		SS5	420.1	392.42	155.79	236.63	11.70
BH22-11		SS1	123.55	119.82	40.22	79.60	4.69
		SS2	123.85	116.14	37.80	78.34	9.84
		SS3	119.92	116.07	38.14	77.93	4.94
		SS4	115.89	110.34	38.04	72.30	7.68
		SS5	409.9	377.20	143.20	234.00	13.97
		SS6	151.82	139.34	38.75	100.59	12.41
		SS7	143.89	134.95	38.22	96.73	9.24
		SS8	142.32	130.71	38.10	92.61	12.54
		SS9	382.9	356.70	152.00	204.70	12.80
		SS10	170.46	153.53	38.15	115.38	14.67
		SS11	142.89	132.75	38.93	93.82	10.81
		SS12	143.82	134.06	40.84	93.22	10.47
		SS13	134.33	125.42	37.80	87.62	10.17
		SS14	159.33	144.53	37.79	106.74	13.87
		SS15	444.19	397.30	141.37	255.93	18.32
BH22-01		SS1	118.41	110.30	39.03	71.27	11.38
		SS2	138.74	123.64	38.10	85.54	17.65
		SS3	130.44	120.27	38.16	82.11	12.39
		SS4	134.72	122.12	38.21	83.91	15.02
		SS5	541.62	498.41	145.60	352.81	12.25

AME - Materials Engineering

Borehole / Soil Sample Moisture Content (LS-700)

Sample No.:	MG-37090 to MG-37101	**Date Sampled:**	
Job No.:	13211.201	**Date Tested:**	13-Jul-22
Job Name:	MTO 2021-3006 Hwy 403, Woodstock	**Tested By:**	SH
Source:	Borehole	**Reviewed By:**	JY
Material Type:	SS	**Results To:**	Behrouz

Borehole No.	Tin No.:	Depth Sample Taken	Wet Sample + Tare (A)	Dry Sample + Tare (B)	Tare (C)	Mass of Sample (D) (B-C)	% Moisture (A-B)/D x100
BH22-03		SS1	140.37	129.67	38.13	91.54	11.69
		SS2	145.25	131.07	38.06	93.01	15.25
		SS3	735.04	681.00	273.06	407.94	13.25
		SS4	630.86	586.30	250.52	335.78	13.27
		SS5	136.39	119.17	38.08	81.09	21.24
BH22-09		SS1	140.7	128.64	38.98	89.66	12.13
		SS2	590.05	559.20	272.21	286.99	10.75
		SS3	109.14	101.98	38.16	63.82	11.22
		SS4	143.18	132.83	41.62	91.21	11.35
		SS5	629.25	586.23	264.44	321.79	13.37
BH22-10		SS1	130.92	110.07	37.87	72.20	28.88
		SS2	121.53	114.13	37.82	76.31	9.70
		SS3	507.01	467.20	140.07	327.13	12.17
		SS4	146.22	134.16	37.91	96.25	12.53
		SS5	145.05	131.89	37.99	93.90	14.01
		SS6	506.5	463.41	160.86	302.55	14.24

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: AECON MATERIALS ENGINEERING CORP
10 PERDUE COURT, UNITS 2
CALEDON, ON L7C 3M6
905-840-5914

ATTENTION TO: Anthony Upper

PROJECT: 13211.201

AGAT WORK ORDER: 22T923280

ROCK ANALYSIS REVIEWED BY: Meredith White, Senior Technician

SOIL ANALYSIS REVIEWED BY: Nivine Basily, Inorganics Report Writer

TRACE ORGANICS REVIEWED BY: Pinkal Patel, Report Reviewer

DATE REPORTED: Jul 28, 2022

PAGES (INCLUDING COVER): 8

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*Notes

Certificate of Analysis

AGAT WORK ORDER: 22T923280
PROJECT: 13211.201

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CLIENT NAME: AECON MATERIALS ENGINEERING CORP

ATTENTION TO: Anthony Upper

SAMPLING SITE:

SAMPLED BY:

(283-042) Sulfide (CGY)

DATE RECEIVED: 2022-07-21

DATE REPORTED: 2022-07-28

			SAMPLE DESCRIPTION:	BH22_02 MW_SS3	BH22_04 MW_SS12	BH22_06 MW_SS3	BH22_09 MW_SS3	BH22_12 MW_SS4
			SAMPLE TYPE:	Soil	Soil	Soil	Soil	Soil
			DATE SAMPLED:	2022-07-06 15:00	2022-07-06 12:00	2022-07-06 09:00	2022-07-06 10:00	2022-07-06 16:00
Parameter	**Unit**	**G / S**	**RDL**	**4117534**	**4117543**	**4117544**	**4117545**	**4117546**
Sulfide	%		0.01	<0.01	0.11	0.01	0.01	0.14

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

Analysis performed at AGAT Calgary (unless marked by *)

Certified By:

AGAT Laboratories

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CANADA L4Z 1Y2
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Certificate of Analysis

AGAT WORK ORDER: 22T923280
PROJECT: 13211.201

CLIENT NAME: AECON MATERIALS ENGINEERING CORP
SAMPLING SITE:

ATTENTION TO: Anthony Upper
SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2022-07-21 | **DATE REPORTED: 2022-07-28**

Parameter	Unit	G / S	RDL	BH22_02 MW_SS3	BH22_04 MW_SS12	BH22_06 MW_SS3	BH22_09 MW_SS3	BH22_12 MW_SS4
			SAMPLE TYPE:	Soil	Soil	Soil	Soil	Soil
			DATE SAMPLED:	2022-07-06 15:00	2022-07-06 12:00	2022-07-06 09:00	2022-07-06 10:00	2022-07-06 16:00
				4117534	4117543	4117544	4117545	4117546
Chloride (2:1)	µg/g		2	65	269	27	285	8
Sulphate (2:1)	µg/g		2	17	55	240	11	98
pH (2:1)	pH Units		NA	8.45	8.41	8.27	8.24	8.33
Electrical Conductivity (2:1)	mS/cm		0.005	0.266	0.674	0.449	0.630	0.292
Resistivity (2:1) (Calculated)	ohm.cm		1	3760	1480	2230	1590	3420
Redox Potential 1	mV		NA	309	315	276	254	186
Redox Potential 2	mV		NA	307	311	273	253	190
Redox Potential 3	mV		NA	311	312	274	255	192

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

4117534-4117546 EC, pH, Chloride and Sulphate were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Resistivity is a calculated parameter.
Redox potential measured on as received sample. Due to the potential for rapid change in sample equilibrium chemistry with exposure to oxidative/reduction conditions laboratory results may differ from field measured results.
Redox potential measurement in soil is quite variable and non reproducible due in part, to the general heterogeneity of a given soil. It is also related to the introduction of increased oxygen into the sample after extraction. The interpretation of soil redox potential should be considered in terms of its general range rather than as an absolute measurement.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO
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Certificate of Analysis

AGAT WORK ORDER: 22T923280
PROJECT: 13211.201

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MISSISSAUGA, ONTARIO
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FAX (905)712-5122
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CLIENT NAME: AECON MATERIALS ENGINEERING CORP
SAMPLING SITE:

ATTENTION TO: Anthony Upper
SAMPLED BY:

Moisture content (Soil)

DATE RECEIVED: 2022-07-21 **DATE REPORTED: 2022-07-28**

			SAMPLE DESCRIPTION:	BH22_02 MW_SS3	BH22_04 MW_SS12	BH22_06 MW_SS3	BH22_09 MW_SS3	BH22_12 MW_SS4
			SAMPLE TYPE:	Soil	Soil	Soil	Soil	Soil
			DATE SAMPLED:	2022-07-06 15:00	2022-07-06 12:00	2022-07-06 09:00	2022-07-06 10:00	2022-07-06 16:00
Parameter	**Unit**	**G / S**	**RDL**	**4117534**	**4117543**	**4117544**	**4117545**	**4117546**
Moisture Content	%		0.1	10.1	10.2	9.6	10.7	10.3

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard
Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

AGAT Laboratories

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Quality Assurance

CLIENT NAME: AECON MATERIALS ENGINEERING CORP | **AGAT WORK ORDER: 22T923280**

PROJECT: 13211.201 | **ATTENTION TO: Anthony Upper**

SAMPLING SITE: | **SAMPLED BY:**

Rock Analysis

RPT Date: Jul 28, 2022			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
(283-042) Sulfide (CGY)															
Total Sulfur	4117534	4117534	<0.01	<0.01	0.0%	< 0.01	98%	90%	110%						
Sulfate	4117534	4117534	<0.01	<0.01	0.0%	< 0.01	100%	80%	120%						

Certified By:

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Quality Assurance

CLIENT NAME: AECON MATERIALS ENGINEERING CORP | **AGAT WORK ORDER: 22T923280**

PROJECT: 13211.201 | **ATTENTION TO: Anthony Upper**

SAMPLING SITE: | **SAMPLED BY:**

Soil Analysis

RPT Date: Jul 28, 2022			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
Corrosivity Package															
Chloride (2:1)	4112675		644	663	2.9%	< 2	100%	70%	130%	99%	80%	120%	NA	70%	130%
Sulphate (2:1)	4112675		78	82	5.0%	< 2	98%	70%	130%	96%	80%	120%	100%	70%	130%
pH (2:1)	4113422		9.46	9.47	0.1%	NA	98%	80%	120%						
Electrical Conductivity (2:1)	4113422		0.239	0.236	1.3%	0.012	108%	80%	120%						
Redox Potential 1	4117534						100%	90%	110%						

Comments: NA signifies Not Applicable.
pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.

Matrix spike NA: Spike level < native concentration. Matrix spike acceptance limits do not apply and are not calculated.

Certified By:

AGAT Laboratories
5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
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Method Summary

CLIENT NAME: AECON MATERIALS ENGINEERING CORP
PROJECT: 13211.201
SAMPLING SITE:

AGAT WORK ORDER: 22T923280
ATTENTION TO: Anthony Upper
SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Chloride (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	modified from EPA 9045D and MCKEAGUE 3.11	PH METER
Electrical Conductivity (2:1)	INOR-93-6075	modified from MSA PART 3, CH 14 and SM 2510 B	PC TITRATE
Resistivity (2:1) (Calculated)	INOR-93-6036	McKeague 4.12, SM 2510 B,SSA #5 Part 3	CALCULATION
Redox Potential 1	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 2	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 3	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Trace Organics Analysis			
Moisture Content	ORG-91-5009	modified from CCME Tier 1 Method	BALANCE

Appendix F - Culvert Installation by Trenchless (Tunneling) Method

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHOD

1.0 SCOPE

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

2.0 REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

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

Ontario Provincial Standard Specifications, Material

OPSS 1004 Material Specification for Aggregates - Miscellaneous
OPSS 1350 Material Specification for Concrete - Materials and Production
OPSS 1440 Steel Reinforcement for Concrete
OPSS 1802 Material Specification for Smooth Walled Steel Pipe
OPSS 1820 Material Specification for Circular and Elliptical Concrete Pipe
OPSS 1840 Material Specification for Non-Pressure Polyethylene (PE) Plastic Pipe Products
OPSS 1841 Material Specification for Non-Pressure Polyvinyl Chloride (PVC) Plastic Pipe Products

CSA Standards

A3000 Cementitious Materials Compendium
B182.6 Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications

B182.8	Profile Polyethylene (PE) Storm Sewer and Drainage Pipe and Fittings
B182.13	Profile Polypropylene (PP) Sewer Pipe and Fittings for Leak-proof Sewer Applications
C22.1	Canadian Electrical Code
W59	Welded Steel Construction

American Society for Testing and Materials (ASTM) International Standards

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

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

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

3.0 DEFINITIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

MTBM means a microtunnelling boring machine.

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

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

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

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

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

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

Reaming means a process for enlarging the bore path.

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

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

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

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

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

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

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

TBM means a tunnel boring machine.

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

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

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

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

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

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

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with the Contract Documents.

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

Preferred, Acceptable, and Not Recommended Trenchless installation methods are provided in the Foundation Inspection and Design Report, Part 2.

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names of the Project Superintendent, and Trenchless Contractor shall be submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five (5) years experience on projects with similar scope and complexity.

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

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five (5) years experience on projects with similar scope and complexity.

4.02.02 Working Drawings

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

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

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

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

a) Plans and Details:

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

- Deviation from required alignment and grade.
- Extended service disruption.
- Damage to the existing Utilities and methods of repair.
- Soil heaving or settlement.
- Contaminated soil or water.
- Alignment passing through buried structures.

b) Designs:

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

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

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

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

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

c) Materials:

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

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

iii. Manufacturer data sheets for drilling systems.

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

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

vi. Compressive strength of concrete pipe products.

vii. Pipe class for all steel pipe products.

viii. Steel for Permanent Casings:

- One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.

- Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.

- The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.

ix. Slurry, drilling fluids, and tunnelling fluids:

- Type, source, and physical and chemical properties of bentonite, polymer or other additives;
- Source of water;
- Method of mixing;
- Water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
- Details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunneling fluids or EPB spoils; and
- Method of disposal of the slurry, drilling fluids and associated spoil.

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

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

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

f) Excavation and Dewatering:

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

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

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

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

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

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

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

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

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

g) Monitoring Method:

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

i. Maintaining the alignment of the installation;

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

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

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

v. Grout injection pressures and volumes;

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

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

4.02.03 As-Built Drawings

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

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

5.0 MATERIALS

5.01 Pipe

5.01.01 General

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

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

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

5.01.03 High Density Polyethylene Pipe

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

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

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

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

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

5.03 Steel Reinforcement

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

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

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

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

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

a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding ground and groundwater pressures at excavation face;
b) lubricate installation of primary liners as required;
c) transport spoil through pipe systems.

5.06 Grout

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

6.0 EQUIPMENT

6.01 Auger Jack & Bore

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

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

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

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

6.02 Pipe Ramming

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

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

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

6.03 Horizontal Directional Drilling

6.03.01 General

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

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

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

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

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

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

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

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

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

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling

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

a) rock or boulder breaking and removal;

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

c) jacking systems;

d) alignment control systems;

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

6.05 Microtunnelling Equipment

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

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

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

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

   i. Allows for operation of the system without the need for personnel to enter the microtunnel.

   ii. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.

   iii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by product pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.

   iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.

   v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.

   vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.

   vii. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.

viii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.

ix. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.

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

i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference.

ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.

iii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

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

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

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

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

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

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

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

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

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

6.05.02 Spoil Separation System

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

6.05.03 Electrical Equipment, Fixtures and Systems

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

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

7.0 CONSTRUCTION

7.01 General

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

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

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

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

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

7.01.01 Layout, Alignment and Depth Control

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

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

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

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

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

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

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

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

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

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

7.01.12 Removal of Obstructions

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

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180.

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

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

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

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

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

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For Pipe Ramming installation the following requirements apply:

- Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.
- A Ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has

passed fully through and beyond the zone of influence of any overlying infrastructure.

- Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator.
- Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed.
- The annular space between the liner pipe and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

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

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

7.04.02 Site Preparation

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

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

7.04.03 Pilot Bore

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

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

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

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

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

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

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.01 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7. 05 Tunnelling Installation

7.05.01 General

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

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

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

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

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

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

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

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

7.05.02 Tunnelling Method

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

7.05.03 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.04 Secondary Liner

7.05.04.01 Placing of Grout

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

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

7.06 Microtunnelling

7.06.01 General

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

7.06.02 Method of Installation

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

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour Working Days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

7.07 Instrumentation and Monitoring

The contractor shall prepare a Geotechnical Instrumentation and Monitoring Plan to address the monitoring requirements. The work specified in this section includes furnishin and installing instruments for monitoring settlement (and heave) and ground stability.

7.07.01 General

The Contractor shall furnish, install and monitor Surface Monitoring Points (SMP) and In-Ground Monitoring Points at the locations shown on the Contract Drawings.
The equipment and procedures used for settlement monitoring during construction must be capable of

surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

7.07.02 Surface Settlement Monitoring Points

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

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

7.07.03 In-Ground Settlement Monitoring Points

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

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

7.07.04 Installation, Replacement and Abandonment

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

7.07.05 Monitoring and Reporting Frequency

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

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

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

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

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

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

7.07.06 Benchmarks

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

7.08 Criteria for Assessment of Roadway Subsidence/Heave

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

a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the Contract Administrator and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:

   i. The cause of the settlement has been identified.

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

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

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

7.09 Certificate of Conformance

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

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

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

10.0 BASIS OF PAYMENT

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

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

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