



Foundation Investigation and Design Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto - **Highway 400 CSP Culvert Replacement (CV-0252-0400-0053)**

GWP: 2044-23-00

Assignment No. 2020-E-0028

MTO Central Region

Latitude: 44.644830; Longitude: -79.651590

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CONSOR Engineers LLC

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Part I: Foundation Investigation Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto - **Highway 400 CSP Culvert Replacement (CV-0252-0400-0053)**

1.0 Introduction

EXP Services Inc. (EXP) was retained by CONSOR Engineers LLC (CONSOR) on behalf of The Ministry of Transportation (MTO) to provide detailed foundation investigation and engineering services and pavement engineering services for the proposed rehabilitation/replacement of 25 Non-Structural Culverts project at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto. The findings, analyses and recommendations related to foundation scope are presented in a Foundation Investigation Design Report created for each culvert location. The work was undertaken under GWP 2044-23-00, Assignment No. 2020-E-0028. The terms of reference (TOR) and the scope of work for the foundation investigation are outlined in Ministry of Transportation Ontario's (MTO) Request for Proposal, dated February 2022. The scope of this report is specifically limited to the proposed replacement of the twin Corrugated Steel Pipe (CSP) culverts on Highway 400 (CV-0252-0400-0053).

The general design drawings for the proposed culvert replacement were provided to EXP by CONSOR. The purpose of the investigation was to evaluate the subsurface conditions along the existing culvert, and based on this data, to permit detailed design for the culvert replacement methods.

The site-specific geotechnical investigation consisted of borings, soil sampling, borehole logging, and field and laboratory testing. The field and laboratory work for this structure was performed by EXP. Based on collected geotechnical data, this report provides an assessment of the geotechnical issues, geotechnical design parameters, and geotechnical foundation design recommendations for the proposed structure. Geotechnical-related construction recommendations are also provided.

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.

2.0 Structure Description

Initially, the existing culverts were proposed to be replaced with a trenchless method, however, during the design process the designer selected the open cut and cover staged construction method for the installation of the new culvert. The 90% contract drawing attached in Appendix B shows the 90% design configuration of the proposed culvert replacement of the Highway 400 culvert. A summary of the proposed structure is as follows:

- The existing culvert is a twin 600 mm CSP culvert; the total length is approximately 60 m. It is proposed to be replaced with a precast concrete box culvert of size 2.2 m wide and 1.4 m high with an opening of 1.8 m wide and 1.2 m high with a waterbody aggregate of about 0.3 m to 0.6 m thick inside the culvert. The existing culvert will be replaced at the same alignment in two segments with a total length of about 27 m under SBL and about 25 m under NBL with an open flow channel at the median ditch. The invert levels of the new culverts are proposed to be at approximate elevations of 202.23 m and 202.21 m at the inlet and outlet of the SBL culvert, respectively, and approximate elevations of 202.21 m and 202.18 m at the inlet and outlet of the NBL culvert, respectively.
- The existing Highway 400 profile grade is planned to remain unchanged.

The 90% contract drawings were included as part of this report and are used for initial context to address the nature and scope of the investigation. It is understood that some changes might occur as a result of normal refinement or the findings of the geotechnical report.

3.0 Site Description and Geological Setting

3.1 Site Description

The CSP culvert is located on Highway 400, about 2.0 km southwest of the intersection of Highway 400 with Highway 19 in the Simcoe region (Latitude: 44.644830; Longitude: -79.651590) in the Ministry of Transportation (MTO) Central Region. Highway 400 generally runs in the north-south direction, however, at the location of Culvert CV-0252-0400-0053, Highway 400 runs in a northeast-southwest direction. At the site, Highway 400 is a four-lane roadway with the northbound lane (NBL) and (southbound lane) SBL separated by a boulevard (two lanes in each direction). Based on the contract drawings, the NBL and SBL roadway is approximately 12.9 m and 12.6 m wide from edge of pavement to edge of pavement, respectively. The boulevard between the NBL and SBL is approximately 20.3 m wide from the edge of pavement to the edge of pavement. The existing CSP culvert is positioned in a northwest-to-southeast direction at a skew angle almost perpendicular to the highway central line. The elevation of the highway pavement centerline at the site is about 204.4 m and 204.5 m at the NBL and the SBL, respectively. The existing embankment height at the culvert location was about 1.6 m and 2 m at the SBL and the NBL, respectively. The sides of the embankment above the culvert slope were about 5H:1V, and 3.3H:1V on the west and east sides, respectively.

Based on the information provided in the drawings, the existing culvert is a twin 600 mm CSP culvert with approximate lengths of 60 m. The invert of the twin culverts was about Elev. 202.5 m and Elev. 202.6 m at the inlet side, and about Elev. 202.4 m and Elev. 202.3 at the outlet side of the north and south culvert, respectively. The invert at the inlet side of the north culvert was in badly damaged condition (refer to photograph 5 in Appendix A). Selected 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 drawings attached in Appendix B.

The general site conditions were assessed during field investigation works that took place by EXP between August 08 and August 11, 2023. At the time of the field investigation, the approximate top of water elevation at the outlet of the north culvert was measured to be approximately 202.5 m. No riprap to protect against scour or erosion was observed on both the inlet and outlet of the culvert. Vegetation at the site consists predominantly of coniferous trees with some deciduous trees wild bushes and shrubs adjacent to the culvert area. The existing culverts were heavily corroded at the top and side and deformed with even a partial separation of pieces of the culverts. Photographs attached in Appendix A show the condition of the culverts. The highway surface in general is observed to be in a mildly deteriorated condition with a large portion of the roadway experiencing extensive longitudinal cracking.

3.2 Geological Setting

Based on a review of geological maps of Southern Ontario (Chapman and Putnam, 1984), the site is situated within the Simcoe Uplands physiographic region where the predominate landforms are broad, rolling till plains separated by steep-sided flat-floored valleys. The numerous shorelines indicate the area lies on the lakebed of glacial Lake Algonquin.

According to the Ministry of Northern Development and Mines, Map 2556 (Quaternary Geology of Ontario, Southern Sheet, 1991) the surface conditions in the vicinity of the project area typically consists of coarse-textured glaciolacustrine deposits comprised predominantly of sandy silt to silt matrix, commonly rich in clasts, often high in total matrix carbonate content. In addition, Map 2544 (Bedrock Geology of Ontario, Southern Sheet, 1991), the bedrock geology at the site consists of limestone, dolostone, shale, arkose, and sandstone belonging to the Ottawa Group and Simcoe Group of the Shadow Lake Formation.

4.0 Previous Investigations

There are no available reports of any previously performed geotechnical investigation at this site in the MTO GEOCRE library. The only available data is from the adjacent sites approximately 2.7 km northeast and 1.6 km southwest from the site. The reports are listed below for reference.

- *Geocres No. 31D00-092; W.P. 99-75-14. "Soils Report for Highway 400 Underpass". E.M. Peto Associates Ltd., dated June, 1960.*
- *Geocres No. 31D00-083. "Soils Report for Highway #400 Underpass at Gravel Rd., Near Coldwater River, W.P. 64-60". E.M. Peto Associates Ltd., dated July, 1960.*

Project reference Geocres No. 31D00-092, is located approximately 2.7 km northeast of the culvert site. The project entailed subsurface investigations aimed at providing requisite geotechnical design data for a proposed Medonte Concession 6 underpass structure. The subsoil at the site was generally a noncohesive fill material followed by firm to very stiff varved clay which is followed by compact to very dense silty sand to sandy silt and followed by very dense sandy gravel and boulders.

Project reference Geocres reference No. 31D00-083 is located approximately 1.6 km southwest of the culvert site. The project entailed subsurface investigations aimed at providing requisite geotechnical design data for the proposed Highway 400 underpass at gravel road, near Coldwater River. The subsoil at the site was generally a fill material consisting of clayey sand to silty sand underlain by very soft to firm clay followed by very soft to firm varved clay which is followed by compact to dense interbedded layers of silt, silty clay, and silty sand and followed by loose sandy till.

5.0 Investigation Procedures

5.1 Site Investigation and Field Testing

A site-specific investigation was undertaken by EXP between August 08 and August 11, 2023, and it included the following:

1. A walkover site assessment was carried out by a Geotechnical Engineer from EXP;
2. Subsequent to the borehole layouts in the field, existing utilities were cleared by public utility companies;
3. Traffic control required to close the driving lanes of Highway 400 during the drilling of on-road boreholes was provided by Barricade Traffic Services.
4. At the time of this report, the program involved the drilling of five (5) boreholes for sampling numbered BH400-053-01 to BH400-053-05. Two (2) boreholes were located at each end of the existing culverts, which were BH400-053-01 and BH400-053-02 at the inlet and outlet respectively. Boreholes BH400-053-04 and BH400-053-05 were drilled on the roadway at the NBL and SBL lanes, respectively. Borehole BH400-053-03 was drilled at the highway median. The locations of the boreholes drilled during this investigation are shown on Drawing 1 in Appendix C. Table 1.1 provides a summary of the boreholes completed by EXP.
5. The roadway/median/offroad boreholes drilled during this fieldwork were advanced using a truck mounted drill: B-53 (BH400-053-01, BH400-053-02, BH400-053-04 and BH400-053-05) and a track mounted drill: M51

5T98-09 (BH400-053-03). The drill rigs were owned and operated by Drilltech drilling Ltd. The machines are equipped with solid stem augers and fitted with capability for Standard Penetration Testing (SPT).

6. Soil samples in the boreholes were taken at frequent intervals of depth by the Standard Penetration Test method (SPT), in general accordance with ASTM D1586. The test consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm O.D. split barrel (SS-split-spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as the Standard Penetration Resistance, or the N-value, of the soil which is indicative of the compactness of granular (or cohesionless) soils (gravels, sands and silts) or the consistency of cohesive soils (clays and clayey soils);
7. Vane shear testing were done in accordance with ASTM D2573/D2573M-15 where saturated clay and silt soils were encountered.
8. The fieldwork was supervised by a member 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;
9. All spoon samples obtained in the Standard Penetration Tests (SPT, ASTM D-1586) were placed in moisture proof bags after field classification. Samples were allocated from the spoon samples for moisture content testing without delay. They were subsequently re-examined under controlled laboratory conditions prior to assigning other laboratory tests;
10. Selected soil samples for chemical analytical testing were sent to the Bureau Veritas Laboratories (formerly Maxxam Analytics), a CALA-certified and accredited laboratory in Mississauga, Ontario. The selected soil samples for the analytical testing were placed in a laboratory prepared glass jar, labelled, and stored in a secure cooler.
11. The borehole locations and their ground surface elevations were surveyed by EXP using a Trimble DA2 GNSS receiver with Trimble Catalyst GNSS positioning, having an accuracy of ± 0.10 m horizontal and vertical directions. MTM NAD83 Zone 10 coordinates and the geodetic elevation for the boreholes are listed in Table 1.1 below. It can also be found on the Record of Borehole Sheet (Appendix D); and
12. Upon completion of drilling and field testing, the boreholes were backfilled with a mixture of bentonite and auger cuttings. groundwater level measurements were carried out in boreholes in accordance with MTO guidelines. The recorded groundwater levels after completion of drilling boreholes were presented in the borehole log sheets in Appendix D.
13. The borehole decommissioning was in general accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act).

Table 1.1: Summary of boreholes completed

Borehole No.	Borehole Location	Location (MTM NAD83 Zone 10)		Latitude	Longitude	Borehole Elevation (m)	Borehole Depth (m)
		Northing	Easting				
BH400-053-01	Inlet, off-road	4944988.9	292774.8	44.644806	-79.651595	203.1	7.3
BH400-053-02	Outlet, off-road	4944974.5	292830.9	44.644719	-79.650903	203.8	8.7

Borehole No.	Borehole Location	Location (MTM NAD83 Zone 10)		Latitude	Longitude	Borehole Elevation (m)	Borehole Depth (m)
		Northing	Easting				
BH400-053-03	Median Boulevard	4944984.6	292803.8	44.644753	-79.651214	203.8	7.5
BH400-053-04	NBL, east shoulder	4944972.4	292823.5	44.644652	-79.650975	204.3	8.5
BH400-053-05	SBL, west shoulder	4944989.4	292784.7	44.644828	-79.651477	204.4	8.2

5.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program performed by EXP included the determination of the natural moisture content on all samples and particle size distribution and Atterberg limits (for cohesive soils) for approximately 25% of the collected soil samples. Chemical analyses were also carried out on one soil sample selected by EXP. The samples were tested at the Bureau Veritas Laboratories (formerly Maxxam Analytics), a CALA-certified and accredited laboratory in Mississauga, Ontario. All of the laboratory tests were carried out according to MTO and/or ASTM Standards as appropriate. The performed laboratory testing program is listed in Table 1.2.

Table 1.2: List of Laboratory Test Completed by EXP

Borehole No.	Moisture Content	Atterberg Limits	Sieve	Hydrometer	Corrosivity
BH400-053-01	13	2	2	2	1
BH400-053-02	13	3	5	4	---
BH400-053-03	10	2	3	2	---
BH400-053-04	13	2	4	3	---
BH400-053-05	9	1	2	1	---

The laboratory test results are provided on the attached borehole log sheets in Appendix D as well as graphically in Appendix E.

6.0 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix D. Laboratory test results of grain size analyses and Atterberg limit tests are provided in Appendix E. The “Explanation of Terms Used in Report” preceding the borehole logs in Appendix D forms an integral part of and should be read in conjunction with this report.

A borehole location plan and cross section subsurface profiles are provided in Appendix C. It should be noted that the stratigraphic boundaries indicated on the borehole log and cross section stratigraphic profiles 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 regarded as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

Below the roadway, the subsurface conditions encountered within the investigated depths of the geotechnical investigation indicates the following subsurface sequence: asphalt underlain by gravelly sand to sand fill followed by predominantly sandy silt to sand and silt, underlain by clayey silt.

At the culvert inlet, the encountered subsurface conditions were observed to consist of topsoil over sand followed by silt and sand underlain by clayey silt. At the outlet, the encountered subsurface conditions were observed to consist of gravelly sand to sand fill over silt and sand underlain by clayey silt.

A detailed description of the subsurface conditions encountered is discussed further in subsequent sections. It should be noted that the following sections are based on the geotechnical investigation conducted by EXP. The lab test results available at the time of writing this draft report are included, while the other results will be added in the next submission of this report.

6.1 Subsoils

6.1.1 Asphalt

Asphalt was encountered at ground surface in boreholes BH400-053-04 and BH400-053-05. The thickness of asphalt was approximately 100 mm and 200 mm respectively.

6.1.2 Topsoil

A topsoil layer was encountered at ground surface of boreholes BH400-053-01 and BH400-053-03. The thickness of this layer was approximately 50 mm and 100 mm respectively.

6.1.3 Gravelly Sand to Sand (SW) (Cohesionless Fill)

A gravelly sand to sand cohesionless fill layer was encountered in boreholes BH400-53-02, BH400-53-03, BH400-53-04 and BH400-53-05. In borehole BH400-53-02, the layer was encountered at the ground surface while in borehole BH400-53-03, the layer was encountered below the topsoil layer. In boreholes BH400-053-04 and BH400-053-05, the layer was encountered below the asphaltic surface. The approximate elevations of the surface and base of each fill layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.3 below:

Table 1.3: Gravelly Sand to Sand Fill Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-053-02	203.8	202.3	0.0	1.5	Gravelly sand to Sand	16 – 17
BH400-053-03	203.7	202.0	0.1	1.7	Gravelly sand to Sand	4 – 11
BH400-053-04	204.2	201.7	0.1	2.5	Gravelly sand to Sand	13 – 34

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-053-05	204.2	202.1	0.2	2.1	Gravelly sand to Sand	11 – 30

The composition of this fill layer was predominantly comprised of sand and gravel with some silt and trace clay; trace asphalt fragments were observed near the surface of the layers near the pavement structure. Cobbles and/or boulders should always be anticipated within the fill layer. The fill was generally brown to grey in colour and ranged from dry to wet. The SPT "N" values within this layer ranged from 4 to 34 blows per 300 mm penetration, corresponding to very loose to dense, but generally compact to dense in compactness condition.

Laboratory testing performed on selected samples consisted of four (13) moisture content tests and five (5) grain size distribution tests. The test results are as follows:

Moisture Content:

- 2% to 23%

Grain Size Distribution:

- 2% to 16% gravel;
- 63% to 81% sand;
- 10% to 30% silt and clay;

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

6.1.4 Sand(SW)

A native sand layer containing some silt, trace gravel and trace organics was encountered below the topsoil in borehole BH400-053-01. The layer was approximately 0.7 m thick, extending from an elevation of approximately 203.0 m. The layer was generally grey in color and ranged from dry to wet. The SPT "N" values within this layer was 6 blows per 300 mm penetration, corresponding to loose in compactness condition.

Laboratory testing performed on selected sample consisted of one (1) moisture content test. The test results are as follows:

Moisture Content:

- 22%

The results of the moisture content test are provided on the record of borehole sheets in Appendix D.

6.1.5 Sandy Silt(ML)/Silty Sand(SM)

A sandy silt/silty sand layer was encountered below the native sand layer in BH400-53-01 and below the cohesionless fill in boreholes BH400-53-02 to BH400-53-05. The approximate elevations of the surface and base of each fill layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.4 below:

Table 1.4: Summary of Sandy Silt/Silty Sand Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-053-01	202.3	200.5	0.8	1.8	Sandy Silt	WH
BH400-053-02	202.3	199.2	1.5	3.1	Sandy Silt	2 – 9
BH400-053-03	202.0	198.9	1.8	3.1	Sandy Silt	WH – 2
BH400-053-04	201.7	200.5	2.6	1.2	Silty Sand	WH – 12
BH400-053-05	202.1	199.8	2.3	2.3	Sandy Silt	WH

Notes:

1. WH – split spoon advanced by static weight of hammer (i.e., 0 blows).

The layer contained traces to some clay and trace gravel with color ranging from brown to grey and wet. The SPT "N" values within this layer ranged from WH to 12 blows per 300 mm penetration, corresponding to very loose to compact in compactness condition.

Laboratory testing performed on selected samples consisted of seventeen (17) moisture content tests, three(3) grain size distribution tests and three (3) Atterberg limit test. The test results are as follows:

Moisture Content:

- 17% to 31%

Grain Size Distribution:

- 0% to 9% gravel;
- 30% to 34% sand;
- 48% to 66% silt;
- 4% to 11% clay;

Atterberg Limit Test:

- 18% to 19% Liquid Limit;

- 13% Plastic Limit;
- 5% to 6% Plasticity Index;

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The result of the grain size distribution tests and Atterberg limit test are also provided on Figure 2 and Figure 3 respectively in Appendix D.

6.1.6 Clayey Silt (CL)

A clayey silt layer was encountered below the sandy silt/silty sand layer in all boreholes. The approximate elevations of the surface and base of each layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.5 below:

Table 1.5: Summary Clayey Silt Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH400-053-01	200.5	195.8	2.6	4.7	Clayey Silt	WH – 2
BH400-053-02	199.2	195.1	4.6	4.1	Clayey Silt	WH – 2
BH400-053-03	198.9	196.3	4.9	2.6	Clayey Silt	WH – 2
BH400-053-04	200.5	195.8	3.8	4.7	Clayey Silt	2
BH400-053-05	199.8	196.2	4.6	3.6	Clayey Silt	WH –3

The layer was generally clayey silt with sand, containing traces to some gravel. The soil ranged from dark brown to dark grey to black in color and wet. The SPT "N" values within this layer ranged from WH to 3 blows per 300 mm penetration, corresponding to very soft in consistency. In-situ vane testing with this layer measured an undrained shear strength of approximately 12 kPa to 24 kPa indicating this material very soft to soft in consistency.

Laboratory testing performed on selected samples consisted of twenty-seven (27) moisture content tests, eight (8) grain size distribution tests, and eight (8) Atterberg limit tests. The test results are as follows:

Moisture Content:

- 16% to 70%

Grain Size Distribution:

- 0% to 18% gravel;

- 9% to 57% sand;
- 36% to 68% silt;
- 5% to 23% clay;

Atterberg Limit Test:

- 18% to 23% Liquid Limit;
- 12% to 13% Plastic Limit;
- 6% to 10% Plasticity Index;

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The result of the grain size distribution tests and Atterberg limit test are also provided on Figure 4 and Figure 5 respectively in Appendix D.

6.2 Groundwater and Surface Water Conditions

Groundwater levels were observed upon completion of the boreholes and in piezometers. Groundwater levels measured on completion of boreholes may not be considered stabilized and therefore may not represent the established long-term average groundwater table. A summary of the groundwater levels observed upon completion of the boreholes and in piezometers are summarized in Table 1.6 and are also presented on the record of borehole sheets in Appendix D.

Table 1.6: Summary of Observed Groundwater Levels

Borehole	Ground Surface Elevation (m)	Water Level Depth/ Elevation (m) ¹	Date Measured	Comments
BH400-053-01	203.1	0.5/202.6	Oct. 11, 2023	Taken upon completion of drilling
BH400-053-02	203.8	2.6/195.8	April 26, 2023	Taken upon completion of drilling
BH400-053-03	203.8	0.63/203.2 0.5/203.3	Jan 29, 2024 Feb. 2, 2024	In piezometer
BH400-053-05	204.4	1.9/202.5	Oct. 10, 2023	Taken upon completion of drilling

Note:

1. Depths are relative to ground surface

The top of the creek water level at the outlet of the north culvert was measured to be approximately 202.5 m (measured on August 10, 2023). Groundwater levels would be expected to reflect levels in the adjacent open water and to fluctuate seasonally. 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.

6.3 Chemical Analysis

One soil sample was selected for chemical analysis during the current investigations performed by EXP. The soil sample collected by EXP was tested at a CALA-certified and accredited laboratory. The results of the corrosion potential chemical analysis testing including sulfide, chloride, sulfate, pH, electrical conductivity, resistivity and redox potential are included in Appendix E and summarized in Table 1.7.

Table 1.7: Summary of chemical analysis results

Borehole ID	Sample	Depth (m)	Chloride (ppm)	Sulphate (ppm)	pH	Electrical Conductivity (umho/cm)	Resistivity (ohm-cm)	Redox Potential (mV)
BH400-053-01	SS3	1.5 – 2.1	54	71	7.66	249	4000	280

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GWP 2044-23-00
Assignment No. 2020-E-0028
Date: May 29, 2024*

Part II: Foundation Investigation and Design Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto - **Highway 400 CSP Culvert Replacement (CV-0252-0400-0053)**

7.0 ENGINEERING DISCUSSION & RECOMMENDATIONS

7.1 General

This section of the report provides geotechnical design recommendations for the replacement of the twin Corrugated Steel Pipe (CSP) culvert on Highway 400 (Culvert ID: CV-0252-0400-0053), located approximately 2.0 km southwest of the intersection of Highway 400 with Highway 19 in the Simcoe region (Latitude: 44.644830; Longitude: -79.651590) in the Ministry of Transportation (MTO) Central Region. The recommendations are based on the interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site. The compiled factual data is presented in **Part I-Foundation Investigation Report** of this report. The interpretation and recommendations provided are intended solely to permit designers to evaluate the subsurface conditions along the existing culvert, and based on this data, to provide detailed design for the culvert replacement and to examine the suitability and methods of replacement. 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 AutoCAD drawings provided by MTO and information provided in the TOR and contract drawings, the existing culverts are a 600 mm twin CSP culvert; the total length of the culverts is approximately 60 m. The existing twin CSP culverts are positioned in a northwest-to-southeast direction having a skew angle almost perpendicular to the highway central line. The invert of the twin culverts was about Elev. 202.5 m and Elev. 202.6 m at the inlet side, and about Elev. 202.4 m and Elev. 202.3 at the outlet side of the north and south culvert, respectively. The elevation of the highway pavement centerline at the site is about 204.4 m and 204.5 m at the NBL and the SBL, respectively. The flow through the culverts is from west to east, following the natural topographic conditions in the vicinity of the site. The existing embankment height at the culvert location was about 1.6 m and 2 m at the SBL and the NBL, respectively. The sides of the embankment above the culvert slope were about 5H:1V, and 3.3H:1V on the west and east sides, respectively.

The existing culvert is proposed to be replaced with a precast concrete box culvert of size 2.2 m wide and 1.4 m high with an opening of 1.8 m wide and 1.2 m high with a waterbody aggregate of about 0.3 m to 0.6 m thick inside the culvert. The existing culvert will be replaced at the same alignment in two segments with a total length of about 27 m under SBL and about 25 m under NBL with an open flow channel at the median ditch. The invert levels of the new culverts are proposed to be at approximate elevations of 202.23 m and 202.21 m at the inlet and outlet of the SBL culvert, respectively, and approximate elevations of 202.21 m and 202.18 m at the inlet and outlet of the NBL culvert, respectively.

Initially, the existing culverts were proposed to be replaced with a trenchless method, however, during the design process the designer selected the open cut and cover staged construction method for the installation of the new culvert.

This part of the report provides comments and recommendations for the geotechnical design and open cut replacement of the existing culvert. These comments and recommendations are provided in accordance with the latest editions of the Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-19), the Canadian Foundation Engineering Manual (CFEM, 2023), MTO Gravity Pipe Design Guidelines (April 2014), Guideline for MTO Foundation Engineering Services Version 03 (April 2022), and generally accepted good practice. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference provided to us in the (MTO) Request for Proposal, dated February 2022. The assessment involved review of options for replacement

of the existing culvert. The use of temporary shoring systems for half and half construction and protection of the construction site by cofferdams is also addressed.

7.2 Expected Ground Conditions

The following ground conditions along the proposed culvert alignment are evident from the current investigation:

- a) Below the pavement structure, the highway embankment fill consists of compact to dense gravelly sand to sand, followed by a layer of very loose silty sand to sandy silt underlain by very soft to soft clayey silt.
- b) At the inlet, the topsoil is underlain by a very loose sandy silt layer followed by very soft to soft clayey silt. However, at the outlet, compact gravelly sand to sand fill layer was encountered at the surface which is followed by a layer of very loose to loose silty sand to sandy silt underlain by very soft to soft clayey silt.
- c) Based on groundwater levels measured in the open boreholes and in the piezometer, the groundwater level is interpreted to be about Elev. 202.6 m to 203.3 m across the site. At the time of the investigation, the creek water level at the outlet of the north culvert was measured to be approximately 202.5 m (measured on August 10, 2023). Groundwater levels would be expected to reflect levels in the adjacent open water. 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.

7.3 Construction Alternatives

Initially, the existing culverts were proposed to be replaced with a trenchless method, however, during the design process the designer preferred to use half-and-half open cut and cover staged construction for the replacement of the culvert. Shoulder strengthening or temporary widening will also be required on both the NBL and SBL shoulders depending on the construction approach being considered. No significant grade change nor widening is expected at the culvert location. It is planned that the new culvert will be placed at the same location as the existing culvert.

Since the open cut and cover construction approach has been preferred for this site, trenchless methods of culvert replacement are not discussed in this report.

Full road closer of Highway 400 with long detours around the area using existing roadways likely is not acceptable, therefore, it was not considered as an option for this culvert replacement.

Considering all the above, the following construction methods were considered as possible construction alternatives for the culvert replacement at this site:

- 1. Half-and-half construction using roadway protection to allow excavation as maintaining one lane of traffic on the existing SBL or NBL embankment during construction. The following two options of excavation and replacement using the half-and-half approach were considered:
 - A. Construction using roadway protection parallel to highway centerline and unsupported excavation of cut sides

B. Construction using roadway protection parallel to highway centerline and braced cut sides

All methods considered utilize a cut and cover approach for culvert replacement which allows complete removal of the existing culvert, but it requires disruption of traffic.

The following Table 2.1 summarizes the advantages and disadvantages of considered construction alternatives. The table also shows the assessed risk/consequences and relative costs of the considered methods. Schematic diagrams of considered alternatives are attached in Appendix H.

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 Highway 400 CSP Culvert Replacement (CV-0252-0400-0053)
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Table 2.1 Open Cut Installation Alternatives for Culvert Replacement (see schematic sketches in Appendix H)

Installation Method	Advantages	Disadvantages	Relative Cost	Rank
Cut and Cover Approach at Existing Alignment				
<i>Half-and-half Construction with TPS Parallel to Highway Centerline and Unsupported Cut Sides (Figure H1.A, Appendix H)</i>	<ul style="list-style-type: none"> Traffic flow maintained at the site during construction Short mobilization time Straight-forward construction and construction procedures 	<ul style="list-style-type: none"> Traffic interruption Roadway protection in the middle of the road of up to 3.5 m high is required to maintain one lane of traffic Require dewatering to provide safe temporary cut slopes High cost of roadway protection system Large amount of soil to be excavated Need to temporarily control existing creek water Risk of cost overrun and inability to finish job: moderate to high 	Less expensive than half and half construction with braced or anchored cut sides;	1
<i>Half-and-half Construction with Braced or Anchored Cut Sides (Figure H1.B, Appendix H)</i>	<ul style="list-style-type: none"> One or possibly two lanes of traffic flow maintained on existing road (e.g., steel decking, but costly) Global stability of excavation enhanced by narrow geometry Less traffic interruption than with an unsupported cut sides approach Temporary decking could be usable over braced cut to allow for excavation of both halves prior to diverting stream and backfilling Cost savings due to limited excavation and backfill Cost saving due to no need for temporary cut slopes and extensive dewatering 	<ul style="list-style-type: none"> Traffic interruption Roadway protection of up to 3.5 m high required to maintain one lane of traffic if steel decking is not possible High cost of roadway protection system and/or decking Require side shoring and bracing Bracing (e.g., struts) may interfere with excavation Excavation of material and placement of bracing required in limited space Need to decommission the shoring system Need to temporarily control existing creek water Risk of cost overrun and instability to finish job: low to moderate 	More expensive than half and half construction with unsupported cut sides due to high costs for shoring system and temporary decking;	2

Among these cut and cover methods, the Half-and-half construction using roadway protection parallel to the highway centerline and with unsupported cut sides might be more economical and practical than braced or anchored cut.

Based on the above list of advantages and disadvantages of possible construction methods, the following ranking of the considered options are recommended:

- 1) open-cut staged replacement using roadway protection parallel to the highway centerline and with unsupported cut sides
- 2) open-cut staged replacement with temporary protection system (braced or anchored cut sides)

7.4 Open Cut Installation

7.4.1 Installation Alternatives

7.4.1.1 Half-and-Half Construction

The half-and-half construction method could be utilized to maintain the flow of traffic on Highway 400 (see Figures H1.A and H1.B, Appendix H). In this method, one lane of the existing highway (NBL or SBL) will be used to maintain the local traffic while the other half of the existing highway will be excavated, and half of the existing culvert under NBL or SBL will be exposed. Then the excavated portion of the existing culvert will be removed and replaced with a new culvert, followed by rebuilding of that half of the embankment to grade. Upon completion of the new embankment, the traffic will be moved onto the new fill and the process will be repeated to complete the construction and culvert replacement.

The temporary excavation at this site required to remove half of the existing embankment would be up to about 3.5 m deep. Therefore, temporary shoring such as a soldier pile and lagging system will be required as a roadway protection system to allow staging excavation/construction. Sheet piling may also be considered as a suitable shoring alternative. It will be the Contractor's responsibility to design a suitable temporary support system for the MTO review prior to installation. The Contractor is to follow OPSS.PROV 902 regarding excavations for structures and OPSS.PROV 539 regarding temporary protection systems. Recommendations for a temporary roadway protection system are given in Section 7.6. Using the half-and-half construction approach, two methods of culvert replacement were considered suitable for this site as discussed below:

- A. Construction using roadway protection and unsupported excavation of cut sides
- B. Construction using roadway protection and braced or anchored cut sides

7.4.1.1.1 Half-and-Half Construction using Roadway Protection and Unsupported Cut Sides

This method provides roadway protection parallel to the highway between two lanes, 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). The roadway protection can take the form of reversible shoring such as a soldier pile and lagging system for horizontal support. Once one lane is completed, the supports can be reversed and the other lane constructed in a similar fashion. The shoring system would likely be decommissioned in place. Temporary surface water flow control must be developed by the Contractor.

This option could be more economical due to possible cost savings when implementing a reversible wall configuration, but it will be more disruptive to the highway embankment than the half-and-half construction with braced or anchored cut sides option since it requires excavation of a larger amount of soil. The temporary cut sides within the Type 3 may require flattening up to 1.5H:1V for the stability of the excavated slopes.

7.4.1.1.2 Half-and-Half Construction with Braced or Anchored Cut Sides

This method provides a braced or anchored cut shoring system perpendicular to the highway 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, which in the relatively narrow working area could create difficulties for installation of the new culvert. Installation of tiebacks could be the alternative solution. The temporary excavation at this site required to remove half of the existing embankment would be approximately 3.5 m in height across both NBL and SBL. Temporary decking could possibly be used over the supported cut to allow for excavation of both halves prior to backfilling. However, decking would be costly. As required in the half-and-half construction with unsupported cut sides option, temporary surface water flow control must be performed/developed by the Contractor.

This option with braced or anchored cut sides will disrupt less of the embankment compared to half-and-half construction with unsupported cut sides, but it might cost more due to the cost of an additional shoring system. However, the global stability of the excavation will be enhanced with that shoring system. Both options require decommissioning of the shoring system upon completion of work.

7.4.2 Culvert Replacement

Based on the contract drawings, it is understood that the designer prefers replacing the existing culvert with a concrete box culvert. However, for completeness, the following options were considered as possible options for the culvert replacement at this site and they are discussed below:

- HDPE Pipe Culvert
- Corrugated Steel Pipe (CSP) culvert,
- Precast rigid frame concrete box culvert,
- Cast-in-place rigid frame concrete box culvert

Based on the subsurface information obtained from the site investigations, 0.4 m of engineered fill over very loose to loose sandy silt is considered suitable for supporting any suggested culvert, assuming that any underlying organic soils (peat) materials are to be replaced with clean and compactable soils.

It is noted that regardless of the option selected, the existing CSP culvert is to be removed. This will require excavation down to the Elevation 200.9 m to 201 m for all options. This suggests the need for surface/groundwater control as discussed in Section 7.7 below.

An evaluation of structure alternatives including advantages, disadvantages, risk/consequences and relative cost from a foundation perspective is provided in Table 2.2.

Table 2.2: Evaluation of culvert replacement alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
High-density poly-ethylene (HDPE) pipe	2	<ul style="list-style-type: none"> ▪ Straightforward construction, easy to install ▪ Reduced construction period, consequently, traffic management and water control period ▪ Reduced excavation depth ▪ Resistant to Corrosion ▪ Low cost, durable, has long design life 	<ul style="list-style-type: none"> ▪ Require larger dia pipe to replace twin culvert and may require lowering invert levels to accommodate substrate ▪ Disturbance of natural streambed ▪ Possible sediment accumulation in the upstream of the culvert ▪ Sensitivity to stress cracking 	Low	<ul style="list-style-type: none"> ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil
Corrugated Steel Pipe (CSP) culvert	3	<ul style="list-style-type: none"> ▪ Straightforward construction ▪ Reduced construction period, consequently, traffic management and water control period ▪ Reduced excavation depth 	<ul style="list-style-type: none"> ▪ Require larger dia pipe to replace twin culvert and may require lowering invert levels to accommodate substrate ▪ Limited design life ▪ Potential for corrosion ▪ Disturbance of natural streambed ▪ Possible sediment accumulation in the upstream of the culvert 	Low	<ul style="list-style-type: none"> ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil ▪ Risk of structure segment loss due to corrosion
Precast rigid frame concrete box culvert	1	<ul style="list-style-type: none"> ▪ Straightforward construction ▪ Can match the existing invert levels accommodating substrate ▪ Reduced construction period; consequently, traffic management and water control period ▪ Reduced excavation depth ▪ Can be more readily installed during cold weather conditions 	<ul style="list-style-type: none"> ▪ If the 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 ▪ Requires bedding material ▪ Disturbance of natural streambed ▪ Possible sediments accumulation in the upstream of the culvert 	Low to medium	<ul style="list-style-type: none"> ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil ▪ Risk of leaking from joints if not properly installed
Cast-in-place rigid frame	4	<ul style="list-style-type: none"> ▪ Suitable if site is not appropriate for heavy equipment for 	<ul style="list-style-type: none"> ▪ Slower construction process 	Likely more expensive than precast due to	<ul style="list-style-type: none"> ▪ Risk of unacceptable differential settlements if the entire foundation is

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
concrete box culvert		installation of precast sections ■ Reduced excavation depth ■ Culvert design can be customized in the field for high stress or load conditions or other site-specific requirements	■ If floor is thin and poorly reinforced, it may heave and crack ■ During high flows, the concrete floor can be undermined ■ Requires concrete curing ■ Disturbance of natural streambed ■ Possible sediments accumulation in the upstream of the culvert	longer duration of installation	not supported on competent soil ■ Risk of disturbance of base during construction

The key findings and conclusions of the assessment for the culvert type are summarized as follows:

HDPE, CSP, and closed concrete box culverts, either precast or cast-in-place, installed with appropriate granular bedding over the subgrade were determined to be feasible. Among these options, the use of a precast concrete box culvert is considered the most feasible option at this site. It should be noted that the proposed structure must meet the required flow capacity and hydraulic requirements.

7.4.3 Culvert Foundations Recommendations

7.4.3.1 Geotechnical Resistances

Based on the subsurface stratigraphy encountered at this site and the proposed replacement of the existing culvert, the following Table 2.3 summarizes the recommended resistances at founding elevations for different types of culverts. The geotechnical resistances provided are for vertical loading conditions only; load eccentricity and load inclination effects should be addressed in accordance with the CHBDC and its commentary. The geotechnical resistances provided in sections below were factored with typical consequence factors of 1.0 at ULS and SLS and high degree of understanding (factor of 0.5 at ULS and factor of 0.9 at SLS) in accordance with Table 6.1 and 6.2 of the CHBDC S6-19.

Table 2.3: Recommended spread footing design parameters

Culvert Type	Founding Elevation/ Excavation Elevation (m)	Footing Size (m)	Founding Soil Type	Factored Geotechnical Resistance at ULS (kPa)	Factored Geotechnical Resistance at SLS ² (kPa)
HDPE pipe, CSP culvert, precast or cast-in-place rigid frame concrete box culvert	~201.43 to 201.41/ ~200.9 (inlet to outlet)- SBL Culvert	~1.0 to 2.2	~ 0.075 levelling course and about 0.4 m thick Granular 'B' Type II ⁽³⁾ Pad underlain by very loose to loose sandy silt/silty sand	150	90
	~ 201.41 to 201.38/ ~200.9 to 200.85 (inlet to outlet)- NBL Culvert				

Notes:

1. The founding level noted above based on the invert levels provided on the 90% drawings package considering the culvert bottom slab thickness of 0.2 m and substrate thickness of 0.6 m.
2. For maximum settlement of 25 mm
3. The granular material used for the granular pad shall be Granular B Type II conforming to OPSS.PROV 1010 and compacted to 98 % SPMDD extended minimum 0.5 m horizontally on either side of the culvert edge.

It is assumed that, if any, underlying organic soils and any other very soft or very loose materials are to be replaced with clean and compactable soil such as Granular B Type II. If the depth of excavation to remove unstable soils is excessive, use a geotextile fabric in accordance with OPSS.PROV 1860, Class II Non-Woven (OPSS 1860 II-N), in conjunction with engineered fill can be considered to assist in providing a stable base for the new culvert. Based on previous experience, typically it should consist of Granular B Type II (OPSS.PROV 1010) with a minimum thickness of 300 mm beneath the culvert and extend a minimum of 500 mm horizontally on either side of the culvert edge. The fabric should be installed in a manner to mitigate the migration of fines from adjacent material. Given that no significant grade raise and/or widening is planned, the anticipated maximum total settlements for the new proposed culvert are not expected to exceed 25 mm for construction done in accordance with these design parameters and assuming good construction practice including sound base preparation.

7.4.3.2 Resistance to Lateral Loads

Resistance to lateral forces/ sliding should be calculated in accordance with Section 6.10.5 of the CHBDC (CAN/CSA S6-19), using the following parameters provided in Table 2.4.

Table 2.4: Recommended parameters for calculation of unfactored horizontal resistance

Interface and Loading Conditions	Parameters
Between Granular A/ Granular B and pre-cast concrete	Coefficient of friction ($\tan \delta$)=0.55

Between Granular A/ Granular B and cast-in-place concrete	Coefficient of friction ($\tan \delta$)=0.6
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The listed values are unfactored; in accordance with the CHBDC (CAN/CSA S6-19), a factor of 0.8 is to be applied in calculating the horizontal resistance.

7.4.3.3 Frost Protection

The frost depth in the area of the culvert is estimated to be approximately 1.6 m in accordance with OPSD 3090.101. Therefore, a minimum of 1.6 m of soil cover or equivalent frost protection should be provided using thermal insulation only to open the footing culvert option (if any). For the box culvert, HDPE, and CSP culvert the frost protection is not required.

7.4.3.4 Culvert Bedding

OPSDs 802.010, 803.010 and MTOD 803.021 which are included in Appendix G provide the bedding, embedment, cover, and backfill standards for the different culvert materials. According to these standards, the culvert bedding for the culvert should consist of Granular A or Granular B Type II (OPSS.PROV 1010) with a minimum 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 in accordance with OPSS.PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used before a subsequent layer is placed in accordance with OPSS. PROV 401. Based on the existing conditions at the site, Granular B Type II is preferred material for the culvert bedding below the water table.

Prior to placing any fill material, the exposed subgrade should be inspected by a qualified geotechnical engineer. 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 .

7.4.3.5 Culvert Backfill

The selection and placing of the backfill and cover should be in accordance with OPSS.PROV 421, OPSS 422 and OPSDs 802.034 (pipe culvert), 803.010 (concrete culvert), and 3101.150 for different culvert materials. The backfill adjacent to the culvert as per these standards should consist of free-draining, non-frost susceptible granular materials conforming to OPSS.PROV 1010.

All granular backfill materials should be placed in thin lifts (i.e. not exceeding 300 mm before compaction) and each lift should be compacted in accordance with OPSS. PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used. The final lift of embankment fills prior to placing pavement sub-base should be compacted to 100 % SPMDD. The Granular A base and Granular B sub-base courses (for pavement) should be compacted to 100% of the material's SPMDD.

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 the same level on both sides of the structure, to avoid lateral displacement of the structure.

Where less than frost depth (1.6 m) of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.030, 803.031, and MTOD 803.021, whichever is applicable. If the frost taper exists at the site it will be reinstalled within the zone of excavation with accordance to OPSD 803.031.

7.4.3.6 Lateral Earth Pressure

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

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

where,

P = earth pressure intensity at depth h , kPa

K = earth pressure coefficient

γ = unit weight of retained soil, kN/m³

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 2.5 lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.

Table 2.5: 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)
Embankment Fill – Gravelly Sand to Sand (loose to compact)	32	0.31	3.25	0.47	21
Clayey Silt (very soft to soft) ¹	26	0.39	2.56	0.56	19
Sandy Silt/Silty sand (very loose to loose)	27	0.38	2.66	0.55	19

Notes:

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

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation (rotation of 0.002 about the base of vertical walls (horizontal displacement divided by wall height) or translation of 0.001 times wall height or combination of these). Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design. 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.

Bracing for the temporary support system (if any) will be required at a maximum interval of 5 m. For multiple support systems refer to Canadian Foundation Engineering Manual (CFEM, 2023) for apparent earth pressure distributions (CFEM, Section 20.8.1.3, Figure 20.20).

7.4.4 Construction Considerations

7.4.4.1 Excavation

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). The embankment fill may be classified as Type 3 soil above the groundwater table and may be classified as Type 4 soil below the groundwater table and native very loose sandy silt to silty sand soils may be classified as Type 4 soil in conformance with the OHSA. In accordance with OHSA regulations, if the excavation contains more than one type of soil, the excavation shall be constructed according to the type with the highest number. Any excavation deeper than 1.2 m should be sloped back to a safe angle of 45 degrees or flatter, according to the Act. Temporary excavation side slopes in Type 3 soils should remain stable at a slope of 1H:1V. Excavation side slopes in Type 4 soils should remain stable at a slope of 3H:1V. The need to excavate flatter side slopes if excessively wet or soft/loose materials, or concentrated seepage zones are encountered, should not be overlooked. Water (i.e., surface water runoff) should not be permitted to enter and/or pond within the construction area.

To 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. The ingress of surface water must be controlled using a suitable system as well, as described in Section 7.7.

Excavations for the proposed culvert construction is expected to extend to depths greater than 1.3 m below existing grades at the inlet and outlet. Basal instability should be anticipated in excavations since the groundwater level is at or above the base of excavation. Ingress of groundwater and surface water has to be controlled. Technical specifications must ensure that the Contractor submits a groundwater and surface water control plan describing the proposed method for control. In this site the existing culvert could be used to convey the creek water during the construction.

7.4.4.2 Embankment Reconstruction

For fills immediately below any roadway, it is recommended that Granular A or B Type II materials be used. Below the pavement base/subbase and above the frost line (1.6 m), the roadway embankment above the culvert should be reconstructed using free-draining, non-frost susceptible granular materials conforming to OPSS.PROV 1010 (Granular A/Granular B Type I or Type II/Selected Subgrade Material (SSM)). As noted in Section 7.4.3.5, proper tapering as per standards should be provided if required. Below a depth of about 1.6 m from any finished road grade, approved compactable fill, such as select subgrade materials (OPSS.PROV 1010), or reused native 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. PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used.

The existing embankment fill and the new fill along the existing roadway embankment slopes should be integrated in accordance with OPSD 208.010. The final embankment side slopes should be protected against erosion by surface water runoff as soon as practical after the completion of slope grading using a combination of materials in accordance with OPSS.MUNI 802, OPSS.PROV 803 and/or OPSS.PROV 804. It is anticipated that the reconstructed embankment will have side slopes flatter than 2H:1V or match the existing side slopes of 3.3H:1V (East slope) to 5H:1V (West slope).

7.5 Seismic Potential Consideration

7.5.1 Seismic Hazard Site Classifications and Values

Seismic characterization of the site should be compliant with the Canadian Highway Bridge Design Code (CHBDC, CSA-S6-19). Table 4.1 in the CHBDC (see Clause 4.4.3.2) shows site classification for seismic site response based on average soil properties in the top 30 m. At the site, the subsoil beneath the embankment fill generally consists of very loose to loose sandy silt to silty sand followed by very soft to soft clayey silt. Bedrock was not encountered within the investigated depth. The groundwater level is at about 0.5 m to 1.9 m depth below the existing Highway 400 road surface. The reported N-values for the native soils ranged from WH to 9 blows for 300 mm of penetration, with an average value being about 2 blows per 300 mm of penetration within the drilled depth. The undrained shear strength of cohesive soil ranged between about 12 Kpa to 24 Kpa with an average value being about 20 Kpa within the drilled depth. Based on these soil characteristics, the site class for this site is assessed to be Class "E" according to Table 4.1. However, these parameters should be reviewed by the Structural Engineer.

From Natural Resources Canada website, 2020 NBC seismic hazard values are obtained using the site location coordinates (44.644830; -79.651590), where the damped spectral accelerations are $S_a(0.2)=0.28g$, $S_a(0.5)=0.318g$, $S_a(1.0)=0.2g$, $S_a(2.0)=0.0975g$ the peak ground acceleration (PGA) is $0.153g$ (g = acceleration due to gravity -9.81 m/s^2). These values are associated with an earthquake having 2 percent probability of exceedance in a 50-year period (1 in 2475-year event) for Site Class E as shown on the GSC seismic hazard calculation data sheet for this site attached in Appendix I. It is noted that the PGA obtained from NBC (2020) is increased relative to the previous NBC (2015) seismic data. Per CHBDC if liquefaction risk is not mitigated, a site-specific evaluation is indicated for Site Class "F".

7.5.2 Seismic Liquefaction Potential

To evaluate the susceptibility of seismic liquefaction of soils at the project site, the distinction of cohesionless and cohesive material is required for each stratigraphic layer, specifically fine-grained layers (silt and clay). As outlined in Boulanger and Idriss (2006), fine-grained soils with a plasticity index of less than 3 are expected to behave “sand-like” while soils with a plasticity index of 7 or more behave “clay-like” when subjected to earthquake loading. Fine-grained soils with a plasticity index between 3 and 6 may exhibit intermediate behavior, therefore detailed in situ and laboratory testing may be required to designate the behavior type for fine-grained soils within this range. In addition, they recommend that the term “liquefaction” be utilized for cohesionless soils (sand-like) and the term “cyclic softening” be used for cohesive soils (clay-like) when describing significant strains or strength loss during seismicity.

Liquefaction of cohesionless soils below the groundwater table at the project site was evaluated through the SPT-based liquefaction triggering procedures described in Boulanger and Idriss (2014) using the site’s $PGA = 0.153g$ based on NBC 2020 (1 in 2475-year event). An SPT ‘N’ value ranging between weight of hammer (WH) to 9 blows per 300 mm penetration was obtained within sandy silt layers, which was assessed to be susceptible to seismically induced liquefaction.

Cyclic softening of the native clayey silt below the groundwater table at the project site was assessed based on methods established by Wang (1979), Bray et al.(2004), and Idriss and Boulanger(2008) as described in CHBDC C6.14.8.1. Based on the obtained $PI < 12\%$ and ratio of moisture content to Liquid Limit > 0.85 the clayey silt was determined to be susceptible to cyclic softening.

As stated above, based on the combination of current seismic data and encountered subsurface conditions, the sandy silt layer and clayey silt layers are determined to be susceptible to liquefaction during seismic events at this site. However, the consequences of liquefaction would be limited to some settlement of the embankment, which can be readily repaired. An earthquake-induced settlement (based on Tokimatsu and Seed(1987)) in a sandy silt layer is estimated to be about 50 mm. Based on the result of stability analysis for seismic conditions of the new embankment, lateral slope displacement is not anticipated at this site. From the seismic standpoint, box culverts in the area have performed satisfactorily to date based on available evidence.

The risk of liquefaction at a site can be significantly reduced or eliminated by the following potential mitigation measures: dewatering, increasing the in-situ density, and making provisions to reduce the time required for relieving the excess pore water pressures generated by earthquake loading. These, except dewatering, may be best achieved by ground improvement techniques. For ground improvement at this site, methods such as compaction piles, chemical grouting, Electrokinetic injection, jet grouting, and gravel drains can be considered to increase soil density/strength or to relieve excess pore water pressure.

7.6 Temporary Protection System

Temporary roadway protection is anticipated to be a part of the half-and-half construction approach that will be required to maintain on-site traffic during the construction. Roadway protection systems shall be designed in accordance with OPSS.PROV 539 and OPSS.PROV 903 as amended by SP109F57. The complete design, construction, monitoring, and removal of the installed protection system should be the responsibility of the Contractor. Due to the nature of this application, it is expected that much of the temporary shoring will be decommissioned in place noting the high cost of 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.

Based on the geotechnical conditions at the site, a shoring system such as a soldier H-pile with lagging or a steel sheet pile of sufficient robust cross-section can be considered for design. It should be designed based on the earth pressures coefficients and soil parameters provided in Table 2.5. If a cantilever system is used, an embedded depth of sheet piles should be determined by balancing moments about the pile tip and it could be approximately 2.0 to 2.5 times its exposed height. Alternatively, a system of rakers can be used for support.

Cobbles and/or boulders were not noted to be contained within the existing embankment fill or native soil deposits at the site during the site investigation. However, their presence should always be anticipated within fill layers. Therefore, it is recommended that care has to be taken during the installation of the shoring. An example of a NSSP for obstructions is provided in Appendix J. Installation of a temporary protection system necessary for the removal of the existing culvert should take into account the culvert's presence.

The protection system shall be designed for 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.

After construction of the new culvert, the protection system could be removed. In that case the details of the procedures associated with the removal of the protection system indicating: method, sequence of work, and removal limits are required from the Contractor as per OPSS.PROV 539. However, if the protection system is decided to be left in place the top should be removed to at least 1.2 m below the finished grade or ground level or at least 0.6 m below the streambed. All disturbed areas should be restored to an equivalent or better condition than what existed prior to the commencement of construction.

7.7 Site Dewatering

7.7.1 Cofferdams

Temporary cofferdams will be required at both the upstream and downstream ends of the culvert to envelop the construction site and keep it free of water during the replacement of the existing CSP culvert. Two types of cofferdams, i) sheet pile wall, and ii) rockfill/earth dam/sandbag, could be considered. During construction, creek flow should be maintained through the temporary flow passage system with a culvert in place. Design and construction specifications for the chosen temporary cofferdam system should be prepared in accordance with OPSS.PROV 539 (Construction Specification for Temporary Protection Systems) by the Contractor.

Based on the geotechnical conditions, suitably designed steel sheet pile walls can be used as cofferdams at this site. Sheet piles perpendicular to the highway at least 3 m into the embankment slopes should be considered to prevent water getting in through the sides. If a cantilever system is used, an embedded depth of sheet piles can be approximately 2.0 to 2.5 times its exposed height. The proposed sheet pile wall should be at least one meter above the designed HWL defined by the Hydraulic Engineer. The required minimum section modulus and embedment pile

length should be designed based on the recommended design parameters. Cobbles and/or boulders were not noted to be contained within the native soil deposits; however their presence should be anticipated and care has to be taken during installation of sheet piles. It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the presence of cobbles and/or boulders at the site. An example of a NSSP for obstructions is provided in Appendix J.

Alternatively, a rockfill/earth cofferdam can be used. The rockfill/earth/sandbag cofferdam will have to be constructed to accommodate all topographic constraints. The size of material suitable for use depends on the erosion potential, stream flow velocity, etc. The rockfill/earth/sandbag cofferdam should be designed with a more impervious water barrier at the outside face to create a more watertight enclosure. Schemes involving 50.8 mm (2") minus crusher run with finer facing material upstream have been successfully used in similar settings. Any required permitting must be determined. The proposed rockfill/earth cofferdam should be at least one meter above the designed high water level (HWL) defined by the Hydraulic Engineer.

As mentioned, which cofferdam system is best suited depends on many technical and economic factors. The advantages and disadvantages of both cofferdam systems are summarized in Table 2.6.

Table 2.6: Evaluation of foundation alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
Steel sheet piles	1	<ul style="list-style-type: none"> Provides more watertight base Structural elements and seals easier to positively construct Increased safety with appropriate design Easily removed Less seepage Reusable 	<ul style="list-style-type: none"> More costly More likely time consuming for installation May present issues for seepage and/or piping Larger machines required May require bracing May face difficulty driving through soil deposits if cobbles and/or boulders are present May require strengthening toe of sheet pile 	Medium to High	<ul style="list-style-type: none"> May take longer to install Environmental permits
Rock fill/ Earth	2	<ul style="list-style-type: none"> Less costly Relatively less time consuming for installation Native material can be usable Not affected by presence of cobbles and/or boulders 	<ul style="list-style-type: none"> Require more space for installation Less safe Subjected to wave erosion Less watertight Prone to land shifts, slides and collapse More likely time consuming to remove 	Low to Medium	<ul style="list-style-type: none"> Less stable and safe. May generate 'mud waves' May take longer to remove May require installing clay cut off More dewatering Environmental permits

Given the soil conditions, topography of the surrounding terrain, and available space, the use of a suitably designed steel sheet pile system of sufficiently robust cross-section is recommended at the inlet and outlet of the existing culvert. The design of these cofferdams, which are temporary retaining structures, is the responsibility of the Contractor. The cofferdam must be designed to withstand the anticipated design loads and to be watertight as practically as possible. The Contractor is also responsible for cofferdam's materials, construction, monitoring and removal.

Design and construction specifications for the chosen temporary cofferdam system should be prepared in accordance with OPSS.PROV 539 (Construction Specification for Temporary Protection Systems) by the Contractor. Piling should be in accordance with OPSS.PROV 903. Cantilevered walls should be designed for the earth pressures shown in Table 2.6 and earth pressure diagram shown in the CFEM Figure 20.15. As mentioned before, besides design and construction of the temporary cofferdam system, the Contractor is also responsible for its removal. The temporary cofferdam shall be fully removed, unless it is specified in the Contract Documents that the cofferdam system may be partially left in place. The method and sequence of removal shall be so that there shall be no damage to the new work, existing work, and facility being protected.

7.7.2 Soil Parameters for Cofferdam Design

The temporary cofferdam system, which is a temporary retaining structure, should properly designed by a Professional Engineer experienced in this type of work and employed by the Contractor.

For unbraced design, the triangular pressure relationship outlined below is applicable, as follows:

$$P = K(\gamma h + q)$$

where,

P = earth pressure intensity at depth h, kPa

K = earth pressure coefficient

γ = unit weight of retained soil/ water, kN/m³

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 within the existing ground and within the depth of the structure, and for water in the creek.

For design purposes, the following parameters given in Table 2.7 can be assumed after installation of retaining system.

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Table 2.7: Soil parameters and lateral earth pressure coefficient information required for temporary cofferdam design

Unit	Relevant Boreholes	Approx. Elevation (m)	Materials	Unit Weight γ (kN/m ³)	GWL/ Creek Water Elevation (m)	Effective Stress Properties			
						Angle of Friction ϕ' (°)	Coefficient of Lateral Earth Pressure		
							K_a	K_p	K_o
Inlet	BH400-053-01	203.0 – 202.3	Sand Loose	19	203.3 / 202.6 (inlet) 202.5 (outlet)	28	0.36	2.77	0.53
		202.3 – 200.5	Sandy Silt Very loose	19		27	0.38	2.66	0.55
		200.5 – 195.8	Clayey Silt ¹ Very Soft to soft	19		26	0.39	2.56	0.56
Outlet	BH400-053-02	203.8 – 202.3	Gravelly Sand to Sand Compact	20		32	0.31	3.25	0.47
		202.3 – 199.2	Sandy Silt Very loose	19		27	0.38	2.66	0.55
		199.2 – 195.1	Clayey Silt ¹ Very Soft to soft	19		26	0.39	2.56	0.56

Notes:

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

K_a = active earth pressure coefficient

K_o = coefficient of earth pressure at rest

K_p = passive earth pressure coefficient

7.7.3 Piping

Given the groundwater conditions and soils present (pervious materials, sands and silts), piping of the soil is anticipated to be a potential issue at the site due to an unbalanced hydrostatic head causing large upward seepage pressures in the soil at the bottom of the inside cofferdam (if one is required). Piping should be controlled by lowering the water table outside the cofferdam or driving the sheeting to sufficient depth to mitigate against piping. If a rock fill/earth cofferdam is used, piping can be controlled by installing a clay cutoff trench, slurry trench or impervious blanket upstream of the cofferdam.

7.7.4 Groundwater Control

The groundwater level at the site was encountered at about Elev. 203.3 m based on a monitoring well reading taken February 2, 2024. However, groundwater levels would be expected to reflect levels in the adjacent open water. At the time of the field investigation, the approximate top of water elevation at the outlet of the north culvert was measured to be about 202.5 m (measured August 2023). Construction for the replacement of the culvert is recommended during the low water level season.

The soils encountered within potential excavation depths will consist of gravelly sand to sand fills and both native cohesive (clayey silt) and cohesionless soils (sandy silt/silty sand). These materials (particularly the deposits with high silt content) are susceptible to disturbance from groundwater and mobilized equipment. As such, the groundwater level needs to be controlled 0.6 m below the excavation level to avoid disturbance and any surface or groundwater seepage should be removed from the excavation before the placement of granular backfill in the dry. Granular B Type II or clear stone with geotextile wrapping can be used in the wet condition. In general, where the excavation base is within 0.5 m of the prevailing groundwater level at the time of construction, the control of seepage can be accomplished by using properly filtered sumps. However, given the conditions at this site, conventional sump pumping may not be effective for deeper excavations below the groundwater table and those conditions will require more positive dewatering systems. Confirmation of control should be verified before general excavation to final levels.

Dewatering shall be carried out in accordance with OPSS.PROV 517 and SP517F01. It is responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions. The method used should not undermine the adjacent existing footings. Alternatively, and in accordance with SP 5017F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5 years' experience.

Dewatering requirements behind the cofferdams to keep the construction site dry will be impacted by water levels in the creek at the time of construction activities. 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. It is the responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions in the creek. The method used should not undermine the existing highway embankment or adjacent side slopes.

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 the construction methods and staging chosen by the Contractor.

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.

7.8 Embankment Stability and Settlement Considerations

7.8.1 Stability Analysis

Using the sub-surface information interpreted from the boreholes, and the proposed embankment configuration of the reconstructed embankment, a stability analysis was carried out for the most critical section of the median ditch side slopes.

Slope stability analyses were performed to assess the global stability of the reconstructed embankment up to 2.1 m high to check if a minimum Factor of Safety of 1.5 for static and 1.1 for seismic permanent conditions and minimum Factor of Safety of 1.3 for static temporary conditions is achieved. The static and seismic 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.

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. The seismic properties given in Appendix I (Section 7.5) were obtained from the Natural Resources Canada website, 2020 NBC, using the site location coordinates. Tabulated below in Table 2.8 are the soil parameters used for the slope stability analyses.

Table 2.8: Soil properties used in slope stability analyses

Soil Type	Bulk Unit Weight γ (kN/m ³)	Undrained Shear Strength C_u (kPa)	Effective Stress Parameters	
			Friction Angle, ϕ' (°)	Cohesion c' (kPa)
Engineered Granular Fill	21	-	32	0
Sandy Silt to Silty Sand (very loose to Loose)	19	-	27	0
Clayey Silt (very soft to soft)	19	20	26	0

Based on the borehole information, the subsoils encountered at the work area consist of cohesionless fill and native cohesionless and cohesive soils. Therefore, effective stress (drained/long-term conditions) and total stress (undrained/short-term) analyses of the slopes were performed taking into consideration the subsoil conditions encountered at the site. The analyses assumes that all organic material (if encountered) will be removed prior to construction. In addition, a traffic surcharge pressure of 16 kPa was adopted in the slope stability assessments. Table 2.9 summarizes the results of performed slope stability analyses. The SLOPE/W graphical printout for the analyses is included in Appendix F (Figures F1 – F3).

Table 2.9: Summary of results of new embankment slope stability analyses

Location	Max Height (m)	Conditions	Min FOS
East Side (min. 2.25H:1V)	2.1 m	Drained long-term conditions, static condition	1.6 (Figure F1)
		Undrained short-term conditions, static condition	1.6 (Figure F2)
		Drained long-term conditions, seismic condition	1.3 (Figure F3)

The results of the slope stability analyses for the reconstructed embankment having side slopes no steeper than 2.25H:1V or flatter (to match the existing slope of the embankment) show that the slopes are stable for static and seismic conditions (i.e., calculated $FOS \geq 1.5$ for static and $FOS \geq 1.1$ for seismic).

7.8.2 Open Cut – Temporary Slopes

7.8.2.1 Stability Analysis

The results of the analysis for temporary open cut forward slopes are shown in Figure F4 and F9 in Appendix F and summarized in Table 2.10. The results suggest that the temporary open cut is stable for static conditions ($FOS > 1.3$) with 1.8H:1V slopes.

Table 2.10: Summary of results of temporary open cut slope stability analyses

Locations	Max Height (m)	Conditions	Min FOS
Temporary open-cut slope (1H:1V)	3.4	Drained long-term conditions, static condition	0.7
		Undrained short-term conditions, static condition	0.7
Temporary open-cut slope (1.5H:1V)	3.4	Drained long-term conditions, static condition	1.1
		Undrained short-term conditions, static condition	1.1
Temporary open-cut slope (1.8H:1V)	3.4	Drained long-term conditions, static condition	1.3
		Undrained short-term conditions, static condition	1.3

It should be noted that the analyses took into consideration that the site would be dewatered due to the high water table levels.

7.8.3 Embankment Settlement

It is not planned to change the existing embankment grade nor significant permanent widening at the culvert location. It is anticipated that there should be negligible additional settlements under the new embankment. However, a settlement of about 25 mm should be allowed due to rebound during the construction.

7.9 Scour/Erosion Protection

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

The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented, and remain effective for the design life of the culvert. The potential for scour below foundations must be incorporated into the design.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics Engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. Such protection may involve 0.5 m thick rock (OPSS.PROV 511) extending from 1 m above the high water level to the toe of the slope and into the stream bed within the plan limits of the culvert. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts, the following are typical options for seepage cutoff approaches: a typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, a cutoff wall incorporated in the apron slab (if one is used) of the culvert, and a cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert. The seepage protection is addressed in the following Section 7.10.

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. If main culvert has already a clay seal, additional clay seal may not be required. However, clay seal has been discussed in following section for report completeness. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS.PROV 1205, as detailed in Section 7.10.1.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic Design Engineer experienced in this field. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters can be determined based on the soils encountered at the site during the investigation.

7.10 Seepage Cut-off Requirements

The seepage cut-off requirements should be reviewed in the following context. The native silty soils at the inlet side and outlet side and below the culvert bedding have a high potential for migration with high seepage gradients. For the culvert replacement and new culvert installation, it is prudent to examine possible methods to avoid piping of material resulting from seepage along the culvert. 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.

7.10.1 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. 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 1×10^{-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. However, it is the responsibility of the designer to select the dimensions of the clay seal.
- 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 $0.73 \times (\text{Liquid Limit} - 20\%)$.
- The clay seal is to be placed in maximum 150 mm thick lifts and compacted to 95% SPMDD within 2% of the optimum moisture content.

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

7.10.2 Cut-Off Trench/Wall

A cut-off trench/wall 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.

7.11 Corrosion Potential and Cement Type

One (1) soil sample was selected for chemical analyses during this investigation. The testing was completed to determine the potential degradation of the concrete in the presence of soluble sulphates and the potential of corrosion of exposed steel used in foundations and buried infrastructure. The analyses results are summarized in Table 1.7 of this report.

The pH, resistivity, and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH value measured at the site was 7.66 which is within the normal range of soil pH of 5.5 to 8.5 and therefore is not considered to be detrimental to culvert durability (AASHTO, 2000/MTO Gravity Pipe Design Guidelines, April 2014). The chemical data indicates moderate ($2000 < R < 4500$ ohm-cm) resistivity of the tested soil which suggests moderate potential for corrosion of buried metallic elements as per Table 3.2 of the MTO Gravity Pipe Design Guideline.

These chemical test results may be used to aid in the selection of coatings and corrosion protection systems for buried steel culverts if selected. If the concrete culvert option is selected, consideration should be given by the designer to design for a « C » type of exposure class of concrete as defined by CSA A23.1:19 Table 1, since the culvert will be exposed to de-icing salt.

The maximum water-soluble sulphate content of the soils tested is about 71 ppm ($\mu\text{g/g}$), i.e. 0.0007%, and being less than 0.10% (as per CSA A23.1:19, Table 3) does not require sulphate resistant cement. The data supports our local experience.

7.12 Obstructions during Installation of Temporary Protection Systems

Cobbles and/or boulders were not noted to be contained within the fill at the site during site investigation. However, their presence should always be anticipated within fill layers. Therefore, care has to be taken since the presence of these obstructions may affect the excavation for culvert replacement and installation of protection system elements including the temporary roadway protection system and temporary dewatering/unwatering systems. It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the presence of cobbles and/or boulders within the overburden soils. An example of NSSP for obstructions is provided in Appendix J.

8.0 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.

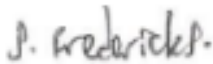
We recommend that we be retained to review our recommendations as the design nears completion to ensure that the final design is in agreement with the assumptions on which our recommendations are based and that our recommendations have been interpreted as intended. If not accorded this review, EXP will 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 Ian Lee, M.Eng., Technical Specialist, Stephen Fredericks, M.Eng., P.Eng., and Nimesh Tamrakar, M.Eng., P.Eng. It was reviewed by TaeChul Kim, M.E.Sc., P.Eng. and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Stephen Fredericks, M.Eng., P.Eng.

EXP Services Inc.



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Designated MTO Foundation Contact



9.0 REFERENCES

Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Canadian Standards Association (CSA), 2019. Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-19. CSA Special Publication.

Highway Standards Branch, Provincial Memorandum, Material Engineering and Research Office (MERO) #2020-01, March 23, 2020

Ministry of Northern Development and Mines, Map 2556. Quaternary Geology of Ontario, Southern Sheet, 1991

Ministry of Northern Development and Mines Map 2544. Bedrock Geology of Ontario, Southern Sheet, 1991

Ministry of Transportation, May 2007. MTO Gravity Pipe Design Guidelines. Circular Culverts and Storm Sewers.

Ministry of Transportation, October 2020. Guideline for MTO Foundation Engineering Services, Version 02

ASTM International:

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

Ontario Provincial Standard Specifications (OPSS):

OPSS.PROV 401 Construction Specification for Trenching, Backfilling and Compacting

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 517 Construction Specification for Dewatering

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.PROV 903 Construction Specification for Deep Foundations

OPSS.PROV 1205 Material Specification for Clay Seal

Ontario Provincial Standard Drawings (OPSD):

OPSD 810.010 Rip-Rap Treatment for Sewer and Culvert Outlets

Special Provisions (SP):

SP 109F57 AMENDMENT TO OPSS 903

SP 517F01 AMENDMENT TO OPSS 517

Ontario Water Resources Act:

R.R.O 1990, Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

Ontario Occupational Health and Safety Act (OHSA):

Ontario Regulation 213/91 Construction Projects

10.0 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 utilized 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



Photograph 1. Aerial view of twin culverts at inlet – August 10, 2023 (taken by EXP)



Photograph 2: Condition of one of the twin existing CSP culvert at inlet side – August 10, 2023 (taken by EXP)



Photograph 3: Entrance at one of the twin existing CSP culvert at inlet side – August 10, 2023 (taken by EXP)



Photograph 4: Aerial view of twin culverts at outlet – August 9, 2023 (taken by EXP)



Photograph 5. Front view of twin culverts at outlet – August 9, 2023 (taken by EXP)



Photograph 6: Entrance at one of the twin existing CSP culvert at outlet side – August 9, 2023 (taken by EXP)



Photograph 7. Typical roadway surface condition (facing north)– August 9, 2023 (taken by EXP)



Photograph 8. Drilling of borehole BH400-053-03 (facing northwest) – August 9, 2023 (taken by EXP)

Appendix B – 90% Contract Drawings

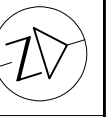
CAD FILE LOCATION AND NAME: A:\V-TPD\Projects\CA\Projects\220766cn... 25 culverts\Drafting\Sheets\Highways\Contract package\1\0220766CN_N02.dwg
MODIFIED: 4/25/2024 3:13:43 PM BY: RMISTRY
DATE PLOTTED: 5/1/2024 11:43:41 AM BY: RMISTRY

MINISTRY OF TRANSPORTATION, ONTARIO
ANS-D
2016-10

CV-0252-0400-0053
(HWY 400)

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

PLATE No
CONT 2024-2025
GWP 2044-23-00



NEW CONSTRUCTION
CV-0252-0400-0053

SHEET
25



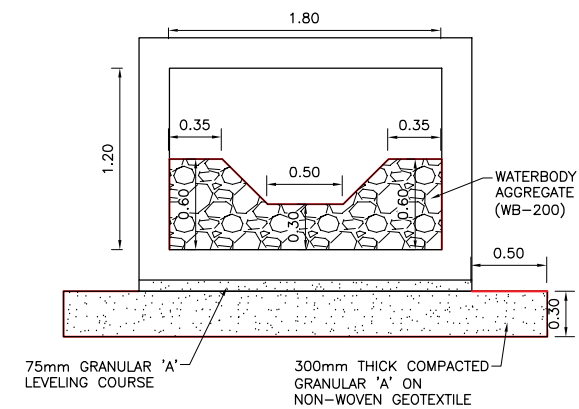
1	SOLID YELLOW,10cm
2	SOLID DOUBLE YELLOW,10cm
3	363 BROKEN YELLOW,10cm
4	SOLID YELLOW,20cm
5	SOLID WHITE,10cm
6	333 BROKEN WHITE,10cm
7	363 BROKEN WHITE,10cm
8	393 BROKEN WHITE,10cm
9	SOLID WHITE,20cm
10	111 BROKEN WHITE,20cm
11	333 BROKEN WHITE,20cm
12	333 BROKEN WHITE ,30cm
13	SOLID WHITE,30cm
14	SOLID WHITE,45cm
15	SOLID WHITE,60cm
20	SYMBOLS
] [LIMITS OF MARKINGS	

LEGEND

- RIP-RAP/WATERBODY AGGREGATE
- CULVERT REPLACEMENT
- CURB AND GUTTER
- GUIDERAIL
- LIGHT-DUTY SILT FENCE BARRIER
- FLOW DIRECTION
- BOTTOM OF DITCH
- TOE OF SLOPE
- MTO ROW
- FENCE LINE

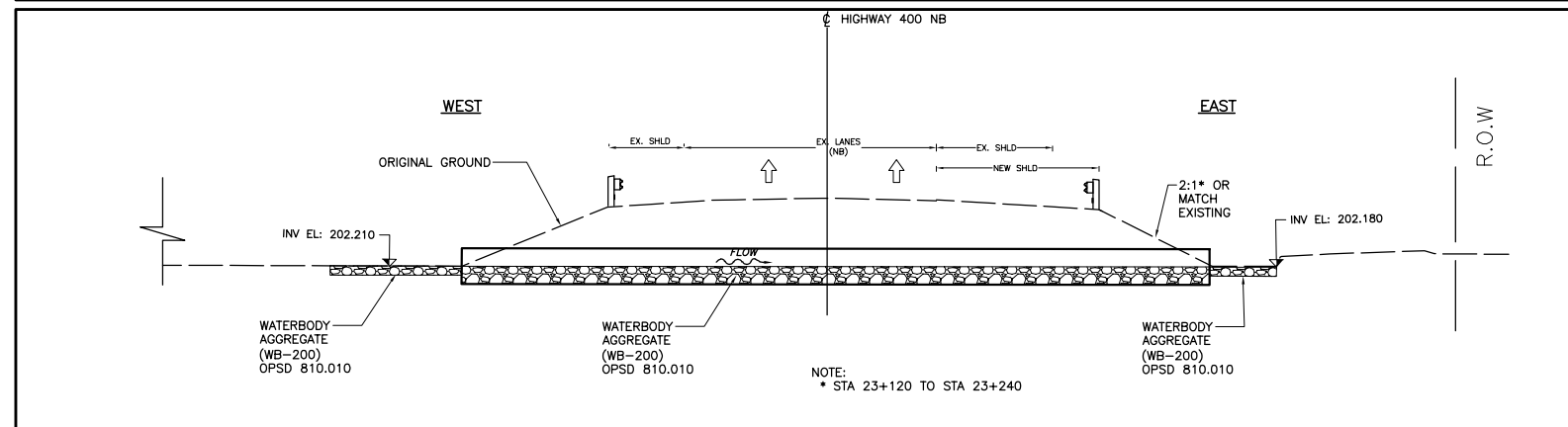
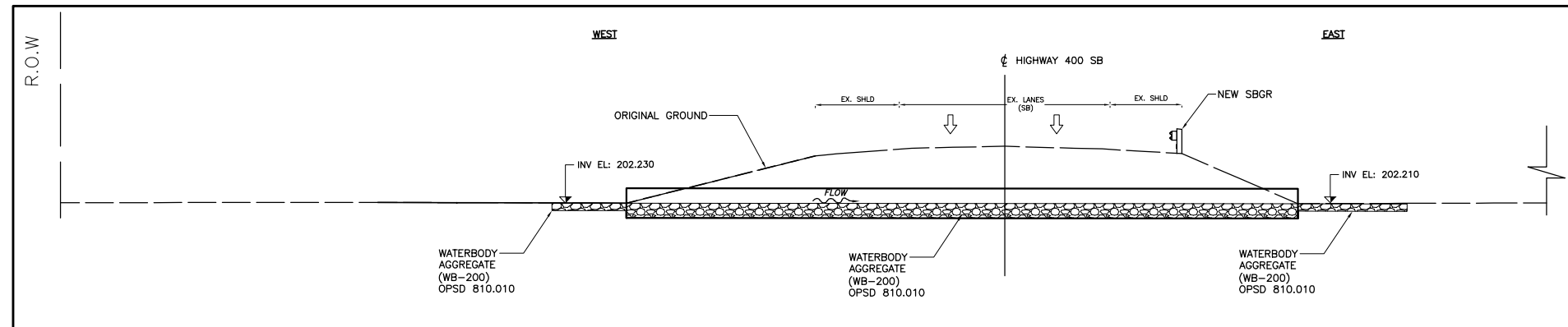
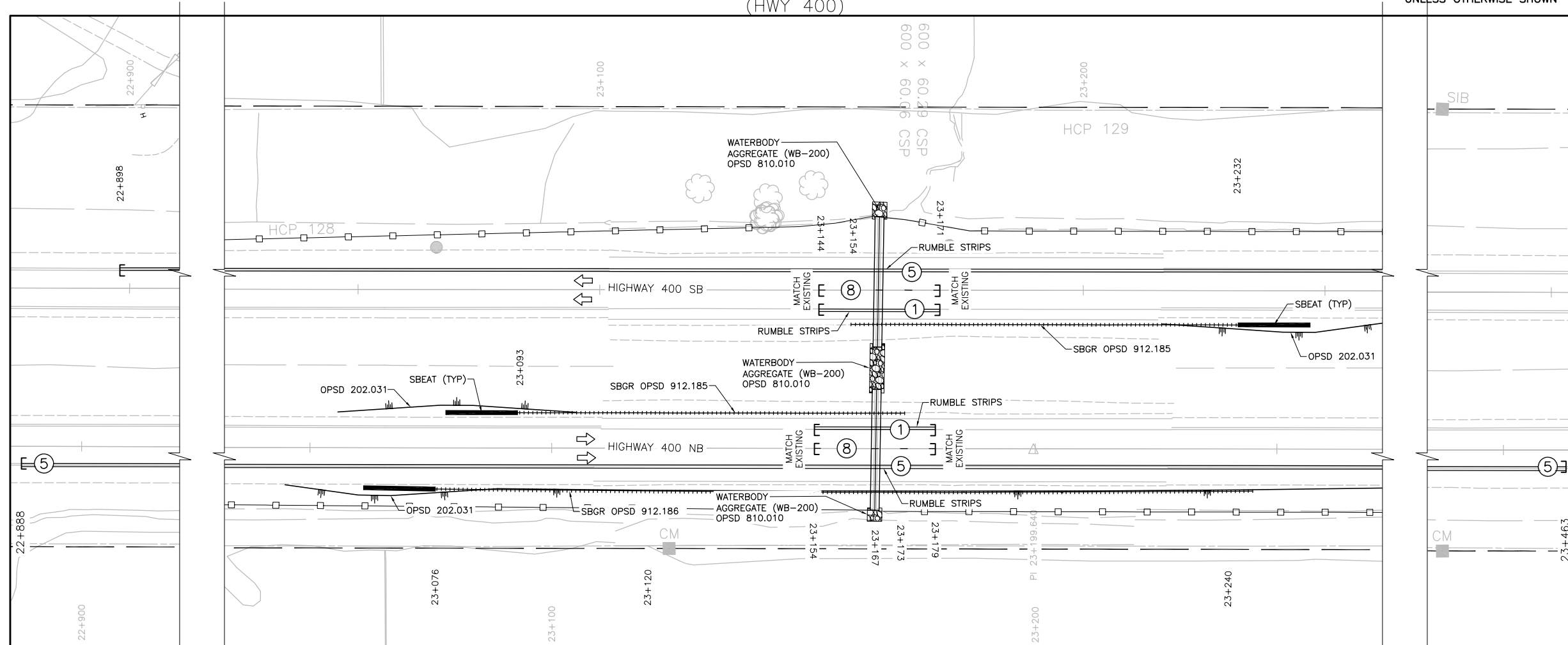
NOTES:

- 333, 363, 393, DENOTES PAVEMENT MARKING SPACING (ie., 3 m line, 3 m gap, 3 m line)
- Use ① to Denote PAVEMENT MARKING
- Use ① to Denote PAVEMENT MARKING, TEMPORARY
- Use ⚠ to Denote PAVEMENT MARKING, TEMPORARY- REMOVABLE
- Use ① to Denote PAVEMENT MARKING, DURABLE
- FROST TAPERS are based on OPSD 803.030, 803.031



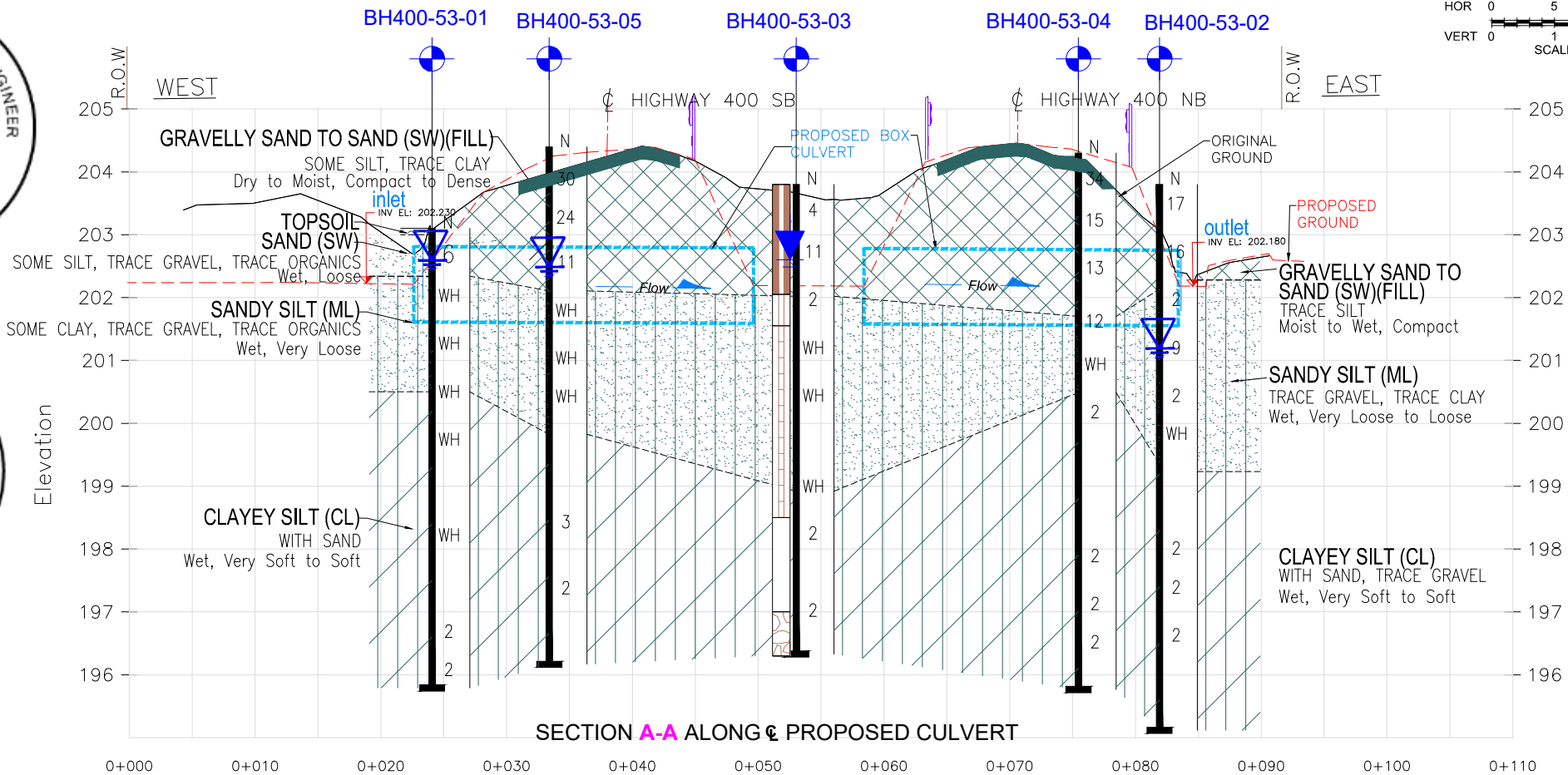
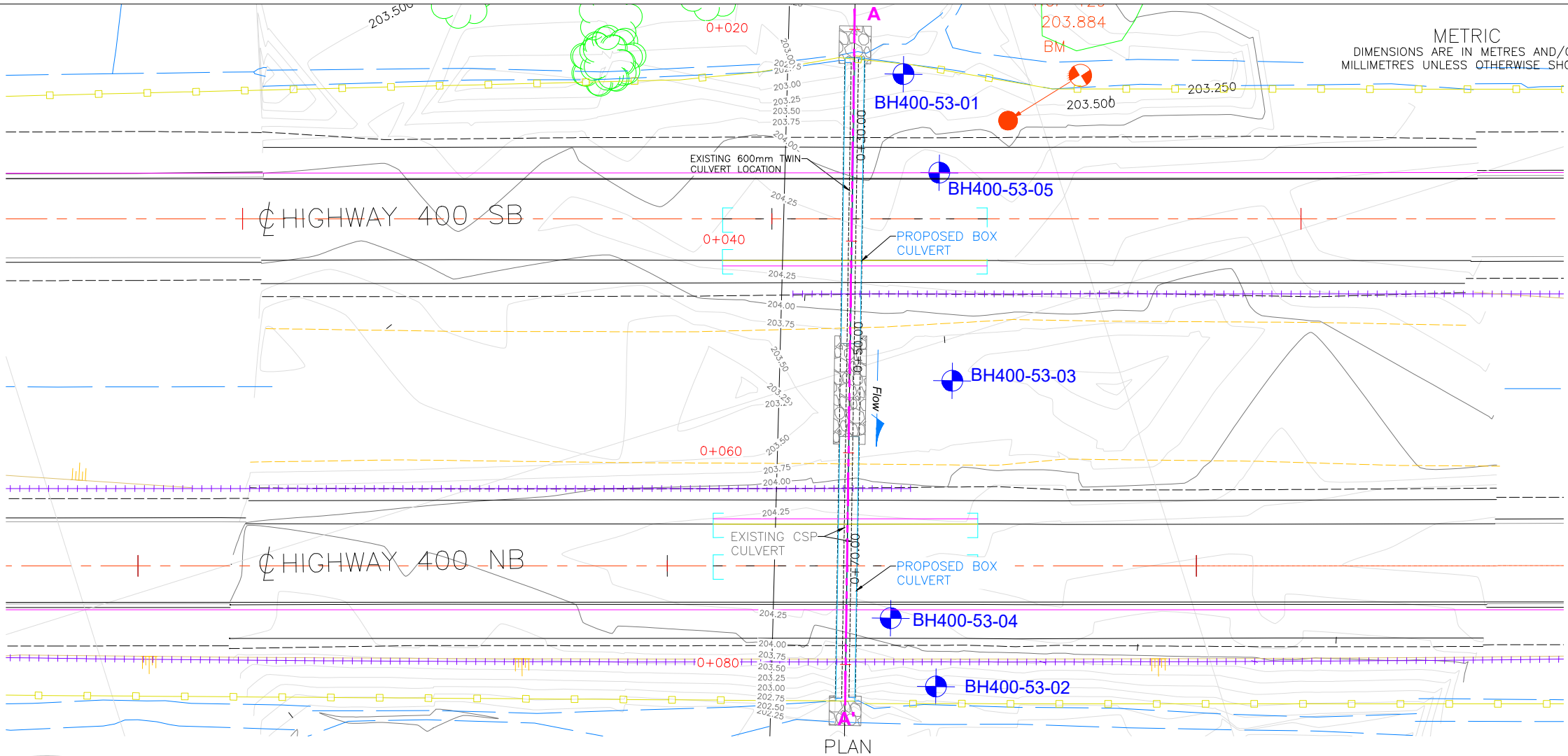
TYPICAL SECTION
1:25

SCALE
5m 0 10m



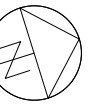
Appendix C – Borehole Location Plan and Soil Strata

FILE NAME: I:\2003-Brampton\Proposals\International\WTO Projects\WTO 2020-E-0028 25 culverts\working drawings\WTO 2020-E-0028-0400-0053_Borehole location plan & soil strata.dwg
MODIFIED: 2024-05-16 08:51



ASSIG No. 2020-E-0028

GWP No. 2044-23-00



HIGHWAY 400 CSP CULVERT REPLACEMENT
SIMCOE, ON (CV-252-400-0053)

Latitude: 44.644830° Longitude: -79.651590°
BOREHOLE LOCATION PLAN & SOIL STRATA

SHEET

1



EXP SERVICES INC.



KEY PLAN
N.T.S.

LEGEND

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

SOIL STRATA SYMBOLS

- TOPSOIL
- ASPHALT
- FILL
- SAND
- SILT AND SAND
- CLAYEY SILT

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
BH400-053-01	203.1	4944988.9	292774.8
BH400-053-02	203.8	4944974.5	292830.9
BH400-053-03	203.8	4944984.6	292803.8
BH400-053-04	204.3	4944972.4	292823.5
BH400-053-05	204.4	4944989.4	292784.7

NOTES

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

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

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

SUBMISSION FOR MTO REVIEW			
NO	DATE	BY	DESCRIPTION
PROJECT No.	ADM-22007871-A0	GEOCREs No.	31D12-003
SUBM'D SH	CHKD. NT	DATE	MAY 21, 2024 SITE-
DRAWN SH	CHKD. TC	APPRD SG	DWG 01

Appendix D – Borehole Logs

Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

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

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

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

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

Terminology describing soil structure:

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

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

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

Fissured: material breaks along plane of fracture.

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

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

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

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

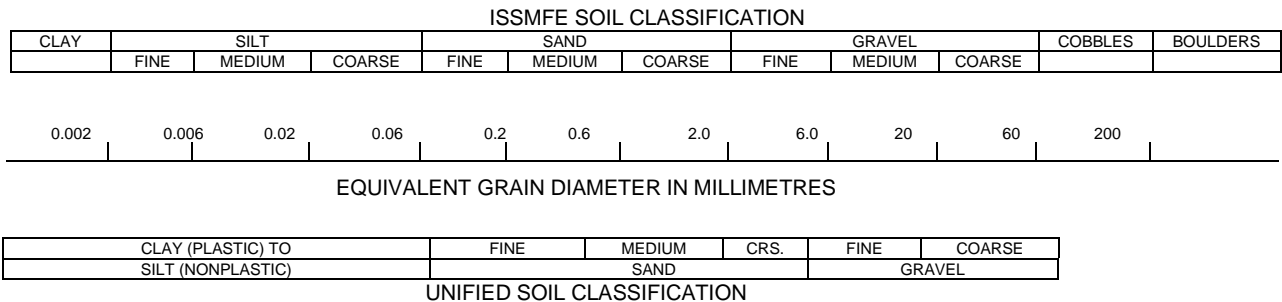
Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

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

Uniformly Graded: predominantly on grain size.

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



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 Canadian Foundation Engineering Manual (CFEM):

Table a: Percent or Proportion of Soil

Term	Description	Criteria
"trace"	trace gravel, trace sand, etc.	1% - 10%
"some"	some gravel, some sand, etc.	10% - 20%
Adjective	gravelly, sandy, silty and clayey	20% - 35%
"and"	and gravel, and sand, etc.	>35%
Noun	gravel, sand, silt, clay	>35% and main fraction

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:

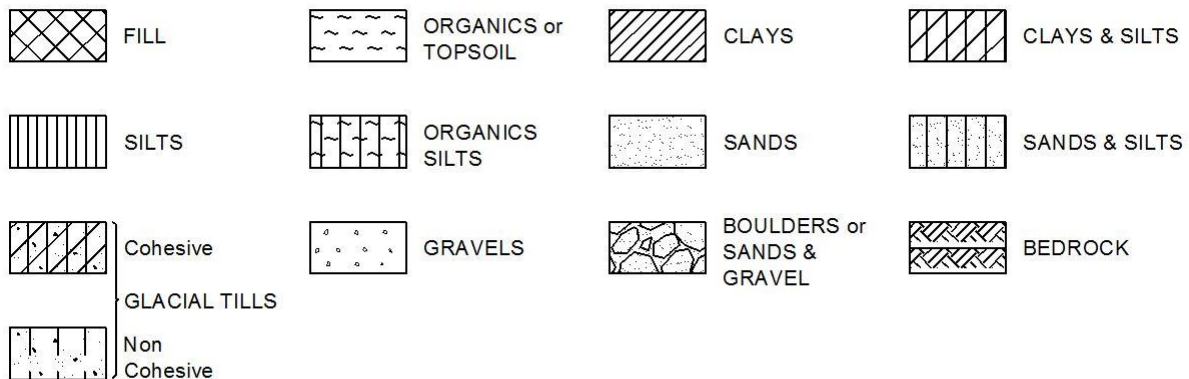
Table c: Consistency of Cohesive Soil

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



Open Borehole or Test Pit



Monitoring Well, Piezometer or Standpipe

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

MECHANICAL PROPERTIES 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

Brampton, Ontario

RECORD OF BOREHOLE No BH-0400-53-01 1 OF 1 METRIC

W.P. GWP 2044-23-00 LOCATION CV-0252-0400-0053, Simcoe, ON, MTM ON-10 292777E 4944989N ORIGINATED BY SF
 DIST Simcoe HWY 400 BOREHOLE TYPE SSA COMPILED BY IL
 DATUM Geodetic DATE 2023.08.11 - 2023.08.11 LATITUDE 44.644806 LONGITUDE -79.651595 CHECKED BY NT

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20	40	60	80	100				
203.1																
203.0	TOPSOIL ~ 50 mm															
0.1	SAND(SW) - some silt, trace gravel, trace organics, grey, wet, loose		1	SS	6		203									
202.3																
0.8	SANDY SILT (ML) - some clay, trace gravel, trace organics, dark brown to grey, wet, very loose		2	SS	WH		202									
			3	SS	WH		201									0 30 59 11
200.5			4	SS	WH		200									
2.6	CLAYEY SILT (CL) - with sand, grey, wet, very soft to soft		5	SS	WH											0 27 57 16
				VANE			199									
			6	SS	WH		198									
				VANE												
							197									
			7	SS	2											
			8	SS	2		196									
195.8																
7.3	END OF BOREHOLE															
	NOTE: 1. Ground water level measured at 0.5 m below ground surface in open hole upon completion of borehole															

ONTARIO MTO CV-0252-0400-0053 - 02072024_SF.GPJ ONTARIO MTO.GDT 5/1/24




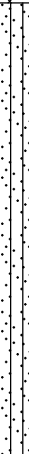

Brampton, Ontario

RECORD OF BOREHOLE No BH-0400-53-02

1 OF 1

METRIC

W.P. GWP 2044-23-00 LOCATION CV-0252-0400-0053, Simcoe, ON, MTM ON-10, 292830E 4944979N ORIGINATED BY SF
 DIST Simcoe HWY 400 BOREHOLE TYPE SSA COMPILED BY IL
 DATUM Geodetic DATE 2023.08.08 - 2023.08.08 LATITUDE 44.6447195 LONGITUDE -79.65090325 CHECKED BY NT

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER											
203.8 0.0	GRAVELLY SAND TO SAND (SW) (FILL) - trace silt. brown, moist to wet, compact		1	SS	17			20	40	60	80	100	20	40	60	GR SA SI CL			
203																			
202.3 1.5	SANDY SILT (ML) - trace gravel, trace clay, black to grey, wet, very loose to loose		2	SS	16			202										11 75 (14)	
			3	SS	2			202											
			4	SS	9			201											0 30 66 4
																			Non-plastic
			5	SS	2			200											
199.2 4.6	CLAYEY SILT (CL) - with sand, trace gravel, grey, wet, very soft to soft - becoming silt and sand with some gravel, trace clay, very loose		6	SS	WH			199											6 28 51 15
			7	TW		198											18 37 38 7		
			8	SS	2														
			9	SS	2	197												0 25 58 17	
			10	SS	2	196													
195.1 8.7	END OF BOREHOLE																		
	NOTE: 1. Ground water level measured at 2.6 m below ground surface in open hole upon completion of borehole																		

ONTARIO MTO CV-0252-0400-0053 - 02072024_SF.GPJ ONTARIO MTO.GDT 5/1/24

Brampton, Ontario

RECORD OF BOREHOLE No BH-0400-53-03

1 OF 1

METRIC

W.P. GWP 2044-23-00 LOCATION CV-0252-0400-0053, Simcoe, ON, MTM ON-10, 292805E 4944983N ORIGINATED BY SF
 DIST Simcoe HWY 400 BOREHOLE TYPE SSA COMPILED BY IL
 DATUM Geodetic DATE 2023.08.09 - 2023.08.09 LATITUDE 44.64475294 LONGITUDE -79.65121428 CHECKED BY NT

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _P W W _L				
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL P. PENETROMETER						
								20 40 60 80 100		20 40 60				
203.8														
203.0	TOPSOIL													
0.1	GRAVELLY SAND TO SAND(SW) (FILL) - some silt, trace clay, trace organics, dark brown, moist to wet, very loose to compact		1	SS	4		203							14 67 (19)
			2	SS	11									
202.0			3	SS	2		202							
1.8	SANDY SILT (ML) - trace to some clay, trace gravel, grey, wet, very loose		4	SS	WH		201							9 34 48 9
			5	SS	WH		200							
198.9			6	SS	WH		199							
4.9	CLAYEY SILT (CL) - trace sand, trace gravel, grey, wet, very soft to soft		7	SS	2		198							0 9 68 23
				VANE										
			8	SS	2		197							
196.3	END OF BOREHOLE													
7.5	NOTE: 1) Ground water level measured at 1.2 m below ground surface in open hole upon completion of borehole. 2) Monitoring Well Readings Date Depth Elev. Feb 02/24 0.5 203.3 m Jan 29/24 0.63 203.2 m													

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

ONTARIO MTO CV-0252-0400-0053 - 02072024_SF.GPJ ONTARIO MTO.GDT 5/1/24

Brampton, Ontario

RECORD OF BOREHOLE No BH-0400-53-04

1 OF 1

METRIC

W.P. GWP 2044-23-00 LOCATION CV-0252-0400-0053, Simcoe, ON, MTM ON-10, 292824E 4944972N ORIGINATED BY SF
DIST Simcoe HWY 400 BOREHOLE TYPE SSA COMPILED BY IL
DATUM Geodetic DATE 2023.08.08 - 2023.08.08 LATITUDE 44.64465178 LONGITUDE -79.65097522 CHECKED BY NT

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL P. PENETROMETER									
204.3	ASPHALT						20	40	60	80	100	20	40	60				
204.0	GRAVELLY SAND TO SAND (SW)(FILL) - brown, dry to moist, dense to compact		1	SS	34													
203.9																		
203.8			2	SS	15													16 74 (10)
203.7																		
203.6			3	SS	13													
203.5																		
203.4																		
203.3																		
203.2																		
203.1																		
203.0																		
202.9																		
202.8																		
202.7																		
202.6																		
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190.4																		
190.3																		
190.2																		
190.1																		
190.0																		
189.9																		
189.8																		
189.7																		
189.6																		

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

ONTARIO MTO CV-0252-0400-0053 - 02072024_SF.GPJ ONTARIO MTO.GDT 5/1/24

RECORD OF BOREHOLE No BH-0400-53-05

1 OF 1

METRIC

W.P. GWP 2044-23-00

LOCATION CV-0252-0400-0053, Simcoe, ON, MTM ON-10, 292784E 4944991N

ORIGINATED BY SF

DIST Simcoe HWY 400

BOREHOLE TYPE SSA

COMPILED BY IL

DATUM Geodetic

DATE 2023.08.10 - 2023.08.10

LATITUDE 44.64482758

LONGITUDE -79.65147731

1 CHECKED BY NT

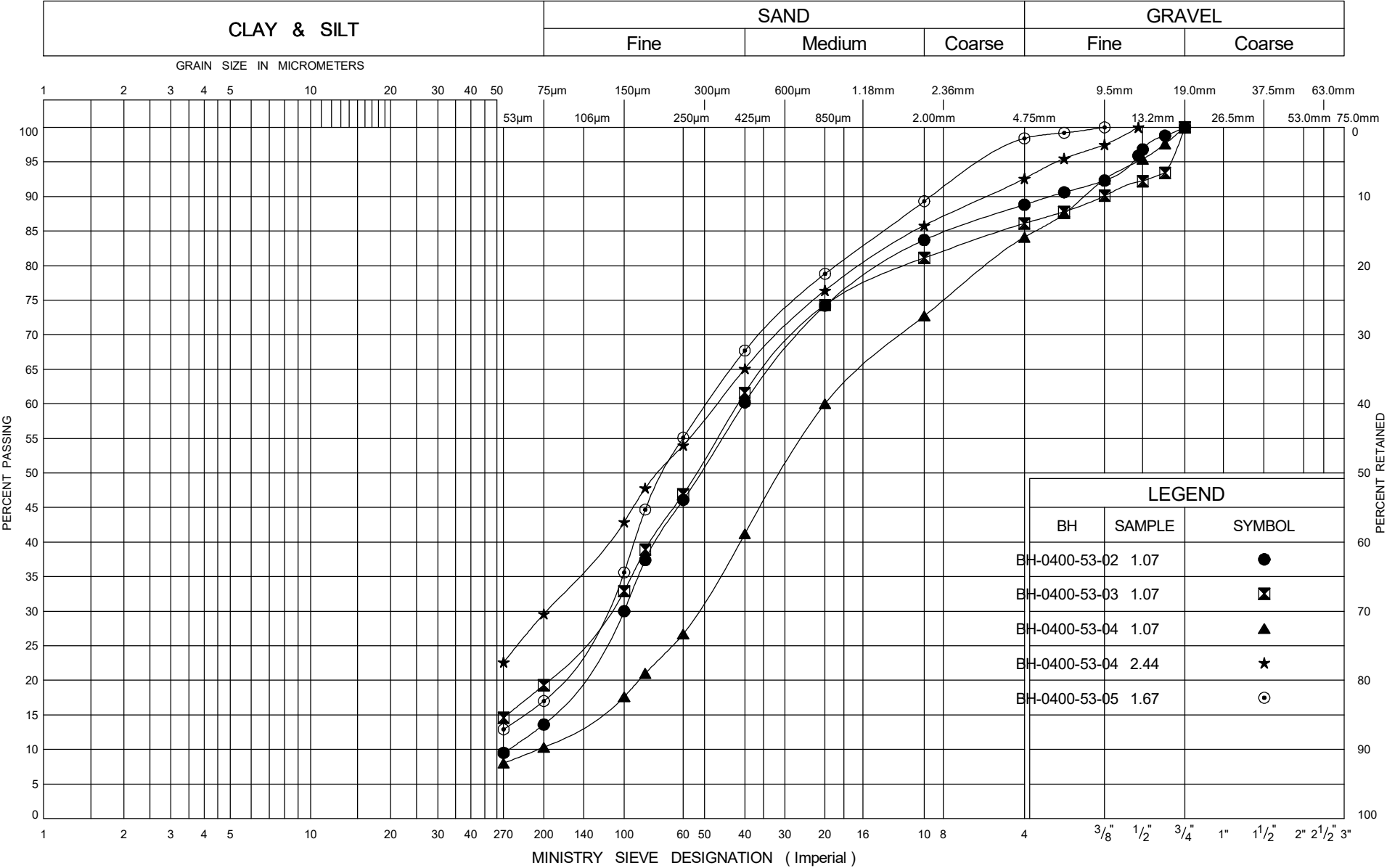
[illegible]

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

ONTARIO MTO CV-0252-0400-0053 - 02072024 SF.GPJ ONTARIO MTO.GDT 5/1/24

Appendix E – Laboratory Data

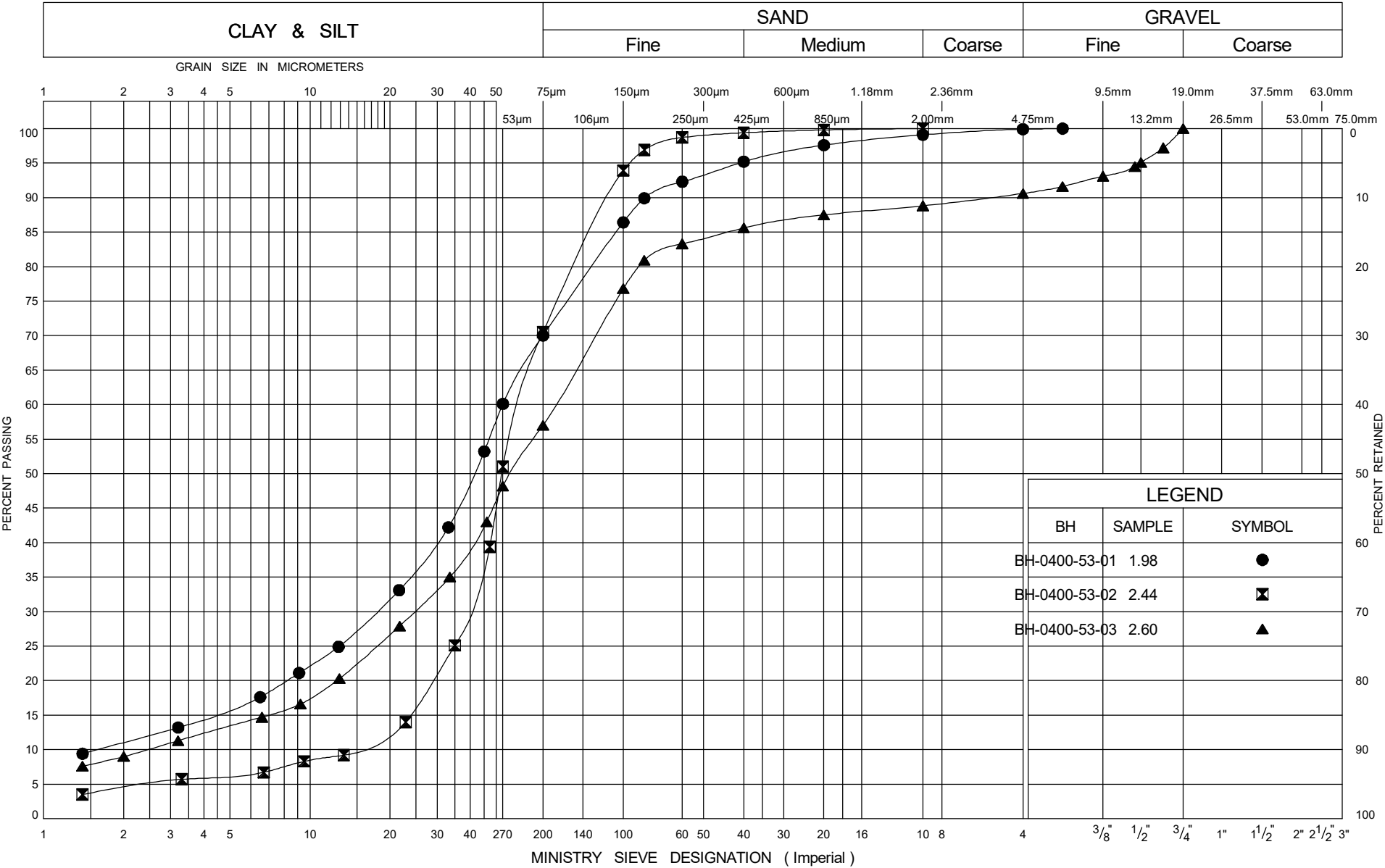
UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
Gravelly Sand to Sand(SW) (Fill)

FIG No 1
W P GWP 2044-23-00
Replacement of 25 Culverts

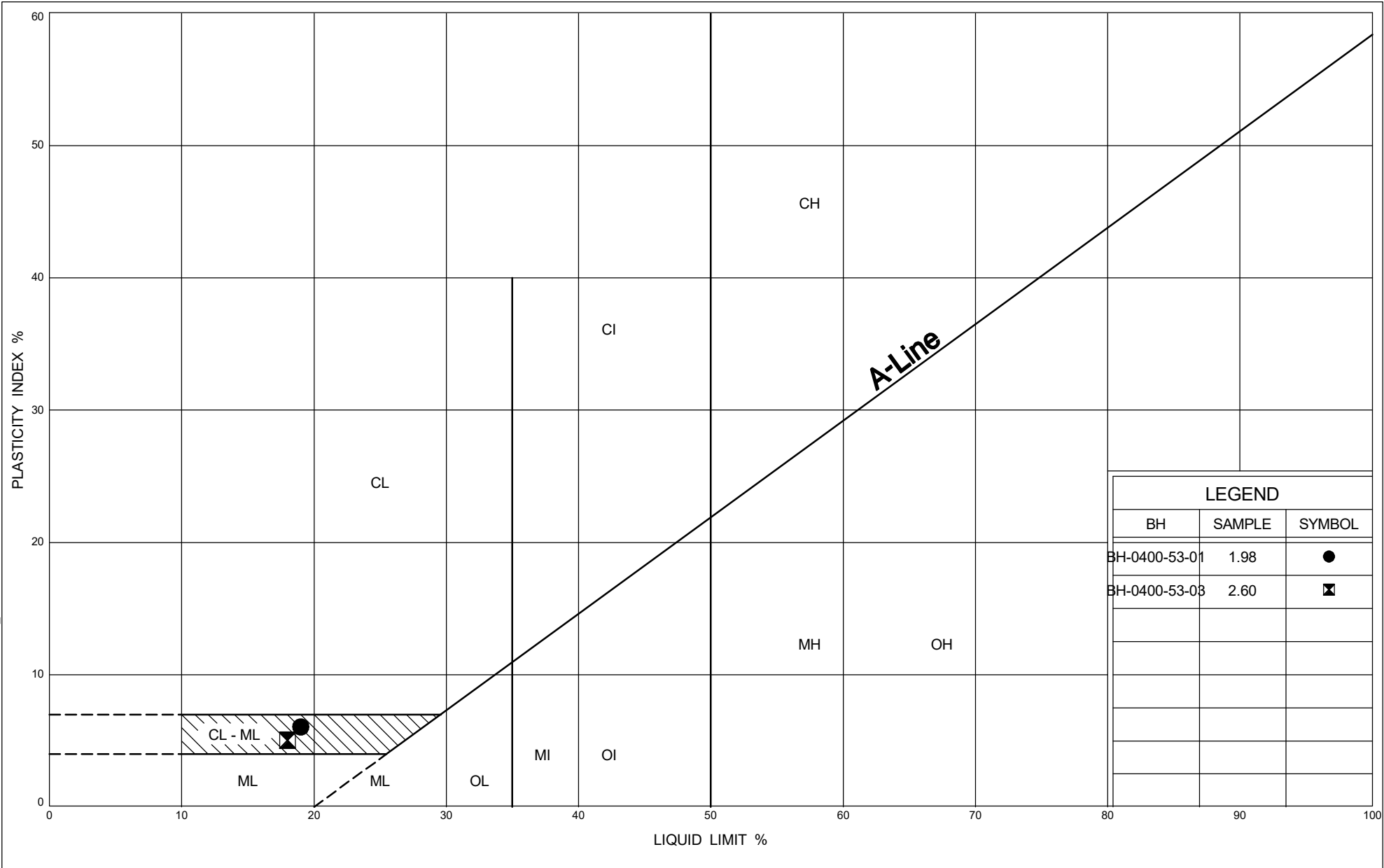
UNIFIED SOIL CLASSIFICATION SYSTEM



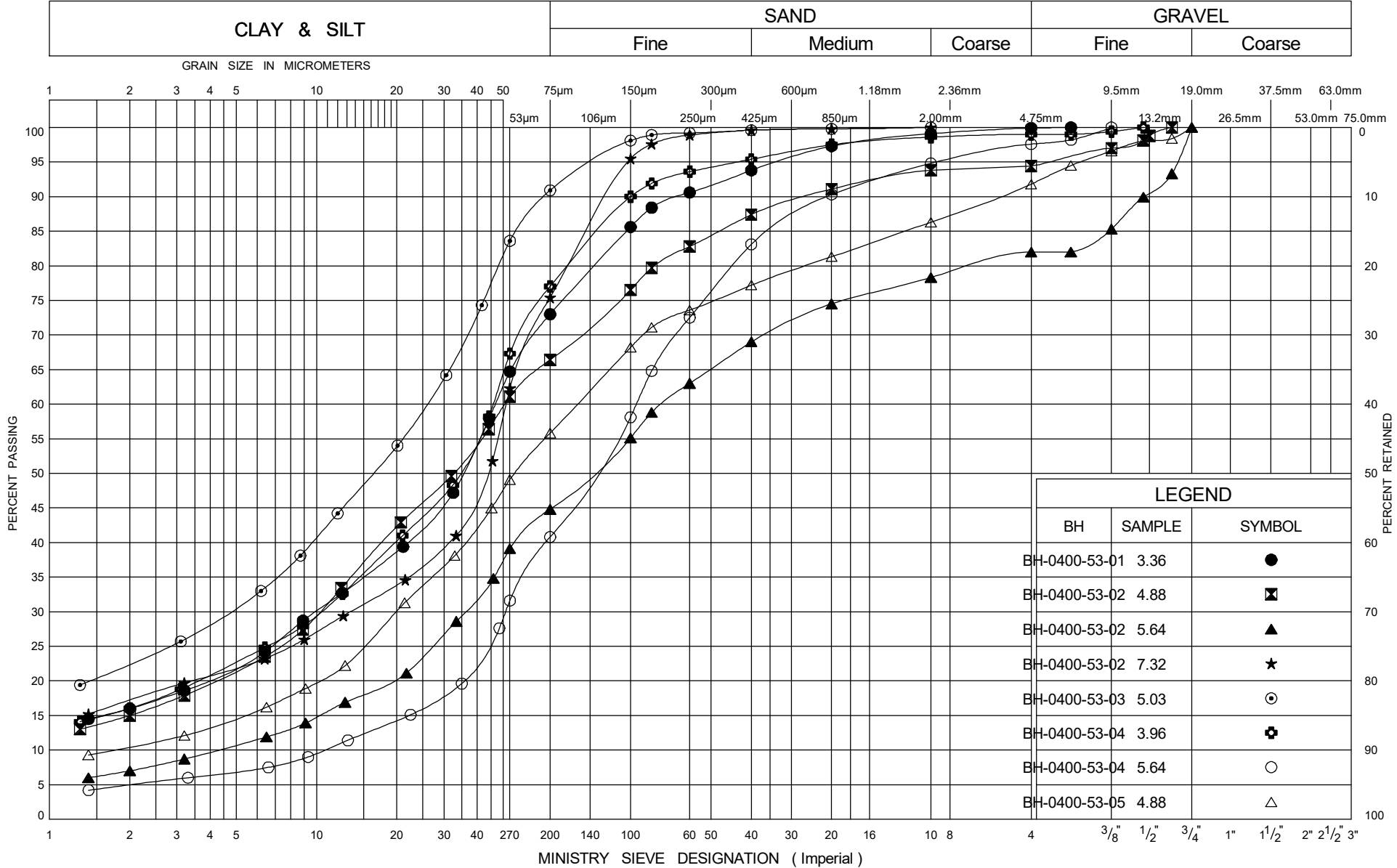
GRAIN SIZE DISTRIBUTION
Sandy Silt(ML)/Silty Sand (SM)

FIG No 2
W P GWP 2044-23-00
Replacement of 25 Culverts

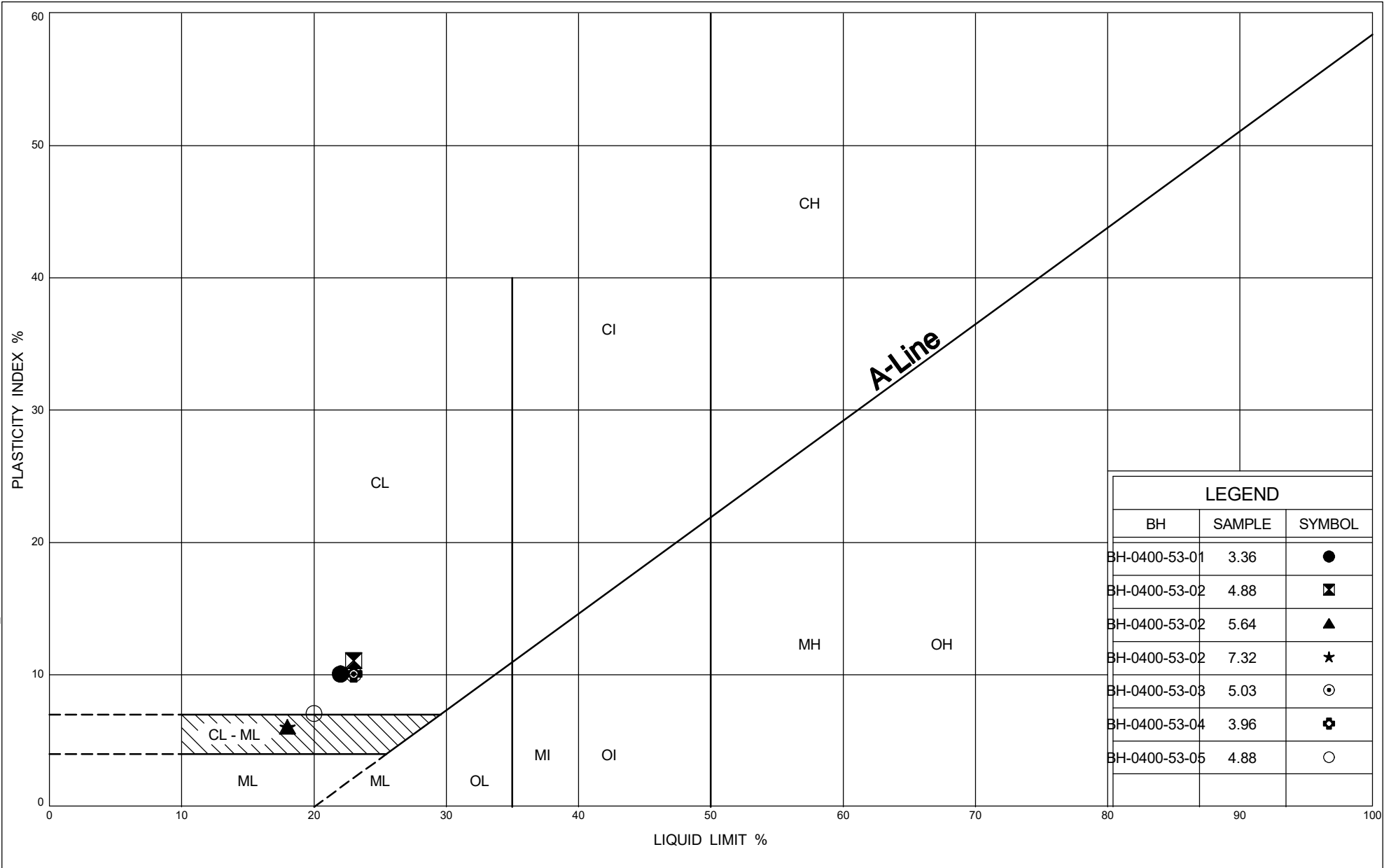
ONTARIO MOT PLASTICITY CHART CV-0252-0400-0053 - 02072024_SF.GPJ ONTARIO MOT.GDT 2/16/24



UNIFIED SOIL CLASSIFICATION SYSTEM



ONTARIO MOT PLASTICITY CHART CV-0252-0400-0053 - 02072024_SF.GPJ ONTARIO MOT.GDT 2/16/24





Your Project #: ADM-22000797-A0
Site Location: Hwy 7 and Coronation Road, Whitby, ON
Your C.O.C. #: 903374-12-01

Attention: Nimesh Tamrakar

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

Report Date: 2023/08/25
Report #: R7781216
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C3O9991

Received: 2023/08/17, 12:07

Sample Matrix: Soil
Samples Received: 3

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	3	2023/08/22	2023/08/23	CAM SOP-00463	MOE E3013 m
Conductivity	3	2023/08/22	2023/08/22	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	3	N/A	2023/08/24	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	3	N/A	2023/08/24	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	2	2023/08/21	2023/08/21	CAM SOP-00413	EPA 9045 D m
pH CaCl2 EXTRACT	1	2023/08/22	2023/08/22	CAM SOP-00413	EPA 9045 D m
Redox Potential (3)	3	2023/08/21	2023/08/22	CAM SOP-00421	SM 2580 B
Resistivity of Soil	3	2023/08/17	2023/08/22	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	3	2023/08/22	2023/08/23	CAM SOP-00464	MOE E3013 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCCFP, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested. When sampling is not conducted by Bureau Veritas, results relate to the supplied samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

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

(1) This test was performed by Bureau Veritas Calgary (19th), 4000 19th Street NE, Calgary, AB, T2E 6P8



Your Project #: ADM-22000797-A0
Site Location: Hwy 7 and Coronation Road, Whitby, ON
Your C.O.C. #: 903374-12-01

Attention: Nimesh Tamrakar

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

Report Date: 2023/08/25
Report #: R7781216
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C3O9991

Received: 2023/08/17, 12:07

- (2) Offsite analysis requires that subcontracted moisture be reported.
(3) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode. The test is therefore, not SCC accredited for this matrix.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to:

Patricia Legette, Project Manager
Email: Patricia.Legette@bureauveritas.com
Phone# (905)817-5799

=====

This report has been generated and distributed using a secure automated process.

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by Rodney Major, General Manager responsible for Ontario Environmental laboratory operations.

**SOIL CORROSIVITY PACKAGE (SOIL)**

Bureau Veritas ID		WSK614			WSK614			WSK615		
Sampling Date		2023/08/11			2023/08/11			2023/08/14 10:15		
COC Number		903374-12-01			903374-12-01			903374-12-01		
	UNITS	BH 400-53-1 SS3	RDL	QC Batch	BH 400-53-1 SS3 Lab-Dup	RDL	QC Batch	BH 400-26-1 SS4	RDL	QC Batch

Calculated Parameters

Resistivity	ohm-cm	4000		8860583				1400		8860583
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CONVENTIONALS

Redox Potential	mV	280	N/A	8865270				270	N/A	8865270
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Inorganics

Soluble (20:1) Chloride (Cl ⁻)	ug/g	54	20	8867988				270	20	8867988
Conductivity	umho/cm	249	2	8868311	249	2	8868311	725	2	8868311
Available (CaCl ₂) pH	pH	7.66		8865823				7.60		8865823
Soluble (20:1) Sulphate (SO ₄)	ug/g	71	20	8868003				36	20	8868003
Sulphide	mg/kg	1.6 (1)	0.5	8874652				<0.5 (1)	0.5	8874652

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Lab-Dup = Laboratory Initiated Duplicate

N/A = Not Applicable

(1) Sample contained greater than 10% headspace at time of extraction.

Bureau Veritas ID		WSK615			WSK616		
Sampling Date		2023/08/14 10:15			2023/08/17 14:40		
COC Number		903374-12-01			903374-12-01		
	UNITS	BH 400-26-1 SS4 Lab-Dup	RDL	QC Batch	BH 401-N1-1 SS5	RDL	QC Batch

Calculated Parameters

Resistivity	ohm-cm				2000		8860583
-------------	--------	--	--	--	------	--	---------

CONVENTIONALS

Redox Potential	mV				190	N/A	8865270
-----------------	----	--	--	--	-----	-----	---------

Inorganics

Soluble (20:1) Chloride (Cl ⁻)	ug/g	280	20	8867988	180	20	8867988
Conductivity	umho/cm				495	2	8868311
Available (CaCl ₂) pH	pH	7.68		8865823	7.90		8867940
Soluble (20:1) Sulphate (SO ₄)	ug/g	29	20	8868003	33	20	8868003
Sulphide	mg/kg				0.7	0.5	8874652

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Lab-Dup = Laboratory Initiated Duplicate

N/A = Not Applicable



RESULTS OF ANALYSES OF SOIL

Bureau Veritas ID		WSK614	WSK615	WSK616		
Sampling Date		2023/08/11	2023/08/14 10:15	2023/08/17 14:40		
COC Number		903374-12-01	903374-12-01	903374-12-01		
	UNITS	BH 400-53-1 SS3	BH 400-26-1 SS4	BH 401-N1-1 SS5	RDL	QC Batch
Physical Testing						
Moisture-Subcontracted	%	22	5.2	6.8	0.30	8876099
RDL = Reportable Detection Limit						
QC Batch = Quality Control Batch						



**BUREAU
VERITAS**

Bureau Veritas Job #: C3O9991

Report Date: 2023/08/25

exp Services Inc

Client Project #: ADM-22000797-A0

Site Location: Hwy 7 and Coronation Road, Whitby, ON

Sampler Initials: IB

TEST SUMMARY

Bureau Veritas ID: WSK614
Sample ID: BH 400-53-1 SS3
Matrix: Soil

Collected: 2023/08/11
Shipped:
Received: 2023/08/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8867988	2023/08/22	2023/08/23	Alina Dobreanu
Conductivity	AT	8868311	2023/08/22	2023/08/22	Taslina Aktar
Moisture (Subcontracted)	BAL	8876099	N/A	2023/08/24	Simranjeet Batth
Sulphide in Soil	SPEC	8874652	N/A	2023/08/24	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8865823	2023/08/21	2023/08/21	Taslina Aktar
Redox Potential	COND	8865270	2023/08/21	2023/08/22	Gurpartee Kaur
Resistivity of Soil		8860583	2023/08/22	2023/08/22	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8868003	2023/08/22	2023/08/23	Alina Dobreanu

Bureau Veritas ID: WSK614 Dup
Sample ID: BH 400-53-1 SS3
Matrix: Soil

Collected: 2023/08/11
Shipped:
Received: 2023/08/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	8868311	2023/08/22	2023/08/22	Taslina Aktar

Bureau Veritas ID: WSK615
Sample ID: BH 400-26-1 SS4
Matrix: Soil

Collected: 2023/08/14
Shipped:
Received: 2023/08/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8867988	2023/08/22	2023/08/23	Alina Dobreanu
Conductivity	AT	8868311	2023/08/22	2023/08/22	Taslina Aktar
Moisture (Subcontracted)	BAL	8876099	N/A	2023/08/24	Simranjeet Batth
Sulphide in Soil	SPEC	8874652	N/A	2023/08/24	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8865823	2023/08/21	2023/08/21	Taslina Aktar
Redox Potential	COND	8865270	2023/08/21	2023/08/22	Gurpartee Kaur
Resistivity of Soil		8860583	2023/08/22	2023/08/22	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8868003	2023/08/22	2023/08/23	Alina Dobreanu

Bureau Veritas ID: WSK615 Dup
Sample ID: BH 400-26-1 SS4
Matrix: Soil

Collected: 2023/08/14
Shipped:
Received: 2023/08/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8867988	2023/08/22	2023/08/23	Alina Dobreanu
pH CaCl2 EXTRACT	AT	8865823	2023/08/21	2023/08/21	Taslina Aktar
Sulphate (20:1 Extract)	KONE/EC	8868003	2023/08/22	2023/08/23	Alina Dobreanu

Bureau Veritas ID: WSK616
Sample ID: BH 401-N1-1 SS5
Matrix: Soil

Collected: 2023/08/17
Shipped:
Received: 2023/08/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8867988	2023/08/22	2023/08/23	Alina Dobreanu



BUREAU
VERITAS

Bureau Veritas Job #: C3O9991

Report Date: 2023/08/25

exp Services Inc

Client Project #: ADM-22000797-A0

Site Location: Hwy 7 and Coronation Road, Whitby, ON

Sampler Initials: IB

TEST SUMMARY

Bureau Veritas ID: WSK616
Sample ID: BH 401-N1-1 SS5
Matrix: Soil

Collected: 2023/08/17
Shipped:
Received: 2023/08/17

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	8868311	2023/08/22	2023/08/22	Taslima Aktar
Moisture (Subcontracted)	BAL	8876099	N/A	2023/08/24	Simranjeet Batth
Sulphide in Soil	SPEC	8874652	N/A	2023/08/24	Princess Nicole Hernaez
pH CaCl2 EXTRACT	AT	8867940	2023/08/22	2023/08/22	Gurparteek KAUR
Redox Potential	COND	8865270	2023/08/21	2023/08/22	Gurparteek KAUR
Resistivity of Soil		8860583	2023/08/22	2023/08/22	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8868003	2023/08/22	2023/08/23	Alina Dobreanu



GENERAL COMMENTS

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

Package 1	-2.0°C
-----------	--------

Results relate only to the items tested.



BUREAU
VERITAS

Bureau Veritas Job #: C3O9991

Report Date: 2023/08/25

QUALITY ASSURANCE REPORT

exp Services Inc

Client Project #: ADM-22000797-A0

Site Location: Hwy 7 and Coronation Road, Whitby, ON

Sampler Initials: IB

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8865270	Redox Potential	2023/08/22			101	95 - 105			0.31	35
8865823	Available (CaCl ₂) pH	2023/08/21			101	97 - 103			1.1	N/A
8867940	Available (CaCl ₂) pH	2023/08/22			101	97 - 103			0.85	N/A
8867988	Soluble (20:1) Chloride (Cl ⁻)	2023/08/23	NC	70 - 130	97	70 - 130	<20	ug/g	3.8	35
8868003	Soluble (20:1) Sulphate (SO ₄)	2023/08/23	NC	70 - 130	100	70 - 130	<20	ug/g	19	35
8868311	Conductivity	2023/08/22			102	90 - 110	<2	umho/cm	0	10
8874652	Sulphide	2023/08/24	43 (1)	75 - 125	95	75 - 125	<0.5	mg/kg	6.6	30
8876099	Moisture-Subcontracted	2023/08/24					<0.30	%		

N/A = Not Applicable

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

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

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

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

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

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



BUREAU
VERITAS

Bureau Veritas Job #: C3O9991

Report Date: 2023/08/25

exp Services Inc

Client Project #: ADM-22000797-A0

Site Location: Hwy 7 and Coronation Road, Whitby, ON

Sampler Initials: IB

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Brad Newman, B.Sc., C.Chem., Scientific Service Specialist

Veronica Falk, B.Sc., P.Chem., QP, Scientific Specialist, Organics

Suwan (Sze Yeung) Fock, B.Sc., Scientific Specialist

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by {0}, {1} responsible for {2} {3} laboratory operations.

Appendix F – Slope Stability Analysis

Replacement/Rehabilitation of 25 Culverts
CV-0252-0400-0053

East side slope - 2.25H:1V or flatter
Static Conditions - Drained

Color	Name	Model	Unit Weight (kN/m ³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
Green	Clayey Silt (Very Soft to Soft)	Mohr-Coulomb	19	0	26	0
Yellow	Engineered granular fill	Mohr-Coulomb	21	0	32	0
Cyan	Sandy Silt to Silty Sand (Very Loose to Loose)	Mohr-Coulomb	19	0	27	0

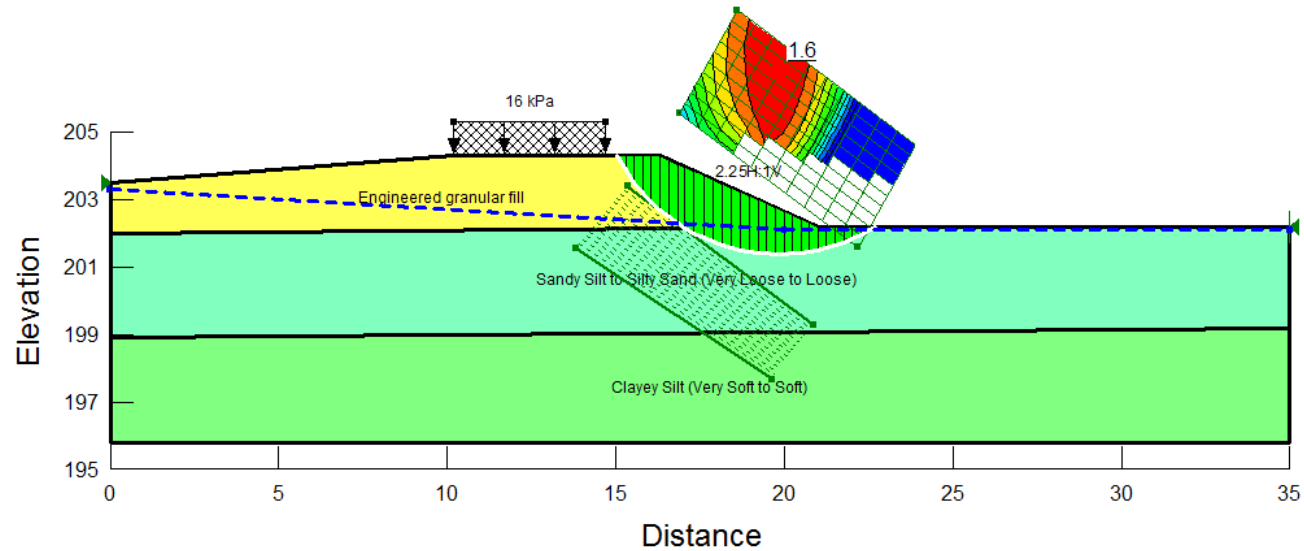





Figure F1: Slope stability analysis for new embankment reconstructed on east side slope with minimum 2.25H:1V or flatter to match existing 3.3H:1V – drained static condition

Replacement/Rehabilitation of 25 Culverts
 CV-0252-0400-0053
 North Bound Lane
 East side slope - 2.25H:1V or flatter
 Static Conditions - Undrained

Color	Name	Model	Unit Weight (kN/m ³)	Cohesion* (kPa)	Phi* (°)	Phi-B (°)	Cohesion (kPa)
	Clayey Silt (Very Soft to Soft)	Undrained (Phi=0)	19				20
	Engineered granular fill	Mohr-Coulomb	21	0	32	0	
	Sandy Silt to Silty Sand (Very Loose to Loose)	Mohr-Coulomb	19	0	27	0	

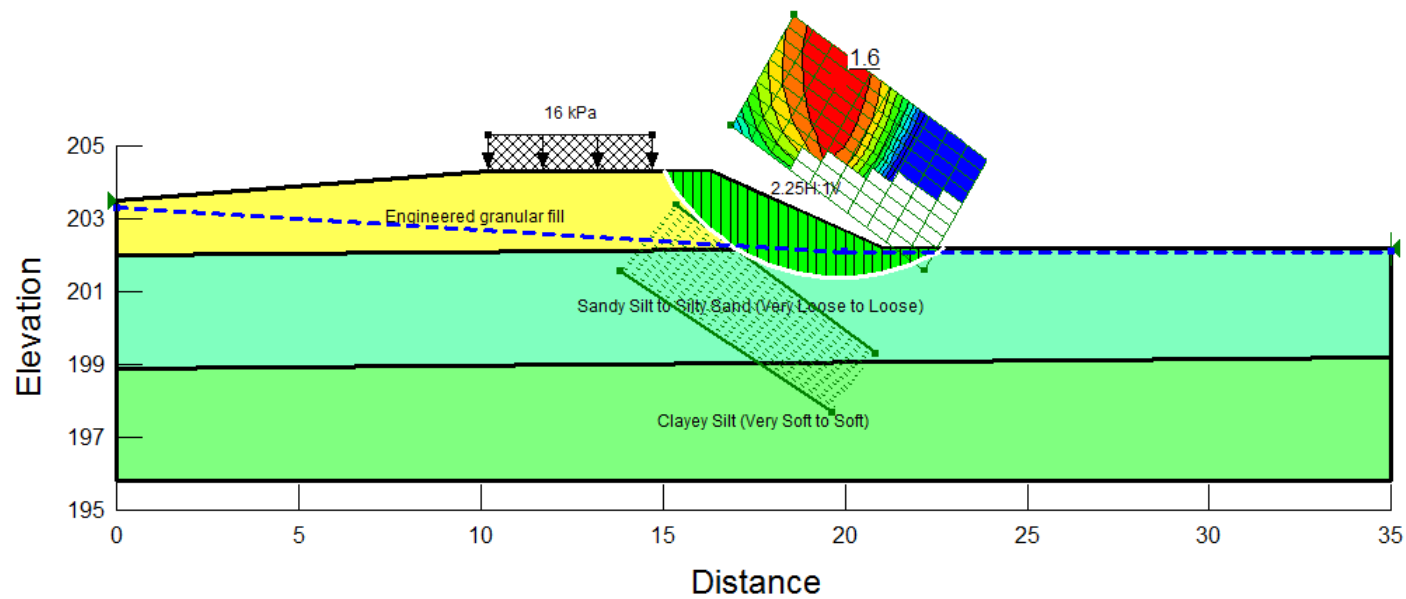


Figure F2: Slope stability analysis for new embankment reconstructed on east side slope with minimum 2.25H:1V or flatter to match existing 3.3H:1V – undrained static condition

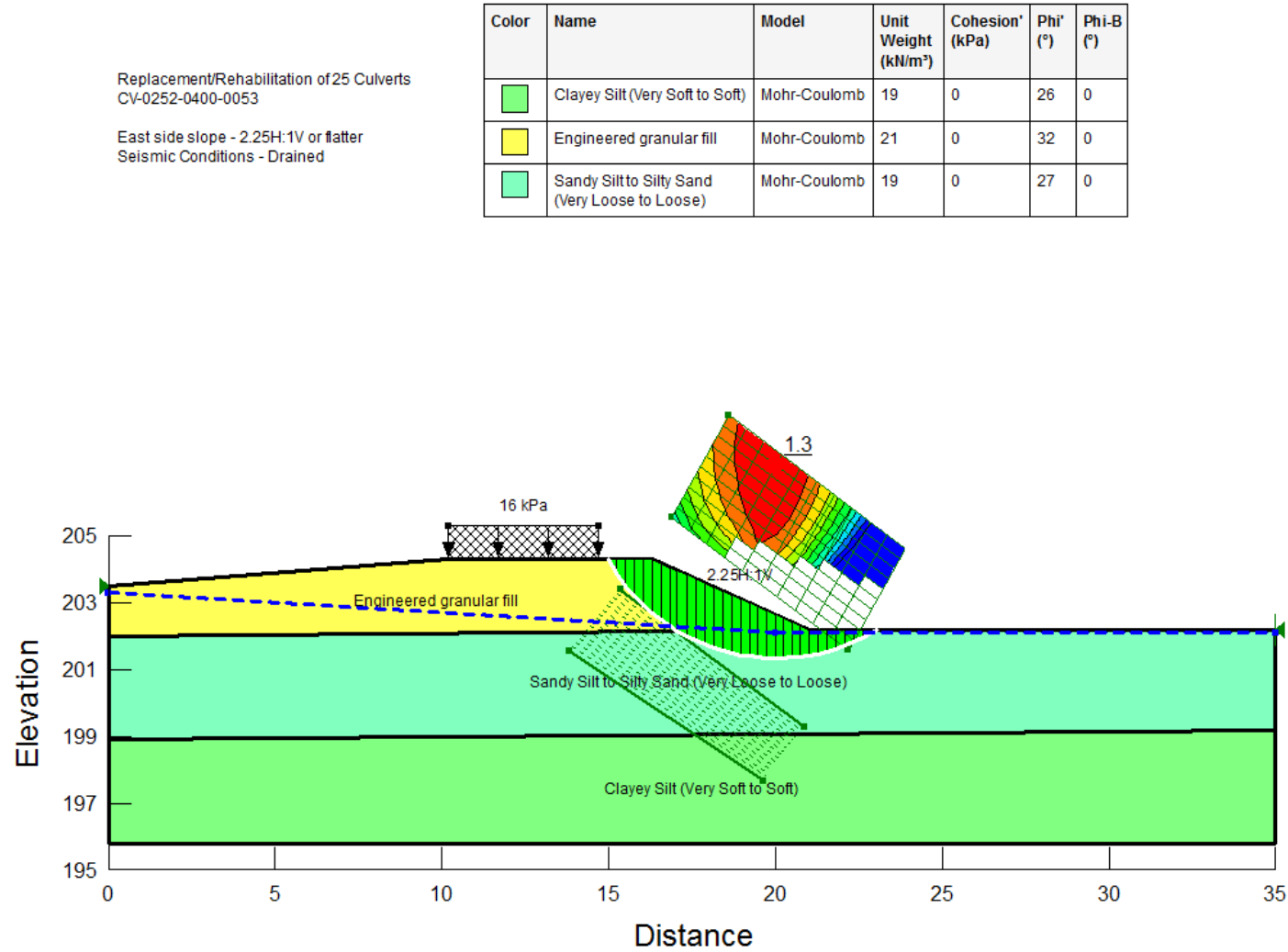





Figure F3: Slope stability analysis for new embankment reconstructed on east side slope with minimum 2.25H:1V or flatter to match existing 3.3H:1V – drained seismic condition

Replacement/Rehabilitation of 25 Culverts
CV-0252-0400-0053
Stage Construction

Proposed Forward Slope Excavation - 1H:1V
Static Conditions - Drained
Dewatered Conditions

Color	Name	Model	Unit Weight (kN/m ³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Clayey Silt (Very Soft to Soft)	Mohr-Coulomb	19	0	26	0
	Gravelly Sand to Sand Fill (Loose to Compact)	Mohr-Coulomb	21	0	32	0
	Sandy Silt to Silty Sand (Very Loose to Loose)	Mohr-Coulomb	19	0	27	0

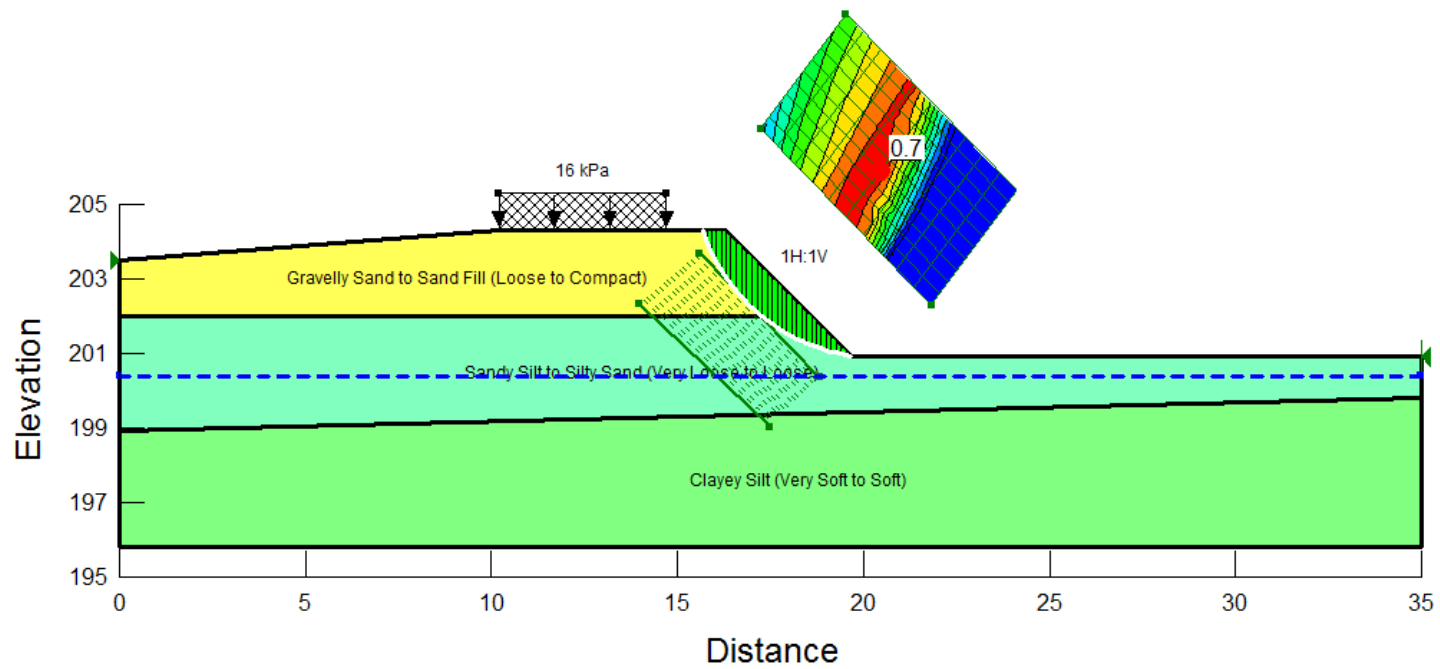





Figure F4: Temporary cut slope 1H:1V – Drained static condition- Dewatered condition

Replacement/Rehabilitation of 25 Culverts
CV-0252-0400-0053
Stage Construction

Proposed Forward Slope Excavation - 1H:1V
Static Conditions - Undrained
Dewatered Conditions

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Clayey Silt (Very Soft to Soft)	Mohr-Coulomb	19	0	26	0
	Gravelly Sand to Sand Fill (Loose to Compact)	Mohr-Coulomb	21	0	32	0
	Sandy Silt to Silty Sand (Very Loose to Loose)	Mohr-Coulomb	19	0	27	0

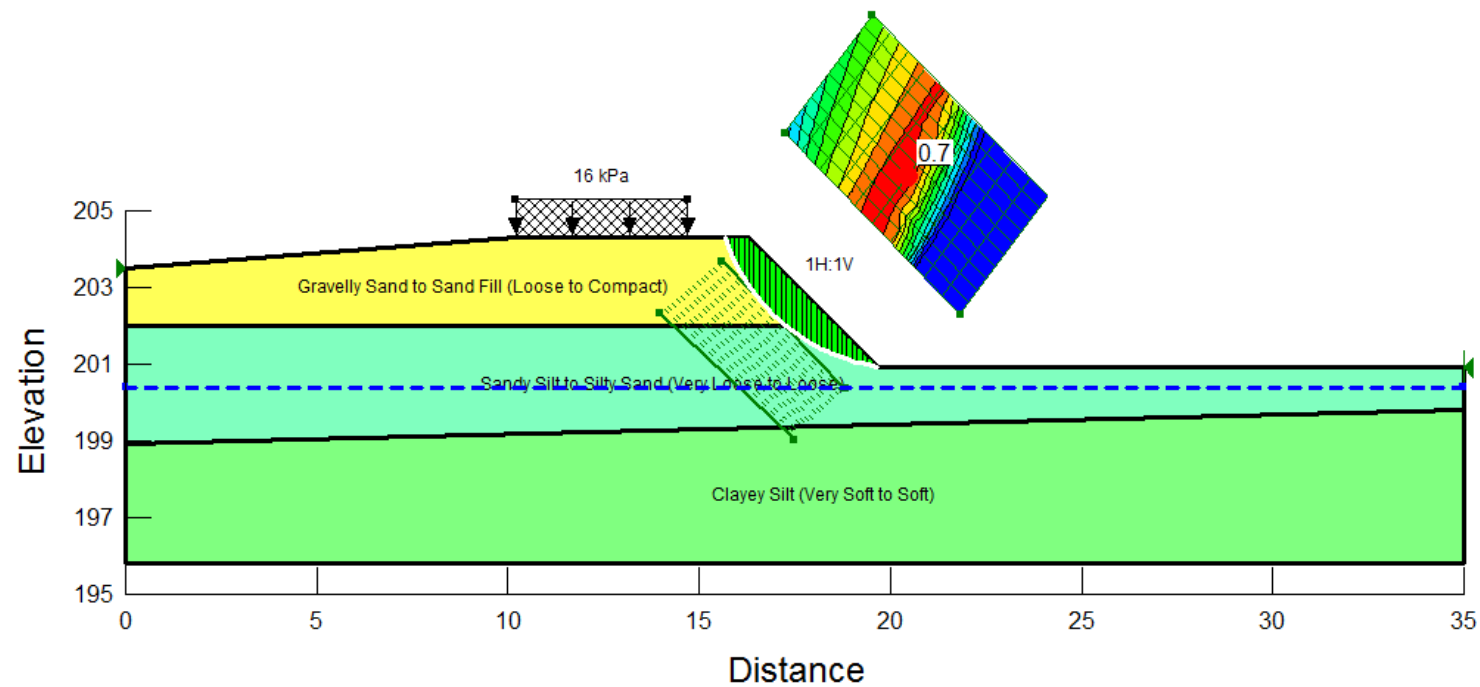





Figure F5: Temporary cut slope 1H:1V – Undrained static condition- Dewatered condition

Replacement/Rehabilitation of 25 Culverts
CV-0252-0400-0053
Stage Construction

Proposed Forward Slope Excavation - 1.5H:1V
Static Conditions - Drained
Dewatered Conditions

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Clayey Silt (Very Soft to Soft)	Mohr-Coulomb	19	0	26	0
	Gravelly Sand to Sand Fill (Loose to Compact)	Mohr-Coulomb	21	0	32	0
	Sandy Silt to Silty Sand (Very Loose to Loose)	Mohr-Coulomb	19	0	27	0

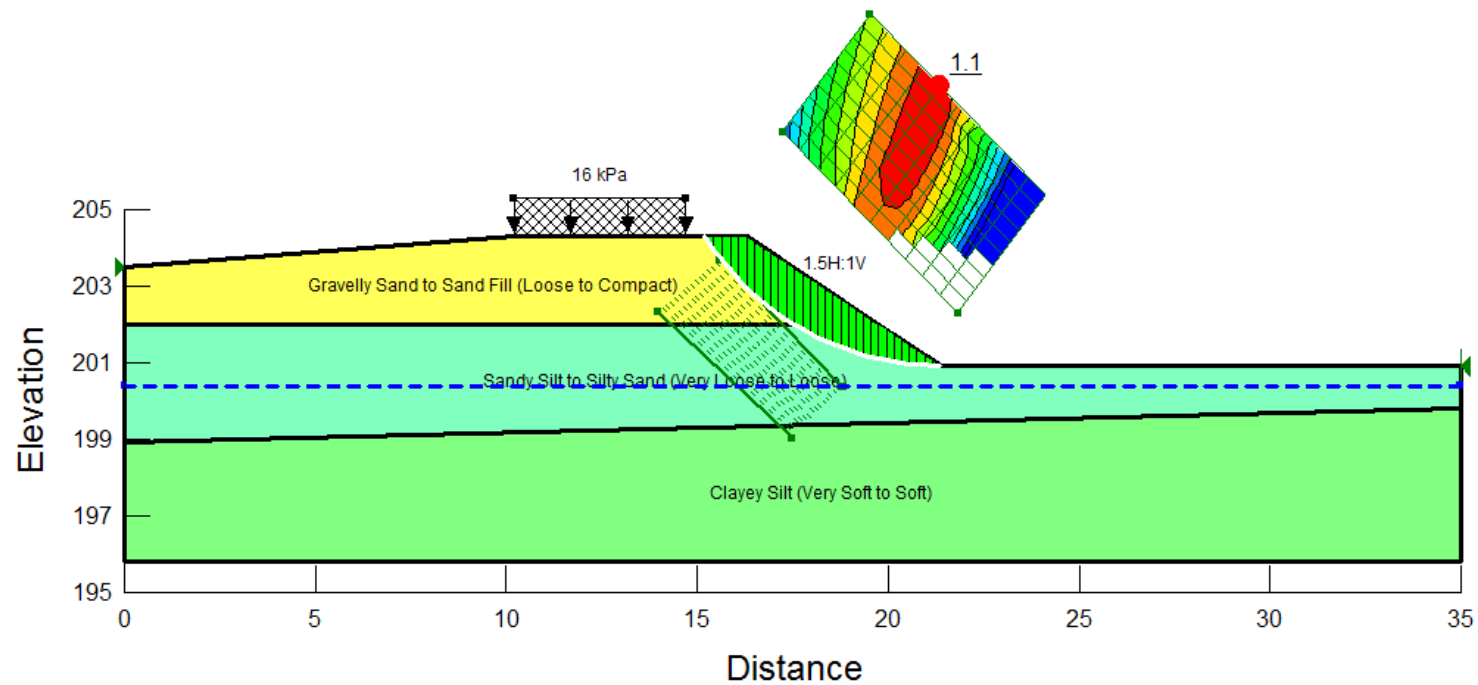





Figure F6: Temporary cut slope 1.5H:1V – Drained static condition- Dewatered condition

Replacement/Rehabilitation of 25 Culverts
CV-0252-0400-0053
Stage Construction

Proposed Forward Slope Excavation - 1.5H:1V
Static Conditions - Undrained
Dewatered Conditions

Color	Name	Model	Unit Weight (kN/m ³)	Cohesion* (kPa)	Phi* (°)	Phi-B (°)	Cohesion (kPa)
	Clayey Silt (Very Soft to Soft)	Undrained (Phi=0)	19				20
	Gravelly Sand to Sand Fill (Loose to Compact)	Mohr-Coulomb	21	0	32	0	
	Sandy Silt to Silty Sand (Very Loose to Loose)	Mohr-Coulomb	19	0	27	0	

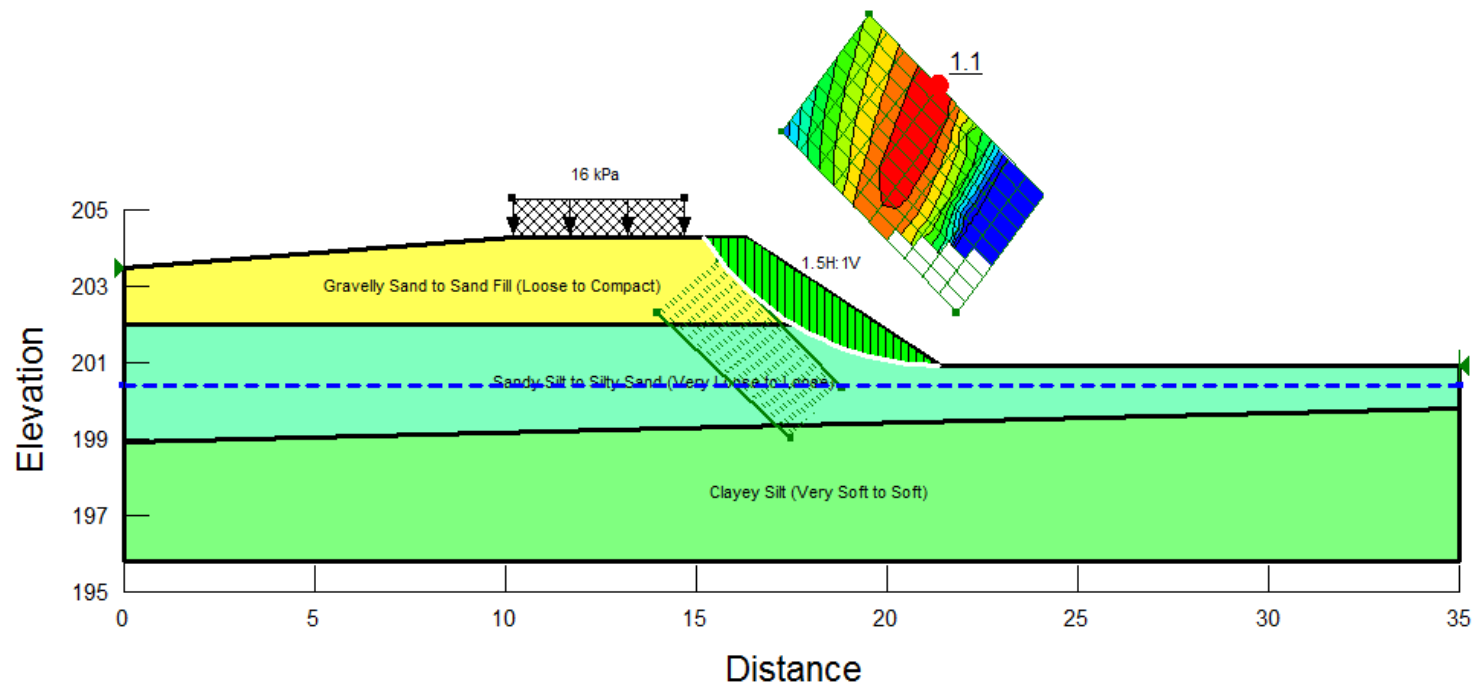





Figure F7: Temporary cut slope 1.5H:1V – Undrained static condition- Dewatered condition

Replacement/Rehabilitation of 25 Culverts
CV-0252-0400-0053
Stage Construction

Proposed Forward Slope Excavation - 1.8H:1V
Static Conditions - Drained
Dewatered Conditions

Color	Name	Model	Unit Weight (kN/m ³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Clayey Silt (Very Soft to Soft)	Mohr-Coulomb	19	0	26	0
	Gravelly Sand to Sand Fill (Loose to Compact)	Mohr-Coulomb	21	0	32	0
	Sandy Silt to Silty Sand (Very Loose to Loose)	Mohr-Coulomb	19	0	27	0

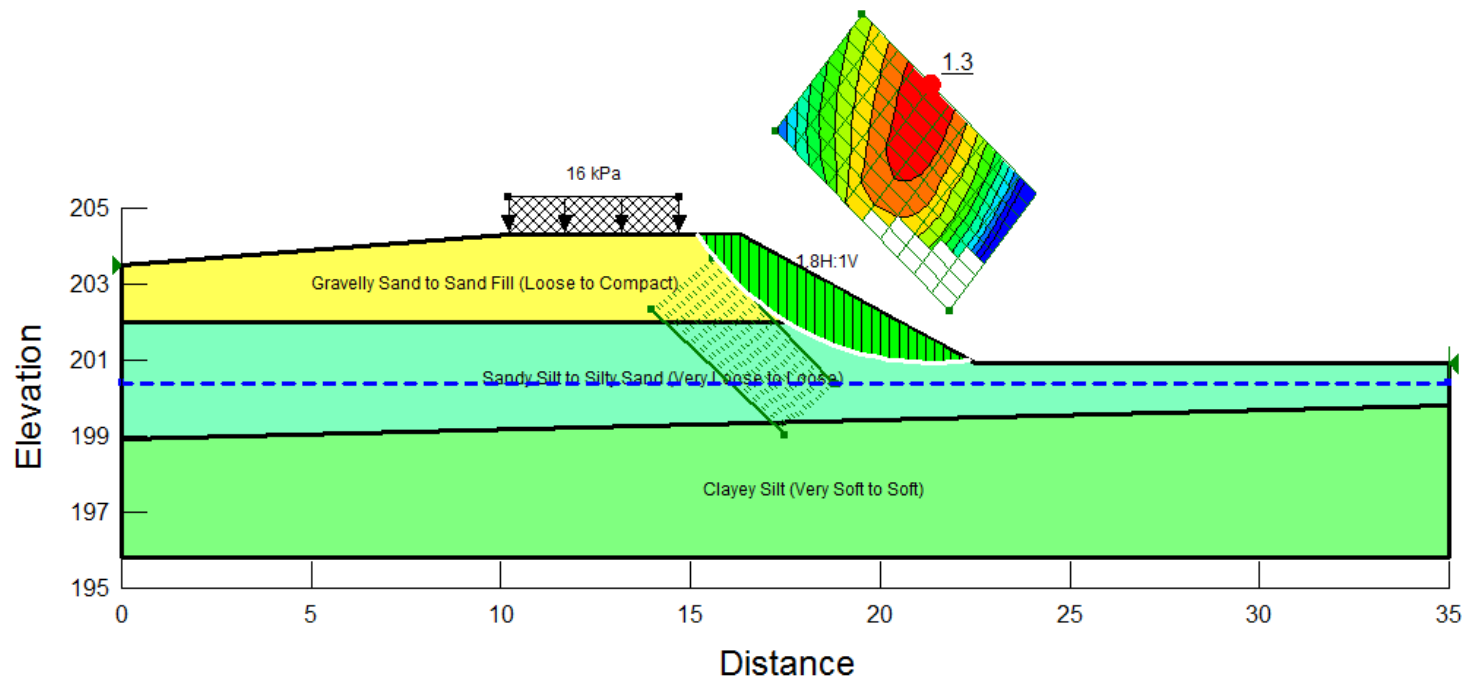





Figure F8: Temporary cut slope 1.8H:1V – Drained static condition- Dewatered condition

Replacement/Rehabilitation of 25 Culverts
CV-0252-0400-0053
Stage Construction

Proposed Forward Slope Excavation - 1.8H:1V
Static Conditions - Undrained
Dewatered Conditions

Color	Name	Model	Unit Weight (kN/m ³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Cohesion (kPa)
	Clayey Silt (Very Soft to Soft)	Undrained (Phi=0)	19				20
	Gravelly Sand to Sand Fill (Loose to Compact)	Mohr-Coulomb	21	0	32	0	
	Sandy Silt to Silty Sand (Very Loose to Loose)	Mohr-Coulomb	19	0	27	0	

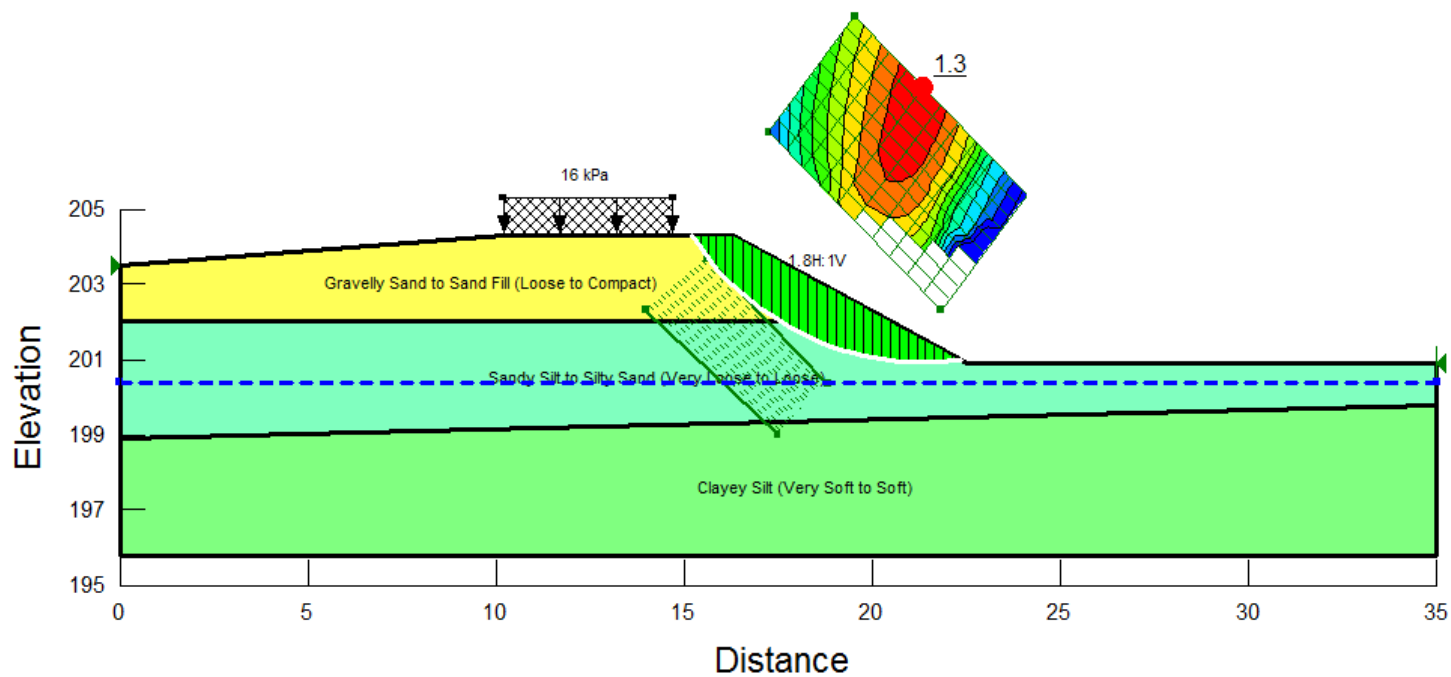
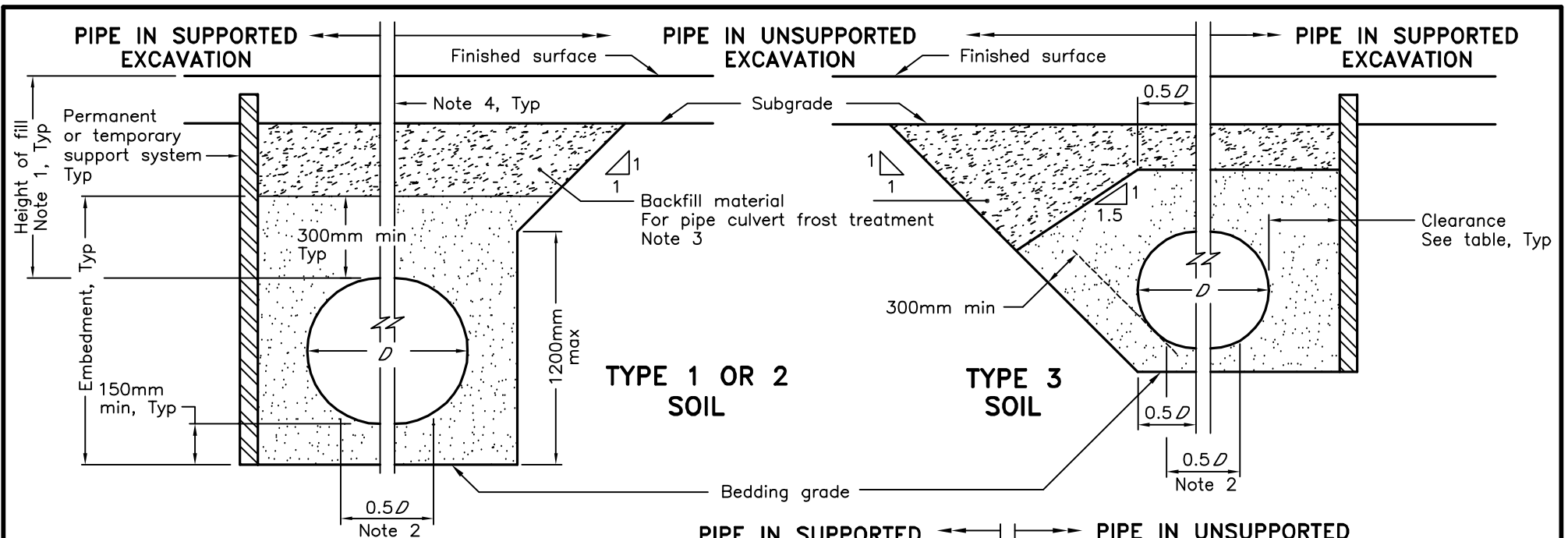


Figure F9: Temporary cut slope 1.8H:1V – Undrained static condition- Dewatered condition

Appendix G – OPSDs

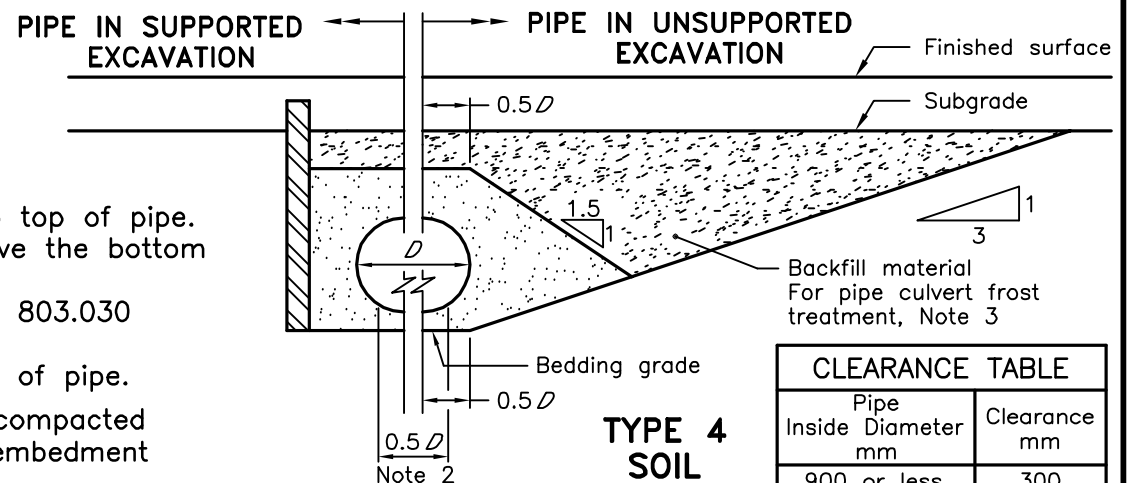


LEGEND:

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 2014

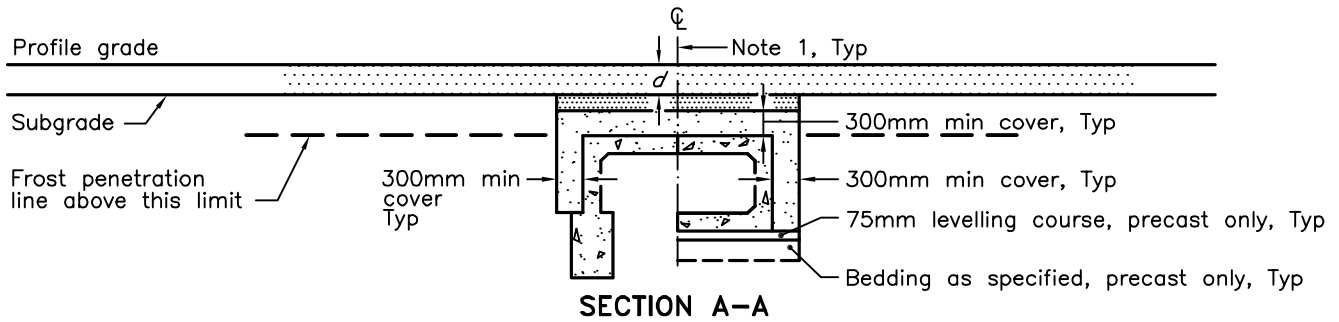
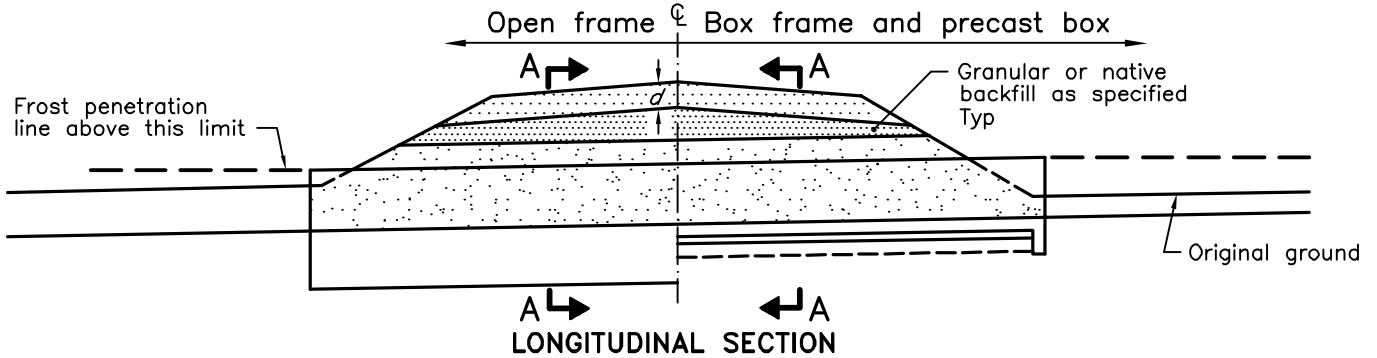
Rev 3

FLEXIBLE PIPE
EMBEDMENT AND BACKFILL
EARTH EXCAVATION

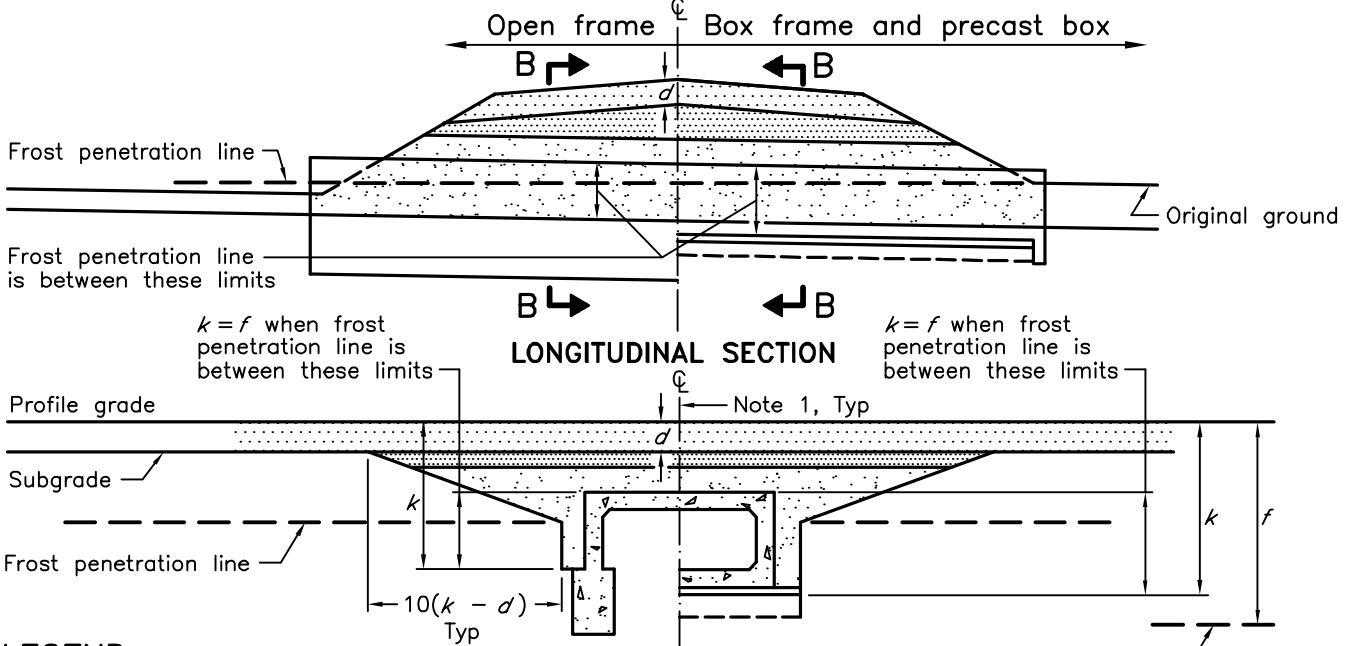
OPSD 802.010



FROST PENETRATION LINE AT OR ABOVE TOP OF CULVERT



FROST PENETRATION LINE BELOW TOP OF CULVERT



LEGEND:

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

NOTES:

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

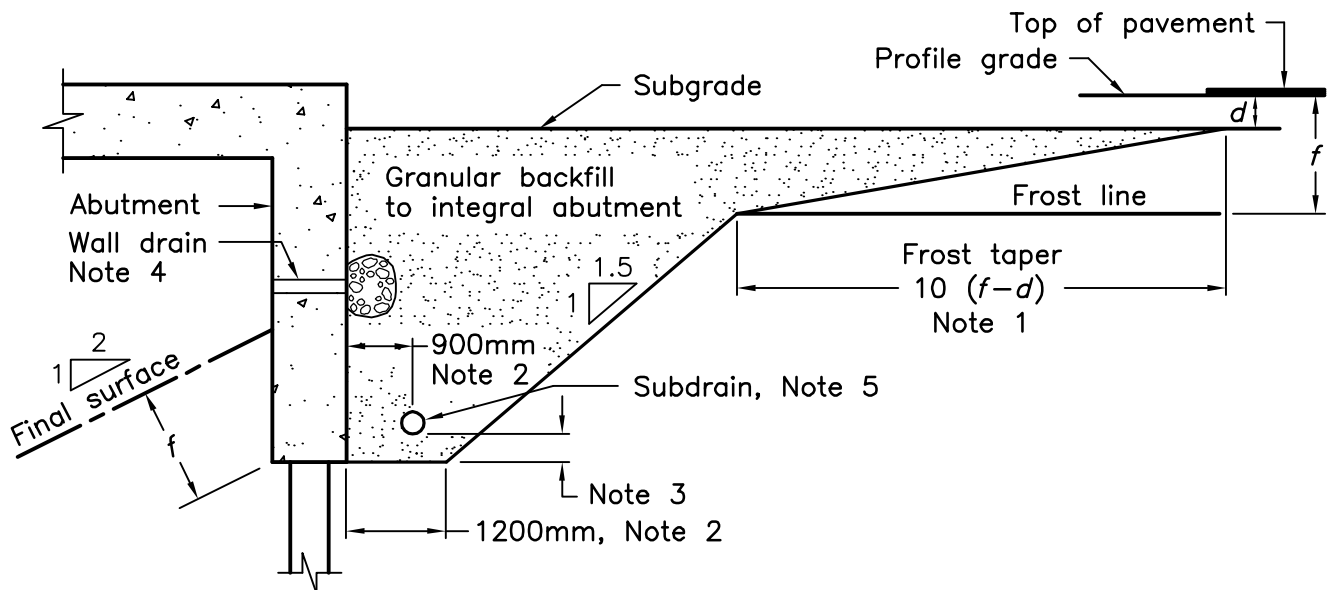
ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2010 Rev 2

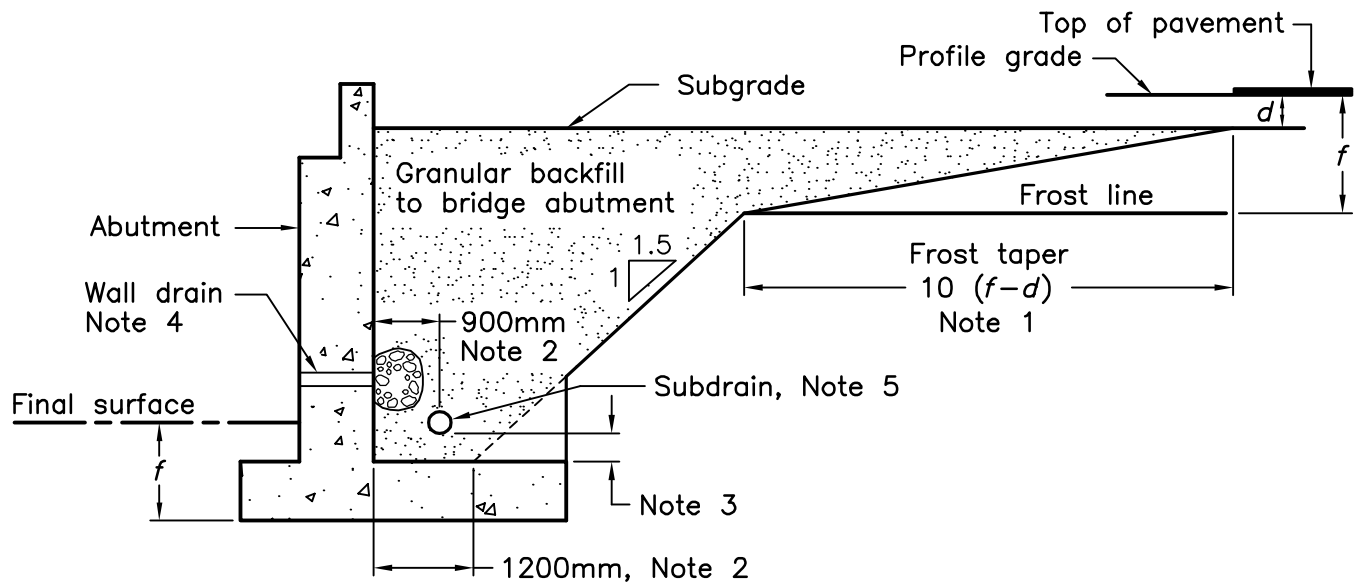
**BACKFILL AND COVER FOR
CONCRETE CULVERTS WITH SPANS
LESS THAN OR EQUAL TO 3.0M**

OPSD 803.010





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

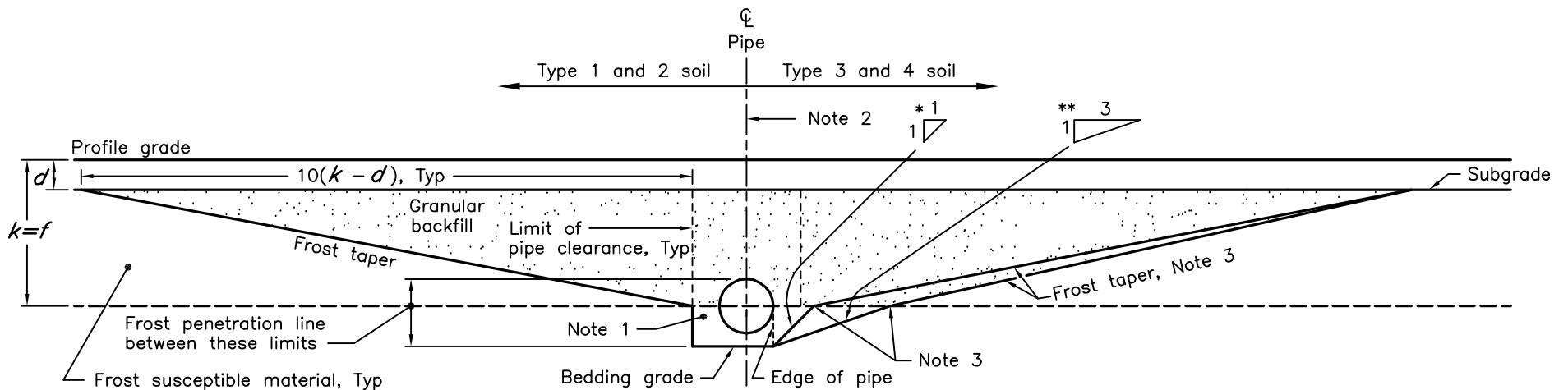
Nov 2010

Rev 1



WALLS
ABUTMENT, BACKFILL
MINIMUM GRANULAR REQUIREMENT

OPSD 3101.150



FROST TREATMENT RIGID AND FLEXIBLE PIPE

NOTES:

- 1 Pipe embedment or bedding, cover, and backfill shall be according to:
 - a) Flexible OPSD 802.010, 802.013, 802.014, 802.020, 802.023, and 802.024.
 - b) Rigid – OPSD 802.030, 802.031, 802.032, 802.033, 802.034, 802.050, 802.051, 802.052, 802.053, and 802.054.
- 2 Condition of frost treatment symmetrical about centreline of pipe.
- 3 Frost tapers shall start at the intersection of the 1H:1V or 3H:1V slope and the frost penetration line.
- A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

LEGEND:

- d – depth of roadbed granular
 k – depth of frost treatment below profile grade
 f – depth of frost penetration below profile grade
 $*$ – Type 3 soil
 $**$ – Type 4 soil

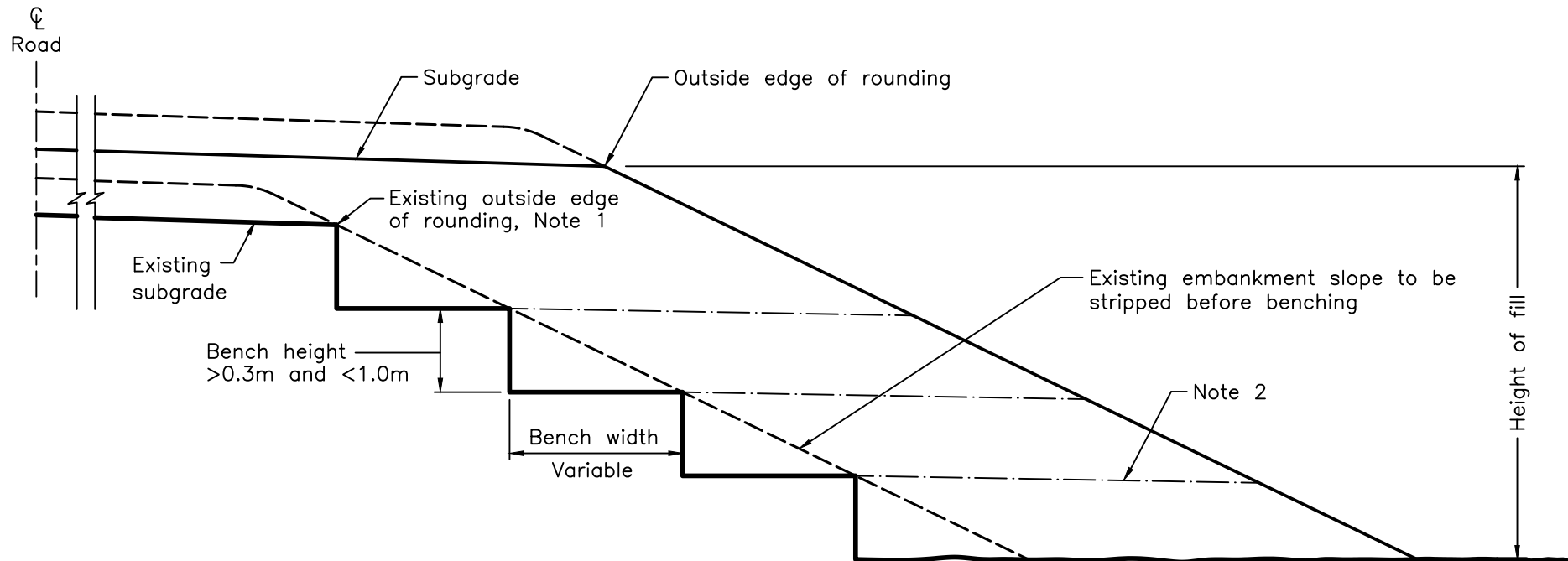
ONTARIO PROVINCIAL STANDARD DRAWING

FROST TREATMENT – PIPE CULVERTS
FROST PENETRATION LINE BETWEEN
TOP OF PIPE AND BEDDING GRADE

Nov 2015 Rev 4



OPSD 803.031



NOTES:

- 1 When the subgrade is below the existing outside edge of rounding, benching shall be carried out below the point where the subgrade intersects the existing slope.
 - 2 Benches shall be excavated one level at a time and the fill placed and compacted before the next bench is excavated.
- A Benching is not required on existing slopes flatter than 3H:1V.

ONTARIO PROVINCIAL STANDARD DRAWING

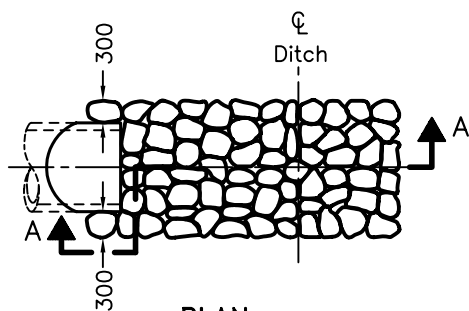
Apr 2019

Rev 4

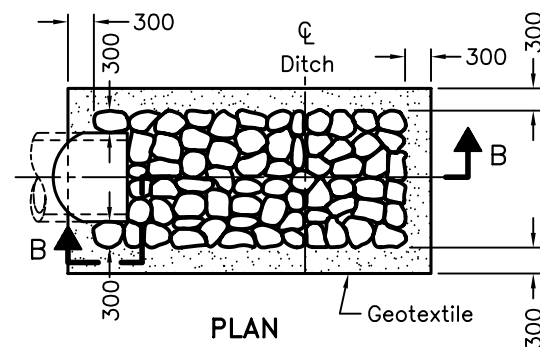
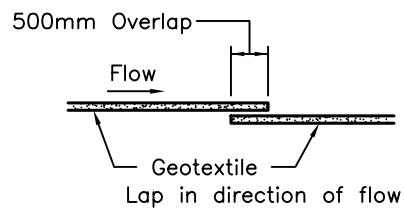
BENCHING OF EARTH SLOPES

OPSD 208.010

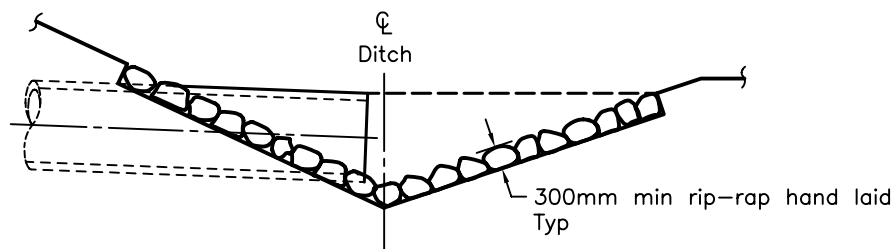




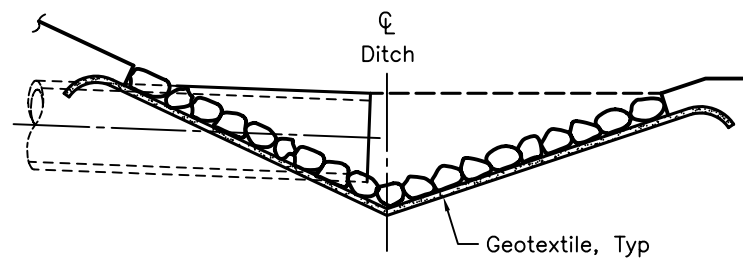
PLAN
CUT OR FILL



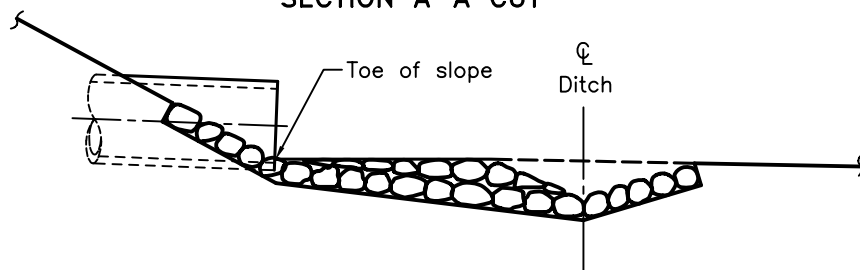
PLAN
CUT OR FILL



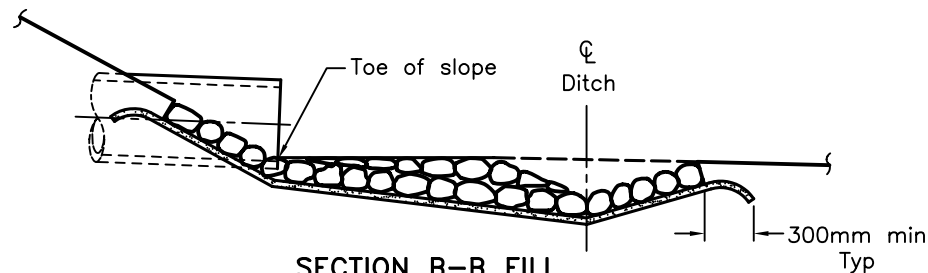
SECTION A-A CUT



SECTION B-B CUT



SECTION A-A FILL
TYPE A – WITHOUT GEOTEXTILE



SECTION B-B FILL
TYPE B – WITH GEOTEXTILE

NOTES:

A All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

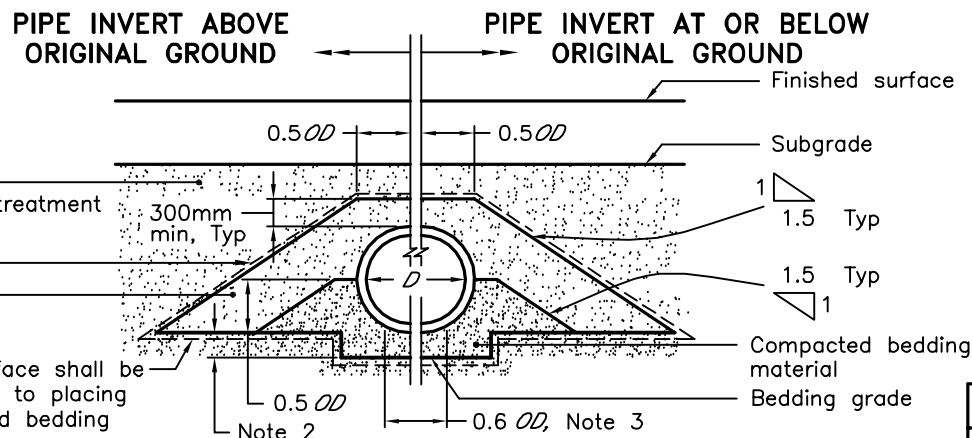
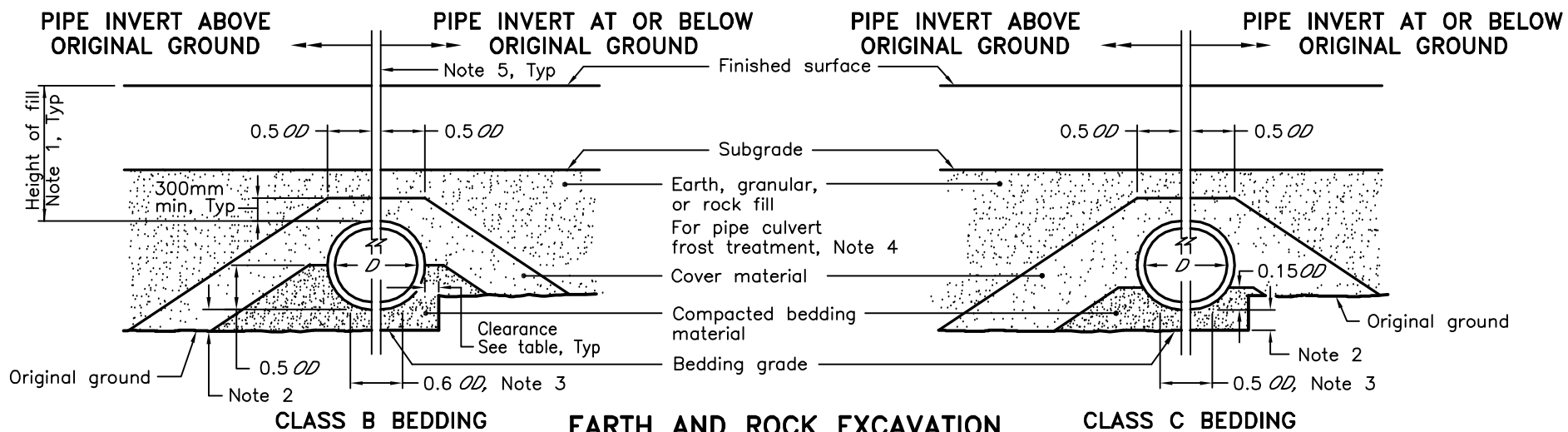
RIP-RAP TREATMENT
FOR SEWER AND CULVERT OUTLETS

Nov 2001

Rev 0



OPSD – 810.010



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 $0.15D$, except on a rock foundation where the minimum bedding depth shall be $0.25D$. In no case shall the minimum 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.
- 6 Bedding and cover material shall be wrapped in non-woven geotextile when specified.

A 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

**RIGID PIPE BEDDING AND COVER
IN EMBANKMENT**
ORIGINAL GROUND: EARTH OR ROCK

Nov 2015

Rev 3

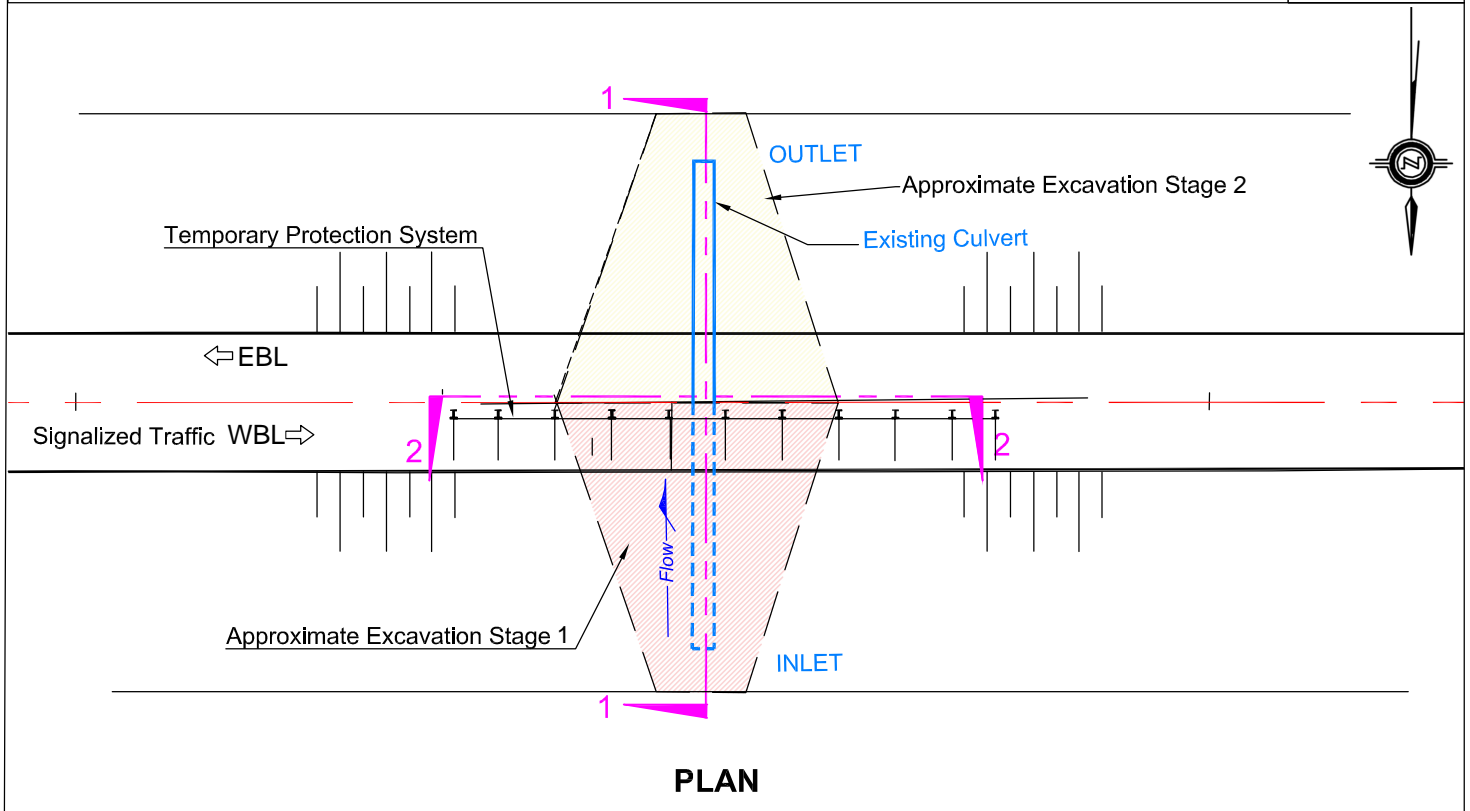


OPSD 802.034

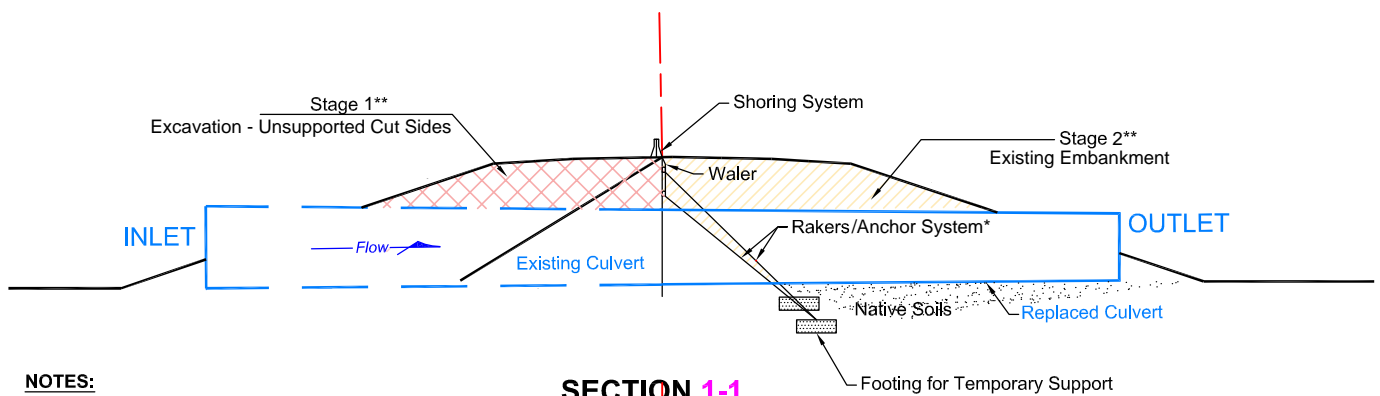
Appendix H – Schematic Diagrams

FIGURE H1A: HALF AND HALF CONSTRUCTION WITH UNSUPPORTED CUT SIDES

SCHEMATIC DIAGRAMS (NST)



Half and Half Construction, Shoring System with either Cut or Anchor System - Unsupported Cut



NOTES:

* Rakers or Anchor System

** Stage 2 Following Stage 1 in Opposite Way

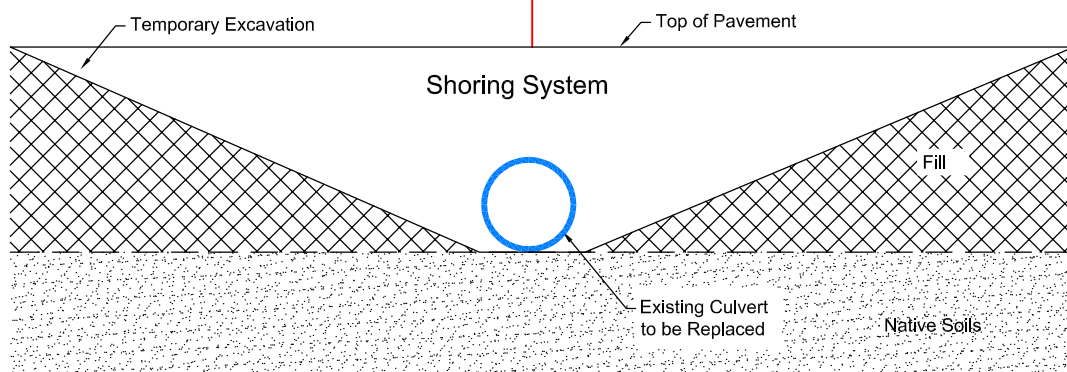
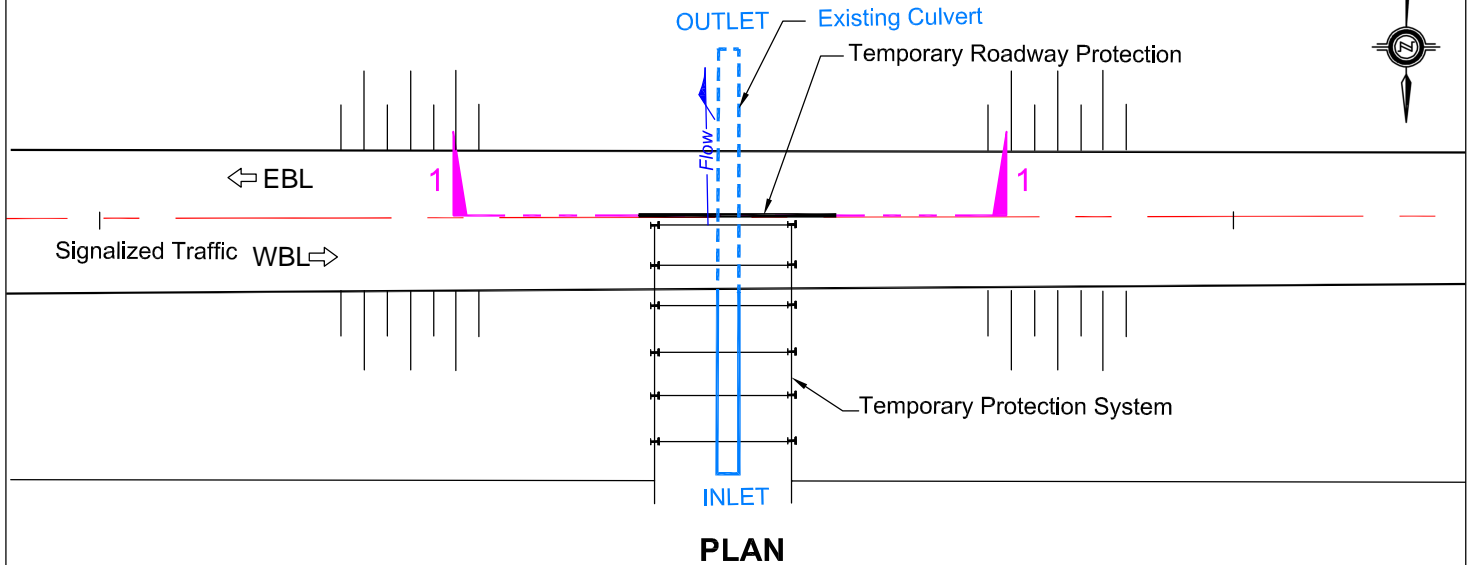


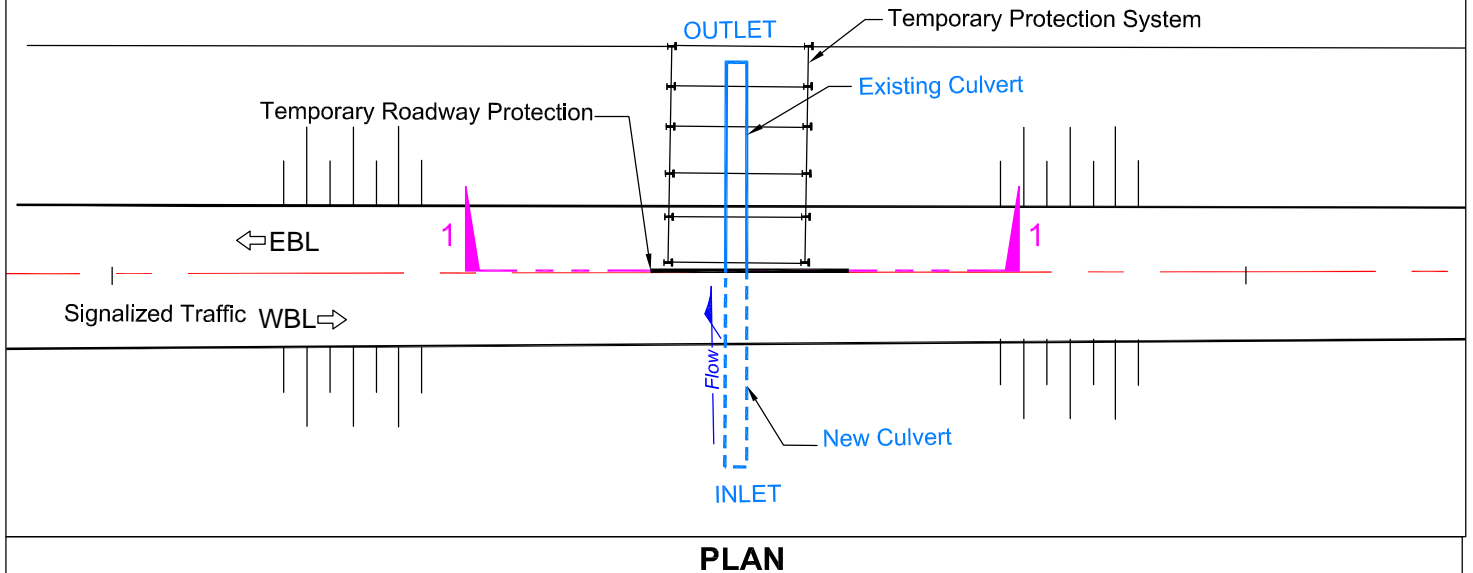
FIGURE H1B: HALF AND HALF CONSTRUCTION WITH BRACED CUT SIDES OR ANCHOR SYSTEM
SCHEMATIC DIAGRAMS (NST)



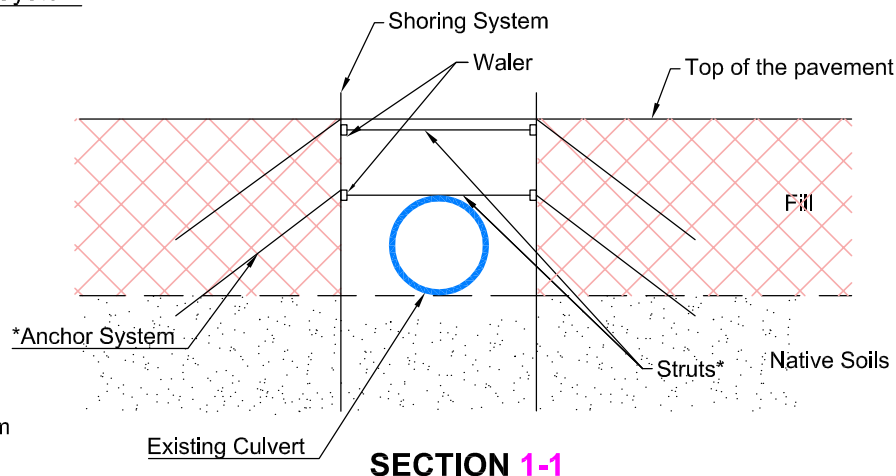
Stage 1



Stage 2



Half and half Construction, Shoring System- Braced Cut Struts or Anchor System



NOTE:

* Struts or Anchor System

Appendix I – Seismic Hazard Calculation



Government
of Canada

Gouvernement
du Canada

Canada.ca › [Natural Resources Canada](#) › [Earthquakes Canada](#)

2020 National Building Code of Canada Seismic Hazard Tool

i This application provides seismic values for the design of buildings in Canada under Part 4 of the National Building Code of Canada (NBC) 2020 as prescribed in Article 1.1.3.1. of Division B of the NBC 2020.

Seismic Hazard Values

User requested values

Code edition	NBC 2020
Site designation X_s	X_E
Latitude (°)	44.645
Longitude (°)	-79.652

Please select one of the tabs below.

NBC 2020

Additional Values

Plots

API

Background Information

The 5%-damped spectral acceleration ($S_a(T,X)$, where T is the period, in s, and X is the site designation) and peak ground acceleration ($PGA(X)$) values are given in units of acceleration due to gravity (g , 9.81 m/s^2). Peak

ground velocity. (PGV(X)) values are given in m/s. Probability is expressed in terms of percent exceedance in 50 years. Further information on the calculation of seismic hazard is provided under the *Background Information* tab.

The 2%-in-50-year seismic hazard values are provided in accordance with Article 4.1.8.4. of the NBC 2020. The 5%- and 10%-in-50-year values are provided for additional performance checks in accordance with Article 4.1.8.23. of the NBC 2020.

See the *Additional Values* tab for additional seismic hazard values, including values for other site designations, periods, and probabilities not defined in the NBC 2020.

NBC 2020 - 2%/50 years (0.000404 per annum) probability

$S_a(0.2, X_E)$	$S_a(0.5, X_E)$	$S_a(1.0, X_E)$	$S_a(2.0, X_E)$	$S_a(5.0, X_E)$	$S_a(10.0, X_E)$	PGA(X_E)	PGV(X_E)
0.28	0.318	0.2	0.0975	0.0261	0.00806	0.153	0.201

The log-log interpolated 2%/50 year $S_a(4.0, X_E)$ value is : **0.0360**

▼ Tables for 5% and 10% in 50 year values

NBC 2020 - 5%/50 years (0.001 per annum) probability

$S_a(0.2, X_E)$	$S_a(0.5, X_E)$	$S_a(1.0, X_E)$	$S_a(2.0, X_E)$	$S_a(5.0, X_E)$	$S_a(10.0, X_E)$	PGA(X_E)	PGV(X_E)
0.173	0.196	0.119	0.0564	0.0141	0.00437	0.0944	0.115

The log-log interpolated 5%/50 year $S_a(4.0, X_E)$ value is : **0.0198**

NBC 2020 - 10%/50 years (0.0021 per annum) probability

$S_a(0.2, X_E)$	$S_a(0.5, X_E)$	$S_a(1.0, X_E)$	$S_a(2.0, X_E)$	$S_a(5.0, X_E)$	$S_a(10.0, X_E)$	PGA(X_E)	PGV(X_E)
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$S_a(0.2, X_E)$	$S_a(0.5, X_E)$	$S_a(1.0, X_E)$	$S_a(2.0, X_E)$	$S_a(5.0, X_E)$	$S_a(10.0, X_E)$	PGA(X_E)	PGV(X_E)
0.112	0.126	0.0748	0.0339	0.0079	0.00246	0.0609	0.0697

The log-log interpolated 10%/50 year $S_a(4.0, X_E)$ value is : **0.0113**

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Date modified: 2021-04-06

Appendix J – NSSPs

NSSP FOR OBSTRUCTIONS

Scope of Work

The Contractor shall be alerted to the potential presence of cobbles and boulders in the fill. Therefore, appropriate equipment and procedures will be required for open cut excavation and installation of roadway protection systems and temporary dewatering/unwatering 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.