FINAL REPORT

FOUNDATION INVESTIGATION AND DESIGN REPORT

Construction of new concrete fish ladder at the outlet of the existing Heyrock Creek Culvert, Highway 21, Bluewater Municipality

Agreement No. 3015-E-0017
Assignment No. 2
GWP 3186-15-00
Geocres No. 40P5-21

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Foundation Investigation and Design Report for construction of new concrete fish ladder at the outlet of the existing Heyrock Creek Culvert, Highway 21, Bluewater Municipality

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Part I: FOUNDATION INVESTIGATION REPORT

1.1 Introduction

This foundation investigation report presents the results of a geotechnical investigation completed by **exp** Services Inc. for construction of a new concrete fish ladder at the outlet of the existing Heyrock Creek culvert. The culvert is located on Hwy 21, in the Municipality of Bluewater (Hay Township), approximately 700 m south of the Village of St. Joseph, in Huron County, the Ministry of Transportation (MTO) West Region. The work was undertaken under Agreement # 3015-E-0017, Assignment No. 2 (GWP 3186-15-00). The terms of reference (TOR) were as provided in the email dated October 6, 2016.

The purpose of the investigation was to evaluate the subsurface conditions along the proposed new concrete fish ladder at the outlet of the existing Heyrock Creek Culvert to permit detailed design of all foundation elements for structures and embankments including replacement of the existing steel sheet pile walls with a retaining wall and assessment of potential impacts of retaining wall construction of the existing high fill embankment. The site specific geotechnical investigation consisted of borings, soil sampling, borehole logging, probing holes and field and laboratory testing.

This foundation investigation report has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The Heyrock Creek Culvert Concrete Fish Ladder site is located on Hwy 21 (Approximate STA 18+532) in the Municipality of Bluewater (Hay Township), approximately 700 m south of the Village of St. Joseph, in Huron County. The location of the culvert and a cross section of the existing culvert alignment are shown on Drawing 1 in Appendix C.

As noted in the GA drawing provided by the MTO/Parsons (attached in Appendix B), the existing rigid frame box type culvert with spillways and flume is 42.7 m long, 5.94m wide and 4.57m in height. At this site Hwy 21 is a two lane, north/south roadway having approximately 2.4 m wide granular shoulders and guardrails subsequently on both sides. It is estimated that the highway embankment from the bottom of culvert at the investigated location is between 13 m (east) and 14 m (west) high having side slopes of approximately 2H: 1V from the top of the embankment to the toe of the embankment. The Concrete Fish Ladder is proposed for construction on the outlet (west) side of the culvert, replacing the existing sheet pile retaining structure. Photographs of the site and outlet of the existing culvert are presented in Appendix A.

The terrain surrounding the culvert location is relatively flat, agricultural table land, with an incisive depression towards the culvert creek. At the site location, water flows from east to west crossing Hwy 21 via the culvert towards the lake Huron. Above the top of the culvert, the inlet and outlet embankments are primarily grass covered with occasional shrubs and saplings. The upper grass covered embankments become generally more tree and shrub covered below the top of the culvert elevation. On the outlet side of the culvert, recent site improvement activities were evident on the northwest embankment and creek bank as indicated by tree stumps and re-vegetated areas with newly introduced rip-rap. Along the southwest creek bank, in the vicinity of the proposed fish ladder and above the existing concrete wing wall, some of the vegetation (trees) had to be removed to facilitate access to the site.

The general, site conditions in the immediate vicinity of the culvert were assessed during the site reconnaissance in October 24, 2016. On the inlet (east) side of the culvert, the embankments, although steep, were noted in an overall stable configuration with no obvious indications of recent slope movement. On the outlet (west) side of the culvert, the embankments exhibit signs of progressive slope movements behind the existing sheet pile walls at the downstream ends of the wing walls. Depressions in the soils of up to 1m were observed behind the sheet pile walls on both sides of the creek. Localized slope instability was noted to have occurred at the west end of the north sheet pile wall as well, also leaving a similar depression. Both sheet pile walls were noted in general deteriorating condition due to corrosion, bowed in the center and leaning toward the creek. Based on visual observation, the culvert and wing walls appeared to be in satisfactory condition with minor indications of age related deterioration. The floor of the culvert and spillway were noted generally intact. Photographs of the soil instabilities are presented in Appendix A.

The water depths of the inlet and outlet streams were about 0.3 m and 0.9 m, respectively where water had pooled in deeper portions of the creek. Water depth within the concrete floored portions of the culvert were between 50mm and 75mm. Water flow through the culvert was unimpeded and the culvert was free from obstructions such as logs, sticks or other debris.

1.2.2 Geological Setting

In accordance with volume 'The Physiography of Southern Ontario, Third Edition, Special Volume 2', by Chapman, L.J. and Putnam, D. F., 1984, the Heyrock Creek Culvert is located within the physiographic region termed the Huron Slope, identified along the eastern shore of Lake Huron. The lakeward border comprises the Algonquin bluff while the eastern boundary of the slope is defined as the Wyoming Moraine sloping up from 182m to 274m above sea level. The slope is generally a till plain with shallow surface lacustrine deposits overlying two clay till sheets. The bluff at the lake rises sharply up to 25m. The fringe of the clay till plain along Lake Huron is dissected by deeply cut gullies created by the numerous streams and creeks flowing toward Lake Huron over the till plain. Hayrock Creek is one of these numerous streams as demonstrated by its narrow channel.

1.3 Investigation Procedures

1.3.1 Site Investigation and Field Testing

The field investigation was performed between November 7 to 16, 2016. The field program consisted of drilling four (4) sampled boreholes (BH-1, BH-2, BH-3 and BH-4) and nine (9) probing in the areas of proposed concrete fish ladder and armourstone scour pool. The boreholes were strategically located to provide subsurface information for the proposed fish ladder, proposed armourstone retaining wall in the GA drawing and existing highway embankment on outlet side,. The locations of the boreholes are generally summarized as follows: (i) BH1 was advanced from embankment crest located approximately 11 m north of the culvert centerline on south bound lane shoulder (outlet site) (ii) BH2 was advanced at accessible location near the new proposed retaining wall at the north-west side located approximately 11 m north of proposed retaining wall and (iii) BH3 and BH4 were advanced at accessible locations near the proposed fish ladder location. BH3 advanced approximately 1.5 m south of existing concrete retaining wall and BH4 was advanced approximately 6 m south of the proposed fish ladder. In addition, nine (9) probe holes PH1 to PH9 were advanced manually using 1.2 m long 'T' bar (see photographs 10, in Appendix A) In the areas of the proposed fish ladder and armourstone scour pool. The borehole and probe hole locations are shown on Drawing 1 in Appendix C.

During the drilling of BH2 at the northwest side of the existing culvert, unexpected auger refusal was encountered at depth of 11.4 m from the ground surface, approximately at Elevation 179.1 m. Assuming that a boulder was hit, BH2 was abandoned, and another BH2A was drilled within an approximately 1.5 m perimeter of BH2. Auger refusal was encountered again at 12.5 m. Technical refusal in soil had occurred at 12.2m just above the auger refusal. BH2 was terminated on suspected boulders on this basis.

The boreholes were advanced using a rubber track mounted Diedrich D50T drill rig and, equipped with hollow stem augers and standard soil sampling equipment operated by a specialist drilling contractor, London Soil Test Ltd. The borehole drilled from embankment crest (BH1) was advanced to depth of about 18 m below road surface and the off-road boreholes (BH2, BH3 and BH4) were advanced to depths of about 12.3 m, 15.7 m and 15.7 m below ground surface, respectively. Prior the geotechnical investigation the tree cutting was performed at the southwest side of the culvert to allow the rig to access at the borehole locations.

The borehole locations (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were surveyed by **exp** personnel using the Benchmark (GBM 72-U-089) located at top of the culvert at the inlet side. The BM elevation 188.57 m was taken based on the horizontal and vertical control sheets (Sheet# 4, Plate# 0266-0021-036) provided by the MTO. The benchmark location is shown on Drawing. 1 in Appendix C.

For the drilling program, soil samples were obtained using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth as shown on the attached borehole logs (Appendix D). The original field (uncorrected) SPT "N" values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM, pg. 40) and used to provide an assessment of in-situ consistency of cohesive soils or relative density of non-cohesive soils. Some field vane tests were attempted. However, the native cohesive soil was generally stiff to very stiff so field vane testing was not successful in measuring the *in-situ* undrained shear strength of those soils. However, several pocket penetrometer readings were taken and recorded on the attached borehole logs (Appendix D).

Upon completion of the boreholes, ground water level measurements were carried out in boreholes in accordance with the Ministry of Transportation guidelines. The measured ground water levels after completion of drilling boreholes were recorded on the borehole log sheets in Appendix D. Two piezometers were also installed in a selected borehole (BH2 and BH3) to permit monitoring of the groundwater level at this location. The piezometers were installed and decommissioned following requirements in Ontario Regulation 903- (Wells Regulation). The piezometer consisted of 50 mm outside diameter PVC tubing with a 3 m long slotted tip that is sealed at a selected depth within borehole.

The boreholes (BH1 and BH4) were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the *Ontario Water Resources Act)*.

The fieldwork was supervised by members of **exp**'s engineering staff who directed the drilling and sampling operation, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification, and retrieved soil samples for subsequent laboratory testing and identification.

All of the recovered soil samples placed in labelled moisture-proof bags returned to **exp**'s Brampton laboratory for additional visual, textual, olfactory examination and selective testing.

1.3.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content and particle size distribution for approximately 25% of the collected soil samples. Atterberg Limits tests were carried out on select cohesive soil samples. All of the laboratory tests were carried out in accordance with MTO and/or ASTM Standards as appropriate.

The laboratory test results are provided on the attached borehole log sheets in Appendix D. The results of the grain size analyses and plasticity chart are presented graphically in Appendix E.

1.4 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix D. Laboratory test results are provided in Appendix E. 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 section 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.

In general, the subsurface conditions at the site consist of a fill layer (i.e. the existing highway embankment) comprised of gravelly sand to sand transition to silty sand in off road boreholes. Underlying the fill, native deposits of clayey silt/ silt underlain by silt till followed by clayey silt/silt was encountered. A more detailed summary of the subsurface conditions encountered in the boreholes is provided in the following sections.

1.4.1 Topsoil

Topsoil was encountered at the surface of boreholes (BH2, BH3 and BH4) and ranged in thickness from approximately 0.13 m to 0.15 m. Topsoil thicknesses may further vary beyond the borehole locations.

1.4.2 Fill: Gravelly Sand to sand

Gravelly sand to sand fill was encountered at the road surface of borehole (BH1). The gravelly sand to sand layer extended to depth of 6.9 m below road surface with elevation about 186.7 m. The explored thickness of this layer was 6.9 m.

The composition of this fill layer is sand and gravel and trace silt. The material is brown in color, and moist. The SPT "N" values within this layer ranged from 4 to 28 blows per 300 mm penetration, suggesting very loose to compact, but generally very loose to loose in compactness condition.

Laboratory testing performed on selected samples consisted of nine (9) moisture content and two (2) grain size distribution tests. The test results are as follows:

Moisture Content:

- 4% to 6%

Grain Size Distribution:

- 10% to 22% gravel;
- 69% to 81% sand; and
- 9% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution tests are also provided on Figure 1 in Appendix E.

1.4.3 Fill: Silty Sand

A layer of silty sand fill was encountered below topsoil in boreholes BH2 and BH3. The silty sand fill extended to depths ranging between 1.5 m to 2.3 m below ground surface with elevations ranging between 188.2 m to 184.5 m. The explored thickness of this layer was between 1.4 m to 2.1 m.

The composition of this fill layer is silt and sand, trace to some clay, trace gravel trace topsoil. The material is brown in color, and moist. The SPT "N" values within this layer ranged from 10 to 17 blows per 300 mm penetration, suggesting compact in compactness condition.

Laboratory testing performed on selected samples consisted of five (5) moisture content and one (1) grain size distribution test. The test results are as follows:

Moisture Content:

- 5% to 15%

Grain Size Distribution:

- 5% gravel;
- 50% sand; and
- 45% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The result of the grain size distribution test is also provided on Figure 2 in Appendix E.

1.4.4 Possible Fill: Clayey Silt

A layer of clayey silt (possible fill) was encountered below silty sand fill in borehole BH3. The clayey silt fill extended to depth of 3.1 below ground surface with elevation about 182.9 m. The explored thickness of this layer was 1.6 m.

The composition of this layer is clay and silt, trace to some sand and trace gravel. The material is grey in color, and moist. The SPT "N" values within this layer was 7 blows per 300 mm penetration, suggesting firm in consistency.

Laboratory testing performed on selected samples consisted of two (2) moisture content and one (1) grain size distribution test. The test results are as follows:

Moisture Content:

- 16% to 22%

Grain Size Distribution:

- 0% gravel;
- 25% sand; and
- 75% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The result of the grain size distribution test is also provided on Figure 3 in Appendix E

1.4.5 Clayey Silt (Upper)

A native clayey silt(upper) layer was encountered in all boreholes. The upper clayey silt layer was encountered below fill in BH1 and BH2, below silt in BH3 and below topsoil in BH4. This layer extended to depths ranging between 8.4 m to 12.3 m below ground surface with elevations ranging between 177.6 m to 182.2 m. BH2 was terminated within this layer. The explored thickness of this layer was between 2.3 m to 10.0 m.

The composition of this layer is clay and silt, trace to some sand and trace gravel. The material is brown to grey in color, and moist. The SPT "N" values within this layer ranged from 9 to 44 blows per 300 mm penetration, suggesting stiff to hard generally stiff to very stiff in consistency. One SPT "N" value within this layer in BH 2 recorded to be 100 blows per 76 mm penetration, this could be influence of refusal (possible boulder) encountered.

Laboratory testing performed on selected samples consisted of thirty-five (35) moisture content, eight (8) grain size distribution and eleven (4) Atterberg Limit tests. The test results are as follows:

Moisture Content:

- 6% to 23%

Grain Size Distribution:

- 0% to 3% gravel;
- 3% to 21% sand;
- 45% to 61% silt; and
- 29% to 47% clay

Atterberg Limits:

- Liquid Limit: 25% to 35%
- Plastic Limit: 12% to 16%
- Plasticity Index: 13% to 19%

The results of the moisture content, grain size distribution and Atterberg Limits tests are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution tests and Atterberg Limits tests are also provided on Figure 4 and 9, respectively, in Appendix E.

1.4.6 Silt

A native silt layer was encountered in all boreholes except BH2. The silt layer was encountered below clayey silt in BH1, below fill in BH3 and below silt till in BH4. This layer extended to depths ranging between 6.1 m to 15.7 m below ground surface with elevations ranging between 171.4 m to 179.9 m. BH4 was terminated within this layer. The explored thickness of this layer was between 3.0 m to 4.3 m.

The composition of this layer is silt, trace to some clay, trace sand and trace to some gravel. Occasional gravelly sand layer was encountered in BH 3 within this layer*. The material is grey in color, and moist to wet. The SPT "N" values within this layer ranged from 19 to 53 blows per 300 mm penetration, suggesting compact to very dense in compactness condition.

Laboratory testing performed on selected samples consisted of twelve (12) moisture content and two (2) grain size distribution tests. The test results are as follows:

Moisture Content:

- 9% to 19%

Grain Size Distribution:

- 0% to 14%* gravel;
- 2% to 71%* sand;
- 15% to 73% silt; and
- 25% clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution tests are also provided on Figure 5 and 6* in Appendix E.

1.4.7 Sandy Silt (Till)

A native sandy silt till layer was encountered below upper clayey silt in BH1, BH3 and BH4. The sandy silt till layer extended to depths ranging between 11.4 m to 18.0 m below ground surface with elevations ranging between 174.5 m to 175.7 m. BH1 was terminated within this layer. The explored thickness of this layer was between 2.0 m to 3.0 m.

The composition of this layer is sand and silt, trace to some gravel and trace to some clay. The material is grey in color, and moist. The SPT "N" values within this layer ranged from 37 to 106 blows per 300 mm, suggesting dense to very dense in compactness condition.

Laboratory testing performed on selected samples consisted of nine (9) moisture content and two (2) grain size distribution tests. The test results are as follows:

Moisture Content:

- 4% to 17%

Grain Size Distribution:

- 11% to 24% gravel;
- 27% to 36% sand; and
- 49% to 53% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution tests are also provided on Figure 7 in Appendix E.

1.4.8 Clayey Silt (Lower)

A native lower clayey silt layer was encountered below silt and sandy silt till layer in BH1 and BH3, respectively. In BH1 lower clayey silt layer was interbedded between silt and sandy silt till layer. The lower clayey silt layer extended to depths ranging between 15.7 m to 16 m below ground surface with elevations ranging between 170.3 m to 177.6. BH3 was terminated within this layer. The explored thickness of this layer was between 1.5 m to 4.3 m.

The composition of this layer is clay and silt, trace to some sand and trace gravel. The material is grey in color, and moist. The SPT "N" values within this layer ranged from 19 to 56 blows per 300 mm penetration, suggesting very stiff to hard in consistency.

Laboratory testing performed on selected samples consisted of six (6) moisture content, two (2) grain size distribution and one (1) Atterberg Limit tests. The test results are as follows:

Moisture Content:

- 8% to 27%

Grain Size Distribution:

- 3% to 5% gravel;
- 15% sand;
- 43% to 45% silt; and
- 25% to 37% clay

Atterberg Limits:

- Liquid Limit: 29%
- Plastic Limit: 14%
- Plasticity Index: 15%

The results of the moisture content, grain size distribution and Atterberg Limits tests are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution tests and Atterberg Limits tests are also provided on Figure 8 and 10, respectively, in Appendix E.

1.4.9 Summary of Probe Hole Findings

The subsurface conditions observed during advancing of probe holes (PH1 to PH9) are summarized in the table below. The probe hole locations are shown on the Drawing 1 in Appendix C.

Table 1.1. Probe hole summary

Probe hole	Approximate Water/Ground Surface Elevation (m)	Creek Water Depth Measured (m)	Description of Encountered Soil Condition at Creek Bottom*
PH1	181.7	1.0	0.15 m thick compact sand and gravel (measured in the existing water pool)
PH2	181.7	0.75	0.5 m thick compact sand and gravel (measured in the existing water pool)
PH3	181.7	0.5	0.7 m thick compact sand and gravel (Measured in the existing water pool)
PH4	181.5	0.1	0.3 m thick cobbles layer followed by stiff clayey silt
PH5	181.5	0.1	0.3 m to 0.6 m thick cobbles layer followed by stiff clayey silt
PH6	181.5	0.1	1 m thick cobbles layers followed by stiff clayey silt
PH7	181.3	0.15	0.5 m thick cobbles layer followed by stiff clayey silt
PH8	181.3	0.15	0.3 m to 0.6 m thick cobbles layer followed by stiff clayey silt
PH9	181.3	-	No cobbles layer, stiff clayey silt
Note: *The presented thickness of layer is below water depth measured			

1.5 Groundwater and Surface Water Conditions

Information on groundwater levels at the site was obtained by measuring the water levels in the piezometers and open boreholes after completion of drilling. Two 50 mm O.D. standpipe piezometers were installed for the long term groundwater monitoring following standard procedures in BH2 and BH3. The groundwater levels encountered in the boreholes are shown on the borehole logs and presented below in Table 1.2.

Table 1.2. Groundwater data

Borehole	Date Completed	Date Measured	Ground Surface Elevation[2]	Depth/ Elevation of Tip of Piezometer (m)	Groundwater measurement Depth/Elevation (m)
BH-1	Nov. 7/16	Nov. 7/16	193.6	N/A	dry
BH-2	Nov. 8/16	Jan. 4/17	190.5	12.3/178.2	12.3/178.2[4]
BH-3	Nov. 9/16	Jan. 4/17	186.0	6.1/179.9	3.0/183.0[4]
BH-4	Nov. 11/16	Nov. 11/16	187.1	N/A	dry
Creek WL Downstream (West) Side	--	Nov 11/16	--	--	182.0[3]

Notes:

1) All units in metres.
2) Elevations surveyed are referenced to the Benchmark (GBM 72-U-089) located at top of the culvert at inlet side. The BM elevation 188.57 m was taken based on the horizontal and vertical control sheets (Sheet# 4, Plate# 0266-0021-036) provided by the MTO.
3) Indicates top of surface water elevation at culvert location.
4) Based on groundwater measurement performed on January 4, 2017

Note that water levels measured in open boreholes and piezometers might not be stabilized due to short term observation.

Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods. Some perched water could exist in the embankment fill as well.

1.6 Chemical Analyses

One soil sample was selected for chemical analyses and was sent to Maxxam Analytics Inc., a CALA-certified and accredited laboratory in Mississauga, Ontario. The analytical laboratory results are presented in Appendix F, and are summarized in Table 1.3, below.

Table 1.3. Corrosivity chemical analysis

Sample Identification	pH (unitless)	Soluble Chloride (ppm)	Soluble Sulphate (ppm)	Resistivity (ohm-cm)	Conductivity (umho/cm)	Redox Potential (mV)	Sulphide (ppm)
BH3-SS5 Native silt	7.82	41	110	3,900	257	174	0.96

Part II: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS

2.1 General

This section of the report provides geotechnical design recommendations for construction of a new concrete fish ladder at outlet of the existing Heyrock Creek culvert located on Hwy 21, in the Municipality of Bluewater (Hay Township), approximately 700 m south of the Village of St. Joseph, in Huron County, the Ministry of Transportation (MTO) West Region. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site and presented in **Part I-Foundation Investigation Report**. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives and design the proposed fish ladder including replacement of the existing steel sheet pile walls with a retaining wall and assessment of potential impacts of retaining wall construction of the existing high fill embankment. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

Based on information provided in the TOR and our conversations with MTO, the concrete fish ladder is proposed for construction on the outlet (south-west) side of the culvert, replacing the existing sheet pile retaining structure. Following the MTO review of draft report, it is understood that the existing sheet pile retaining structure on the north-west side of the culvert is intended to retain in place to reduce the impact to the embankment instead of replacement of the existing sheet pile retaining structure with a new armourstone retaining wall along alignment as initially proposed and shown on the GA drawings provided by MTO/Parsons (attached in Appendix B) with maximum height estimated approximately 5.5 m. It is also understood that a concrete fish ladder with an estimated span of 3 m, approximately 20.8 m long and an approximately 10 m long concrete weir system are proposed.

This part of the report addresses the geotechnical design of the foundation for the proposed fish ladder and retaining wall by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the *Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-14)*, the *Canadian Foundation Engineering Manual (CFEM)* (2006), *MTO Gravity Pipe Design Guidelines* (May 2007) and generally accepted good practice. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference from the MTO letter dated October 6, 2016..

2.2 Expected Ground Conditions

The following ground conditions along the proposed fish ladder and retaining wall alignment are evident from the current investigation:

a. Hwy 21 is a two lane, north/south roadway having approximately 2.4 m wide granular shoulders and guardrails subsequently on both sides. It is estimated that the highway embankment at the investigated location is between 13 m (east) and 14 m (west) high from the bottom of culvert having side slopes of approximately 2H:1V from the top of the embankment to the toe of the embankment. The current elevation of the crest of the roadway is about 193.6 m.

b. The highway embankment consists of granular fill (6.9 m thick) underlain by native stiff clayey silt (~4.5 m thick) followed by compact silt (~ 3.1 m), very stiff clayey silt (~ 1.5 m thick) and very dense sandy silt till (2.0 m thick).
c. At the proposed retaining wall location, a layer of topsoil (0.15 m thick) underlain by compact silty sand fill (~2.1 m thick) followed by native stiff to very stiff clayey silt (~10.0 m thick) was encountered.
d. At the proposed fish ladder location, in BH 3 a layer of topsoil (~0.125 m thick) underlain by silty sand fill (~1.4 m thick) to clayey silt possible fill (~ 1.6 m thick) followed by native compact silt (~3.0 m thick), stiff to hard clayey silt (~2.3 m thick), dense to very dense sandy silt till (~3.0 m thick) and very stiff to hard clayey silt (~4.3 m thick) was encountered, BH4 revealed a layer of topsoil (~0.15 m thick) underlain by native stiff to very stiff clayey silt (~8.9 m thick) followed by dense to very dense sandy silt till (~2.3 m thick) and dense to very dense silt (~4.3 m thick).
e. The foundation soil at the fish ladder location is anticipated to be native compact silt to stiff clayey silt at about Elev. 180.4 m. Typical 'N' values ranged from 11 to 27.
f. The foundation soil at the armourstone retaining wall location proposed in the GA drawing is anticipated to be native very stiff clayey silt at about Elev. 180.0 m. Typical 'N' values about 20 blows per 300 mm penetration.
g. At the time of investigation, the approximate creek water elevation at outlet was about 182.0 m. The groundwater table in the embankment fill is expected to be at approximate elevation 182.5 m, or slightly higher. However, seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year (such as spring thaw and late fall) and lower levels during drier periods. Some groundwater mounding within the embankment and perched water should be anticipated.

2.3 Structure Foundations

2.3.1 Concrete Fish Ladder

It is understood that, precast/cast-in place concrete fish ladder supported on granular base, with about 1.2 m key in side wall below slab is proposed for construction.

Based on the subsurface information obtained from the site investigation, the native clayey silt/silt encountered is considered suitable for supporting the proposed fish ladder.

It is noted that for the construction of fish ladder, excavation below the creek water level will be required. This suggests the need for surface/ groundwater control as discussed in Section 2.5.4 below.

Any loose and/or soft soils encountered below the founding level should be sub-excavated and removed to firm bearing of native soils and grade restored with engineered fill. If the depth of excavation to remove unstable soils is excessive, using a geotextile fabric, such as Terrafix 270R or equivalent, in conjunction with engineered fill can be considered to assist in providing a stable base for support of the new structure. Based on previous experience, typically a minimum of 450 mm of a clear stone over geotextile fabric would establish a stable bearing surface. The fabric should be installed a manner to mitigate the migration of fines from adjacent material.

Based on the subsoil condition, Table 2.1 illustrates the advantages and disadvantages of the proposed fish ladder foundation.

Table 2.1 Advantages and disadvantages of proposed foundation

Proposed foundation	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
Precast/Cast-in-Place concrete fish ladder supported on granular base	▪ Straightforward construction ▪ Reduce construction period, consequently traffic management and water control period ▪ Reduce excavation depth	▪ If floor is thin and poorly reinforced, it may heave and crack ▪ During high flows, the concrete floor can be undermined ▪ Require bedding material ▪ Risk of differential settlement	▪ Low	▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil

2.3.1.1 Geotechnical Resistance

Based on the subsurface stratigraphy encountered at this site, the recommended founding depths and geotechnical resistances for a structure founded on undisturbed competent natural soil/ compacted granular fill set over natural soil is tabulated below.

Table 2.2 Recommended spread or strip footing design parameters

Foundation Type	Founding Elevation (m)	Assumed Footing Size (m)	Founding Soil Type	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS* (kPa)
Precast/Cast-in-Place concrete fish ladder supported on granular base with about 1.2 m Key in side wall below the slab	Varies (~182. 0 m to ~180.4 m)	3	Minimum 0.3 m compacted granular material (Granular A or Granular B Type II) native compact silt/ stiff clayey silt	375	250

Notes:

** for maximum settlement of 25 mm*

It is presumed that if any soft or very loose materials are encountered to be replaced with clean and compactable soil such as Granular A or Granular B Type II.

2.3.1.2 **Resistance to Lateral Loads**

Resistance to lateral forces/ sliding should be calculated in accordance with Section 6.10.5 of the CHBDC, using the following parameters:

Table 2.3 Recommended parameters for calculation of unfactored horizontal resistance

Interface and loading conditions	Parameters
Between Granular A and concrete	Coefficient of friction (tan δ)=0.7
Between cast-in-place concrete and native silt/clayey silt	Coefficient of friction (tan δ)=0.57

The listed values are unfactored; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

2.3.1.3 **Frost Protection**

The frost depth in the area of the proposed site is 1.2 m in accordance with OPSD 3090.101

2.3.2 Retaining Walls

Retaining walls should be either provided with permanent back drainage to prevent buildup of hydrostatic pressure or designed to resist hydrostatic pressures. Backfill material, placement and compaction requirements for backfill behind retaining walls should be as described in Section 2.5.3 of this report. Light compaction equipment should be used near the wall to avoid overstressing the walls.

As indicated Section 2.1, following the review of the draft report, it is understood that the existing sheet pile retaining structure on the North-West side of the culvert is intended to be retained in place to minimize impact to the highway embankment. During this investigation, it is revealed that the existing steel sheet pile retaining wall on the North-West side of the existing culvert is not in good condition to be used. It is deteriorated and tilted (see photographs 4 and 8 in Appendix A). Therefore, it is recommended that the existing retaining wall will be replaced with a new sheet pile retaining wall or restrained temporarily by strengthening during construction of a new armourstone retaining wall.

Installation of a new sheet pile wall behind the existing sheet pile wall can be considered at this site as a viable option. The major benefits of this option is that, the new sheet pile wall will protect the embankment from movement during removal of the existing sheet pile wall and that it can be installed permanently without temporary support. However, due to the significant height of the embankment fill on the North-West side of the culvert, some lateral movement of the embankment might be possible. Therefore, to minimize the movement, installation of anchor systems, bracing or deadman might be required.

Alternatively, construction of a new armourstone wall with temporarily strengthening of the existing sheet pile wall during its construction can be considered. The existing sheet pile wall can be temporary restrained by installation of anchor systems, bracing or deadman.

The retaining wall, for the both options, should be designed to resist the lateral pressures presented in

Section 2.6 of this report. Additional anchorage or tiebacks may be required for lateral resistance. Conventional practice is to incorporate either buried deadman anchors or grouted soil anchors. Deadman anchors or grouted soil anchors can be designed as discussed in Section 2.7, below.

The foundation design recommendations for the armourstone retaining wall option (initially considered) presented below was only for the information purpose. However, if the option is considered for replacement of the existing sheet pile wall, the information presented below can be used for the design of armourstone retaining wall.

2.3.2.1 **Geotechnical Resistance**

Based on the subsurface stratigraphy encountered at this site, the recommended founding depths and geotechnical resistances for a retaining wall founded on undisturbed competent natural soil is tabulated below.

Table 2.4 Recommended spread or strip footing design parameters

Foundation Type	Founding Elevation (m)	Assumed Footing Size (m)	Founding Soil Type	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS** (kPa)
Armourstone Retaining wall	~179.2*	1.2	Minimum 200 mm levelling base over native very stiff clayey silt	375	250

Notes:

**Below the frost line, elevation based on lowest surrounding elevation.*

*** for maximum settlement of 25 mm*

It is presumed that if any soft or very loose materials are encountered to be replaced with clean and compactable soil such as Granular A or Granular B Type II.

2.3.2.2 **Resistance to Lateral Loads**

Resistance to lateral forces/ sliding should be calculated in accordance with Section 6.10.5 of the CHBDC, using the following parameters:

Table 2.5 Recommended parameters for calculation of unfactored horizontal resistance

Interface and loading conditions	Parameters
Between Granular fill and armourstone	Coefficient of friction (tan δ)=0.7

The listed values are unfactored; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

2.4 Site Preparation Works

The site preparation work should include stripping of all vegetation, topsoil, organic or deleterious materials and cobbles at the bottom of the creek (if it is within the footprint) in order to develop the required construction grades for fish ladder, retaining walls etc. Stripping depths will likely vary locally and should be adjusted to remove all unsuitable material.

It is recommended that a Geotechnical Engineer monitors the stripping operations to ensure that unsuitable materials have been fully removed prior to construction works or the placement of any required engineered fill. Unacceptable areas identified are to be remediated as soon as practicable, the procedures for which would be dependent upon conditions encountered. This could include additional undercutting of unsuitable materials and replaced with controlled, engineered fill as prescribed in Section 2.5.3 of this report.

2.5 Excavation and Backfill

2.5.1 Temporary Excavation

It is assumed that the majority of the foundation excavations will be open cut. However, in some areas with high fill embankment temporary shoring may required to support the excavation. The temporary shoring system should be designed as described in Section 2.7 of this report.

In order to enable entry into excavations during the construction process, all excavations must comply with the definitions prescribed by the "Occupational Health and Safety Act" (OHSA), Ontario Regulation 213/91 "Construction Projects". Based on the findings of the investigation it is considered that excavation of the fill soils and overburden deposits at the site can be carried out using a conventional backhoe excavator. Allowances must be made to allow for cobbles and boulders that may be encountered in the fill and till deposits due to the nature of the depositional environment. Therefore, a Non-Standard Special Provision (NSSP) to alert the contractor about the presence of cobbles and/or even boulders in the embankment fill or till deposit should be considered. Suggestions for the NSSP are included in Appendix I.

Conventional open cut excavation methods are usually undertaken by means of a steep-sided excavation, the widths of which are set out by the Ontario Provincial Standard Specifications (OPSS). The contractor should be aware that slope height, slope inclination, or excavation depths (including utility trench excavations) should in no case exceed those specified in local, provincial or federal safety regulations. Such regulations are strictly enforced and, if not followed, the owner, the contractor or earthwork or utility subcontractors could be liable for substantial penalties. For the purpose of the act, the native deposits are considered as Type 3 soils above the groundwater table and Type 4 soils below the groundwater table. Temporary excavations (i.e. those that are open only for a short period) above the groundwater table may be made with side slopes not steeper than about 1H:1V, while the temporary slopes below the groundwater table have to be formed at 3H:1V unless a suitable dewatering system is installed to lower the water level below the base of the excavation.

It is important to note that soils encountered in the construction excavations may vary significantly across the site. Our preliminary soil classifications are based solely on the materials encountered in widely spaced explorations. The contractor should verify that similar conditions exist throughout the proposed area of excavation. If different subsurface conditions are encountered at the time of construction, it is recommended that **exp** be contacted immediately to evaluate the conditions encountered.

2.5.2 Bedding for Fish ladder

The bedding for the fish ladder should consist of Granular A (OPSS.PROV. 1010) with thickness of 300 mm beneath the fish ladder. The bedding material should be placed in layers not exceeding 200 mm in thickness, loose measurement, and compacted accordance with OPSS 501 before a subsequent layer is placed in accordance with OPSS 514.

Prior to placing any fill material, the exposed native subgrade should be inspected according to OPSS 902. A non-woven geotextile separator is to be placed between the approved subgrade and the compacted fill to assist in material placement and maintain the integrity of the founding soil along the entire length of the fish ladder. The geotextile separator is to be a Class II non-woven material with an equivalent opening size of 75-150 μm.

2.5.3 Backfill

Backfill should be placed from the base of the fish ladder side wall to the full height of the wall and extend a minimum 1.2 m horizontal distance from the outside wall (as per Figure C6.20 of the CHBDC**)**. This horizontal distance may be reduced by the use of suitable insulation (such as a heavy duty STYROFOAM). The insulation should be placed against the outside wall of the fish ladder from the base of the fish ladder to its total height. The material should be installed as per the manufacturer's instructions.

The backfill should consist of free-draining, non-frost susceptible granular materials such as Granular A or Granular B (OPSS.PROV 1010).

All granular backfill materials should be placed in thin lifts (i.e. not exceeding 300 mm before compaction) and each lift should be compacted accordance with OPSS 501. The final lift of embankment fills prior to placing pavement sub-base should be compacted to 98 % SPMDD.

The use of heavy compaction equipment should be avoided immediately adjacent the fish ladder/ retaining wall, as per MTO practice.

Backfilling behind any retaining (wing) walls should consist of granular materials in accordance with the MTO standards. Free draining backfill materials and perforated drains (as per Figure C6.20 of the CHBDC), suitably outleted etc. should be provided in order to prevent hydrostatic pressure build-up. For the armourstone retaining wall backfill should be design by the designer.

2.5.4 Groundwater and Surface Water Control

The soils encountered below the groundwater table and within potential excavation depths consist of native silt to clayey silt. The materials are susceptible to disturbance from groundwater and mobilized equipment. The groundwater level needs to be controlled to at least 0.6 m below the excavation level to avoid disturbance, and any surface or groundwater seepage should be removed from the excavation prior to the fish ladder bedding material placement of granular backfill in the dry. In general, pumping using properly filtered sumps, and/or filtered drains placed along the base of the excavation should provide sufficient groundwater control during foundation works where the groundwater level is 0.6 m or less above the excavation level. For deeper excavations relative to the groundwater level, more positive dewatering/ groundwater control in the form of steel pile confinement or well point systems would be required. This would for instance apply to deeper excavations for spread or strip footings option.

Design of temporary works is the responsibility of the contractor. Cofferdams will likely be required at both upstream and downstream ends to envelop the construction site and keep it free of water during construction. The stream flow must be transferred to the downstream side during construction activities. Based on provided GA drawing, it is understood that Terrafix Metre Bags cofferdam along with pipe line pumping system will likely be consider for creek water control.

Dewatering may require water taking permits (i.e. Permit To Take Water -PTTW). A PTTW is required for any water taking if the volume exceeds 50,000 L/day. The rate and volume required for dewatering will be dependent on construction methods and staging chosen by the Contractor. However, based on the limited subsurface investigation performed at the site and the preliminary seepage analysis performed at the approximate excavation surface for the construction of fish ladder, the rate and volume required for dewatering between the cofferdam does not exceed 50, 000 L/day. Therefore, PTTW is not required at this site.

2.6 Lateral Earth Pressure

Retaining wall, fish ladder side walls and temporary shoring that may be required for excavation should be designed to resist lateral earth pressure. The expression for calculating lateral earth pressure is given by:

$$P = K(\gamma h + q) \text{ for non-braced cut, or } K(0.65\gamma h + q) \text{ for braced cut}$$

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

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater levels measured on the site. Table 2.6 lists earth pressure parameters for given materials.

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation. Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design.

The effect of compaction surcharge should be taken into account in the calculations of active and at-rest earth pressures. The lateral pressure due to compaction should be taken as at least 12 kPa at the surface, and its magnitude should be assumed to diminish linearly with depth to zero at the depth where the active (or at rest) pressure is equal to 12 kPa. This pressure distribution should be added to the calculated active (or at rest) pressure. Notwithstanding, lighter compaction equipment and smaller lifts should be used adjacent to culvert walls to prevent overstressing.

It is likely that bracing for the temporary support system will be required at a maximum interval of 5 m.

For multiple support systems refer to *Canadian Foundation Engineering Manual* (CFEM) for apparent earth pressure distributions (CFEM, Section 26.10.3, Figure 26.8)

Table 2.6 Material types and earth pressure properties

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)
Gravelly Sand to Sand Fill (compact to loose)	32	0.31	3.25	0.47	21
Silty Sand Fill (compact)	32	0.31	3.25	0.47	21
Clayey Silt Fill (firm)	29	0.35	2.88	0.52	20
Clayey Silt (stiff)	29	0.35	2.88	0.52	19
Silt (compact to very dense)	30	0.33	3.0	0.5	20
Sandy silt till (dense to very dense	32	0.31	3.25	0.47	21
Clayey Silt (Very Stiff)	31	0.32	3.12	0.48	20

2.7 Temporary Shoring

Temporary excavation support systems, if any, should be designed and constructed in accordance with OPSS.PROV 539. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539. The complete design, construction, monitoring and removal of the installed protection system should be a responsibility of the contractor. Due to nature of this application it is expected that much of temporary shoring will be decommissioned in place noting the high cost for removal. Decommissioning must be consistent with good practice to avoid interference with highway systems and utilities, if any. The protection system should be designed to provide protection for excavations as required by the OHSA, at locations specified in the contract, and at any locations where the stability, safety or function of an existing structure and/or utility may be impaired by construction work.

At this site shoring system such as steel sheet pile walls and soldier piles and timber lagging may be considered for design. It should be designed based on the earth pressures coefficients and soil parameters provided in Section 2.6. For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided that the center-to-center spacing of the soldier piles does not exceed 2.5 m. Temporary shoring system with additional anchorage or tiebacks may be required for lateral resistance. Conventional practice is to incorporate either buried deadman anchors or grouted soil anchors.

Deadman anchors can be designed based on the earth pressure coefficients and soil parameters provided in Section 2.4, above. 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 loose to compact soils at this site, the estimated factored (0.4) ULS resistance of grouted anchors would be 40 kN/m length. Detailed design would be completed following the design of the wall and the loads have been established. Normally, such anchors are supplied and installed/tested by specialist vendors/contractors.

The protection system should be designed for the Performance Level 2 (for small, less important sections). The minimum requirements for monitoring should include the survey measurements of 6 m apart scaled targets attached to the shoring wall at the elevations specified. If movement approaches the allowable limit of 25 mm (Performance level 2), suitable measures should be taken to ensure stability of the protection system and to ensure that the movement does not exceed the performance level specified.

At this site, the temporary excavation support systems may require for the construction of fish ladder and it can be designed as discussed above. For the construction of fish ladder, temporary shoring such as steel sheet pile walls and soldier piles and timber lagging, behind the existing sheet pile wall, may be considered for design. Backfill behind the fish ladder side wall (retaining wall) should be carried out as discussed in Section 2.5.3, above.

2.8 Slope Stability and Settlement Assessment

2.8.1 Internal Stability of Armourstone Retaining Wall

The internal stability of the armourstone retaining wall should be assessed by the designer

2.8.2 External(Global) Slope Stability Assessment

A preliminary slope stability analysis was performed to assess the global stability of the retaining wall and existing embankment and to check that a minimum Factor of Safety of 1.3 will be achieved for the retaining wall and embankment at the location of the proposed retaining wall location. The static slope stability analyses were performed using the Morgenstern-Price method developed on the basis of limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

Stability assessments of existing slopes under static conditions were performed on (1) the cross-section perpendicular to the proposed armourstone retaining wall with 4H:1V slope above and (2) the cross-section perpendicular to existing Highway 21 at culvert location with 2H:1V side slope. The cross-section of the existing embankment with the approximate slopes of 2H:1V was established based on **exp**'s survey data and the drawing provided by MTO. The stratigraphy and groundwater condition at the site were developed based on the results of the geotechnical investigation presented in Part I - Foundation Investigation Report.

Based on the borehole information, the subsoils encountered at the work area consist of embankment fill, underlain by silt to clayey silt deposits. Therefore, an effective stress analysis for a long term and total stress for short term stability assessment of the retaining wall and the existing embankment slope was performed taking into consideration the subsoil conditions encountered beneath the proposed retaining walls and the existing embankment.

The SLOPE/W graphical printout, for analysis performed is included in Appendix G. The result of the slope analysis performed for the retaining wall and embankment slope is presented in Appendix G.

Tabulated below in Table 2.7 are the soil parameters used for the slope stability analysis. The soil parameters were generally estimated based on the results of field and laboratory investigation.

Table 2.7 Soil properties used in slope stability analysis

Soil Type	Short-term Conditions			Long-term Conditions		
	ϕ (degrees)	c (kPa)	γ (kN/m^3)	ϕ' (degrees)	c' (kPa)	γ' (kN/m^3)
Retaining Wall (BH2 and BH4)						
Silty Sand Fill (compact)	32	0	21	32	0	21
Clayey Silt (Stiff)	0	60	19	29	0	19
Clayey Silt (Very Stiff)	0	120	20	31	0	20
Sandy silt till (Dense to Very Dense)	32	0	21	32	0	21
Silt (Dense to Very Dense)	30	0	20	30	0	20
Highway embankment (BH1 and BH2)						
Gravelly Sand to Silty Sand Fill (compact to loose)	32	0	19	32	0	19
Clayey Silt (Firm to Stiff)	0	40	19	29	0	19
Silt (Compact to Very Dense)	29	0	20	29	0	20
Clayey Silt (Very Stiff to Hard)	0	90	20	31	0	20
Sandy silt till (Very Dense)	32	0	21	32	0	21

The results of global slope stability analyses performed on the sections perpendicular to armourstone retaining wall with 4H:1V slope above and the cross-section perpendicular to the existing highway embankment side slope with 2H:1V slope using undrained (short term stability) and drained (long term stability) soil parameters are presented graphically in Appendix G. As shown on the figures (attached in Appendix G), the results of stability analyses suggest that the FOS greater than required FOS of 1.5 and 1.3 for static conditions can be obtained for armourstone retaining wall and the highway embankment side slope, respectively.

Use of heavy crane and the like on or near the slope during construction should be evaluated to ensured that they do not initiate instability. This would require assessment of the particular machine loading condition required travel paths and any mitigation in the form of support mat and granular pad. This is normally responsibility of the contractor.

2.8.3 Settlement Considerations

The fish ladder ponding pool floor elevation varies between about 182.4 m (upstream) to 180.8 m (downstream). In view of the topography, it is anticipated some regrading (cut and fill) will be carried out at the site. Since most of the area will be cut, no significant settlement is expected. Where there is fill (about 0.3 m is proposed at some portion of fish ladder), total and deferential settlements are not expected to exceed 25 mm and 19 mm, respectively.

2.9 Scour Protection

The scour design including any required mitigation measures is the responsibility of and should be carried out by a qualified hydraulics engineer. Geotechnical soil parameters pertinent to scour analyses are the following: SPT N-value, insitu moisture content, percent passing the No. 200 sieve (% 200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). The parameters for this site can be found / interpreted on the borehole logs and on the graphs attached in Appendix E. All tested soils were classified using the Unified Soil Classification System which can be used for evaluation of erosion rates. Pertinent geotechnical parameters to support this design have been provided in this report as noted above. Foundation recommendations outlined in this report assumes that proper scour protection is designed and implemented. The following additional information is provided for general guidance.

2.9.1 Erosion Protection

The requirement for and detailed design of erosion protections measures is the responsibility of and should be carried out by the hydraulics engineer. Based on the drawing provided, it is understood that armourstone scour pool is proposed to be constructed at this site. The need for any additional protection should be accessed by the hydraulics engineer including any rip-rap protection. The size of the rip-rap is a function of the creek's hydrology and the impacts of the structure. 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. OPSD 810.010, which is included in Appendix H of this report, shows typical creek bed rip-rap protection.

Where the embankment side slopes have been scarred and/or excavated (beyond rip-rap limit) to facilitate the construction of fish ladder the scarred and/or reinstated embankment side slopes are to be vegetated with sodding, seeding or planting as necessary depending on the flow rate and volume.

Should seeding be utilized, a 100 mm thick layer of topsoil should be placed along with a degradable erosion blanket to help minimize erosion until the vegetation begins to grow.

2.10 Corrosion Protection

One soil sample was selected for chemical analyses and was sent to Maxxam Analytics Inc., a CALA-certified and accredited laboratory in Mississauga, Ontario. The analytical laboratory results are summarized in section 1.6 of this report and detailed results are included in Appendix F.

Similar to our experience with the soils in the area, the chemical data indicates medium resistivity, which indicates a moderately potential for corrosion of buried metallic elements, particularly pipes and appurtenances. The maximum chloride content reported is 41 ppm (μg/g) i.e. 0.0041% which indicates a low potential for additional corrosion.

The maximum water soluble sulphate content of the soils tested is 110 ppm (μg/g), i.e. <0.011% and being less than 0.10%, does not indicate the potential to corrode normal Portland cement concrete. These data also support our local experience.

Part III: 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.

We recommend that we be retained to review our recommendations as the design nears completion to ensure that the final design is in agreement with the assumptions on which our recommendations are based and that our recommendations have been interpreted as intended. If not accorded this review, exp will assume no responsibility for the interpretation and use of the recommendations in this report.

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 in order to assess this additional information and our recommendations, as appropriate. It may then be necessary to perform additional investigation and analysis.

Contractors bidding on or undertaking any proposed work at this site should, relative to the subsurface conditions, decide on their own investigations, if deemed necessary, as well as their own interpretations of the factual results provided herein, so they may draw their own conclusions as to how the subsurface conditions may affect them.

This Foundation Investigation and Design Report has been prepared by Nimesh Tamrakar, M.Eng, EIT., and Silvana Micic, Ph.D., P.Eng. It was reviewed by TaeChul Kim, P.Eng. and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Robert Walker.

Yours truly,

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Part IV: 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

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Appendix A –
Site Photographs

Photo 1: HWY 21 Crossing Heyrock Creek Culvert – Looking North

Photo 2: HWY 21 Crossing Heyrock Creek Culvert – Looking South

Photo 3: Heyrock Creek Culvert Outlet – Looking West from Shoulder of HWY 21

Photo 4: Heyrock Creek Culvert Outlet – Looking East

Photo 5: Heyrock Creek Culvert Outlet – South Side Retaining Wall

Photo 6: Heyrock Creek Culvert Outlet – North Side Retaining Wall

Photo 7: Heyrock Creek Culvert Outlet – – South Side Wing Wall

Photo 8: Heyrock Creek Culvert Outlet – – North Side Wing Wall

Photo 9: Looking west (downstream) from the culvert outlet

Photo 10: Probe hole using 'T' bar

Appendix B –
GA Drawings

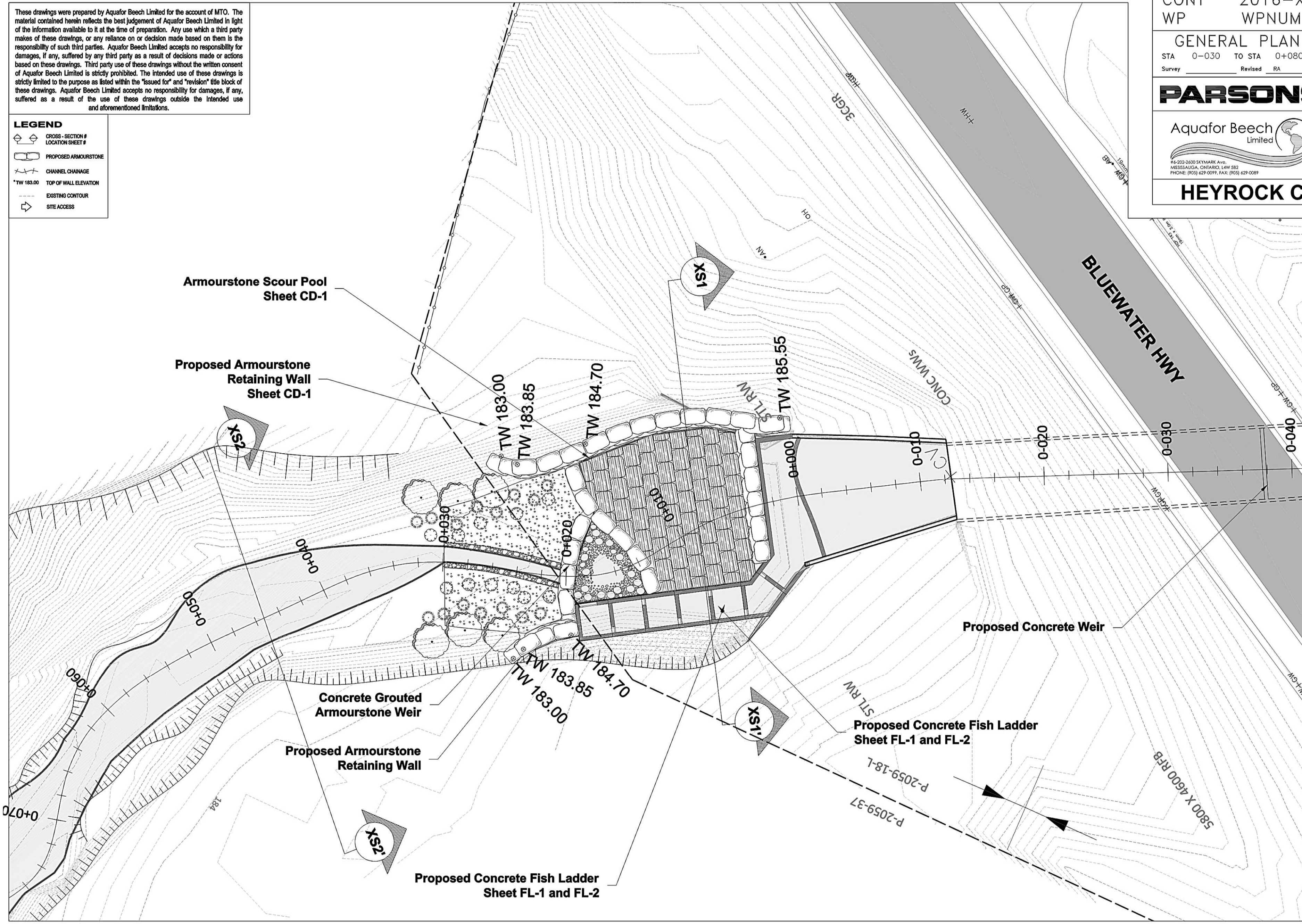

PLATE No

CONT 2016–XX

WP WPNUM

GENERAL PLAN

STA 0–030 TO STA 0+080

Survey ______ Revised RA

PARSONS

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#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

HEYROCK CREEK

DRAWN

SCALE:

CHECKED

DRAWING NAME: 65887_V16.DWG

CREATED:

MODIFIED:

MINISTRY OF TRANSPORTATION, ONTARIO

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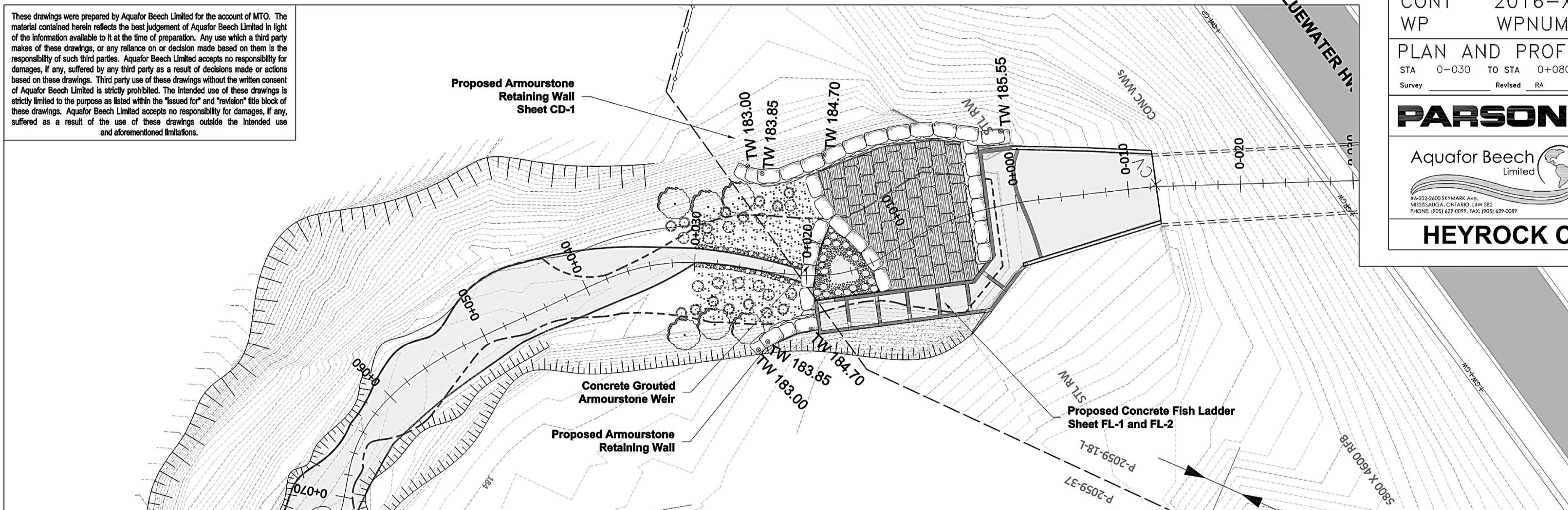


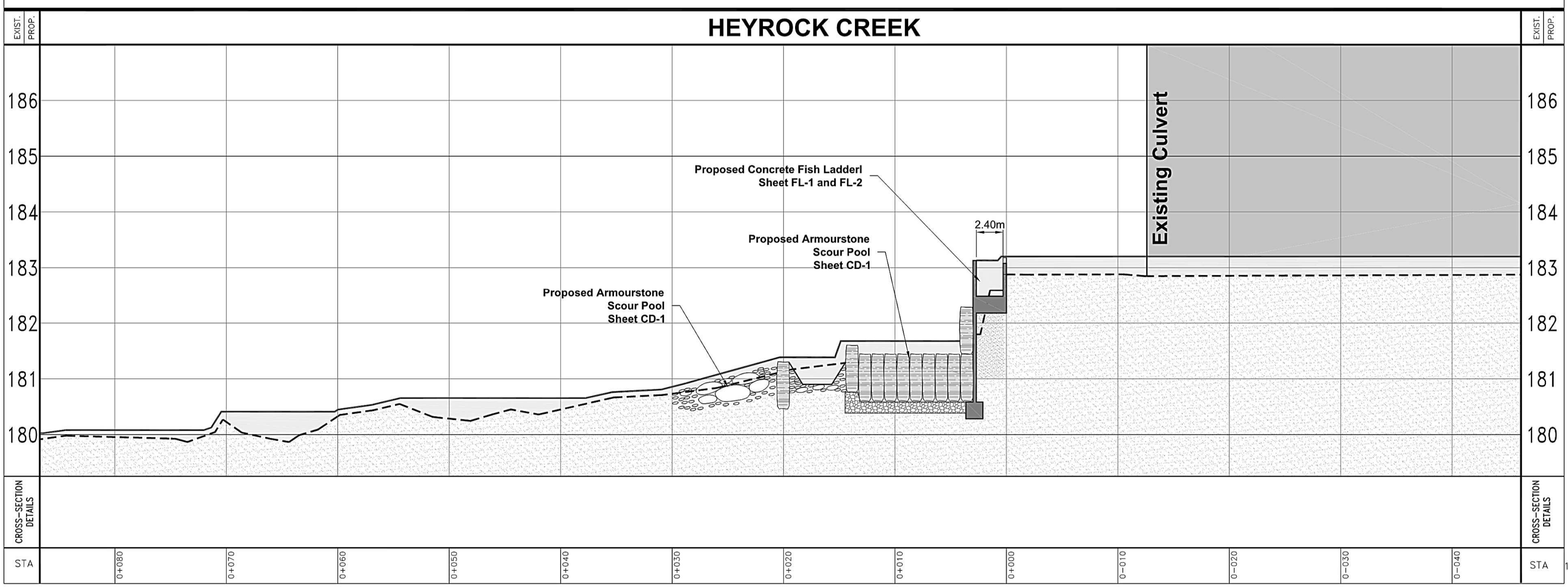
PLATE No
CONT 2016-XX
WP WPNUM

PLAN AND PROFILE
STA 0-030 TO STA 0+080

PARSONS

Aquafor Beech Limited

HEYROCK CREEK



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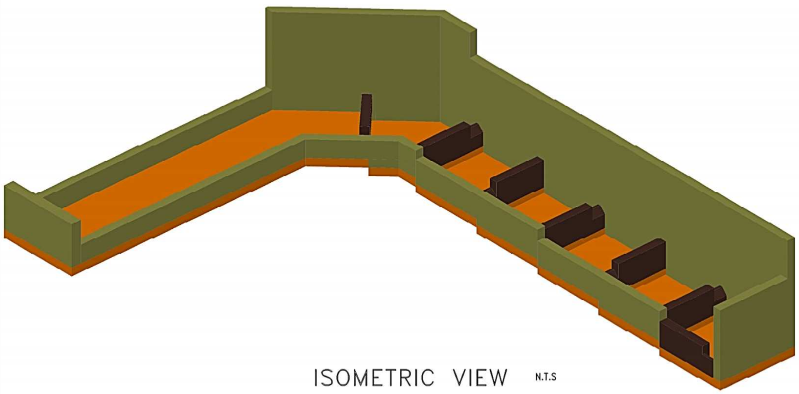

ISOMETRIC VIEW N.T.S

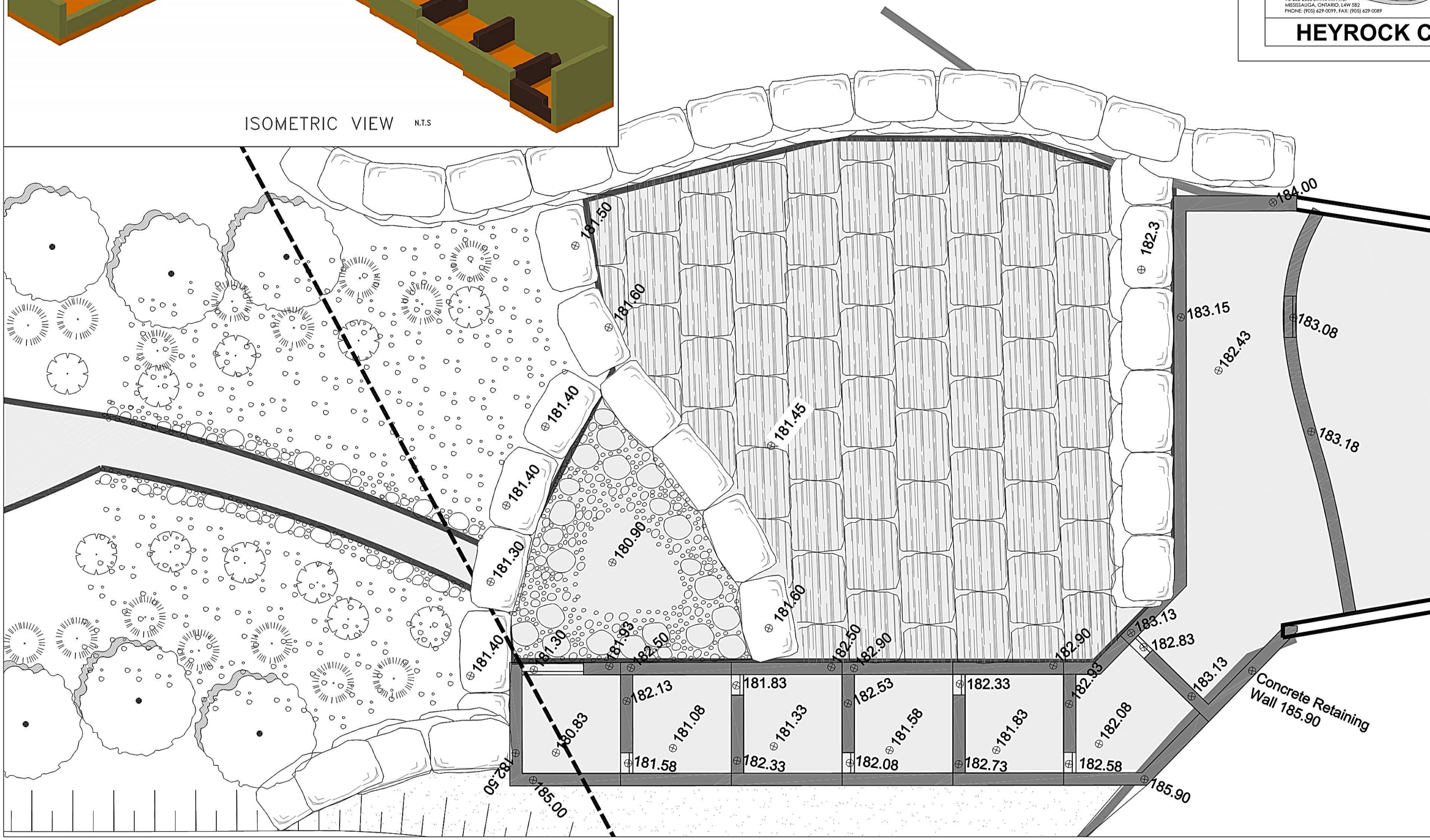

PLATE No	
CONT	2016–XX
WP	WPNUM

FISH LADDER DETAIL

STA 0–030 TO STA 0+080

Survey ______ Revised RA

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HEYROCK CREEK

SH

FL

10/

DRAWN B

SCALE:

CHECKED

SCAL

1m 0

Horizon

METRIC

PLATE No
CONT 2016–XX
WP WPNUM

FISH LADDER DETAIL

STA TO STA
Survey Revised RA

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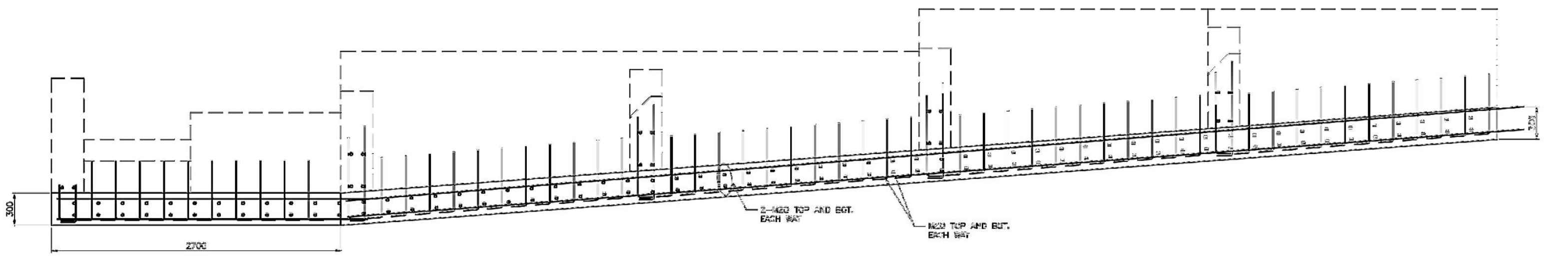
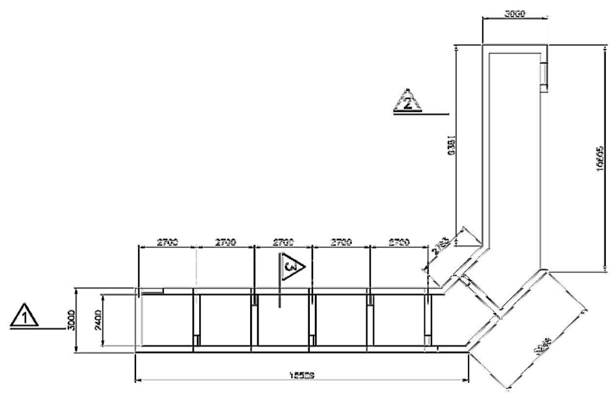
HEYROCK CREEK

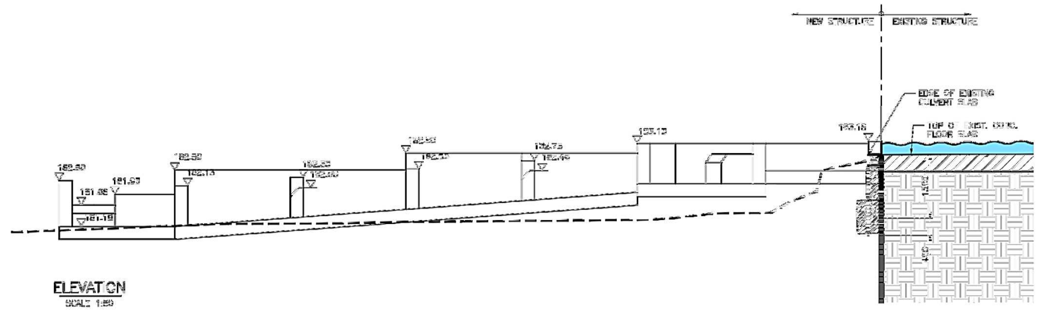
DRAWN
SCALE:
CHECKED



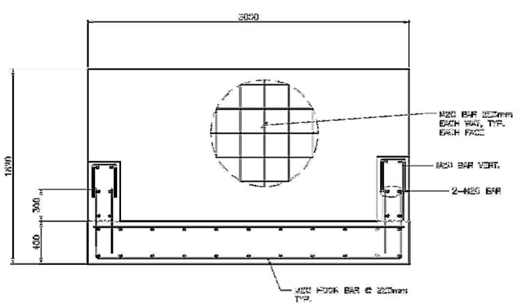
SECTION 1
SCALE 1:20



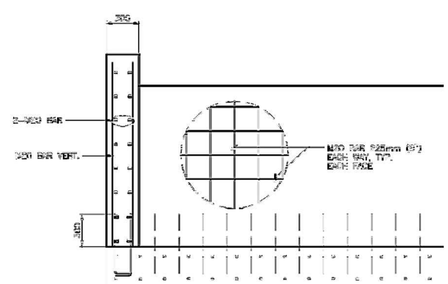
PLAN
SCALE 1:100



ELEVATION
SCALE 1:50



SECTION 2
SCALE 1:20



SECTION 3
SCALE 1:20

MINISTRY OF TRANSPORTATION, ONTARIO

DRAWING NAME: 65887_V16.DWG
CREATED:
MODIFIED:

METRIC

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PLATE No
CONT 2016–XX
WP WPNUM

SECTIONS
STA TO STA
Survey Revised RA

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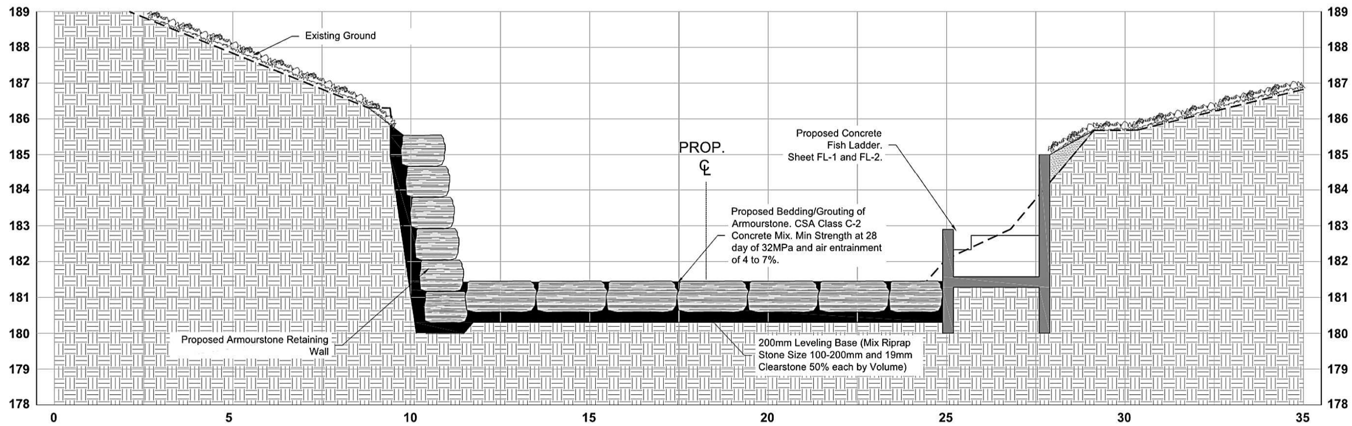
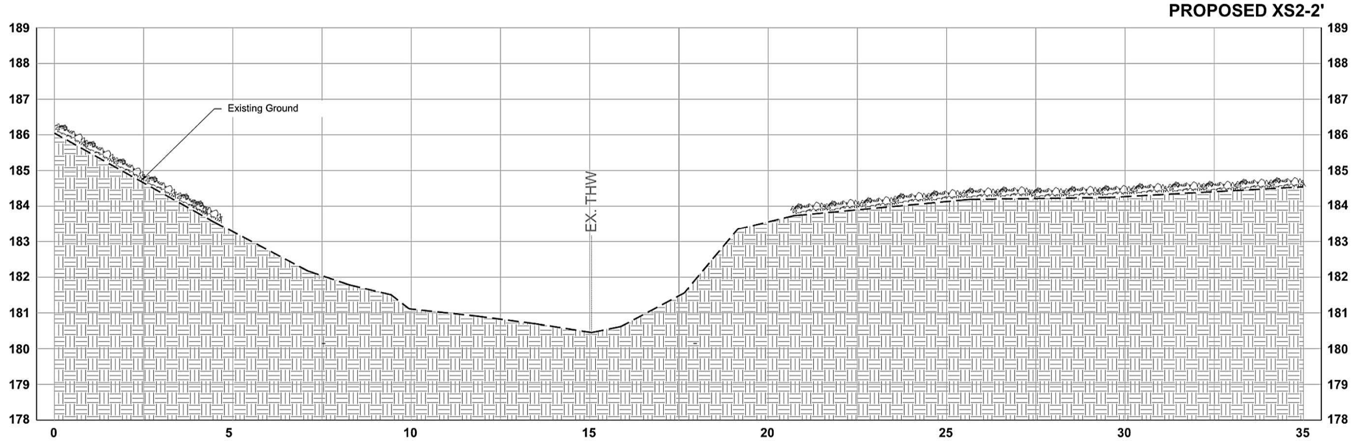
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

HEYROCK CREEK

PROPOSED XS1-1'



PROPOSED XS2-2'



SH
CS
10/
DRAWN
SCALE:
CHECKED
SCAL
0.5m 0
Horizo

MINISTRY OF TRANSPORTATION, ONTARIO
PR-x-xxx xx-x
DRAWING NAME: 65887_V16.DWG
CREATED:
MODIFIED:

METRIC

PLATE No
CONT 2016–XX
WP WPNUM

STAGING PLAN

STA TO STA

Survey Revised RA

PARSONS

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MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

HEYROCK CREEK

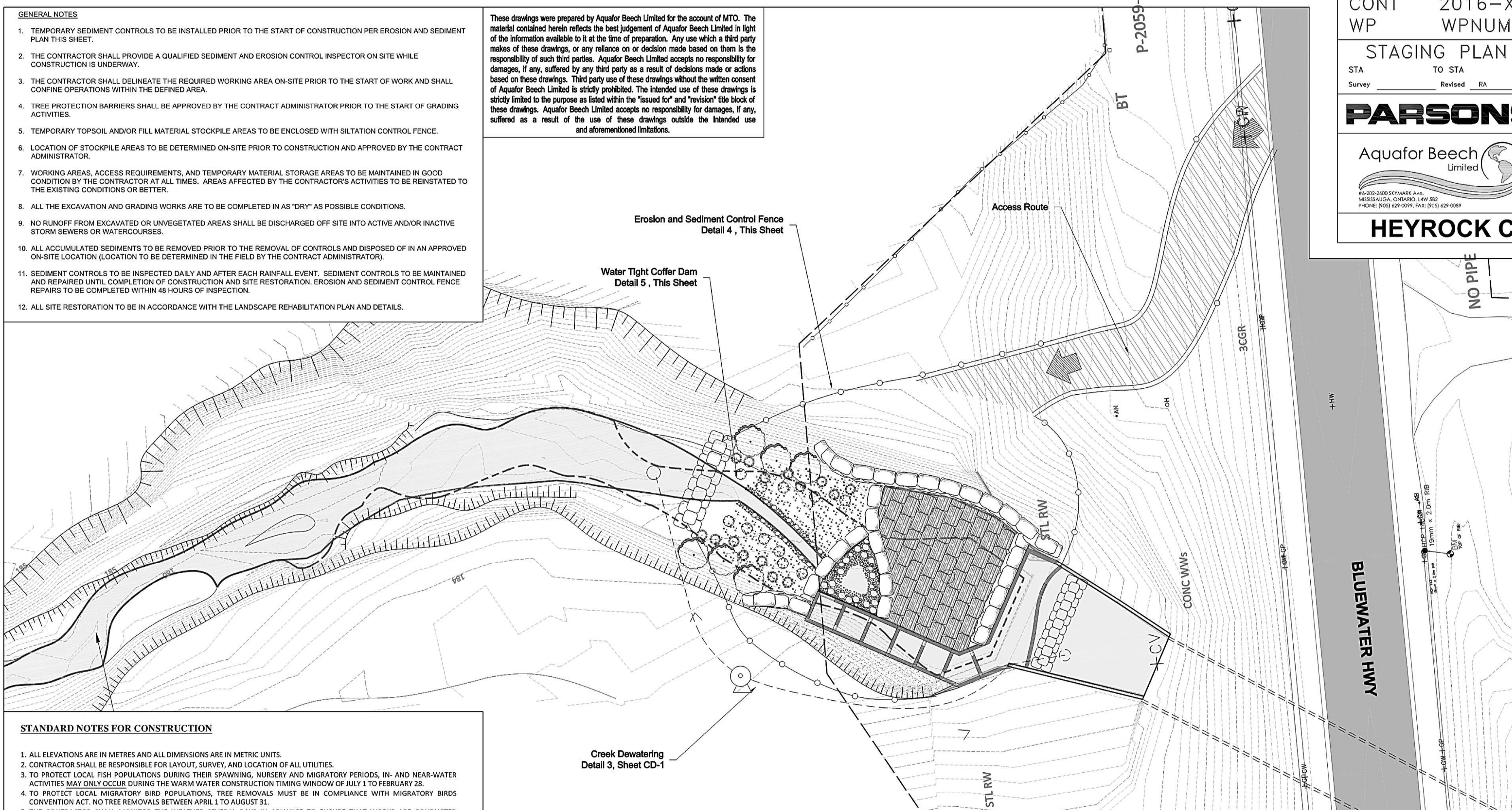
DRAWN BY:
SCALE:
CHECKED

MINISTRY OF TRANSPORTATION, ONTARIO

DRAWING NAME: 65887_V16.DWG
CREATED:
MODIFIED:

GENERAL NOTES

1. TEMPORARY SEDIMENT CONTROLS TO BE INSTALLED PRIOR TO THE START OF CONSTRUCTION PER EROSION AND SEDIMENT PLAN THIS SHEET.
2. THE CONTRACTOR SHALL PROVIDE A QUALIFIED SEDIMENT AND EROSION CONTROL INSPECTOR ON SITE WHILE CONSTRUCTION IS UNDERWAY.
3. THE CONTRACTOR SHALL DELINEATE THE REQUIRED WORKING AREA ON-SITE PRIOR TO THE START OF WORK AND SHALL CONFINE OPERATIONS WITHIN THE DEFINED AREA.
4. TREE PROTECTION BARRIERS SHALL BE APPROVED BY THE CONTRACT ADMINISTRATOR PRIOR TO THE START OF GRADING ACTIVITIES.
5. TEMPORARY TOPSOIL AND/OR FILL MATERIAL STOCKPILE AREAS TO BE ENCLOSED WITH SILTATION CONTROL FENCE.
6. LOCATION OF STOCKPILE AREAS TO BE DETERMINED ON-SITE PRIOR TO CONSTRUCTION AND APPROVED BY THE CONTRACT ADMINISTRATOR.
7. WORKING AREAS, ACCESS REQUIREMENTS, AND TEMPORARY MATERIAL STORAGE AREAS TO BE MAINTAINED IN GOOD CONDITION BY THE CONTRACTOR AT ALL TIMES. AREAS AFFECTED BY THE CONTRACTOR'S ACTIVITIES TO BE REINSTATED TO THE EXISTING CONDITIONS OR BETTER.
8. ALL THE EXCAVATION AND GRADING WORKS ARE TO BE COMPLETED IN AS "DRY" AS POSSIBLE CONDITIONS.
9. NO RUNOFF FROM EXCAVATED OR UNVEGETATED AREAS SHALL BE DISCHARGED OFF SITE INTO ACTIVE AND/OR INACTIVE STORM SEWERS OR WATERCOURSES.
10. ALL ACCUMULATED SEDIMENTS TO BE REMOVED PRIOR TO THE REMOVAL OF CONTROLS AND DISPOSED OF IN AN APPROVED ON-SITE LOCATION (LOCATION TO BE DETERMINED IN THE FIELD BY THE CONTRACT ADMINISTRATOR).
11. SEDIMENT CONTROLS TO BE INSPECTED DAILY AND AFTER EACH RAINFALL EVENT. SEDIMENT CONTROLS TO BE MAINTAINED AND REPAIRED UNTIL COMPLETION OF CONSTRUCTION AND SITE RESTORATION. EROSION AND SEDIMENT CONTROL FENCE REPAIRS TO BE COMPLETED WITHIN 48 HOURS OF INSPECTION.
12. ALL SITE RESTORATION TO BE IN ACCORDANCE WITH THE LANDSCAPE REHABILITATION PLAN AND DETAILS.

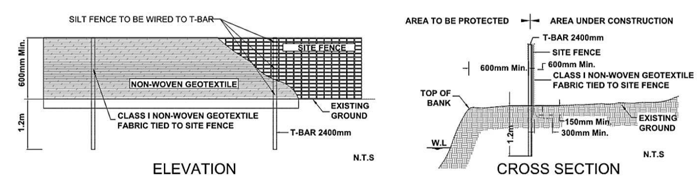


STANDARD NOTES FOR CONSTRUCTION

1. ALL ELEVATIONS ARE IN METRES AND ALL DIMENSIONS ARE IN METRIC UNITS.
2. CONTRACTOR SHALL BE RESPONSIBLE FOR LAYOUT, SURVEY, AND LOCATION OF ALL UTILITIES.
3. TO PROTECT LOCAL FISH POPULATIONS DURING THEIR SPAWNING, NURSERY AND MIGRATORY PERIODS, IN- AND NEAR-WATER ACTIVITIES MAY ONLY OCCUR DURING THE WARM WATER CONSTRUCTION TIMING WINDOW OF JULY 1 TO FEBRUARY 28.
4. TO PROTECT LOCAL MIGRATORY BIRD POPULATIONS, TREE REMOVALS MUST BE IN COMPLIANCE WITH MIGRATORY BIRDS CONVENTION ACT. NO TREE REMOVALS BETWEEN APRIL 1 TO AUGUST 31.
5. THE CONTRACTOR SHALL MONITOR THE WEATHER SEVERAL DAYS IN ADVANCE TO ENSURE THAT WORKS ARE CONDUCTED DURING FAVOURABLE WEATHER CONDITIONS. SHOULD AN UNEXPECTED STORM ARISE, THE PROPONENT/CONTRACTOR SHALL REMOVE ALL ITEMS FROM THE REGIONAL STORM FLOOD PLAIN THAT WOULD HAVE THE CAPACITY TO CAUSE AN OBSTRUCTION TO FLOW OR A SPILL (I.E. FUEL TANKS, UNFIXED EQUIPMENT, ETC.).

CONSTRUCTION STAGING SEQUENCE

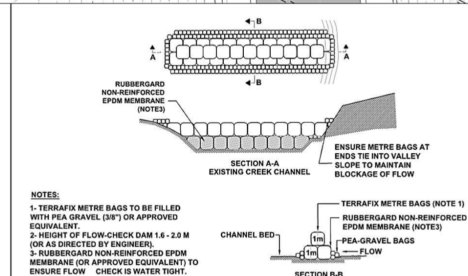
1. TEMPORARY SEDIMENT AND EROSIONS CONTROLS TO BE INSTALLED PRIOR TO THE START OF CONSTRUCTION.
2. CLEARING, GRUBBING AND REMOVAL OF TREES AS REQUIRED
3. INSTALLATION OF TREE PROTECTION/HORDING AREAS
4. CREATE WATERTIGHT COFFER DAM WITHIN THE OUTLET. CONTRACTOR TO MEET PUMPING REQUIREMENTS TO MAINTAIN DRY WORKING AREA.
5. INSTALL DOWNSTREAM CHECK DAM AS DEFINED ON THE DETAILED DESIGN DRAWINGS.
6. INITIATE PUMPING WITH SCOUR OUTLET PROTECTIONS.
7. COMPLETE FISH RESCUE THROUGH REACH. FISH REMOVAL IS TO BE DONE BY QUALIFIED FISHERIES BIOLOGIST UNDER MNR PERMIT.
8. DEWATER WORK AREA AS REQUIRED (I.E., SCOUR POOL DOWNSTREAM OF CULVERT) THROUGH FILTER BAG WITHIN FLOODPLAIN.
9. EXCAVATE / CONSTRUCT CONCRETE FISH LADDER AS PER DETAIL.
10. EXCAVATE / CONSTRUCT ENGINEERED SCOUR POOL WITH GROUTED / STACKED ARMOURSTONE AS PER DETAIL.
11. COMPLETE ROUGH GRADING OF SLOPES AS PER DESIGN DRAWINGS.
12. CONSTRUCT ARMOURSTONE RETAINING WALLS.
13. COMPLETE BANK RESTORATION GRADING AND TOPSOIL APPLICATION
14. DECOMMISSION PUMP, REMOVE UPSTREAM COFFER DAM.
15. IMPLEMENT RESTORATION OF STUDY AREA AS PER RESTORATION PLAN AND DETAILS.
16. REGRADE AND BURY ACCESS ROUTE WITH 15CM OF TOPSOIL.
17. REMOVE ALL SEDIMENT AND EROSION CONTROL MEASURES AFTER DEMOBILIZATION FOR PLANTING MATURATION.



NOTES:

- Materials removed from trench shall be replaced on top of filter cloth
- Filter cloth shall be horizontally overlapped 500mm
- Silt fence installation work shall avoid the destruction of existing woody vegetation (ie. Shrubs ad trees) other than those species which have been approved for removal
- All topsoil stockpiles to be surrounded with sediment control fencing.

DETAIL 4 - SEDIMENT CONTROL FILTER FENCE



NOTES:

1- TERRAFIX METRE BAGS TO BE FILLED WITH PEA GRAVEL (3/8") OR APPROVED EQUIVALENT.
2- HEIGHT OF FLOW-CHECK DAM 1.6 - 2.0 M (OR AS DIRECTED BY ENGINEER).
3- RUBBERGARD NON-REINFORCED EPDM MEMBRANE (OR APPROVED EQUIVALENT) TO ENSURE FLOW CHECK IS WATER TIGHT.

DETAIL 5 - TEMPORARY WATER TIGHT COFFER DAM

SCALE
1m 0
Horizontal

Appendix C –
Borehole Location Plan and Stratigraphic Section

Agreement No. 3015-E-0017
Assignment No. 2
GWP 3186-15-00

CONSTRUCTION OF CONCRETE FISH LADDER AT OUTLET OF THE EXISTING HEYROCK CREEK CULVERT

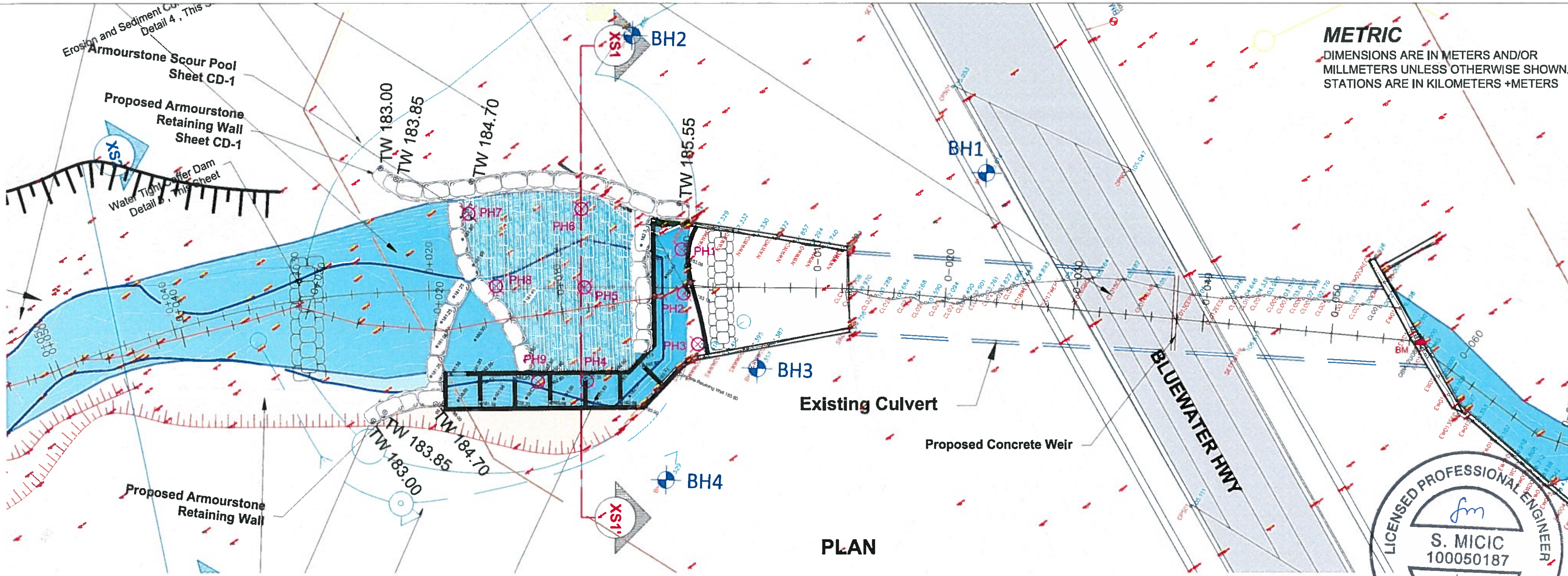
BOREHOLE LOCATION PLAN AND PROFILE

SHEET 1

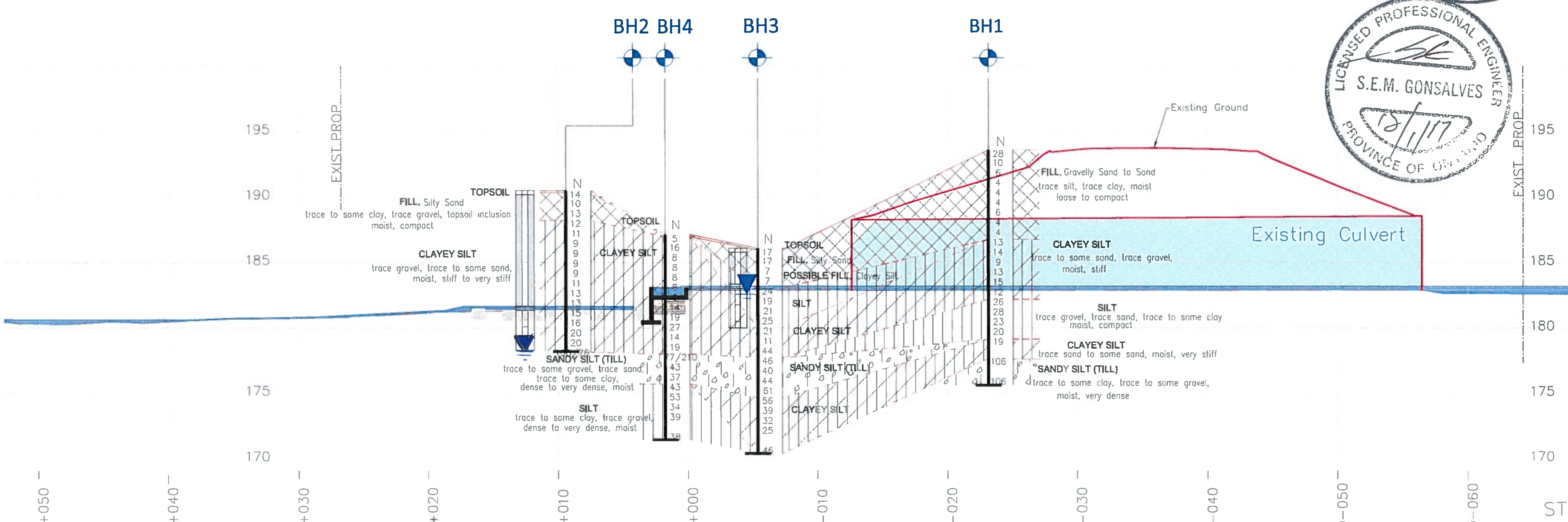
exp Services Inc.

METRIC

DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETERS +METERS



NOTE: THE PLAN AND PROFILE ARE PROVIDED BY MTO/ PARSONS.



PROFILE ALONG HEYROCK CREEK

LEGEND

- Location of Drilled Boreholes
- N — Standard Penetration Test (Blows/0.3 m)
- Water Level in Piezometer
- Bench Mark (EL. 188.57m)
- Proposed Probe Location
- Piezometer

SOIL STRATA SYMBOLS

- TOPSOIL
- SANDY SILT TILL
- FILL
- SILT
- CLAYEY SILT

BH No.	APPROX. ELEV.	MTM CO-ORDINATES	
		NORTH	EAST
BH1	193.6	4807741.8	369033.7
BH2	190.5	4807765.9	369016.8
BH3	186.0	4807739.3	369010.6
BH4	187.1	4807736.2	368999.9
GBM	188.57	4807712.1	369054.1

NOTE

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

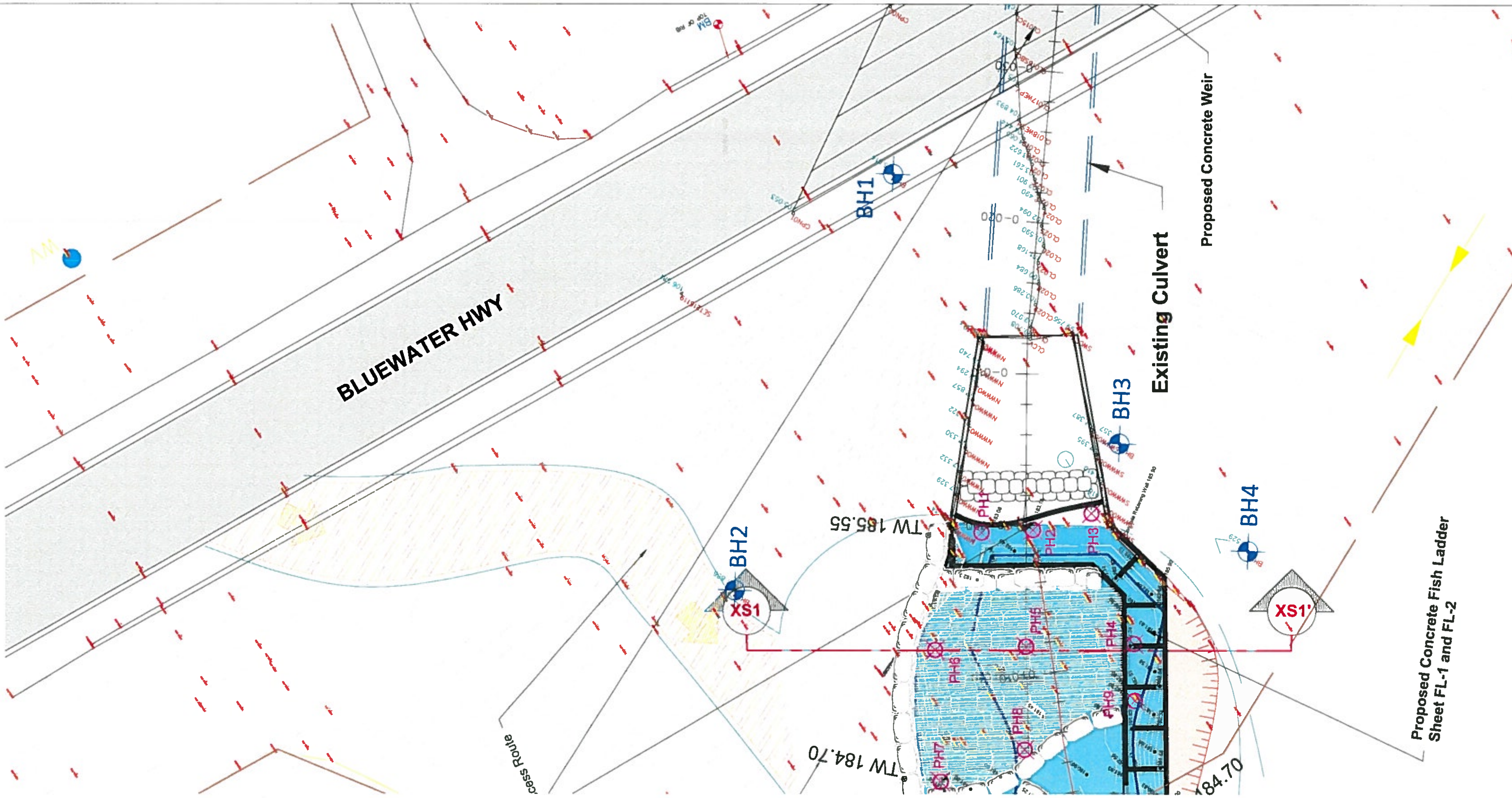
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section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

0 5 10 m
scale

DATE	BY	DESCRIPTION
15/12/2016	SM	SUBMISSION FOR MTO REVIEW

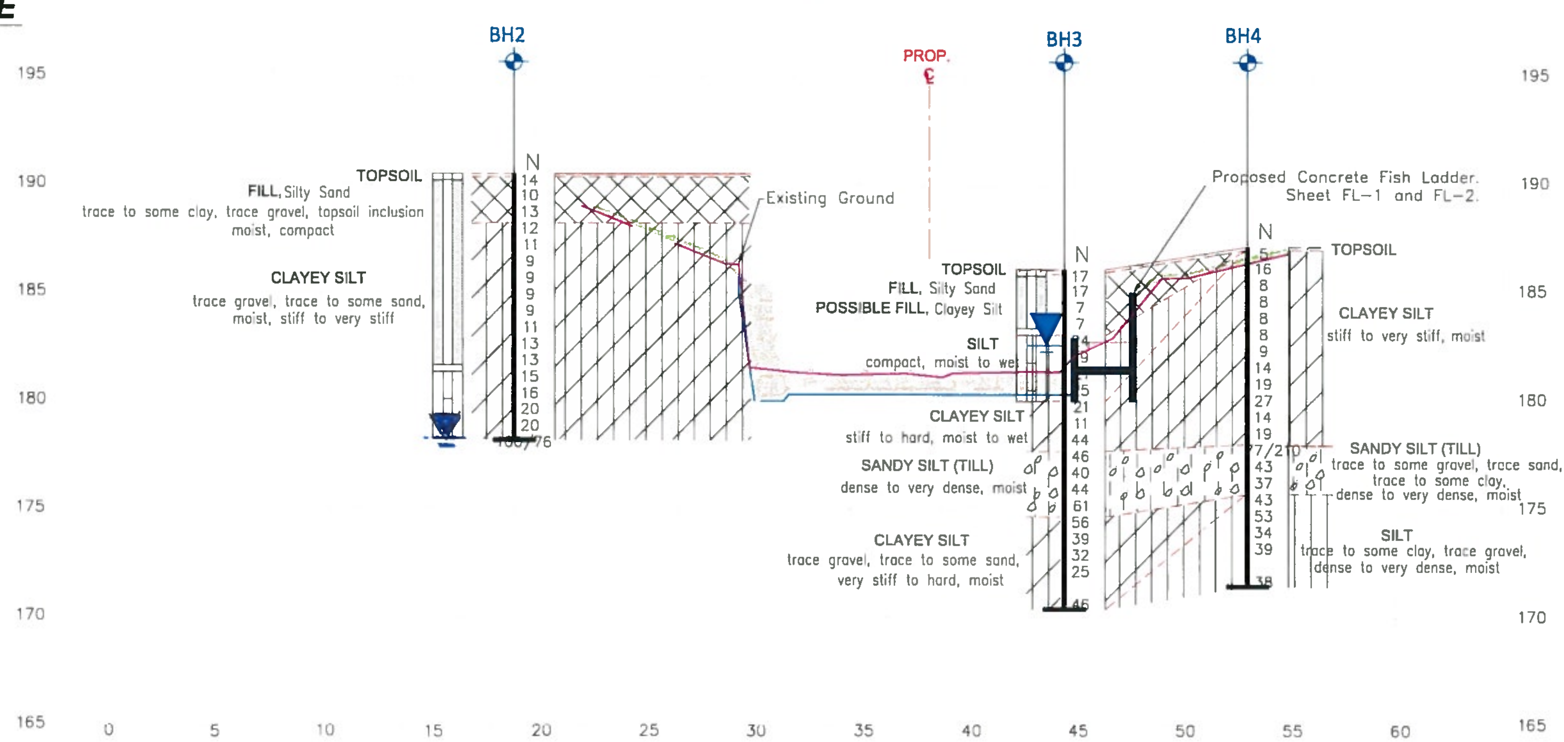
GEOCRES NO. 40P5-21
PROJECT NO. ADM-00235197-B0

SUBM'D SM	CHECKED SM	DATE	15/12/2016
DRAWN SH	CHECKED SG	APPROVED	DWG. 1



PLAN

NOTE: THE PLAN AND PROFILE ARE PROVIDED BY MTO/ PARSONS.



SECTION XS1-1'

METRIC

DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETERS +METERS

Agreement No. 3015-E-0017
Assignment No. 2
GWP 3186-15-00

CONSTRUCTION OF CONCRETE FISH LADDER AT OUTLET OF THE EXISTING HEYROCK CREEK CULVERT
BOREHOLE LOCATION PLAN AND PROFILE

SHEET 1

exp Services Inc.

LEGEND

- Location of Drilled Boreholes
- N — Standard Penetration Test (Blows/0.3 m)
- Water Level in Piezometer
- Bench Mark (EL. 188.57m)
- Proposed Probe Location
- Piezometer

SOIL STRATA SYMBOLS

- TOPSOIL
- SANDY SILT TILL
- FILL
- SILT
- CLAYEY SILT

BH No.	APPROX. ELEV.	MTM CO-ORDINATES	
		NORTH	EAST
BH1	193.6	4807741.8	369033.7
BH2	190.5	4807765.9	369016.8
BH3	186.0	4807739.3	369010.6
BH4	187.1	4807736.2	368999.9
GBM	188.57	4807712.1	369054.1

LICENSED PROFESSIONAL ENGINEER
S. MICIC
100050187
11/1/'17
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
S.E.M. GONSALVES
PROVINCE OF ONTARIO

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0 5 10 m
scale

DATE	BY	DESCRIPTION
04/01/2017	SM	SUBMISSION FOR MTO REVIEW

GEOCRES NO. 40P5-21
PROJECT NO. ADM-00235197-B0

SUBM'D SM	CHECKED SM	DATE	04/01/2017
DRAWN SH	CHECKED SG	APPROVED	DWG. 2

Appendix D – Borehole Logs

Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil: mixture of soil and humus capable of supporting good vegetative growth.

Peat: fibrous fragments of visible and invisible decayed organic matter.

Fill: where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

Till: the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

Desiccated: having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

Stratified: alternating layers of varying material or color with the layers greater than 6 mm thick.

Laminated: alternating layers of varying material or color with the layers less than 6 mm thick.

Fissured: material breaks along plane of fracture.

Varved: composed of regular alternating layers of silt and clay.

Slickensided: fracture planes appear polished or glossy, sometimes striated.

Blocky: cohesive soil that can be broken down into small angular lumps which resist further breakdown.

Lensed: inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

Well Graded: having wide range in grain sized and substantial amounts of all predominantly on grain size.

Uniformly Graded: predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.

ISSMFE SOIL CLASSIFICATION

CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		

0.002 0.006 0.02 0.06 0.2 0.6 2.0 6.0 20 60 200

EQUIVALENT GRAIN DIAMETER IN MILLIMETRES

CLAY (PLASTIC) TO	FINE	MEDIUM	CRS.	FINE	COARSE
SILT (NONPLASTIC)	SAND			GRAVEL	

UNIFIED SOIL CLASSIFICATION

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Note 16 in ASTM D2488-09a:

Table a: Percent or Proportion of Soil, Pp

	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	5≤Pp≤10%
Little	15≤Pp≤25%
Some	30≤Pp≤45%
Mostly	50≤Pp≤100%

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	N<5
Loose	5≤N<10
Compact	10≤N<30
Dense	30≤N<50
Very Dense	50≤N

The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

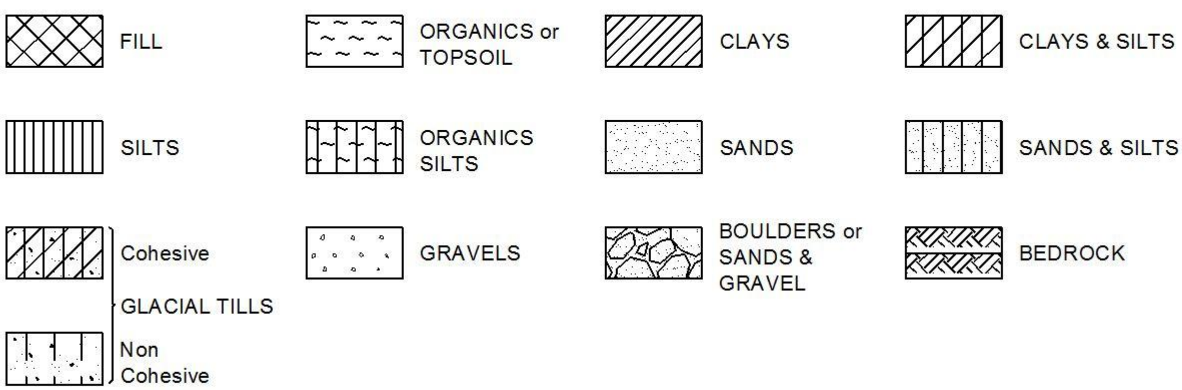
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



WATER LEVEL MEASUREMENT

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

STRESS AND STRAIN

u_w	kPa	Pore water pressure
r_u	1	Pore pressure ratio
σ	kPa	Total normal stress
σ'	kPa	Effective normal stress
τ	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
ε	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
μ	1	Coefficient of friction

MECHANICALL PROPERIES OF SOIL

m_v	kPa^{-1}	Coefficient of volume change
c_c	1	Compression index
c_s	1	Swelling index
c_r	1	Recompression index
c_v	m^2/s	Coefficient of consolidation
H	m	Drainage path
T_V	1	Time factor
U	%	Degree of consolidation
σ'_{v0}	kPa	Effective overburden pressure
σ'_P	kPa	Preconsolidation pressure
τ_f	kPa	Shear strength
c'	kPa	Effective cohesion intercept
ϕ'	$-^\circ$	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	$-^\circ$	Apparent angle of internal friction
τ_R	kPa	Residual shear strength
τ_r	kPa	Remoulded shear strength
S_t	1	Sensitivity = c_u/τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m^3	Density of solid particles
γ_s	kN/m^3	Unit weight of solid particles
ρ_w	kg/m^3	Density of water
γ_w	kN/m^3	Unit weight of water
ρ	kg/m^3	Density of soil
γ	kN/m^3	Unit weight of soil
ρ_d	kg/m^3	Density of dry soil
γ_d	kN/m^3	Unit weight of dry soil
ρ_{sat}	kg/m^3	Density of saturated soil
γ_{sat}	kN/m^3	Unit weight of saturated soil
ρ'	kg/m^3	Density of submerged soil
γ'	kN/m^3	Unit weight of submerged soil
e	1, %	Void ratio
n	1, %	Porosity
w	1, %	Water content
S_r	%	Degree of saturation
W_L	%	Liquid limit
W_P	%	Plastic limit
W_s	%	Shrinkage limit
I_P	%	Plasticity index = $(W_L - W_P)$
I_L	%	Liquidity index = $(W - W_P)/I_P$
I_C	%	Consistency index = $(W_L - W)/I_P$
e_{max}	1, %	Void ratio in loosest state
e_{min}	1, %	Void ratio in densest state
I_D	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
D_n	mm	N percent - diameter
C_u	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m^3/s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m^3	Seepage force

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Brampton, Ontario

RECORD OF BOREHOLE No BH-1

METRIC

W. P. 3186-15-00	LOCATION Heyrock Creek MTM ON11 4807742N, 369034E	ORIGINATED BY RW	
DIST Bluewater Mun. HWY Hwy 21	BOREHOLE TYPE Continuous Flight Hollow Stem Augers	COMPILED BY NT	
DATUM Geodetic	DATE 2016/11/07 - 2016/11/07	CHECKED BY SM	

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
193.6	Road Surface						
	FILL: GRAVELLY SAND TO SAND - trace silt, trace clay, brown, moist loose to compact	1	SS	28			
		2	SS	10	193		22 69 (9)
		3	SS	6	192		
		4	SS	4	191		
		5	SS	4			
		6	SS	4	190		
		7	SS	6	189		
		8	SS	4	188		10 81 (9)
		9	SS	4	187		
186.7 / 6.9	**CLAYEY SILT** - trace to some sand, trace gravel, grey, moist, stiff	10	SS	13			
		11	SS	14	186		PP = 294 kPa
		12	SS	9	185		1 10 47 42
		13	SS	13			PP = 147 kPa
		14	SS	15	184		
		15	SS	12	183		PP = 196 kPa
182.2 / 11.4	**SILT** - trace gravel, trace sand, trace to some clay, grey, moist, compact	16	SS	26	182		

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

Continued Next Page

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

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RECORD OF BOREHOLE No BH-1

METRIC

W. P. 3186-15-00 | LOCATION Heyrock Creek MTM ON11 4807742N, 369034E | ORIGINATED BY RW

DIST Bluewater Mun. HWY Hwy 21 | BOREHOLE TYPE Continuous Flight Hollow Stem Augers | COMPILED BY NT

DATUM Geodetic | DATE 2016/11/07 - 2016/11/07 | CHECKED BY SM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILT - trace gravel, trace sand, trace to some clay, grey, moist, compact *(continued)*	17	SS	28	181	o	
		18	SS	23	180	o	0 2 73 25
		19	SS	20		o	
179.1 / 14.5	**CLAYEY SILT** - trace to some sand, grey, moist, very stiff	20	SS	19	179	wP–w–wL	PP = 196 kPa; 3 15 45 37
					178		
177.6 / 16.0	**SANDY SILT (TILL)**- trace to some clay, trace to some gravel, grey, moist, very dense	21	SS	106	177	o	11 36 (53)
		22	SS	106	176	o	
175.6 / 18.0	**End of Borehole at 18 m depth**						

Notes:
1. This borehole log is to be read with the subject report and project numbers as presented above.
2. Groundwater level was dry in open hole upon completion of drilling.
3. Hole open upto 17.5 m upon completion

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

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

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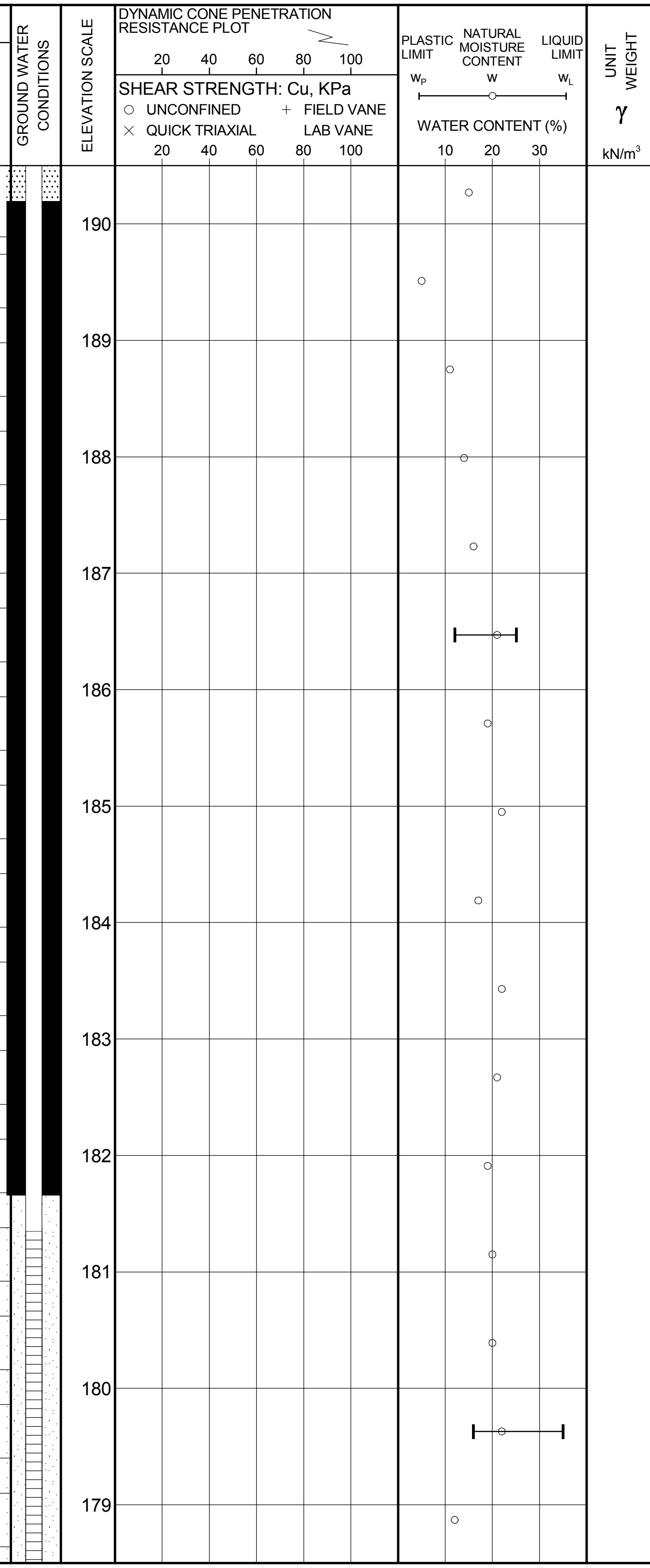
Foundation Design

RECORD OF BOREHOLE No BH-2

METRIC

W. P.	3186-15-00	LOCATION	Heyrock Creek MTM ON 11 4807765N, 369017E	ORIGINATED BY	RW
DIST	Bluewater Mun. HWY Hwy 21	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers	COMPILED BY	NT
DATUM	Geodetic	DATE	2016/11/08 - 2016/11/08	CHECKED BY	SM

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
190.5	Ground Surface				
190.4 / 0.2	**TOPSOIL** - 152 mm topsoil; **FILL: SILTY SAND** - trace to some clay, trace gravel, topsoil inclusion, brown, moist, compact	1	SS	14	
		2	SS	10	5 50 (45)
		3	SS	13	
188.2 / 2.3	**CLAYEY SILT** - trace gravel, trace to some sand, brown to grey, moist, stiff to very stiff	4	SS	12	
		5	SS	11	PP = 245 kPa
		6	SS	9	2 21 48 29
		7	SS	9	
		8	SS	9	PP = 196 kPa
		9	SS	9	
		10	SS	11	1 5 47 47
		11	SS	13	
		12	SS	13	
		13	SS	15	PP = 196 kPa
		14	SS	16	
		15	SS	20	1 4 49 46
	- unexpected auger refusal @ 11.4 m, drilled another borehole within approx. 1.5 m perimeter of original BH	16	SS	20	



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

RECORD OF BOREHOLE No BH-2

METRIC

W. P. 3186-15-00	LOCATION Heyrock Creek MTM ON 11 4807765N, 369017E	ORIGINATED BY RW
DIST Bluewater Mun. HWY Hwy 21	BOREHOLE TYPE Continuous Flight Hollow Stem Augers	COMPILED BY NT
DATUM Geodetic	DATE 2016/11/08 - 2016/11/08	CHECKED BY SM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH: Cu, 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	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
									○		
178.2 12.3	-hit large stone @ 12.25 m, Split Spoon/ auger refusal **Split Spoon/ Auger Refusal at 12.25 m (Possible boulder encountered)** **End of Borehole** Notes: 1. This borehole log is to be read with the subject report and project numbers as presented above. 2. Groundwater monitoring well installed to depth 12.2 m. Date Water Level Elevation(m) Upon Completion dry Jan. 4, 2017 178.2 m		17	SS	100/ 76 mm						

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

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RECORD OF BOREHOLE No BH-3

METRIC

W. P. 3186-15-00 | LOCATION Heyrock Creek MTM ON 11 4807739N, 369011E | ORIGINATED BY RW

DIST Bluewater Mun. HWY Hwy 21 | BOREHOLE TYPE Continuous Flight Hollow Stem Augers | COMPILED BY NT

DATUM Geodetic | DATE 2016/11/09 - 2016/11/09 | CHECKED BY SM

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH: Cu, 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; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV / DEPTH	DESCRIPTION
186.0	**Ground Surface**
185.8 / 0.1	**TOPSOIL** 125 mm thickness trace organics, dark brown, moist
	FILL: SILTY SAND trace to some gravel, trace to some clay , topsoil inclusion, brown, moist, compact
184.5 / 1.5	**POSSIBLE FILL: CLAYEY SILT** trace gravel, trace sand, grey, firm, moist
182.9 / 3.1	**SILT** trace to some sand, trace to some gravel, trace clay, grey, compact, moist to wet
	- becoming gravely sand @ 4.6 m
179.9 / 6.1	**CLAYEY SILT** trace gravel, trace sand, grey, stiff to hard, moist to wet
	- Stone in tip of spoon @ 7.65 m
177.6 / 8.4	**SANDY SILT (TILL)** trace to some gravel, trace to some clay, grey, dense to very dense, moist
174.5 / 11.4	**CLAYEY SILT** trace gravel, trace to some sand, grey, very stiff to hard, moist

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	17	
2	SS	17	
3	SS	7	0 25 (75)
4	SS	7	
5	SS	24	
6	SS	19	
7	SS	21	14 71 (15)
8	SS	25	
9	SS	21	PP = 294 kPa; 3 6 51 40
10	SS	11	
11	SS	44	
12	SS	46	24 27 (49); PP = 441 kPa
13	SS	40	
14	SS	44	
15	SS	61	
16	SS	56	

Elevation scale: 185, 184, 183, 182, 181, 180, 179, 178, 177, 176, 175

Continued Next Page

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

RECORD OF BOREHOLE No BH-3

METRIC

W. P.	3186-15-00	LOCATION	Heyrock Creek MTM ON 11 4807739N, 369011E	ORIGINATED BY	RW
DIST	Bluewater Mun. HWY Hwy 21	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers	COMPILED BY	NT
DATUM	Geodetic	DATE	2016/11/09 - 2016/11/09	CHECKED BY	SM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT trace gravel, trace to some sand, grey, very stiff to hard, moist *(continued)*		17	SS	39					PP = 245 kPa
							173			
			18	SS	32					5 15 43 37
			19	SS	25		172			
							171			
170.3			20	SS	46					
15.7	**End of Borehole**									

Plot legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH: Cu, 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.

Notes:
1. This borehole log is to be read with the subject report and project numbers as presented above.
2. Groundwater monitoring well installed to depth 6.1 m.

Date	Water Level Elevation(m)
Upon Completion	(182.0 m)
Nov. 11, 2016	(182.5 m)
Jan. 04, 2017	(183.0 m)

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

RECORD OF BOREHOLE No BH-4

METRIC

W. P. 3186-15-00	LOCATION Heyrock Creek MTM ON 11 4807736N, 368100E		ORIGINATED BY RW
DIST Bluewater Mun.	HWY Hwy 21	BOREHOLE TYPE Continuous Flight Hollow Stem Augers	COMPILED BY NT
DATUM Geodetic	DATE 2016/11/10 - 2016/11/11		CHECKED BY SM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
187.1	**Ground Surface**					
187.0 / 0.2	**TOPSOIL** 152 mm thickness trace organics, dark brown, moist				187	
	CLAYEY SILT some silty sand, trace gravel, ,brown to grey,stiff to very stiff, moist	1	SS	5		
		2	SS	16	186	
		3	SS	8	185	
		4	SS	8		PP = 147 kPa 3 9 45 43
		5	SS	8	184	
		6	SS	8	183	
		7	SS	9		PP = 196 kPa 0 6 49 45
		8	SS	14	182	
		9	SS	19	181	1 3 61 35
		10	SS	27	180	
		11	SS	14	179	PP = 343 kPa
		12	SS	19		
178.0 / 9.1	**SANDY SILT (TILL)** trace to some gravel, trace to some clay, grey, dense to very dense, moist	13	SS	77/ 210 mm	178	
		14	SS	43	177	
		15	SS	37	176	
175.7 / 11.4	**SILT** trace to some clay, trace gravel, grey, dense to very dense, moist -Large stone in spoon tip @ 11.45 m,	16	SS	43		

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH: Cu, 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

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

RECORD OF BOREHOLE No BH-4

METRIC

W. P.	3186-15-00	LOCATION	Heyrock Creek MTM ON 11 4807736N, 368100E	ORIGINATED BY	RW
DIST	Bluewater Mun. HWY Hwy 21	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers	COMPILED BY	NT
DATUM	Geodetic	DATE	2016/11/10 - 2016/11/11	CHECKED BY	SM

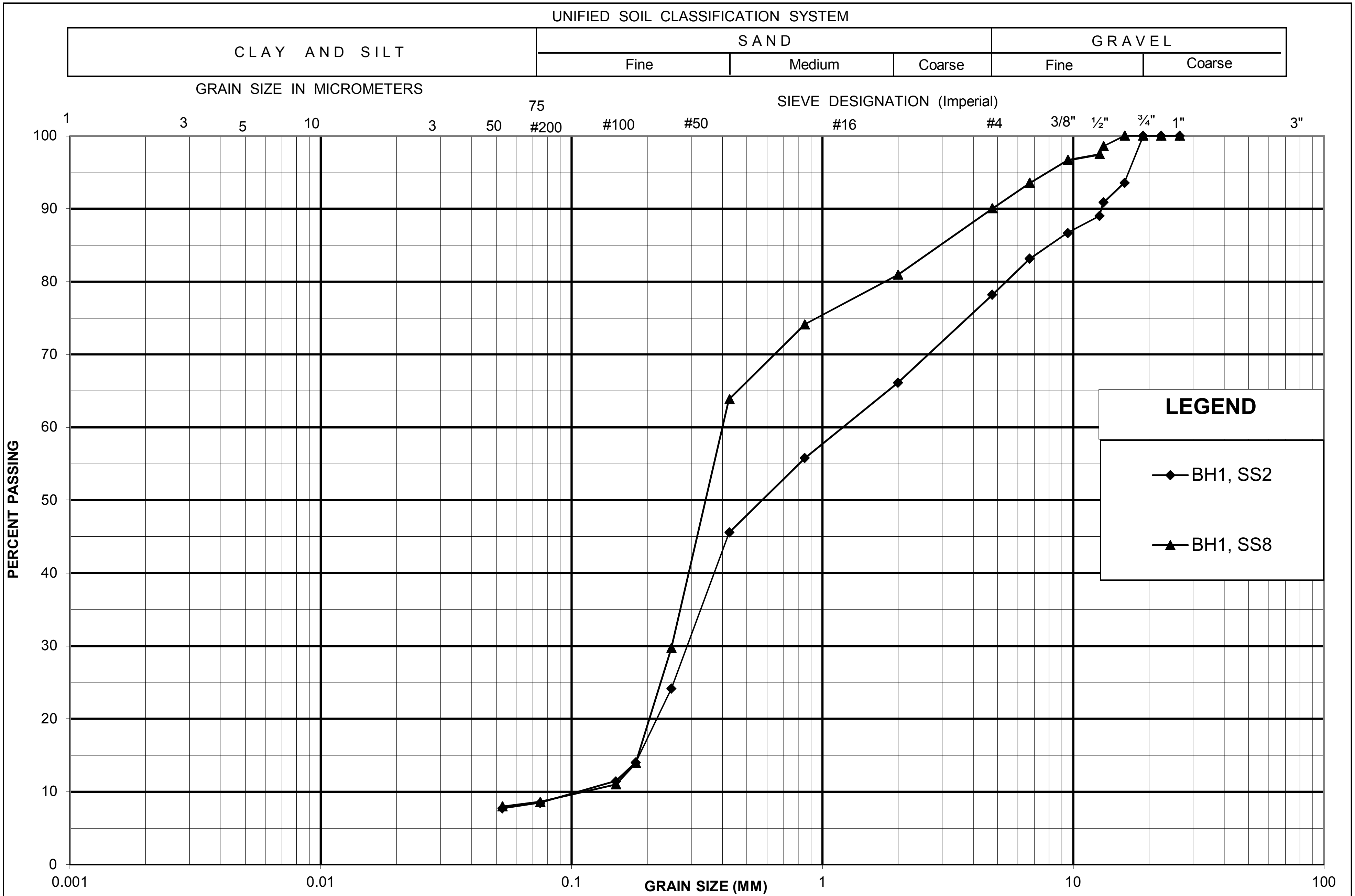
ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%) w
	no sample recover **SILT** trace to some clay, trace gravel, grey, dense to very dense, moist *(continued)*				175	
		17	SS	53		o
		18	SS	34	174	o
		19	SS	39		o
					173	
					172	
	-becoming clayey silt @ 15.25 m	20	SS	38		o
171.4 / 15.7	**End of Borehole**					

Notes:
1. This borehole log is to be read with the subject report and project numbers as presented above.
2. Groundwater level was dry in open hole upon completion of drilling.
3. Hole open upto 15.25 m upon completion

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH: Cu, 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; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

Appendix E – Laboratory Data

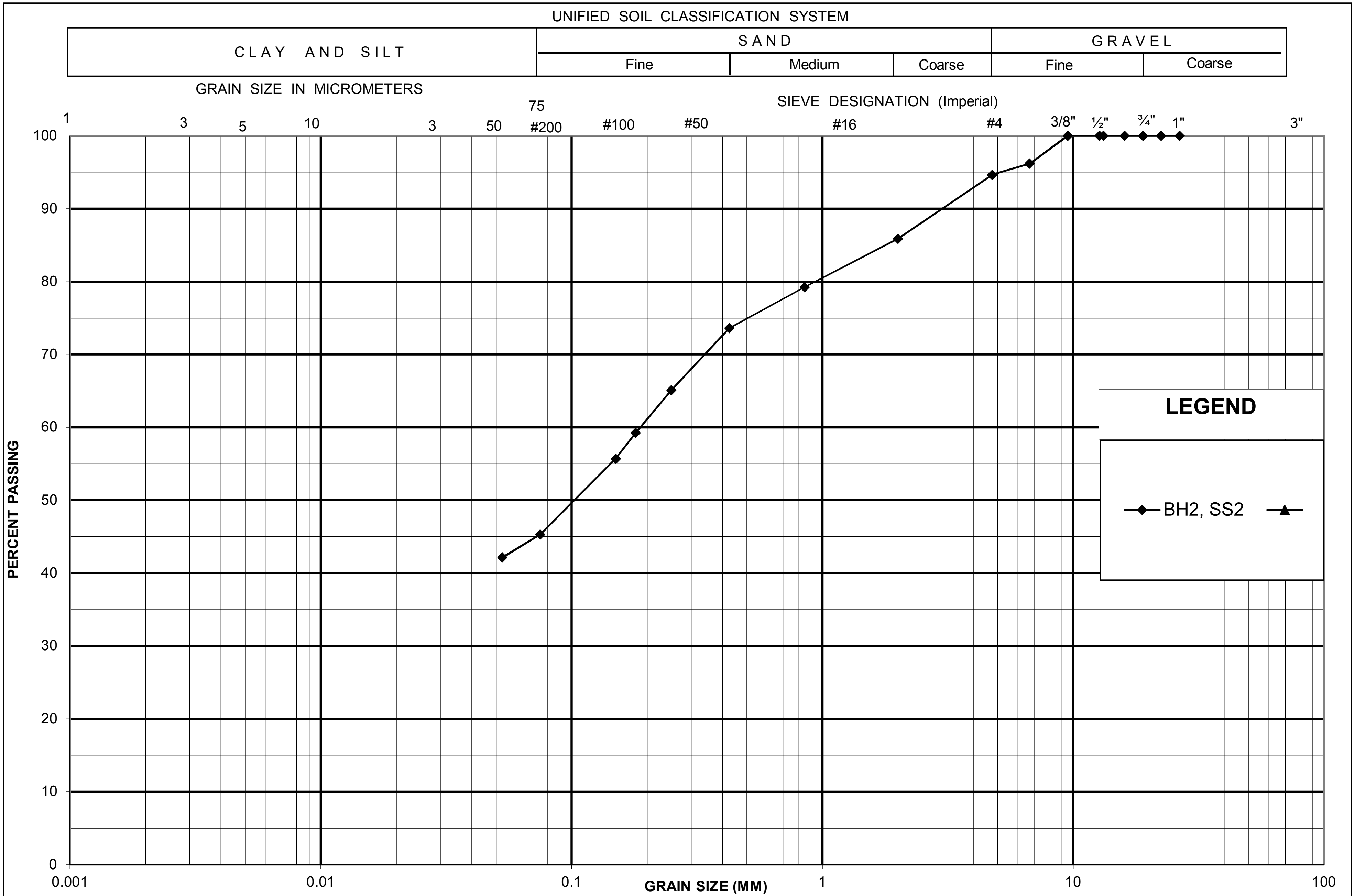


exp.

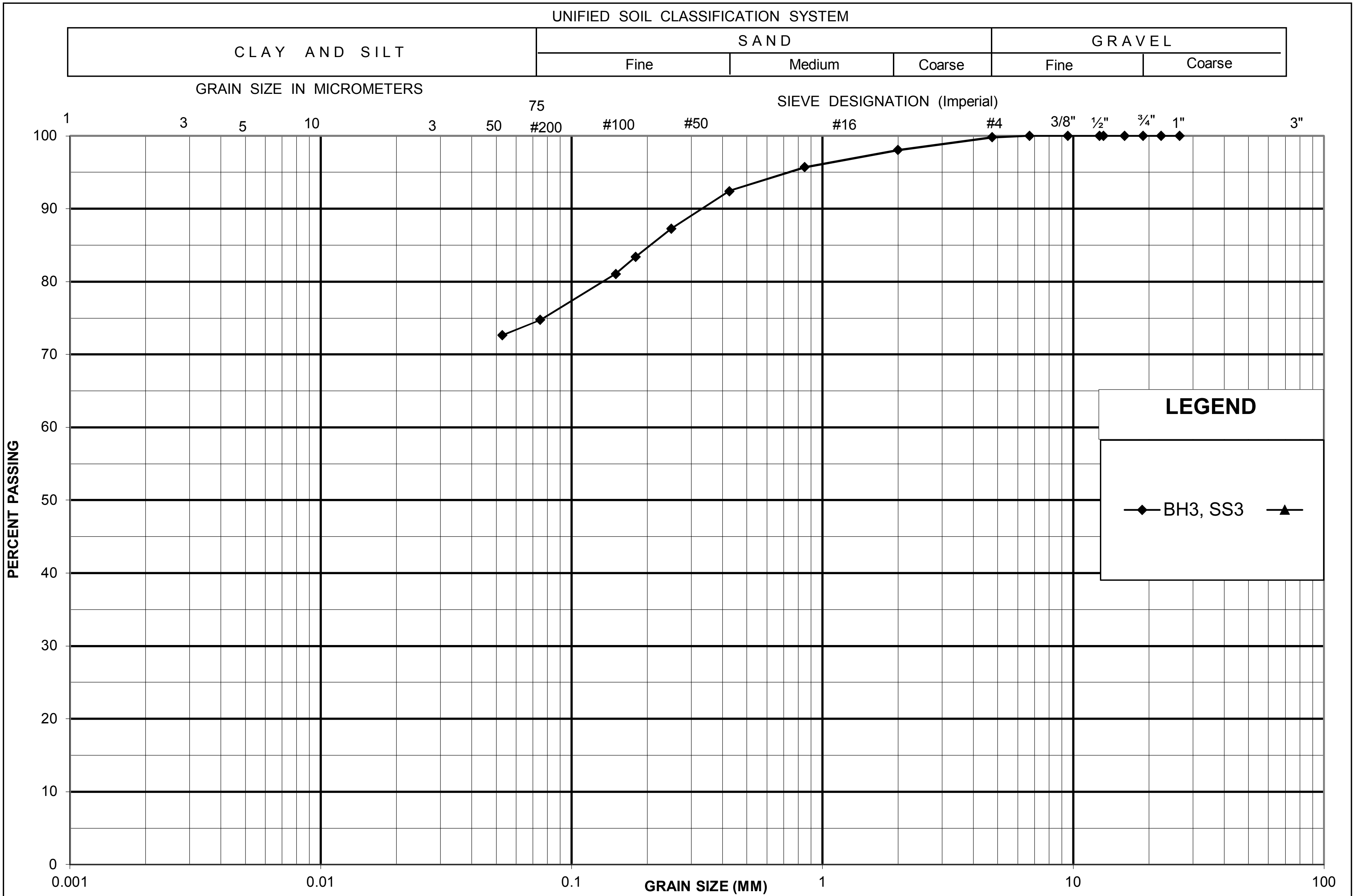
GRAIN SIZE DISTRIBUTION

FILL: GRAVELLY SAND TO SAND

FIGURE No. 1	
GWP :	3186-15-00
DATE	November, 2016



exp.	GRAIN SIZE DISTRIBUTION ***FILL: SILTY SAND***	FIGURE No. 2 GWP : 3186-15-00 DATE November, 2016



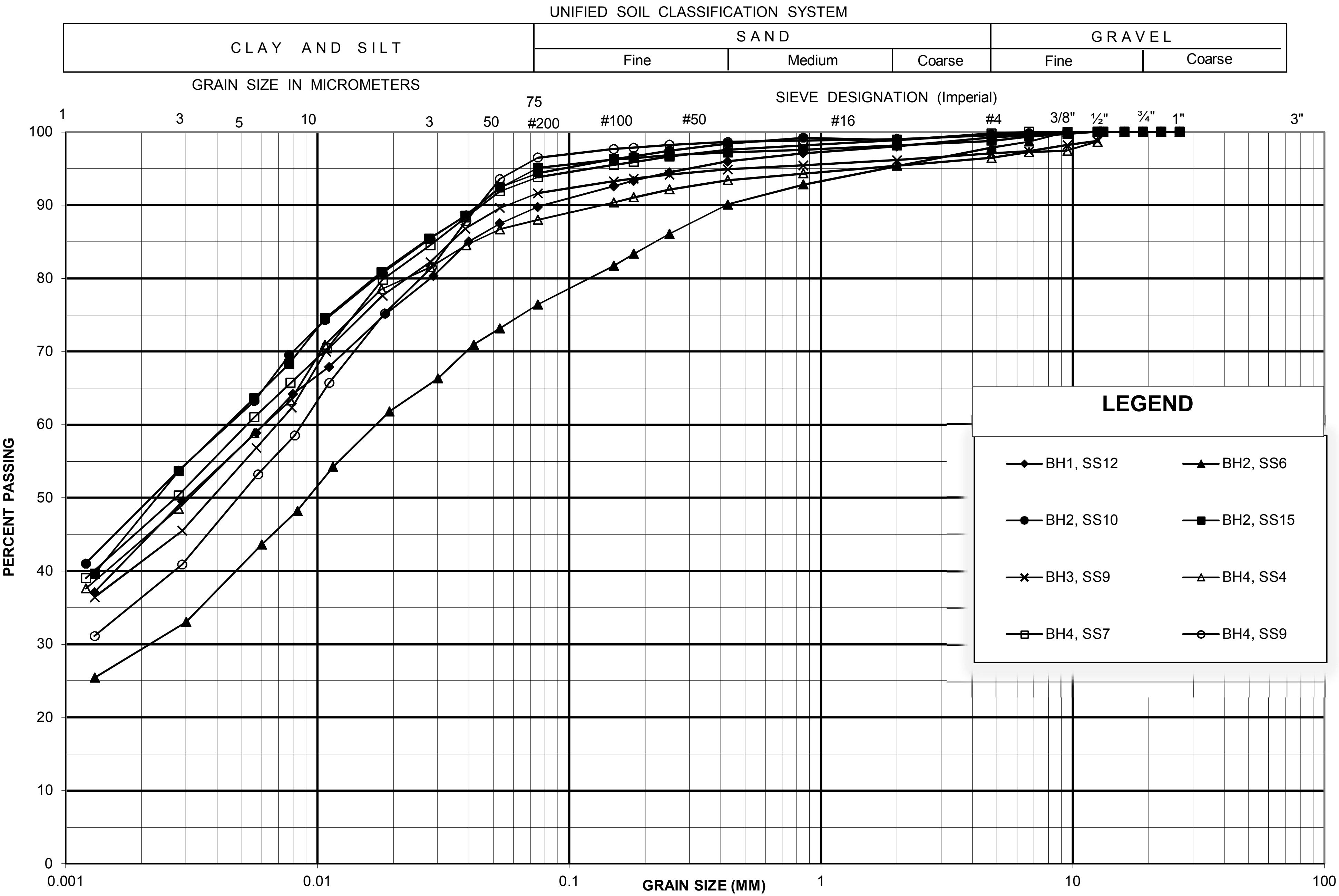
GRAIN SIZE DISTRIBUTION

POSSIBLE FILL: CLAYEY SILT

FIGURE No. 3

GWP : 3186-15-00

DATE November, 2016

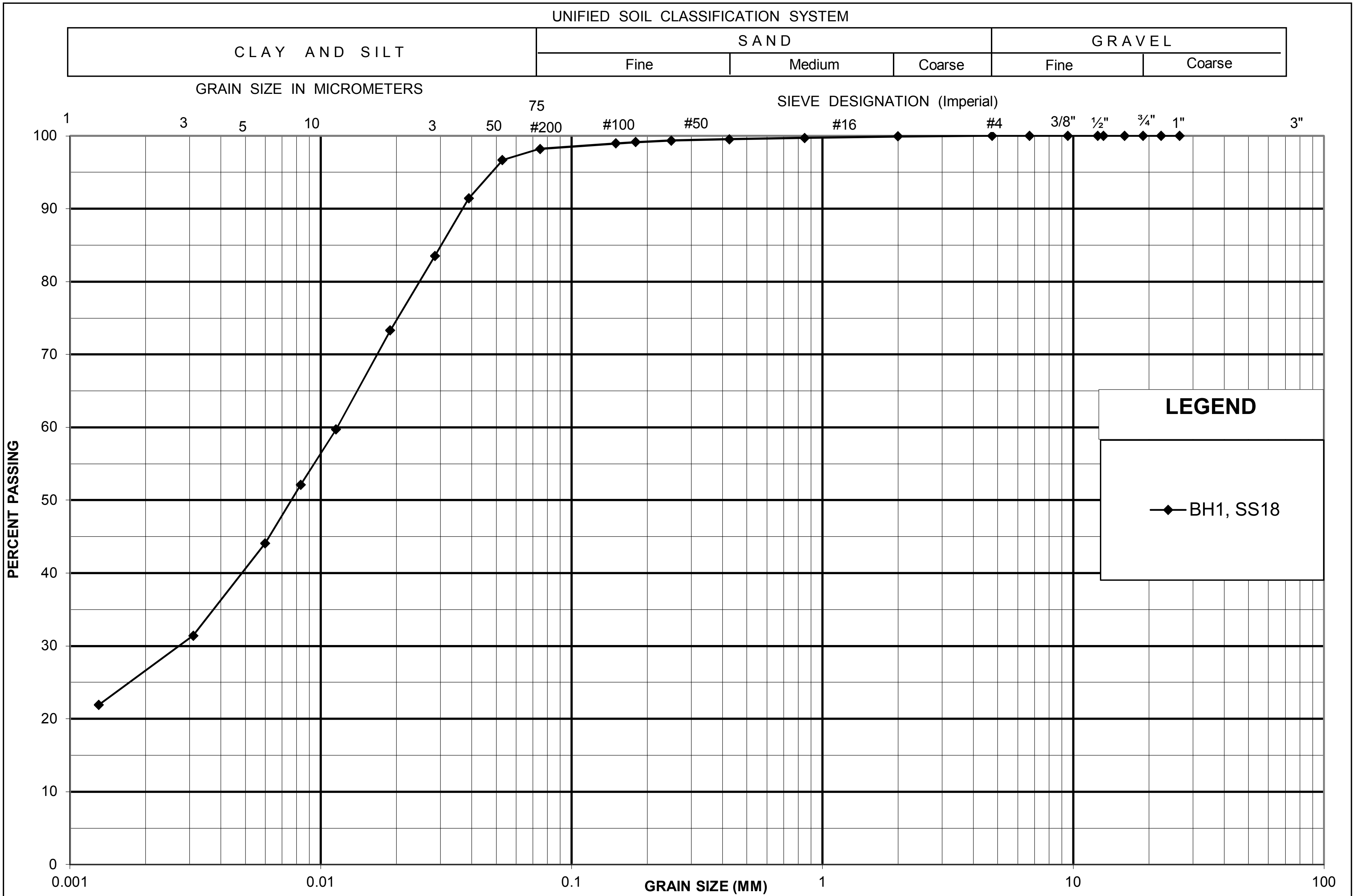


exp.

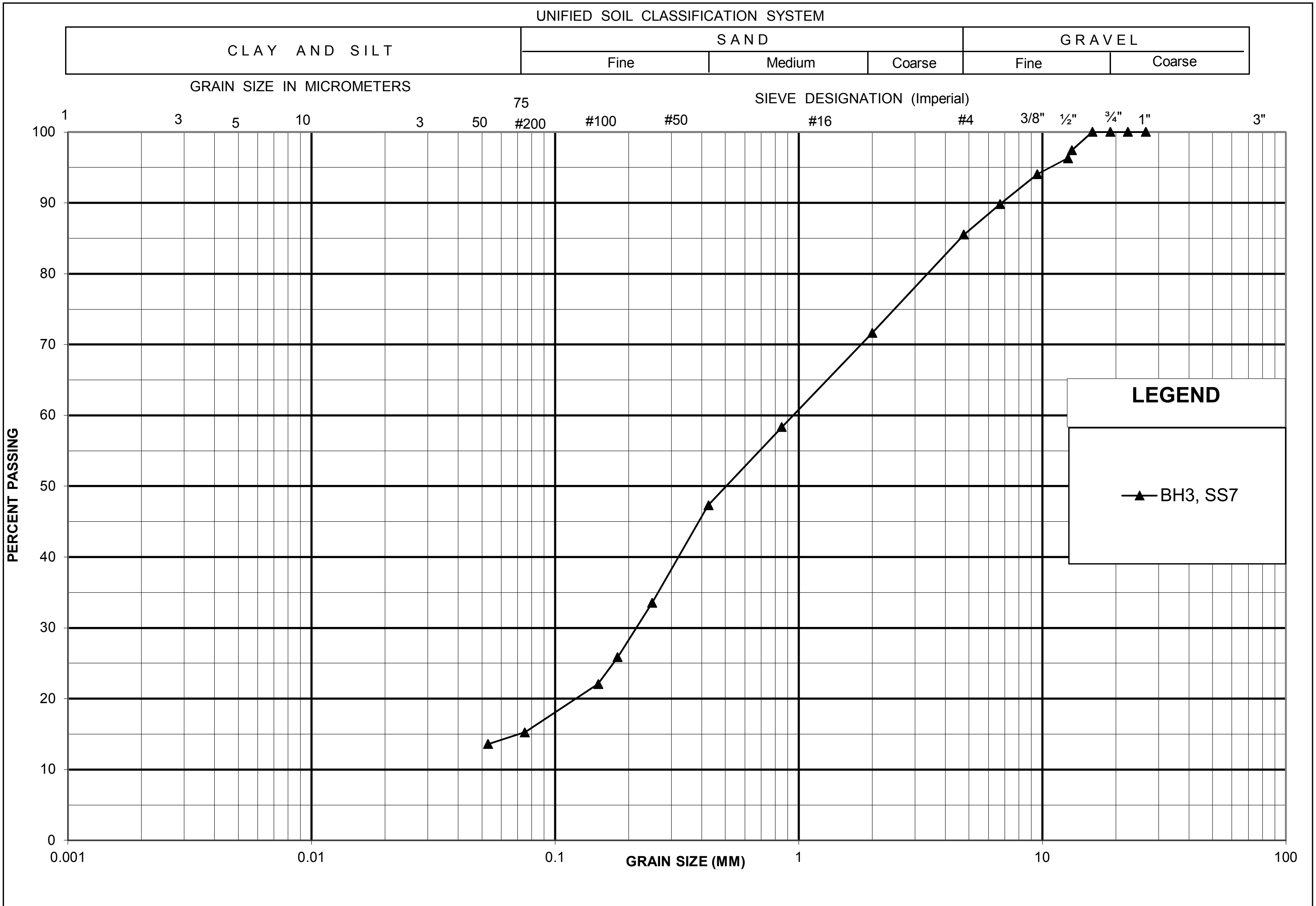
GRAIN SIZE DISTRIBUTION

CLAYEY SILT(UPPER)

FIGURE No. 4	
GWP : 3186-15-00	
DATE	November, 2016



exp.	GRAIN SIZE DISTRIBUTION ***SILT***	FIGURE No. 5 GWP : 3186-15-00 DATE November, 2016



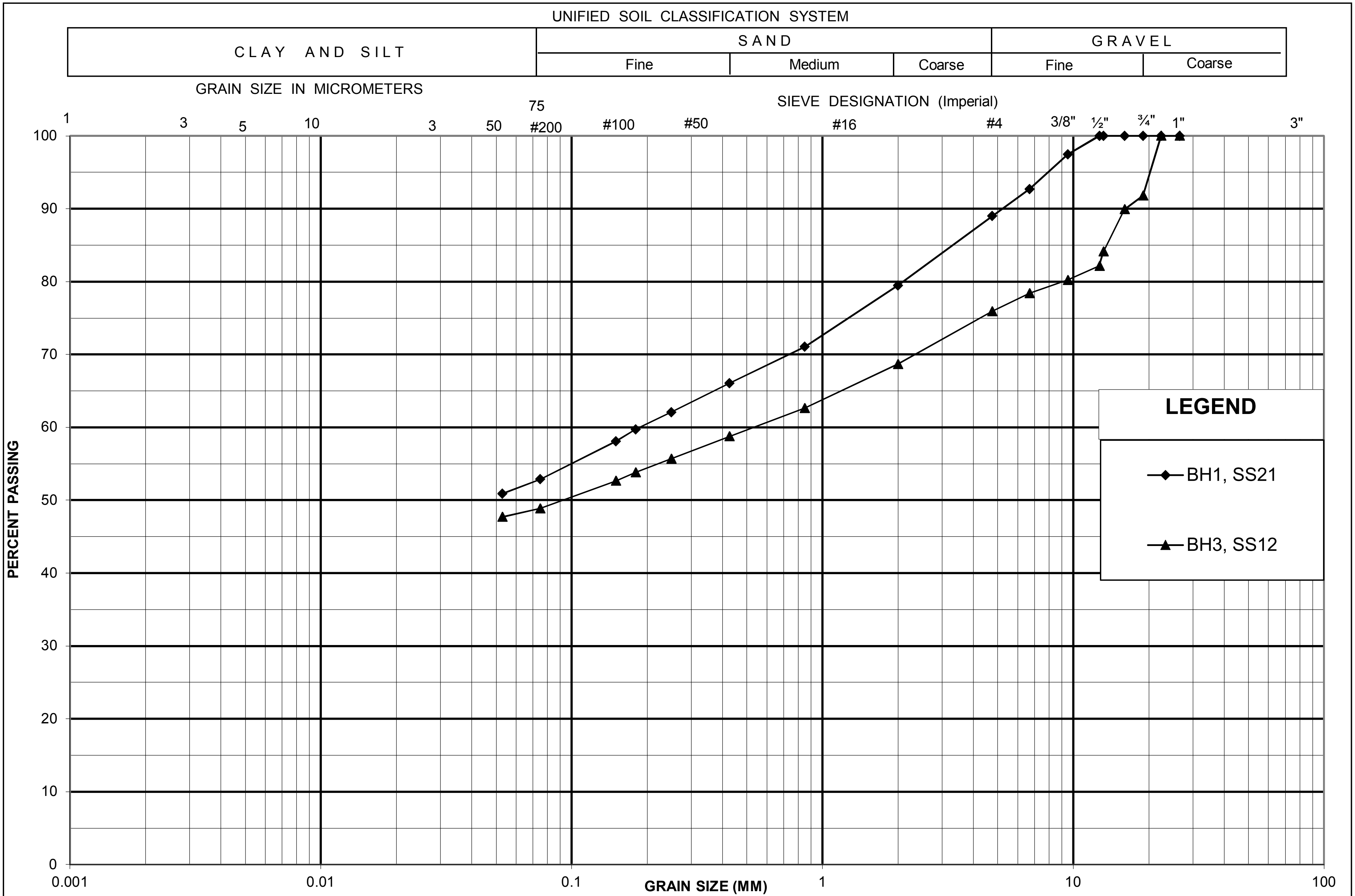
GRAIN SIZE DISTRIBUTION

GRAVELLY SAND

FIGURE No. 6

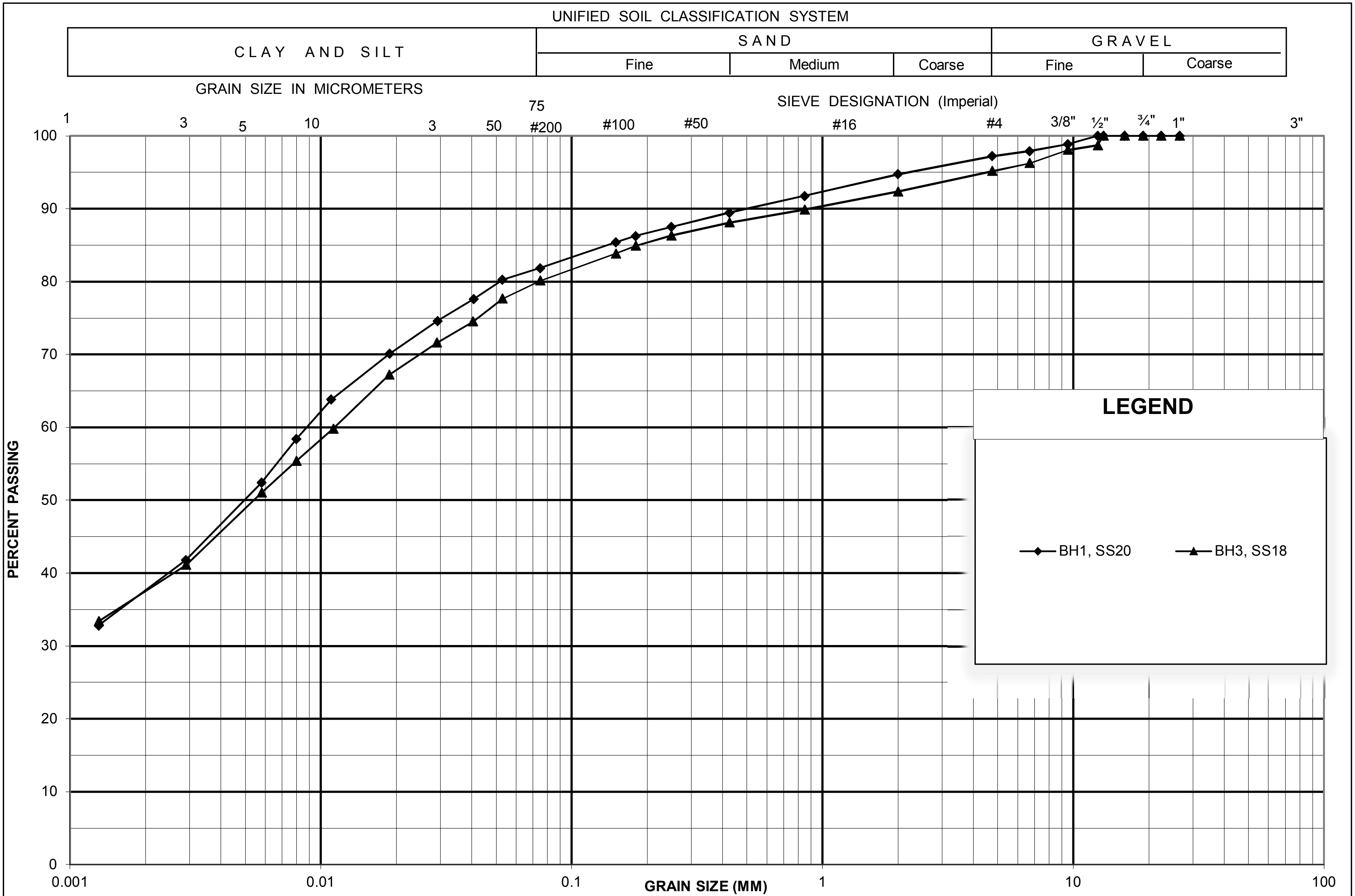
GWP : 3186-15-00

DATE November, 2016



exp.	**GRAIN SIZE DISTRIBUTION** ***SANDY SILT(TILL)***

FIGURE No. 7
GWP : 3186-15-00
DATE November, 2016



exp.

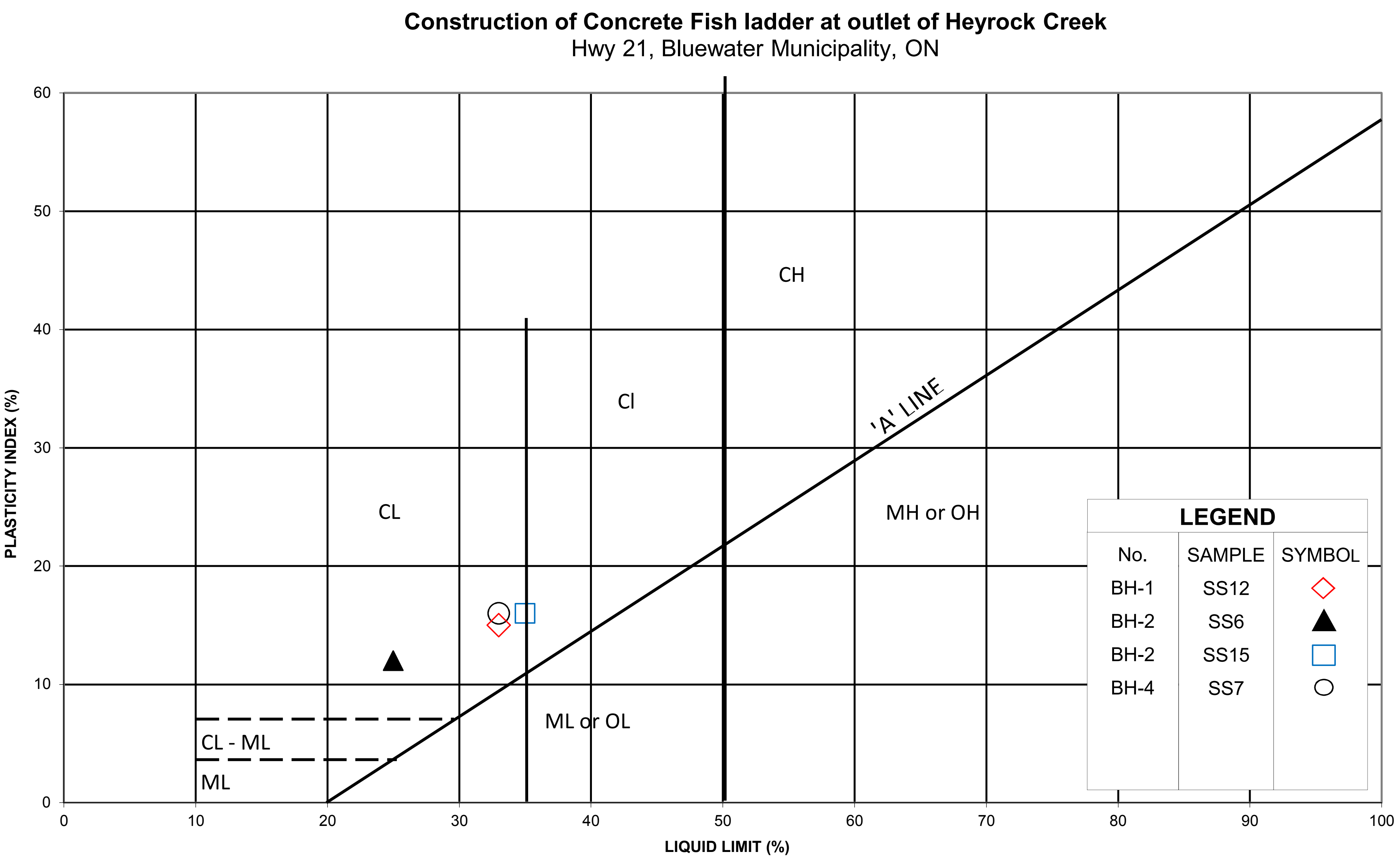
GRAIN SIZE DISTRIBUTION

CLAYEY SILT(LOWER)

FIGURE No. 8

GWP : 3186-15-00

DATE November, 2016



PLASTICITY CHART

Clayey Silt (Upper)

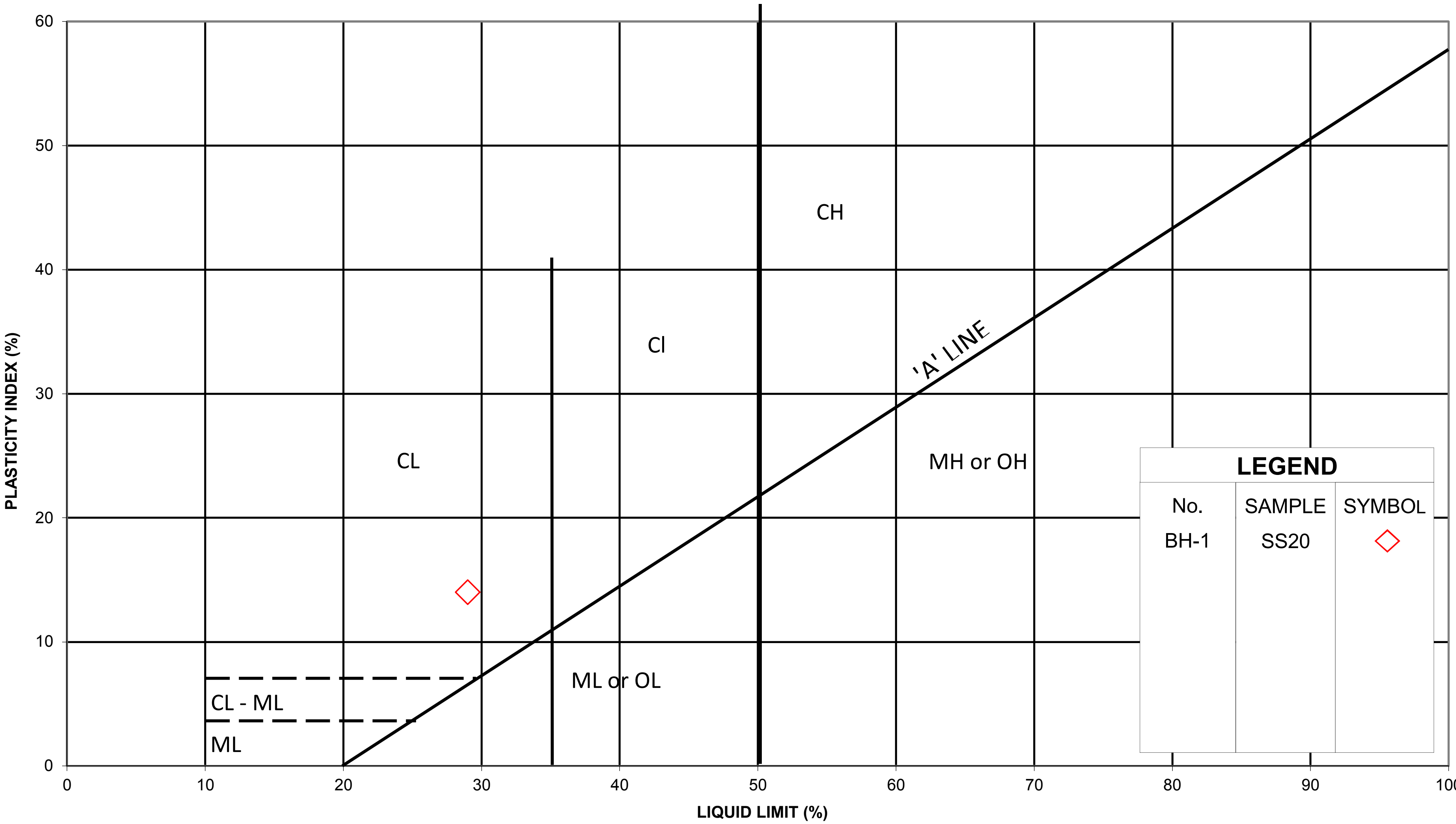
FIGURE NO.: 9

GWP: 3186-15-00

DATE: November 2016

Construction of Concrete Fish ladder at outlet of Heyrock Creek

Hwy 21, Bluewater Municipality, ON



LEGEND		
No.	SAMPLE	SYMBOL
BH-1	SS20	◇

exp.	PLASTICITY CHART ***Clayey Silt (Lower)***	FIGURE NO.: 10 GWP: 3186-15-00 DATE: November 2016

Appendix F –
Chemical Analyses

Your P.O. #: GEO
Your Project #: ADM-00235197-130
Site Location: HWY 21
Your C.O.C. #: na

Attention:Nimesh Tamrakar

exp Services Inc
1595 Clark Blvd
Brampton, ON
L6T 4V1

Report Date: 2016/11/21
Report #: R4253783
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6O6837
Received: 2016/11/14, 09:38

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	1	N/A	2016/11/17	CAM SOP-00463	EPA 325.2 m
Conductivity	1	N/A	2016/11/16	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	1	2016/11/17	2016/11/17	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2016/11/14	2016/11/17	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	1	N/A	2016/11/18	CAM SOP-00464	EPA 375.4 m
Oxidation-Reduction Potential (1, 2)	1	2016/11/16	2016/11/21	SLA SOP-00101	In house

Remarks:

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All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods. Results relate to samples tested.
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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Maxxam Sladeview Petrochemical
(2) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Your P.O. #: GEO
Your Project #: ADM-00235197-130
Site Location: HWY 21
Your C.O.C. #: na

Attention:Nimesh Tamrakar

exp Services Inc
1595 Clark Blvd
Brampton, ON
L6T 4V1

Report Date: 2016/11/21
Report #: R4253783
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6O6837
Received: 2016/11/14, 09:38

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Sara Singh, B.Sc, Senior Project Manager
Email: sarasingh@maxxam.ca
Phone# (905)817-5730
==
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A Bureau Veritas Group Company

Maxxam Job #: B6O6837
Report Date: 2016/11/21

exp Services Inc
Client Project #: ADM-00235197-130
Site Location: HWY 21
Your P.O. #: GEO
Sampler Initials: RT

SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		DLD976	DLD976		
Sampling Date		2016/11/14 08:50	2016/11/14 08:50		
COC Number		na	na		
	UNITS	**BH3 (SS5)**	**BH3 (SS5) Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters					
Resistivity	ohm-cm	3900			4746791
Inorganics					
Soluble (20:1) Chloride (Cl)	ug/g	39	41	20	4751032
Conductivity	umho/cm	257		2	4749169
Available (CaCl2) pH	pH	7.82			4750836
Soluble (20:1) Sulphate (SO4)	ug/g	110	100	20	4751033
Subcontracted Analysis					
Oxidation-Reduction Potential	mV	+174			4750837

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

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Maxxam Job #: B6O6837
Report Date: 2016/11/21

exp Services Inc
Client Project #: ADM-00235197-130
Site Location: HWY 21
Your P.O. #: GEO
Sampler Initials: RT

TEST SUMMARY

Maxxam ID: DLD976
Sample ID: BH3 (SS5)
Matrix: Soil

Collected: 2016/11/14
Shipped:
Received: 2016/11/14

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4751032	N/A	2016/11/17	Alina Dobreanu
Conductivity	AT	4749169	N/A	2016/11/16	Tahir Anwar
pH CaCl2 EXTRACT	AT	4750836	2016/11/17	2016/11/17	Neil Dassanayake
Resistivity of Soil		4746791	2016/11/17	2016/11/17	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4751033	N/A	2016/11/18	Deonarine Ramnarine
Oxidation-Reduction Potential	PH	4750837	2016/11/16	2016/11/21	Grace Sison

Maxxam ID: DLD976 Dup
Sample ID: BH3 (SS5)
Matrix: Soil

Collected: 2016/11/14
Shipped:
Received: 2016/11/14

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4751032	N/A	2016/11/17	Alina Dobreanu
Sulphate (20:1 Extract)	KONE/EC	4751033	N/A	2016/11/18	Deonarine Ramnarine

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

GENERAL COMMENTS

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

Package 1	8.0°C

Results relate only to the items tested.

Maxxam Job #: B6O6837
Report Date: 2016/11/21

QUALITY ASSURANCE REPORT

exp Services Inc
Client Project #: ADM-00235197-130
Site Location: HWY 21
Your P.O. #: GEO
Sampler Initials: RT

			Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
4749169	Conductivity	2016/11/16			99	90 - 110	<2	umho/cm	0.93	10		
4750836	Available (CaCl2) pH	2016/11/17			99	97 - 103			0.13	N/A		
4750837	Oxidation-Reduction Potential						+74	mV	0.72	20	+243	238 - 248
4751032	Soluble (20:1) Chloride (Cl)	2016/11/17	NC	70 - 130	103	70 - 130	<20	ug/g	NC	35		
4751033	Soluble (20:1) Sulphate (SO4)	2016/11/18	NC	70 - 130	104	70 - 130	<20	ug/g	7.6	35		

N/A = Not Applicable

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

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

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

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

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

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

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Maxxam Job #: B6O6837
Report Date: 2016/11/21

exp Services Inc
Client Project #: ADM-00235197-130
Site Location: HWY 21
Your P.O. #: GEO
Sampler Initials: RT

VALIDATION SIGNATURE PAGE

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

Cristina Carriere, Scientific Services

Grace Sison, B.Sc., C.Chem, Senior Project Manager - Petroleum Division

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Your Project #: MB6O6837
Site Location: ADM-00235197-130
Your C.O.C. #: 08431035

Attention:SUB CONTRACTOR

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2016/11/17
Report #: R2302222
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6A2593
Received: 2016/11/16, 11:00

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Moisture	1	2016/11/16	2016/11/17	BBY8SOP-00017	BCMOE BCLM Dec2000 m
Sulfide (AVS) (soil)	1	2016/11/16	2016/11/16	BBY6SOP-00006	SM 22 4500 S2- D m

Remarks:

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All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods. Results relate to samples tested.
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Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Your Project #: MB6O6837
Site Location: ADM-00235197-130
Your C.O.C. #: 08431035

Attention:SUB CONTRACTOR
MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2016/11/17
Report #: R2302222
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6A2593
Received: 2016/11/16, 11:00

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Amandeep Nagra, Account Specialist
Email: ANagra@maxxam.ca
Phone# (604)639-2602
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Maxxam Job #: B6A2593
Report Date: 2016/11/17

MAXXAM ANALYTICS
Client Project #: MB6O6837
Site Location: ADM-00235197-130

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		QB0779		
Sampling Date		2016/11/14 08:50		
COC Number		08431035		
	UNITS	**BH3 (SS5) (DLD976)**	**RDL**	**QC Batch**
MISCELLANEOUS				
Sulphide	ug/g	0.96 (1)	0.75	8472399

RDL = Reportable Detection Limit
(1) RDL raised due to sample matrix interference.

PHYSICAL TESTING (SOIL)

Maxxam ID		QB0779		
Sampling Date		2016/11/14 08:50		
COC Number		08431035		
	UNITS	**BH3 (SS5) (DLD976)**	**RDL**	**QC Batch**
Physical Properties				
Moisture	%	12	0.30	8472421
RDL = Reportable Detection Limit				

TEST SUMMARY

Maxxam ID: QB0779
Sample ID: BH3 (SS5) (DLD976)
Matrix: Soil

Collected: 2016/11/14
Shipped:
Received: 2016/11/16

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8472421	2016/11/16	2016/11/17	Lolita Obusan
Sulfide (AVS) (soil)	SPEC/COL	8472399	2016/11/16	2016/11/16	Jamie Sun

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

GENERAL COMMENTS

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

Package 1	1.3°C

Results relate only to the items tested.

Maxxam Job #: B6A2593
Report Date: 2016/11/17

QUALITY ASSURANCE REPORT

MAXXAM ANALYTICS
Client Project #: MB6O6837
Site Location: ADM-00235197-130

			Matrix Spike		Spiked Blank		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8472399	Sulphide	2016/11/16	56 (1)	75 - 125	94	75 - 125	<0.50	ug/g	NC	30
8472421	Moisture	2016/11/17					<0.30	%	0.60	20

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

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

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

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

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

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Maxxam Job #: B6A2593
Report Date: 2016/11/17

MAXXAM ANALYTICS
Client Project #: MB6O6837
Site Location: ADM-00235197-130

VALIDATION SIGNATURE PAGE

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

Andy Lu, Ph.D., P.Chem., Scientific Specialist

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

CHAIN OF CUSTODY RECORD

Page ____ of ____

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required
Company Name:	Exp services Inc.	Company Name:		Quotation #:		☑ Regular TAT (5-7 days) Most analyses
Contact Name:	Nimesh Tamrakar	Contact Name:		P.O. #/ AFE#:	GEO	PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS
Address:	56 Queen St. East	Address:		Project #:	ADM-00235197-BO	Rush TAT (Surcharges will be applied)
	Suite 301, Brampton			Site Location:	HWY 21	☐ 1 Day ☐ 2 Days ☐ 3-4 Days
Phone:	905-796-3200 Fax:	Phone: Fax:		Site #:		
Email:	nimesh.tamrakar@exp.com	Email:		Sampled By:	Nimesh Tamrakar	Date Required:

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Rush Confirmation #:

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

Other Regulations
☐ CCME ☐ Sanitary Sewer Bylaw
☐ MISA ☐ Storm Sewer Bylaw
☐ PWQO Region ______
☐ Other (Specify) ______
☐ REG 558 (MIN. 3 DAY TAT REQUIRED)

Include Criteria on Certificate of Analysis: Y / N

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

LABORATORY USE ONLY

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

COOLING MEDIA PRESENT: (Y) / N

Analysis Requested (REFER TO BACK OF COC)

	SAMPLE IDENTIFICATION	DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI	BTEX/ PHC F1	PHCs F2 - F4	VOCs	REG 153 METALS & INORGANICS	REG 153 ICPMS METALS	REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B)	corrosivity Package	sulphides						HOLD- DO NOT ANALYZE	COMMENTS
1	BH 3 (SS5)	2016/11/14	8:50	Soil	1								✓	✓							
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

RELINQUISHED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)
Nimesh Tamrakar	2016/11/14	8:50	Asra Bhatti	2016/11/14	09:38

14-Nov-16 09:38
Sara Singh
B6O6837
RK6 ENV-626

Appendix G –
Slope Stability Analyses

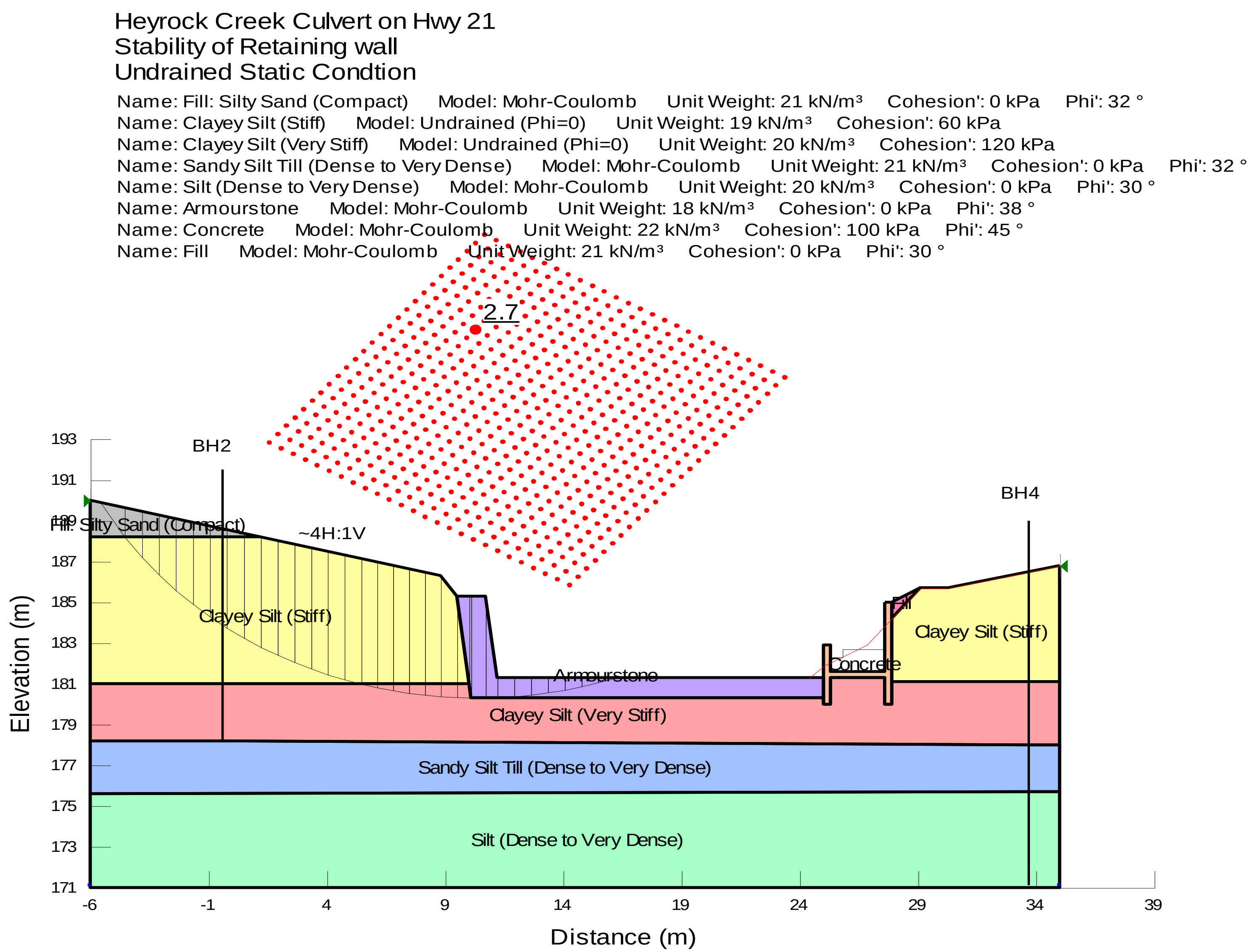


Figure 1: Slope stability analysis for retaining wall – undrained static conditions

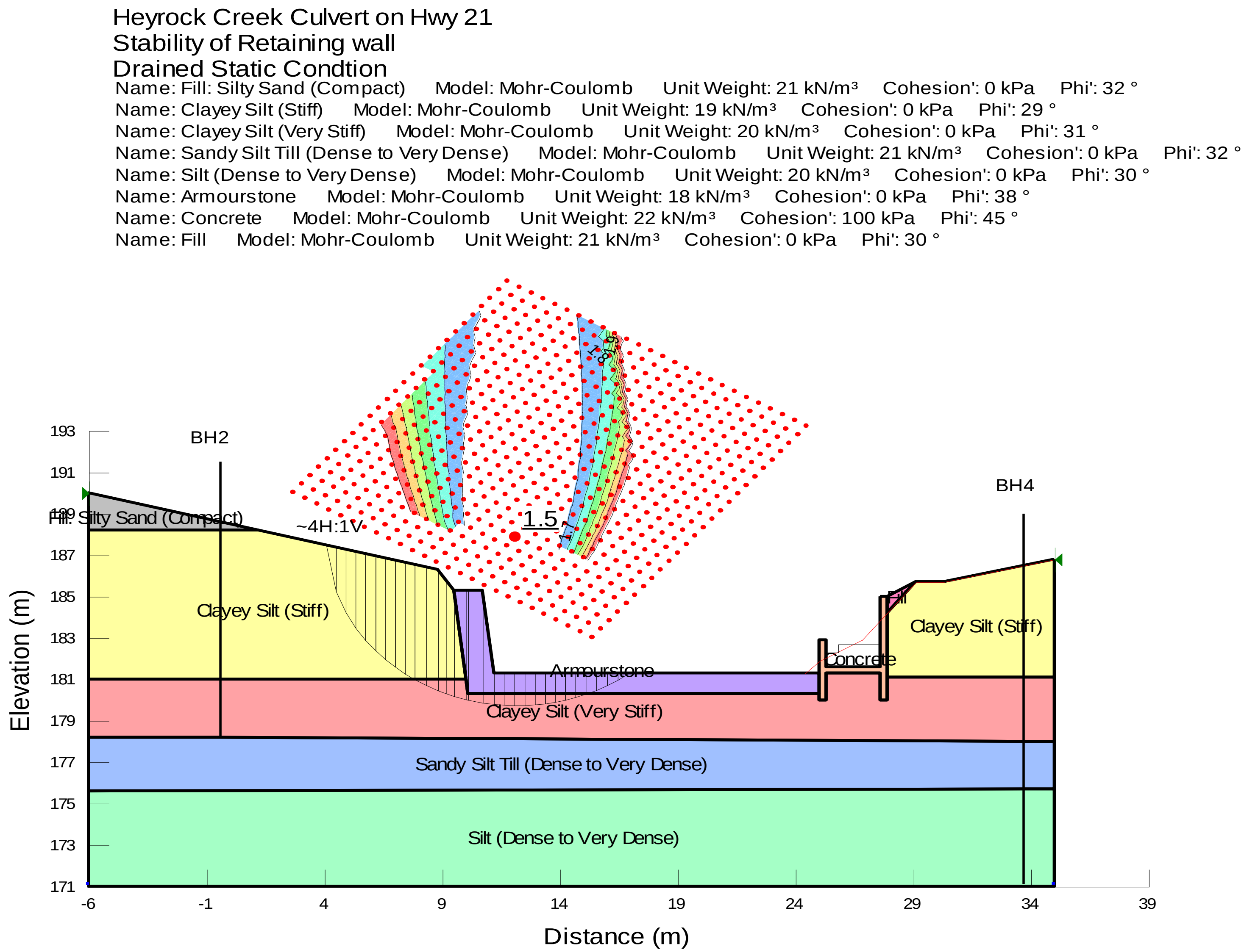


Figure 2: Slope stability analysis for retaining wall – drained static conditions

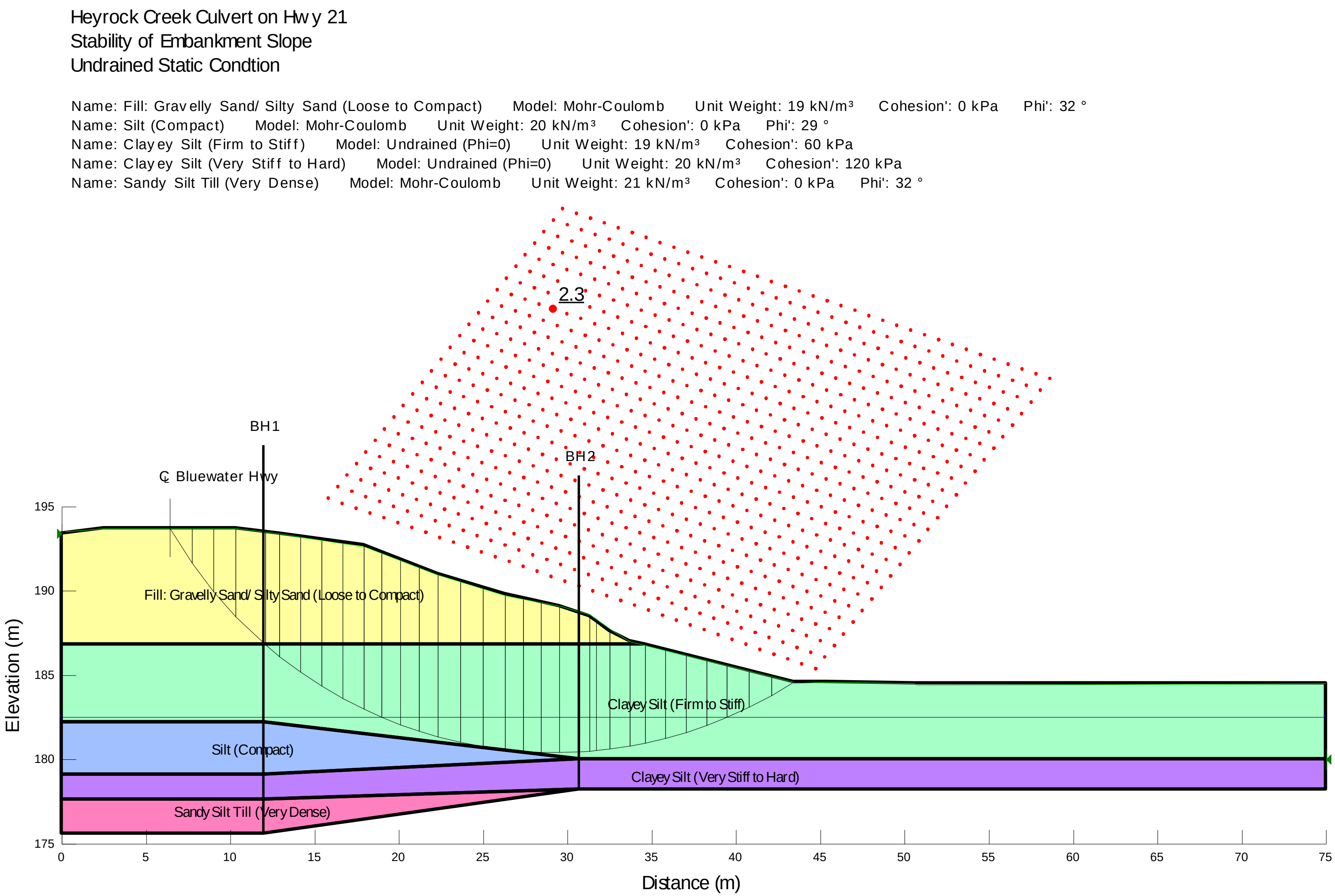


Figure 3: Slope stability analysis for embankment slope – undrained static conditions

exp.

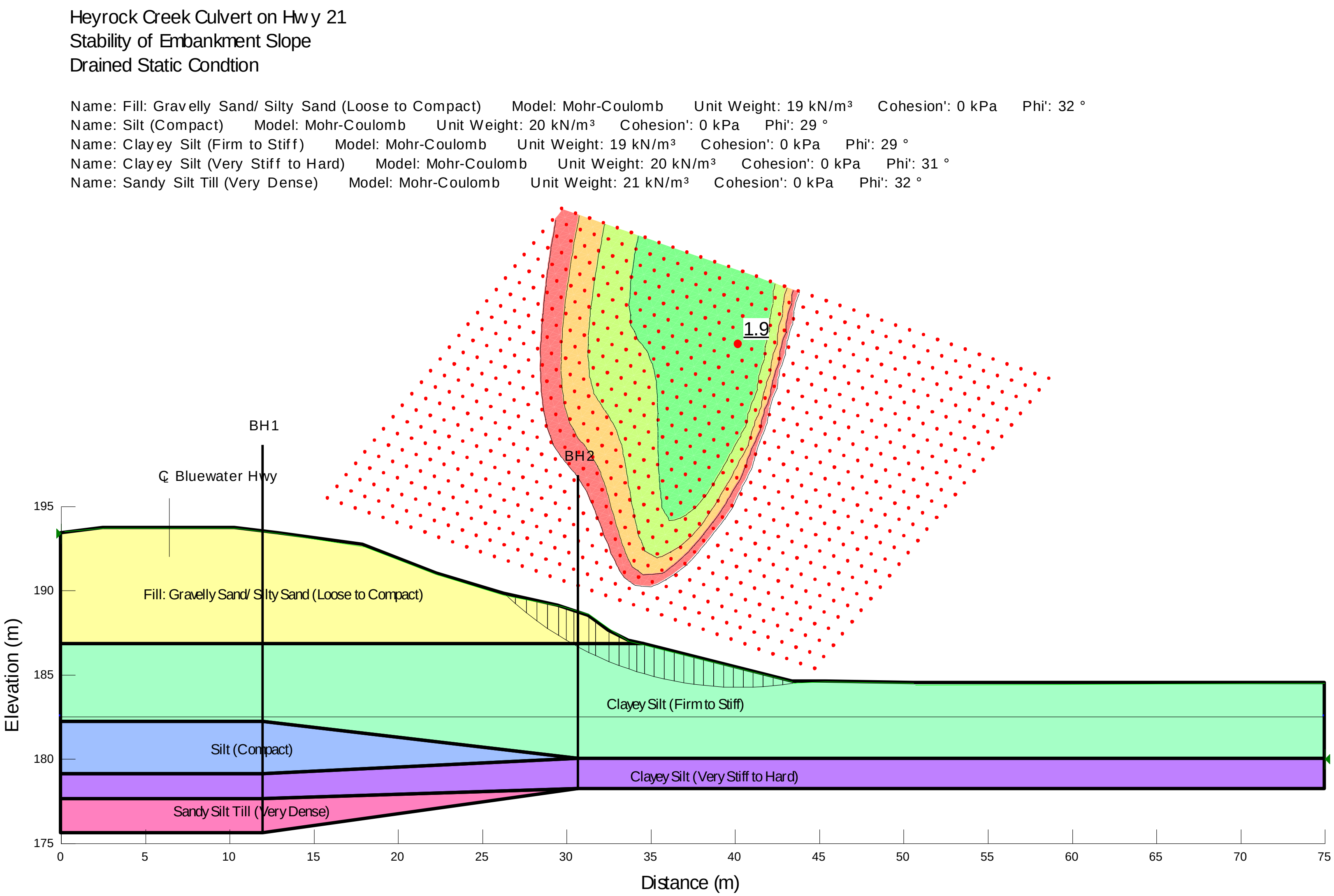
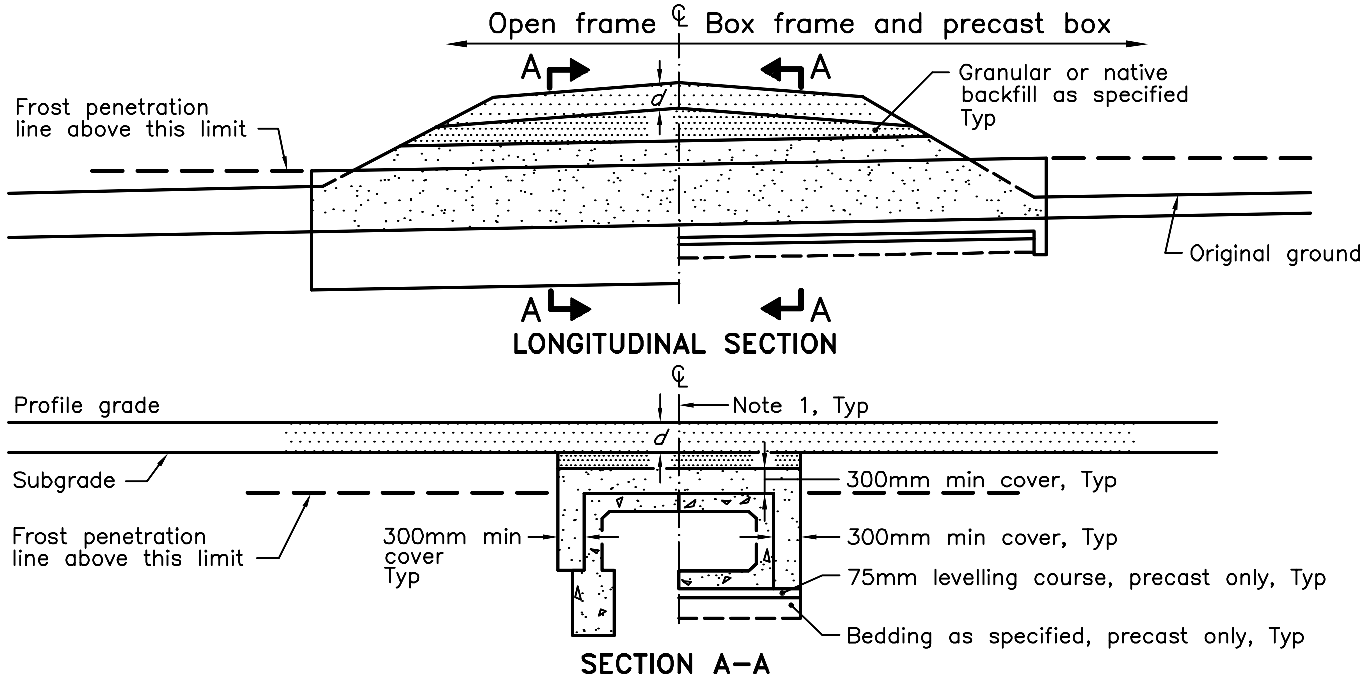


Figure 4: Slope stability analysis for embankment slope – drained static conditions

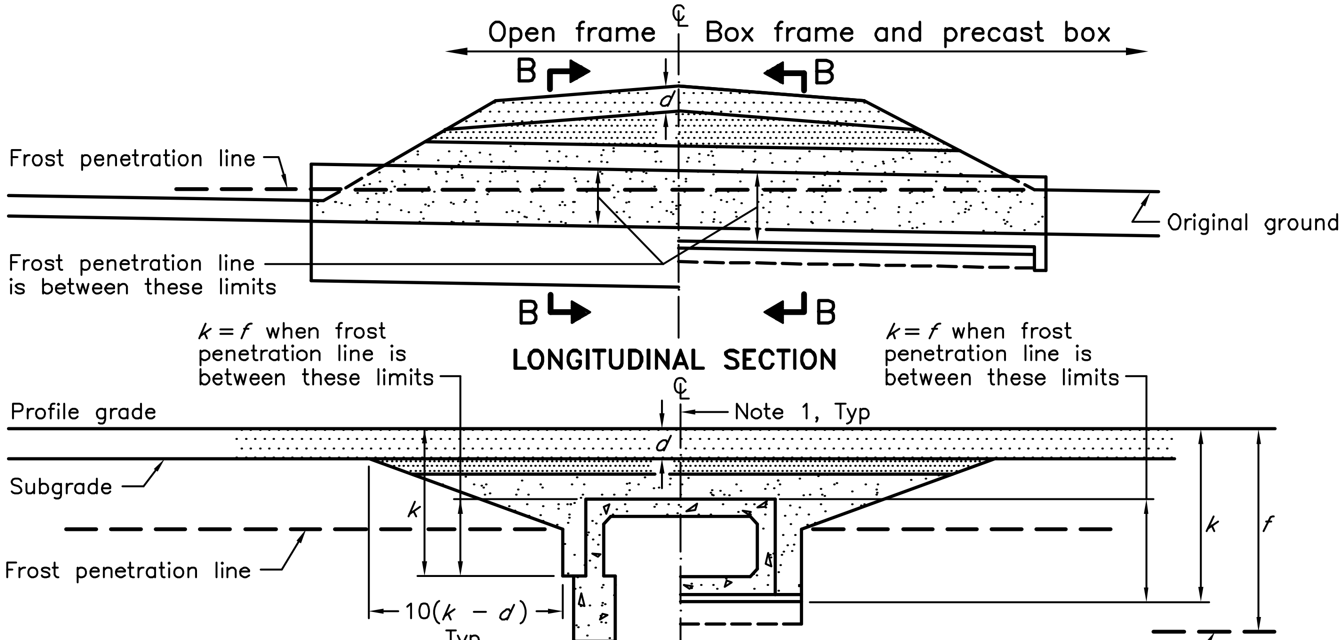
exp.

Appendix H – OPSDs

FROST PENETRATION LINE AT OR ABOVE TOP OF CULVERT



FROST PENETRATION LINE BELOW TOP OF CULVERT



LEGEND:

d = depth of roadbed granular
k = depth of frost treatment below profile grade
f = depth of frost penetration below profile grade

NOTES:

1 Condition of frost treatment symmetrical about centreline of culvert.

A Bedding, levelling, and cover material shall be granular as specified.
B The depth of roadbed granular shall be 600mm minimum.
C The maximum depth of frost treatment shall be bottom of box frame or top of footing.
D All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2010 | Rev 2

BACKFILL AND COVER FOR CONCRETE CULVERTS WITH SPANS LESS THAN OR EQUAL TO 3.0M

OPSD 803.010

- A drainage system behind a retaining structure should ensure that a groundwater table does not exist above the footing level. Preferably, the ground water level is controlled by the use of free-draining granular backfill and a collection system such as weep holes or perforated drains at the footing level. These weep holes and drains should be inspected and maintained to ensure that they do not become blocked. If free-draining, granular backfill is not employed, the permeability of the backfill and the hydrostatic head will control the extent to which the groundwater table can be depressed locally by seepage towards a footing drain. In practice, design for frost protection is best done using free-draining backfill.
  The design should also consider the risk of unusually large inflows of water creating a temporary hydrostatic head of water behind the wall. An example is the overtopping of a retaining wall, adjoining a large body of water, by storm waves. Measures such as the use of quarried rock backfill, design for full hydrostatic pressure, or provision of a sloped impermeable surface layer should be considered.
  Measurements have shown that earth pressures can vary seasonally, but the effects have normally been neglected in design, except for winter frost pressures. These latter can be very large if the backfill is frost susceptible and for this reason free-draining granular backfill is recommended.
- Figure C6.20 shows examples of minimum backfill requirements.
  The distance, x, should be equal to or greater than the estimated vertical frost penetration. This distance may be reduced if the wall abuts a vertical face of bedrock that is not susceptible to frost. The frost penetration may be reduced by the use of suitable insulation, in which case a thermal analysis should be performed by a Geotechnical Engineer.
  If rock fill is used as a backfill material, consideration should be given to the possible deterioration of the rockfill with time, which could result in the reduction or even the total loss of free-draining properties and, hence, increased frost susceptibility.

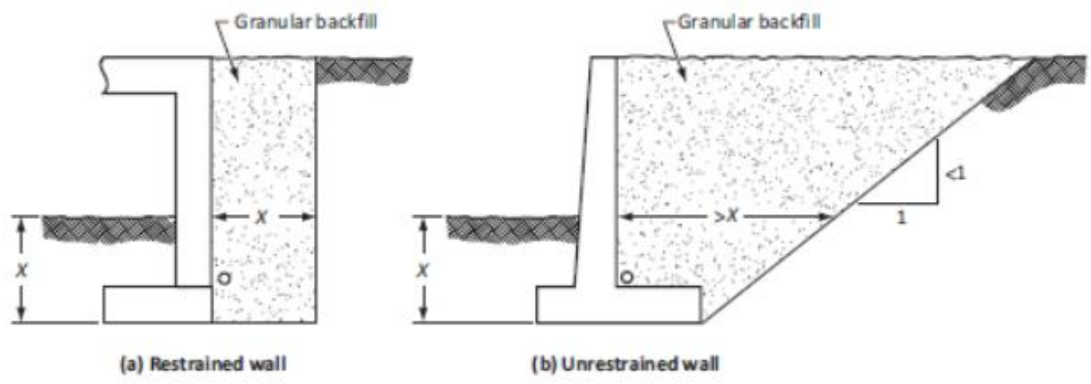


Figure C6.20
Backfill for frost protection
(See Clause C6.12.1.)

C6.12.2 Lateral ground pressures

C6.12.2.1 General

Earth pressure acting on a structure depends on the relative movement of the structure, the backfill, the type of soil adjacent to the backfill, and the soil below the footing or supporting piles. Appropriate geotechnical parameters should be chosen for the calculation of lateral pressures based on recognized geotechnical theories as specified in Clause 6.12.2.2 for the backfill behind the wall. Geotechnical parameters frequently used in allowable stress design methods are applicable in limit states design pressure calculation. Where the possibility exists, hydrostatic pressure needs to be considered, e.g., in situations where walls are partially submerged or where non-free-draining backfill is used.

Appendix I – NSSPs

NSSP FOR COBBLES AND/OR BOULDERs OBSTRUCTIONS

Scope of Work

The Contractor should be aware that the embankment at the site consists of granular fill underlain by clayey silt/silt and silt till materials which may contain cobbles and/or boulders. Appropriate equipment and procedures will be required to penetrate/remove cobbles and/or boulders that are encountered during excavation.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.