



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
PROPOSED SIGN SUPPORTS FOR
QUEUE AND STOPPED VEHICLE ADVISORY SYSTEM
HIGHWAY 405
NIAGARA FALLS, ONTARIO
G.W.P. NO. 2171-19-00**

GEOCRES No. 30M3-323

VMS#1	Latitude 43.153060 ° , Longitude -79.134650 °
VMS#2	Latitude 43.148748 ° , Longitude -79.110141°
VMS#3	Latitude 43.149284 ° , Longitude -79.084175 °
VMS#4	Latitude 43.152328 ° , Longitude -79.075581 °

Submitted

To

LEA CONSULTING LTD.

Date: February 8, 2021
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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted for four proposed Queue and Stopped Vehicle Advisory System (QSVAS) sign locations along Highway 405 from approximately 50 m west of Concession 6 Road to 1.1 km east of Stanley Avenue in Niagara Falls, Ontario.

The purpose of this investigation was to explore the subsurface conditions near the proposed locations of the sign supports and, based on this data, to provide a borehole location plan, records of boreholes, laboratory test results and a written description of the subsurface conditions.

During the preparation of this report, reference has been made to information on subsurface conditions contained in previous foundation investigations which were conducted in the general vicinity of these sites. The titles of these reports are listed as follows:

- Foundation Investigation and Design Report, Median Sinkhole Area, Station 14+860 to Station 15+050, Highway 405 Rehabilitation from QEW to Queenston-Lewiston Border Crossing, G.W.P. 2445-04-00, Geocres No. 30M3-234, Report No. 06-11111-036, prepared by Golder Associates, dated February 2007 (Reference 1).



- Overpass at Highway 8 and Q.E.W. Extension (Highway 405) Township of Stamford, City of Welland, District No.4, W.J. 61-F6, W.P. 285-59, Geocres No. 30M03-037, dated March 28, 1961 (Reference 2).
- Foundation Investigation and Design Report, Proposed Watermain Installation, Highway 405 Encroachment at St. Paul Avenue, Town of Niagara-On-The-Lake, Ontario, Project No. 091854, prepared by Coffey Geotechnics, St. Catharines, GEOTBURL01244AA, Geocres No. 30M03-285, dated August 6, 2002 (Reference 3).

Thurber was retained by LEA to carry out the site investigation under the Ministry of Transportation Ontario (MTO) Request for Bid (RFB) # 13074.

2. SITE DESCRIPTION

The proposed QSVAS will involve construction/installation of four Variable Message Signs (VMS) to be located on Highway 405 eastbound lanes (EBL) from approximately 50 m west of Concession 6 Road to approximately 1.1 km east of Stanley Avenue, in Niagara Falls, Ontario. The general locations of the proposed signs are shown on plan on the Borehole Location Plan drawing in Appendix D.

The land use adjacent to this section of Highway 405 is largely rural and agricultural, although some residential and commercial developments are observed near St. Paul Avenue. Between the four sign locations, Highway 405 grade varies from approximate Elevations 134.7 to 187.3.

Based on the Ontario Geological Survey Special Volume 2, The Physiography of Southern Ontario, Third Edition by Chapman and Putnam, the site lies within the physiographic regions known as the Niagara Escarpment and Iroquois Plain. The Niagara Escarpment separates the lower Iroquois Plain to the north from the Haldimand Clay Plain physiographic region to the south. The Niagara Escarpment is essentially a ridge of durable cap rock over comparatively soft and extensively fractured shale and sandstones several hundred metres high in some locations. In the Niagara Region, the escarpment base is located at about Elevation 105 m and the top reaches about Elevation 190 m. The escarpment itself consists of dolostone, limestone, sandstone and shale bedrock, mantled



by relatively thin deposits of silty clay till, sandy silt till, sands and silt. The depth to bedrock is shallow, varying between approximately 1 m and 6 m.

Comprised mostly of permeable sands, the Lake Iroquois Plain was created about 12,500 years ago along the shores of glacial Lake Iroquois. This physiographic region is an area of gentle slope, from the shoreline of Lake Ontario, back about 3 km to 5 km. The plain was smoothed over time by wave action and lacustrine deposits. Now this physiographic region is composed of a thin veneer of glacio-lacustrine sand and silty sand.

3. INVESTIGATION PROCEDURES

A geotechnical investigation was conducted from December 7 to 9, 2020 and consisted of drilling four boreholes (numbered VMS-01 to VMS-04) near the proposed locations of the VMS's. The boreholes were located on the south shoulder of the Highway 405 EBL. The boreholes were terminated at depths ranging from 7.4 m to 10.0 m depth (Elevations 126.5 to 179.9). Boreholes VMS-02 to VMS-04 were advanced into bedrock by coring 3.0 m to 3.1 m in each borehole. The Record of Borehole sheets are included in Appendix A.

The approximate locations of the four boreholes are shown on the Borehole Locations Plan drawing in Appendix D, and presented in Table 3.1.

Table 3.1 – VMS locations

Borehole	VMS	Approximate Station along Highway 405
VMS-01	VMS #1	11+889
VMS-02	VMS #2	13+972
VMS-03	VMS #3	16+333
VMS-04	VMS #4	17+112

Thurber surveyed the boreholes in the field, and obtained the borehole coordinates and ground surface elevations. Coordinates of boreholes are related to MTM NAD 83 Zone 10. The survey equipment used was a Trimble R10 GNSS system with a horizontal precision of 3 mm and a vertical precision of 3.5 mm. The coordinates and elevations of the boreholes are given on the drawings and on the individual Record of Borehole Sheets in Appendix A.



Lane closures and traffic control were arranged and provided by the Contractor (Black and MacDonald) during drilling of the boreholes for this investigation. Prior to commencement of drilling, utility clearances were obtained for all borehole locations.

The boreholes were advanced using a track-mounted drill rig with hollow stem augers. Soil samples were obtained at selected intervals using a 50 mm outside diameter split-spoon sampler driven in conjunction with the Standard Penetration Test (SPT) in general accordance with ASTM D1586. NQ rock coring equipment was used to recover core samples of the underlying bedrock where encountered in three of the boreholes.

All rock cores were logged and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and Fracture Indices (FI) were determined.

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who marked/staked the boreholes in the field, arranged for the clearance of subsurface utilities, supervised the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Boreholes were backfilled upon completion of drilling in general conformance with O.Reg. 903 as amended by O.Reg.128/03. The paved surface at each borehole was reinstated upon completion using cold patch asphalt.

4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. All the laboratory tests were carried out in accordance with MTO and/or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A, and also presented on the figures included in Appendix B.

Bedrock core samples were subjected to geological logging. Point load tests were carried out on selected samples of intact limestone/dolostone upon arrival at the laboratory to assist in evaluation of the compressive strength of the bedrock. Detailed results of point load tests on the selected rock core samples are included in Appendix B and summarized



on the Record of Borehole sheets in Appendix A. Rock core photos are presented in Appendix C.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In general, the soil stratigraphy encountered in the boreholes during the present investigation consists of pavement structure (asphalt on granular) and typically stiff to very stiff silty clay embankment fill, overlying native stiff to hard silty clay to clayey silt, compact to very dense silt and silt till, and dense to very dense silty sand till. The site is underlain by limestone and dolostone bedrock. The groundwater level observed in two boreholes ranged from 3.3 m to 5.6 m depth below ground surface.

5.1 Pavement Structure

Pavement structure consisting of approximately 150 mm to 175 mm of asphalt overlying granular (sand and gravel fill) road base was encountered in Boreholes VMS-01, VMS-03 and VMS-04 advanced through the Highway 405 platform. The granular fill was 600 mm thick.

5.2 Embankment Fill

Embankment fill was encountered below the pavement structure in Boreholes VMS-01, VMS-03 and VMS-04, and consisted of dark brown, brown and grey silty clay containing trace clay, trace gravel, occasional silt seams and rootlets, and reddish brown silty sand containing trace clay. Embankment fill consisting of brown sand and gravel, was contacted surficially in Borehole VMS-02. The thickness of the embankment fill varied from 0.7 m to 1.5. The depth to the base of the fill ranged from 0.8 m to 2.3 (Elevations 133.2 and 185.0).



The SPT 'N' values recorded in the silty clay fill ranged from 9 to 19 blows per 0.3 m of penetration, indicating a stiff to very stiff consistency. An SPT 'N' value measured in the silty sand fill was 26 blows per 0.3 m of penetration indicating a compact state. Moisture contents measured in the silty sand to sand and gravel fill were 5 and 15 percent. The natural moisture contents measured on samples of the cohesive fill generally ranged from 19 percent to 27 percent.

The results of grain size analyses conducted on a sample of the silty clay fill are provided on the Record of Borehole sheets in Appendix A, and illustrated on Figure B1 of Appendix B. The results are summarized as follows:

Soil Particle	Embankment Silty Clay Fill (Percent)
Gravel	0
Sand	10
Silt	63
Clay	27

The results of Atterberg Limits tests conducted on a sample of the silty clay fill are presented on the Record of Borehole sheets in Appendix A, and illustrated in Figure B6 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	37
Plasticity Index	19

The results of the Atterberg Limits testing indicate that the silty clay fill is of medium plasticity with a group symbol of CI.

5.3 Silty Clay and Clayey Silt

A native layer of brown silty clay containing trace to some sand, trace gravel and occasional grey silt seams was contacted below the fill in Boreholes VMS-01, VMS-03 and VMS-04 at 1.5 m and 2.3 m depth. Brown clayey silt containing trace to some sand and trace gravel was contacted below the silty clay at 5.6 m depth in Borehole VMS-01, and below the sand and gravel fill at 0.8 m depth in Borehole VMS-02. The thickness of the



silty clay and clayey silt layers was typically 0.7 m, except locally in Borehole VMS-01 where the combined thickness was 5.7 m.

The depth to the base of the silty clay was at 1.5 m and 3.0 m in Boreholes VMS-02, VMS-03 and VMS-04 (Elevations 158.3 and 184.3), and at 7.2 m (Elevation 127.5) in Borehole VMS-01.

In Boreholes VMS-02 to VMS-04, the SPT 'N' values recorded in the silty clay and clayey silt ranged from 12 to 29 blows per 0.3 m of penetration, indicating a stiff to very stiff consistency. In Borehole VMS-01, SPT 'N' values of 18 to 61 blows per 0.3 m of penetration were measured in these cohesive soils indicating a very stiff to hard consistency. Moisture contents measured in the cohesive soils ranged from 13 percent to 24 percent.

The results of grain size analyses conducted on samples of the silty clay to clayey silt are provided on the Record of Borehole sheets in Appendix A, and illustrated on Figure B2 of Appendix B. The results are summarized as follows:

Soil Particle	Silty clay / Clayey silt (Percent)
Gravel	0 to 2
Sand	8 to 13
Silt	52 to 64
Clay	22 to 38

The results of Atterberg Limits tests conducted on samples of the silty clay to clayey silt are presented on the Record of Borehole sheets in Appendix A, and illustrated in Figure B7 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	34 to 48
Plasticity Index	9 to 19

The results of the Atterberg Limits testing indicate that the silty clay to clayey silt have low to medium plasticity with group symbols of CL to CI.



5.4 Silt

Reddish brown silt containing trace gravel, trace to some sand and trace to some clay was contacted below the silty clay and clayey silt at 7.2 m, 1.5 m and 3.0 m depth in Boreholes VMS-01, VMS-02 and VMS-03, respectively. The thickness of the silt was 2.4 m and 4.0 m in Boreholes VMS-02 and VMS-03, respectively. Borehole VMS-01 was terminated within the silt layer at 8.2 m depth (Elevation 126.5). The depth to the base of the silt was at 3.9 m and 7.0 m (Elevations 155.9 and 180.3) in Boreholes VMS-02 and VMS-03, respectively.

In Boreholes VMS-02 and VMS-03, the silt is in a compact to dense condition based on typical SPT 'N' values ranging from 26 to 49 blows for 0.3 m of penetration. In Borehole VMS-01, an SPT 'N' value of 92 blows per 0.3 m of penetration, indicating a very dense state, was measured near Elevation 126.8. The natural moisture content of the silt ranged from 14 percent to 23 percent.

Selected silt samples were subjected to gradation testing, the results of which are summarized below. These results are also summarized on the Record of Borehole sheets included in Appendix A and the grain size distribution curves are presented on Figure B3 of Appendix B.

Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	1 to 11
Silt	87 to 98
Clay	0 to 11

The results of Atterberg Limits tests conducted on a sample of the silt are presented on the Record of Borehole sheets in Appendix A, and illustrated in Figure B8 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	26
Plasticity Index	4

The results of the Atterberg Limits testing indicate that the silt has slight plasticity with a group symbol of ML.



5.5 Silt Till

Reddish brown silt till containing some sand, some clay, trace gravel and occasional cobbles was contacted below the silty clay at 3.0 m depth in Borehole VMS-04. Resistance to augering inferred the presence cobbles and boulders below 3.9 m depth. The thickness of the silt till was 1.3 m. The depth to the base of the silt till was at 4.3 m (Elevation 183.0).

An SPT 'N' value of 35 blows per 0.3 m of penetration, indicating a dense state, was measured in the silt till. The natural moisture content in the silt till was 20 percent.

A sample of the silt till was subjected to gradation testing, the results of which are summarized below. These results are also summarized on the Record of Borehole sheets included in Appendix A and the grain size distribution curves are presented on Figure B4 of Appendix B.

Soil Particle	Percentage (%)
Gravel	2
Sand	14
Silt	74
Clay	10

The results of Atterberg Limits tests conducted on a sample of the silt till are presented on the Record of Borehole sheets in Appendix A, and illustrated in Figure B9 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	31
Plasticity Index	4

The results of the Atterberg Limits testing indicate that the silt till has slight plasticity with a group symbol of ML.

Glacial tills inherently contain cobbles and boulders.



5.6 Silty Sand Till

Native reddish brown silty sand till containing some gravel to gravelly, trace clay and occasional cobbles and boulders was contacted below the silt at 3.9 m depth in Borehole VMS-02. Resistance to augering inferred the presence cobbles and boulders below 3.9 m depth. The thickness of the silty sand till was 3.1 m. The depth to the base of the silty sand till was at 7.0 m (Elevation 152.8).

SPT 'N' value of 37 blows per 0.3 m of penetration and 100 blows for less than 0.3 m of penetration, indicating a dense to very dense condition, were measured in the silty sand till. The high 'N' value also indicated the possible presence of cobbles or boulders. The natural moisture contents in the silty sand till were 9 and 12 percent.

A sample of the silty sand till was subjected to gradation testing, the results of which are summarized below. These results are also summarized on the Record of Borehole sheets included in Appendix A and the grain size distribution curves are presented on Figure B5 of Appendix B.

Soil Particle	Percentage (%)
Gravel	29
Sand	40
Silt	28
Clay	3

Glacial tills inherently contain cobbles and boulders.

5.7 Bedrock

The soils described above were found to be underlain by bedrock which was encountered in Boreholes VMS-02 to VMS-04. The bedrock consisted of grey limestone with thin seams of shale typically less than 1 mm thick. In Borehole VMS-03, grey dolostone bedrock was contacted below the limestone. Both rock types were typically in a moderately to slightly weathered state, except in Borehole VMS-04 where the upper 0.5m was highly weathered, and in Borehole VMS-03 where there was a highly weathered zone just above termination depth. Rock core photos are presented in Appendix C.



Depth and elevations of the top of bedrock and sound bedrock encountered in the present investigation are shown in Table 5.1.

Table 5.1 – Depth and Elevation of Top of Bedrock

Borehole	Depth to Bedrock (m)	Top of Bedrock Elevation (m)	Top of Sound Bedrock (m)
VMS-02	7.0	152.8	152.8
VMS-03	7.0	180.3	180.3
VMS-04	4.3	183.0	182.0

For this project, sound bedrock refers to rock that is moderately to slightly weathered or fresh, good to excellent quality based on RQD values and no broken core (rubble) zones.

Bedrock cores were collected using NQ sized coring equipment. Core recovery, TCR, varied from 91 percent to 100 percent.

RQD values ranged from 66 to 95 indicating a fair to excellent rock quality. FI of the rock, expressed as fractures per 0.3 m of core, typically ranged from 0 to 4, and greater than 5 where the value corresponded to a rubble/broken zone in Run 2 of Borehole VMS-03 and Run 1 of Borehole VMS-04.

Unconfined compressive strengths interpreted from point load tests conducted on selected rock cores typically varied from 53 MPa to 218 MPa, indicating a medium strong to very strong rock. A point load test conducted on a rock core sample in Borehole VMS-02 was 38 MPa indicating a medium strong zone. Results of point load tests conducted on the rock core samples are included in Appendix B.

5.8 Groundwater Conditions

Groundwater conditions were observed during drilling operations. Groundwater levels were measured in the open boreholes upon completion of drilling and are summarized below.



Table 5.2 – Water Level Measurements

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
VMS-01	December 7, 2020	Dry	-	Open borehole
VMS-02	December 7, 2020	3.3	156.5	Open borehole
	December 8, 2020	4.9	154.9	
VMS-03	December 7, 2020	5.6	181.7	Open borehole
VMS-04	December 9, 2020	Dry	-	Open borehole

The groundwater levels above are short-term readings, and seasonal fluctuations of the groundwater levels are to be expected. The groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

6. MISCELLANEOUS

Thurber marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the boreholes, and obtained coordinates and ground surface elevations.

Walker Drilling of Utopia, Ontario supplied a track mounted drill rig and conducted the drilling, sampling and in-situ testing operations for the present investigation.

Full time supervision of the field activities was carried out by Mr. Amir Fereidouni of Thurber. Overall supervision of the field program was performed by Mr. Stephane Loranger, C.E.T. of Thurber.

Overall project management was provided by Dr. Sydney Pang, P.Eng. Interpretation of the field data and preparation of this report was completed by Ms. Rocío Palomeque Reyna, P.Eng. The report was reviewed by Dr. Sydney Pang, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



THURBER ENGINEERING LTD.



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This part of the report presents foundation recommendations for the design of the four proposed Queue and Stopped Vehicle Advisory System (QSVAS) sign locations along Highway 405 from approximately 50 m west of Concession 6 Road to 1.1 km east of Stanley Avenue in Niagara Falls, Ontario.

The QSVAS includes four Variable Message Signs (VMS) to be installed on Highway 405 EBL to display messages that will provide warning to the motorists about approaching queues and/or stopped vehicles leading to the Queenston-Lewiston Bridge.

The proposed VMS's will consist of single support structures (pole mounted) founded on concrete footings (caissons) at the following locations:

Borehole	VMS	Approximate Station along Highway 405
VMS-01	VMS #1	11+889
VMS-02	VMS #2	13+972
VMS-03	VMS #3	16+333
VMS-04	VMS #4	17+112

This foundation investigation and design report with the interpretation and



recommendations are intended for the use of the Ministry of Transportation and LEA, and shall not be used or relied upon for any other purposes or by any other parties including the construction contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the proposed locations of the signs was provided to Thurber by LEA. The Record of Borehole sheets are presented in Appendix A. Table 1 immediately following the text of this report presents a simplified subsurface stratigraphy and the recommended foundation parameters for the design of the VMS foundations.

It is important to note that the boreholes advanced near VMS #2, VMS #3 and VMS #4 encountered bedrock within the investigated depth. Depending on the required founding depths, the design of some or all three of these signs may be governed by the depth of bedrock as discussed below. Although not encountered within the borehole depth of 8.2m, bedrock may be also encountered at the location of VMS #1 depending on the depth of caisson foundation and variation of bedrock surface.

7.1 Foundation Design Parameters

Design of the sign support foundations should be carried out in accordance with the following document:

- Ministry of Transportation, Ontario (2019) "Sign Support Manual", Highway Standards Branch, Bridge Office (Reference 4).

Reference should also be made to the following documents:

- Ministry of Transportation, Ontario (2004) "Guidelines for the Design of High Mast Pole Foundations", Fourth Edition, BRO-009, Engineering Standards Branch, Bridge Office (Reference 5).
- Canadian Highway Bridge Design Code and Commentary (2019). (Reference 6).



It is recommended that MTO's standard drawings for the appropriate sign type/class and other relevant foundation design recommendations in Reference 4 be used as a basis for the sign support design. The foundation design parameters in Table 1 may be used in conjunction with Reference 5 to confirm that the standard design is adequate.

In order to take into account frost action and surficial disturbance, the ultimate lateral passive resistance in front of a caisson within the upper 1.2 m below final grade should be neglected in foundation design. It is recommended that all topsoil and organics be neglected in determining lateral resistance.

According to the Drawings SS118-3 and SS118-11 in the Ministry of Transportation, Ontario (2019) "Sign Support Manual" (Reference 4), the standard caisson length for pole mounted VMS range from 5.0 to 6.5 m (depending on sign class) below the frost penetration depth. A Note to Designer on SS118-3 also indicates to the effect that if sound rock is encountered at a depth, Y, that is less than the standard caisson length L below the frost layer (1.2 m), the actual caisson length may be reduced according to the formula shown in the note upon Ministry's approval.

For VMS #2 and VMS #3, bedrock was encountered at 5.8 m (7.0 - 1.2) below frost depth. For VMS #4 and not considering the upper 0.5 m of highly weathered rock, bedrock was encountered at 3.6 m (4.3 + 0.5 - 1.2) below frost depth. Depending on the required caisson depth, it is possible that the caisson for VMS #2 and VMS #3 may be formed directly on the bedrock surface. The caisson for VMS #4 is likely required to be socketted within sound bedrock.

It is noted for the purpose of this project that sound bedrock is as defined in Part 1, Section 5.7 and Table 5.1.

It is recommended that the designers confirm the required caisson depth on a case by case basis and discuss with the Ministry on the final caisson depth, from which the depth of bedrock coring may be established.

It is anticipated that the caisson support for VMS #1 would be formed within soils.

Where downward sloping fill or native soil exists in front of a caisson, reduction of lateral passive resistance should be taken into consideration during design. For foundation



design of the caissons, it should be assumed that full lateral resistance can only be mobilized where the width of the soil in front of or behind the caisson is equal to or greater than approximately four (4) times the diameter of the caissons. For sloping ground in front of a caisson, the magnitude of the mobilized passive resistance can be estimated by interpolating between zero passive resistance at the level where the slope face intersects the pile, and full passive resistance at the level where the slope face is at a horizontal distance equal to or greater than four (4) times the diameter of the caisson.

When designing for portions of the caissons below the groundwater level in cohesionless sands and silts, the submerged soil unit weight, γ' , should be used. The required depth of the caisson will be governed by lateral loads, including wind loads, acting on the sign. The length of the caisson should also be sufficient to counteract frost jacking (upward) forces. For weathered bedrock containing multiple fractures, parameters pertaining to frictional materials have been provided for foundation design.

An equivalent caisson width equal to two (2) times the caisson diameter may be assumed for lateral resistance calculations. Appropriate load and resistance factors should be applied for caisson design.

7.2 Caisson Installation

Caisson installation should generally be carried out in accordance with OPSS.PROV 903.

The contract documents should contain an NSSP alerting the contract bidders of the specific aspects relating to caisson construction for VMS foundation supports at this site. Suggested wordings for this NSSP are provided in Appendix E.

Cobbles, boulders and other obstructions are present in the glacial tills and fill. Caisson installation equipment must be able to dislodge, handle and remove cobbles and boulders, to penetrate obstructions within the fill and to drill through the dense to very dense cohesionless till, where encountered. This equipment should also be capable of coring through the very strong limestone/dolostone bedrock to form the rock socket and reach the design caisson base.

It must be noted that the depth to the top of limestone bedrock may be variable across the site and may be encountered at a higher elevation than that shown in the borehole logs.



Contractor's caisson installation equipment must be capable of drilling/coring through the bedrock to the design depth of the caisson.

Groundwater was observed in very short term in the open boreholes at depths ranging from 3.3 m to 5.6 m below existing ground surface, but local shallower groundwater levels should be expected. Soil sloughing and water seepage will occur in unsupported holes especially in sands and silts below the groundwater level. Temporary liners must be available to support the caisson sidewalls and to provide partial seepage cut-off where required. Any accumulated water may have to be pumped out from the hole prior to placing concrete. All rock socket sidewalls and bases should be cleaned of loose rock fragments and debris prior to concreting. Should it be considered impractical to remove the accumulated water inside the hole, it is recommended that the concrete be placed by the pumped tremie method.

7.3 Construction Concerns

Concerns during caisson construction mainly involve the handling and removal of cobbles or boulders, or other obstructions in the fill, drilling through very dense soils, soil sloughing and water seepage from caisson sidewalls, basal instability and rock coring through the limestone/dolostone bedrock. Recommendations on how to address these issues have been outlined in the previous section.

7.4 Construction Inspection and Testing

Caisson construction should be monitored by qualified geotechnical personnel as per OPSS.PROV 903 to verify the soil and bedrock conditions and to confirm that those conditions are consistent with the design assumptions in this report.



THURBER ENGINEERING LTD.



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TABLE 1
FOUNDATION DESIGN PARAMETERS
VARIABLE MESSAGE SIGN (VMS) SUPPORTS
HIGHWAY 405, NIAGARA FALLS, ONTARIO

VMS Locations	Reference Borehole	Reference Simplified Subsurface Stratigraphy For Design	Depth Below Existing Ground Surface (m)	Foundation Design Parameters						
				q_u (kPa)	ϕ' (deg.)	n_h (MN/m ³)	K_p	γ (kN/m ³)	γ' (kN/m ³)	Design Groundwater Depth (m)
VMS #1 11+889	VMS-01	Very Stiff Silty Clay (Fill)	1.2 – 1.5	100	-	-	-	20	-	3
		Very stiff to hard	1.5 – 7.2	350	-	-	-	20	-	
		Silty Clay/Clayey Silt								
		Very dense Silt	7.2 – 8.2	-	32	4.0	3.2	20	10	
VMS #2 13+972	VMS-02	Very stiff Clayey Silt	1.2 – 1.5	300	-	-	-	19	-	3
		Dense to compact Silt	1.5 – 3.9	-	32	4.0	3.2	20	10	
		Dense to very dense	3.9 – 7.0	-	34	6.0	3.5	21	11	
		Silty Sand Till								
		Limestone (weathered)	7.0 – 7.5	-	42	17.0	5.0	23	-	
		Limestone (rigid base)	Below 7.5	-	-	-	-	-	-	
VMS #3 16+333	VMS-03	Compact Silty Sand (Fill)	1.2 – 1.5	-	30	3.0	3.0	20	-	5
		Stiff Silty Clay (Fill)	1.5 – 2.3	100	-	-	-	19	-	
		Stiff Silty Clay	2.3 – 3.0	150	-	-	-	18	-	
		Compact to Dense Silt	3.0 – 7.0	-	32	4.0	3.2	21	11	
		Limestone (weathered)	7.0 – 7.5	-	42	17.0	5.0	23	-	
		Limestone (rigid base)	Below 7.5	-	-	-	-	-	-	
VMS #4 17+112	VMS-04	Stiff Silty Clay (Fill)	1.2 – 2.3	100	-	-	-	19	-	5
		Stiff Silty Clay	2.3 – 3.0	150	-	-	-	18	-	
		Dense Silt Till	3.0 – 4.3	-	33	5.0	3.4	21	11	
		Limestone (weathered)	4.3 – 4.8	-	42	17.0	5.0	23	-	
		Limestone (rigid base)	Below 4.8	Note 4						
All signs	-	New Fill – SSM (see Note 3)	Variable height above ground surface	-	30	3.0	3.0	20	-	Below base of new fill

Notes:

1. This table must be read in conjunction with the text of this report.
2. In order to take into account frost action and surficial disturbance, the ultimate lateral passive resistance in front of the caisson within the upper 1.2 m below final grade should be neglected in the foundation design.
3. If new fill is placed, some caissons may be partially embedded within the new fill.
4. If detailed analysis is deemed necessary, a coefficient of horizontal subgrade reaction for intact limestone can be provided upon request.

LEGEND

q_u	=	Unconfined Compressive Strength ($= 2 \times C_u$, undrained shear strength) (kPa)
ϕ'	=	Angle of Internal Friction (degrees)
n_h	=	Coefficient related to soil density (MN/m^3 or $\times 10^3 \text{ kN/m}^3$)
K_p	=	Coefficient of Passive Earth Pressure
γ	=	Soil Unit Weight (kN/m^3)
γ'	=	Submerged Soil Unit Weight (kN/m^3) – to be used only for cohesionless soils below the groundwater table



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$


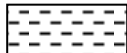



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
<u>TERMS</u>		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.				
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No VMS-01

1 OF 1

METRIC

GWP# 2171-19-00 LOCATION VMS #1, MTM NAD83-10 N 4 779 310.8 E 334 514.0 ORIGINATED BY AF
DIST HWY 405 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2020.12.07 - 2020.12.07 LATITUDE 43.153060 LONGITUDE -79.134650 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						PLASTIC LIMIT w _p NATURAL MOISTURE CONTENT w LIQUID LIMIT w _L								
134.7	GROUND SURFACE							20	40	60	80	100										
0.0	ASPHALT: (175mm)							20	40	60	80	100										
0.2	SAND, some gravel, trace silt Brown Moist (FILL)		1	GS			134															
133.9																						
0.8	Silty CLAY, trace sand, trace gravel Very Stiff Brown Moist (FILL)		2	SS	19																	
133.2																						
1.5	Silty CLAY, trace sand, occasional grey silt seams Hard to Very Stiff Brown Moist		3	SS	42		133											0	8	54	38	
			4	SS	28		132															
			5	SS	61																	
							131															
			6	SS	18		130															
129.1							129															
5.6	Clayey SILT, some sand, trace gravel Very Stiff Brown Moist		7	SS	28														1	13	64	22
							128															
127.5																						
7.2	SILT, some clay, trace sand Very Dense Reddish Brown Moist						127															
			8	SS	92														0	2	87	11
126.5																						
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.																					

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No VMS-02

1 OF 2

METRIC

GWP# 2171-19-00 LOCATION VMS #2, MTM NAD83-10 N 4 778 840.8 E 336 509.6 ORIGINATED BY AF
DIST HWY 405 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2020.12.07 - 2020.12.08 LATITUDE 43.148748 LONGITUDE -79.110141 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)		
								20 40 60 80 100						PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		
159.8	GROUND SURFACE															
0.0	SAND and GRAVEL , trace silt Brown Moist (FILL)		1	GS												
159.0																
0.8	Clayey SILT , trace sand Very Stiff Reddish Brown Moist		2	SS	29											
158.3																
1.5	SILT , some sand, trace gravel Dense to Compact Reddish Brown Moist		3	SS	49											
			4	SS	26								1 11 88 0			
			5	SS	40											
155.9																
3.9	Silty SAND , some gravel to gravelly, trace clay, occasional cobbles and boulders Dense Reddish Brown Wet (TILL) Auger grinding from 3.9m to 4.6m Auger grinding from 5.8m to 5.9m Cobbles and boulders Very Dense Spoon bouncing Coring started at 7.0m		6	SS	37								29 40 28 3			
			7	SS	100/ 0.075											
152.8																
7.0	LIMESTONE , moderately to slightly weathered, grey, with thin seams of shale (less than 1 mm thick), laminated, horizontally bedded Horizontal fractures at 7.1m, 7.2m, 7.3m, 7.5m, 7.7m, 7.8m, 7.9m, 8.1m and 8.2m Clay seams (25mm) at 7.2m and 7.9m Horizontal fractures at 8.9m, 9.1m, 9.2m, 9.4m, 9.7m and 9.9m		1	RUN									RUN #1 TCR=91% SCR=91% RQD=78% UCS=167MPa (Average)			

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No VMS-02

2 OF 2

METRIC

GWP# 2171-19-00 LOCATION VMS #2, MTM NAD83-10 N 4 778 840.8 E 336 509.6 ORIGINATED BY AF
 DIST HWY 405 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2020.12.07 - 2020.12.08 LATITUDE 43.148748 LONGITUDE -79.110141 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W P W W L				WATER CONTENT (%)	GR	SA	SI	CL
								20	40	60	80	100	20						
10.0	Continued From Previous Page END OF BOREHOLE AT 10.0m. WATER LEVEL AT 3.3m UPON COMPLETION OF SOIL DRILLING ON DEC. 7, 2020. WATER LEVEL AT 4.9m ON DEC. 8, 2020. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.																		

ONTMT4S2 MTO-29302.GPJ 2017TEMPLATE(MTO).GDT 2/3/21

METRIC

GWP#	2171-19-00	LOCATION	VMS #3, MTM NAD83-10 N 4 778 910.5 E 338 621.2			ORIGINATED BY	AF
DIST	HWY 405	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring			COMPILED BY	AN
DATUM	Geodetic	DATE	2020.12.08 - 2020.12.08	LATITUDE	43.149284	LONGITUDE	-79.084175
		CHECKED BY	RPR				

[illegible]

+³, ×³: Numbers refer to Sensitivity

CONTMT4S2 MTO-29302.GPJ 2017TEMPLATE(MTO).GDT 2/3/21

RECORD OF BOREHOLE No VMS-03

2 OF 2

METRIC

GWP# 2171-19-00 LOCATION VMS #3, MTM NAD83-10 N 4 778 910.5 E 338 621.2 ORIGINATED BY AF
 DIST HWY 405 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2020.12.08 - 2020.12.08 LATITUDE 43.149284 LONGITUDE -79.084175 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
10.0	END OF BOREHOLE AT 10.0m. WATER LEVEL AT 5.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.																

ONTMT4S2 MTO-29302.GPJ 2017TEMPLATE(MTO).GDT 2/3/21

RECORD OF BOREHOLE No VMS-04

1 OF 1

METRIC

GWP# 2171-19-00 LOCATION VMS #4, MTM NAD83-10 N 4 779 252.1 E 339 318.5 ORIGINATED BY AF
DIST HWY 405 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2020.12.09 - 2020.12.09 LATITUDE 43.152328 LONGITUDE -79.075581 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
187.3	GROUND SURFACE												
0.0	ASPHALT: (150mm)												
0.2	SAND, some gravel, trace silt Brown Moist (FILL)		1	GS			187						
186.5													
0.8	Silty CLAY, trace sand, trace gravel, occasional rootlets Stiff Dark Brown to Brown Moist (FILL)		2	SS	11		186						
			3	SS	12								0 10 63 27
185.0													
2.3	Silty CLAY, trace sand, trace gravel, occasional silt seams Stiff Reddish Brown Moist		4	SS	14		185						
184.3													
3.0	SILT, some sand, some clay, trace gravel, occasional cobbles Dense Reddish Brown Moist (TILL) Auger grinding from 3.9m to 4.3m Spoon bouncing Coring started at 4.3m		5	SS	35		184						2 14 74 10
183.0													
4.3	LIMESTONE, highly weathered, grey, with thin seams of shale (less than 1 mm thick), laminated, horizontally bedded Moderately weathered Rubble zone from 4.3m to 4.5m Horizontal fractures at 4.5m, 4.8m, 5.1m, 5.2m, 5.3m, 5.4m, 5.5m, 5.7m and 5.8m Vugs observed from 6.2m to 7.2m Horizontal fractures at 5.9m, 6.2m, 6.3m, 6.5m, 6.6m, 6.8m, 6.9m, 7.0m and 7.2m Quartz/gypsum inclusion from 6.8m to 6.9m		1	RUN			183					FI >>5 2 3	RUN #1 TCR=100% SCR=92% RQD=66% UCS=125MPa (Average)
							182					3	
												2	
							181					2	RUN #2 TCR=100% SCR=90% RQD=90% UCS=124MPa (Average)
			2	RUN								3	
												2	
179.9							180					1	
7.4	END OF BOREHOLE AT 7.4m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.												

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE



Appendix B

Geotechnical Laboratory Test Results

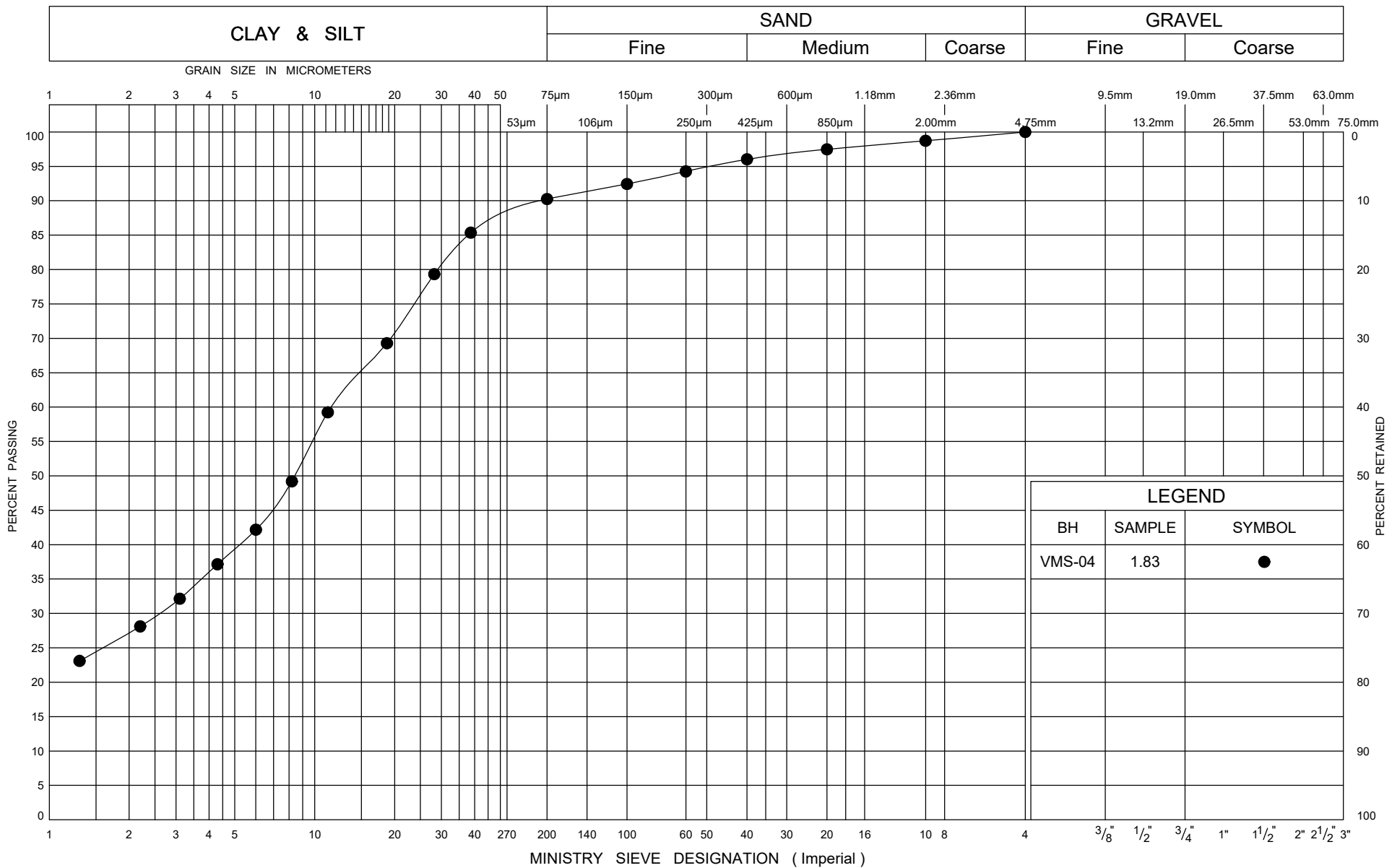
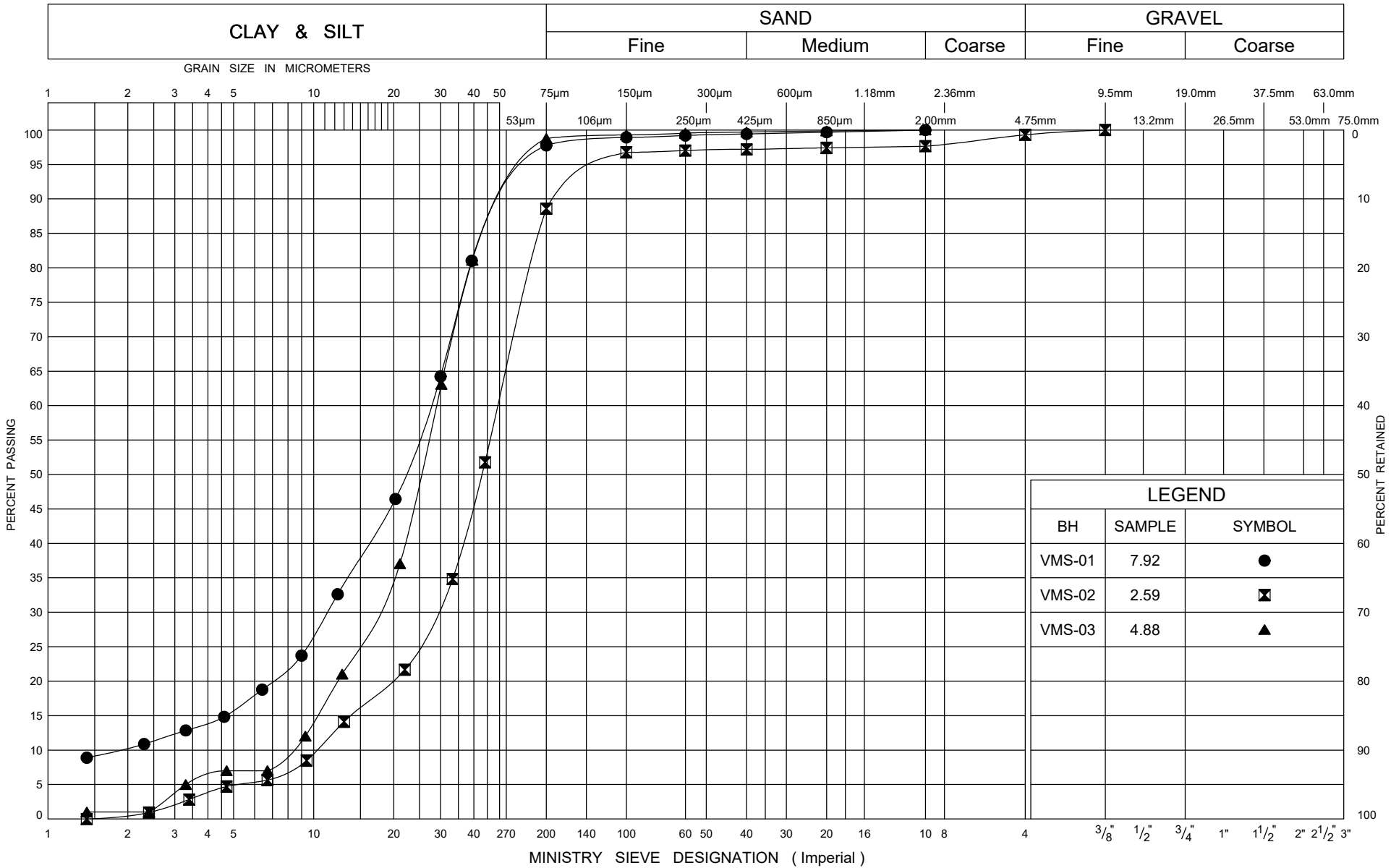
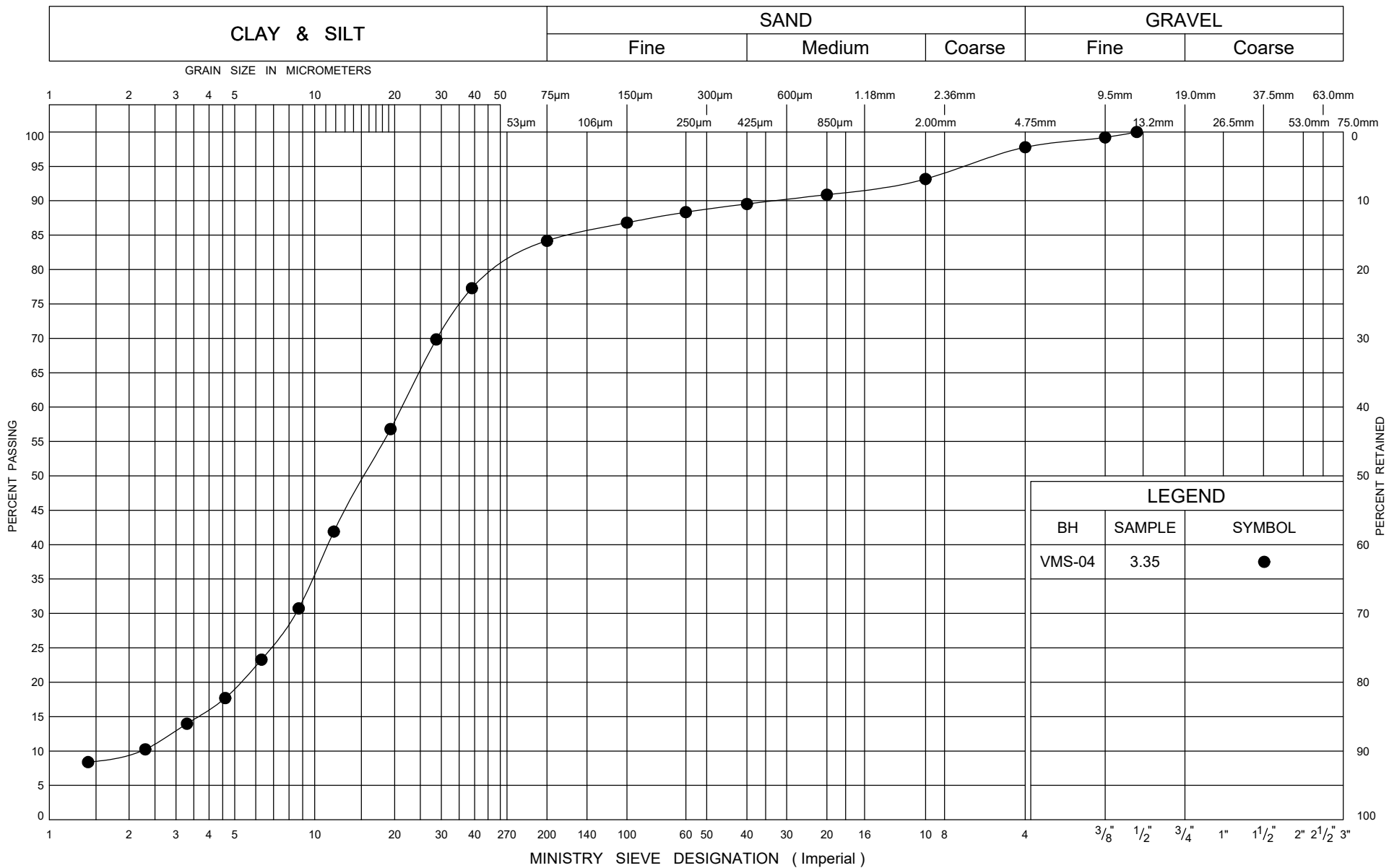


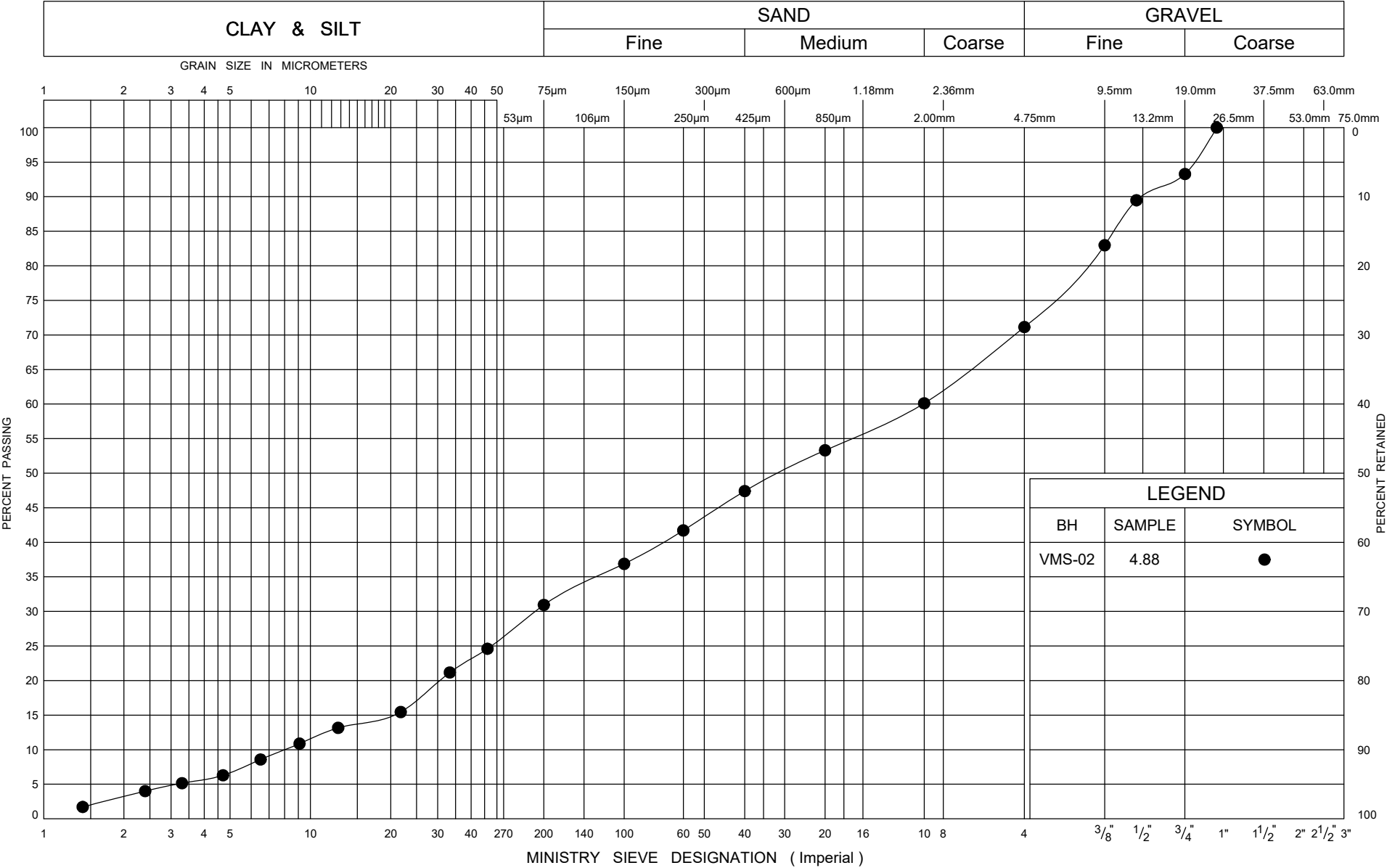


FIG No B2

G W P 2171-19-00

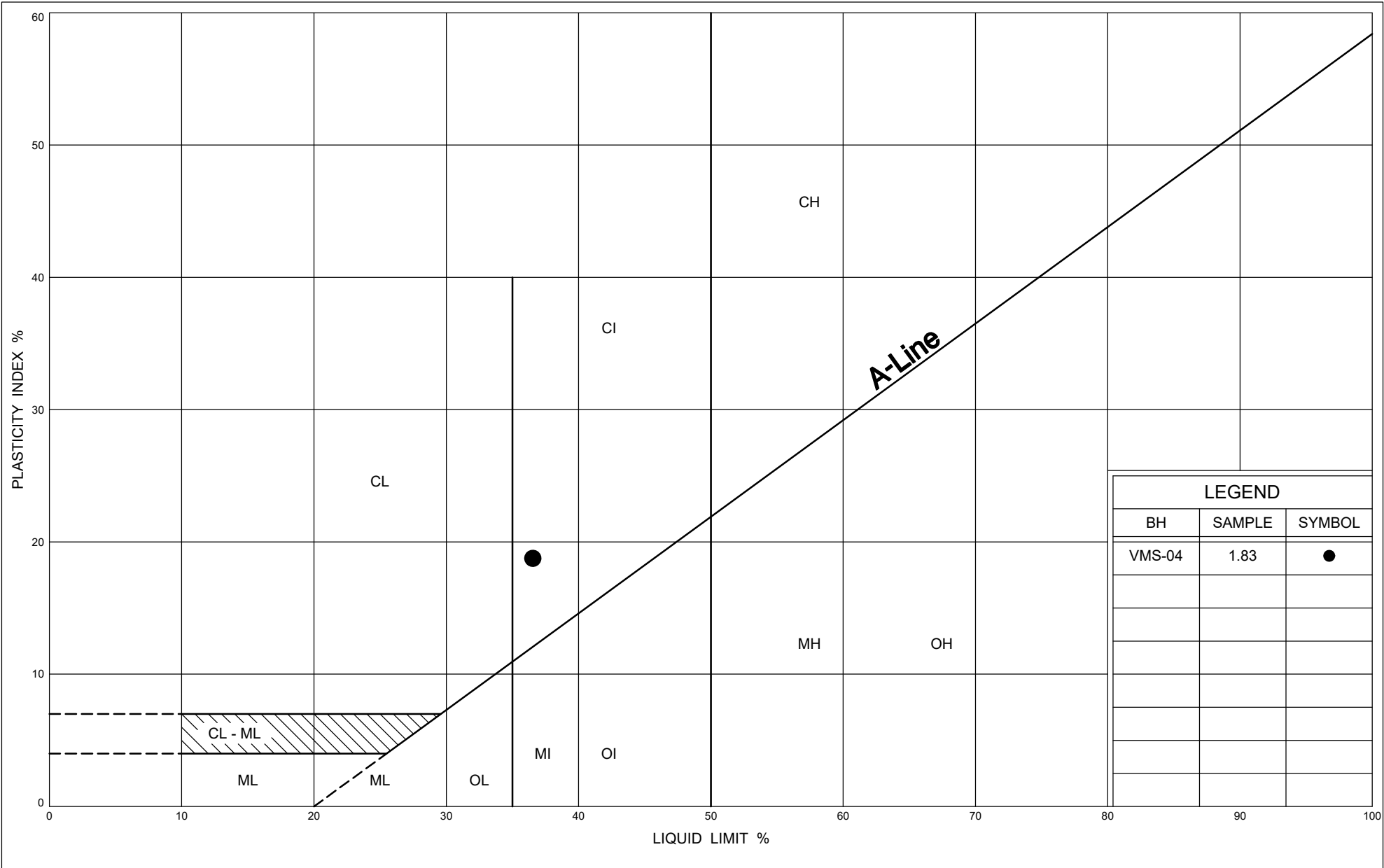




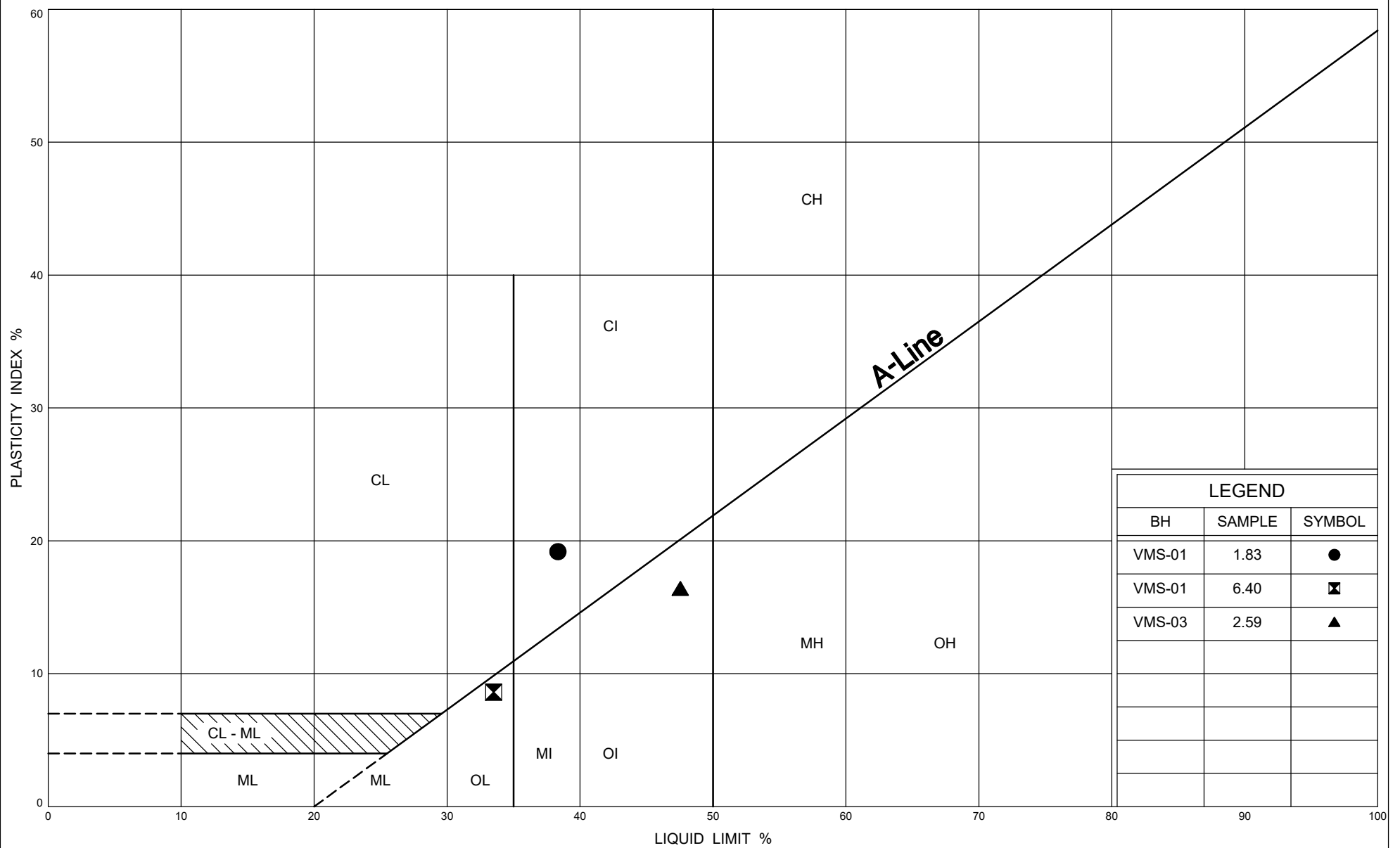


GRAIN SIZE DISTRIBUTION
Silty SAND TILL

FIG No B5
G W P 2171-19-00



LEGEND		
BH	SAMPLE	SYMBOL
VMS-04	1.83	●



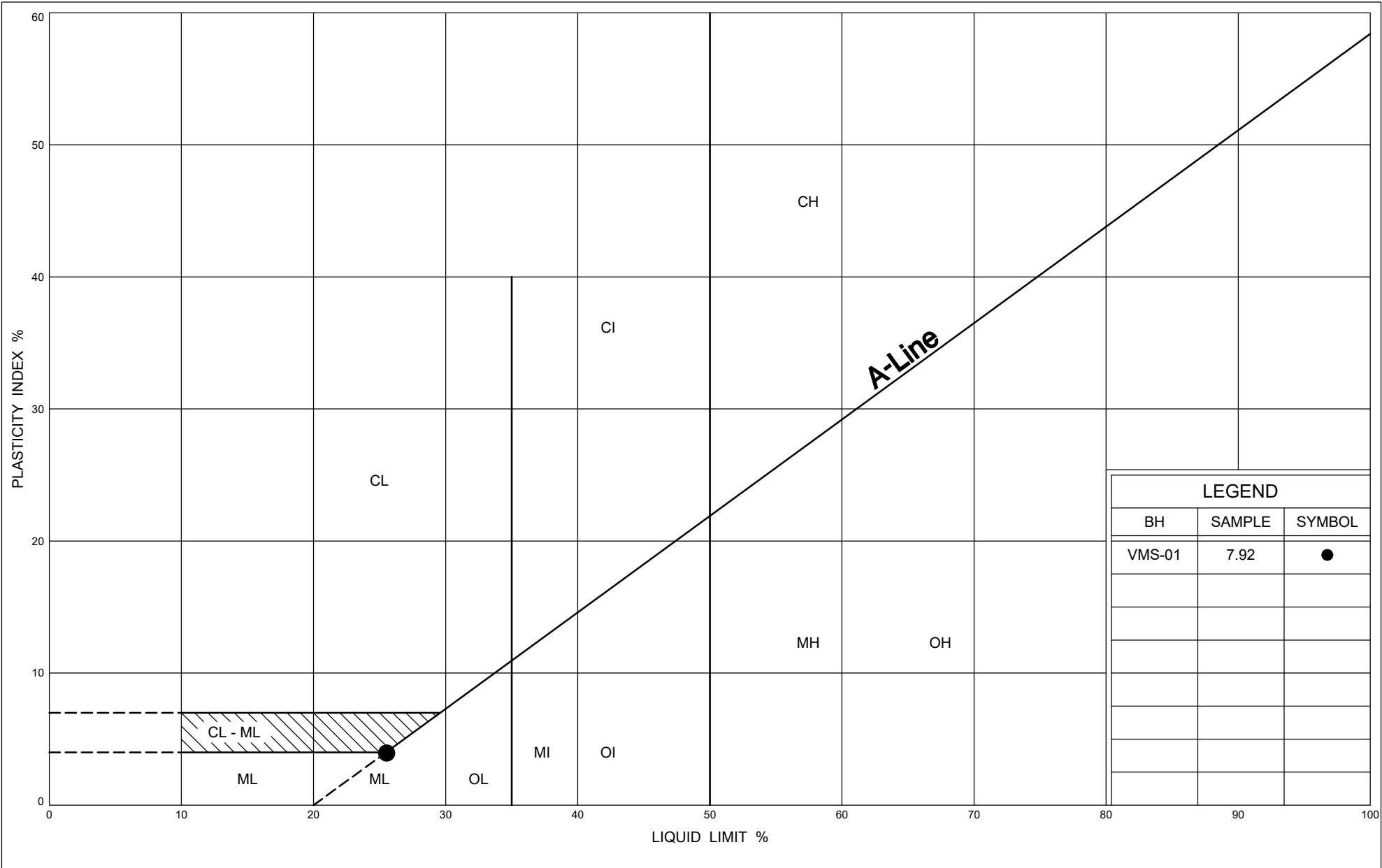
Ministry of
Transportation

PLASTICITY CHART

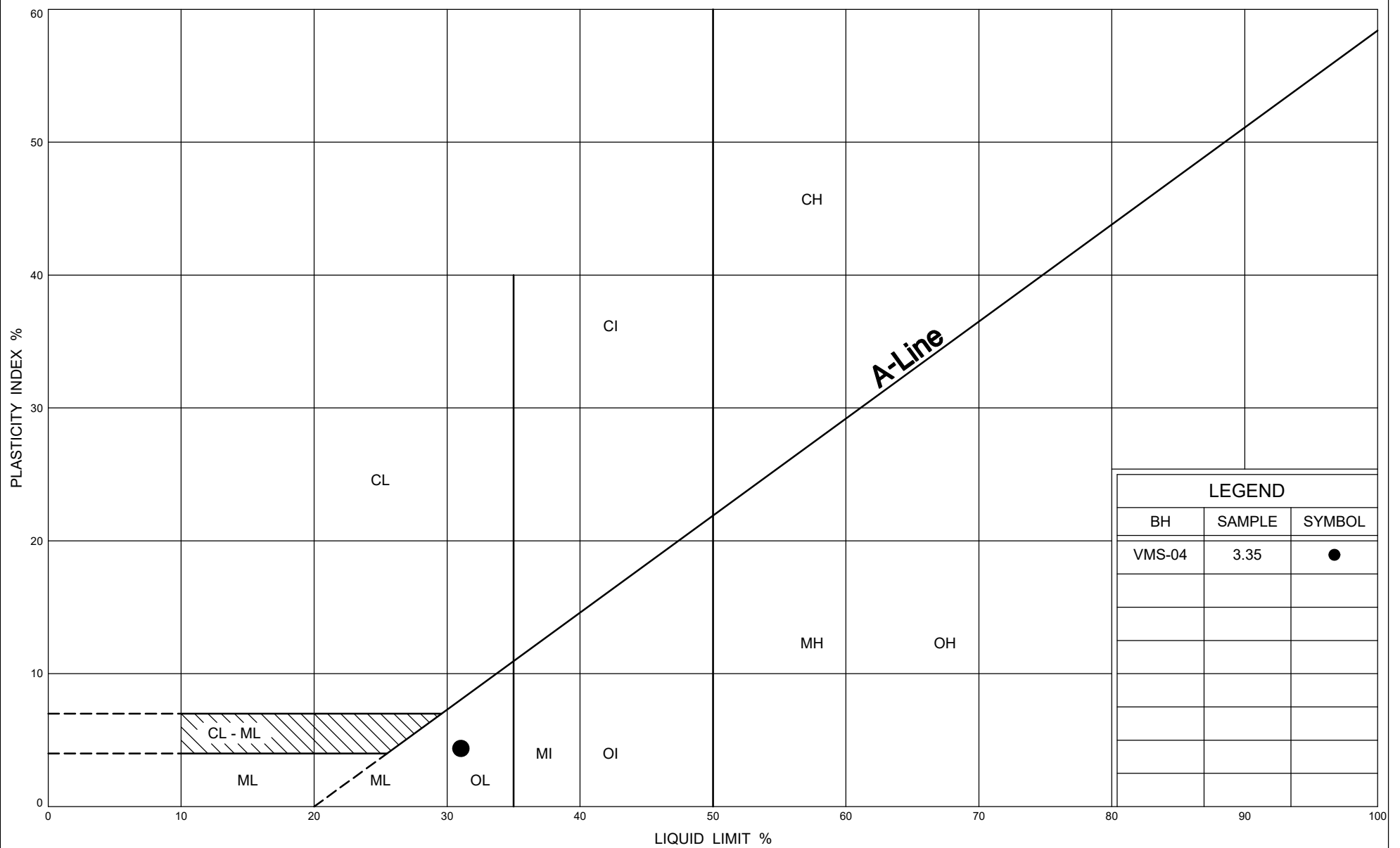
Silty CLAY to Clayey SILT

FIG No B7

G W P 2171-19-00



LEGEND		
BH	SAMPLE	SYMBOL
VMS-01	7.92	●





ASTM D5731-08

Date Drilled: Dec 09/2020

Date Tested: Dec 10/2020

Tester: MV

Reviewed by: _____

- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
- Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.

Last Modified: September 14, 2016

**THURBER ENGINEERING LTD.****POINT LOAD TEST SHEET****ASTM D5731-08**

Job No: 29302
Client:
Project Name: Hwy 405
Core Size: NQ **BH No :** VMS-3

Date Drilled: Dec 09/2020
Date Tested: Dec 10/2020
Tester: MV
Reviewed by:

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	7.1	D	8.8	45.0	146.0	3.9	93.8	Limestone	Strong
2	1	7.3	A	20.9	45.9	66.2	5.6	135.4	Limestone	Very Strong
3	1	7.7	A	23.7	46.3	62.0	6.7	161.0	Limestone	Very Strong
4	1	8.1	D	12.3	46.2	150.0	5.3	126.0	Limestone	Very Strong
5	2	9.0	A	13.3	46.6	64.0	3.6	87.3	Dolostone	Strong
6	2	9.4	D	8.0	45.9	168.0	3.5	83.1	Dolostone	Strong
7	2	9.6	A	11.8	46.3	68.0	3.1	74.3	Dolostone	Strong
8	2	9.7	D	6.2	46.1	127.0	2.7	63.7	Dolostone	Strong

- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
- Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.

Last Modified: September 14, 2016

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 29302

Client: _____

Project Name: Hwy 405

Core Size: NQ **BH No :** VMS-4

Date Drilled: Dec 09/2020

Date Tested: Dec 10/2020

Tester: MV

Reviewed by: _____

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24.

Last Modified: September 14, 2016



Appendix C

Rock Core Photos

PHOTOGRAPHS OF ROCK CORES

BOREHOLE VMS-2
RUNS 1 AND 2

TOP



Run 1

Run 2

BOTTOM

Run #	Depth (m)
1	7.0 – 8.5
2	8.5 – 10.0

PHOTOGRAPHS OF ROCK CORES

**BOREHOLE VMS-2
RUNS 1 AND 2**

Run 1

Run 2



PHOTOGRAPHS OF ROCK CORES

**BOREHOLE VMS-2
RUNS 1 AND 2**

Run 1

Run 2



PHOTOGRAPHS OF ROCK CORES

**BOREHOLE VMS-2
RUNS 1 AND 2**

Run 1

Run 2



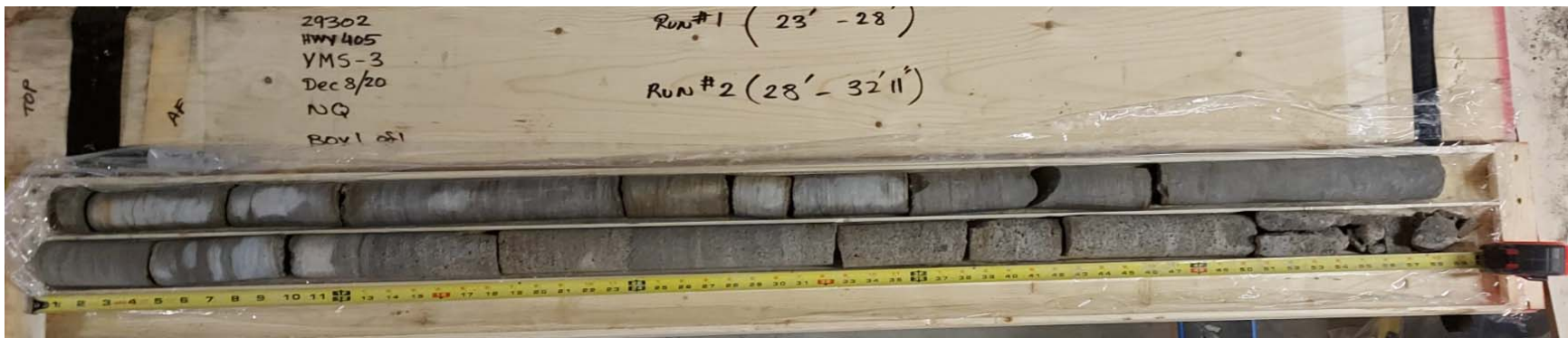
PHOTOGRAPHS OF ROCK CORES

BOREHOLE VMS-3 RUNS 1 AND 2

TOP

Run 1

Run 2



BOTTOM

Run #	Depth (m)
1	7.0 – 8.5
2	8.5 – 10.0

PHOTOGRAPHS OF ROCK CORES

**BOREHOLE VMS-3
RUNS 1 AND 2**

Run 1

Run 2



PHOTOGRAPHS OF ROCK CORES

BOREHOLE VMS-3
RUNS 1 AND 2

Run 1



Run 2



Run 1



Run 2



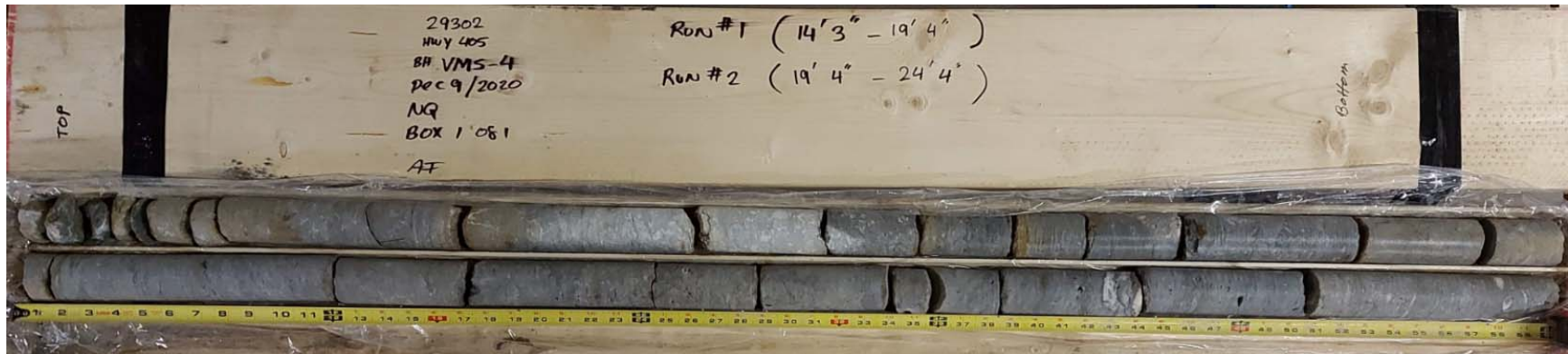
PHOTOGRAPHS OF ROCK CORES

BOREHOLE VMS-4 RUNS 1 AND 2

TOP

Run 1

Run 2



BOTTOM

Run #	Depth (m)
1	4.3 – 5.9
2	5.9 – 7.4

PHOTOGRAPHS OF ROCK CORES

BOREHOLE VMS-4
RUNS 1 AND 2

Run 1

Run 2



Run 1

Run 2



PHOTOGRAPHS OF ROCK CORES

**BOREHOLE VMS-4
RUNS 1 AND 2**

Run 1

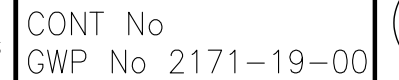
Run 2



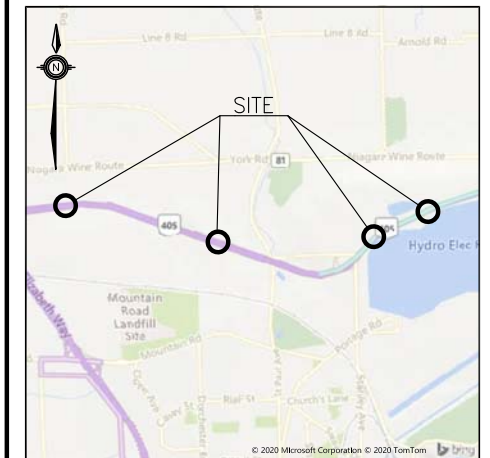


Appendix D

Borehole Location Plan








SHEET



KEYPLAN

LEGEND

	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

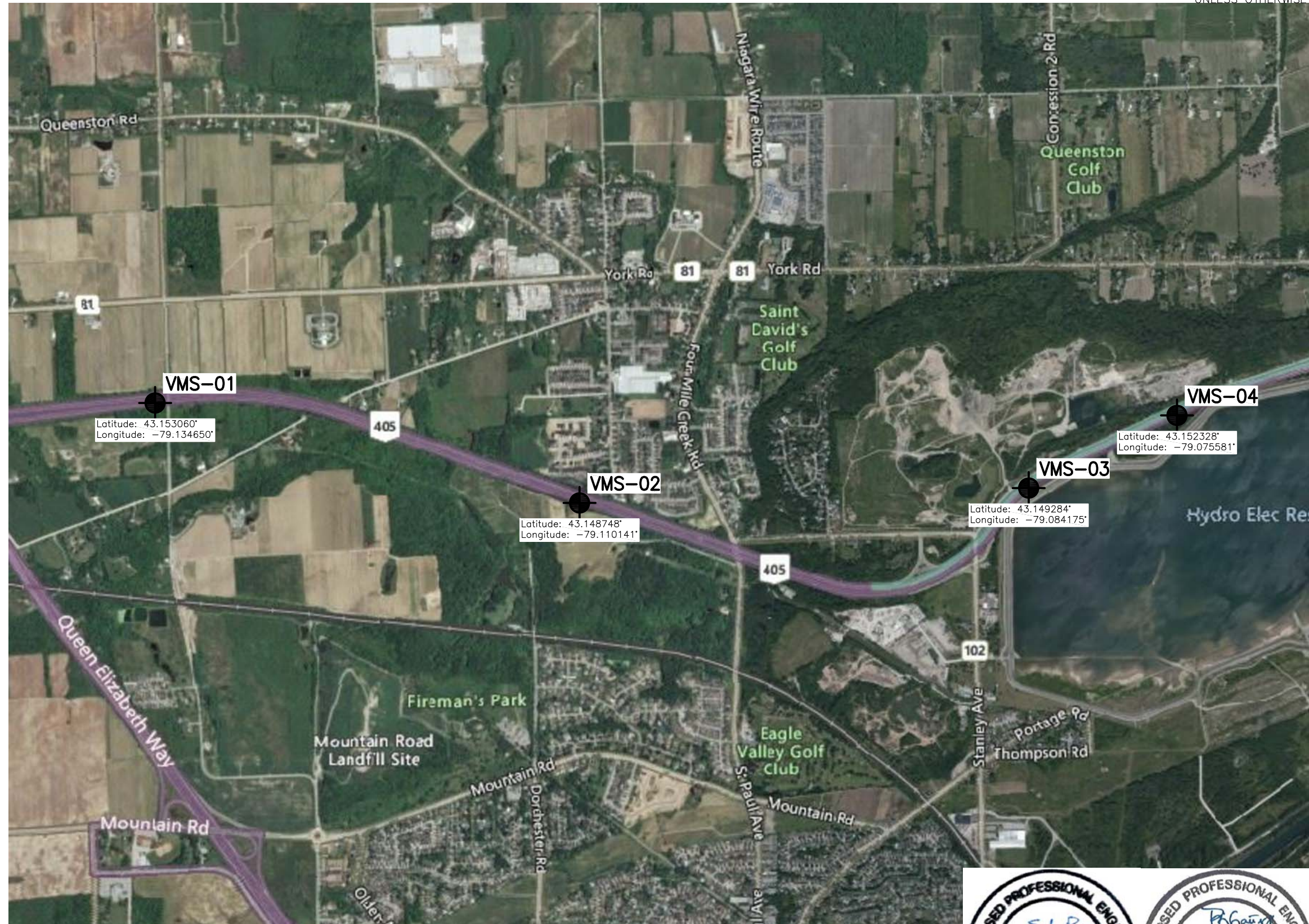
NO	ELEVATION	NORTHING	EASTING
VMS-01	134.7	4 779 310.8	334 514.0
VMS-02	159.8	4 778 840.8	336 509.6
VMS-03	187.3	4 778 910.5	338 621.2
VMS-04	187.3	4 779 252.1	339 318.5

-NOTES-

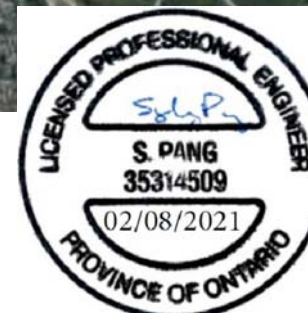
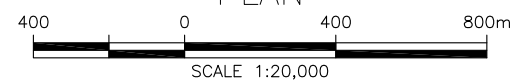
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 10.

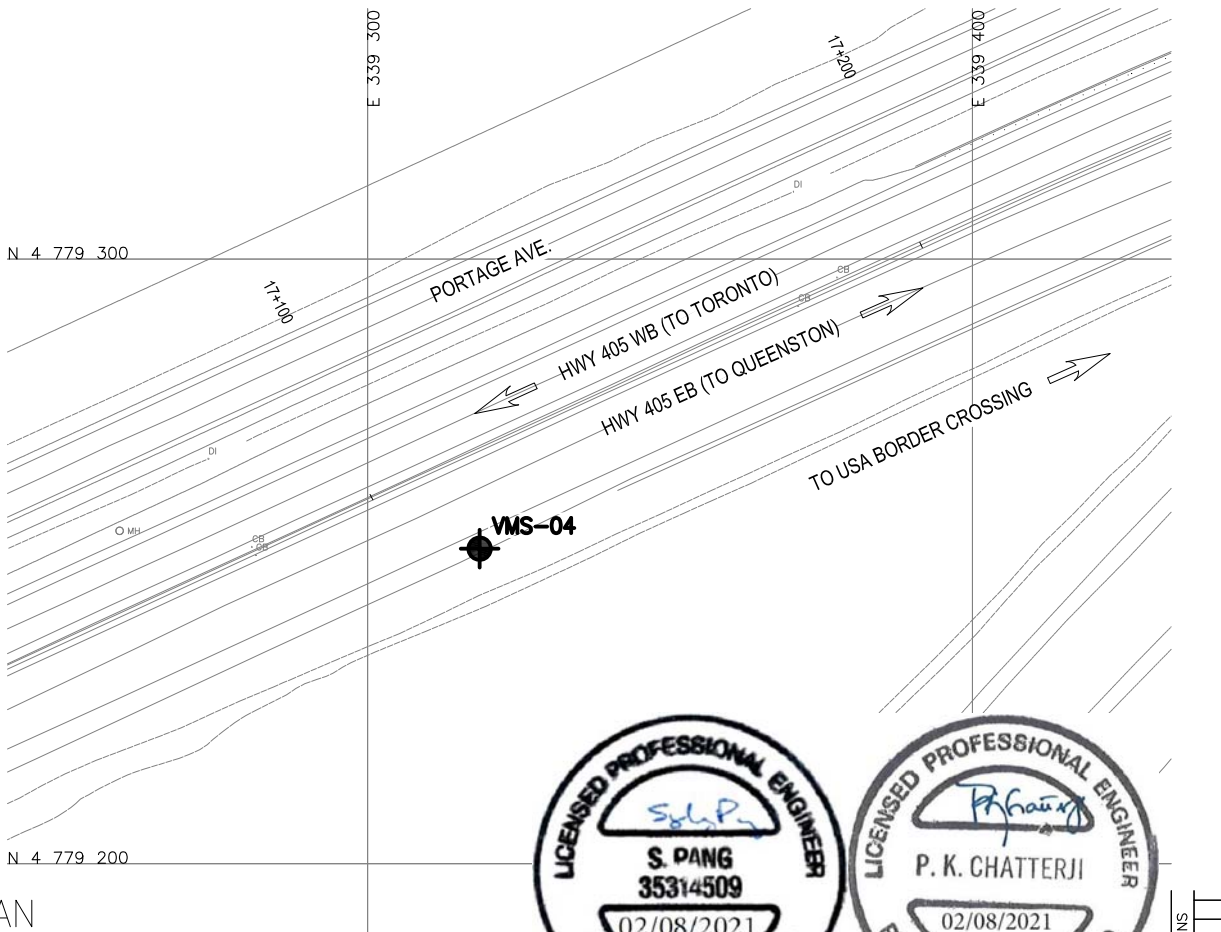
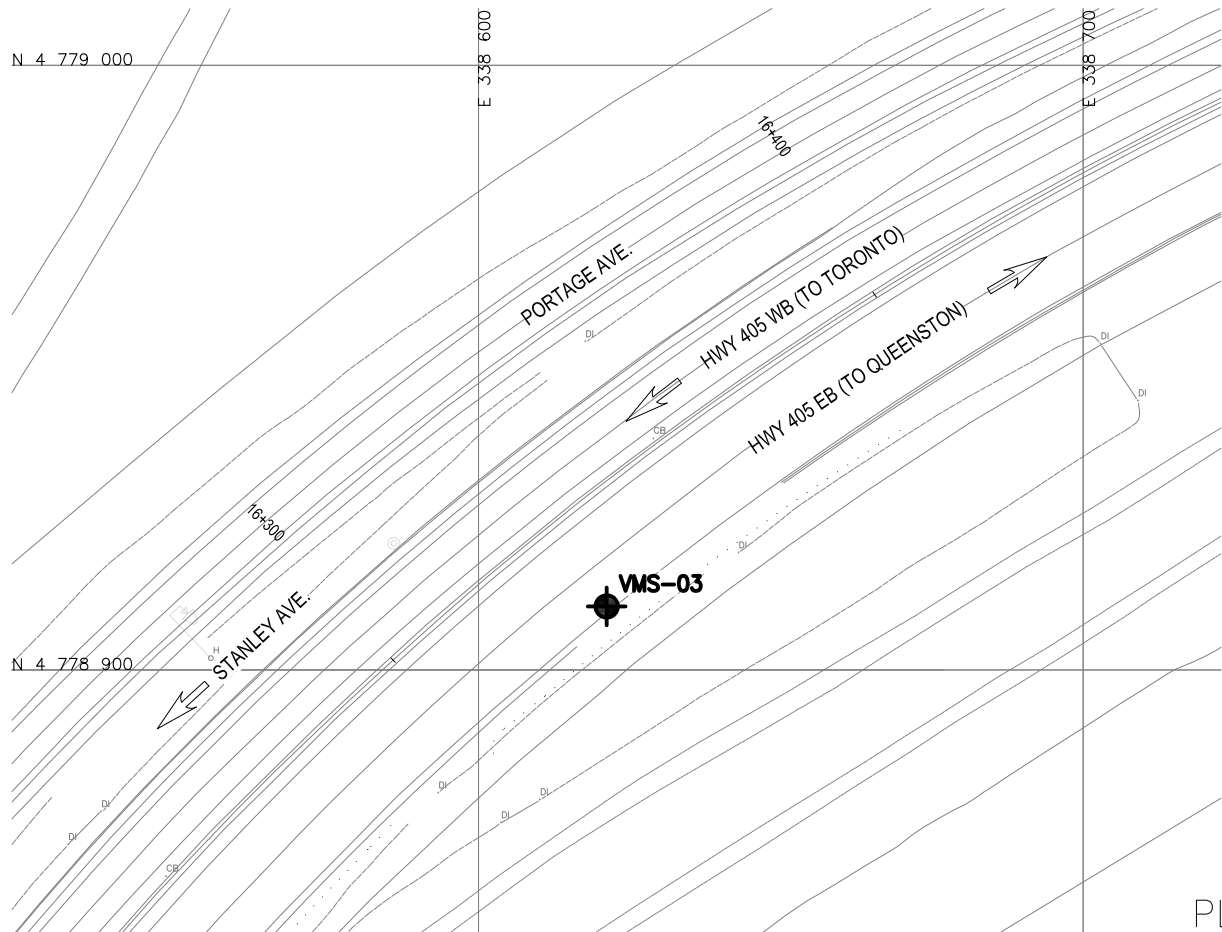
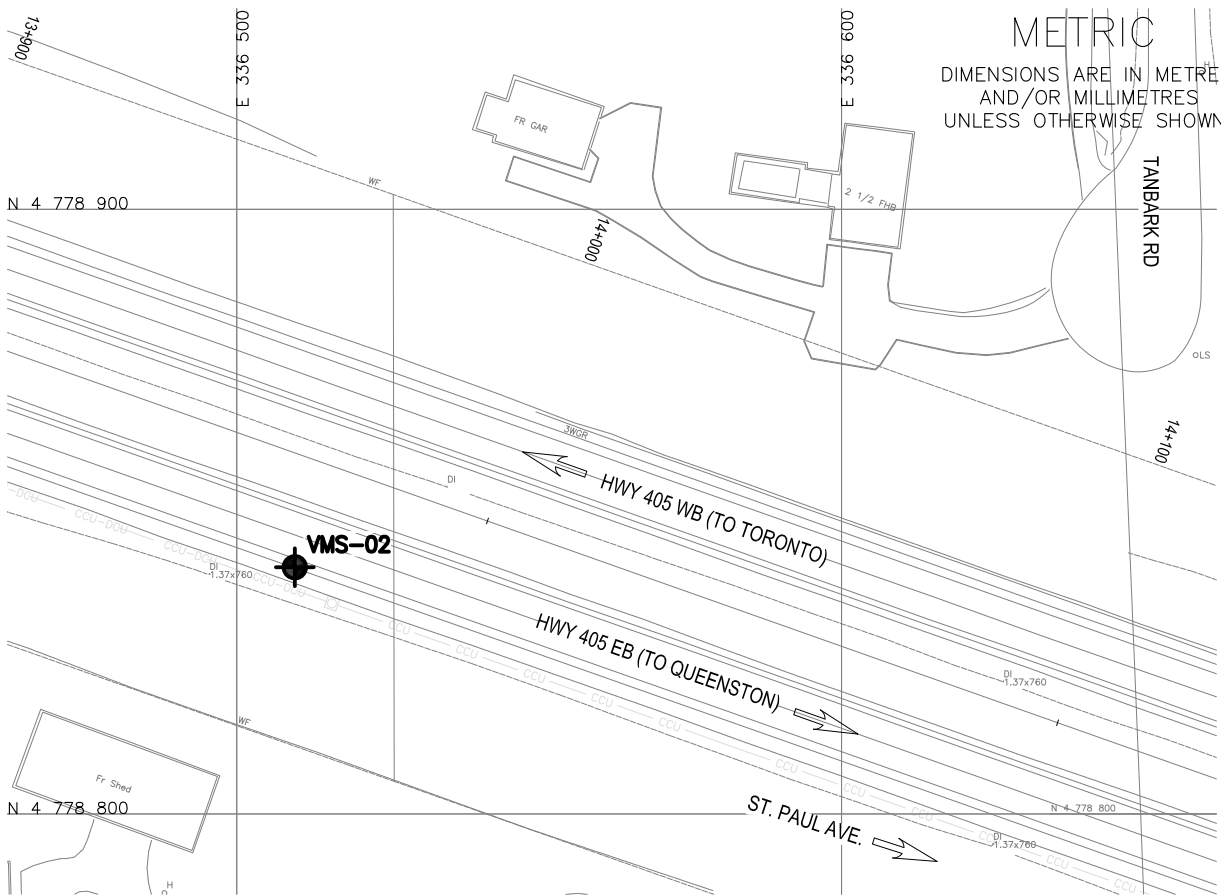
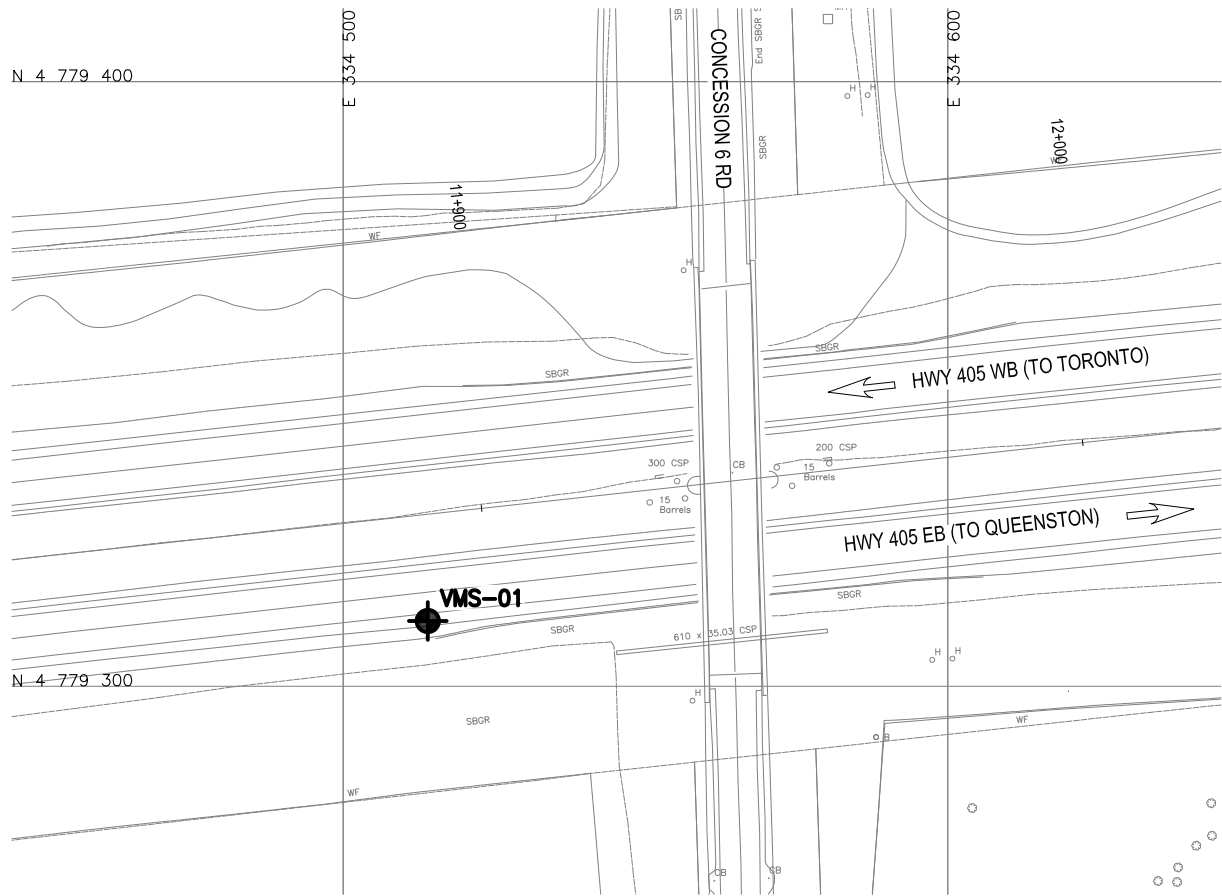
GEOCRES No. 30M3-323

REVISIONS									
	DATE	BY				DESCRIPTION			
DESIGN	RPR	CHK	SKP			LOAD		DATE	FEB 2021
DRAWN	AN	CHK	RPR			SITE		STRUCT	DWG 1



PLAN





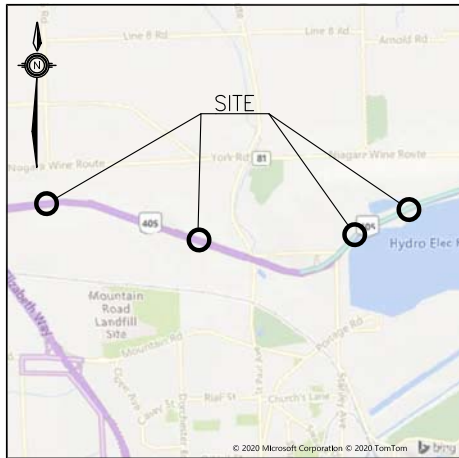
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 2171-19-00

HWY 405 PROP. SIGN SUPPORTS
QUEUE AND STOPPED VEHICLE
ADVISORY SYSTEM
BOREHOLE LOCATIONS PLAN



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
VMS-01	134.7	4 779 310.8	334 514.0
VMS-02	159.8	4 778 840.8	336 509.6
VMS-03	187.3	4 778 910.5	338 621.2
VMS-04	187.3	4 779 252.1	339 318.5

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M3-323

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK SKP	CODE
DRAWN	AN	CHK RPR	SITE
			LOAD
			STRUCT
			DWG 2
			DATE FEB 2021



Appendix E

List of Special Provisions and Suggested Text for NSSP



1. List of Special Provisions and OPSS Documents Referenced in this Report

OPSS.PROV 903 Construction specification for deep foundations

2. Suggested text for a NSSP on:

“Augered Caisson Construction for VMS Foundations”

Caisson installation should generally be carried out in accordance with OPSS.PROV 903.

The Contractor is advised that variable types of subsurface materials may be encountered at the location of the VMS foundations. For additional information regarding subsurface conditions, the Contractor is referred to the Foundation Investigation Report.

For bidding purposes, the Contractor shall assume the following:

1. Obstructions including rubble, cobbles and boulders may be present within the fill. Cobbles and boulders may be encountered within the native glacial tills. The soil is anticipated to become denser/harder with depth. The limestone/dolostone bedrock is considered to be very strong. Caisson installation equipment must be capable of dislodging, handling, removing or otherwise penetrating these obstructions and very dense/hard layers, and to drill/core through the bedrock to form the rock sockets and reach the design depth of the caisson. As such, rock coring equipment, pneumatic rock splitting/breaking equipment, ripping machinery etc. capable of advancing through the very strong bedrock must be available on site.



2. The groundwater levels observed are very short term. Higher groundwater levels must be expected during installation especially through the wet seasons. Water seepage and/or soil sloughing into the caisson hole will occur from existing fill and cohesionless soils. The cohesionless soils would be susceptible to disturbance and base boiling under conditions of unbalanced hydrostatic head. A balancing head of fluid may be required to maintain basal stability. Temporary liners shall be available on site to support the caisson sidewalls and provide seepage cut-off where required. Any accumulated water may have to be pumped out from the hole prior to placing concrete. All rock sockets shall be cleaned of loose rock fragments and debris prior to concreting. Should it be considered impractical to remove the accumulated water inside the hole, it is recommended that the concrete be placed by the pump tremie method.

The Contractor is responsible for constructing the VMS foundations without disturbing the material at the sides or bases of the foundations.