FINAL REPORT

FOUNDATION INVESTIGATION AND DESIGN REPORT

Non-Structural Culvert Replacement and Slope Stability Analysis, At Highway 85-Bridgeport Road Interchange, Kitchener, ON

Agreement No. 3015-E-0017
Assignment No. 5
W.O. 2017-11009
Geocres No. 40P8-244

Prepared for:

Ontario Ministry of Transportation
Regional Director's Office -West Region
Geotechnical Section
659 Exeter Road
London, ON N6E 1L3
Attn: Muhammad Kamran Khan, P.Eng., PMP

Ontario Ministry of Transportation
Pavements and Foundations Section
Materials Engineering and Research Office, Room 223, 2/F
145 Sir William Hearst Avenue
Toronto, ON M3M 0B6
Attn: David Staseff, P.Eng.

exp Services Inc.
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Western Region – Geotechnical Section

Foundation Investigation and Design Report

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Foundation Investigation and Design Report for Non- Structural Culvert Replacement and Slope Stability Analysis at Hwy 85-Bridgeport Interchange, Kitchener, ON

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Prepared by:
Nimesh Tamrakar, M.Eng.
Silvana Micic, Ph.D., P.Eng.

Reviewed by:
TaeChul Kim, M.E.Sc., P.Eng.
Stan E. Gonsalves, M.Eng., P.Eng.

exp Services Inc.
56 Queen St, East, Suite 301
Brampton, ON L6V 4M8
Canada

Silvana Micic, Ph.D., P.Eng.
Senior Geotechnical Engineer
Project Manager

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

Date Submitted:
July 7, 2017

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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. (**exp**) for the replacement of an existing non-structural culvert and slope stability analysis at STA 24+470 on Highway 85 and Bridgeport Road Interchange, Kitchener, part of the Ministry of Transportation (MTO) West Region. The work was undertaken under Agreement No. 3015-E-0017, Assignment No. 5. The terms of reference (TOR) were as presented in the MTO document entitled “Foundation Engineering Terms of Reference, MTO West Region – Foundations Retainer Assignment, Assignment 5 – Culvert Replacement and Slope Stability Analysis Hwy 85-Brigeport Interchange” provided via e-mail on March 16, 2017.

Based on information provided by MTO, it was initially understood that the slope failure was only in the vicinity of existing non-structural culvert. During a site reconnaissance, additional slope failure above the storm water drainage outlet located south of the existing culvert was noted. Following discussion with MTO, the initial scope was modified to incorporate the additional slope failure identified during site visit.

The purpose of the investigation is to determine the subsurface conditions along the culvert alignment and to permit detailed design for the culvert replacement including assessment of the slope failure to provide detailed recommendations with clear alternatives to rectify the problem. The site specific geotechnical investigation consisted of borings, soil sampling, borehole logging, 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

At the culvert replacement site location, the Highway 85 and Bridgeport road interchange ramps E/W-N and N-E/W runs on east side of the Highway 85 and Bridgeport road interchange. The ramps are single lane asphalt roadway and is about 6.8 m wide from edge to edge of road lane marks, with approximately 2.0 m wide paved shoulder on one side. The road surface elevations of ramps E/W-N and N-E/W along the culvert centerline is approximately at Elev. 321.1 m.

Based on the information provided in the TOR, the existing culvert is concrete culvert with a 1.37 m internal diameter runs from a catch basin at the curb of the E/W-N ramp for a length of 14 m to outlet. At the time of writing this report the type and dimensions of the new culvert is not known. Select photographs of the site and existing culvert are presented in Appendix A. The site plan and cross-section profiles for the proposed culvert alignment are shown on the drawing attached in Appendix B.

The area surrounding the culvert site at inlet side is gently sloping towards the catch basin and at outlet side the embankment is 5.2 m high with approximate side slope of ~2.5H:1V. Highway 85 runs in north-south direction and Bridgeport road runs in east-west direction under the Highway 85 at interchange. The overall drainage at the existing culvert site is from the west to east direction. The culvert crosses the ramps (N-E/W and E/W-N) and discharge at drain runs along the toe of the embankment with bends at two shafts (located at shoulder of N-E/W ramp and between two ramps at median ditch). The storm water pipe located on south of the existing culvert also discharge at the drain on east side of the ramp and the drain further flows toward south. some vegetation was observed along the flow area at the inlet side of the culvert. However, no obstruction in flow were observed. At the time of the investigation, the bottom of the existing culvert at inlet and outlet of the culvert were measured at approximate Elevations 318.0 m and 314.7 m, respectively. The bottom of the storm water pipe on outlet side was also measured and it was at approximate Elev. 316.5 m. The elevation of ramps N-E/W and E/W-N at the culvert centerline is approximately Elev. 321.1 m.

The failure scarps are situated approximately at stations 24+355 and 24+470 on the E/W-N ramp side slope. The slope failure had occurred above outlet end of the culvert and the storm water drainage pipe. During a field reconnaissance, formation of a sink holes and depressions on the embankment slope were observed due to washouts. it was observed that the washouts of the embankment slope at the outlet side of the existing culvert and the storm water pipe were observed causing sink holes and depressions (see Photos 11,12,13 and 14, in Appendix A). Some concrete pieces on top of the existing culvert and the storm water pipe were observed (see photo 7 and 9, in Appendix A), that appears to have been temporarily repaired.

1.2.2 Geological Setting

The Map P.2715 (Physiography of Southern Ontario, Third Edition,1984) of the Ministry of Natural Resources indicates that the project area is in a spillway. The Map 2556 (Quaternary Geology of Ontario, Southern Sheet, 1991) of the Ministry of Northern Development and Mines, indicates that the surface conditions consist of Port Stanley till of silt to sandy silt matrix becoming silty to silty clay near Lake Erie, strongly calcareous, moderate to low clast content decreasing southward. The Map 2544 (Bedrock Geology of Ontario, Southern Sheet, 1991) of the Ministry of Northern Development and Mines, indicates that the bedrock formation in the project area consists of Salina formation of shale, limestone, dolostone, sandstone, gypsum and salt.

1.3 Investigation Procedures

1.3.1 Site Investigation and Field Testing

The field investigation was performed between May 1st and 5th, 2017. The field program consisted of drilling nine (9) sampled boreholes, numbered BH-1 to BH-9. Four (4) boreholes (BH-1, BH-2, BH-3, and BH-5) were strategically located along the existing culvert alignment to provide subsurface information for the design of the proposed new culvert. Boreholes BH-1 and BH-3 were advanced at accessible locations near the inlet and outlet of the culvert, respectively. Borehole BH-2 was advanced approximately 2.5 m north of the culvert alignment in the grass median and Borehole BH-5 was advanced approximately 2.5 m south of the culvert alignment in the shoulder of the HWY 85 E/W-N ramp. Two (2) boreholes (BH-4 and BH-6) were advanced on the shoulder of the HWY 85 E/W-N ramp and in the grass median to provide subsurface information for the temporary road protection at distances of approximately 25 m north and south of the culvert, respectively. Additionally, three (3) boreholes (Boreholes BH-7, BH-8, and BH-9) were advanced in the area of the existing stormwater pipe to investigate the cause of the slope failure. Boreholes BH-7 and BH-8 were advanced at the stormwater inlet and outlet, respectively and Borehole BH-9 was advanced approximately 25 m south of the stormwater inlet in the shoulder of the HWY 85 E/W-N ramp. The borehole locations are shown on Drawing No. 1 in Appendix B.

The boreholes drilled on the E/W-N ramp (Boreholes BH-4, BH-5, BH-7, and BH-9) were advanced to depths ranging from 11.3 to 15.9 m below grade using a truck mounted CME-75 drill rig. The boreholes drilled at the culvert inlet and median (Boreholes BH-1, BH-2, and BH-6) were advanced to depths 10.5 to 11.3 m below grade using a track mounted CME-75 drill rig. The truck and track mounted drills were equipped with hollow stem augers and standard soil sampling equipment. Due to the limited access at the culvert and stormwater outlets, Boreholes BH-3 and BH-8 were advanced using manual SPT equipment (70-pound hammer with 15 inch drop height) to a depth of 3.1 m below grade. The boreholes were advanced by a specialist drilling contractor, Aardvark Drilling Inc.

The borehole locations (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were surveyed by **exp** personnel using a Temporary Benchmark (TBM). The TBM used was the catch basin at the west curb of the HWY 85 E/W-N ramp and located approximately 105 m north of the existing culvert. Based on the Information provided on as contract drawings (Contract No. 68-62, W.P. 619-64, Dwg. 134) provided by the MTO, the TBM was assigned an approximately geodetic elevation of 322 m. The temporary benchmark location is shown on Drawing. 1 in Appendix B.

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 C). 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 or relative density of non-cohesive soils. The SPT “N” values shown on the borehole logs of Borehole BH-3 and BH-8 are corrected for the reduced energy input of the manual equipment.

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

1.3.2 Previous Investigation

No foundation reports are available in the MTO GEOCRES library for this site. However, one foundation report related to the adjacent site on Hwy 85 was recovered from the MTO GEOCRES library. The document is as follows:

- Foundation Investigation Report for Bridgeport Road Overpass, Kitchner-Waterloo Expressway; District #4 (Hamilton) W.J. 66-F-64; W.P. 640-64; Geocres No. 40-P08-050; Department of Highways Ontario; August 17, 1966.

1.3.3 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 of all samples and particle size distribution for approximately 25% of the collected soil samples. Atterberg limits tests were carried out on select cohesive soil samples. One corrosivity test was also performed for a selected sample. 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 C as well as graphically in Appendix D.

The corrosivity test was performed by AGAT Laboratories, a CALA-certified and accredited laboratory in Mississauga, Ontario. Details of the chemical testing are discussed below and the lab results are presented 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 C. Laboratory test results are provided in Appendix D. The "Explanation of Terms Used in Report" preceding the borehole logs in Appendix C 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 B. 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 along the existing culvert alignment consists of a layer of sand to silty sand fill underlain by native deposit of silty clay. A more detailed description of the subsurface conditions encountered in the boreholes is discussed further in subsequent sections.

1.4.1 Asphalt

Asphalt was encountered at the surface of boreholes advanced on the roadway, i.e. BH-4, BH-5, BH-7 and BH-9, and thickness of about 0.100 m. Asphalt thicknesses may further vary beyond the borehole locations.

1.4.2 Topsoil

Topsoil was encountered at the surface of the off-road boreholes (BH-1, BH-2, BH-3, BH-6 and BH-8), and ranged in thickness from approximately 0.2 m to 0.3 m. Topsoil thicknesses may further vary beyond the borehole locations.

1.4.3 Fill: Sand and Gravel

Sand and gravel fill was encountered below the asphalt in all boreholes (BH-4, BH-5, BH-7 and BH-9) advanced through the road surface. The sand and gravel fill extended to depths ranging between 0.4 m to 0.5 m below ground surface with elevations ranging between 321.2 m to 320.7 m. The explored thickness of this layer was between 0.3 m to 0.4 m.

The composition of this fill layer is sand and gravel and trace silt. The material is brown in color, and dry to moist. The SPT “N” values within this layer ranged from 21 to 34 blows per 0.3 m penetration, suggesting compact to dense relative density.

Laboratory testing performed on selected samples consisted of four (4) moisture content tests. The test results are as follows:

Moisture Content:

- 4% to 11%

The results of the moisture content tests are provided on the record of borehole sheets in Appendix C.

1.4.4 Fill: Sand to Silty Sand

Sand to silty sand fill was encountered below the sand and gravel fill in all boreholes advanced through the road surface (BH-4, BH-5, BH-7 and BH-9) and below the topsoil in all off-road boreholes (BH-1, BH-2, BH-3, BH-6 and BH-8). The sand to silty sand fill extended to depths ranging between 2.4 m to 6.9 m below ground surface with elevations ranging between 316.0 m to 313.4 m. The explored thickness of this layer was between 2.2 m and 6.4 m.

The composition of this fill layer is sand and silt, some clay, trace to some gravel, trace organics, wood fibres and occasional plastic debris. The material is brown in color, and moist to wet. The SPT “N” values within this layer ranged from 1 to 50 blows per 0.3 m penetration, suggesting very loose to very dense relative density but generally very loose to compact relative density.

Laboratory testing performed on selected sample consisted of fifty-four (54) moisture content tests and thirteen (13) grain size distribution tests. The test results are as follow:

Moisture Content:

- 4% to 36%

Grain Size Distribution:

- 0% to 24% gravel;
- 21% to 84% sand;
- 16% to 61% silt and clay;
- 40% to 60% silt; and
- 14% to 19% clay

The results of the moisture content and gain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 1 and 2 in Appendix D.

1.4.5 Fill: Clayey Silt

Clayey silt fill was encountered below the sand to silty sand fill in BH-4. The clayey silt fill extended to depth of about 6.9 below ground surface with elevation about 314.3 m. The explored thickness of this layer was about 0.8 m.

The composition of this fill layer is silt and clay and trace gravel. The material is light brown in color, and moist. One SPT "N" value within this layer was 8 blows per 0.3 m penetration, suggesting firm consistency.

Laboratory testing performed on selected sample consisted one (1) moisture content test. The test result is as follow:

Moisture Content:

- 21%

The result of the moisture content test is provided on the record of borehole sheets in Appendix C.

1.4.6 Organic Silty Clay

A layer of organic silty clay was encountered below the sand to silty sand fill in BH-2, BH-5 and BH-6. The organic silty clay extended to depths ranging between 5.3 m to 6.9 m below ground surface with elevations ranging between 315.4 m to 314.2 m. The explored thickness of this layer was between 0.7 m and 0.8 m.

The composition of this layer is silt and clay, some organics and some rootlets. The material is black in color, and moist. The SPT "N" values within this layer ranged from 5 to 7 blows per 0.3 m penetration, suggesting firm i consistency.

Laboratory testing performed on selected sample consisted three (3) moisture content tests. The test results are as follows:

Moisture Content:

- 29% to 50%

The result of the moisture content test is provided on the record of borehole sheets in Appendix C.

1.4.7 Peat

A layer of peat was encountered below the sand to silty sand fill in BH-7 and BH-9. The peat layer extended to depths ranging between 6.3 m to 7.6 m below ground surface with elevations ranging between 315.3 m to 313.9 m. The explored thickness of this layer was about 0.7 m.

The composition of this layer is peat, some rootlets and wood fragments. The material is black in color, and moist. The SPT “N” values within this layer ranged from 6 to 7 blows per 0.3 m penetration, suggesting firm consistency.

Laboratory testing performed on selected sample consisted two (2) moisture content tests. The test results are as follows:

Moisture Content:

- 145% to 227%

The result of the moisture content test is provided on the record of borehole sheets in Appendix C.

1.4.8 Silty Clay

Native silty clay was encountered below the sand to silty sand fill in BH-1, BH-3 and BH-8; below the clayey silt fill in BH-4; below the organics silty clay in BH-2, BH-5 and BH-6; below the peat in BH-7 and below the gravelly sand in BH-9. The silty clay layer extended to depths ranging between 3.1 m to 15.9 m below ground surface with elevations ranging between 313.7 m to 305.2 m. The explored thickness of this layer was between 0.7 m and 9.0 m. All the boreholes were terminated within this layer.

The composition of this layer is silt and clay and occasional sand pockets/layers. The material is brown to grey in color, and moist. The SPT “N” values within this layer ranged from 10 to 38 blows per 0.3 m penetration, suggesting stiff to hard consistency but generally stiff to very stiff consistency.

Laboratory testing performed on selected sample consisted of fourty six (46) moisture content tests, thirteen (15) grain size distribution tests and twelve (14) Atterberg Limit tests. The test results are as follow:

Moisture Content:

- 15% to 35%

Grain Size Distribution:

- 0% to 1% gravel;
- 0% to 24%sand;
- 45% to 90% silt; and
- 8% to 49% clay

Atterberg limits

- Liquid Limit: 40% to 42%

- Plastic Limit: 13% to 21%
- Plasticity Index: 19% to 29%

The results of the moisture content, gain size distribution tests and Atterberg Limit tests are provided on the record of borehole sheets in Appendix C. The result of the grain size distribution tests and Atterberg Limit tests are also provided on Figure 4,5,6 and 7 in Appendix D.

1.4.9 Gravelly Sand

Native gravelly sand was encountered below the peat in BH-9. The gravelly sand layer extended to depth of about 8.4 m below ground surface with elevation about 313.2 m. The explored thickness of this layer was about 2.1 m.

The composition of this layer is sand and gravel, trace silt. The material is brown to grey in color, and moist. The SPT "N" values within this layer ranged from 8 to 20 blows per 0.3 m penetration, suggesting loose to compact relative density.

Laboratory testing performed on selected sample consisted of three (3) moisture content tests and one (1) grain size distribution tests. The test results are as follow:

Moisture Content:

- 15% to 21%

Grain Size Distribution:

- 24% gravel;
- 67%sand;
- 9% silt and clay

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

1.5 Groundwater & Surface Water Conditions

Information on groundwater levels at the site was obtained by measuring water levels in the open boreholes after completion of drilling. The groundwater levels encountered in the boreholes are shown on the borehole logs and presented below in Table 1.1.

Table 1.1. Groundwater data

Borehole	Date Completed	Date Measured	Ground Surface Elevation[2]	Depth to Water[3]	Groundwater Elevation
BH-1	May 01/17	May 01/17	319.3	7.6	311.7
BH-2	May 02/17	May 02/17	320.3	6.1	314.2
BH-3	May 05/17	May 05/17	315.9	0.3	315.6
BH-4	May 04/17	May 04/17	321.2	3.1	318.1[4]

Borehole	Date Completed	Date Measured	Ground Surface Elevation[2]	Depth to Water[3]	Groundwater Elevation
BH-5	May 03/17	May 03/17	321.1	9.2	311.9
BH-6	May 02/17	May 02/17	320.7	4.3	316.4
BH-7	May 04/17	May 04/17	321.5	7.6	313.9
BH-8	May 05/17	May 05/17	316.8	0.3	316.5
BH-9	May 03/17	May 03/17	321.6	3.1	318.5[4]

Notes:
1) All units in metres.
2) Elevations surveyed are referenced to a temporary benchmark (TBM) set on top of catch basin at maiden ditch approximately 105 m north of the existing culvert alignment on south of highway. The TBM elevation (322.0 m) is assumed based on the Information provided on as built drawings provided by the MTO.
3) Depths are relative to ground surface.
4) High groundwater level could be due to borehole caved at shallow depth

Note that water levels measured in open boreholes might not be stabilized due to short term observation. At the time of investigation, water level in culvert at inlet and outlet sides were measured at approximate Elevations 318.5 m and 314.9 m, respectively. Observations at the time of investigation infer groundwater at about Elevation 318.5 m at inlet reduces down to about 316.5 and 316.0 m near BH-2 at center, and BH-5 at the crest edge; respectively. At the outlet, the groundwater level is inferred to be at about Elevation 315.0 m. In the area of storm water drainage pipe (BH-7 and BH-8) the ground water level is inferred to be near Elevation 316.5 m.

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 mounded and perched water could exist in the embankment fill as well and this would be affected by the prevailing weather conditions with higher levels occurring during wet periods.

1.6 Chemical Analyses

One soil sample was selected for chemical analysis and was sent to AGAT laboratories, a CALA-certified and accredited laboratory in Mississauga, Ontario. The analytical laboratory results are presented in Appendix E, and are summarized in Table 1.2, below.

Table 1.2. Corrosivity chemical analysis

Sample Identification	pH (unitless)	Soluble Chloride (ppm)	Soluble Sulphate (ppm)	Resistivity (ohm-cm)	Conductivity (mS/cm)	Redox Potential (mV)	Sulphide (%)
BH1-SS2 Sand to Silty Sand Fill	8.77	94	16	3100	0.323	206	<0.05

PART II: ENGINEERING DISCUSSION & RECOMMENDATIONS

2.1 General

This section of the report provides geotechnical design recommendations for replacement of an existing non-structural culvert, engineering assessment the slope failure in the vicinity and recommendation of construction strategies including guidance regarding stability and mitigation or control measures that would be required for rectification of the problem. The site is located on Highway 85 and Bridgeport Road Interchange, Kitchener, Ontario, the Ministry of Transportation (MTO) Western Region. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site. The compiled factual results of these investigations are presented in **Part I-Foundation Investigation Report**. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives, design/replacement of the new culvert and to adopt mitigation or stabilization method of slope failure. 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 the information provided in the TOR, the existing culvert is concrete culvert with a 1.37 m internal diameter runs from a catch basin at the curb of the E/W-N ramp for a length of 14 m to outlet. At the time of writing this report the type and dimensions of the new culvert is not known. It is understood that, there is approximately 5m of fill on the culvert at the top of the slope. The condition of the slope and amount of separation has not changed much for the last two years. It is noted that this may have been like this for quite a few years. It is also understood that for the replacement of existing culvert the trenchless technology was considered the preferred option. The skewed design of the existing culvert is proposed to be replaced by a straight alignment.

At the outlet side of the existing culvert, some signs of instability in the embankment was noticed and reported by MTO. During the **exp's** site visit with MTO staff, washout of the embankment slope forming sink hole and depression at the outlet end of the existing culvert were observed. In addition, washout of the embankment slope forming sink hole and depression was also observed at the outlet end of the existing storm water drainage pipe located south of the existing culvert. The reason for the washout of the portion of slope at the storm water pipe location, we infer that the distress is due to either progressive failure due to ground loss at stream interface (outlet) and or piping around the existing storm water pipe (at least to the level at which distress was observed); and for the washout of the portion of slope at the existing culvert location, the reason is likely inflow from displacement joints and or piping. To provide additional information to support the assessment, inspection by camera at both location might use.

Methods of remediation measures of washout are discussed in Section 2.2. In general, for the storm water pipe rehabilitation of the existing storm water pipe including control of scour and piping is proposed. The existing culvert will include replacement of the culvert including measures to avoid piping and address slope instability.

This part of the report addresses the geotechnical design of the foundation for the new culvert 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. It also provides discussion about the suitability of traditional cut and cover, and trenchless methods of culvert replacement at the specific site and the construction strategies to mitigate and stabilize the slope failure. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference provided to us at March 16, 2017 together with the MTO request email.

2.2 Storm Water Pipe Location

Based on the field investigations, rehabilitation of the existing storm water pipe including control of scour and piping is recommended. So, the replacement option is not discussed at this location. Possible remedial measure for the slope failure at this location is discussed below.

2.2.1 Slope Stabilization

2.2.1.1 Assessment of slope condition

Based on the field observations at the storm water pipe location, as mention above it is evident that progressive erosion either due to ground loss at stream interface (outlet) and or piping around the existing storm water pipe (at least to the level at which distress was observed) cause distress in slope forming sink hole and depression in embankment slope. In this section, a fan-shaped sinkhole located about 3 m above from outlet along the storm water pipe alignment was observed (Photograph 13 and 14, in Appendix A). The size of the hole on the surface of the slope was approximately 2.0 m in diameter. The height of the embankment fill in this section is approximately 5.2 m having the general slope of ~2.5H:1V towards the stream (runs along the toe of embankment).

2.2.1.2 Slope Stability Analyses

Based on the results of this geotechnical investigation and site geometry, slope stability assessments of the existing slope at storm water pipe location is performed. The results of slope stability analyses for the ~2.5H:1V east side slope of the existing embankment at the storm water drainage pipe location using undrained (short term stability) and drained (long term stability) soil parameters are presented in Table 2.7 in Section 2.9 below and graphically in Figures presented in Appendix F. A minimum Factor of Safety is more than 1.3, indicating that the global stability of the existing embankment is stable.

2.2.1.3 Possible Remedial Measures

When dealing with the embankment slope instability of this nature, two approaches are generally possible: (i) avoid the problem; fix seepage of water/ leakage of joints to prevent movement of fine particles; (ii) change strength properties of the material within the slope to increase shear resistance and provide protection at toe.

To correct the ongoing erosion and slope regression, it is recommended to rehabilitate the existing storm water drainage pipe and restored the failure area to original slope with Granular material. Depending on rehabilitation method chosen for the existing storm water drainage pipe, protection systems may be required for existing roadway and embankment slope. Recommendations for the protection systems are presented in Section 2.9.

It is also recommended that the slope be protected against erosion either by placing rip-rap or any other erosion control blanket based on geosyntetics products which can allow permanent revegetation of the slope. For revegetation of the slope, soil bioengineering vegetation techniques such us live staking, seeding and rooted plants can be used. The rip-rap configuration at the toe and creek bed should generally follow the OPSD 810.010. The treatment should extend at least 1 m into the stream and 1 m up the slope failure. The lateral limits may extend at least 5 m north of the current slope failure at existing culvert outlet location and 5 m south of the current slope failure at storm water drainage pipe outlet location.

2.3 Existing Culvert Location

Based on information provided in TOR and the CAD drawing it is understood that, it is proposed to be replaced the existing skewed designed culvert by a straight alignment. The detail description about the replacement options are discussed in the sections following. Possible remedial measure for the slope failure at this location is discussed below.

2.3.1 Slope Stabilization

2.3.1.1 Assessment of slope condition

Based on the field observations at the existing location, as mention above it is evident that progressive erosion likely due to inflow from displacement joints or ground loss at stream interface (outlet) and or piping around the existing storm water pipe cause distress in slope forming sink hole and depression in embankment slope. In this section, a failure scarp located about 1.5 m above from outlet along the existing alignment was observed (Photograph 11 and 12, in Appendix A). The slope failure on the surface of the slope was approximately 7 m wide and 5 m long along the slope. The height of the embankment fill in this section is approximately 5.2 m having the general slope of ~2.5H:1V towards the stream (runs along the toe of embankment).

2.3.1.2 Slope Stability Analyses

Based on the results of this geotechnical investigation and site geometry, slope stability assessments of the existing slope at storm water pipe location is performed. The results of slope stability analyses for the ~2.5H:1V east side slope of the existing embankment at the storm water drainage pipe location using undrained (short term stability) and drained (long term stability) soil parameters are presented in Table 2.7 in Section 2.9 below and graphically in Figures presented in Appendix F. A minimum Factor of Safety is more than 1.3, indicating that the global stability of the existing embankment is stable.

It is recommended to excavate and restored the failure area to original slope with Granular material. Depending on replacement method (open cut excavation or trenchless method of installation) chosen for the existing culvert, the excavation and restoration process can be performed during culvert installation (for open cut excavation method) or before culvert installation (for trenchless installation). The protection systems may be required for existing roadway and embankment slope during slope stabilization process. Recommendations for the protection systems are presented in Section 2.9.

It is also recommended that the slope be protected against erosion either by placing rip-rap or any other erosion control blanket based on geosyntetics products which can allow permanent revegetation of the slope. For revegetation of the slope, soil bioengineering vegetation techniques such us live staking, seeding and rooted plants can be used. The rip-rap configuration at the toe and creek bed should generally follow the OPSD 810.010. The treatment should extend at least 1 m into the stream and 1 m up the slope failure. The lateral limits may extend at least 5 m north of the current slope failure at existing culvert outlet location and 5 m south of the current slope failure at storm water drainage pipe outlet location.

2.4 Existing Culvert Replacement

2.4.1 Expected Ground Conditions

According to the results of current foundation investigation, the following ground conditions along the proposed culvert alignment are evident:

a) Ramps N-E/W and E/W-N are single lane asphalt roadway and is about 6.8 m wide from edge to edge of road lane marks, with approximately 2.0 m wide paved shoulder on one side. Based on the observations, the roadway embankment at inlet side is less than 2 m high with side slope of about 4H:1V and at outlet side about 5.2 high with side slope of about ~2.5H:1V. The road surface elevation of ramps E/W-N and N-E/W along the culvert centerline is approximately at Elev. 321.1 m.

b) The ramps embankment consists of granular fill (0.3 m to 0.4 m thick) around paved area and topsoil (0.2 m to 0.3 m thick) around unpaved area. The granular fill/topsoil is underlain by very loose to very dense sand to silty sand fill (4.8 m to 6.4 m thick). Embankment fill is underlain by organic silty clay/peat (0.7 m to 0.9 m thick) followed by loose to compact gravelly sand (2.1 m thick)/ stiff to hard silty clay (2.9 m to 9.0 m thick) All boreholes drilled from ramps embankment are terminated within this layer.

c) At inlet side of the existing culvert, a layer of topsoil (~0.3 m thick) is underlain by very loose to loose sand to silty sand fill (3.5 m thick) followed by stiff to hard silty clay (6.7 m thick), BH-1 terminated within this layer. At outlet side of the existing culvert/storm water drainage pipe a layer of topsoil (~0.2 m thick) is underlain by very loose to loose sand to silty sand fill followed by stiff silty clay (0.7 m thick), BH-3 and BH-8 are terminated within this layer.

d) If cut and cover method is used for the culvert replacement, the foundation soil at the invert of the new culvert is anticipated to be very loose to loose sand to silty sand fill at inlet and outlet locations about Elev. 318.0 m and 314.5 m, respectively.

e) At the time of investigation, water level in culvert at inlet and outlet sides were measured at approximate elevations 318.5 m and 314.9 m, respectively. Observations at the time of investigation infer groundwater at about Elevation 318.5 m at inlet reduces down to about 316.5 and 316.0 m near BH-2 at center, and BH-5 at the crest edge; respectively. At the outlet, the groundwater level is inferred to be at about Elevation 315.0 m. In the area of storm water drainage pipe (BH-7 and BH-8) the ground water level is inferred to be near Elevation 316.5

m. 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 would be anticipated and this would be affected by prevailing weather conditions with higher levels occurring during wet periods.

Regardless of the trenchless method was the preferred option for the installation of new culvert at this site; as an alternative several possible, open cut excavation, options are also discussed below. Replacement of the existing structure is only recommended at the existing culvert location. At the location of storm water pipe, rehabilitation of the existing pipe and remediation of existing slope failure has been recommended. It is also recommended to access the existing storm water drainage pipe condition and functionality by the hydraulics engineer. The detail of the slope stabilization method has been discussed in Section 2.8.3 below.

2.5 Structure Foundations

For preliminary design purpose, several possible options are considered for the replacement of the existing culvert, if the culvert installation by open cut excavation method is considered:

- Rigid frame concrete box/pipe culvert less than 3 m span (precast or cast-in-place),
- Rigid concrete pipe culvert supported on shallow foundations,
- Corrugated steel pipe culvert supported on shallow foundations,

Based on the subsurface information obtained from the site investigations, the native stiff silty clay is considered suitable for support of all replacement options. However, the choice of culvert type will also depend on parameters such as the initial cost, maintenance costs, hydraulic performance, ease of construction, salvageability and local availability of material and equipment.

It is noted that regardless of the option selected for the open cut excavation installation method, the existing 1.37 m dia. concrete culvert is to be removed. This will require excavation down to the existing founding elevation for all options. This suggests the need for surface/groundwater control as discussed in Section 2.8.5 below.

Any loose and/or soft soils encountered below the existing embankment/culvert should be excavated and removed to firm bearing of native soils and the 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 the new culvert. Based on previous experience, typically a minimum thickness of 450 mm of a clear stone (OPSS 1004) 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 below compares the possible structure options from a foundations design and constructability perspective with their advantages and disadvantages. Although the foundation soils can provide adequate support for all options listed in the table, the use of a precast rigid frame box culvert is ranked highest for the criteria evaluated.

Table 2.1 Evaluation of foundation alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
Precast rigid frame box culvert	2	▪ Straightforward construction ▪ Reduced construction period, consequently traffic management and water control period ▪ Can be more readily installed during cold weather conditions	▪ If floor is thin and poorly reinforced, it may heave and crack ▪ During high flows, the concrete floor can be undermined ▪ Susceptible to defects/leakage at joints	▪ Low	▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil ▪ Risk of leaking from joints if not properly installed
Rigid concrete pipe culvert	1	▪ Suitable also for trenchless method ▪ Straightforward construction ▪ Reduced construction period, consequently traffic management and water control period	▪ During high flows, the concrete floor can be undermined ▪ Susceptible to defects/leakage at joints	▪ Low	▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil Risk of leaking from joints if not properly installed
Corrugated steel pipe culvert	3	▪ Straightforward construction ▪ Reduced construction period, consequently traffic management and water control period	▪ Limited design life ▪ Potential for corrosion	▪ Low to medium	▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil ▪ Risk of structure segment loss due to corrosion

2.5.1 Shallow Foundations

2.5.1.1 Geotechnical Resistance

Based on the subsurface stratigraphy encountered at this site and the assumed invert elevation of the new culvert, the recommended founding depths and geotechnical resistances for a structure founded on undisturbed competent natural soils are tabulated below.

Table 2.2 Recommended spread footing design parameters

Culvert Type	Founding/ Excavation Elevation (m)	Assumed Footing Size (m)	Founding Soil Type	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS* (kPa)
Rigid frame box culvert, rigid concrete pipe or CSP pipe culvert	~318 or below/ 317.7 (inlet)	3.0 m	Minimum 0.3 m compacted granular material (Granular A or Granular B Type II) over very loose to loose sand to silty sand fill	190	125
	~314.5 or below/ 314.2 (outlet)				
Rigid frame box culvert, rigid concrete pipe or CSP pipe culvert	~318 or below/ 315.5 (inlet)	3.0 m	Minimum 2.5 m compacted granular material (Granular A or Granular B Type II) over native compact stiff to very stiff silty clay	450	300
	~316.3 or below/ 314.2 (mid)		Minimum 2.1 m compacted granular material (Granular A or Granular B Type II) over native compact stiff to very stiff silty clay		
	~314.5 or below/ 313.4 (outlet)		Minimum 1.1 m compacted granular material (Granular A or Granular B Type II) over native compact stiff to very stiff silty clay		

Notes:
** for maximum settlement of 25 mm*

It is assumed that if any underlying organic fibers and any other soft or very loose materials are to be replaced with clean and compactable soil such as Granular A or Granular B Type II. Given that no (or minimal) grade raise is planned, the anticipated maximum total settlements for the new culvert is not expected to exceed 25 mm for construction done in accordance with these design parameters and assuming good construction practice including sound base preparation.

2.5.1.2 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 pre-cast concrete	Coefficient of friction (tan δ)=0.5

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

2.5.1.3 Frost Protection

The frost depth in the culvert is estimated to be approximately 1.4 m in accordance with OPSD 3090.101. During construction of any temporary and permanent support system using shallow foundations should be provided a minimum 1.4 m of soil cover or equivalent frost protection should be provided using thermal insulation. Frost protection is not required for the box culvert, concrete pipe or CSP pipe culvert.

If the frost penetration line is at or above top of the culvert the backfill and cover for these culverts should be as per OPSD 803.010. Where less than 1.4 m of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.010 for the concrete culverts with spans less than or equal to 3.0 m.

2.6 Lateral Earth Pressure

Culvert walls and temporary shoring should be designed to resist lateral earth pressure. The expression for calculating lateral earth pressure is given by:

$P = K(\gamma h + q)$ for non-braced cut, or $K(0.65\gamma h + q)$ 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 2.4 lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.

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. This would normally be the case for concrete box culverts.

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.

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 2.4 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/m^3)
Sand and Gravel Fill	32	0.31	3.25	0.47	21
Sand to Silty Sand Fill (very loose to compact)	30	0.33	3	0.50	19
Clayey Silt fill (stiff)	28	0.36	2.77	0.53	19
Organic Silty Clay (firm)	25	0.41	2.46	0.58	17
Peat	20	0.49	2.0	0.66	12
Gravelly Sand (loose to compact	32	0.31	3.25	0.47	21
Silty Clay (stiff to hard)	28	0.36	2.77	0.53	19

2.7 Seismic and Liquefaction Potential Consideration

Seismic characterization of the site must be compliant with the Canadian Highway Bridge Design Code CHBDC (CAN/CSA-S6-14). The potential for seismic loading must be considered for design in accordance with Section 4.4 of the CHDBC with respect to soil conditions encountered at the site. Table 4.1 in CHBDC (see Clause 4.4.3.2) shows site classification for seismic site response based on soil average properties in top 30 m. The borehole information shows the presence of native stiff soil. Based on these soil characteristics, the site class for this site is estimated to be Class "D" according to Table 4.1.

From the Natural Resources Canada website, 2015 NBCC seismic hazard values are obtained using the site location coordinates (43.47616°N, 80.49276°W) and the damped reference spectral accelerations for the project site are Sa(0.2)=0.057g, Sa(0.5)=0.038g, Sa(1.0)=0.022g, Sa(2.0)=0.010g and the reference peak ground acceleration (PGA) is 0.032g (g=acceleration due to gravity -9.81 m/s^2).

These values are associated with an earthquake having 10 percent probability of exceedance in a 50-year period.

Based on soils and groundwater condition encountered at the site, no liquefaction is expected due to the ground motion from an earthquake having 10% probability of exceedance in a 50-year period.

2.8 Construction Options

The selection of appropriate construction methods for new culvert installation considered (i) whether disruption of the traffic is acceptable or not; (ii) whether a new alignment is proposed or not; (iii) soil conditions at zone of culvert installation; and (iv) diameter and length of the new culvert. Further, several items to keep in mind during the selection were: (i) only approach that would allow removal of the existing culvert is a cut and cover method; (ii) the trenchless (tunneling) approaches involve construction adjacent to the current alignment with the need to decommission the existing culvert including grouting and sealing; (iii) the area of slope failure above the culvert should be restored to original ~2.5H:1V slope using compacted granular material properly benched into the existing channel (iv) even though cobbles and boulders were not encountered at the proposed levels of tunnelling, appropriate equipment and construction method shall be selected based on ability to accommodate these obstructions; and (v) provision must be made to maintain surface water flow to the outlet.

Considering all above, the several options were considered as possible alternatives for the new culvert installation method:

- Traditional cut and cover methods (i.e. construct temporary detour and open cut /unsupported excavation; and half-and-half construction using shoring system); and
- Trenchless (tunnelling) methods (i.e. jack and auger bore; pipe ramming; micro-tunnelling; and TBM tunnelling)

Full road closer of ramps with long detours around the area using existing roadways likely is not acceptable, therefore, these were not considered as an option for this culvert replacement.

Pipe bursting, pipe splitting and pipe swallowing methods for trenchless replacement of this culvert were also not considered as applicable in this project, since the size and nature of the host concrete 1.37 m in diameter classify this culvert as an unsuitable candidate for these techniques. According to OPSS 463 only pipes up to 900 mm in diameter should be considered for their replacement using these techniques. The interior replacement method is another installation method without disrupting traffic, but considering the fact that the culvert capacity will be reduced, this method is assessed as an unviable option.

Table 2.5 summarizes advantages, disadvantages and respective estimated cost of suggested methods.

Table 2.5 Installation methods for culvert replacement along the new proposed culvert alignment

Installation Method (see schematic sketches in Appendix H)			Advantages	Disadvantages	Relative Cost*	Ranking**
Cut and Cover Methods	*Close the ramp or Construct Temporary Detour and Open Cut Unsupported Excavation*		• Foundation soil assessment is possible • The existing culvert can be used to maintain the surface water flow during the construction • Existing culvert will completely remove and replaced with new culvert • Adaptable to changing ground conditions	• Traffic interruption • Time need to build the detour road • Large amount of soil to be excavated • High costs to build detour road on limited space • Risk of cost overrun and inability to finish job: low to moderate	More expensive than other cut and cover methods with shoring systems due to high costs to build detour roads	3 (if traffic interruption is acceptable)
	Half and Half Construction using shoring system	*Shoring System with Sloping Cuts*	• Short mobilization time • Low capital investment • Straight forward construction and construction procedures • Foundation soil assessment is possible • The existing culvert can be used to maintain the surface water flow during the construction • Existing culvert will completely remove and replaced with new culvert • Slope stabilization can be done while construction	• Traffic interruption • Roadway protection required for up to 8 m deep excavation • High cost of shoring system (i.e. road protection) • Large amount of soil to be excavated • Dewatering is required • Risk of cost overrun and instability to finish job: low to moderate	Likely less expensive than other cut and cover methods and trenchless methods *high cost of shoring*	1 (if traffic interruption is acceptable)

Installation Method (see schematic sketches in Appendix H)			Advantages	Disadvantages	Relative Cost*	Ranking**
		Shoring System with Braced Cut	• Possibly traffic flow maintained on existing road (e.g. steel decking, but costly) • Foundation soil assessment is possible • Global stability of excavation enhanced by narrow geometry • The existing culvert can be used to maintain the surface water flow during the construction • Less traffic interruption than shoring system with sloping cuts approach • Slope stabilization can be done while construction	• Bracing (e.g. struts) may interfere with excavation • Excavation material and placement of bracing required in limited space • Decommissioning of old covert required including grouting and sealing • Dewatering is required • More expensive due to cost of shoring	More expensive than other cut and cover methods with shoring systems due to higher costs of shoring	2 (if traffic interruption is acceptable)

Installation Method (see schematic sketches in Appendix H)		Advantages	Disadvantages	Relative Cost*	Ranking**
Trenchless (Tunnelling) Methods	*Jack and Auger Bore* (Non-entry Method)	• No traffic interruption and requirement for detour route • Handles wide variety of ground conditions (however, high groundwater level is problematic) • Relatively lower construction costs than microtunneling • Minimal surface disruption (if experienced contractors know how to control soil face when a change in ground or water conditions occur) • Very accurate (slope of 0.2% easily achieved) • Relative simple operation (if the ground and water conditions are favorable) • Common use in Ontario • Short mobilization time • Suitable for steel pipes up to 1.8 m in diameter • The existing culvert can be used to maintain the surface water flow during the construction	• Requires large area for jacking shaft and support equipment • Obstructions problematic • Presence of peat and organic silty clay layer might be problem • Short and long term settlement possible leading to a high risk to surface infrastructure • It is susceptible to ground loss in very fine-wet soil where soil can travel back via auger; sudden loss of the face can happen leading to ground loss and potentially endangering the workforce. In mixed face condition the problem is worsened. • Fluid to support annular space required • To prevent or minimize the ground water infiltration into tunnel, dewatering and/or remedial grouting are required along route • Requires decommissioning of old culvert, including grouting and sealing	Less expensive than other trenchless methods but more expensive than cut and cover method with shoring systems due to high cost of associated with tunneling/ constructing launching pits	1 (if traffic interruption is not acceptable)
	Pipe Ramming (Non-entry Method)	• No traffic interruption and requirement for detour route • Not very sensitive to ground condition • Suitable for steel pipes up to 1.8 m in diameter and best up to 50 m long • Accommodates obstructions well • Little surface settlement • Soil removed after pipe in place	• Pipe can be difficult to steer/direct • Requires decommissioning of old culvert, including grouting and sealing • Presence of peat and organic silty clay layer might be problem • Excavation and possible shoring required to achieve starting grade • Requires removal of rock fill at the entry and exit locations	Slightly more expensive than jack and bore method	4 (if traffic interruption is not acceptable)

Installation Method (see schematic sketches in Appendix H)		Advantages	Disadvantages	Relative Cost*	Ranking**
		• The existing culvert can be used to maintain the surface water flow during the construction	• Large entry pit size • Ground heave • Vibrations could potentially impact the stability of the existing slope • Slower than other trenchless methods • Dewatering possibly required at launching and receiving pits • More expensive than cut and cover methods and jack and bore method • Risk of cost overrun and instability to finish job: moderate to high		
Trenchless	*Micro- tunnelling* (Non-entry Method)	• Handles wide variety of ground conditions • Steerable horizontally to maintain and adjust alignment • Suitable for tunneling under groundwater table • Maintain the face in stable condition at all times (minimum ground subsidence if operated properly) • Alignment can be adjusted to avoid obstructions • Suitable for installation of pipes with minimum 1.5 m in diameter and 150 m length • Suitable for steel, reinforced concrete, and fiberglass pipes • Local contractors available • The existing culvert can be used to maintain the surface water flow during the construction	• High construction cost • Obstruction problematic • Presence of peat and organic silty clay layer might be problem • Requires decommissioning of old culvert, including grouting and sealing • Excavation and shoring require to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment • Requires large area for jacking shaft and support equipment • Not suitable for short drive • Dewatering possibly required at launching and receiving pits • More expensive than cut and cover method and jack and bore method	Significantly more expensive than jack and bore method	2 (if traffic interruption is not acceptable)

Installation Method (see schematic sketches in Appendix H)		Advantages	Disadvantages	Relative Cost*	Ranking**
	TBM Tunnelling (Man-entry Method)	• No traffic interruption and requirement for detour route • Good control of settlement • Safe to use in mixed ground condition • Ability to access obstructions during tunnelling • Cost may be reduced if and where existing contractor's suitable TBM is available • The existing culvert can be used to maintain the surface water flow during the construction	• High capital investment • Not practical for small diameter pipe (min. 1.8 m diameter) • Presence of peat and organic silty clay layer might be problem • Requires decommissioning of old culvert, including grouting and sealing • Dewatering possibly required at launching and receiving pits • Excavation and shoring require to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment • More expensive than open cut and jack and auger bore methods • Risk of cost overrun and instability to finish job: low to moderate	Significantly more expensive than jack and bore method	3 (if traffic interruption is not acceptable)

Notes:

* R*elative Cost* is determined for 0.9 m to 1.8 m diameter pipes based on Table 1 "Average cost of trenchless techniques with more than five data records, in Construction and Rehabilitation Costs for Buried Pipe with Focus on Trenchless Technologies", NRC-CNRC report No. IRC-RR-101.

** The ranking presented distinguishes two cases: (i) disruption of traffic is acceptable, and (ii) disruption of traffic is not acceptable.

Based on the above list of advantages and disadvantages of cut and cover, and trenchless (tunneling) construction methods, cut and cover methods might be considered as more viable methods from a geotechnical and/or foundation perspective, if disruption of traffic at Hwy 85 ramps are allowed. The major advantages of this approach are possibility to assess the foundation soil below locations of the new culvert, to open and fix the slope failure, and to remove the existing culvert, if the new culvert is installed along the existing alignment. On the other hand, the major disadvantage is disruption of traffic. Among these cut and cover methods, the half-and-half excavation/construction using shoring system with open cut sides appears to be the most economical. The detour option using open unsupported excavation is estimated as a less economical and practical option due to limited space for construction of detour road and high costs and time required for building the detour road. The other half-and-half excavation/construction method using shoring system with braced cut also appears less economical and practical considering the high price of the shoring.

However, if the Regional Traffic office requires replacing the culvert without disrupting traffic, then trenchless (tunnelling) installation methods listed in Table 2.5 are more viable. The major disadvantages of these trenchless installation methods are higher cost of installation than the cut and cover methods and the need to decommission the existing culvert by grouting and sealing. The slope failure occurred at outlet side of the embankment slope should be grouted and backfilled to prevent from ground movement during tunneling. Among these tunnelling methods, the jack and auger bore method is assessed as the most economical. On the other hand, groundwater infiltration into the tunnel could be problematic and the jack and auger bore and pipe ramming methods could be difficult to steer which can be problematic because of proximity of the existing culvert. Micro-tunnelling and TBM tunnelling are ranked as less viable tunnelling methods since the size of the tunnel is not favorable for these methods (i.e. the tunnel is relatively short to be economical for these two methods). The pipe ramming method is ranked as the least viable trenchless method at this site since resulting vibration during installation could potentially impact the stability of the existing embankment slope which is currently assessed to be marginal.

Therefore, based on the site conditions and method characteristics elaborated above, the following options for the culvert construction at the proposed alignment are discussed in the following sections:

- Culvert installation by cut and cover methods: open cuts with detours; half-and-half construction using shoring system and unsupported cut sides along with temporary detour to divert traffic from one of the ramp; and using roadway protection and braced cut sides
- Culvert installation by trenchless (tunnelling) methods: jack and auger bore, pipe ramming, micro-tunnelling and TBM tunnelling

2.8.1 Culvert Installation by Cut and Cover Method

Constructing a temporary detour followed by open cut unsupported excavation appears to be one of the viable culvert replacement methods if the temporary detour approach west of ramp N-E/W maintain two-way traffic is acceptable and feasible (see Figure H.1 in Appendix H). With this approach, grouting and sealing of the existing culvert (i.e. decommissioning) will be eliminated since this option will allow removal of the existing pipe. It will also allow for the assessment of the foundation soils below the proposed location, and if any peat or soft materials are encountered they can be removed. The existing culvert could be used for maintenance and diversion of surface water flow during the construction. However, as mentioned before, the method with the temporary detour could be very expensive and impractical due to limited space available for detour construction and high costs to build the detour road.

Therefore, the staged construction with shoring system (i.e. half-and-half construction) along the centerline of the road and unsupported cut sides is assessed as a more viable culvert replacement method for this project, assuming that, traffic from one of the ramp will divert through temporary detour build between two ramps. The construction sequences for this method may include: (i) construct temporary detour between two ramps; traffic of one of the ramp utilized this temporary detour while the ramp is excavated; (ii) half the new culvert is constructed and rebuilt the embankment to grade in this side; and (iii) the traffic could be moved onto the new fill and the process is repeated to complete the construction.

2.8.1.1 Construct Temporary Detour and Open Cut Unsupported Excavation

On the west side of the current ramps, temporary on-site detour ramps may be constructed (assuming available space is sufficient for construction) to maintain the two-way traffic flow during the construction of the new culvert (see Figure H.3 in Appendix H). The excavation scheme should follow the excavation practices outlined in Section 2.8.2. The surface water flow could be maintained by the existing culvert.

Compacted engineered fill for construction of the temporary detour road is recommended. Prior to construction of the temporary detour embankment, the site will need to be cleared and grubbed of any existing bushes and vegetation. All surficial topsoil (if exists), organics and softened or loosened soil should be stripped form below the proposed temporary detour road embankment. All subgrade soils should be proof-rolled prior to fill placement and embankment fill should be placed in accordance with OPSS. PROV 206 (dated November 2014).

2.8.1.2 Half-and-Half Construction Using Shoring System

Since the excavation in the road embankment is relatively high (up to 8 m) a temporary shoring system will be required as a roadside protection system. A shoring system such as soldier pile and lagging or sheet piles can be employed for the temporary excavation. Given the setting, the internal bracing for horizontal support, such as a system of walers and rakers, would be required and the impact on excavation operations must be accommodated. It will be the Contractors' responsibility to design a suitable temporary support system for the MTO review prior to installation. The Contractor should follow OPSS 902, regarding excavations for structures, and OPSS 539, regarding temporary protection systems. Recommendations for a temporary roadway protection are given in Section 2.9. Using the half-and-half construction approach, two methods of culvert replacement were considered for this site suitable as discussed below:

A. Construction using roadway protection and unsupported excavation of cut sides along with temporary detour to divert traffic from one of the ramp
B. Construction using roadway protection and braced or anchored cut sides

Option A could be more economical due to possible cost savings for reversible wall configuration, but it will be more disruptive to the highway embankment. Option 1.B will disrupt less of the embankment but would cost more, i.e. about 1.8 times of Option 1.A. Excavation and backfilling operations will also be more challenging with Option 1.B. Both options require decommissioning of shoring system upon completion of the work.

Option A: Half-and-Half Construction with Roadway Protection and Unsupported Cut Sides along with temporary detour to divert traffic from one of the ramp

This method provides roadway protection parallel to the existing ramps between two ramps, and allows to divert traffic to the one side and undertake open cut with sloping sides at the other side (see Figure H1.A, Appendix H). However, this method also required construction of a temporary detour for diversion of traffic from one of the ramp. The construction of temporary detour and moving traffic may impact the existing storm water pipe line located on south of the existing culvert. Since, soil investigation is not conducted at the location of construction of detour between ramps and no subsurface soil information is available; to prevent from unwanted deformation, grouting of the subsurface soil under the existing storm water pipe is recommended. The roadway protection can take the form of reversible shoring such as a solder pile and lagging with rakers or anchors for horizontal support. Where the cut extends below prevailing groundwater a suitable control/system is required. Once one side is completed the supports can be reversed and the other lane constructed in similar fashion. The shoring system would likely be decommissioned in place. Temporary surface water flow control must be developed by contractor.

Option A could be more economical due to possible cost savings for reversible wall configuration, but it will be more disruptive to the highway embankment than Option B since it needs to excavate a large amount of soil and construction of detour route.

Option B: Half-and-Half Construction with Braced or Anchored Cut Sides

This method provides braced or anchored cut shoring system perpendicular to the ramps for face protection and to allow culvert construction (see Figure H1.B., Appendix H). Excavation in this case would have to accommodate the necessary cross-bracing such as struts. With this option, consideration would have been given to how the new culvert sections will be installed given the relatively narrow work area and potential for obstructions form the lateral bracing using struts. Installation of tiebacks could be the solution. Temporary decking could possibly be used over the supported cut to allow for excavation of both halves prior to diverting stream and backfilling. However decking would be costly. As well as Option 1.A, decommissioning of the shoring system and temporary surface water flow control must be performed/developed by contractor.

Option B will disrupt less of the embankment than Option A but would cost more, i.e. about 1.8 times of Option A, due to the cost of shoring system. Excavation and backfilling operations will also be more challenging with Option B. Both options require decommissioning of shoring system upon completion of the work.

2.8.2 Excavations

All excavations at this site must be conducted in accordance with the Occupational Health and Safety Act (OHSA) and Regulations for Construction (O. Reg. 213/91). All fills (i.e. sand and gravel fill and sand to silty sand fill) and native silty clay may be classified as a Type 3 soil above the groundwater table in conformance with the OHSA. The sandy soils below the groundwater table may be classified as a Type 4 soil. It is expected that most of excavations will be above the groundwater levels except those at the invert level. To avoid disturbance of the founding subgrade and to allow placement of backfill in dry conditions, groundwater must be controlled to below the proposed invert excavation levels prior to digging to final levels. As mentioned before, the ingress of surface water must be controlled using a suitable system as well.

Temporary excavation side slopes for Type 3 soil should not exceed 1H:1V in accordance with OHSA. Temporary excavation side slopes for Type 4 soils should not exceed 3H:1V where applicable. There is a potential for sloughing to occur if the trench remains open for an extended period of time (i.e. > 24 hours) or during a rainfall event. In addition, some localized surficial sloughing may be experienced in areas of perched groundwater seepage (i.e. within the embankment fill).

2.8.3 Culvert Bedding

OPSDs 802.010, 802.031, 802.032 and 803.010 which are included in Appendix G provide the bedding, embedment, cover and backfill standards for the different culvert material. According to these standards the culvert bedding should consist of Granular A (OPSS.PROV. 1010) with thickness of 300 mm beneath the culvert and extend a minimum of 500 mm horizontally on either side of the culvert edge. 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. PROV 401. Bedding on each side of the culvert (i.e. CSP pipe) shall be completed simultaneously. At no time, shall the levels on each side differ more than the 200 mm uncompacted layers.

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 culvert. The geotextile separator is to be a Class II non-woven material with an equivalent opening size of 75-150 μm.

For the site area, a frost penetration depth of approximately 1.4 m can occur in open, unheated areas without snow cover. At the culvert inlet and outlet, and beneath the proposed culvert, mostly the native soils consist of silty clay. This material has medium to high frost susceptibility based upon the MTO Frost Classification guideline of percent particles between 5 to 75 μm. Therefore, non-frost susceptible materials such as sand and gravel need to be provided to the limit of frost penetration beneath the inlet and outlet of the culvert. However, considering that cold air blowing through the culvert during the winter season will freeze soil next to the culvert, a minimum 500 mm thick layer of non-susceptible material should be considered to be placed as a bedding along the entire culvert length.

2.8.4 Culvert Backfill

The selection and placing of the backfill and cover should be in accordance with OPSS 902, OPSS.PROV 421, OPSS 422 and OPSD 803.010 for concrete and pipe culverts. The backfill should consist of free-draining, non-frost susceptible granular materials confirming to OPSS.PROV 1010.

For fills immediately below any roadway, it is recommended that Granular A or B materials be used. Where necessary, proper tapering as per standards should be provided. Below a depth of about 1.4 m from any finished road grade, approved compactable fill, such as select subgrade materials (OPSS.PROV 1010) or imported fill can be used.

All granular backfill materials should be placed in thin lifts (i.e. not exceeding 300 mm before compaction) and each lift should be compacted in accordance with OPSS 501.

The use of heavy compaction equipment should be avoided immediately adjacent and above the culvert, as per MTO practice. The minimum height of fill cover above the crown of the culvert before power operated tractors or rolling equipment shall be 900 mm, unless otherwise noted by the structural engineer. During backfill placement, the height of the backfill should be maintained at approximately same level on both sides of the structure, to avoid lateral displacement of the structure.

Where less than 1.4 m of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.010, 803.030 and 803.031.

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 C6.20a of the CHBDC), suitably outleted etc. should be provided in order to prevent hydrostatic pressure build-up.

2.8.5 Groundwater and Surface Water Control

The soils encountered below the groundwater table and within potential excavation depths consist of sand to silty sand fill to native silty clay. The material could be susceptible to disturbance from groundwater and mobilized equipment. In general, the groundwater level needs to be controlled to at least 0.5 m below the excavation level to avoid disturbance, and any surface or groundwater seepage should be removed from the excavation prior to the culvert 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.

Provided that the existing culvert is to remain in use during construction of the new culvert, the majority of the upstream flow of the existing culvert can be diverted around the construction area. If the existing culvert is to be removed prior to completion of the new culvert, a system of sumps and pumps will be required to divert the surface water up and over the existing embankment.

Dewatering shall be carried out in accordance with OPSS 517. It is responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions for prior approval of the MTO. The method used should not undermine the existing road embankment or adjacent side slopes. In this connection, the provision of toe protection at side slopes during drawdown may be required to minimize sloughing and undercutting during dewatering.

Erosion and sediment control during culvert construction should be as per the MTO Drainage Manual, Volume 2. Silt fences and other sediment control measures should be included to protect the downstream environment from the construction activities.

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 replacement of existing culvert, 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.

2.8.6 Culvert Installation by Trenchless (Tunnelling) Method

Tunnelling will be a viable installation method for culvert replacement along the new culvert alignment if interruption of traffic on Hwy 85 and Bridgeport Road interchange is not acceptable. Some tunnelling methods are considered and discussed in Section 2.8 above based on soil and groundwater conditions at the site and the dimensions of the new culvert. For all trenchless installation methods the procedures should conform to all relevant Ontario Provincial Standard Specifications (OPSS), Non Standard Special Provisions (NSSP) such as Pipe Installation by Trenchless Method (Attached in Appendix I) and industrial standards. However, since the existing pipe is proposed to be abandoned, it is recommended that the new alignment has to be at least 3 pipe diameter offset to the south, relative to the existing culvert. The existing abandoned culvert must be properly decommissioned including grouting and sealing. It should be noted that the stability of face must be maintained at all times for culvert installation by trenchless method. It is recommended that the failed area to be restored to 2.5H:1V slope using granular material and to be pressurized cementitious grouted of the existing slope failure. It is also recommended to be used shoring systems for excavation of entry and exit pits.

It is projected that the culvert trenchless (tunneling) excavation will be carried out generally through sand to silty sand fill, assuming that the approximate elevation of the new culvert invert is between Elev. 318.0 m at the inlet and 314.5 m at the outlet. Based on the measurements during this investigation, the inferred ground water level within the embankment was estimated to be at approximate Elevation of 318.5 m or slightly above, which appears to be above the tunnel invert. However, seasonal variations in the groundwater table should be expected.

The soil above the tunnel crown will consist of the embankment fill. **Since there is less than 2 diameters soil cover above the tunnel crown, there could be significant risk of excessive ground settlement if the vertical profile of the culvert remains unaltered.** This should be red flagged**.**

The Tunnelman's Ground Classification System (Terzaghi, 1950) is commonly used to describe the potential behaviour of and unsupported tunnel face during excavation. This system uses qualitative "stand up time" criteria to classify the ground into six principal categories. Based on this system, for an exposed tunnel face, it is anticipated that the sandy soils to organic silty clay/ silty clay within the tunnel horizon would generally behave as "flowing" to "squeezing" ground. Therefore, tunnelling methodologies that involve and exposed and unsupported tunnel face may not be feasible for this project, unless the groundwater level is lowered in advanced of tunnelling.

Cobbles and boulders were not encountered in the zone of tunnelling during borehole investigations, however some organics and wood fibres were encountered at the zone of tunneling. Due to the nature of fill, cobbles and boulders can be expected that they may be present in the embankment fill. The NSSP for these obstructions in the fill and tunneling zone is included in Appendix I.

The best viable tunnel excavation methods assessed in Table 2.5 above are discussed in the subsequent sections, as well general tunnelling construction considerations.

2.8.6.1 Tunnel Excavation Methods

2.8.6.1.1 Pipe Jack and Auger Bore

Pipe jack and auger bore method involves jacking a pipe through the soil with a hydraulic ram and removal of soil with an auger. A cutting head is fixed to the leading edge of the pipe. The auger transports spoils from the cutting head back to the bore pit. The direction of the auger head can only be controlled using a rudimentary steering system where minor adjustments can be made. The procedures should conform to all relevant OPPS (i.e OPSS 416) and industrial standards. One of the advantages of using the jack and bore method for the pipe installation is that the auger can be manually removed to permit cleaning of obstructions such as cobbles and boulders. Further, the auger can be adopted to use rock-cutting teeth, if necessary. However, the steering ability and grade is limited.

The elevation and gradient of the pipe must be closely controlled during the course of the jack and bore. For the proposed jack and bore installation in "mixed face" soil, boring and jacking operations should be performed simultaneously. It is recommended that auger would always be maintained at least 1 m behind the cutter edge. The jacking and boring operations should be continued without stoppage until completion. To reduce (but not eliminate) loss of ground and associated disturbance, consideration may be given to jacking the pipe across the alignment as far as practical, prior auguring. However, obstacles, if encountered in the embankment fill, could make this difficult or impractical. Lubrication may be provided to reduce the friction between the pipe and the borehole walls. The characteristics of the surrounding soil should be considered in selecting the appropriate lubricant.

Considering the soil conditions at the site and the length of the new culvert, the pipe jack and auger bore method is suitable for installation of the new culvert, however, there are several items that must be addressed when considering this method. First, the problem associated with this method is deviation from the alignment, if not executed properly. The installation of the proposed culvert must not interfere with existing utilities, if any, and/or new proposed installation. Therefore, driving of the pipes must be very accurate. Second, due to presence of groundwater above the tunnel crown and presence cohesionless soil around tunnelling zone, control of the face of excavation could be difficult. Groundwater infiltration from the inlet through fill is expected. Using of pumps of sufficient capacity from jacking pit and design of suitable dewatering along the culvert alignment may required to prevent groundwater infiltration into the tunnel. Conversely, grouting will be required during jacking and boring.

Design of the suitable dewatering is the responsibility of the Contactor. Furthermore, any significant voids between the casing and the surrounding soil should be filled with pressurized cementitious grout to prevent / minimize ground loss. Based on the current investigation data and assumed invert levels, it appears that the pipe jacking and boring will be performed through very loose to compact sand to silty sand fill, and the groundwater level will be above the invert of the pipe. This would likely utilize the existing culvert prior to its decommissioning.

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

2.8.6.1.2 Pipe Ramming

Pipe ramming is a trenchless method for installation of steel pipes over distances typically up to 50 m long and up to 1.8 m in diameter. The method uses pneumatic percussive blows to drive the pipe into ground. Spoil removal from the pipe can be done by auger. It typically requires excavation of two pits, but the ramming can be launched without an insertion pit if the ram is design to start at the side of a slope.

Considering the soil condition and the length of the proposed culvert, the pipe ramming method is assessed as suitable for its installation. The required length of 50 m is at the upper limit of the method, and the tunnelling will be in soft to stiff clayey soils mostly above the water table. However, installation is very noisy and difficult to steer, and its vibration could destabilize the embankment slope.

For this method surface water has to be controlled, and the existing culvert has to be properly decommissioned.

2.8.6.1.3 Micro-tunnelling

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

The major advantage of micro-tunnelling method is that its performance is not affected by high groundwater levels, so the dewatering is not required. Major disadvantages of micro-tunnelling for this project are considered to be the relatively high cost of mobilization and not viable for relatively short length. This option may become more attractive if potential bidders have available equipment in house.

For excavation of the launching pit, a protection system might be required to minimize possible negative impact on the stability of the existing embankment slope.

2.8.6.1.4 TBM Tunnelling

TBM tunnelling is a man-entry tunnelling method and encompasses the use of a tunnel boring machine (TBM). This method utilizes laser-guided targeting that achieves a very accurate line and grade to the pipe being installed. To control ground movement behind the TBM a primary liner must be installed. TBM can employ single pass or two pass system. In the two pass system the temporary liner can be ribs and lagging with the permanent liner cast-in-place afterwards. The primary liner can be provided by steel, cast iron or precast concrete liner plates. The space on the outside of the liner plates should be grouted as soon as possible, to reduce ground loss and ground settlement. Primary support can be also provided by jacking a pipe from a jacking station behind the boring machine. Pipes may be made of various materials (concrete, steel, fibreglass, etc.).

The launching pit and jacking station should be constructed at the inlet side. If there is no sufficient depth to construct a thrust wall for jacking, the jack reaction can be resisted by means of a structural framework constructed above ground having adequate restrain provided by means of piles, ground anchors or other such methods for transferring horizontal loads. TBM tunnelling with pipe jacking method is limited by the jacking force available. A protection system might be required to minimize possible negative impact on the stability of the existing roadway.

TBM tunnelling might be the most expensive method for the installation of the proposed culvert considering the short length of the tunnel. In addition, this method would require oversizing of pipe to minimum 1.8 m. Cost might be reduced if, and where, existing Contractor’s suitable TBM is available.

2.8.6.2 Considerations of Tunnelling

2.8.6.2.1 Groundwater Control

As mentioned before, groundwater seepage into the tunnel should be expected in the zone of tunneling. The dewatering or grouting might be required in the launching pit prior to advancing the pipe to ensure dry working conditions and stabilize the excavation in that zone. The dewatering would need to be carried out to temporary lower the groundwater level to at least 1 m below the base of the excavation. Dewatering requirements will be governed by the time of the year when the construction is performed. It is the responsibility of the Contractor to propose a suitable dewatering system based on the time of construction and groundwater levels. The method used should not undermine the existing highway. Dewatering shall conform to OPSS.PROV 517.

As indicated above, if jack and bore technique is considered for installation of culvert, suitable dewatering systems along the culvert alignment should be designed to prevent groundwater infiltration into the tunnel. Conversely, grouting will be required during jacking and boring. The ingress of groundwater and surface water into the jacking pit should be controlable to handle by using pumps of sufficient capacity.

2.8.6.2.2 Ground Settlement

Settlement around the culvert is a combination of ground loss or “immediate” settlement caused by tunnelling, and consolidation settlement. The immediate settlement is a direct result of the overcut and movement of ground at the heading during tunnelling. The factors that influence the immediate settlement include the soil strength, the method of tunneling, the tunnel size and depth, the form of primary support, the grouting procedure used to fill voids outside of the primary liner, the timing of the grouting and the contractor's workmanship. Based on soil characteristics of the site, an experienced Contractor should be able to keep the settlement under the MTO's required limit of 10 mm. Technical specifications should ensure that:

- The use of over-cutters (excavating to a diameter greater than the pipe diameter) is kept under 10 mm;
- The overcut area is grouted in a timely manner (if a man-entry tunnel is constructed grout should be injected immediately after support is installed); and
- The program of instrumentation is carried out as per MTO guidelines.

In the event that the settlement is greater than the allowable 10 mm, some soil stabilization measures such as grouting or ground freezing might be applied to arrest or reduce settlement.

Generally, there is a risk of over-excavation and the formation of voids around the liner pipe in any tunneling operation. To minimize ground surface settlement and to avoid unbalanced loads on the liner, grouting around the liner is generally recommended.

The need for grouting around the liner pipe should be evaluated once tunneling is complete. The amount of spoil removed during tunneling should be monitored to determine whether over-excavation is occurring. If there is suspicion that over-excavation has occurred, and/or if the settlement monitoring indicated that the ground surface has settled, then a plan should be in place for investigating of presence of gaps/voids in the soil above the pipe and for remediation measures such as filling the gaps/voids with grout. The contractor should develop a contingency plan incorporating appropriate soil volume monitoring to address loss of material from outside the pipe during the tunnelling operation, as discussed in Section 2.8.6.3.

Before the construction of the new culvert starts, the existing culvert must be decommissioned and sinkholes, if any, made good by filling and/or grouting.

2.8.6.2.3 Excavation Pits

The launching and receiving pits for the tunnelling equipment are expected to be located at the inlet and outlet of the proposed culvert location, respectively. The bases of the pits are expected to be set at about 0.5 to 1 m depth from invert of the proposed culvert. Excavations for launching and receiving pits will be conducted through stiff silty clay. In order to provide the required excavation geometry for the drilling (e.g. vertical front face for tunnel entry and a vertical rear face with a ballast system to act as a reaction force), the sides of the excavation will have to be shored. Recommendations for shoring are addressed in Section 2.8.6.4 of this report. Ingress of groundwater and surface water has to be controlled as explained previously in Section 2.8.6.2.1 of this report. Technical specifications must ensure that the Contractor submits a groundwater and surface water control plan describing the proposed method for control.

2.8.6.2.4 Backfilling in Pits

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

All excavations should be backfilled with inorganic on-site soils placed in maximum 200 mm thick lifts and compacted to at least 98% of the Standard Proctor Maximum Dry Density (SPMDD). Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials.

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

2.8.6.3 Monitoring and Contingency Plan

It is emphasized that the resulting performance of the installed culvert will largely be dependent upon construction procedures and techniques. However, regardless of the method of tunnelling selected for this project, it is recommended that the contractor develop a contingency plan incorporating appropriate soil volume monitoring to address loss of material from outside the pipe during the tunnelling operation. This plan should include at a minimum the following items:

a) an “Alert” level(s), e.g. the percentage of soil in excess of 100% of the displaced soil, at which the plan would be implemented;
b) a means to close the tunnel, and preferably to pressurize the pipe; and
c) an emergency personnel/agency contact list.

Settlements should be monitored during construction to ensure compliance with MTO guidelines and the contract requirements. The instrumentation program should adequately verify effects of tunnelling on the overlying highway and obtain advance warning of ground movements. The scope and layout of settlement instruments should be in general accordance with the MTO guidelines (Appendix: Settlement Monitoring Guideline – Tunnelling). This should include a series of surface monitoring points placed at a maximum spacing of 5 m along the entire length of the proposed culvert. All monitoring points located in the unpaved portion of the right-of-way are to be founded below the frost penetration depth, which is typically 1.4 m in this area.

A reading schedule should be as follows:

- A minimum one set of readings prior to construction.
- A minimum three sets of readings during construction provided the movements are within the anticipated limits. Otherwise, the reading frequency may have to be increased.
- A minimum of two sets of readings on a weekly basis after completion of the work.

Instrumentation plans should be finalized once the Contractor is selected and when his construction methods are known.

As mentioned, control of ground settlement on this project depends on the behaviour of soil at the tunnel face and on the tunnelling methodology employed by the Contractor. Therefore, it is recommended that a geotechnical engineer be present during active excavation to verify that the ground conditions are consistent with those encountered in the investigation boreholes. Furthermore, it is recommended that the volume of the material removed from the tunnel be monitored and continuously compared to the rate of tunnel advance. This will provide an indication if any over-excavation is taking place.

The criteria for evaluation of settlement should be based on the following action levels:

1. *Review Level:* If a maximum value of 10 mm relative to the baseline readings is reached, the method, rate or sequence of construction, or ground stabilization measures shall be reviewed or modified to mitigate further ground displacements.

2. *Alert Level:* If a maximum of 15 mm relative to the baseline readings is reached, the Contractor shall be required to cease construction operation or to execute pre-planned measures to secure the site to mitigate further unacceptable settlement and to assure safety of public.

2.8.6.4 Protection Systems

Depending on the tunnelling method chosen for this project and the excavations that will be required to implement them, protection system(s) may be required for the existing roadway. The need for these systems will depend on the proposed geometry of the required excavations and their proximity to the existing highway structure. If required, protection systems (design, materials, construction, maintenance, monitoring and removal) will be required to meet the specifications set out in OPSS.PROV 539. Recommendations for the protection systems are presented in Section 2.9.

2.9 Temporary Roadway Protection

Temporary roadway protection is anticipated to be a part of the half-and-half construction approach and rehabilitation of existing storm water drainage pipe, that will be required to maintain on-site traffic during the construction. It is recommended that roadway protection system be 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 a shoring system, such as 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

2.4. The actual depth of embedment should be determined by balancing moments about the pile tip. 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. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours.

As mentioned above, 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.

2.10 Embankment Design

2.10.1 Embankment Stability

A preliminary slope stability analysis was performed to assess the global stability of the existing embankment and to check that a minimum Factor of Safety of 1.3 will be achieved for the new embankment at the location of the proposed culvert and existing storm water drainage pipe. 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 the cross-section perpendicular to the roadway at the proposed culvert location and the existing storm water drainage pipe location. The cross-section of the existing embankment with the approximate slopes of 2.5H:1V was developed based on the drawings 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 silty clay deposits. Therefore, an effective stress analysis for a long term and total stress for short term assessment of the embankment slope was performed taking into consideration the subsoil conditions encountered beneath the existing embankment.

The SLOPE/W graphical printout, for analysis performed is included in Appendix F. Since the geometry and soil stratigraphy at the east side slopes are critical than that at the west side slopes, the result of the slope analysis performed for the east side slope, is only presented.

Tabulated below in Table 2.6 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 2.6 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)
Sand and Gravel Fill	32	0	21	32	0	21
Sand to Silty Sand Fill	30	0	19	30	0	19
Clayey Silt fill	0	50	19	28	0	19
Organic Silty Clay	0	35	17	25	0	17
Peat	0	25	12	20	0	12
Gravelly Sand	32	0	21	32	0	21
Silty Clay	0	80	19	28	0	19

The results of slope stability analyses for the ~2.5H:1V east side slope of the existing embankment (at the proposed culvert alignment and the storm water drainage pipe location) using undrained (short term stability) and drained (long term stability) soil parameters are presented in Table 2.7 below and graphically in Figures presented in Appendix F. A minimum Factor of Safety is more than 1.3, indicating that the existing embankment is stable. The slope stability analyses performed for the new embankment constructed of engineered fill show that the embankment is stable if it is constructed with current side slope (i.e. ~2.5H:1V, Figure 3 and 4 in Appendix F).

Table 2.7. Summary of stability analysis results for existing slope conditions

Section	Location	Min. Factor of Safety*		Figures in Appendix F	
		Total Stress Analyses	Effective Stress Analyses	Total Stress Analyses	Effective Stress Analyses
1	Existing culvert	1.5	1.5	Figure 1	Figure 2
	After construction	1.5	1.5	Figure 3	Figure 4
2	Storm water drainage pipe	1.5	1.5	Figure 5	Figure 6

2.10.2 Embankment Settlement

It is not planned to change significantly the existing embankment grade at the culvert location. Therefore, there should be negligible additional settlements under the existing embankment. However, a settlement of about 25 mm should be allowed for due to rebound during the construction.

2.11 Inlet and Outlet

2.11.1 Erosion Protection

Erosion/scour protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions for preliminary guidance considering native material anticipated. In general, rip-rap protection should be provided where the culvert discharges into the open creek. The rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow the OPSD 810.010, which is included in Appendix G of this report. The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends.

Where the embankment side slopes have been scarred and/or excavated (beyond rip-rap limit) to facilitate the existing culvert replacement, 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.

2.11.2 Stream Bed Rip-Rap

The stream bed rip-rap thickness is to be at least twice the median particle size, and/or 300 mm thick as a minimum as outlined by OPSD 810.010 included in Appendix G of this report.

2.11.3 Seepage Cut-off Requirements

The seepage cut-off requirements should be reviewed in the following context. The native silty soils at the inlet, outlet side has a high potential for migration with high seepage gradients. For the culvert replacement and new culvert installation, methods to avoid piping/undermining/scouring of material resulting from seepage along the culvert must be considered and implemented. To prevent surface water from flowing beneath the culvert (potentially causing undermining/scouring) or around the culvert (seeping through embankment fill) these flows should be restricted. For culverts the following are typical methods: (i) clay seal, (ii) steel or wooden sheet pile cutoff at the upstream end of culvert, (iii) cut-off wall incorporated in the apron slab (if one is used) of the culvert, (iv) cut-off trench constructed with geotextile, and (v) rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert. Only the clay seal and cut-off trench will be addressed since the sheet pile cut-off will require the understanding of the hydraulics of the stream.

2.11.3.1 Clay Seal

Where readily available a clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment (OPSD 802.095, Appendix G). OPSS. PROV 1205 specifies that material used for clay seals shall be natural clay, clay mixture (1 part Bentonite powder and 3.5 parts Granular "A") or a geosynthetic clay liner (GCL). The coefficient of permeability shall not exceed 1 x 10^{-6} cm/s.

The following outlines the installation procedures and minimum material requirement of the clay seal:

- The clay seal should be placed along the sides and top of the culvert a minimum of 1.0 m along the side of the culvert and extending out laterally 1.0 m from the culvert.
- The clay seal should be placed from the top of the culvert footings and extend along the side and the top of the culvert. The clay must not be placed below the culvert.
- The clay should have a Liquid Limit greater than 40% and a Plasticity Index greater than 0.73 x (Liquid Limit – 20%).
- The clay seal is to be place in maximum 150 mm thick lifts and compacted to 95% SPMDD within 2% of the optimum moisture content.

If the GCL is used as a clay seal its material specifications containing the physical, mechanical and hydraulic properties shall be obtained from the manufacture. It is estimated that an approximately 12 mm thick GCL should be installed a minimum 1.0 m along the side of the culvert.

2.11.3.2 Cut-Off Trench

A cut-off trench can be used at both the upstream and downstream ends of the culvert and can be incorporated when the rip-rap apron at both ends of the culvert are being installed. In general, a trench is dug across the stream alignment to well beyond the walls of the culvert and a geomembrane liner is laid on the side of the trench keyed into the culvert at the top and on the base of the trench. The trench is then backfilled with graded rip-rap.

2.12 Corrosion Protection

One soil sample was selected for chemical analyses and was sent to AGAT laboratories, 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 E.

The chemical data indicates low resistivity of the tested soil (2000 to 4500 ohm-cm), which indicates a moderate potential for corrosion of buried metallic elements, particularly pipes and appurtenances (MTO Gravity Pipe Design Guidelines, Page 25). Therefore, some level of pipe protection requires, depending upon the pipe material type. The maximum chloride content reported is 94 ppm (µg/g) which indicates a low potential for additional corrosion.

The maximum water soluble sulphate content of the soils tested is < 16 ppm (µg/g), i.e. <0.016% and being less than 0.10%, does not indicate the potential to corrode normal Portland cement concrete.

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 Aziz Abdelmessih.

exp Services Inc.

Nimesh Tamrakar, M.Eng., EIT.
Technical Specialist

Silvana Micic, Ph.D., P.Eng.
Senior Geotechnical Engineer
Project Manager

LICENSED PROFESSIONAL ENGINEER
S. MICIC
100050187
10/7/17
PROVINCE OF ONTARIO

TaeChul Kim, M.E.Sc., P.Eng.
Senior Geotechnical/Foundation Specialist

Stan E. Gonsalves, M.Eng., P.Eng.
Principal Engineer
Designated MTO Foundation Contact

LICENSED PROFESSIONAL ENGINEER
S.E.M. GONSALVES
10/7/17
PROVINCE OF ONTARIO

exp.

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

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

REPORT FORMAT

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

Appendix A –
Site Photographs

Photo 1: Looking north on Ramp E/W-N from Bridgeport Road

Photo 2: Looking south-east at inlet of the existing culvert

Photo 3: Looking west from the inlet of the existing culvert

Photo 4: Looking north towards inlet of existing culvert

Photo 5: Looking north on east side slope (outlet side)

Photo 6: Looking east from top of the embankment towards outlet of the existing culvert

Photo 7: Looking north from the existing culvert outlet

Photo 8: Looking south from the existing culvert outlet

Photo 9: Looking north from the storm water pipe outlet

Photo 10: Looking south from the storm water pipe outlet

Photo 11: Slope failure above the existing culvert looking west-north from the outlet

Photo 12: Slope failure above the existing culvert looking west from the outlet

Photo 13: Slope failure above the storm water pipe looking north from the outlet

Photo 14: Slope failure above the storm water pipe looking west from the outlet

Appendix B – Drawings

WR Agreement No. 3015-E-0017
Assignment No. 5
W.O. 2017-11009

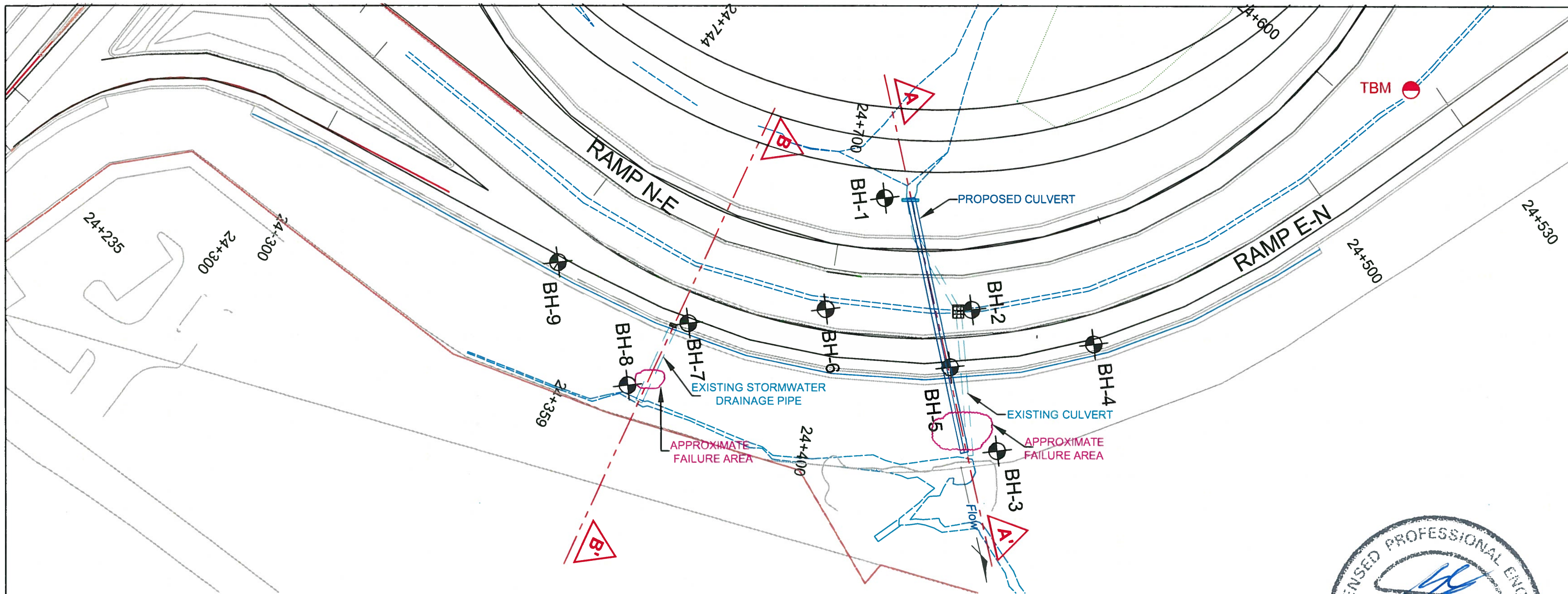
CULVERT REPLACEMENT
HWY 85, BRIDGEPORT INTERCHANGE
BOREHOLE LOCATION PLAN AND SOIL STRATA

SHEET

exp. **exp Services Inc.**

METRIC

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



PLAN

LICENSED PROFESSIONAL ENGINEER
S.E.M. GONSALVES
10/7/17
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
S. MICIC
100050187
10/7/17
PROVINCE OF ONTARIO

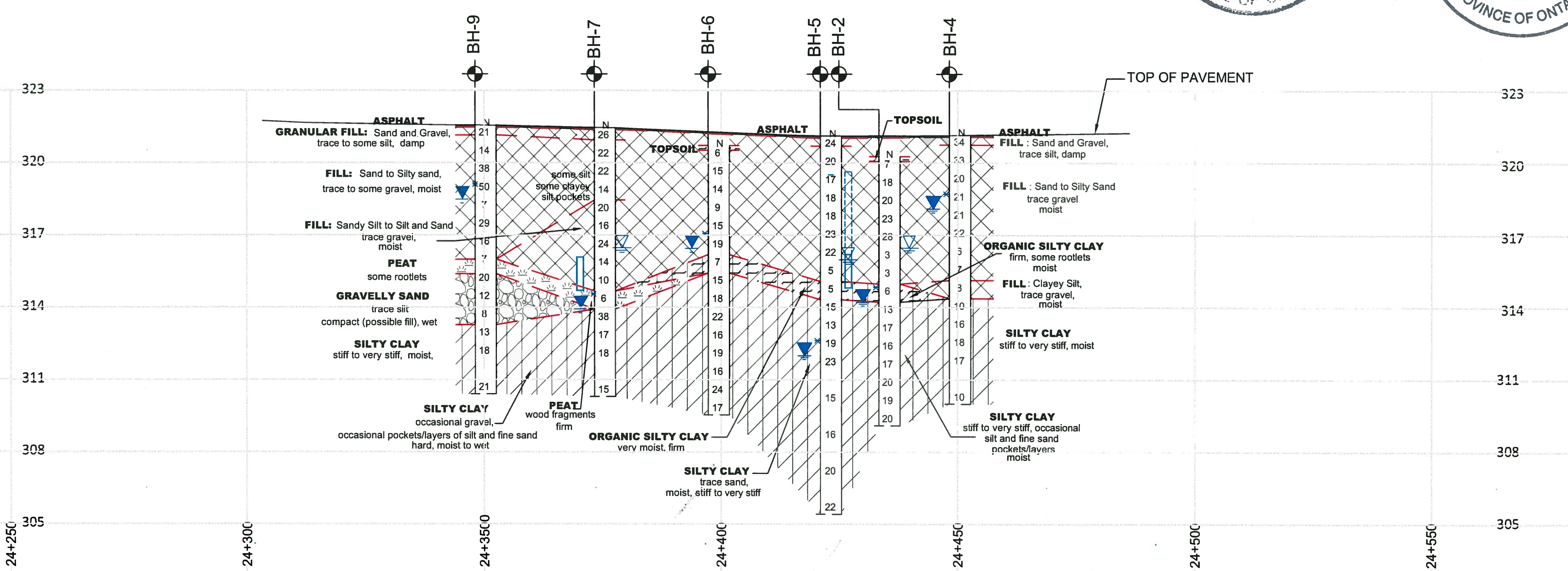
KEY PLAN

LEGEND

⌖	New Borehole by EXP
N	Standard Penetration Test (Blows/0.3 m)
▼	Water Level Upon Completion of Drilling
▽	Inferred GWL at Time of Investigation
●	Temprary Bench Mark

SOIL STRATA SYMBOLS

ASPHALT, TOPSOIL, FILL, ORGANIC SILTY CLAY, SILTY CLAY, GRAVELLY SAND, PEAT



PROFILE ALONG C/L RAMP E, W-N

NOTE: The size and the depth of the the existing culvert, stormwater drainage pipe and the shaft are assumed approximately based on field limited observation.

BH No.	APPROX. ELEV.	MTM CO-ORDINATES	
		NORTH	EAST
BH-1	319.3	4815565.1	224474.5
BH-2	320.3	4815591.7	224473.6
BH-3	315.9	4815615.8	224485.3
BH-4	321.2	4815610.5	224458.8
BH-5	321.1	4815598.0	224483.2
BH-6	320.7	4815575.3	224495.7
BH-7	321.5	4815562.2	224518.0
BH-8	316.8	4815564.8	224534.1
BH-9	321.6	4815538.5	224531.2
TBM	322.0	4815607.3	224382.6

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.

the size and the depth of the the existing culvert, stormwater drainage pipe and the shaft are assumed approximately based on field limited observation.

SCALE HOR 0 — 25 m
VRT 0 — 5 m

10/07/2017	-	SUBMISSION FOR MTO REVIEW
DATE	BY	DESCRIPTION
		GEOCRES NO. 40P8-244
		PROJECT NO. ADM-00235197-F0

SUBM'D SM	CHECKED SM	DATE	10/07/2017
DRAWN SH	CHECKED SG	APPROVED SG	DWG. 1

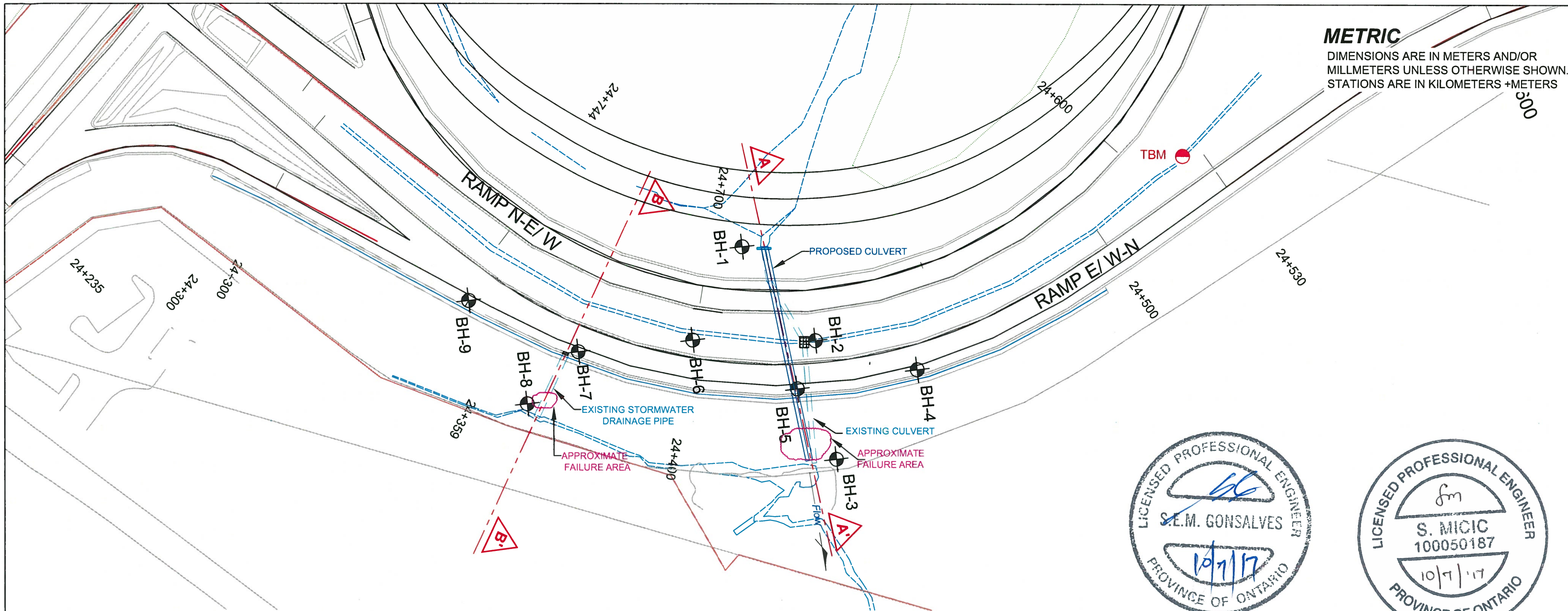
WR Agreement No. 3015-E-0017
Assignment No. 5
W.O. 2017-11009

CULVERT REPLACEMENT
HWY 85, BRIDGEPORT INTERCHANGE
BOREHOLE LOCATION PLAN AND SOIL STRATA

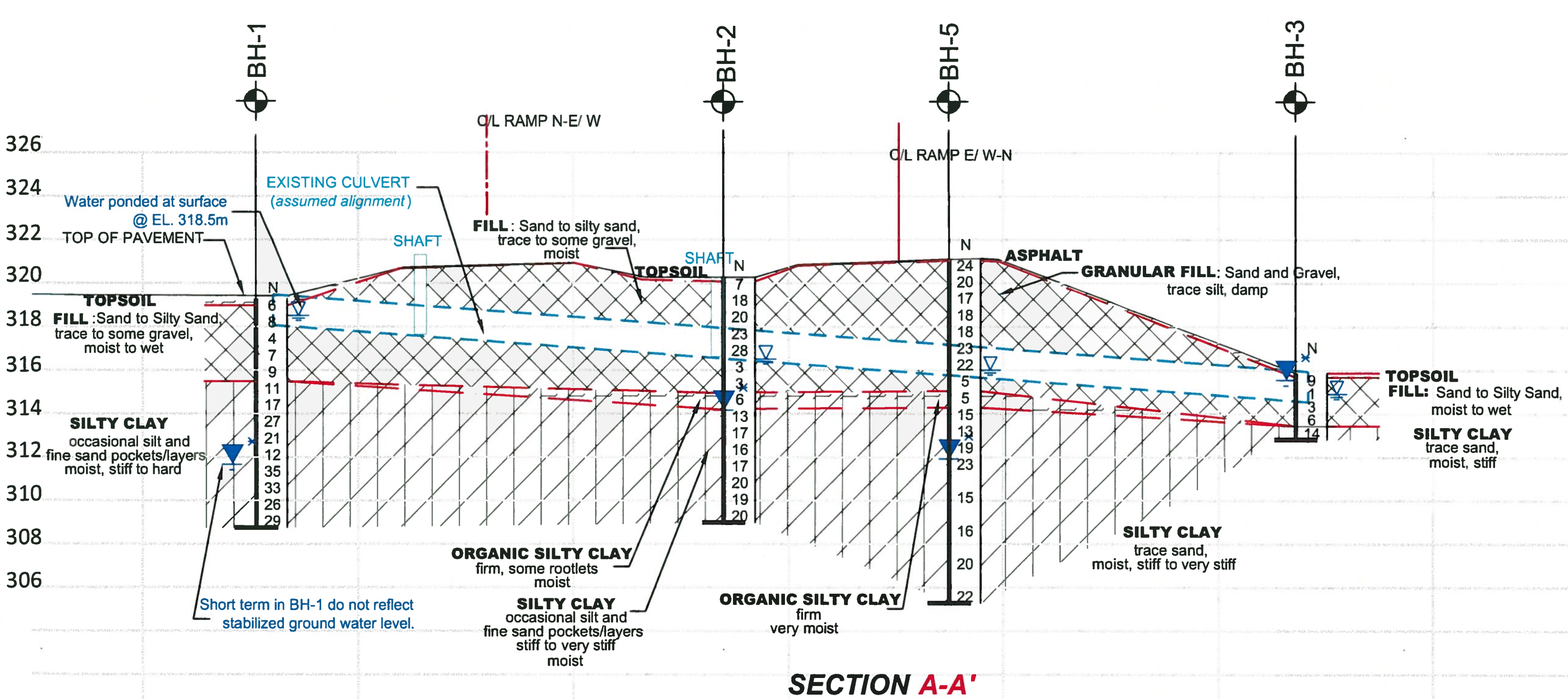
SHEET

exp Services Inc.

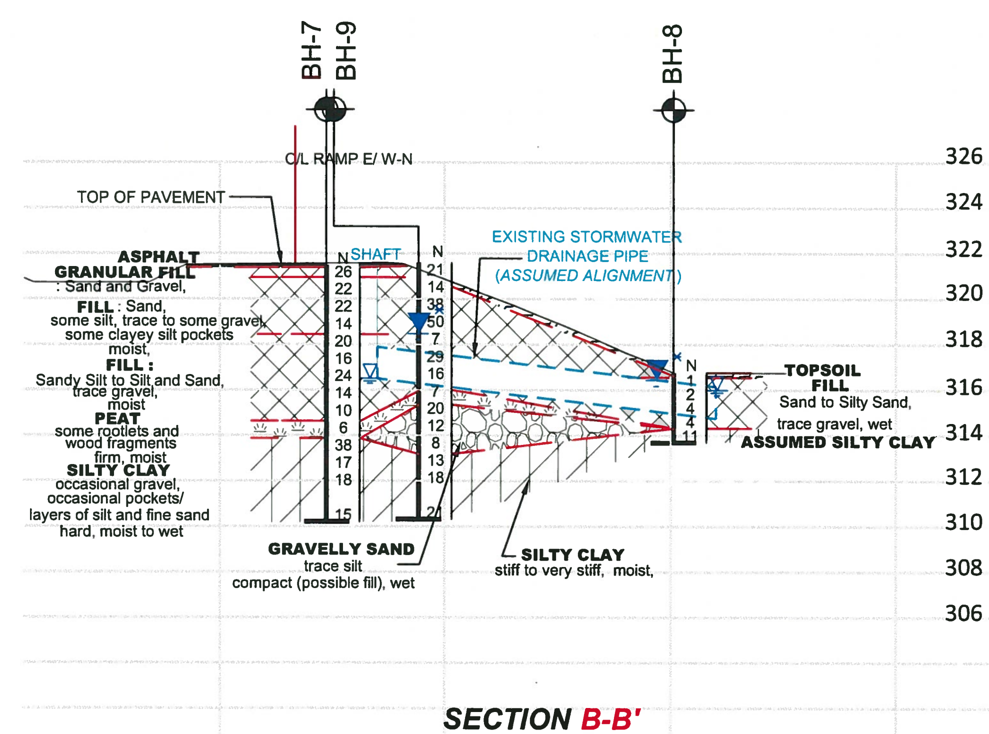
METRIC
DIMENSIONS ARE IN METERS AND/OR MILLMETERS UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETERS +METERS



PLAN



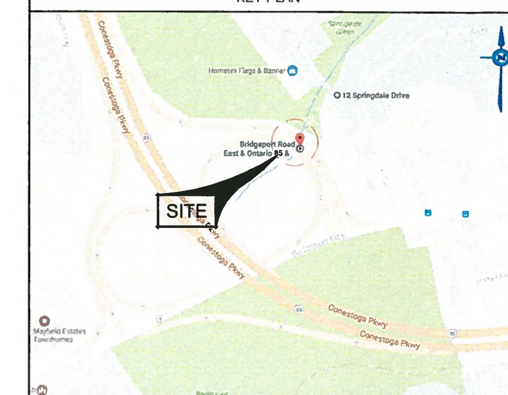
SECTION A-A'



SECTION B-B'

NOTE: The size and the depth of the the existing culvert, stormwater drainage pipe and the shaft are assumed approximately based on field limited observation.

KEY PLAN



LEGEND

- New Borehole by EXP
- N — Standard Penetration Test (Blows/0.3 m)
- Water Level Upon Completion of Drilling
- Inferred GWL at Time of Investigation
- Temprary Bench Mark

SOIL STRATA SYMBOLS

ASPHALT, TOPSOIL, FILL, ORGANIC SILTY CLAY, SILTY CLAY, GRAVELLY SAND, PEAT

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SCALE 0 — 10 m

DATE	BY	DESCRIPTION
10/07/2017	-	SUBMISSION FOR MTO REVIEW

GEOCRES NO. 40P8-244
PROJECT NO. ADM-00235197-F0

SUBM'D SM	CHECKED SM	DATE	10/07/2017
DRAWN SH	CHECKED SG	APPROVED SG	DWG. 2

Appendix C – 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.

exp.

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:

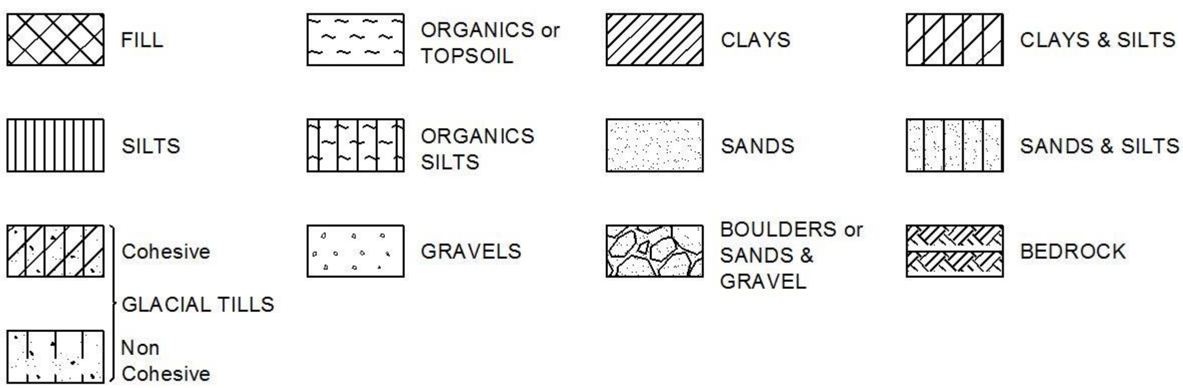
Table c: Consistency of Cohesive Soil

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'	$-°$	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	$-°$	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

Appendix D – Laboratory Data

Exp Services Inc.

Brampton, Ontario

Foundation Design

RECORD OF BOREHOLE No BH-1

1 OF 1 **METRIC**

W.P. 2017-11009 LOCATION Hwy 85, Kitchner, MTM ON10 N4815565.1, E224474.5 ORIGINATED BY AA

DIST Waterloo HWY 85 TEST PIT TYPE Continuous Flight Hollow Stem Augers COMPILED BY JG

DATUM TBM (322.00 m) DATE 2017.05.01 - 2017.05.01 LATITUDE 43.4756897 LONGITUDE -80.4928833 CHECKED BY SM

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
319.3	Ground Surface						
0.0	**TOPSOIL:** (~305 mm thick)	1	SS	6		319	
319.0 / 0.3	**FILL: SAND TO SILTY SAND** trace to some gravel, brown, very moist	2	SS	8		318	18 55 (27)
		3	SS	4			
	dark brown to black, some organics and wood fibres below 2.3 m depth	4	SS	7		317	
	light brown, wet, trace rootlets, occasional plastic debris below 3.1 m depth	5	SS	9		316	
315.5 / 3.8	**SILTY CLAY:** brown to grey, moist, stiff to hard, occasional silt and fine sand pockets/layers	6	SS	11		315	0 24 49 27 Wet Spoon
		7	SS	17			
	-Becoming silt, trace sand and trace clay @ 5.3 m	8	SS	27		314	0 8 84 8
		9	SS	21		313	0 3 57 40
		10	SS	12		312	
		11	SS	35	▽		
		12	SS	33		311	
		13	SS	26		310	
		14	SS	29		309	
308.8 / 10.5	**End of borehole at 10.5 m depth. Water level at 7.6 m upon completion of drilling. Borehole open to 9.15 m and water level measure at 7.6 m upon completion of drilling**						

Notes:
1. This drawing is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured in open hole upon completion of drilling.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No BH-2

METRIC

W.P. 2017-11009 LOCATION Hwy 85, Kitchner, MTM ON10 N4845591.7, E224473.6 ORIGINATED BY AA

DIST Waterloo HWY 85 TEST PIT TYPE Continuous Flight Hollow Stem Augers COMPILED BY JG

DATUM TBM (322.00 m) DATE 2017.05.02 - 2017.05.02 LATITUDE 43.475929 LONGITUDE -80.4928983 CHECKED BY SM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
320.3	Ground Surface					
320.1 0.0	**TOPSOIL:** (~200 mm thick)					
0.2	**FILL: SAND TO SILTY SAND** trace to some gravel, brown, moist	1	SS	7		
		2	SS	18		
	some silty clay pockets at 1.5 m depth	3	SS	20		
	layer of moist, grey, clayey silt at 2.3 m depth	4	SS	23		
		5	SS	28		10 53 (37)
	saturated below 3.8 m depth	6	SS	3		Wet Spoon
	dark brown to black, some organics and wood fibres below 4.6 m depth	7	SS	3		
315.0 5.3	**ORGANIC SILTY CLAY:** black, moist, firm, some rootlets	8	SS	6		
314.2 6.1	**SILTY CLAY:** brown, moist, stiff to very stiff, occasional silt and fine sand pockets/layers	9	SS	13	▽	0 13 55 32
	light brown to grey below 6.9 m depth	10	SS	17		
		11	SS	16		
		12	SS	17		
		13	SS	20		0 6 55 39
		14	SS	19		
		15	SS	20		0 0 90 10
309.0 11.3	**End of borehole at 11.3 m depth. Borehole open to 8.85 m and water level measured at 6.1 m upon completion of drilling**					

Elevation scale: 320, 319, 318, 317, 316, 315, 314, 313, 312, 311, 310, 309

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Notes:
1. This drawing is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured in open hole upon completion of drilling.

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

RECORD OF BOREHOLE No BH-3

METRIC

W.P. 2017-11009 LOCATION Hwy 85, Kitchner, MTM ON10 N4815615.8, E224485.3 ORIGINATED BY AA

DIST Waterloo HWY 85 TEST PIT TYPE Manual SPT COMPILED BY JG

DATUM TBM (322.00 m) DATE 2017.05.05 - 2017.05.05 LATITUDE 43.4761472 LONGITUDE -80.4927573 CHECKED BY SM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
315.9	Ground Surface					
315.7 / 0.0	**TOPSOIL:** (~200 mm thick)					
0.2	**FILL: SAND TO SILTY SAND** brown, moist to wet	1	SS	9	∇	
	wet, pockets of organic silt and rootlets below 0.8 m depth	2	SS	1		
		3	SS	3		0 84 (16)
		4	SS	6		
313.4 / 2.4	**SILTY CLAY:** trace sand, brown, moist, stiff	5	SS	14		0 6 57 37
312.8 / 3.1	**End of borehole at 3.1 m depth. Borehole open to 0.76 m and water level measured at 0.3 m upon completion of drilling**					

Elevation scale: 315, 314, 313

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Notes:
1. This drawing is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured in open hole upon completion of drilling.
3. SPT "N" values corrected for manual operations (70 lb drop weight, 15 inch drop height)

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

RECORD OF BOREHOLE No BH-4

1 OF 1 **METRIC**

W.P. 2017-11009 LOCATION Hwy 85, Kitchner, MTM ON10 N4815610.5, E224458.8 ORIGINATED BY AA

DIST Waterloo HWY 85 TEST PIT TYPE Continuous Flight Hollow Stem Augers COMPILED BY JG

DATUM TBM (322.00 m) DATE 2017.05.04 - 2017.05.04 LATITUDE 43.4760967 LONGITUDE -80.493084 CHECKED BY SM

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.2	Road Surface				
321.1 / 0.1	**ASPHALT:** (~100 mm thick)				
320.8 / 0.4	**FILL: SAND AND GRAVEL** sand and gravel, trace silt, brown, damp (~330 mm thick)	1	SS	34	
	FILL: SAND TO SILTY SAND trace gravel, brown, moist	2	SS	33	1 72 (27)
		3	SS	20	
	clayey silt, trace sand layer at 2.3 m depth	4	SS	21	0 21 60 19
	gravelly, some silty clay pockets, trace wood fibres below 3.1 m depth	5	SS	21	
	trace gravel, dark brown, some organic staining below 3.8 m depth	6	SS	22	3 69 (28)
	light brown to grey, wet below 4.6 m depth	7	SS	6	Wet Spoon
	brown and dark brown, occasional rootlets below 5.3 m depth	8	SS	7	
315.1 / 6.1	**FILL: CLAYEY SILT** trace gravel, light brown, moist	9	SS	8	
314.3 / 6.9	**SILTY CLAY:** light brown, moist, stiff to very stiff	10	SS	10	
		11	SS	16	
	grey below 8.4 m depth	12	SS	18	0 0 64 36
		13	SS	17	
	very moist below 10.7 m depth	14	SS	10	
309.9 / 11.3	**End of borehole at 11.3 m depth. Borehole open to 4.3 m and water level measured at 3.1 m upon completion of drilling**				

Groundwater level symbol shown at approx. elevation 318.1 (3.1 m depth).

Notes:
1. This drawing is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured in open hole upon completion of drilling.

Chart columns: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20, 40, 60; UNIT WEIGHT γ kN/m³. Elevation scale 321 to 310.

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

Exp Services Inc.

Brampton, Ontario

RECORD OF BOREHOLE No BH-5

METRIC

W.P. 2017-11009	LOCATION Hwy 85, Kitchner, MTM ON10 N4815598.0, E224483.2		ORIGINATED BY AA
DIST Waterloo HWY 85	TEST PIT TYPE Continuous Flight Hollow Stem Augers		COMPILED BY JG
DATUM TBM (322.00 m)	DATE 2017.05.03 - 2017.05.03	LATITUDE 43.4759868 LONGITUDE -80.4927806	CHECKED BY SM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
321.1	Road Surface
321.0 / 0.1	**ASPHALT:** (~100 mm thick)
320.7 / 0.4	**FILL: SAND AND GRAVEL** sand and gravel, trace silt, brown, damp (~330 mm thick)
	FILL: SAND TO SILTY SAND trace gravel, brown, moist
	some silty clay pockets below 1.5 m depth
	black, very moist, some organics and wood fibres below 5.3 m depth
315.0 / 6.1	**ORGANIC SILTY CLAY:** black, very moist, firm
314.2 / 6.9	**SILTY CLAY:** trace sand, light brown, moist, stiff to very stiff
	light brown to grey below 7.6 m depth
	some sand pockets below 13.7 m depth

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	24	
2	SS	20	
3	SS	17	
4	SS	18	
5	SS	18	0 46 40 14
6	SS	23	Wet Spoon
7	SS	22	0 57 (43)
8	SS	5	
9	SS	5	
10	SS	15	
11	SS	13	
12	SS	19	
13	SS	23	0 6 55 39
14	SS	15	1 3 53 43
15	SS	16	
16	SS	20	0 19 61 20

GROUND WATER CONDITIONS: water level symbol at approx. elevation 312.1

ELEVATION SCALE: 321, 320, 319, 318, 317, 316, 315, 314, 313, 312, 311, 310, 309, 308, 307

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

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

Exp Services Inc.
Brampton, Ontario

Foundation Design

RECORD OF BOREHOLE No BH-5

METRIC

W.P. 2017-11009 LOCATION Hwy 85, Kitchner, MTM ON10 N4815598.0, E224483.2 ORIGINATED BY AA
DIST Waterloo HWY 85 TEST PIT TYPE Continuous Flight Hollow Stem Augers COMPILED BY JG
DATUM TBM (322.00 m) DATE 2017.05.03 - 2017.05.03 LATITUDE 43.4759868 LONGITUDE -80.4927806 CHECKED BY SM

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY: trace sand, light brown, moist, stiff to very stiff *(continued)*		17	SS	22		306		○ (approx. 20)		
305.2 / 15.9	**End of borehole at 15.9 m depth. Water level at 9.2 m upon completion of drilling.** Notes: 1. This drawing is to be read with the subject report and project numbers as presented above. 2. Groundwater level was measured in open hole upon completion of drilling.										

$+^3, \times^3$: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

ONTARIO MTO ASSIGNMENT#5.GPJ ONTARIO MTO.GDT 7/11/17

RECORD OF BOREHOLE No BH-6

METRIC

W.P. 2017-11009 | LOCATION Hwy 85, Kitchner, MTM ON10 N4815575.3, E224495.7 | ORIGINATED BY AA

DIST Waterloo HWY 85 | TEST PIT TYPE Continuous Flight Hollow Stem Augers | COMPILED BY JG

DATUM TBM (322.00 m) | DATE 2017.05.02 - 2017.05.02 | LATITUDE 43.4757838 | LONGITUDE -80.4926228 | CHECKED BY SM

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
320.7	Ground Surface					
320.9 / 0.0	**TOPSOIL:** (~230 mm thick)					
0.2	**FILL: SAND TO SILTY SAND** brown, moist	1	SS	6		
		2	SS	15		
		3	SS	14		15 56 (29)
		4	SS	9		
		5	SS	15		
	wet to saturated below 3.8 m depth	6	SS	19	▽	Wet Spoon
316.1 / 4.6	**ORGANIC SILTY CLAY:** black, moist, firm, some rootlets	7	SS	7		
315.4 / 5.3	**SILTY CLAY:** brown, moist, very stiff, occasional silt and fine sand pockets/layers	8	SS	15		0 12 55 33
	light brown to grey below 6.1 m depth	9	SS	18		
		10	SS	22		
		11	SS	16		
		12	SS	19		0 6 59 35
		13	SS	16		
		14	SS	24		
		15	SS	17		
309.4 / 11.3	**End of borehole at 11.3 m depth.** Borehole open to 4.3 m and water level measured at 4.3 m upon completion of drilling					

Notes:
1. This drawing is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured in open hole upon completion of drilling.

Elevation scale: 320, 319, 318, 317, 316, 315, 314, 313, 312, 311, 310

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No BH-7

METRIC

W.P. 2017-11009	LOCATION Hwy 85, Kitchner, MTM ON10 N4815562.2, E224518.0		ORIGINATED BY AA
DIST Waterloo HWY 85	TEST PIT TYPE Continuous Flight Hollow Stem Augers		COMPILED BY JG
DATUM TBM (322.00 m)	DATE 2017.05.04 - 2017.05.04	LATITUDE 43.4756683 LONGITUDE -80.4923452	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 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 (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

ELEV / DEPTH	DESCRIPTION
321.5	Road Surface
321.4 / 0.1	**ASPHALT:** (~100 mm thick)
321.0 / 0.5	**FILL: SAND AND GRAVEL** sand and gravel, trace to some silt, brown, damp (~430 mm thick)
	FILL: SAND some silt, trace to some gravel, brown, moist, some clayey silt pockets brown, moist, clayey silt layer at 2.3 m depth
318.4 / 3.1	**FILL: SANDY SILT TO SILT AND SAND** trace gravel, light brown, moist grey, moist, clayey silt layer at 3.8 m depth
314.6 / 6.9	**PEAT:** black, moist, firm, some rootlets and wood fragments
313.9 / 7.6	**SILTY CLAY:** occasional gravel, grey, moist to wet, hard, occasional pockets/layers of silt and fine sand very stiff below 8.4 m depth
310.2 / 11.3	**End of borehole at 11.3 m depth.** Borehole open to 10 m and water level measured at 7.6 m upon completion of drilling

NUMBER	TYPE	"N" VALUES	REMARKS / GRAIN SIZE (GR SA SI CL)
1	SS	26	
2	SS	22	
3	SS	22	
4	SS	14	
5	SS	20	9 30 (61)
6	SS	16	
7	SS	24	10 41 (49)
8	SS	14	
9	SS	10	
10	SS	6	(water content 145)
11	SS	38	1 5 45 49
12	SS	17	
13	SS	18	0 5 61 34
14	SS	15	

Ground water level symbol ∇ at approx. elev. 314.

Elevation scale: 321, 320, 319, 318, 317, 316, 315, 314, 313, 312, 311

Notes:
1. This drawing is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured in open hole upon completion of drilling.

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

RECORD OF BOREHOLE No BH-8

METRIC

W.P. 2017-11009	LOCATION Hwy 85, Kitchner, MTM ON10 N4815564.8, E224534.1		ORIGINATED BY AA
DIST Waterloo HWY 85	TEST PIT TYPE Manual SPT		COMPILED BY JG
DATUM TBM (322.00 m)	DATE 2017.05.05 - 2017.05.05	LATITUDE 43.4756934 LONGITUDE -80.4921466	CHECKED BY SM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
316.8	Ground Surface								
316.6 / 0.0	**TOPSOIL:** (~200 mm thick)								
0.2	**FILL: SAND TO SILTY SAND** trace gravel, brown, wet		1	SS	1	∇			
	wet, pockets of organic silt and rootlets below 0.8 m depth		2	SS	2		316		10 64 (26)
			3	SS	4				
	mixed with clayey silt below 1.8 m below grade		4	SS	4		315		
314.4 / 2.4	**ASSUMED SILTY CLAY** unable to retrieve sample due to caving sand conditions. Assumed native silty clay below 2.4 m depth based on SPT "N" values.		5	SS	11		314		
313.7 / 3.1	**End of borehole at 3.1 m depth.** Borehole open to 0.61 m and water level measured at 0.3 m upon completion of drilling								

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

Notes:
1. This drawing is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured in open hole upon completion of drilling.
3. SPT "N" values corrected for manual operations (70 lb drop weight, 15 inch drop height)

ONTARIO MTO ASSIGNMENT#5.GPJ ONTARIO MTO.GDT 7/11/17

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

Exp Services Inc.

Brampton, Ontario

Foundation Design

RECORD OF BOREHOLE No BH-9

METRIC

W.P. 2017-11009 LOCATION Hwy 85, Kitchner, MTM ON10 N4815538.5, E224531.2 ORIGINATED BY AA

DIST Waterloo HWY 85 TEST PIT TYPE Continuous Flight Hollow Stem Augers COMPILED BY JG

DATUM TBM (322.00 m) DATE 2017.05.03 - 2017.05.03 LATITUDE 43.4754564 LONGITUDE -80.4921786 CHECKED BY SM

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
321.6	Road Surface					
321.5 / 0.1	**ASPHALT:** (~100 mm thick)					
321.2 / 0.4	**FILL: SAND AND GRAVEL** sand and gravel, trace to some silt, brown, damp (~330 mm thick)	1	SS	21		
	FILL: SAND TO SILTY SAND trace to some gravel, brown, moist some silty clay pockets below 0.8 m depth	2	SS	14		
		3	SS	38		
	light brown below 2.3 m depth	4	SS	50		
	wet to saturated below 3.1 m depth	5	SS	7	▽	24 55 (21)
		6	SS	29		
		7	SS	16		
316.0 / 5.6	**PEAT:** black, moist, firm, some rootlets	8	SS	7		227 (water content)
315.3 / 6.3	**GRAVELLY SAND:** trace silt, dark grey, wet, compact (possible fill)	9	SS	20		
		10	SS	12		24 67 (9)
	loose below 7.6 m depth	11	SS	8		
313.2 / 8.4	**SILTY CLAY:** brown, moist, stiff to very stiff	12	SS	13		
	grey below 9.1 m depth	13	SS	18		
		14	SS	21		
310.3 / 11.3	**End of borehole at 11.3 m depth. Borehole open to 6.1 m and water level measured at 3.1 m upon completion of drilling.**					

Notes:
1. This drawing is to be read with the subject report and project numbers as presented above.
2. Groundwater level was measured in open hole upon completion of drilling.

ELEVATION SCALE: 321, 320, 319, 318, 317, 316, 315, 314, 313, 312, 311

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

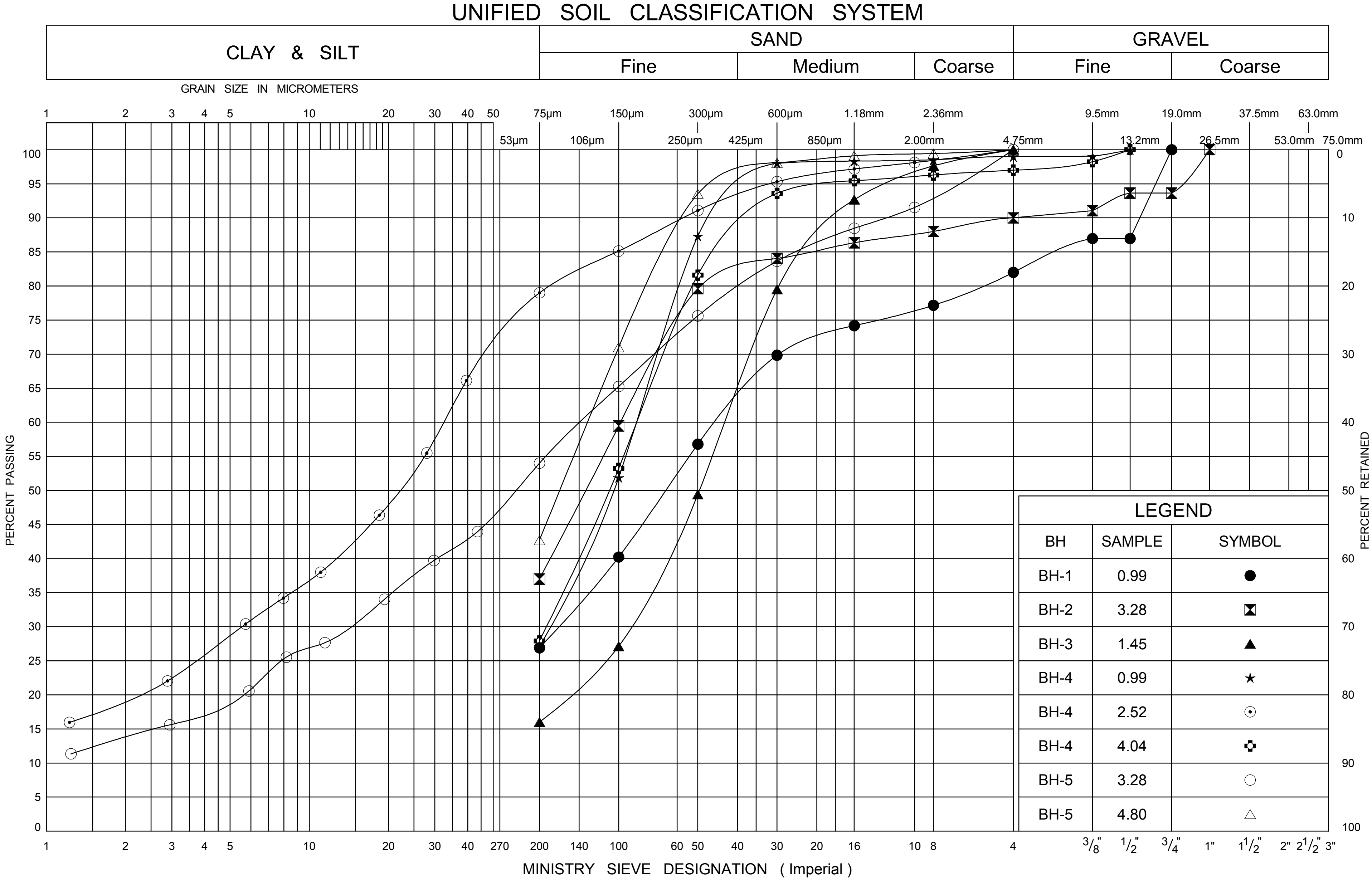
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

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

Appendix D –
Laboratory Data

78 12 M



LEGEND		
BH	SAMPLE	SYMBOL
BH-1	0.99	●
BH-2	3.28	⧗
BH-3	1.45	▲
BH-4	0.99	★
BH-4	2.52	⊙
BH-4	4.04	✣
BH-5	3.28	○
BH-5	4.80	△

Ministry of Transportation
Ontario

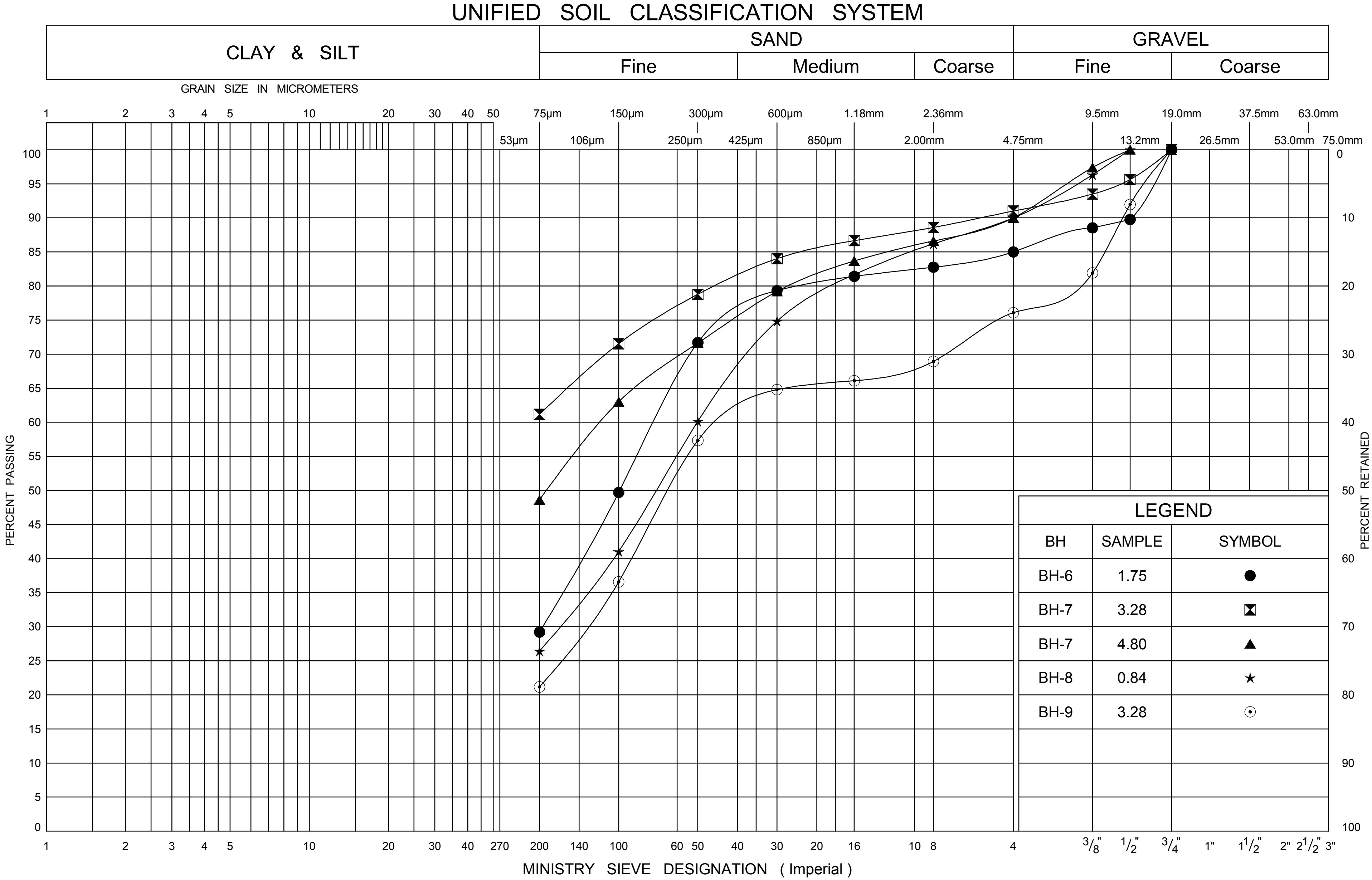
GRAIN SIZE DISTRIBUTION

FIG No 1

W P 2017-11009

3015-E-0017, Assignment 5

78 12 M



LEGEND		
BH	SAMPLE	SYMBOL
BH-6	1.75	●
BH-7	3.28	⧗
BH-7	4.80	▲
BH-8	0.84	★
BH-9	3.28	⊙

ONTARIO MOT GRAIN SIZE ASSIGNMENT#5.GPJ ONTARIO MOT.GDT 6/7/17

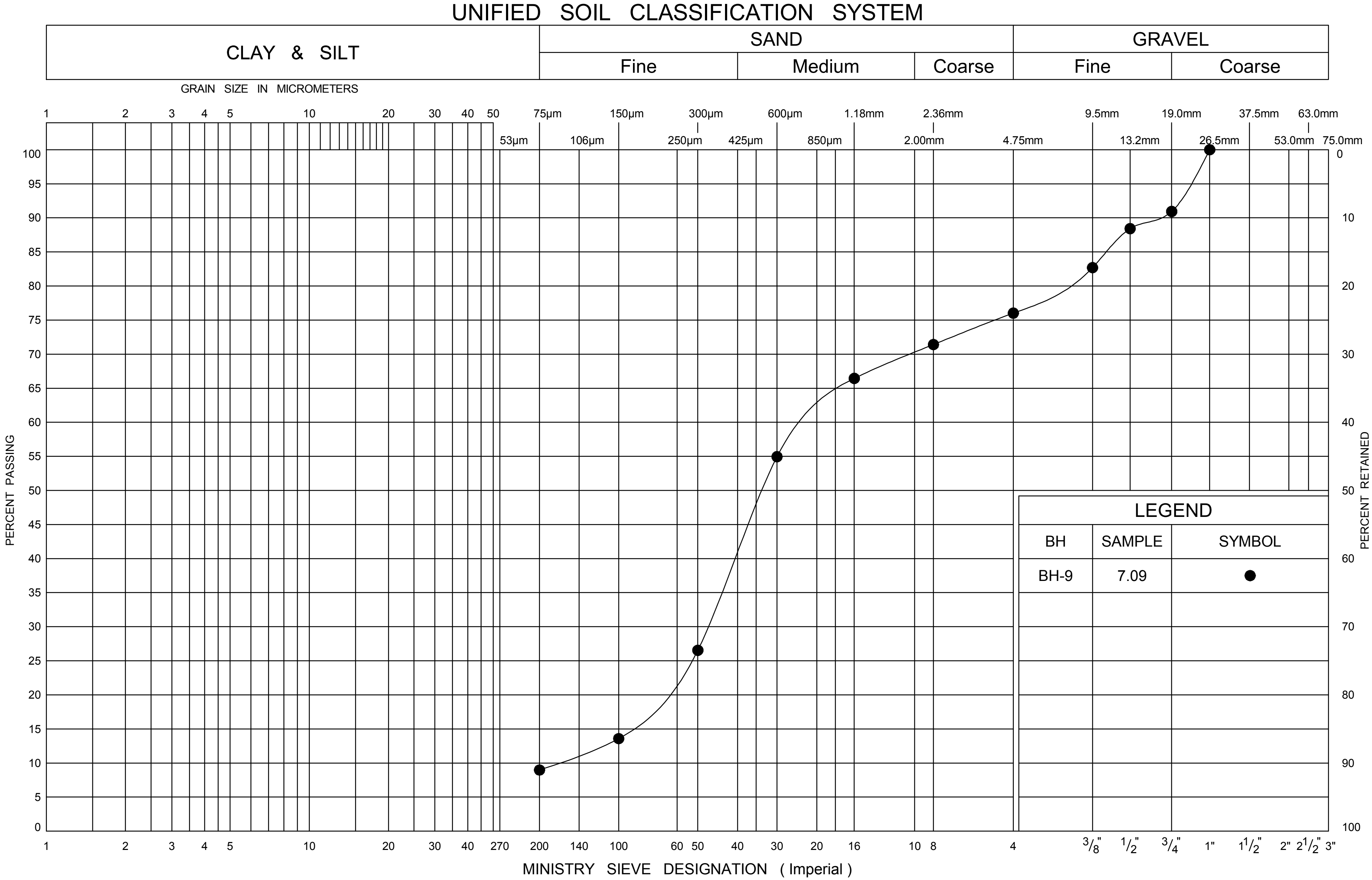
Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

FIG No 2

W P 2017-11009

3015-E-0017, Assignment 5



BH	SAMPLE	SYMBOL
BH-9	7.09	●

Ministry of Transportation
Ontario

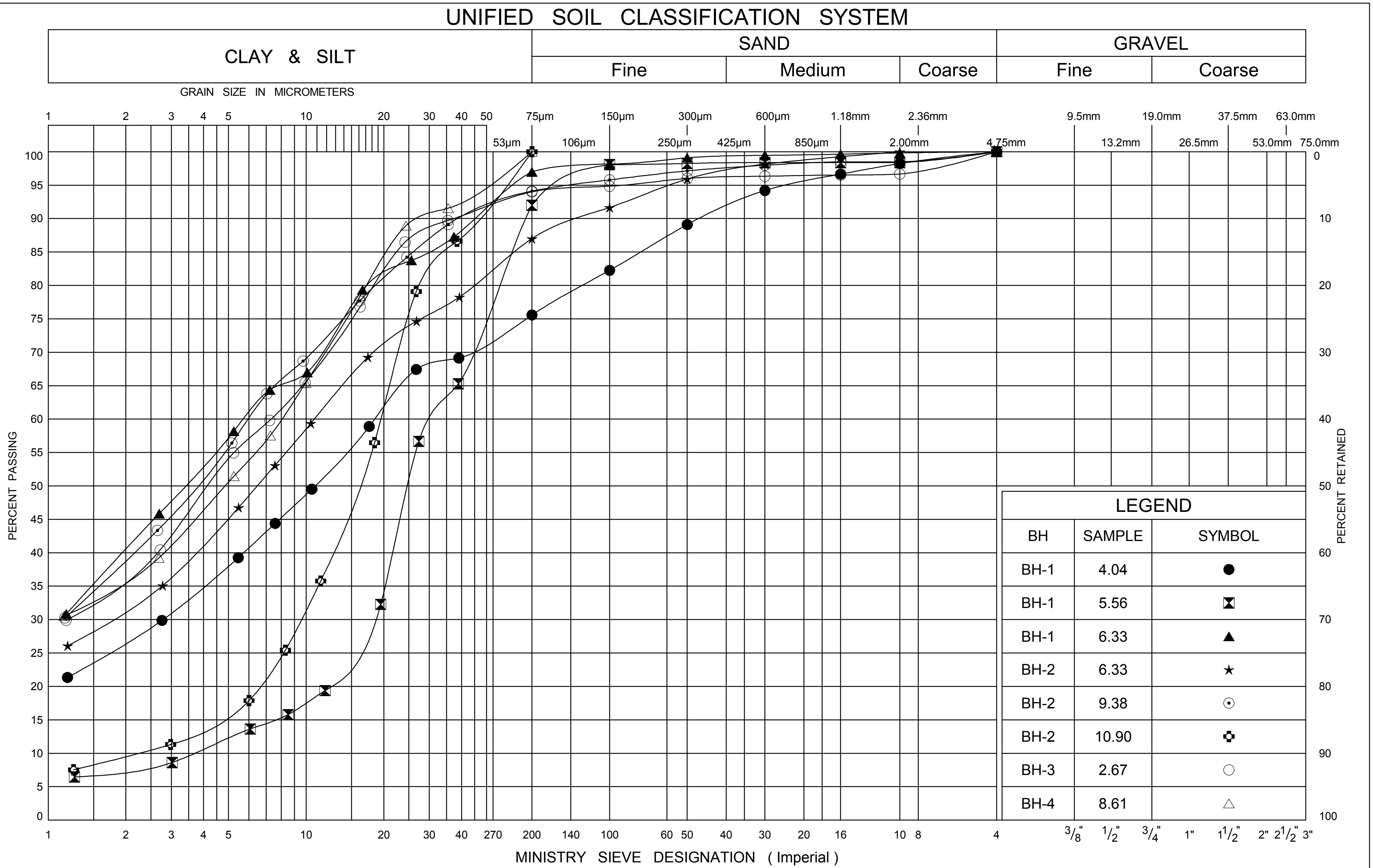
GRAIN SIZE DISTRIBUTION

FIG No 3

W P 2017-11009

3015-E-0017, Assignment 5

78 12 M



LEGEND

BH	SAMPLE	SYMBOL
BH-1	4.04	●
BH-1	5.56	⧗
BH-1	6.33	▲
BH-2	6.33	★
BH-2	9.38	⊙
BH-2	10.90	✿
BH-3	2.67	○
BH-4	8.61	△

ONTARIO MOT GRAIN SIZE ASSIGNMENT#5 .GPJ ONTARIO MOT.GDT 6/27/17

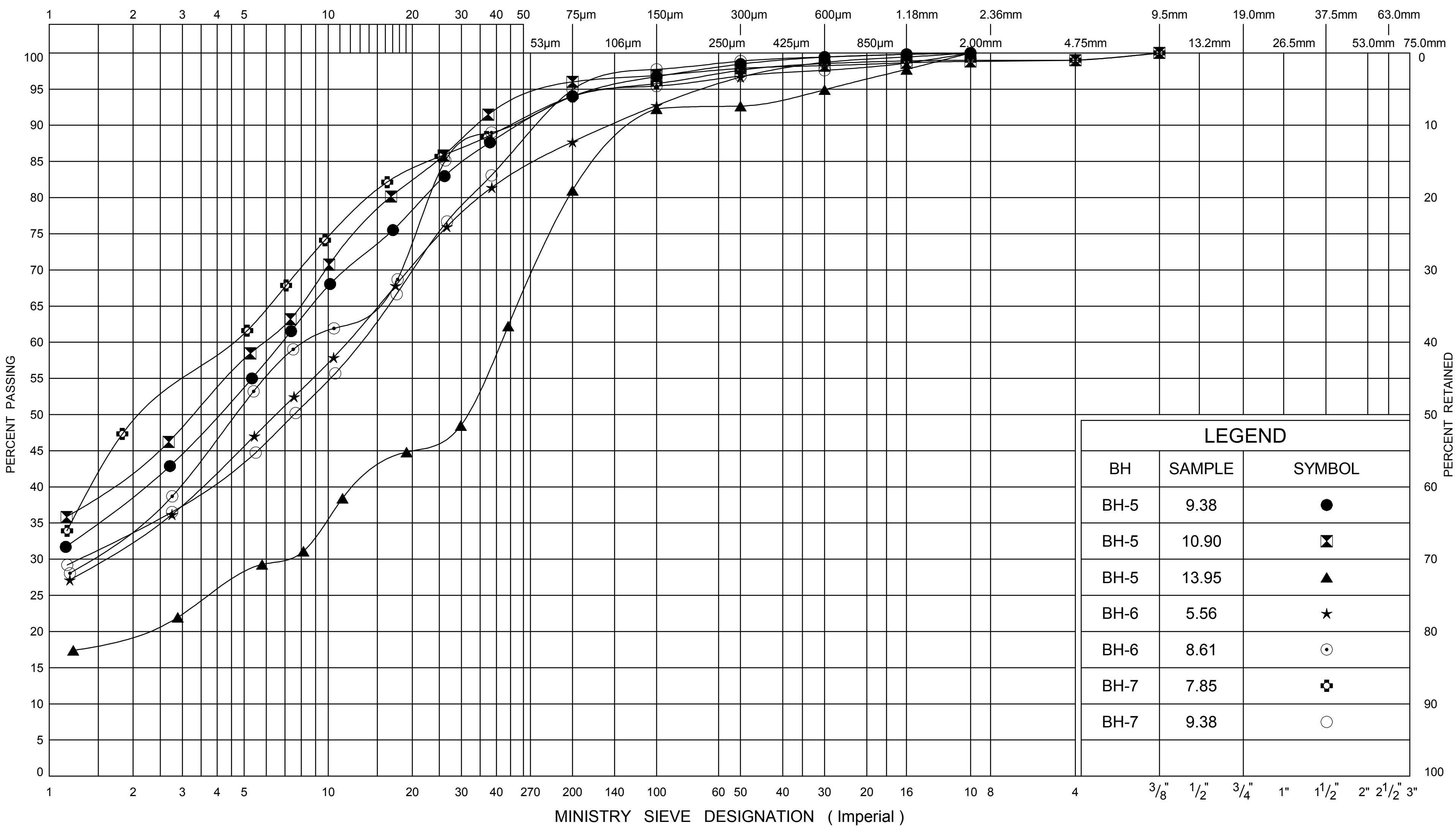
Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

FIG No 4	
W P 2017-11009	
3015-E-0017, Assignment 5	

78 12 M

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND

BH	SAMPLE	SYMBOL
BH-5	9.38	●
BH-5	10.90	⧗
BH-5	13.95	▲
BH-6	5.56	★
BH-6	8.61	⊙
BH-7	7.85	✿
BH-7	9.38	○

Ministry of Transportation
Ontario

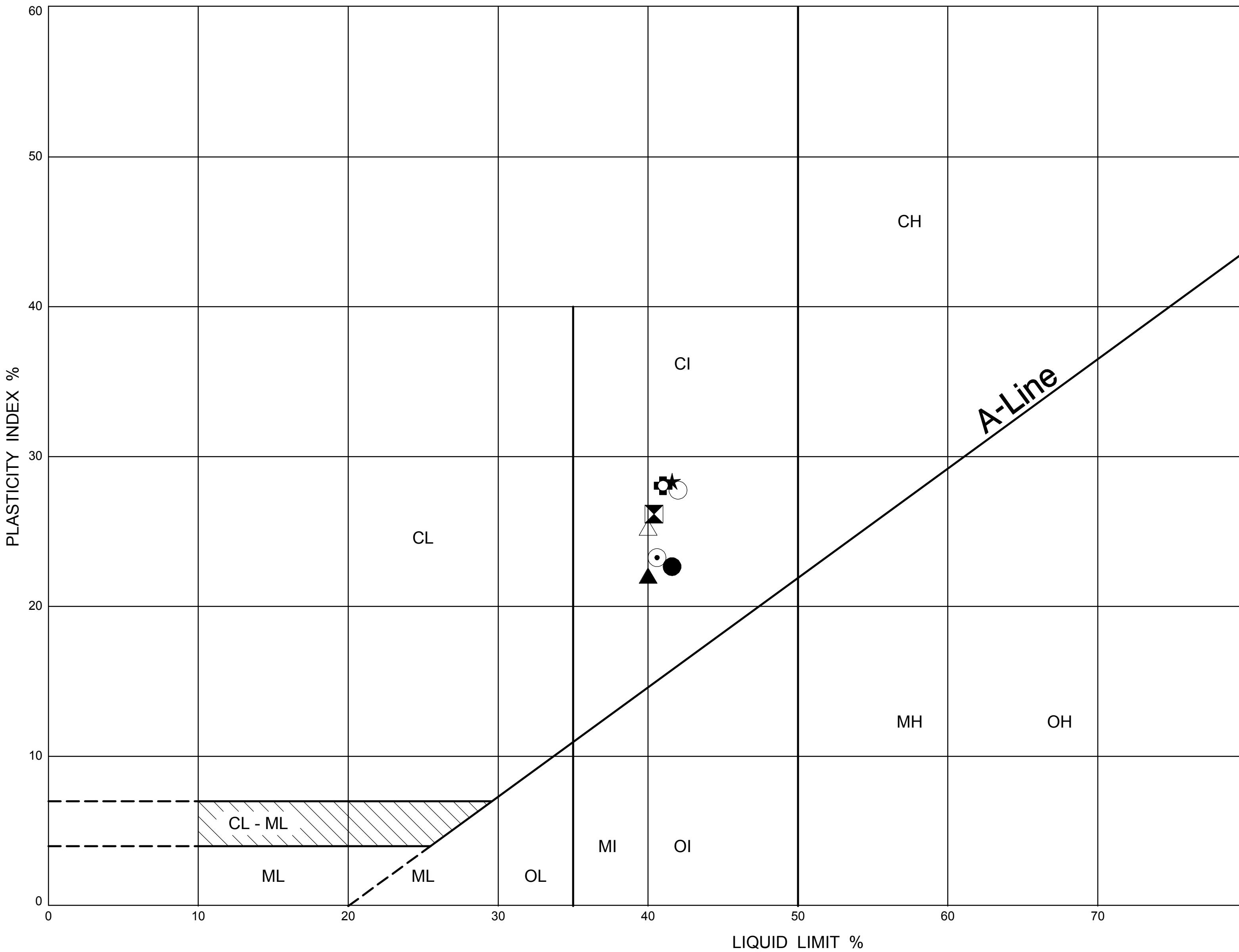
GRAIN SIZE DISTRIBUTION

FIG No 5

W P 2017-11009

3015-E-0017, Assignment 5

Oct 75, FF - S - 21



LEGEND		
BH	SAMPLE	SYMBOL
BH-1	4.04	●
BH-1	6.33	⧗
BH-2	6.33	▲
BH-2	9.38	★
BH-2	10.90	⊙
BH-3	2.67	✿
BH-4	8.61	○
BH-5	7.09	△

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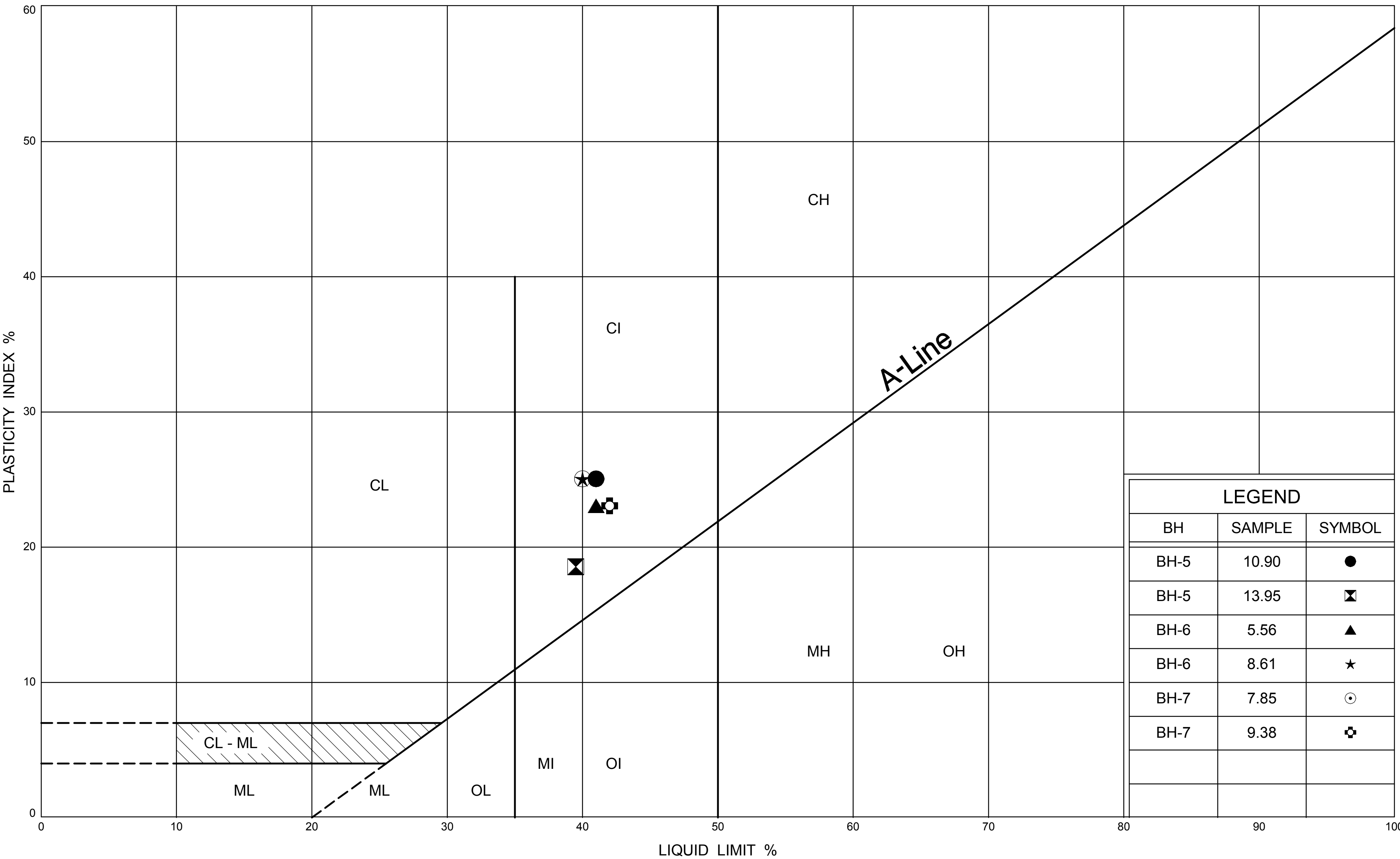
PLASTICITY CHART

FIG No 6

W P 2017-11009

3015-E-0017, Assignment 5

Oct 75, FF - S - 21



LEGEND

BH	SAMPLE	SYMBOL
BH-5	10.90	●
BH-5	13.95	⧗
BH-6	5.56	▲
BH-6	8.61	★
BH-7	7.85	☉
BH-7	9.38	✪

Ministry of Transportation
Ontario

PLASTICITY CHART

FIG No 7

W P 2017-11009

3015-E-0017, Assignment 5

Appendix E – Chemical Analyses

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

CLIENT NAME: EXP. SERVICES INC.
80 BANCROFT STREET
HAMILTON, ON L8E2W5
(905) 573-4000

ATTENTION TO: Jeff Golder

PROJECT: ADM-00235197-F0

AGAT WORK ORDER: 17T215110

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: May 18, 2017

PAGES (INCLUDING COVER): 5

VERSION*: 1

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

NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 17T215110

PROJECT: ADM-00235197-F0

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

CLIENT NAME: EXP. SERVICES INC.

ATTENTION TO: Jeff Golder

SAMPLING SITE:Hwy 85, Kichener

SAMPLED BY:Aziz

Corrosivity Package

DATE RECEIVED: 2017-05-11

DATE REPORTED: 2017-05-18

			SAMPLE DESCRIPTION:	BH-1 SS2
			SAMPLE TYPE:	Soil
			DATE SAMPLED:	2017-05-01
Parameter	**Unit**	**G / S**	**RDL**	**8388149**
*Sulphide	%		0.05	<0.05
Chloride (2:1)	µg/g		2	94
Sulphate (2:1)	µg/g		2	16
pH (2:1)	pH Units		NA	8.77
Electrical Conductivity (2:1)	mS/cm		0.005	0.323
Resistivity (2:1)	ohm.cm		1	3100
Redox Potential (2:1)	mV		5	206

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

8388149 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

*Sulphide analyzed at AGAT Vancouver

Certified By: Amanjot Bhela

AGAT Laboratories

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

Quality Assurance

CLIENT NAME: EXP. SERVICES INC.
PROJECT: ADM-00235197-F0
SAMPLING SITE:Hwy 85, Kichener

AGAT WORK ORDER: 17T215110
ATTENTION TO: Jeff Golder
SAMPLED BY:Aziz

Soil Analysis

RPT Date: May 18, 2017			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
Corrosivity Package															
*Sulphide	8386576		<0.05	<0.05	NA	< 0.05	95%	80%	120%						
Chloride (2:1)	8388149	8388149	94	94	0.0%	< 2	93%	80%	120%	101%	80%	120%	101%	70%	130%
Sulphate (2:1)	8388149	8388149	16	15	6.5%	< 2	95%	80%	120%	103%	80%	120%	102%	70%	130%
pH (2:1)	8388149	8388149	8.77	8.70	0.8%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	8388149	8388149	0.323	0.328	1.5%	< 0.005	95%	90%	110%	NA			NA		
Redox Potential (2:1)	8388149	8388149	206	200	3.0%	< 5	101%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.
Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By: Amanjot Bhela

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

Method Summary

CLIENT NAME: EXP. SERVICES INC. | **AGAT WORK ORDER: 17T215110**

PROJECT: ADM-00235197-F0 | **ATTENTION TO: Jeff Golder**

SAMPLING SITE:Hwy 85, Kichener | **SAMPLED BY:Aziz**

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
*Sulphide	INOR-181-6027	modified from ASTM E1915-11	COMBUSTION
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B,SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE

AGAT Laboratories

5835 Coopers Avenue
Mississauga, Ontario L4Z 1Y2
Ph: 905.712.5100 Fax: 905.712.5122
webearth.agatlabs.com

1 Sun

Laboratory Use Only

Work Order #: 17T215110

Cooler Quantity:

Arrival Temperatures: 5.6 | 5.8 | 5.8 / 4.6 | 4.8 | 4.8

Custody Seal Intact: ☐ Yes ☐ No ☐ N/A

Notes:

Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water intended for human consumption)

Report Information:

Company: exp Services Inc.
Contact: Jeffrey Golder
Address: 80 Bancroft Street, Hamilton, ON L8E 2W5
Phone: 905.573.4000 x5022 Fax:
Reports to be sent to:
1. Email: jeffrey.golder@exp.com
2. Email:

Regulatory Requirements: ☐ No Regulatory Requirement

(Please check all applicable boxes)

☒ Regulation 153/04
Table ____ (Indicate One)
☐ Ind/Com
☐ Res/Park
☐ Agriculture
Soil Texture (Check One)
☐ Coarse
☐ Fine

☐ Sewer Use
☐ Sanitary
☐ Storm
Region ____ (Indicate One)

☐ Regulation 558
☐ CCME
☐ Prov. Water Quality Objectives (PWQO)
☐ Other ____ (Indicate One)

Is this submission for a **Record of Site Condition?** ☐ Yes ☒ No

Report Guideline on Certificate of Analysis ☐ Yes ☒ No

Turnaround Time (TAT) Required:

Regular TAT ☒ 5 to 7 Business Days

Rush TAT (Rush Surcharges Apply)

☐ 3 Business Days ☐ 2 Business Days ☐ 1 Business Day

OR Date Required (Rush Surcharges May Apply):

Please provide prior notification for rush TAT
**TAT is exclusive of weekends and statutory holidays*

Project Information:

Project: ADM-00235197-FO
Site Location: HWY 85, Kitchener
Sampled By: AZ/2
AGAT Quote #: 159061 PO:

Please note: If quotation number is not provided, client will be billed full price for analysis.

Invoice Information:

Bill To Same: Yes ☒ No ☐

Company:
Contact:
Address:
Email:

Sample Matrix Legend

Code	Matrix
B	Biota
GW	Ground Water
O	Oil
P	Paint
S	Soil
SD	Sediment
SW	Surface Water

Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/ Special Instructions	Field Filtered - Metals, Hg, CrVI (Please Circle) Y / N	Metals and Inorganics	Metal Scan	Hydride Forming Metals	Client Custom Metals	ORPs: ☐ B-HWS ☐ Cl⁻ ☐ CN⁻ ☐ Cr⁶⁺ ☐ EC ☐ FOC ☐ NO_3/NO_2 ☐ Total N ☐ Hg ☐ pH ☐ SAR (Check Applicable)	Nutrients: ☐ TP ☐ NH_3 ☐ TKN ☐ NO_3 ☐ NO_2 ☐ NO_3/NO_2 (Check Applicable)	Volatiles: ☐ VOC ☐ BTEX ☐ THM (Check Applicable)	CCME Fractions 1 to 4	ABNs	PAHs	Chlorophenols	PCBs	Organochlorine Pesticides	TCLP Metals/Inorganics	Sewer Use	Corrosivity Pack						
BH-1 SS2	May 1	—	1	S																		X					

Samples Relinquished By (Print Name and Sign)	Date	Time	Samples Received By (Print Name and Sign)	Date	Time
Jeff Golder [signature]	May 11, 2017	2:51	D. Brown 2017/05/11		3:00
D. Brown 2017/05/11		4:35			

Page 1 of 1

No:

Pink Copy - Client | Yellow Copy - AGAT | White Copy- AGAT

Appendix F – Slope Stability Analysis

Bridgeport Interchange Culvert Replacement on Hwy 85
East side of Embankment (Outlet)
Undrained Static Condtion

Name: Sand and Gravel Fill Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion': 0 kPa Phi': 32 °
Name: Sand to Silty Sand Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion': 0 kPa Phi': 30 °
Name: Organic Silty Clay Model: Undrained (Phi=0) Unit Weight: 17 kN/m³ Cohesion': 35 kPa
Name: Silty Clay Model: Undrained (Phi=0) Unit Weight: 19 kN/m³ Cohesion': 80 kPa

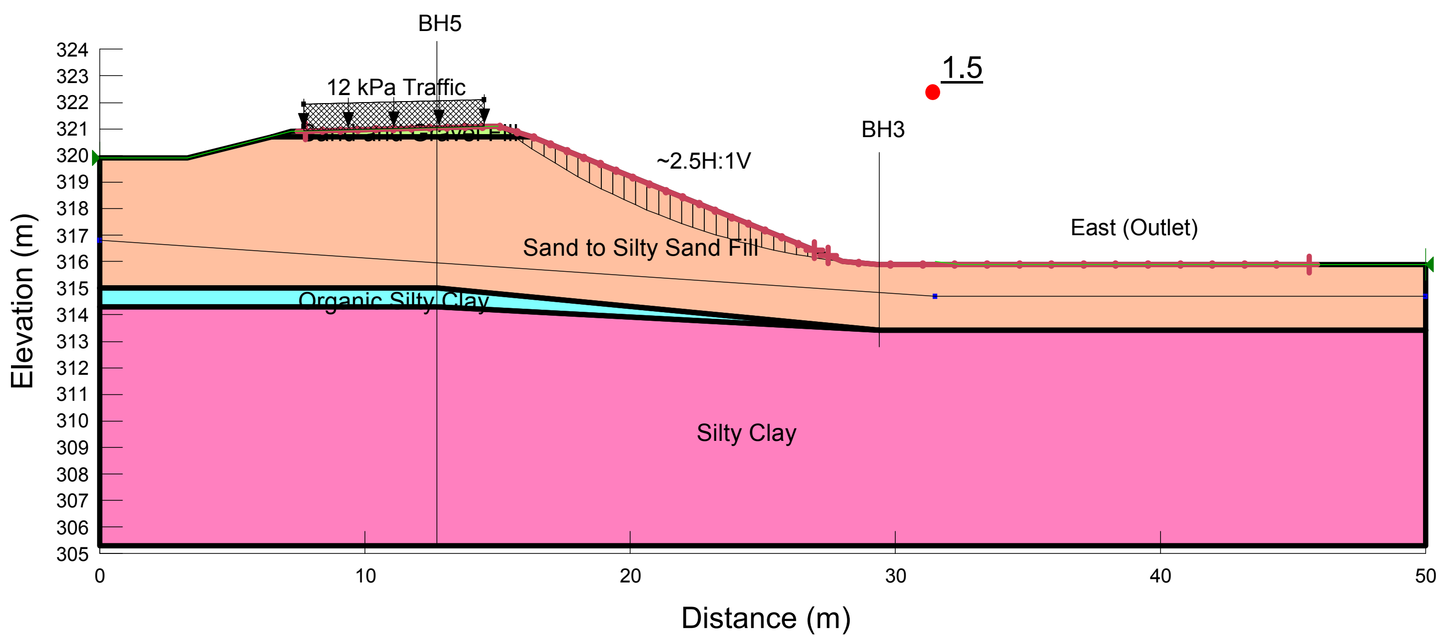


Figure 1: Slope stability analysis for existing embankment – undrained static conditions

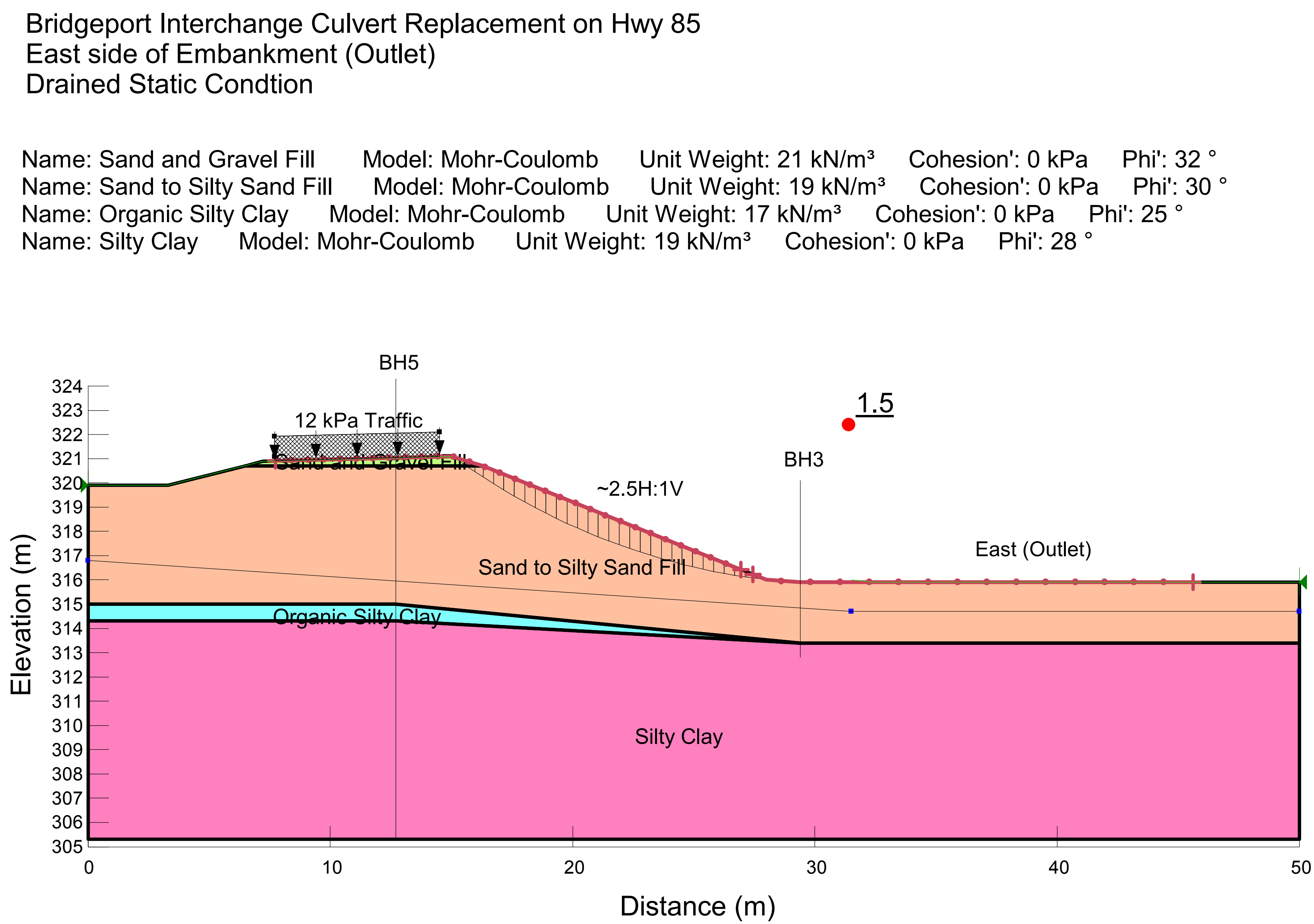


Figure 2: Slope stability analysis for existing embankment – drained static conditions

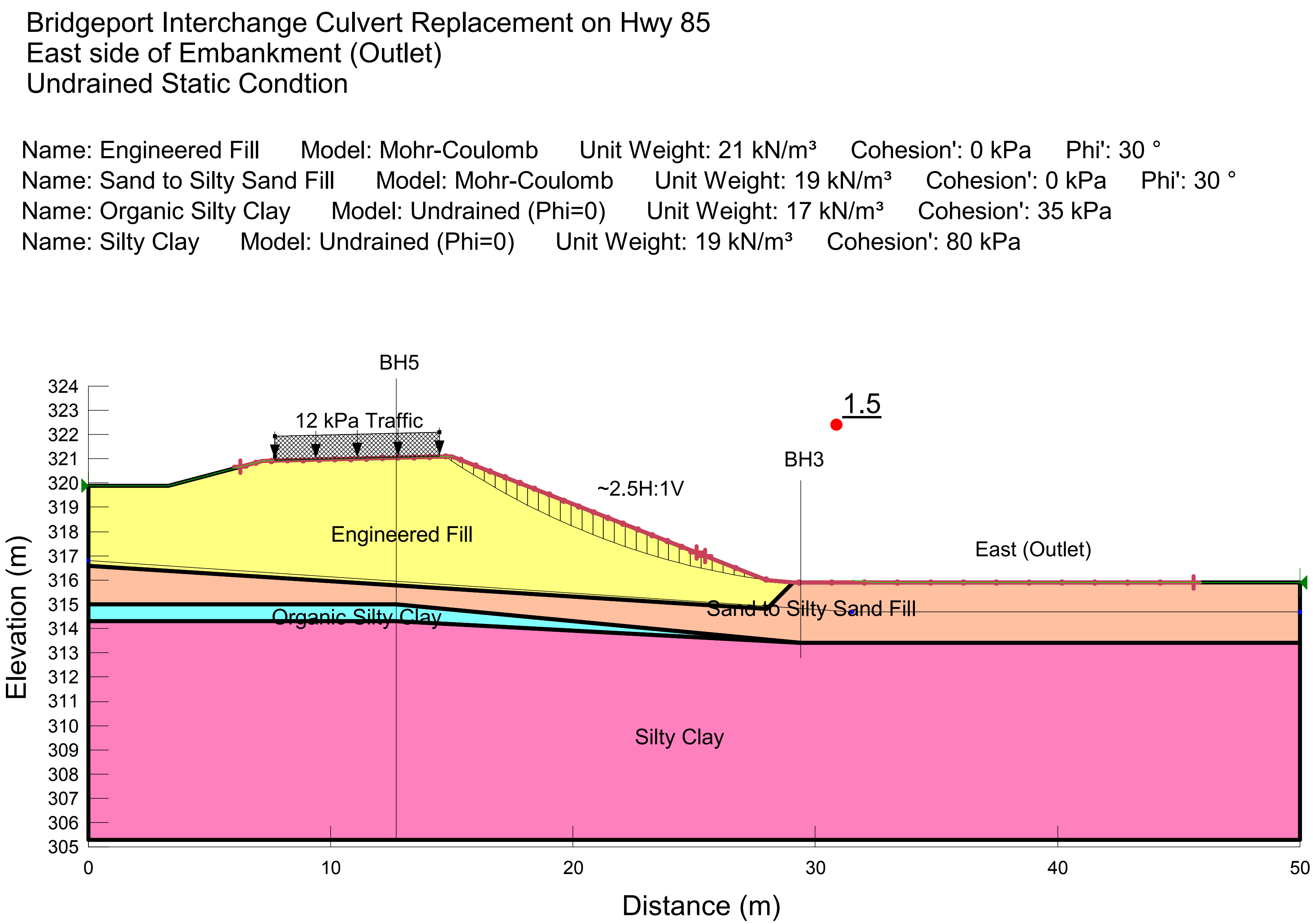


Figure 3: Slope stability analysis for replaced embankment – undrained static conditions

Bridgeport Interchange Culvert Replacement on Hwy 85
East side of Embankment (Outlet)
Drained Static Condtion

Name: Engineered Fill Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion': 0 kPa Phi': 30 °
Name: Sand to Silty Sand Fill Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion': 0 kPa Phi': 30 °
Name: Organic Silty Clay Model: Mohr-Coulomb Unit Weight: 17 kN/m³ Cohesion': 0 kPa Phi': 25 °
Name: Silty Clay Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion': 0 kPa Phi': 28 °

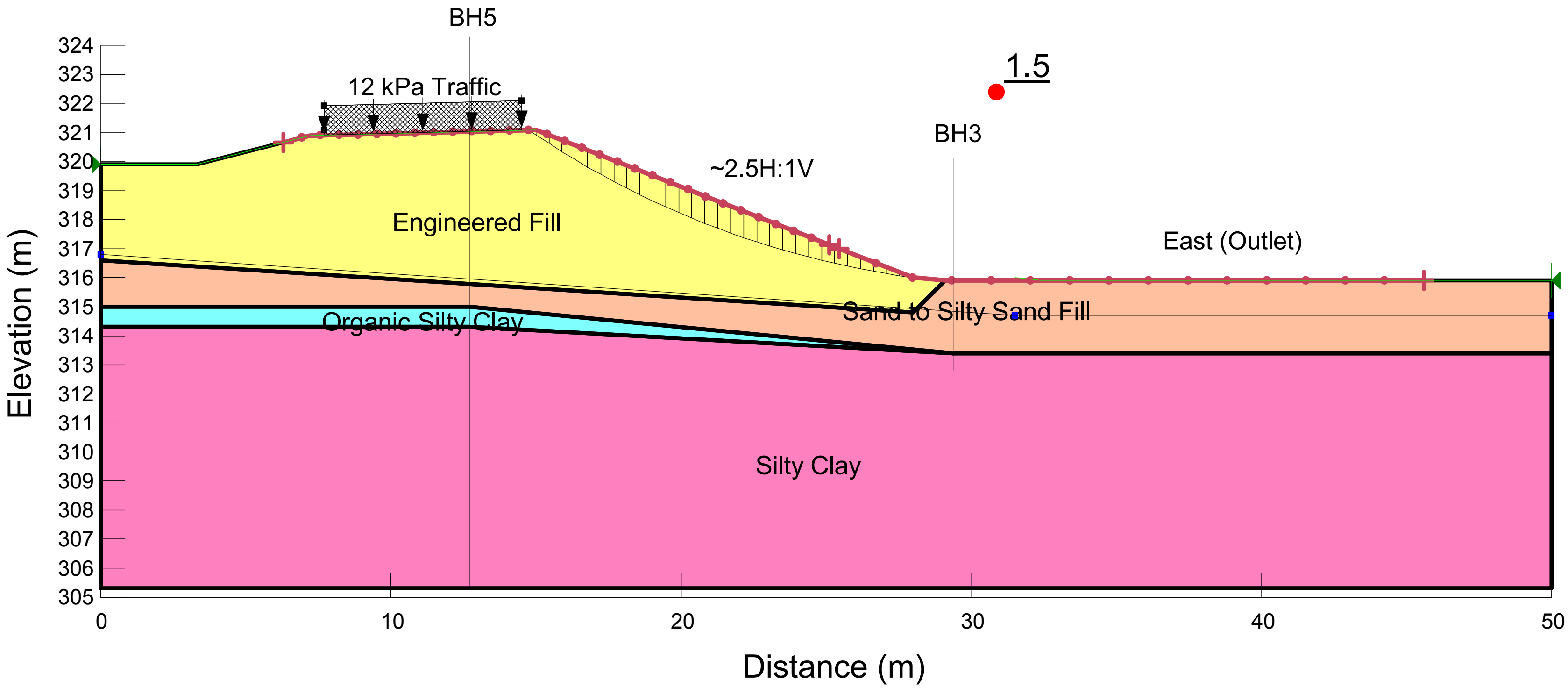


Figure 4: Slope stability analysis for replaced embankment – drained static conditions

Bridgeport Interchange Culvert Replacement on Hwy 85
East side of Embankment at Storm Water Outlet
Undrained Static Condtion

Name: Sand and Gravel Fill   Model: Mohr-Coulomb   Unit Weight: 21 kN/m³   Cohesion': 0 kPa   Phi': 32 °
Name: Sand to Silty Sand Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion': 0 kPa   Phi': 30 °
Name: Peat   Model: Undrained (Phi=0)   Unit Weight: 12 kN/m³   Cohesion': 25 kPa
Name: Silty Clay   Model: Undrained (Phi=0)   Unit Weight: 19 kN/m³   Cohesion': 80 kPa

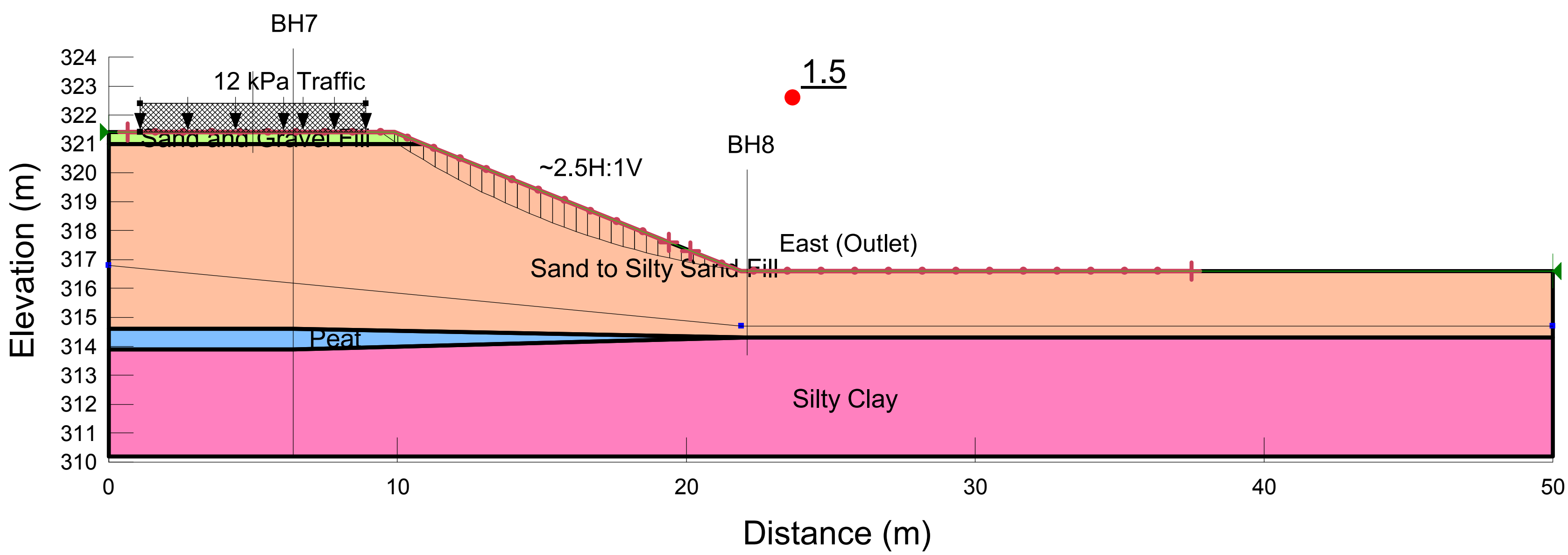


Figure 5: Slope stability analysis for existing embankment at storm water outlet – undrained static conditions

Bridgeport Interchange Culvert Replacement on Hwy 85
East side of Embankment at Storm Water Outlet
Drained Static Condtion

Name: Sand and Gravel Fill   Model: Mohr-Coulomb   Unit Weight: 21 kN/m³   Cohesion': 0 kPa   Phi': 32 °
Name: Sand to Silty Sand Fill   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion': 0 kPa   Phi': 30 °
Name: Peat   Model: Mohr-Coulomb   Unit Weight: 12 kN/m³   Cohesion': 0 kPa   Phi': 20 °
Name: Silty Clay   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion': 0 kPa   Phi': 28 °

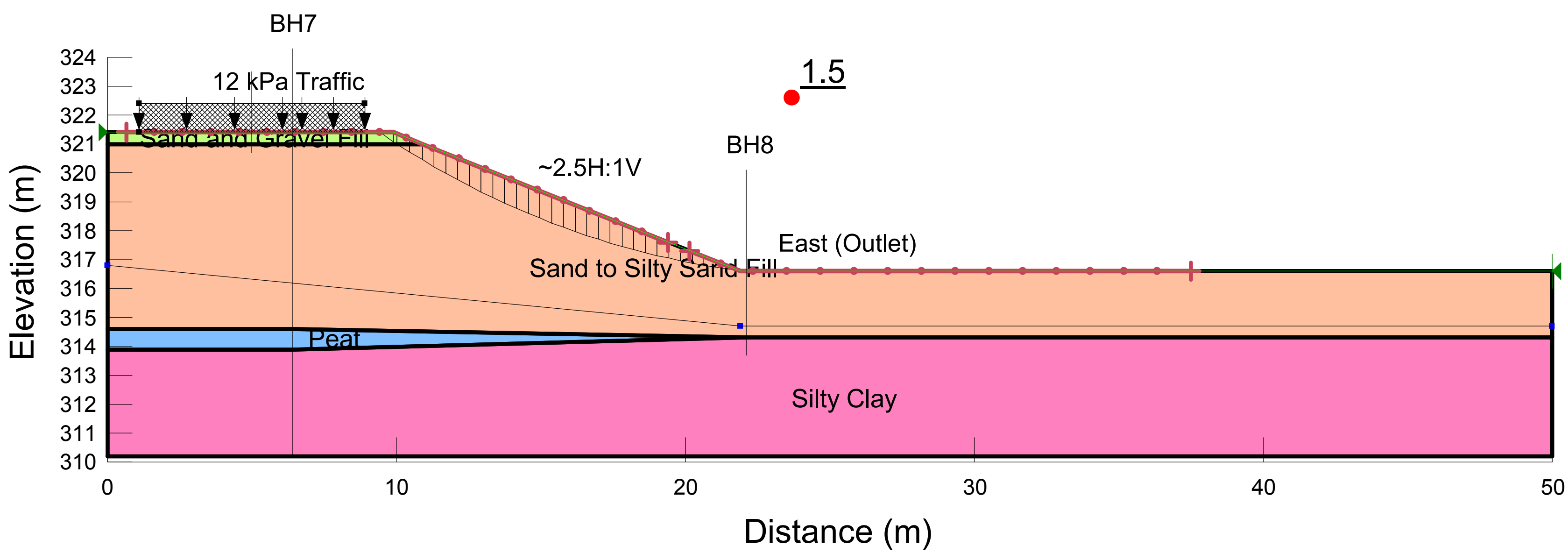
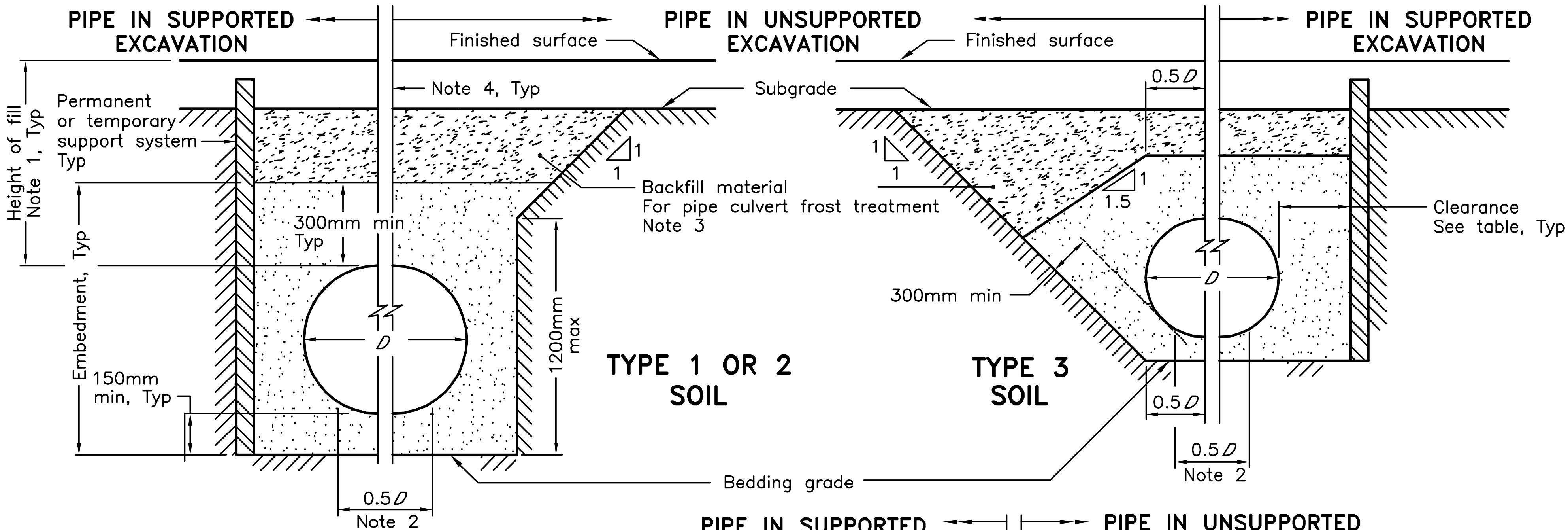


Figure 6: Slope stability analysis for existing embankment at storm water outlet – drained static conditions

Appendix G –
Ontario Provincial Standard Drawings



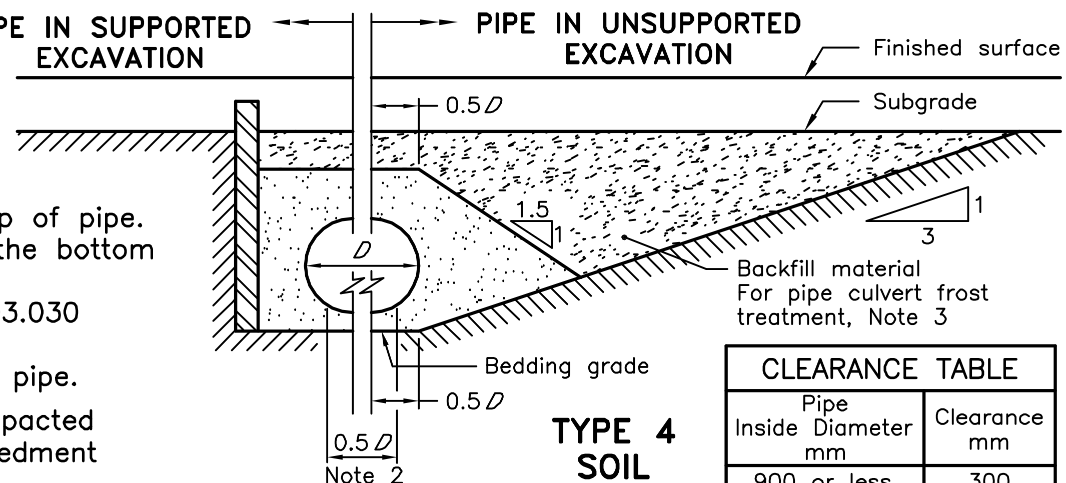
LEGEND:

D – Inside diameter

NOTES:

1 Height of fill is measured from the finished surface to top of pipe.
2 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
3 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.
4 Condition of excavation is symmetrical about centreline of pipe.

A Granular material placed in the haunch area shall be compacted prior to placing and compacting the remainder of the embedment material.
B Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.
C All dimensions are in metres unless otherwise shown.



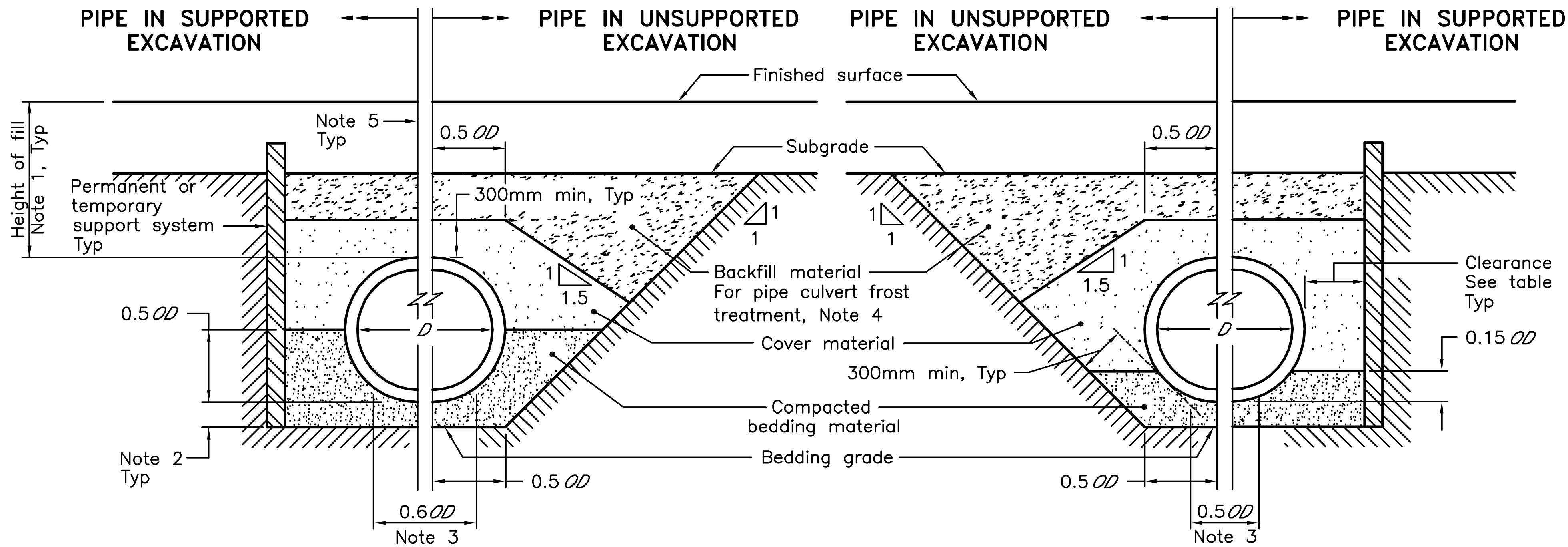
CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2010 | Rev 2

FLEXIBLE PIPE EMBEDMENT AND BACKFILL EARTH EXCAVATION

OPSD 802.010



CLASS B BEDDING

CLASS C BEDDING

NOTES:

1 Height of fill is measured from the finished surface to top of pipe.
2 The minimum bedding depth below the pipe shall be 0.15*D*. In no case shall this dimension be less than 150mm or greater than 300mm.
3 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
4 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.
5 Condition of excavation is symmetrical about centreline of pipe.
A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.
B All dimensions are in metres unless otherwise shown.

LEGEND:

D – Inside diameter
OD – Outside diameter

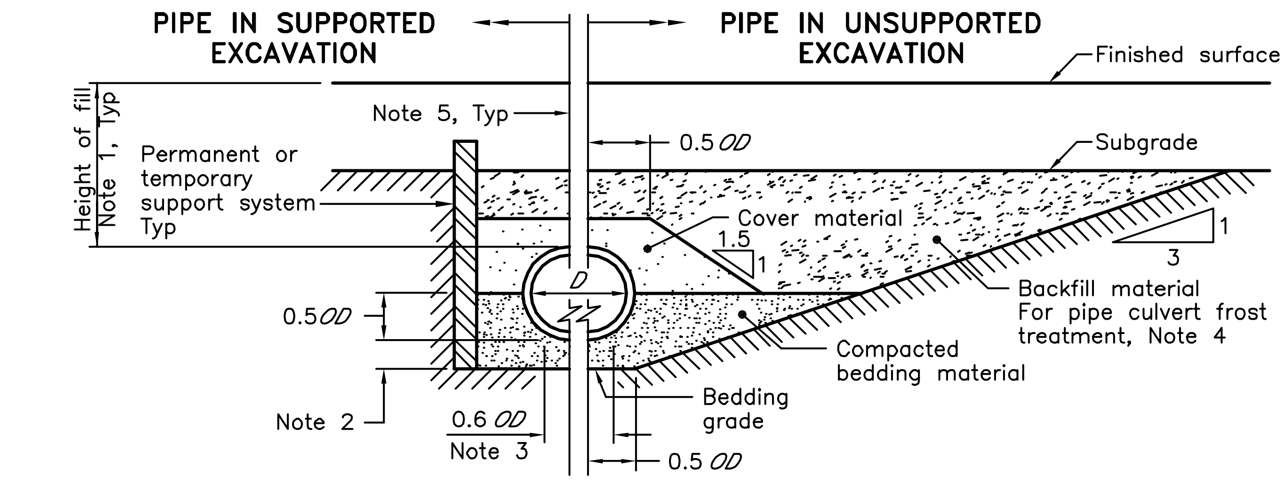
CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

ONTARIO PROVINCIAL STANDARD DRAWING

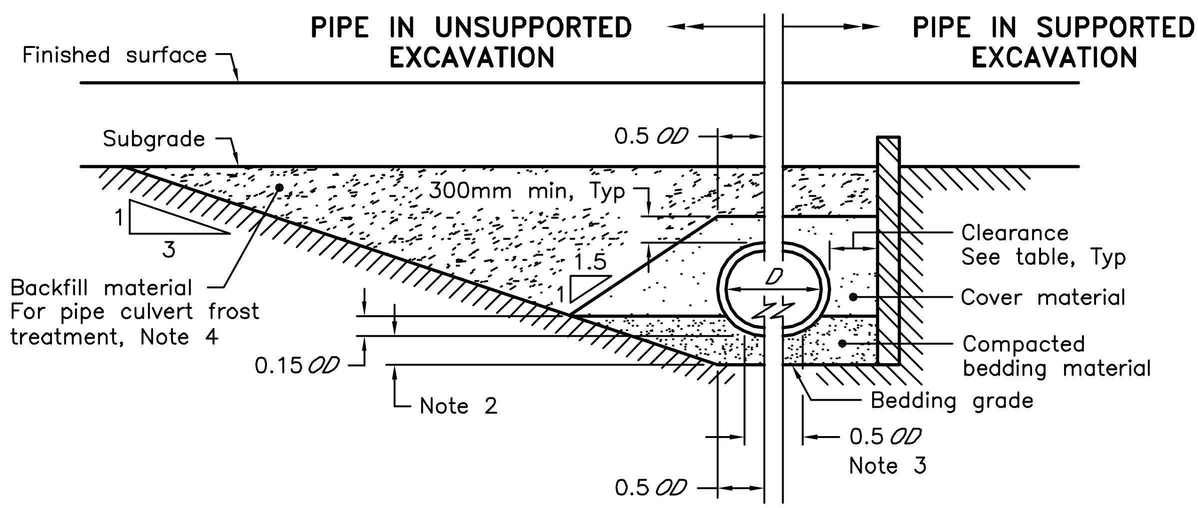
Nov 2010 Rev 2

RIGID PIPE BEDDING, COVER, AND BACKFILL TYPE 3 SOIL – EARTH EXCAVATION

OPSD 802.031



CLASS B BEDDING



CLASS C BEDDING

CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

LEGEND:

D – Inside diameter

OD – Outside diameter

NOTES:

1 Height of fill is measured from the finished surface to top of pipe.

2 The minimum bedding depth below the pipe shall be 0.15*D*. In no case shall this dimension be less than 150mm or greater than 300mm.

3 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.

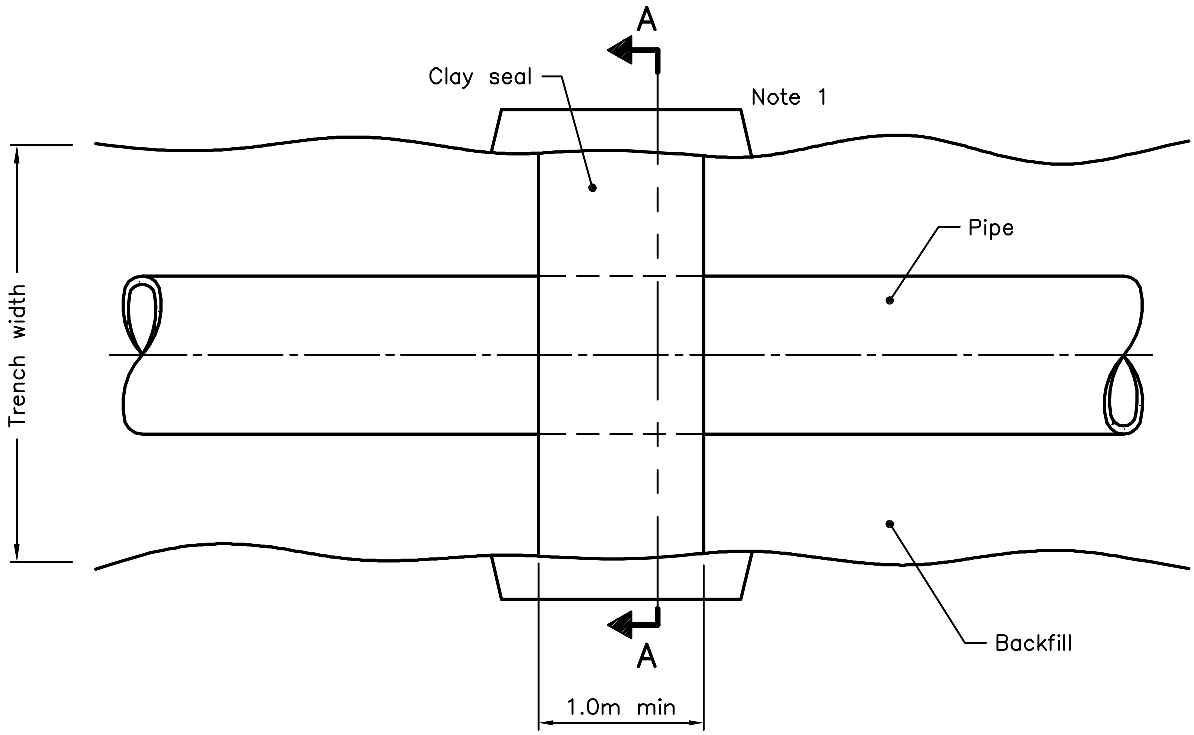
4 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.

5 Condition of excavation is symmetrical about centreline of pipe.

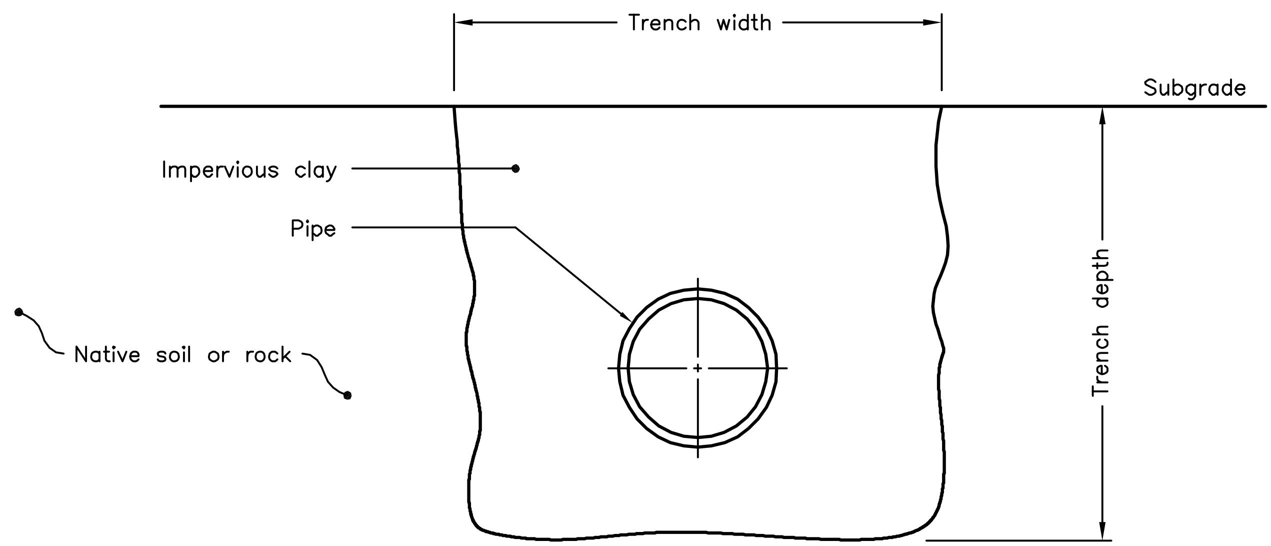
A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

B All dimensions are in metres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2010	Rev 2
RIGID PIPE BEDDING, COVER, AND BACKFILL TYPE 4 SOIL – EARTH EXCAVATION	**OPSD 802.032**	



PLAN



SECTION A–A

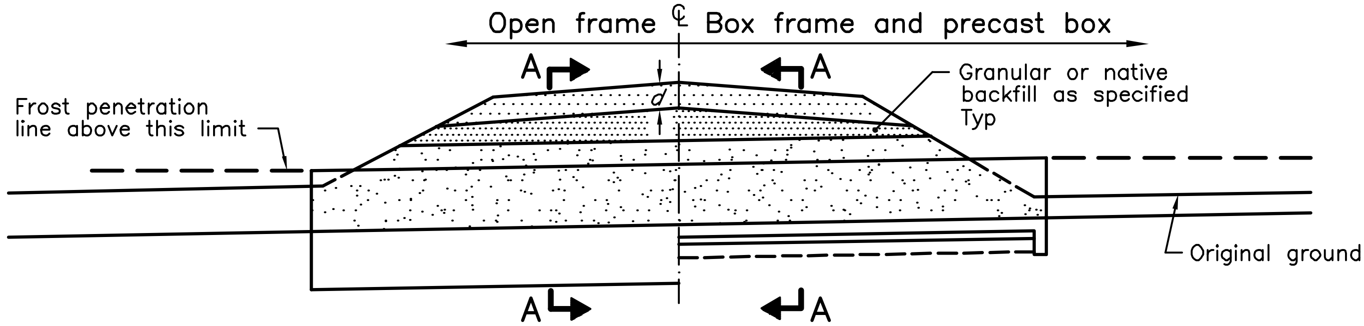
NOTES:

1. Key into undisturbed trench soil.

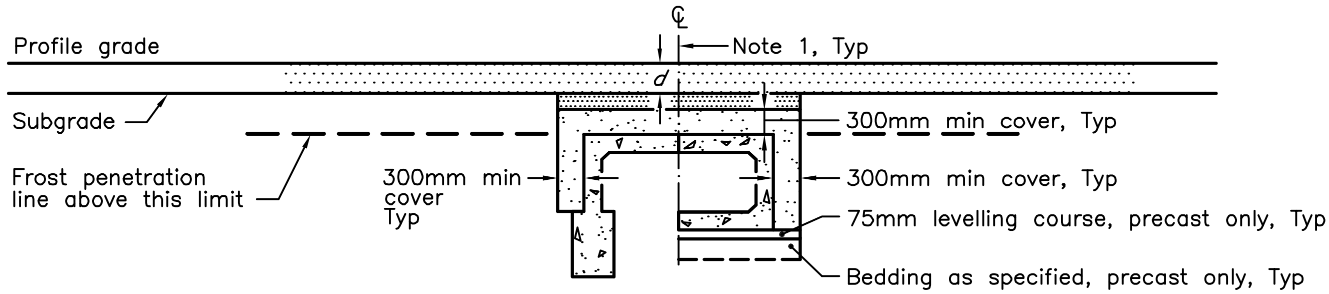
A Clay seal shall extend from bottom of trench excavation to the subgrade.
B Clay seal shall be located so that no pipe joints are within the clay seal material.
C All dimensions are in metres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2011	Rev 1
CLAY SEAL FOR PIPE TRENCHES		
	OPSD 802.095	

FROST PENETRATION LINE AT OR ABOVE TOP OF CULVERT

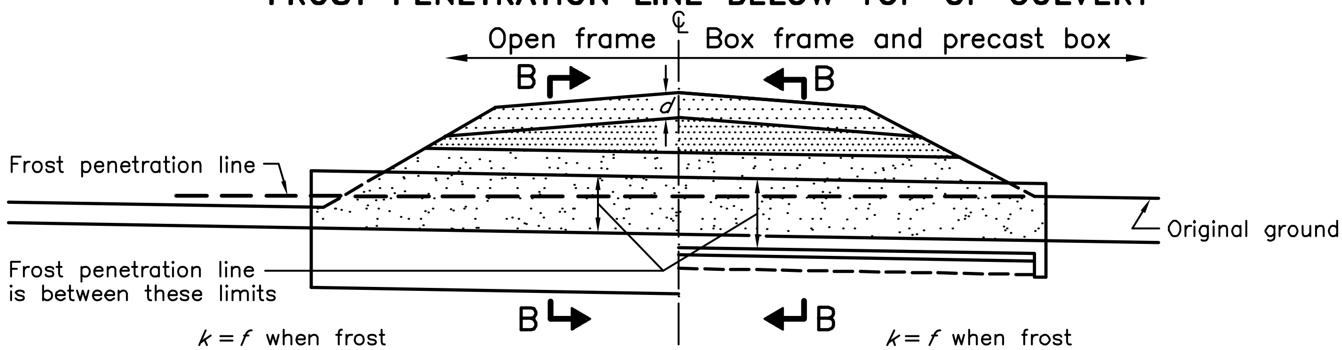


LONGITUDINAL SECTION

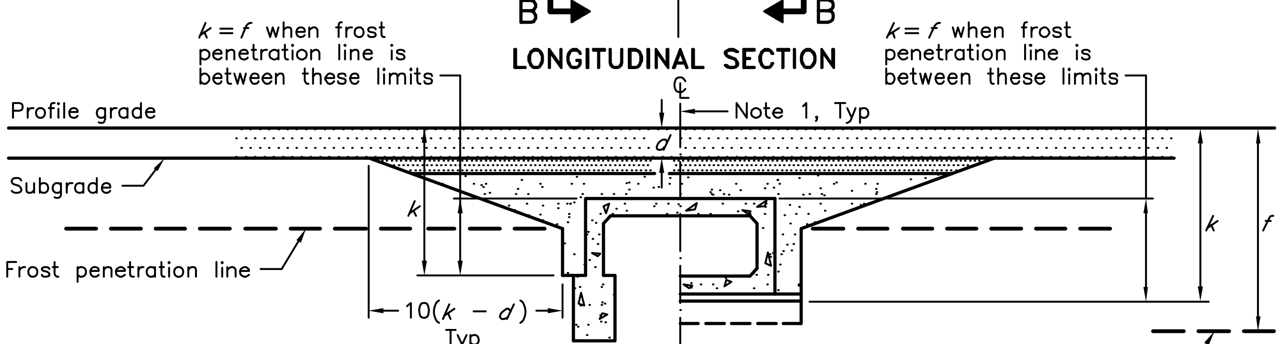


SECTION A–A

FROST PENETRATION LINE BELOW TOP OF CULVERT



LONGITUDINAL SECTION



Frost penetration line below bottom of culvert footing or slab

SECTION B–B

LEGEND:

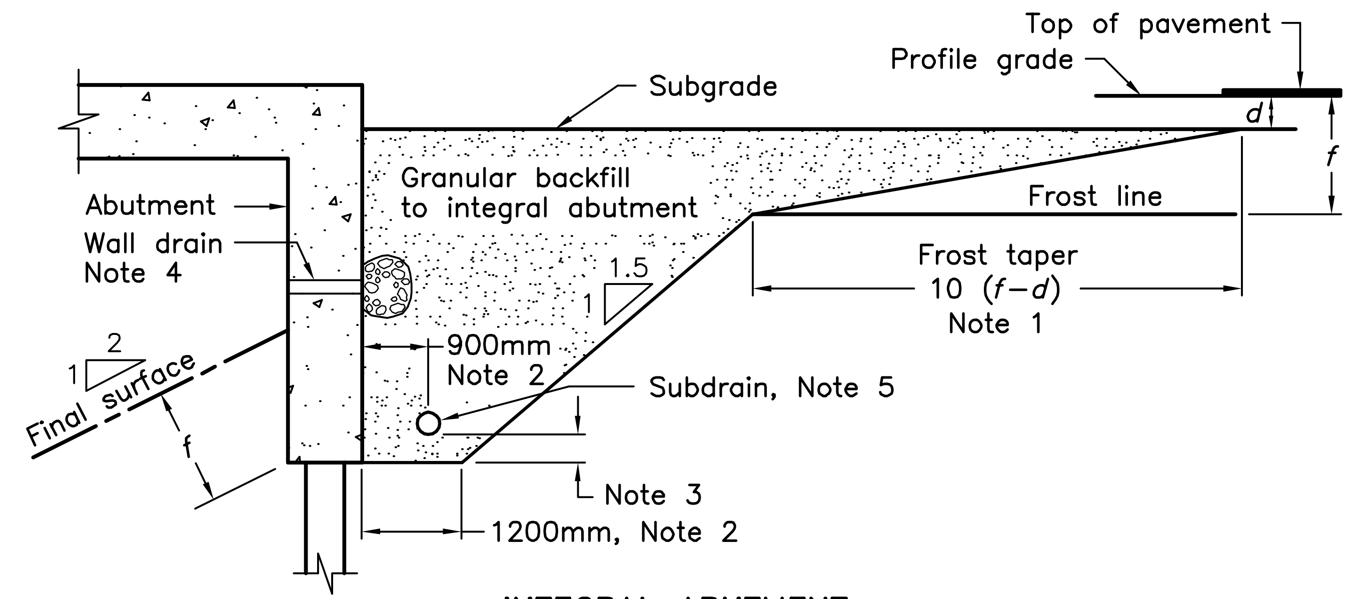
d = depth of roadbed granular
k = depth of frost treatment below profile grade
f = depth of frost penetration below profile grade

NOTES:

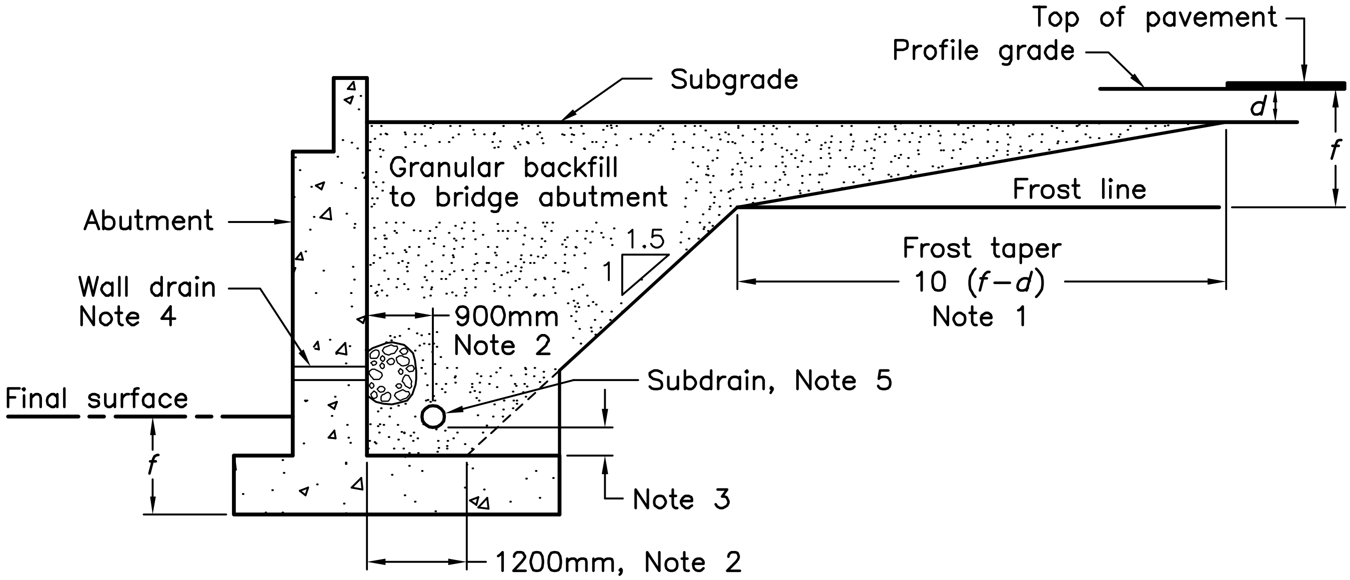
1 Condition of frost treatment symmetrical about centreline of culvert.

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



INTEGRAL ABUTMENT



ABUTMENT

NOTES:

1 d = depth of combined base and subbase courses
  f = frost penetration depth as specified

2 Dimensions perpendicular to back face of abutment.

3 Height to be consistent with positive drainage of subdrain as specified.

4 Where specified, wall drains shall be installed according to OPSD 3190.100.

5 150mm dia perforated pipe subdrain wrapped with geotextile.

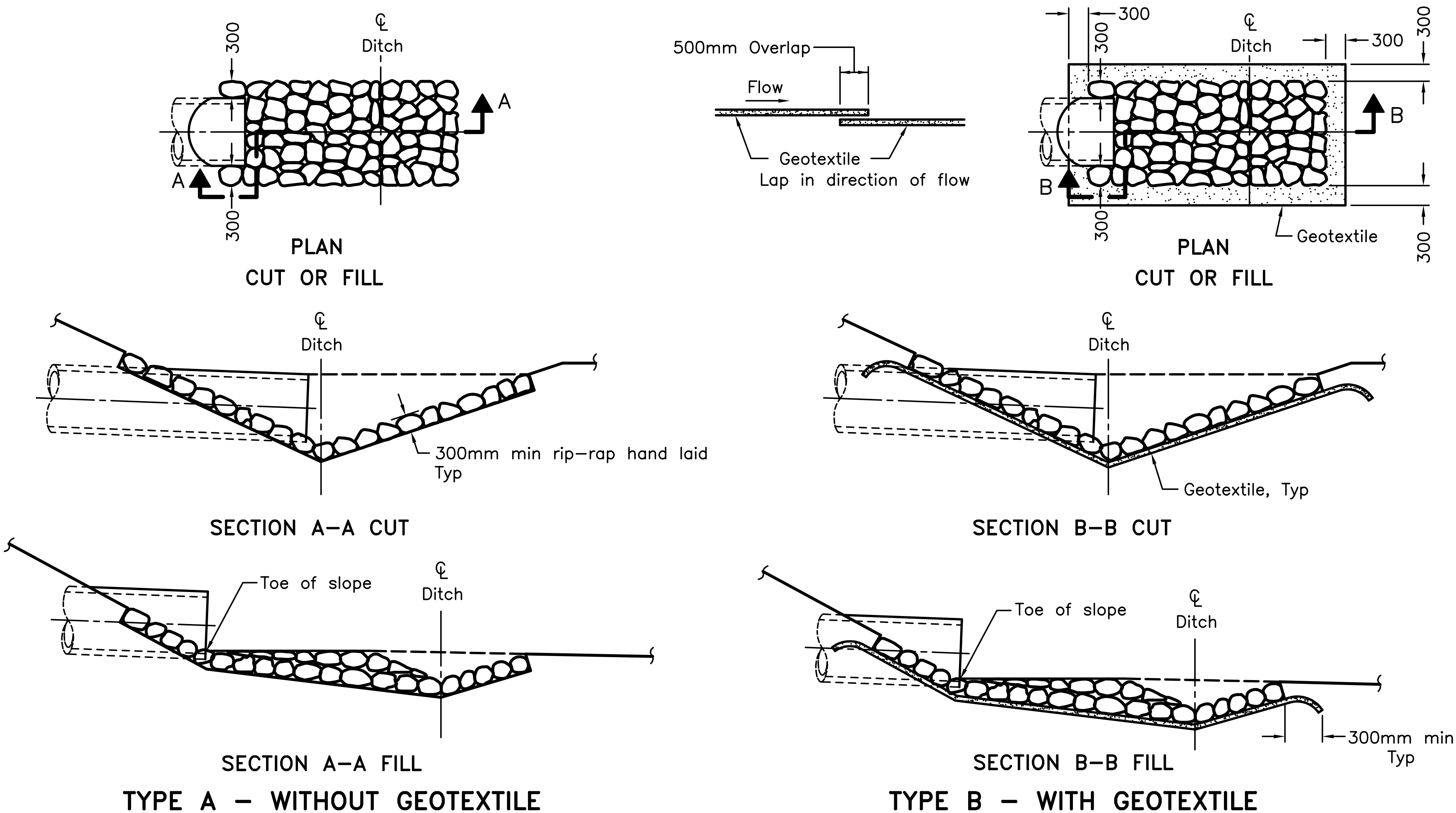
A Lateral limits of granular backfill to bridge abutment to be inside face to inside face of retaining wall or wingwall. Frost taper shall extend the full width of the backfill unless interrupted by the retaining wall or wingwall.

B Sections shown are parallel to centreline of roadway.

C Subdrain shall be installed with a 2% gradient behind wall.

D All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2010	Rev 1
WALLS ABUTMENT, BACKFILL MINIMUM GRANULAR REQUIREMENT	OPSD 3101.150	



NOTES:

A All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2001	Rev 0
RIP–RAP TREATMENT FOR SEWER AND CULVERT OUTLETS		
	OPSD – 810.010	

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.

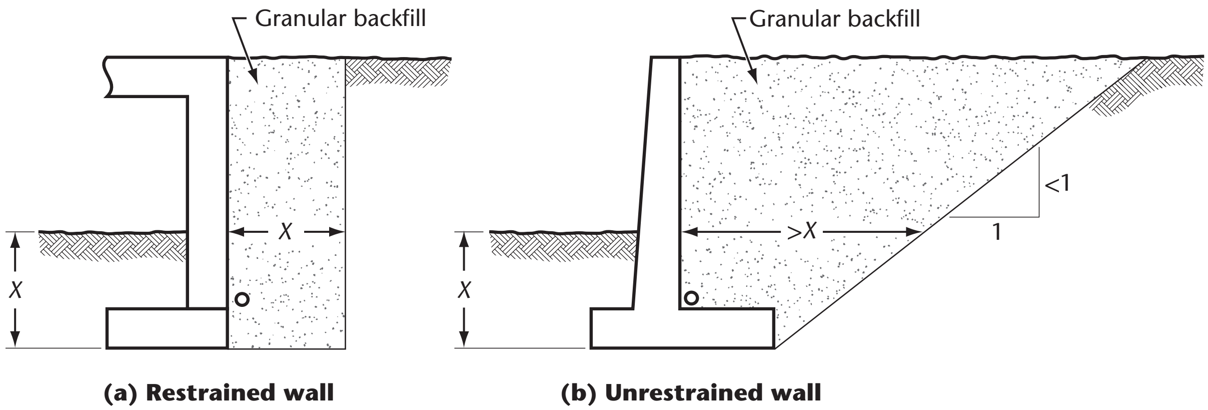


Figure C6.20
Backfill for frost protection
(See Clause C6.9.1.)

C6.9.2 Lateral pressures

C6.9.2.1 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 6.9.2.2 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.

Clause 6.9.2.1 includes the specification of four lateral pressure conditions for design. The first two cases apply to unrestrained structures, with Item (a) applying to the sizing of the base or pile arrangement with respect to external stability, and Item (b) to the sizing of the structural sections with respect to internal stability. Such sections could be of structural concrete, structural steel, or a proprietary product.

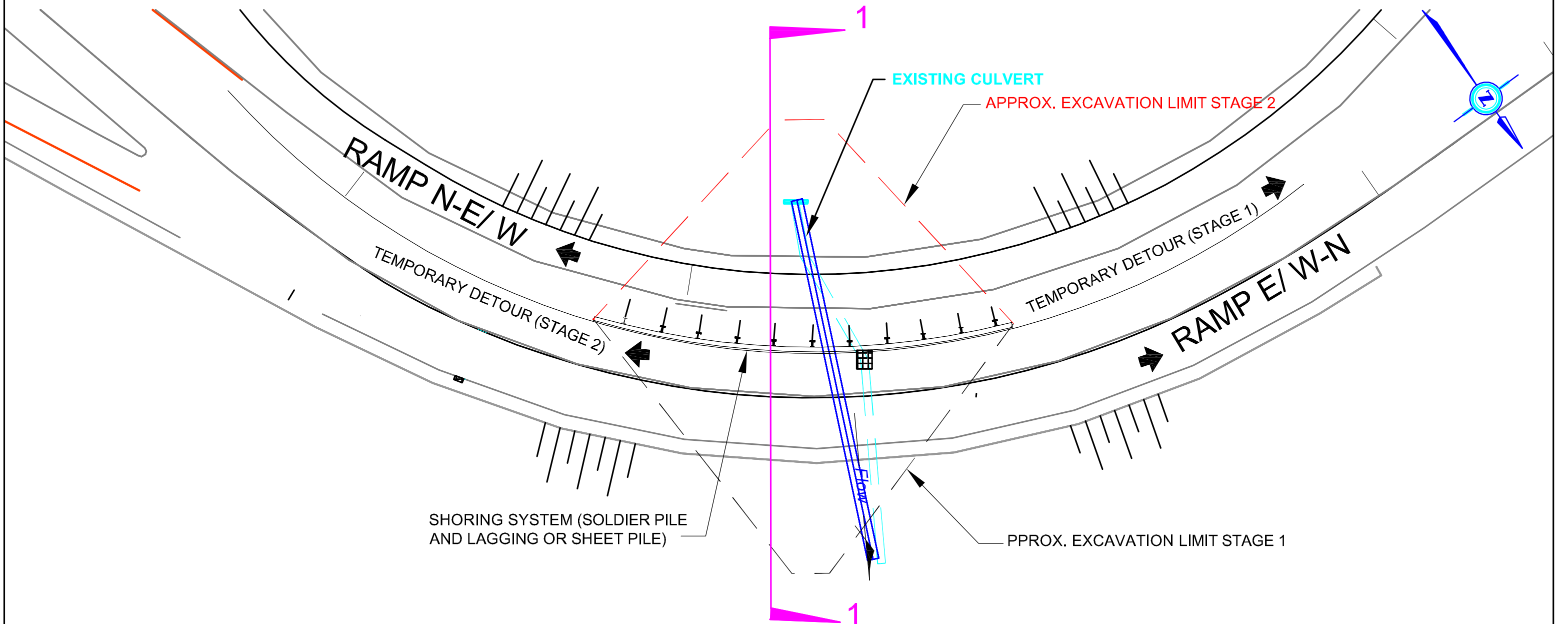
An unrestrained structure is one in which active pressure is mobilized in the backfill due to movement in the supporting structure. This movement corresponds to a rotation of approximately 0.002 about the base of a vertical wall, a horizontal translation of 0.001 times the height of the wall, or a combination of these movements. The lateral pressure applied to the wall for the condition described is an active pressure.

The supporting material will generally be more robust than what is assumed by the Geotechnical Engineer for factored conditions in design. Hence, following installation of the backfill, movement sufficient to cause active condition will generally not have taken place. Horizontal or rotational movement of the base will occur during the installation of each lift of the backfill. Wall deflection during each application and compaction of the backfill will add to the existing deformations. For such a post placement of the fill condition, Item (b) applies, the forces acting on the retaining structure being a function of the compacting equipment and the flexural stiffness of the wall. The residual horizontal pressures due to compaction are largest at the top of the wall, and this is reflected in Clause 6.9.3.

Appendix H – Schematic Sketches for Construction Alternatives

FIGURE H.1A : HALF AND HALF CONSTRUCTION WITH UNSUPPORTED CUT SIDES WITH TEMPORARY LOCAL DETOUR (OPTION 1.A)

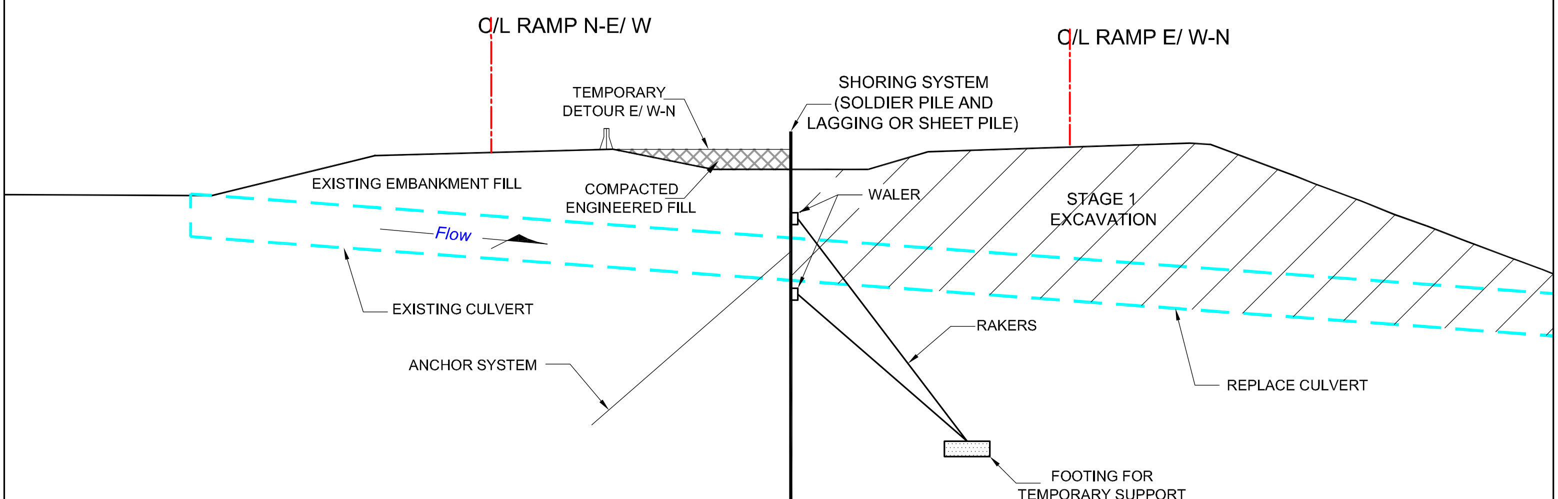
SCHEMATIC DIAGRAMS (NTS)



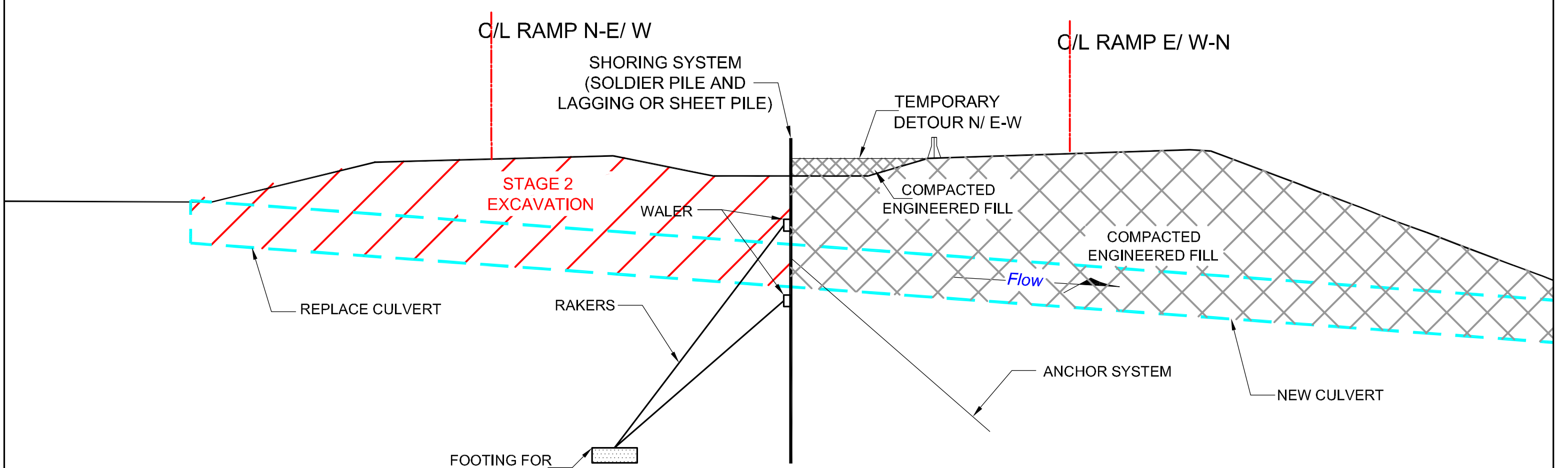
PLAN

RECOMMENDED STAGES:

STAGE 1: BUILD TEMPORARY DETOUR ON ONE SIDE OF PROTECTION/ EXCAVATE AND CONSTRUCT CULVERT/ TRAFFIC TO RAMP E/ W-N SHIFTED TO DETOUR.



STAGE 2: BUILD TEMPORARY DETOUR ON OTHER SIDE OF PROTECTION/ EXCAVATE AND CONSTRUCT CULVERT/ TRAFFIC TO RAMP N-E/W SHIFTED TO DETOUR.

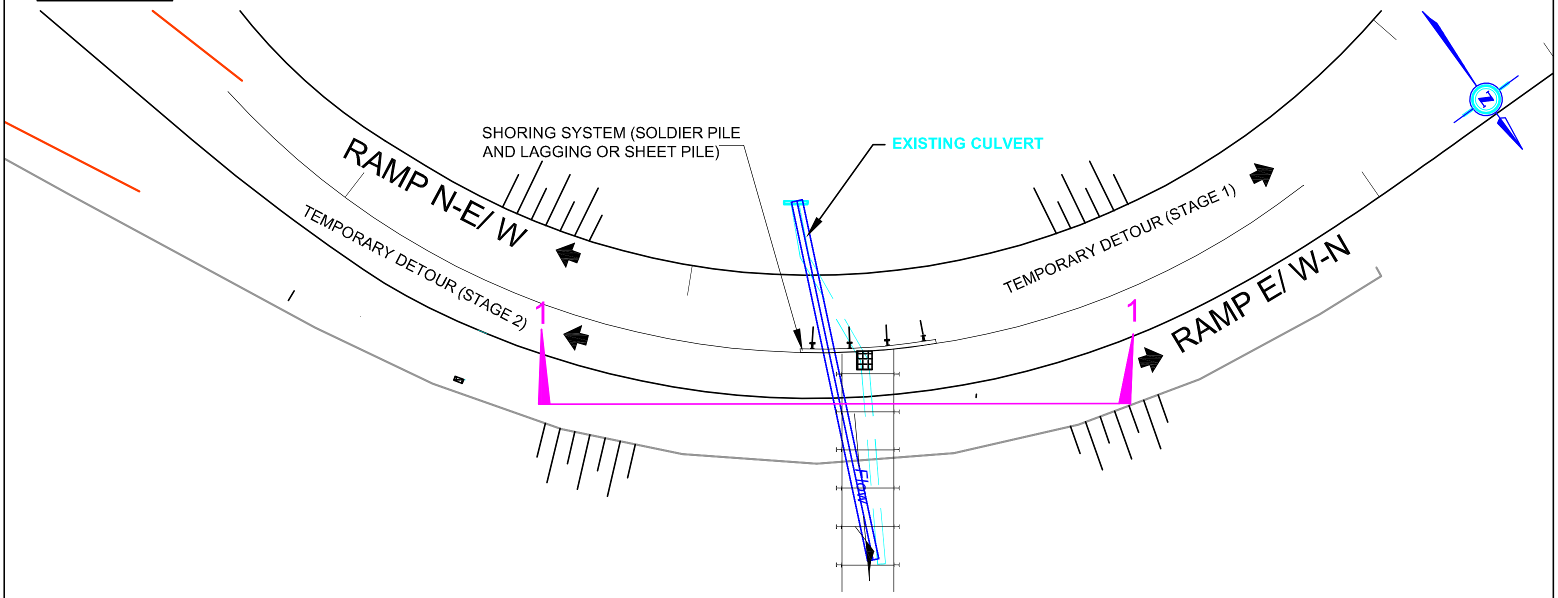


SECTION 1-1

FIGURE H.1B : HALF AND HALF CONSTRUCTION WITH BRACED CUT SIDES OR ANCHOR SYSTEM (OPTION 1.B)

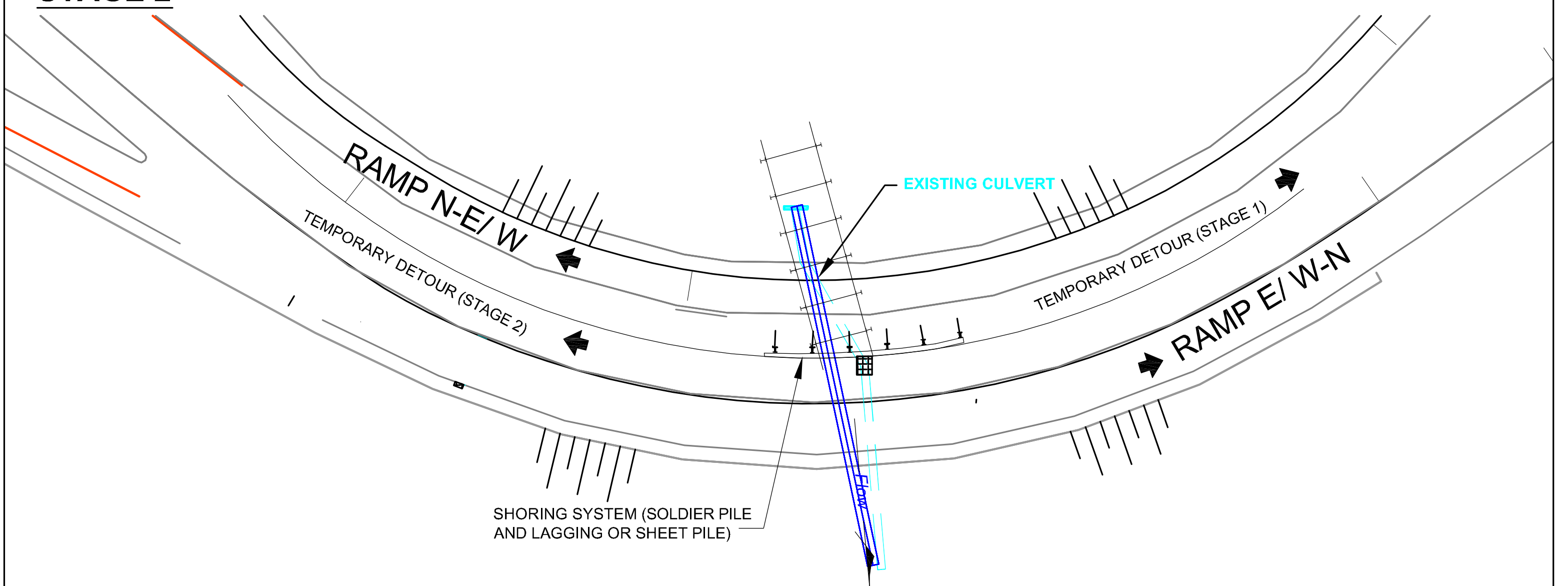
SCHEMATIC DIAGRAMS (NTS)

STAGE 1

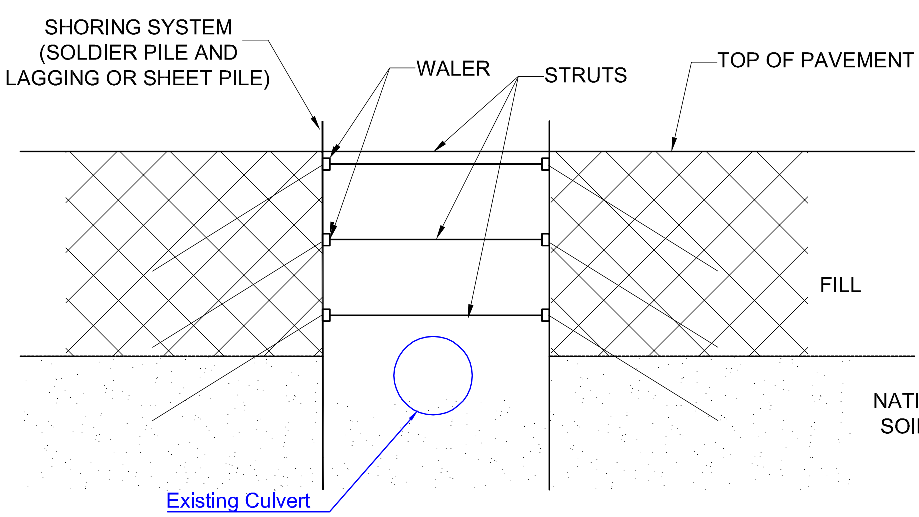


PLAN

STAGE 2



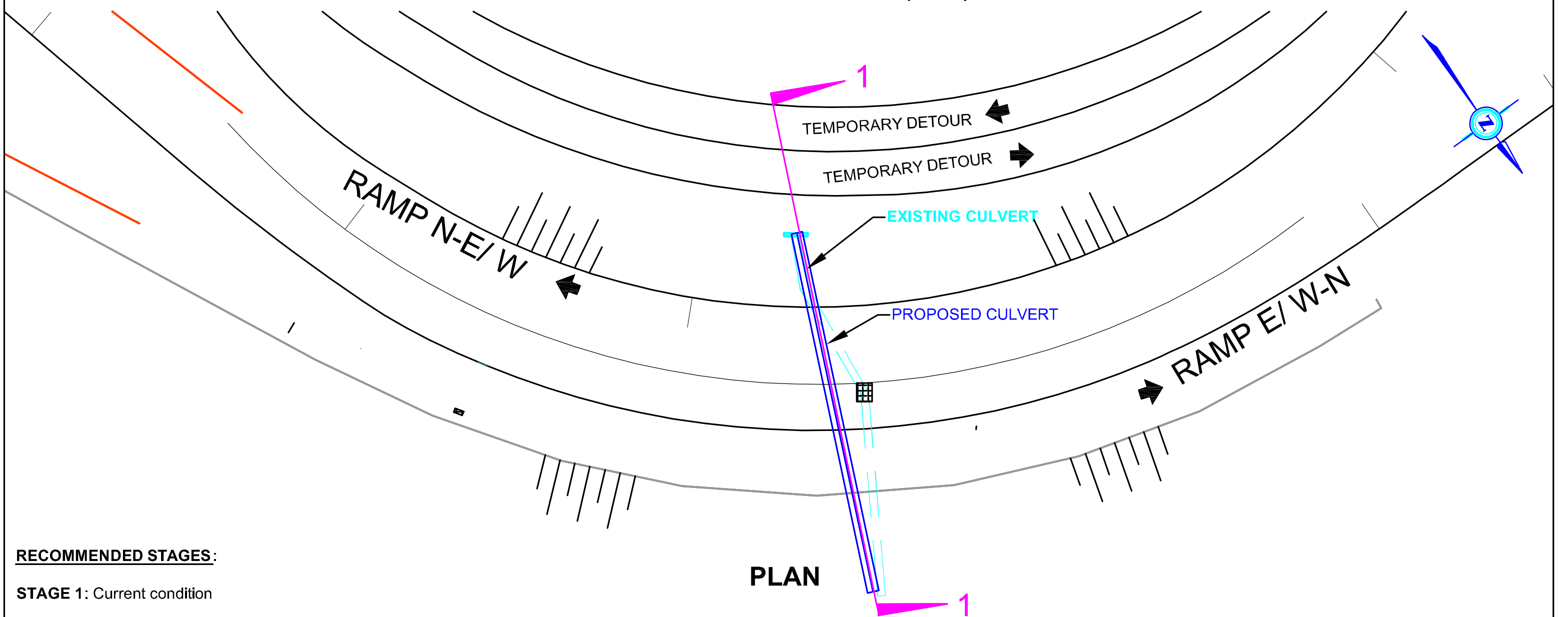
PLAN



SECTION 1-1

FIGURE H.3: TEMPORARY LOCAL DETOUR AND OPEN CUT UNSUPPORTED EXCAVATION (OPTION 3)

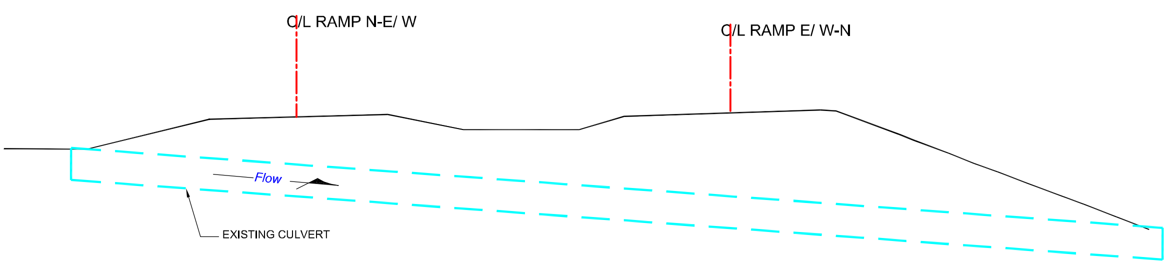
SCHEMATIC DIAGRAMS (NTS)



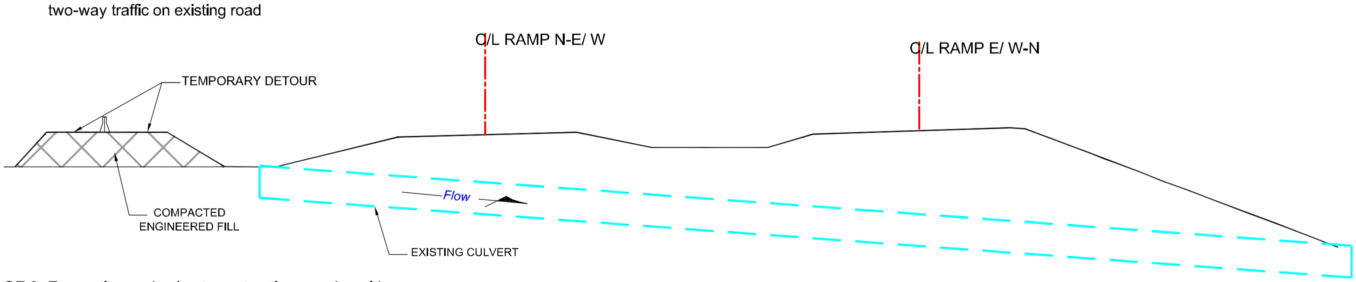
PLAN

RECOMMENDED STAGES:

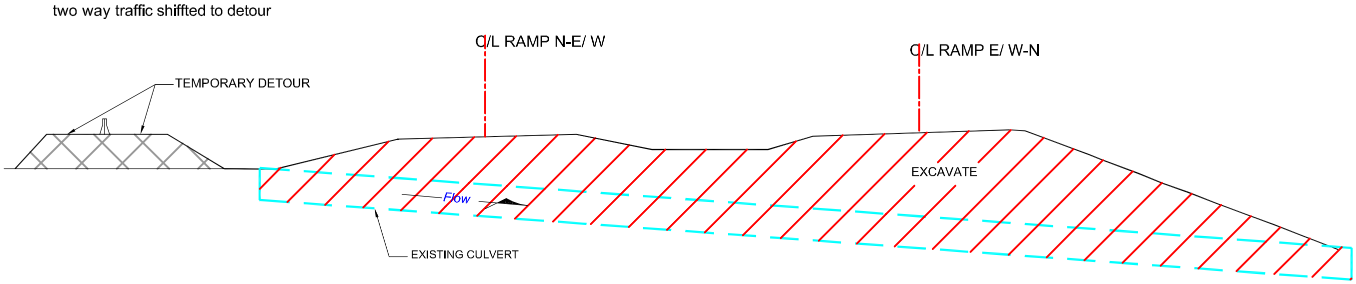
STAGE 1: Current condition



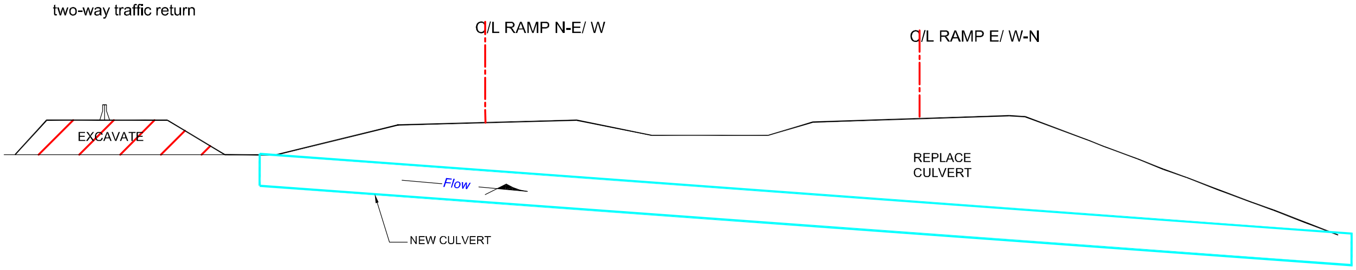
STAGE 2: Build temporary detour one side
two-way traffic on existing road



STAGE 3: Excavation and culvert construction on other side;
two way traffic shiffted to detour



STAGE 4: Build the embankment to existing alignment;
two-way traffic return



SECTION 1-1

Appendix I –
Non-Standard Special Provision

NSSP FOR COBBLES AND/OR BOULDERs OR WOOD FIBRES OBSTRUCTIONS

Scope of Work

The Contractor should be aware that the embankment at the site consists of granular fill which may contain cobbles and/or boulders and around the original ground surface it may contain wood fragments, rootlets or stumps. Which may impact excavations, tunnelling and/or elements of temporary protection systems. Appropriate equipment and procedures will be required to penetrate/remove cobbles and/or boulders and other obstructions that are encountered during excavation, tunnelling or advancing elements of the temporary protection systems.

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.

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

2. REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180	Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS.PROV 1004	Aggregates - Miscellaneous
OPSS.PROV 1350	Concrete - Materials and Production
OPSS.PROV 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS.PROV 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-10	Welded and Seamless Steel Pipe Piles
ASTM D2657-07	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350-14	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894-13	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6-15	Profile Polyethylene Sewer Pipe and Fittings for leak proof sewer applications
CAN/CSA A5-93	Portland Cement

CSA W59-13	Welded Steel Construction (Metal Arc Welding)
CSA B182.8-15	Profile Polyethylene Sewer Pipe and Fittings

3. DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or “Jack and Mine) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid’s pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the flow of unexpected fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Trenchless Installation: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report or elsewhere in the Contract Documents.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;

- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:
- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:
- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:
- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:
- Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:
- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method:
- The methods to be employed to monitor and maintain the alignment of the installation.

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, lay-out the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

Site Surveying (as noted in Section 4.02)

Excavation for pits including dewatering of excavations
Jacking/Ramming/Directional Drilling of Casing/Liner
Installation of the Product
Grouting Operations

Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

The product shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS.PROV 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS.PROV 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS.PROV 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS.PROV 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.
Use of explosives is prohibited.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be submitted to the Contract

Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS.PROV 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA’s may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer’s handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS.PROV 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the inlet end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS.PROV 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.

7. 05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in-ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.06, the following represents trigger levels that define magnitude of movement and corresponding action:

- Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:

- The cause of the settlement has been identified.
- The Contractor submits a corrective/preventive plan.
- Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
- The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor’s operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.