



## **FINAL REPORT**

### **FOUNDATION INVESTIGATION AND DESIGN REPORT**

**Culvert Replacement, Highway 6, 1.03 km south of Side Road 3WGR, West Grey  
Municipality, Grey County**

**Agreement No. 3015-E-0017**

**Assignment No. 3**

**GWP 3062-14-00**

**Geocres No. 41A-239**

**Prepared for:**

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January 11, 2017

# Ministry of Transportation

## Western Region – Geotechnical Section

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Foundation Investigation and Design Report for Culvert Replacement

Highway 6, 1.03 km south of Side Road 3 WGR, West Grey Municipality, Grey County, ON

#### Project Number:

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# Table of Contents

<b>PART I:</b>	<b>FOUNDATION INVESTIGATION REPORT .....</b>	<b>1</b>
1.1	Introduction .....	1
1.2	Site Description and Geological Setting .....	1
1.2.1	Site Description.....	1
1.2.2	Geological Setting.....	2
1.3	Investigation Procedures .....	2
1.3.1	Site Investigation and Field Testing.....	2
1.3.2	Laboratory Testing.....	3
1.4	Subsurface Conditions .....	3
1.4.1	Asphalt.....	4
1.4.2	Topsoil .....	4
1.4.3	Fill: Sand and Gravel .....	4
1.4.4	Fill: Silty Sand/Silty Sand and Gravel.....	5
1.4.5	Silty Sand and Gravel.....	5
1.4.6	Sand and Silt .....	6
1.4.7	Bedrock.....	6
1.5	Groundwater & Surface Water Conditions .....	7
1.6	Chemical Analyses .....	7
<b>PART II:</b>	<b>ENGINEERING DISCUSSION &amp; RECOMMENDATIONS .....</b>	<b>9</b>
2.1	General .....	9
2.2	Expected Ground Conditions.....	9
2.3	Structure Foundations .....	10
2.3.1	Shallow Foundations .....	12
2.4	Lateral Earth Pressure.....	13
2.5	Seismic and Liquefaction Potential Consideration .....	14
2.6	Construction Alternatives.....	15
2.6.1	Half-and-Half Construction (Options 1) .....	18
2.7	Temporary Roadway Protection .....	20
2.8	Culvert Bedding .....	21
2.9	Culvert Backfill .....	22
2.10	Groundwater and Surface Water Control .....	22

2.11	Embankment Design .....	23
2.12	Inlet and Outlet .....	24
2.13	Corrosion Protection .....	26
<b>PART III:</b>	<b>CLOSURE .....</b>	<b>27</b>
<b>PART IV:</b>	<b>LIMITATIONS AND USE OF REPORT .....</b>	<b>28</b>

## List of Appendices

### Appendix

Site Photographs .....	A
Drawings.....	B
Borehole Logs .....	C
Laboratory Data.....	D
Rock Core Photographs .....	E
Result of Stability Analysis .....	F
Ontario Provincial Standard Drawings .....	G
Schematic Sketches for Construction Alternatives .....	H
Non-Standard Special Provision (NSSP) .....	I

## **PART I: FOUNDATION INVESTIGATION REPORT**

### **1.1 Introduction**

This foundation investigation report presents the results of a geotechnical investigation completed by **exp** Services Inc. (**exp**) for the replacement of an existing concrete culvert located on Highway 6, at station 25+643, approximately 1.03 km south of Side Road 3 WGR in West Grey municipality, Grey county part of the Ministry of Transportation (MTO) West Region. The work was undertaken under Agreement No. 3015-E-0017, Assignment No. 3. The terms of reference (TOR) were as presented in the MTO document entitled "Foundation Engineering Terms of Reference, MTO West Region – Foundations Retainer Assignment, Assignment 3 – Culvert Replacement Hwy 3 Jarvis and Hwy 6 Dundalk" provided via e-mail on October 13, 2016.

The purpose of the investigation is to determine the subsurface conditions along the culvert alignment and to permit detailed design for the culvert replacement including temporary protection systems for culvert replacement. The site specific geotechnical investigation consisted of borings, soil and bedrock sampling, borehole logging, and field and laboratory testing.

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

### **1.2 Site Description and Geological Setting**

#### **1.2.1 Site Description**

At the culvert replacement site location, Highway 6 is a two-lane asphalt roadway and is about 7.0 m wide from edge to edge of asphalt, with approximately 2.2 m wide sand and gravel shoulders on both sides. Based on the observations, the roadway embankment is less than 2m high with side slope of about 3H:1V.

Based on the CAD drawings provided by the MTO, the existing culvert is a 0.91 m × 0.91 m × 25.5 m concrete rigid framed- open footing structure. The existing culvert is intended to be replaced with a new culvert along the same alignment. Select photographs of the site and existing culvert are presented in Appendix A. The site plan and cross-section profiles for the proposed culvert alignment are shown on the drawing attached in Appendix B.

The area surrounding the culvert site is generally flat land with private property on both east and west side. In the vicinity of the culvert at inlet and outlet embankments are primarily grass covered becoming generally trees and shrub covered towards private property. A mix of low lying vegetation/shrubs were observed on the stream bank at both inlet and outlet sides, and in the path of the stream on the inlet side. However, no visible sign of flow restriction was observed due to the vegetation.

Highway 6 runs in a north-south direction and the water in culvert flows from east to west beneath the highway. At the time of investigation, the elevation of the water in the culvert was approximately 345.9 m. The elevation of highway centerline at the culvert centerline is approximately 347.9 m.

The general site conditions in the immediate vicinity of the culvert were assessed during the site reconnaissance and drilling operations between November 16, 2016 and November 18, 2016. The embankments were noted to be in an overall stable configuration with no obvious indications of recent slope movement. Some longitudinal cracking was observed on south bound lane on south of culvert at the site. Due to the water in the culvert, existing foundation observation was restricted. However, based on visual observation, the culvert appeared to be in satisfactory condition with no significant damage.

## **1.2.2 Geological Setting**

The Map P.2715 (Physiography of Southern Ontario, Third Edition, 1984) Bedrock Geology of Ontario, Southern Sheet, 1991) of the Ministry of Natural Resources indicates that the project area is located in a shallow till and rock ridges. The Map 2556 (Quaternary Geology of Ontario, Southern Sheet, 1991) of the Ministry of Northern Development and Mines, indicates that the surface conditions consist of glaciofluvial outwash deposits including gravel and sand; includes proglacial river and deltaic deposits. The Map 2544 (Bedrock Geology of Ontario, Southern Sheet, 1991) of the Ministry of Northern Development and Mines, indicates that the bedrock formation in the project area consists of guelph formation of sandstone, shale, dolostone, siltstone.

## **1.3 Investigation Procedures**

### **1.3.1 Site Investigation and Field Testing**

The field investigation was performed between November 16 and 18, 2016. The field program consisted of drilling five (5) sampled boreholes, numbered BH-1 to BH-5. Three (3) boreholes were strategically located along the existing culvert alignment to provide subsurface information for the design of the proposed new culvert. Boreholes BH-1 and BH-2 were advanced at accessible locations near the outlet and inlet of the culvert, respectively. Borehole BH-4 was advanced within the travelled southbound lane and located about 2.3 m south of the culvert centerline. Two (2) additional boreholes (BH-3 and BH-5) were strategically located on the embankment to provide subsurface information for the temporary roadway protection. Boreholes BH-3 and BH-5 were advanced in the southbound and northbound travelled lane approximately 25 m north and south side of the existing culvert, respectively. Two additional holes BH-1A and BH-1B were advanced about 1.1 m and 2.2 m north, respectively, from BH-1 to verify the depth of refusal and in these additional holes the refusal was encountered generally at similar depth that encountered in BH-1. The borehole locations are shown on Drawing No. 1 in Appendix B.

Four boreholes (BH-1, BH-2, BH-3 and BH-5) were advanced using a rubber tire mounted buggy CME 75 drill rig equipped with hollow stem augers and standard soil sampling equipment, operated by a specialist drilling contractor, Ontario Soil Drilling. Since due to not availability of rock coring equipment with drill rig operated by Ontario Soil Drilling, the BH-4 was advanced using a truck mounted CME 75 drill rig equipped with how stem augers and standard soil sampling equipment, operated by a specialist drilling contractor, Aardvark Drilling. The boreholes were advanced to auger refusal on the bedrock surface at depths ranging from 2.1 m to 5.8 m below the ground surface. Samples of the bedrock were retrieved at Borehole BH-4 using NQ coring equipment.

The borehole locations (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were surveyed by **exp** personnel using a temporary benchmark (TBM) set on top of culvert (south corner) at outlet side. The elevation of temporary benchmark (TBM) was assumed 347.0 m based on the CAD drawing provided by the MTO. The TBM location is shown on Drawing 1 in Appendix B.

For the drilling program, soil samples were obtained using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth as shown on the attached borehole logs (Appendix C). The original field (uncorrected) SPT “N” values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM, pg. 40) and used to provide an assessment of in-situ relative density of non-cohesive soils. When a hard stratum was reached sampling of hard material was performed by diamond core drilling, using a 1.5 m long NQ double tube wireline core barrel.

Upon completion of the boreholes, ground water level measurements were carried out in boreholes in accordance with MTO guidelines. The recorded ground water levels after completion of drilling boreholes were presented in the borehole log sheets in Appendix C. The boreholes were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the *Ontario Water Resources Act*).

The fieldwork was supervised by an **exp** geotechnical representative who directed the drilling and sampling operation, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification, and retrieved soil and bedrock samples for subsequent laboratory testing and identification.

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

### 1.3.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content of all samples and particle size distribution for approximately 25% of the collected soil samples. Corrosivity and sulphides tests were also performed for a selected sample. All of the laboratory tests were carried out in accordance with MTO and/or ASTM Standards, as appropriate.

The laboratory test results are provided on the attached borehole log sheets in Appendix C. The results of the grain size analyses are presented graphically in Appendix D. The chemical test results (corrosivity and sulphides) are presented in Appendix E.

## 1.4 Subsurface Conditions

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

Appendix D. The “Explanation of Terms Used in Report” preceding the borehole logs in Appendix C forms an integral part of, and should be read in conjunction with, this report.

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

In general, the subsurface conditions along the proposed culvert alignment consist of a layer of granular fill overlying native silty sand and gravel followed by sand and silt and bedrock. A more detailed summary of the subsurface conditions encountered in the boreholes is provided in the following sections.

#### **1.4.1 Asphalt**

Asphalt was encountered at the surface of boreholes advanced on the highway, i.e. Boreholes BH-3 to BH-5, and thickness of about 190 mm. Asphalt thicknesses may further vary beyond the borehole locations.

#### **1.4.2 Topsoil**

Topsoil was encountered at the surface of Boreholes BH-1 and BH-2, and ranged in thickness from approximately 150 to 175 mm. Topsoil thicknesses may further vary beyond the borehole locations.

#### **1.4.3 Fill: Sand and Gravel**

Sand and gravel fill was encountered below the asphalt/topsoil in all boreholes except BH1 and BH2. The sand and gravel fill extended to depths ranging between 1.5 m to 2.3 m below ground surface with elevations ranging between 345.6 m to 346.5 m. The explored thickness of this layer was between 1.3 m to 2.1 m.

The composition of this fill layer is sand and gravel, trace to some silt, trace asphalt inclusions. Locally this layer become silty sand some gravel fill at a depth of 0.8 m below ground surface in BH4. The material is brown in color, and moist. The SPT “N” values within this layer ranged from 8 to 62 blows per 300 mm penetration, suggesting loose to very dense, but generally compact to very dense relative density.

Laboratory testing performed on selected samples consisted of seven (7) moisture content, two (2) grain size distribution tests. The test results are as follows:

Moisture Content:

- 2.3% to 14.1%

Grain Size Distribution:

- 10% to 29% gravel;



- 56% to 77% sand; and
- 13% to 15% silt and clay

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

#### **1.4.4 Fill: Silty Sand/Silty Sand and Gravel**

Silty sand/Silty Sand and Gravel fill was encountered below the topsoil in BH1 and BH2. The silty sand fill extended to depths ranging between 0.8 m and 1.5 m below ground surface with elevations ranging between 344.5 m to 345.6 m. The explored thickness of this layer was between 0.6 m and 1.3 m.

The composition of this fill layer is silt and sand, some gravel and trace clay. The material is brown in color, and moist. The SPT “N” values within this layer ranged from 2 to 23 blows per 300 mm penetration, suggesting very loose to compact relative density.

Laboratory testing performed on one sample consisted of three (3) moisture content test. The test results are as follow:

Moisture Content:

- 13% to 27.6%

#### **1.4.5 Silty Sand and Gravel**

Native silty sand and gravel was encountered below the sand and gravel fill in BH1, BH3 and BH5. The silty sand and gravel extended to depths ranging between 2.0 m to 3.8 m below ground surface with elevations ranging between 344.3 m to 346.5 m. The explored thickness of this layer was between 1.3 m to 2.1 m.

The composition of this layer is silt, sand and gravel, trace cobbles. Locally this layer become sandy gravel at a depth of 1.55 m below ground surface in BH5. The material is brown in color, and moist to very moist. The SPT “N” values within this layer ranged from 24 to 37 blows per 300 mm penetration, suggesting compact relative density. One SPT “N” value of 67 blows per 275 mm penetration was obtained in BH 1, suggesting very dense relative density. It could be influence of underlying possible bedrock.

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

Moisture Content:

- 3.0% to 15%

Grain Size Distribution:

- 38% to 50% gravel;

- 35% to 38% sand; and
- 12% to 27% silt and clay

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

#### **1.4.6 Sand and Silt**

Native sand and silt was encountered below the sand and gravel fill in BH3 and BH4, below silty sand fill in BH2 and below silty sand and gravel in BH5. The sand and silt extended to depths ranging between 2.3 m to 5.4 m below ground surface with elevations ranging between 342.6 m to 344.0 m. The explored thickness of this layer was between 1.4 m to 2.0 m.

The composition of this layer is silt and sand, trace to some gravel, trace clay. The material is brown to milky brown in color, and moist to very moist. The SPT “N” values within this layer ranged from 2 to 22 blows per 300 mm penetration, suggesting very loose to compact, but generally loose to compact relative density.

Laboratory testing performed on selected samples consisted of seven (7) moisture content, three (3) grain size distribution tests. The test results are as follows:

Moisture Content:

- 8.2% to 19.8%

Grain Size Distribution:

- 4% to 12% gravel;
- 49% to 53% sand;
- 39% to 45% silt; and
- 2% to 3% clay

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

#### **1.4.7 Bedrock**

The presence of bedrock was found to be approximately between 2.0 m to 2.3 m below ground surface in offroad boreholes (BH-1 and BH-2) and approximately between 4.3 m to 5.4 m below the road surface in boreholes drilled from the road (BH-3 to BH-5). The bedrock was inferred from auger/split spoon refusal in BH-1, BH-2, BH-3 and BH-5 or confirmed coring 3.5 depth in BH-4. Some split spoon samplers were attempted in BH-2, BH-3 and BH-5 and the SPT “N” values obtained within top layer of bedrock ranged from 60 blows per 10 mm penetration to 60 blows per 75 mm penetration. All the boreholes were terminated in bedrock. The elevation of the inferred or actual bedrock surface below

this site ranges from Elev. 342.6 m to 344.0 m. The inferred or actual bedrock surface depth and elevation encountered at these borehole locations are listed in Table 1.

*Table 1.1 Depth and elevation of bedrock surface*

Borehole	Depth Below Ground Surface (m)	Elevation (m)	Comments
BH1	2.0	344.0	Inferred/ Spoon Refusal
BH2	2.3	344.0	Inferred/ Spoon Refusal
BH3	5.4	342.6	Inferred/ Spoon Refusal
BH4	4.3	343.6	Bedrock Cored
BH5	4.4	343.5	Inferred/ Spoon Refusal

Based on the bedrock cores recovered and fragments of rock recovered in split spoon samples, the bedrock consists of dolostone. In general, the bedrock samples are described as light grey/milky white in colour and have a fine grained structure, moderately weathered with presence of vugs, intensively to moderately fractured and close joint opening. The Rock Quality Designation (RQD) measured on the core samples typically ranged from approximately 35% to 75%, indicating a rock mass of poor to fair quality. Photographs of rock cores are included in Appendix E.

## 1.5 Groundwater & Surface Water Conditions

Groundwater conditions were monitored in the open boreholes during and upon completion of the drilling operations. Groundwater was encountered at Borehole BH-3 at depth of about 5.0 m below ground surface upon completion of the drilling operations. Boreholes BH-1, BH-2 and BH-5 were dry upon completion of drilling. BH-4 remained dry prior to advancing the rock coring equipment. The groundwater levels are not considered to have stabilized during the short term of the investigation.

At the time of investigation water through the culvert was observed to be at approximate Elev. 345.9 m. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods.

## 1.6 Chemical Analyses

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

Table 1.2. Corrosivity chemical analysis

Sample Identification	pH (unitless)	Soluble Chloride (ppm)	Soluble Sulphate (ppm)	Resistivity (ohm-cm)	Conductivity (umho/cm)	Redox Potential (mV)	Sulphide (ppm)
BH2-SS2 Silty Sand Fill	7.81	55	<20	5,600	177	+172	<0.5

## PART II: ENGINEERING DISCUSSION & RECOMMENDATIONS

### 2.1 General

This section of the report provides geotechnical design recommendations for replacement of the existing culvert, located on Highway 6 at Station 25+643, about 1.03 km south of Side Road 3 WGR in West Grey municipality, Grey county, Ontario, the Ministry of Transportation (MTO) Western Region. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site and presented in **Part I-Foundation Investigation Report**. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives and design the new culvert and 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 CAD drawings provided by the MTO, the existing culvert is a 0.91 m x 0.91 m x 25.5 m concrete rigid framed- open footing structure. It is understood that the existing culvert would be replaced with a new culvert along the same alignment with no or minimum grade change anticipated at the culvert location. The size and type of the new culvert is not firmly defined at the time of writing this report. However, for preliminary design purposes, the following options are being considered for the replacement in this report: rigid frame box culvert (precast or cast-in place) and rigid frame open footing culvert.

This part of the report addresses the geotechnical design of the foundation for the new culvert by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the *Canadian Highway Bridge Design Code (CHBDC)* (CAN/CSA-S6-14), the *Canadian Foundation Engineering Manual (CFEM)* (2006), *MTO Gravity Pipe Design Guidelines* (May 2007) and generally accepted good practice. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference provided to us at October 13, 2016 together with the MTO request email. The assessment involved review of options for replacement of the existing culvert along the same alignment.

### 2.2 Expected Ground Conditions

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

- a) Hwy 6 is a two lanes roadway and is about 7.0 m wide from edge of pavement to edge of pavement, with approximately 2.5 m wide sand and gravel shoulders. Based on drawings provided, the roadway embankment is less than 2.0 m high with side slopes about 3H:1V at the culvert inlet and outlet. The current elevation of the crest of the roadway is about 347.9 m.
- b) The highway embankment consists of granular fill (1.3 m to 2.1 m thick) underlain by compact silty sand and gravel (~1.6 m to 2.3 m thick) followed by very loose to compact sand and silt (~1.3 m to 2.0 m thick) and bedrock.

- c) At the inlet and outlet, the layer of topsoil (~0.15 m to 0.175 m thick) underlain by very loose to compact silty sand and gravel fill (BH1, 1.3 m thick)/ compact silty sand fill (BH2, 0.6 m thick) followed by very dense silty sand and gravel (BH1, 0.5 m thick/ compact sand and silt (BH2, 1.5 m thick) and bedrock.
- d) All the boreholes were terminated in bedrock level. Bedrock was cored up to 3.5 depth in BH4
- e) The foundation soil at the invert of the new culvert is anticipated to be compact silty sand and gravel fill to compact sand and silt at about Elev. 345.6 m. Typical 'N' values ranged from 2 to 23.
- f) At the time of investigation, the approximate stream water elevation at culvert was about 345.9 m. The groundwater table in the embankment fill is expected to be at approximate elevation 345.9 m, or slightly higher. However, seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year (such as spring thaw and late fall) and lower levels during drier periods. Some groundwater mounding within the embankment and perched water would be anticipated.

## 2.3 Structure Foundations

For preliminary design purpose, several possible options are considered for the replacement of the existing culvert:

- Rigid frame box culvert (precast or cast-in-place),
- Rigid frame open footing culvert supported on shallow foundations,
- Corrugated steel plate culvert supported on shallow foundations,

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

It is noted that regardless of the option selected, the existing 0.91 m × 0.91 m × 25.5 m concrete rigid frame-open footing culvert is to be removed. This will require excavation down to the existing founding elevation for all options. This suggests the need for surface/groundwater control as discussed in Section 2.10 below.

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

Based on the subsoil condition, Table 2.1 below compares the possible structure options from a foundations design and constructability perspective with their advantages and disadvantages. Although the foundation soils can provide adequate support for all options listed in the table, the use of precast rigid frame box culvert is ranked highest for the criteria evaluated.

Table 2.1 Evaluation of foundation alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
Precast rigid frame box culvert	1	<ul style="list-style-type: none"> <li>▪ Straightforward construction</li> <li>▪ Reduced construction period, consequently traffic management and water control period</li> <li>▪ Reduced excavation depth</li> </ul>	<ul style="list-style-type: none"> <li>▪ If floor is thin and poorly reinforced, it may heave and crack</li> <li>▪ During high flows, the concrete floor can be undermined</li> <li>▪ Requires bedding material</li> </ul>	<ul style="list-style-type: none"> <li>▪ Low</li> </ul>	<ul style="list-style-type: none"> <li>▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil</li> <li>▪ Risk of leaking from joints if not properly installed</li> </ul>
Cast-in-place rigid frame box culvert	3	<ul style="list-style-type: none"> <li>▪ Suitable if site is not conducive to heavy equipment for installation of precast sections</li> <li>▪ Reduced excavation depth</li> </ul>	<ul style="list-style-type: none"> <li>▪ Slower construction process</li> <li>▪ If floor is thin and poorly reinforced, it may heave and crack</li> <li>▪ During high flows, the concrete floor can be undermined</li> <li>▪ Requires concrete curing</li> </ul>	<ul style="list-style-type: none"> <li>▪ Low to medium</li> </ul>	<ul style="list-style-type: none"> <li>▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil</li> <li>▪ Risk of disturbance of base during construction</li> </ul>
Rigid frame open footing concrete culvert	4	<ul style="list-style-type: none"> <li>▪ Wider span may be considered to maintain existing channel</li> </ul>	<ul style="list-style-type: none"> <li>▪ Deeper excavation or below water excavation may required</li> <li>▪ More extensive dewatering system may required</li> <li>▪ May require placement of lean concrete</li> </ul>	<ul style="list-style-type: none"> <li>▪ Likely more expensive than Option 1</li> </ul>	<ul style="list-style-type: none"> <li>▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil</li> <li>▪ Risk of delay in construction if excavation required below water in more permeable zones</li> <li>▪ Higher risk of scour</li> </ul>

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
Corrugated Steel Pipe Culvert	2	<ul style="list-style-type: none"> <li>▪ Straightforward construction</li> <li>▪ Reduced construction period, consequently traffic management and water control period</li> <li>▪ Reduced excavation depth</li> </ul>	<ul style="list-style-type: none"> <li>▪ Requires bedding material</li> <li>▪ Limited design life</li> <li>Potential for corrosion</li> </ul>	<ul style="list-style-type: none"> <li>▪ Low to medium</li> </ul>	<ul style="list-style-type: none"> <li>▪ Risk of unacceptable differential settlements if the entire foundation is not supported on the competent soil</li> <li>▪ Risk of structure segment loss due to corrosion</li> </ul>

## 2.3.1 Shallow Foundations

### 2.3.1.1. Geotechnical Resistance

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

Table 2.2 Recommended spread footing design parameters

Culvert Type	Founding Elevation (m)	Assumed Footing Size (m)	Founding Soil Type	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS** (kPa)
Rigid frame box culvert and CSP pipe culvert	~345.6 or below	3.0 to 4.0 m	Minimum 300 mm compacted granular material (Granular A or Granular B Type II) Native compact sand and silt/ silty sand and gravel fill	300	200
Rigid frame open footing concrete culvert and retaining (wing) wall	~344.3*	1.0	Native compact sand and silt/ silty sand and gravel over bedrock	300	200

Notes:

\*Below the frost line

\*\* for maximum settlement of 25 mm



It is presumed that if any underlying organic fibers and any other soft or very loose materials are to be replaced with clean and compactable soil such as Granular A or Granular B Type II. Given that no (or minimal) grade raise is planned, the anticipated maximum total settlements for the new 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.

#### 2.3.1.2. Resistance to Lateral Loads

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

Table 2.3 Recommended parameters for calculation of unfactored horizontal resistance

Interface and loading conditions	Parameters
Between Granular A and pre-cast concrete	Coefficient of friction ( $\tan \delta$ )=0.7
Between cast-in-place concrete and native sand and silt	Coefficient of friction ( $\tan \delta$ )=0.55

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

#### 2.3.1.3. Frost Protection

The frost depth in the area of the culvert is estimated to be approximately 1.5 m in accordance with OPSD 3090.101. During construction of any temporary and permanent support system using shallow foundations should be provided a minimum 1.5 m of soil cover or equivalent frost protection should be provided using thermal insulation. This frost protection requirement applies to the rigid frame open footing culvert option. Frost protection is not required for the box culvert.

If the frost penetration line is at or above top of the culvert the backfill and cover for these culverts should be as per OPSD 803.010. Where less than 1.5 m of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.010 for the concrete culverts with spans less than or equal to 3.0 m or OPSD 3101.150 for the culvert with span more than 3.0 m.

## 2.4 Lateral Earth Pressure

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

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

where

$P$  = earth pressure intensity at depth  $h$ , kPa

$K$  = earth pressure coefficient

$\gamma$  = unit weight of retained soil, kN/m<sup>3</sup>

$q$  = surcharge near wall, kPa

$h$  = depth to point of interest, m

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater levels measured on the site. Table 2.4 lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.

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

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

It is likely that bracing for the temporary support system will be required at a maximum interval of 5 m. For multiple support systems refer to *Canadian Foundation Engineering Manual* (CFEM) for apparent earth pressure distributions (CFEM, Section 26.10.3, Figure 26.8)

Table 2.4 Material types and earth pressure properties

Material	Unfactored Friction Angle $\phi'$	Coefficient of Active Earth Pressure ( $K_a$ )	Coefficient of Passive Earth Pressure ( $K_p$ )	Coefficient of Earth Pressure At-Rest ( $K_0$ )	Unit Weight $\gamma$ kN/m <sup>3</sup>
Sand and Gravel Fill	32	0.31	3.25	0.47	21
Silty Sand and Gravel Fill/Silty Sand Fill (compact)	30	0.33	3.0	0.50	19
Silty Sand and Gravel (compact to dense)	30	0.33	3.0	0.50	20
Sand and Silt (loose to compact)	29	0.35	2.88	0.52	19

## 2.5 Seismic and Liquefaction Potential Consideration

Seismic characterization of the site must be compliant with the Canadian Highway Bridge Design Code CHBDC (CAN/CSA-S6-14). The potential for seismic loading must be considered for design in accordance with Section 4.4 of the CHBDC with respect to soil conditions encountered at the site. Table 4.1 in CHBDC (see Clause 4.4.3.2) shows site classification for seismic site response based on

soil average properties in top 30 m. The borehole information shows the presence of native compact soil and bedrock. Based on these soil characteristics, the site class for this site is estimated to be Class "C" according to Table 4.1.

From the Natural Resources Canada website, 2015 NBCC seismic hazard values are obtained using the site location coordinates (44°17'13.8"N, 80°50.55'2"W) and the damped reference spectral accelerations for the project site are  $S_a(0.2)=0.039g$ ,  $S_a(0.5)=0.030g$ ,  $S_a(1.0)=0.018g$ ,  $S_a(2.0)=0.0052g$  and the reference peak ground acceleration (PGA) is 0.013g ( $g$ =acceleration due to gravity  $-9.81 \text{ m/s}^2$ ). These values are associated with an earthquake having 10 percent probability of exceedance in a 50-year period.

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

## 2.6 Construction Alternatives

For the proposed culvert replacement, the following methods were considered as possible alternatives for the new culvert installation at this site:

1. Half-and-half construction using roadway protection to allow excavation as maintaining signalized one lane of traffic on the existing embankment during construction. The following two options of excavation and replacement using the half-and-half approach were considered:
  - A. Construction using roadway protection and unsupported excavation of cut sides
  - B. Construction using roadway protection and braced cut sides
2. Full road closure followed by open cut/unsupported excavation to replace culvert;
3. Construct temporary detour embankments at the site followed by open cut/unsupported excavation to expose and replace culvert

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. In contrast, a trenchless approach for culvert replacement does not require disruption of traffic. However, considering the size and nature of the existing culvert and topography of the surrounding terrain, tunneling for trenchless replacement of this culvert was not considered as an applicable option. The other trenchless methods such as pipe bursting, pipe splitting, pipe swallowing and interior replacement methods were also not considered as applicable in this project, since the type of the precast culvert is an unsuitable candidate for these techniques. For all approaches provision must be made to maintain surface water flow to the outlet.

The following Table 2.5 summarize advantages and disadvantages of considered construction alternatives. The table also shows assessed risk/consequences and relative costs of the considered methods. Schematic diagrams of considered alternatives are attached in Appendix H.

Table 2.5 Construction alternatives for culvert replacement (see schematic sketches in Appendix H)

Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
<p>OPTION 1.A</p> <p>Half-and-half Construction with Unsupported Cut Sides (Figure H3.A, Appendix H)</p>	<ul style="list-style-type: none"> <li>• Traffic flow maintained at the site during construction</li> <li>• Short mobilization time</li> <li>• Straight forward construction and construction procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Traffic interruption</li> <li>• Roadway protection of up to 3.5 m high required to maintain one lane of traffic</li> <li>• High cost of roadway protection system</li> <li>• Large amount of soil to be excavated</li> <li>• Need to temporarily control existing creek water</li> <li>• Risk of cost overrun and inability to finish job: low to moderate</li> </ul>	<p>Relatively more expensive than full road closure due to high costs of roadway protection system</p>	1
<p>OPTION 1.B</p> <p>Half-and- half Construction with Braced or Anchored Cut Sides (Figure H3.B, Appendix H )</p>	<ul style="list-style-type: none"> <li>• One or possibly two lanes of traffic flow maintained on existing road (e.g. steel decking, but costly)</li> <li>• Global stability of excavation enhanced by narrow geometry</li> <li>• Less traffic interruption than with unsupported cut sides approach</li> <li>• Temporary decking could be usable over braced cut to allow for excavation of both halves prior to diverting stream and backfilling</li> <li>• Cost savings due to limited excavation and backfill</li> </ul>	<ul style="list-style-type: none"> <li>• Traffic interruption</li> <li>• Roadway protection of up to 3.5 m high required to maintain one lane of traffic if steel decking is not possible</li> <li>• High cost of roadway protection system and/or decking</li> <li>• Require side shoring and bracing</li> <li>• Bracing (e.g. struts) may interfere with excavation</li> <li>• Excavation of material and placement of bracing required in limited space</li> <li>• Need to decommission the shoring system</li> <li>• Need to temporarily control existing creek water</li> <li>• Risk of cost overrun and instability to finish job: low to moderate</li> </ul>	<p>More expensive than full road closure and other open cut sides approach due to high costs for shoring system and temporary decking (if feasible) to maintain continuous flow of traffic</p>	2

Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
<p>OPTION 2</p> <p>Full Road Closure using Existing Local Roadways and Open Cut Unsupported Excavation (Figure H1, Appendix H)</p>	<ul style="list-style-type: none"> <li>Existing culvert will completely remove and replaced with new culvert</li> <li>No construction of detour roads or roadway protection required</li> <li>No excavation support required</li> <li>Install entire new culvert at once</li> <li>Straightforward construction</li> <li>Short mobilization time</li> <li>Low capital investment; cost saving in time and materials required for construction</li> </ul>	<ul style="list-style-type: none"> <li>Traffic interruption</li> <li>Long detour around site using other existing roads required</li> <li>Large amount of soil to be excavated</li> <li>Existing fills and native soils require 2H:1V side slopes to maintain stability</li> <li>Erosion control of temporary cuts required</li> <li>Need to temporarily control existing creek water</li> <li>Potential claims to compensate vehicle occupants and local business for delays or time lost due to detour routes</li> <li>Risk of cost overrun and inability to finish job: low</li> </ul>	<p>Relatively less expensive than other methods due to cost savings in time and materials required for construction, but potential claims to compensate vehicle occupants and local business for delays or time lost due to detour routes</p>	3
<p>OPTION 3</p> <p>Build Temporary Detour and Open Cut Unsupported Excavation (Figure H2, Appendix H)</p>	<ul style="list-style-type: none"> <li>Traffic flow maintained at the site during construction</li> <li>Simple detour roads can be constructed</li> <li>Existing culvert will completely remove and replaced with new culvert</li> <li>No excavation support required</li> <li>Install entire new culvert at once</li> </ul>	<ul style="list-style-type: none"> <li>Construction of detour embankments required at one side of highway</li> <li>Possible extra cost to purchase of private property</li> <li>Increased time for construction of detour</li> <li>Large amount of soil to be excavated</li> <li>Erosion control of temporary cuts required</li> <li>Need to temporarily control existing creek water</li> <li>Risk of cost overrun and inability to finish job: low to moderate</li> <li>Possible extra cost to purchase of private property</li> </ul>	<p>More expensive than full road closure due to high costs to build local detours</p>	4

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

1. OPTION 1.A: Half-and-half construction with unsupported cut sides (Figure H3.A, Appendix H)
2. OPTION 1.B: Half-and-half construction with braced or anchored cut sides (Figure H3.B, Appendix H)
3. OPTION 2: Full road closure using existing local roadways and open cut unsupported excavation (Figure H1, Appendix H)
4. OPTION 3: Build temporary detour and open cut unsupported excavation (Figure H2, Appendix H)

The following sections discuss these options in more details.

## 2.6.1 Half-and-Half Construction (Options 1)

The half-and-half construction method could be utilized to maintain the flow of the traffic on Hwy 6 (see Figures H3.A, and H3.B, Appendix H). In this method, one lane of the existing highway will be used to maintain the local traffic while the other half of the existing highway will be excavated and the half of the existing culvert 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 required to remove half of the existing embankment would be up to 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. It will be the Contractors responsibility to design a suitable temporary support system for the MTO review prior to installation. The Contractor is to follow OPSS 902, regarding excavations for structures, and OPSS.PROV 539, regarding temporary protection systems. Recommendations for a temporary roadway protection are given in Section 2.7. Using the half-and-half construction approach, two methods of culvert replacement were considered for this site suitable as discussed below:

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

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

### **2.6.1.1 Option 1.A: Half-and-Half Construction with 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 H3.A, Appendix H). The roadway protection can take the form of reversible shoring such as a soldier pile and lagging or sheet pile with rakers or anchors for horizontal support. Where the cut extends below prevailing groundwater a suitable control/system is required. Once one lane is completed the supports can be reversed and the other lane constructed in similar fashion. The shoring system would likely be decommissioned in place. Temporary surface water flow control must be developed by contractor.

Option 1.A could be more economical due to possible cost savings for reversible wall configuration, but it will be more disruptive to the highway embankment than Options 1.B since it needs to excavate a large amount of soil.

### **2.6.1.2 Option 1.B: Half-and-Half Construction with Braced or Anchored Cut Sides**

This method provides braced or anchored cut shoring system perpendicular to the highway for face protection and to allow culvert construction (see Figure H3.B., Appendix H). Excavation in this case would have to accommodate the necessary cross-bracing such as struts. With this option, consideration would have been given to how the new culvert sections will be installed given the relatively narrow work area and potential for obstructions from the lateral bracing using struts. Installation of tiebacks could be the solution. Temporary decking could possibly be used over the supported cut to allow for excavation of both halves prior to diverting stream and backfilling. However decking would be costly. As well as Option 1.A, decommissioning of the shoring system and temporary surface water flow control must be performed/developed by contractor.

Option 1.B will disrupt less of the embankment than Option 1.A but would cost more, i.e. about 1.8 times of Option 1.A, due to the cost of shoring system. Excavation and backfilling operations will also be more challenging with Option 1.B. Both options require decommissioning of shoring system upon completion of the work.

## **2.6.2 Detour Options (Options 2 and 3)**

Both detour options, the option with full closure of Hwy 6 and long detours around the area using existing local roadways (see Figure H1, Appendix H), and the option with the detour embankment construction at the site to maintain the local flow of traffic during the replacement (see Figure H2, Appendix H), allow for open cut, unsupported excavation to facilitate the replacement of the existing culvert. A major benefit of these options is that the existing culvert will be completely removed once and replaced the new culvert. The other advantages are that neither excavation support nor roadway protection is required with these options. The major disadvantages of both options are traffic interruption, large amounts of excavated soils and need for temporary construction unwatering and dewatering systems (i.e. cofferdams, and sumps and pumps, etc.) to prevent existing creek water and groundwater flow into the construction area which is the responsibility of the contractor.

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

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

The detour construction alternative would involve construction of a temporary on-site embankment at the one side of the existing embankment depending on the available space and suitable terrain. Compacted engineered fill for construction of the temporary detour road is recommended. Prior to construction of the temporary detour embankment, the site will need to be cleared and grubbed of any existing bushes and vegetation. All surficial topsoil (if exists), organics and softened or loosened soil should be stripped from below the proposed temporary detour road embankment. All subgrade soils should be proof-rolled prior to fill placement and embankment fill should be placed in accordance with OPSS. PROV 206 (dated November 2014).

## **2.7 Temporary Roadway Protection**

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

At this site shoring system such as soldier piles and timber lagging or steel sheet pile walls may be considered for design. It should be designed based on the earth pressures coefficients and soil parameters provided in Section 2.4. The actual depth of embedment should be determined by balancing moments about the pile tip. However, considering relatively shallow depth of the bedrock at Elev. 343.6 m, the piles could extend to a maximum depth of 2.2 m below the planned excavation depth. Therefore, temporary shoring system with additional anchorage or tiebacks may be required for



lateral resistance. Conventional practice is to incorporate either buried deadman anchors or soil grouted anchors. Alternatively, a system of rakers can be used for support.

Deadman anchors can be designed based on the earth pressure coefficients and soil parameters provided in Section 2.4. For this project, either continuous or individual concrete block anchors would likely be appropriate. The anchor resistance is provided by a combination of the dead weight and passive resistance. For the full passive resistance to be realized with no load transfer to the wall, the anchor needs to be fully beyond the active wedge acting on the wall. Pressure grouted soil anchors can be designed in a preliminary fashion in accordance with Section 26 of the CFEM (2006). Based on the generally compact soils at this site, the estimated factored (0.4) ULS resistance of grouted anchors would be 40 kN/m length. Detailed design would be completed following the design of the wall and the loads have been established. Normally, such anchors are supplied and installed/tested by specialist vendors/contractors.

For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided that the center-to-center spacing of the soldier piles does not exceed 2.5 m. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours.

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

## **2.8 Culvert Bedding**

OPSDs 802.010, 802.031, 802.032, 803.010 and Figure C6.20 of (CHBDC) or OPSD 3101.150 which are included in Appendix G provide the bedding, embedment, cover and backfill standards for the different culvert material. According to these standards the culvert bedding should consist of Granular A (OPSS.PROV. 1010) with thickness of 300 mm beneath the culvert and extend a minimum of 500 mm horizontally on either side of the culvert edge. The bedding material should be placed in layers not exceeding 200 mm in thickness, loose measurement, and compacted accordance with OPSS 501 before a subsequent layer is placed in accordance with OPSS 514. Bedding material placed in the haunches must be compacted prior to continued placement of cover material. Bedding on each side of the culvert (i.e. CSP pipe) shall be completed simultaneously. At no time shall the levels on each side differ more than the 200 mm uncompacted layers.

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

For the site area, a frost penetration depth of approximately 1.5 m can occur in open, unheated areas without snow cover. At the culvert inlet and outlet, and beneath the proposed culvert, mostly the native soils consist of silty clay/clay. This material has medium to high frost susceptibility based upon the MTO Frost Classification guideline of percent particles between 5 to 75  $\mu\text{m}$ . Therefore, non-frost susceptible materials such as sand and gravel need to be provided to the limit of frost penetration beneath the inlet and outlet of the culvert. However, considering that cold air blowing through the culvert during the winter season will freeze soil next to the culvert, a minimum 500 mm thick layer of non-susceptible material should be considered to be placed as a bedding along the entire culvert length.

## 2.9 Culvert Backfill

Backfill should be placed from the base of the culvert to the full height of the culvert and extend a minimum 1.5 m horizontal distance from the outside wall (as per Figure C6.20a of the CHBDC). This horizontal distance may be reduced by the use of suitable insulation (such as a heavy duty STYROFOAM). The insulation should be placed against the outside wall of the culvert from the base of the culvert to its total height. The material should be installed as per the manufacturer's instructions.

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

All granular backfill materials should be placed in thin lifts (i.e. not exceeding 300 mm before compaction) and each lift should be compacted accordance with OPSS 501. The final lift of embankment fill 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 same level on both sides of the structure, to avoid lateral displacement of the structure.

For fills immediately below any roadway, it is recommended that Granular A or B aggregates be used. Where necessary, proper tapering as per standards should be provided. Below a depth of about 1.5 m from any finished road grade, approved compactable fill, such as select subgrade materials (SSM) can be used.

Where less than 1.5 m of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.030 and 803.031 or OPSD 3101.150.

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

## 2.10 Groundwater and Surface Water Control

The soils encountered below the groundwater table and within potential excavation depths consist of native sand and silt. These soils are susceptible to disturbance from groundwater and mobilized equipment. The groundwater level needs to be controlled to at least 0.5 m below the excavation level

to avoid disturbance, and any surface or groundwater seepage should be removed from the excavation prior to the culvert bedding material placement of granular backfill in the dry. In general, pumping using properly filtered sumps, and/or filtered drains placed along the base of the excavation should provide sufficient groundwater control during foundation works.

A Non-Standard Special Provision (NSSP) for the potential issues associated with the excavation below groundwater level and requirement of groundwater control to kept excavation stable during construction should be included with the contract documents and sample has been provided in Appendix I of this report.

The upstream flow of the existing culvert can be diverted around the construction area. For the control of the water flow in the creek might require a cofferdam. If the existing culvert is to be removed prior to completion of the new culvert, a system of sumps and pumps will be required to divert the surface water up and over the existing embankment.

Dewatering requirements behind the cofferdams to keep the construction site dry will be impacted by water levels in the stream at the time of construction activities. Dewatering shall be carried out in accordance with OPSS 517 and OPSS 518. It is responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions for prior approval of the MTO. The method used should not undermine the existing road embankment or adjacent side slopes. In this connection the provision of toe protection at side slopes during drawdown may be required to minimize sloughing and undercutting during dewatering.

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

## **2.11 Embankment Design**

### **2.11.1 Embankment Stability**

A preliminary slope stability analysis was performed to assess the global stability of the existing embankment and to check that a minimum Factor of Safety of 1.3 will be achieved for the new embankment at the location of the proposed culvert. Given the embankment height and side slope geometry, slope stability is not considered an issue. This analysis is provided for completeness. The static slope stability analyses were performed using the Morgenstern-Price method developed on the basis of limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

Stability assessments of existing slopes under static conditions were performed on the cross-section perpendicular to the highway at the proposed culvert location. The cross-section of the existing embankment with the approximate slopes of 3H:1V was developed based on the cross-sections provided by MTO. The stratigraphy and groundwater condition at the site were developed based on the results of the geotechnical investigation presented in Part I - Foundation Investigation Report.

Based on the borehole information, the subsoils encountered at the work area consist of embankment fill, underlain by silty sand with gravel to sand and silt deposits. Therefore, an effective stress analysis

for a long term assessment of the embankment slope was performed taking into consideration the subsoil conditions encountered beneath the existing embankment.

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

Tabulated below in Table 2.6 are the soil parameters used for the slope stability analysis. The soil parameters were generally estimated based on the results of field and laboratory investigation.

*Table 2.6 Soil properties used in slope stability analysis*

Soil Type	Long-term Conditions		
	$\phi'$ (degrees)	$c'$ (kPa)	$\gamma'$ (kN/m <sup>3</sup> )
Sand and Gravel Fill	32	0	21
Silty Sand and Gravel Fill/ Silty Sand Fill (Compact)	30	0	19
Silty Sand and Gravel (very dense)	30	0	20
Sand and Silt (Compact)	29	0	19

The results of slope stability analyses for the 3H:1V west side slope of the existing embankment using drained (long term stability) soil parameters are presented graphically in Figure 1 in Appendix F. A minimum Factor of Safety more than 1.3, indicating that the embankment is stable. In addition, the slope stability analyses were performed for the new embankment constructed of engineered fill (Figure 2 and 3 in Appendix F) and more than a minimum Factor of Safety of 1.3 was achieved, suggesting that the new embankment will be stable if the same slope of 3H:1V or conventional slope of 2H:1V is followed (Figure 2 and 3 in Appendix F).

## 2.11.2 Embankment Settlement

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

## 2.12 Inlet and Outlet

### 2.12.1 Erosion Protection

The requirement for and detailed design of erosion protections measures is the responsibility of and should be carried out by the hydraulics engineer. In general, rip-rap protection should be provided where the culvert discharges into the open creek. The rip-rap should extend approximately 5 m beyond

the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow the OPSD 810.010, which is included in Appendix G of this report.

Where the embankment side slopes have been scarred and/or excavated (beyond rip-rap limit) to facilitate the existing culvert replacement, the scarred and/or reinstated embankment side slopes are to be vegetated with sodding, seeding or planting as necessary depending on the flow rate and volume. Should seeding be utilized, a 100 mm thick layer of topsoil should be placed along with a degradable erosion blanket to help minimize erosion until the vegetation begins to grow.

### **2.12.2 Stream Bed Rip-Rap**

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

### **2.12.3 Seepage Cut-off Requirements**

The seepage cut-off requirements should be reviewed in the following context. The native silty soils at the inlet, outlet side and below the culvert bedding has 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.

#### **2.12.3.1 Clay Seal**

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

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

- The clay seal should be placed along the sides and top of the culvert a minimum of 1.0 m along the side of the culvert and extending out laterally 1.0 m from the culvert.
- The clay seal should be placed from the top of the culvert footings and extend along the side and the top of the culvert. The clay must not be placed below the culvert.

- The clay should have a Liquid Limit greater than 40% and a Plasticity Index greater than  $0.73 \times (\text{Liquid Limit} - 20\%)$ .
- 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 the 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.

#### 2.12.3.2 Cut-Off Trench

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

### 2.13 Corrosion Protection

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

The chemical data indicates medium resistivity of the tested soil ( $> 5,000 \text{ ohm-cm}$ ), which indicates a low potential for corrosion of buried metallic elements, particularly pipes and appurtenances (MTO Gravity Pipe Design Guidelines, Page 25). The maximum chloride content reported is 55 ppm ( $\mu\text{g/g}$ ) which indicates a low potential for additional corrosion.

The maximum water soluble sulphate content of the soils tested is  $< 20 \text{ ppm } (\mu\text{g/g})$ , i.e.  $< 0.02\%$  and being less than  $0.10\%$ , does not indicate the potential to corrode normal Portland cement concrete. These data also support our local experience.



## PART III: CLOSURE

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

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

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

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

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

exp Services Inc.



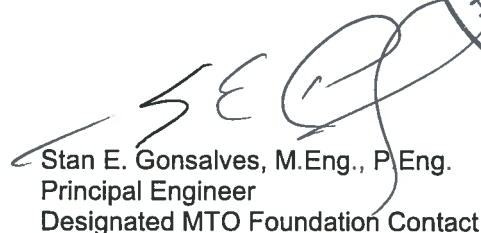
Nimesh Tamrakar, M.Eng., EIT.  
Technical Specialist



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



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



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



## **PART IV: LIMITATIONS AND USE OF REPORT**

### **BASIS OF REPORT**

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

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

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

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

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

### **RELIANCE ON INFORMATION PROVIDED**

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to exp by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. exp has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or



inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to exp.

## **STANDARD OF CARE**

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

## **COMPLETE REPORT**

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

## **USE OF REPORT**

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

## **REPORT FORMAT**

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

## **Appendix A – Site Photographs**



Photo 1: Hwy 6 looking north from the culvert location



Photo 2: Embankment side slope(east) looking north from south of the culvert





Photo 3: Looking north from south of the culvert showing BH1 and TBM location



Photo 4: Embankment side slope(west) looking south from north of the culvert





Photo 5: Hwy 6 looking south from the culvert location



Photo 6: Looking west from the culvert inlet location





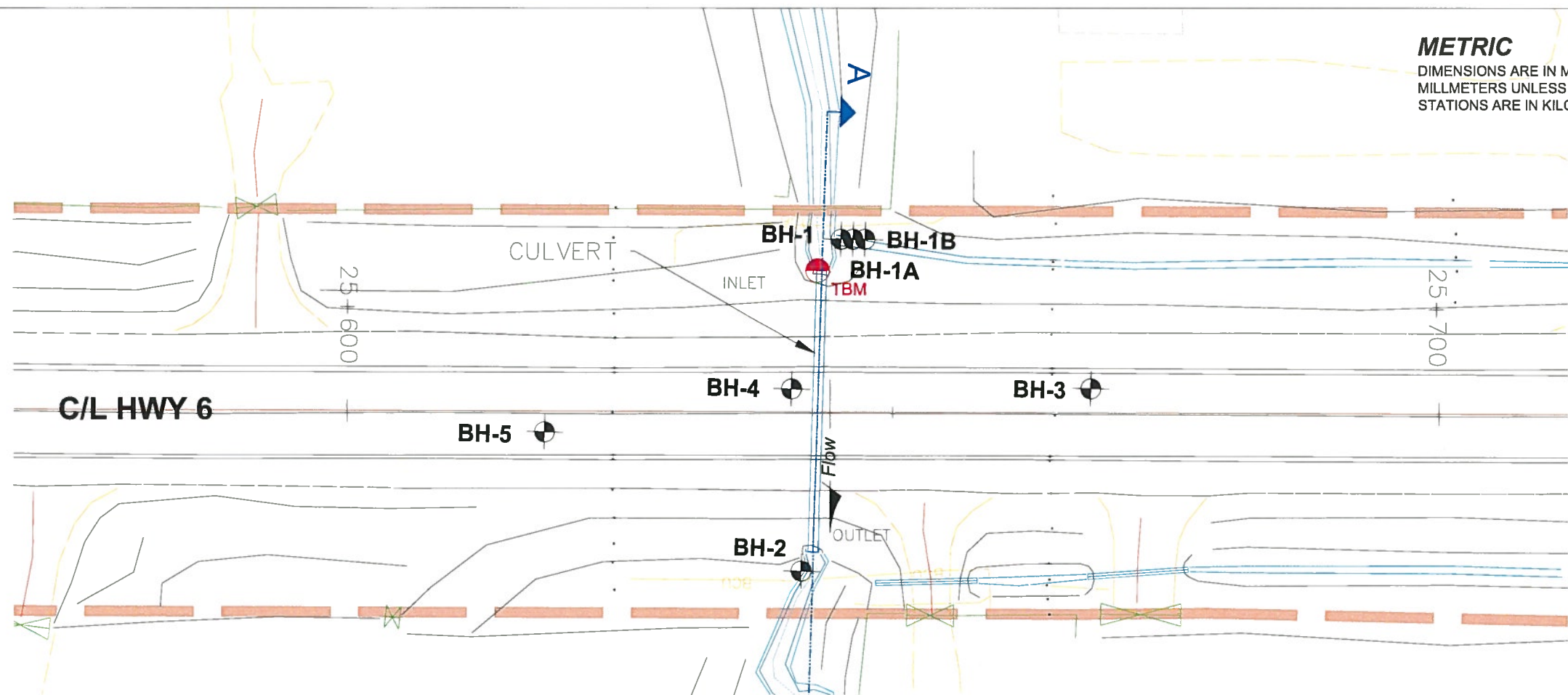
Photo 7: Looking east from the culvert outlet location



Photo 8: TBM location at top of culvert at outlet location

## **Appendix B – Drawings**





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

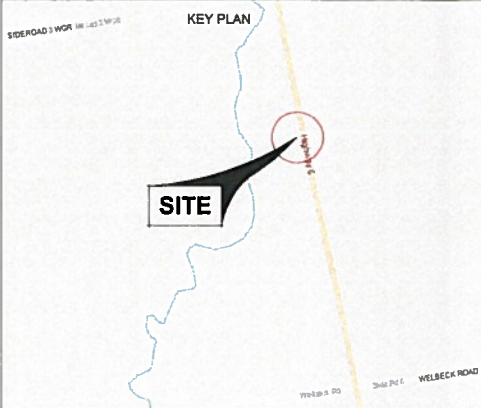
Agreement No. 3015-E-0017  
Assignment No. 3  
GWP - 3062-14-00



**CULVERT REPLACEMENT  
HWY 6, 1.03 Km SOUTH OF SIDE ROAD 3WGR,  
WEST GREY  
BOREHOLE LOCATION PLAN AND PROFILE**

SHEET

exp Services Inc.



**LEGEND**

- Location of Drilled Boreholes
- Standard Penetration Test (Blows/0.3 m)
- Water Level Upon Completion of Drilling
- Temporary Bench Mark (EL. 347.0m)

**SOIL STRATA SYMBOLS**

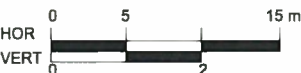
- ASPHALT
- FILL
- SAND AND SILT
- SILTY SAND WITH GRAVEL
- BEDROCK

BH No.	APPROX. ELEV.	MTM CO-ORDINATES	
		NORTH	EAST
BH-1	346.0	4906124.9	197144.3
BH-2	346.3	4906127.3	197174.6
BH-3	348.0	4906150.0	197153.1
BH-4	347.9	4906123.1	197158.5
BH-5	347.9	4906101.7	197166.9

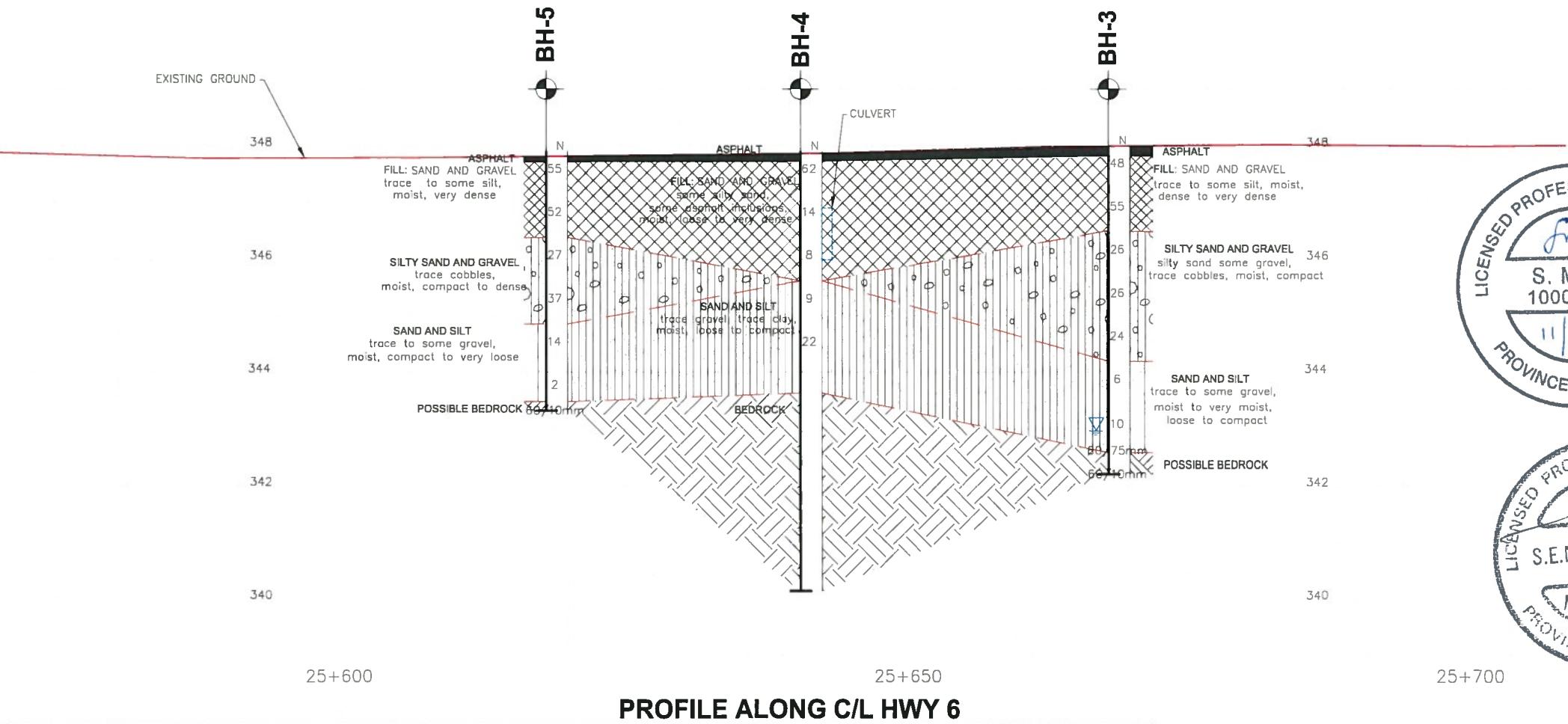
**NOTE**

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

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

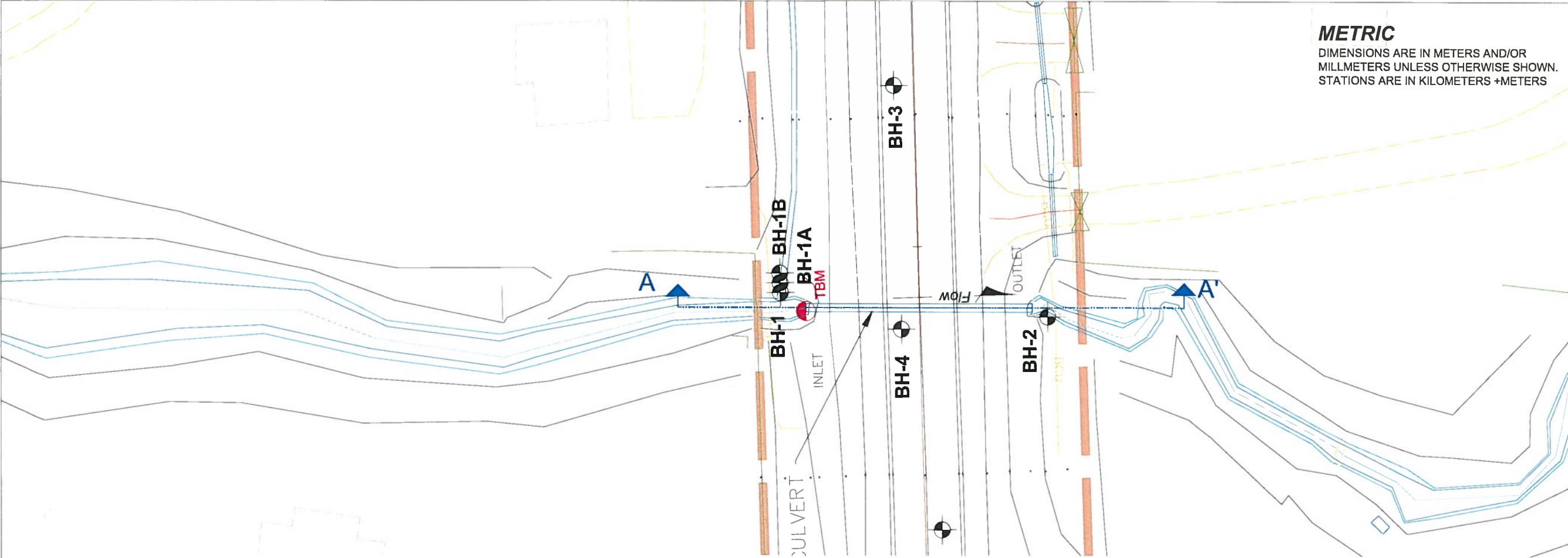


30/11/2016	SM	SUBMISSION FOR MTO REVIEW	
DATE	BY	DESCRIPTION	
		GEOCRE NO. 41A-239	
		PROJECT NO. ADM-00235197-C0	
SUBMD	SM	CHECKED	SM
DRAWN	SH	CHECKED	SG
DATE	30/11/2016	APPROVED	SG
DWG.	01		

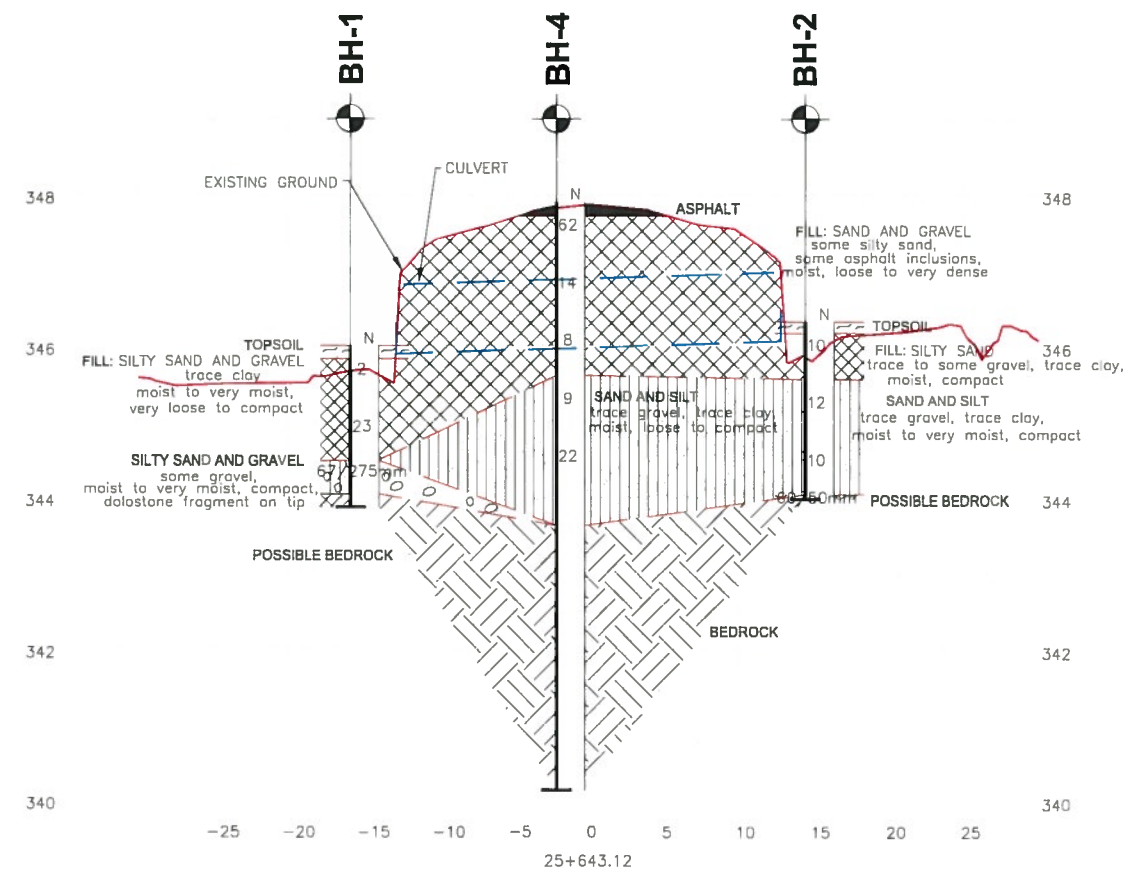


**PROFILE ALONG C/L HWY 6**





PLAN



SECTION A-A'

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

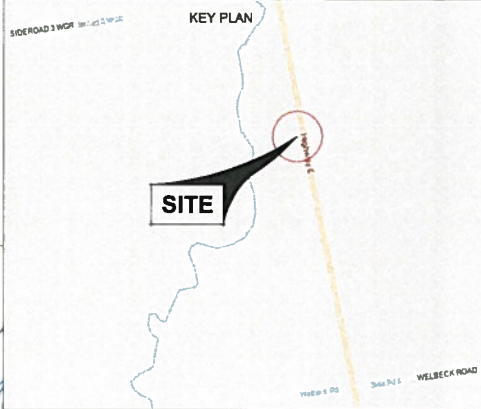
Agreement No. 3015-E-0017  
Assignment No. 3  
GWP - 3062-14-00



**CULVERT REPLACEMENT**  
HWY 6, 1.03 KM SOUTH OF SIDE ROAD 3WGR,  
WEST GREY  
**BOREHOLE LOCATION PLAN AND SECTION A-A'**

SHEET

exp. **exp Services Inc.**



LEGEND

- Location of Drilled Boreholes
- Standard Penetration Test (Blows/0.3 m)
- Water Level Upon Completion of Drilling
- Temporary Bench Mark (EL. 347.0m )

SOIL STRATA SYMBOLS

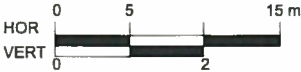
- ASPHALT
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BH No.	APPROX. ELEV.	MTM CO-ORDINATES	
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BH-5	347.9	4906101.7	197166.9

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30/11/2016	SM	SUBMISSION FOR MTO REVIEW	
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		PROJECT NO. ADM-00235197-C0	
SUBM'D	SM	CHECKED	SM
DRAWN	SH	CHECKED	SG
DATE	30/11/2016	APPROVED	SG
		DWG.	02



## **Appendix C – Borehole Logs**

# Explanation of Terms Used on Borehole Records

## SOIL DESCRIPTION

Terminology describing common soil genesis:

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

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

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

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

Terminology describing soil structure:

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

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

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

*Fissured:* material breaks along plane of fracture.

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

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

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

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

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

*Homogeneous:* same color and appearance throughout.

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

*Uniformly Graded:* predominantly on grain size.

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

ISSMFE SOIL CLASSIFICATION											
CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		
<div><div>0.002</div><div>0.006</div><div>0.02</div><div>0.06</div><div>0.2</div><div>0.6</div><div>2.0</div><div>6.0</div><div>20</div><div>60</div><div>200</div></div>											
EQUIVALENT GRAIN DIAMETER IN MILLIMETRES											
CLAY (PLASTIC) TO				FINE		MEDIUM		CRS.	FINE	COARSE	
SILT (NONPLASTIC)				SAND				GRAVEL			
UNIFIED SOIL CLASSIFICATION											

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

Table a: Percent or Proportion of Soil, Pp

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

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

Table b: Apparent Density of Cohesionless Soil

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

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:

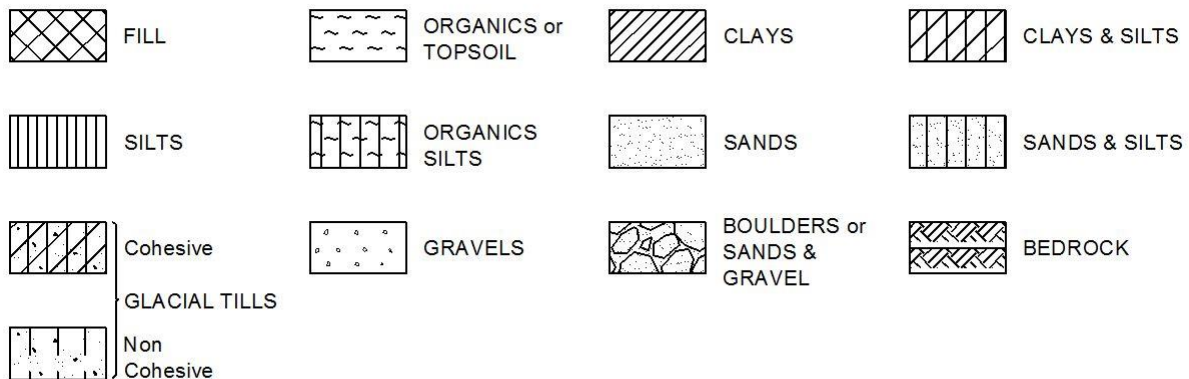
Table c: Consistency of Cohesive Soil

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
$\sigma$	kPa	Total normal stress
$\sigma'$	kPa	Effective normal stress
$\tau$	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
$\varepsilon$	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
$\mu$	1	Coefficient of friction

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$\text{kPa}^{-1}$	Coefficient of volume change
$c_c$	1	Compression index
$c_s$	1	Swelling index
$c_r$	1	Recompression index
$c_v$	$\text{m}^2/\text{s}$	Coefficient of consolidation
H	m	Drainage path
$T_v$	1	Time factor
U	%	Degree of consolidation
$\sigma'_{v0}$	kPa	Effective overburden pressure
$\sigma'_p$	kPa	Preconsolidation pressure
$\tau_f$	kPa	Shear strength
$c'$	kPa	Effective cohesion intercept
$\phi'$	$^\circ$	Effective angle of internal friction
$c_u$	kPa	Apparent cohesion intercept
$\phi_u$	$^\circ$	Apparent angle of internal friction
$\tau_R$	kPa	Residual shear strength
$\tau_r$	kPa	Remoulded shear strength
$S_t$	1	Sensitivity = $c_u/\tau_r$

### PHYSICAL PROPERTIES OF SOIL

$P_s$	$\text{kg}/\text{m}^3$	Density of solid particles
$\gamma_s$	$\text{kN}/\text{m}^3$	Unit weight of solid particles
$\rho_w$	$\text{kg}/\text{m}^3$	Density of water
$\gamma_w$	$\text{kN}/\text{m}^3$	Unit weight of water
$\rho$	$\text{kg}/\text{m}^3$	Density of soil
$\gamma$	$\text{kN}/\text{m}^3$	Unit weight of soil
$\rho_d$	$\text{kg}/\text{m}^3$	Density of dry soil
$\gamma_d$	$\text{kN}/\text{m}^3$	Unit weight of dry soil
$\rho_{sat}$	$\text{kg}/\text{m}^3$	Density of saturated soil
$\gamma_{sat}$	$\text{kN}/\text{m}^3$	Unit weight of saturated soil
$\rho'$	$\text{kg}/\text{m}^3$	Density of submerged soil
$\gamma'$	$\text{kN}/\text{m}^3$	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	$\text{m}^3/\text{s}$	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	$\text{kN}/\text{m}^3$	Seepage force

Brampton, Ontario

## RECORD OF BOREHOLE No BH-1

1 OF 1

METRIC

W.P. 3062-14-00 LOCATION Hwy 6, West Grey, MTM ON10 4906125N, 197144E ORIGINATED BY DP  
 DIST Grey County HWY 6 BOREHOLE TYPE CME-75/ Continuous Flight Hollow Stem Auger COMPILED BY NT  
 DATUM TBM (347.0 m) DATE 2016.11.16 - 2016.11.17 LATITUDE 44.28716 LONGITUDE -80.84889 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE														
346.0	Ground Surface							20	40	60	80	100		20	40	60	85.9	GR SA SI CL				
345.8	TOPSOIL: (~175 mm thick)																					
0.2	FILL: SILTY SAND AND GRAVEL: trace clay, brown, moist to very moist, very loose to compact		1	SS	2		345							○								
			2	SS	23									○								
344.5																						
1.5	SILTY SAND AND GRAVEL: silty sand some gravel, brown and milky brown, moist to very moist, compact, dolostone fragment on tip		3	SS	67/ 275mm									○				38 35 (27)				
344.0																						
343.9	POSSIBLE BEDROCK: Intermediate grinding from 1.96m to 2.13m, refusal to auger and SPT						344															
2.1	End of Borehole at 2.13 m depth.																					
	Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Groundwater level was measured in open hole upon completion of drilling. 3. Borehole open upto 0.3 m below ground surface 4. Borehole was dry in open hole 5. Two additional holes BH1A and BH1B were advanced 1.1 m and 2.2 m north, respectively from BH1 to verify the refusal. The refusal encountered at depth 2.1 m and 2.2 at BH1A and BH1B																					

+ 3, × 3: Numbers refer to  
Sensitivity

○ 3% STRAIN AT FAILURE



Brampton, Ontario

## RECORD OF BOREHOLE No BH-2

1 OF 1

METRIC

W.P. 3062-14-00 LOCATION Hwy 6, West Grey, MTM ON10 4906127N, 197175E ORIGINATED BY DP  
 DIST Grey County HWY 6 BOREHOLE TYPE CME-75/ Solid Stem Auger COMPILED BY NT  
 DATUM TBM (347.0 m) DATE 2016.11.17 - 2016.11.17 LATITUDE 44.28719 LONGITUDE -80.84851 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		w <sub>p</sub>	w	w <sub>L</sub>			WATER CONTENT (%)
346.3	Ground Surface							20	40	60	80	100			
346.0	<b>TOPSOIL:</b> (~150 mm thick)														
0.2	<b>FILL: SILTY SAND:</b> silty sand, trace to some gravel, trace clay, brown, moist, compact		1	SS	10		346								
345.6															
0.8	<b>SAND AND SILT:</b> sand and silt, trace gravel, trace clay, brown to milky brown, moist to very moist, compact		2	SS	12		345								
			3	SS	10										4   49   45   2
344.0															
344.0	<b>POSSIBLE BEDROCK:</b> Intermediate grinding from 2.3 m to 2.34 m depth, auger/ split spoon refusal. Dolostone fragment, milky white, hard		4	SS	60/50mm		344								
2.3	<b>End of Borehole at 2.34 m depth.</b>														
	Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole open upto 1.90 m below ground surface upon completion of drilling. 3. Borehole   dry upon completion of drilling														

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

Brampton, Ontario

## RECORD OF BOREHOLE No BH-3

1 OF 1

METRIC

W.P. 3062-14-00 LOCATION Hwy 6, West Grey, MTM ON10 4906150N, 197153E ORIGINATED BY DP  
 DIST Grey County HWY 6 BOREHOLE TYPE CME-75/ Solid Stem Auger COMPILED BY NT  
 DATUM TBM (347.0 m) DATE 2016.11.16 - 2016.11.16 LATITUDE 44.28739 LONGITUDE -80.84879 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL	×					
348.0	Road Surface						20	40	60	80	100						
349.8	ASPHALT: (~190 mm thick)																
0.2	FILL: SAND AND GRAVEL: trace to some silt, brown, moist, dense to very dense		1	SS	48								○				29 56 (15)
			2	SS	55								○				
346.5	SILTY SAND AND GRAVEL: silty sand some gravel, trace cobbles, brown, moist, compact		3	SS	26								○				
1.5			4	SS	26								○				
			5	SS	24								○				
344.2	SAND AND SILT: trace to some gravel, brown, moist to very moist, loose to compact		6	SS	6								○				12 49 (39)
3.8			7	SS	10								○				
5.4	POSSIBLE BEDROCK: Intermediate grinding from 5.42 m to 5.79 m, dolostone fragment on tip, milky brown		8	SS	60/75mm								○				
5.8	End of Borehole at 5.8 m depth.		9	SS	60/10mm												
Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole open upto 5.18 m upon completion of drilling. 3. Groundwater at 5.03 m at open borehole upon completion of drilling																	

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

ONTARIO MTO ADM-00235197-C0 - HWY 6 CULVERT.GPJ ONTARIO MTO.GDT 19/17

Brampton, Ontario

## RECORD OF BOREHOLE No BH-4

1 OF 1

METRIC

W.P. 3062-14-00 LOCATION Hwy 6, West Grey, MTM ON10 4906123N, 197158E ORIGINATED BY DP  
 DIST Grey County HWY 6 BOREHOLE TYPE CME-75/ Continuous Flight Hollow Stem Auger/ NW/NQ COMPILED BY NT  
 DATUM TBM (347.0 m) DATE 2016.11.18 - 2016.11.18 LATITUDE 44.28715 LONGITUDE -80.84872 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+ FIELD VANE								
								● QUICK TRIAXIAL	× LAB VANE								
347.9	Road Surface						20	40	60	80	100						
349.9	ASPHALT: (~190 mm thick)																
0.2	FILL: SAND AND GRAVEL: sand and gravel some silty sand, some asphalt inclusions, brown, moist, loose to very dense  - becoming silty sand some gravel fill		1	SS	62												
			2	SS	14												
			3	SS	8												
345.6																	
2.3	SAND AND SILT: sand and silt, trace gravel, trace clay, moist, loose to compact		4	SS	9												
			5	SS	22												
343.6																	
4.3	BEDROCK: fine grained, light grey to milky white dolostone, poor to fair quality, moderately weathered with vugs, intensively to moderately fractured, close joint opening NQ Coring  Length (m) RQD (%) Run 1 0.50 75 Run 2 1.47 71 Run 3 1.52 35		6	NQ													
			7	NQ													
			8	NQ													
340.1																	
7.8	End of Borehole at 7.77 m depth.  Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole dry prior to advance the rock coring equipment																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO ADM-00235197-C0 - HWY 6 CULVERT.GPJ ONTARIO MTO.GDT 19/17

Brampton, Ontario

## RECORD OF BOREHOLE No BH-5

1 OF 1

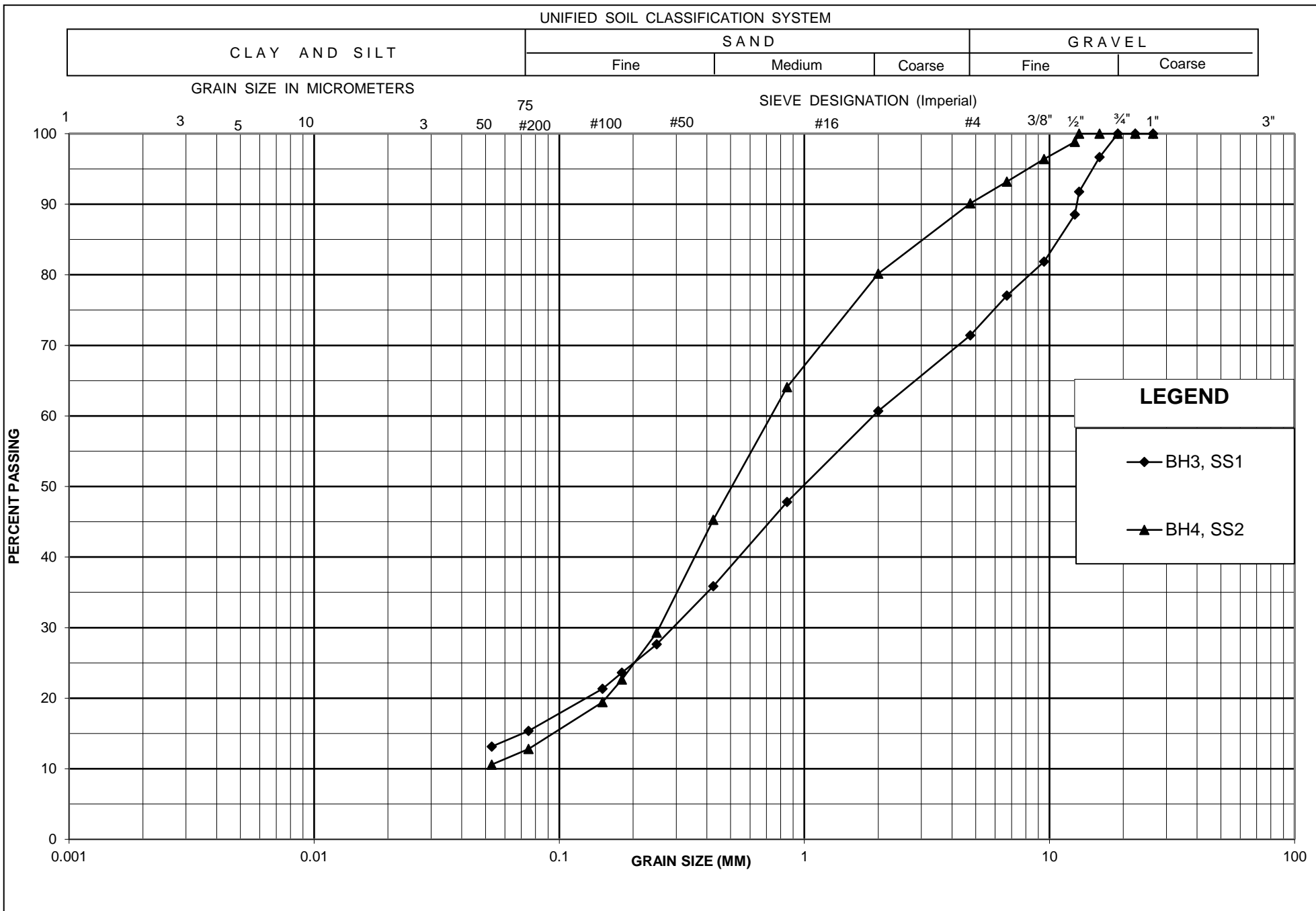
METRIC

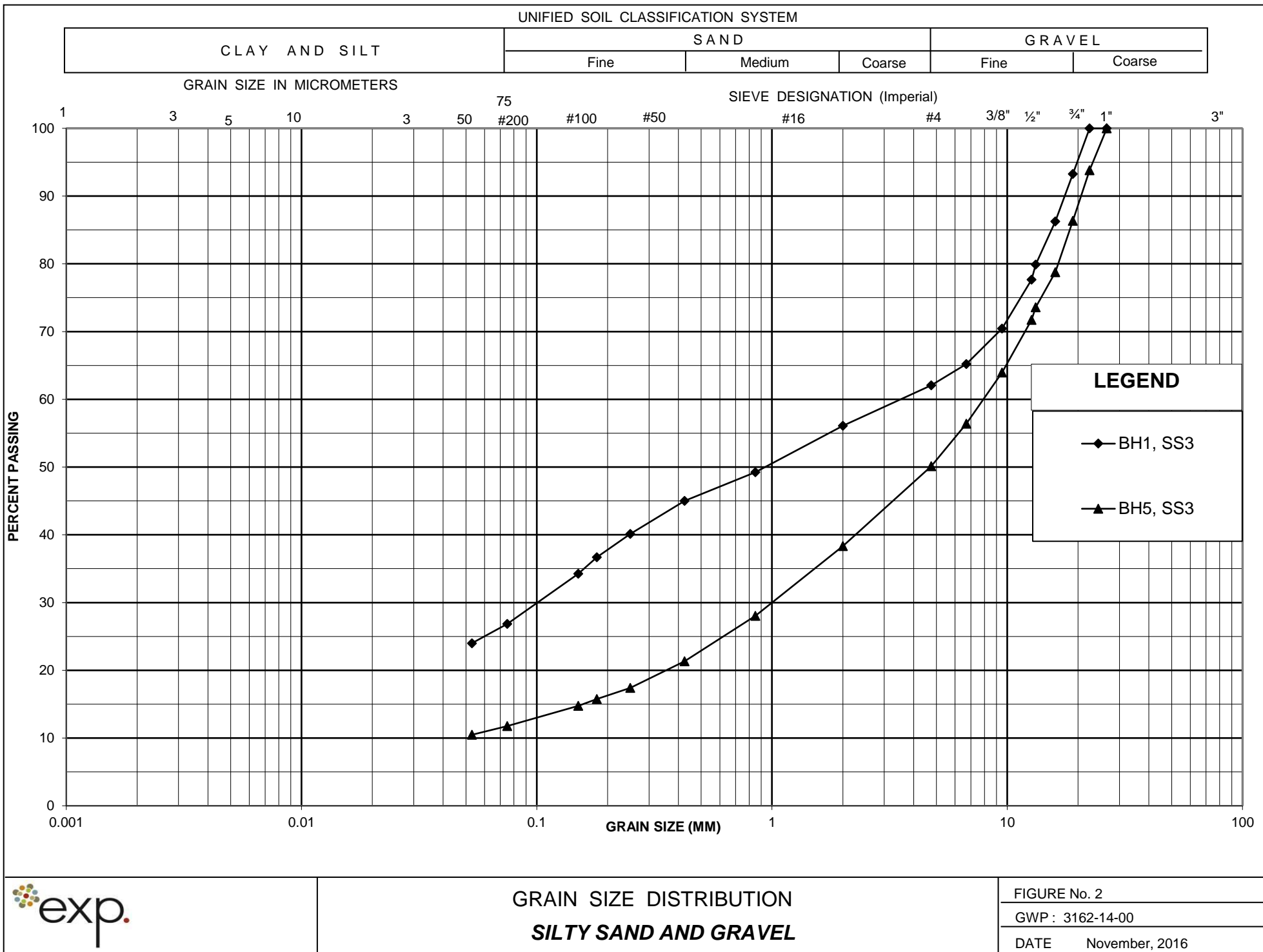
W.P. 3062-14-00 LOCATION Hwy 6, West Grey, MTM ON10 4906102N, 197167E ORIGINATED BY DP  
 DIST Grey County HWY 6 BOREHOLE TYPE CME-75/ Solid Stem Auger COMPILED BY NT  
 DATUM TBM (347.0 m) DATE 2016.11.16 - 2016.11.16 LATITUDE 44.28696 LONGITUDE -80.8486 CHECKED BY SM

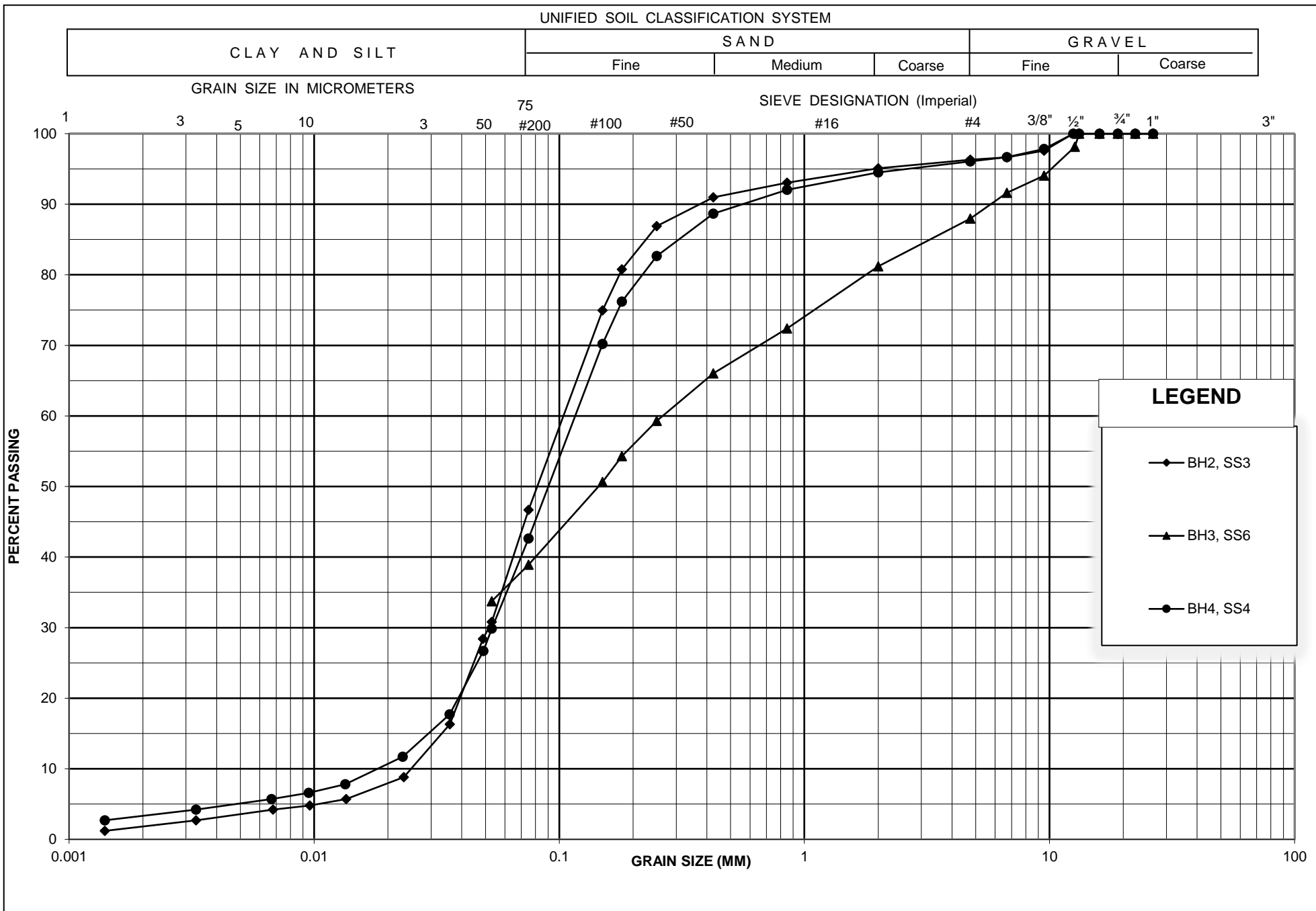
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL						× LAB VANE		
347.9	Road Surface							20	40	60	80	100								
349.9	ASPHALT: (~190 mm thick)																			
0.2	FILL: SAND AND GRAVEL: trace to some silt, brown, moist, very dense		1	SS	55		347													
			2	SS	52															
346.4																				
1.5	SILTY SAND AND GRAVEL: Silty sand and gravel, trace cobbles, brown, moist, compact to dense		3	SS	27		346													
			4	SS	37															
344.9							345													
3.1	SAND AND SILT: trace to some gravel, brown, moist, compact to very loose		5	SS	14															
							344													
			6	SS	2															
343.5																				
343.4	POSSIBLE BEDROCK: Intermediate grinding from 4.42 m to 4.57 m, dolostone fragment on tip, milky white, refusal to auger/split spoon		7	SS	60/10mm															
4.6	End of Borehole at 4.58 m depth.																			
	Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole open upto 4.12 m upon completion of drilling. 3. Borehole dry upon completion of drilling.																			

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

## **Appendix D – Laboratory Data**









Your Project #: ADM#00235179-C0

Site Location: HWY#6

Your C.O.C. #: 61496

**Attention:Nimesh Tamrakar**

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

**Report Date: 2016/11/28**

Report #: R4265883

Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B6P2867**

**Received: 2016/11/21, 13:10**

Sample Matrix: Soil  
# Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	1	N/A	2016/11/25	CAM SOP-00463	EPA 325.2 m
Conductivity	1	N/A	2016/11/25	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl <sub>2</sub> EXTRACT	1	2016/11/25	2016/11/25	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2016/11/21	2016/11/25	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	1	N/A	2016/11/25	CAM SOP-00464	EPA 375.4 m
Oxidation-Reduction Potential (1, 2)	1	2016/11/23	2016/11/25	SLA SOP-00101	In house

**Remarks:**

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

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

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

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

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

(1) This test was performed by Maxxam Sladeview Petrochemical

(2) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode.

Your Project #: ADM#00235179-C0  
Site Location: HWY#6  
Your C.O.C. #: 61496

**Attention:Nimesh Tamrakar**

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

**Report Date: 2016/11/28**  
Report #: R4265883  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B6P2867**

**Received: 2016/11/21, 13:10**

**Encryption Key**

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Sara Singh, B.Sc, Senior Project Manager

Email: sarasingh@maxxam.ca

Phone# (905)817-5730

=====

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### SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		DMH631	DMH631		
Sampling Date		2016/11/21 10:00	2016/11/21 10:00		
COC Number		61496	61496		
	<b>UNITS</b>	<b>BH 2 SS2</b>	<b>BH 2 SS2 Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Calculated Parameters</b>					
Resistivity	ohm-cm	5600			4758040
<b>Inorganics</b>					
Soluble (20:1) Chloride (Cl)	ug/g	55		20	4764910
Conductivity	umho/cm	179	177	2	4765422
Available (CaCl2) pH	pH	7.81			4764163
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	20	4764911
<b>Subcontracted Analysis</b>					
Oxidation-Reduction Potential	mV	+174	+172		4761613
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate					

Maxxam Job #: B6P2867  
Report Date: 2016/11/28

exp Services Inc  
Client Project #: ADM#00235179-C0  
Site Location: HWY#6  
Sampler Initials: DP

## TEST SUMMARY

**Maxxam ID:** DMH631  
**Sample ID:** BH 2 SS2  
**Matrix:** Soil

**Collected:** 2016/11/21  
**Shipped:**  
**Received:** 2016/11/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4764910	N/A	2016/11/25	Deonarine Ramnarine
Conductivity	AT	4765422	N/A	2016/11/25	Tahir Anwar
pH CaCl2 EXTRACT	AT	4764163	2016/11/25	2016/11/25	Neil Dassanayake
Resistivity of Soil		4758040	2016/11/25	2016/11/25	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4764911	N/A	2016/11/25	Alina Dobreanu
Oxidation-Reduction Potential	PH	4761613	2016/11/23	2016/11/25	Grace Sison

**Maxxam ID:** DMH631 Dup  
**Sample ID:** BH 2 SS2  
**Matrix:** Soil

**Collected:** 2016/11/21  
**Shipped:**  
**Received:** 2016/11/21

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	4765422	N/A	2016/11/25	Tahir Anwar
Sulphate (20:1 Extract)	KONE/EC	4764911	N/A	2016/11/25	Alina Dobreanu
Oxidation-Reduction Potential	PH	4761613	2016/11/23		Grace Sison

Maxxam Job #: B6P2867  
Report Date: 2016/11/28

exp Services Inc  
Client Project #: ADM#00235179-C0  
Site Location: HWY#6  
Sampler Initials: DP

#### GENERAL COMMENTS

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

Package 1	9.7°C
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**Results relate only to the items tested.**

## QUALITY ASSURANCE REPORT

exp Services Inc  
Client Project #: ADM#00235179-C0  
Site Location: HWY#6  
Sampler Initials: DP

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
4761613	Oxidation-Reduction Potential						+67	mV	1.2	20	+246	238 - 248
4764163	Available (CaCl2) pH	2016/11/25			99	97 - 103			0.11	N/A		
4764910	Soluble (20:1) Chloride (Cl)	2016/11/25	NC	70 - 130	102	70 - 130	<20	ug/g	15	35		
4764911	Soluble (20:1) Sulphate (SO4)	2016/11/25	110	70 - 130	103	70 - 130	<20	ug/g	NC	35		
4765422	Conductivity	2016/11/25			100	90 - 110	<2	umho/cm	1.2	10		

N/A = Not Applicable

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

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

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

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

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

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

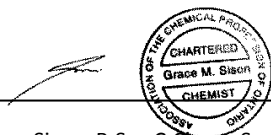
NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

### VALIDATION SIGNATURE PAGE

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



Brad Newman, Scientific Specialist



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

---

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Your Project #: B6P2867  
Site Location: ADM#00235179-C0  
Your C.O.C. #: 08432074

**Attention: SUB CONTRACTOR**

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

**Report Date: 2016/11/25**  
Report #: R2307115  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B6A5240**

**Received: 2016/11/23, 10:50**

Sample Matrix: Soil  
# Samples Received: 1

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Moisture	1	2016/11/25	2016/11/25	BBY8SOP-00017	BCMOE BCLM Dec2000 m
Sulfide (AVS) (soil)	1	2016/11/25	2016/11/25	BBY6SOP-00006	SM 22 4500 S2- D m

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

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

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



Your Project #: B6P2867  
Site Location: ADM#00235179-C0  
Your C.O.C. #: 08432074

**Attention:SUB CONTRACTOR**

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

**Report Date: 2016/11/25**  
Report #: R2307115  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B6A5240**  
**Received: 2016/11/23, 10:50**

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Amandeep Nagra, Account Specialist

Email: ANagra@maxxam.ca

Phone# (604)639-2602

=====

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Maxxam Job #: B6A5240  
Report Date: 2016/11/25

MAXXAM ANALYTICS  
Client Project #: B6P2867  
Site Location: ADM#00235179-C0

### RESULTS OF CHEMICAL ANALYSES OF SOIL

<b>Maxxam ID</b>		QC6350	QC6350		
<b>Sampling Date</b>					
<b>COC Number</b>		08432074	08432074		
	<b>UNITS</b>	<b>BH 2 SS2 (DMH631)</b>	<b>BH 2 SS2 (DMH631) Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>
<b>MISCELLANEOUS</b>					
Sulphide	ug/g	<0.50 (1)	<0.50	0.50	8484242
RDL = Reportable Detection Limit Lab-Dup = Laboratory Initiated Duplicate (1) Headspace in sample jar was noted at the time of extraction. Matrix spike exceeds acceptance limits due to matrix interference. Re-analysis yields similar results.					

Maxxam Job #: B6A5240  
Report Date: 2016/11/25

MAXXAM ANALYTICS  
Client Project #: B6P2867  
Site Location: ADM#00235179-C0

### PHYSICAL TESTING (SOIL)

Maxxam ID		QC6350		
Sampling Date				
COC Number		08432074		
	UNITS	BH 2 SS2 (DMH631)	RDL	QC Batch
<b>Physical Properties</b>				
Moisture	%	16	0.30	8484688
RDL = Reportable Detection Limit				

Maxxam Job #: B6A5240  
Report Date: 2016/11/25

MAXXAM ANALYTICS  
Client Project #: B6P2867  
Site Location: ADM#00235179-C0

## TEST SUMMARY

**Maxxam ID:** QC6350  
**Sample ID:** BH 2 SS2 (DMH631)  
**Matrix:** Soil

**Collected:**  
**Shipped:**  
**Received:** 2016/11/23

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8484688	2016/11/25	2016/11/25	Cyrhea Goda
Sulfide (AVS) (soil)	SPEC/COL	8484242	2016/11/25	2016/11/25	Prabhleen Sodhi

**Maxxam ID:** QC6350 Dup  
**Sample ID:** BH 2 SS2 (DMH631)  
**Matrix:** Soil

**Collected:**  
**Shipped:**  
**Received:** 2016/11/23

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulfide (AVS) (soil)	SPEC/COL	8484242	2016/11/25	2016/11/25	Prabhleen Sodhi

Maxxam Job #: B6A5240  
Report Date: 2016/11/25

MAXXAM ANALYTICS  
Client Project #: B6P2867  
Site Location: ADM#00235179-C0

### GENERAL COMMENTS

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

Package 1	6.0°C
-----------	-------

**Results relate only to the items tested.**



Maxxam Job #: B6A5240  
Report Date: 2016/11/25

## QUALITY ASSURANCE REPORT

MAXXAM ANALYTICS  
Client Project #: B6P2867  
Site Location: ADM#00235179-C0

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8484242	Sulphide	2016/11/25	60 (1)	75 - 125	92	75 - 125	<0.50	ug/g	NC	30

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

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

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

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

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

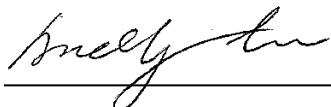
(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

Maxxam Job #: B6A5240  
Report Date: 2016/11/25

MAXXAM ANALYTICS  
Client Project #: B6P2867  
Site Location: ADM#00235179-C0

### VALIDATION SIGNATURE PAGE

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



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

---

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## **Appendix E – Rock Core Photographs**

Project NO: ADM-00235197-C0  
BH NO: 4  
Run NO: 1  
Sample Depth: 4.3 m to 4.8 m  
Elevation: 343.6 m to 343.1 m  
RQD: 75%  
Date: November 18, 2016



**Photo 1.** Core Sample(Run1) for BH 4 from Elevation 343.6 m to 343.1 m

Project NO: ADM-00235197-C0  
BH NO: 4  
Run NO: 2  
Sample Depth: 4.8 m to 6.27 m  
Elevation: 343.1 m to 341.63 m  
RQD: 71%  
Date: November 18, 2016



**Photo 2.** Core Sample(Run 2) for BH 4 from Elevation 343.1 m to 341.63 m

Project NO: ADM-00235197-C0  
BH NO: 4  
Run NO: 3  
Sample Depth: 6.27 m to 7.8 m  
Elevation: 341.63 m to 340.1 m  
RQD: 35%  
Date: November 18, 2016



**Photo 3.** Core Sample(Run3) for BH 4 from Elevation 341.63 m to 340.1 m

## **Appendix F – Slope Stability Analysis**

# Culvert on Hwy 6 Stability of Embankment Slope Drained Static Condition

Name: Sand and Gravel Fill    Model: Mohr-Coulomb    Unit Weight: 21 kN/m<sup>3</sup>    Cohesion': 0 kPa    Phi': 32 °  
Name: Silty Sand and Gravel Fill/Silty Sand Fill (Compact)    Model: Mohr-Coulomb    Unit Weight: 19 kN/m<sup>3</sup>    Cohesion': 0 kPa    Phi': 30 °  
Name: Sand and Silt (Compact)    Model: Mohr-Coulomb    Unit Weight: 19 kN/m<sup>3</sup>    Cohesion': 0 kPa    Phi': 29 °  
Name: Silty Sand and Gravel (Very Dense)    Model: Mohr-Coulomb    Unit Weight: 20 kN/m<sup>3</sup>    Cohesion': 0 kPa    Phi': 30 °  
Name: Bedrock    Model: Bedrock (Impenetrable)

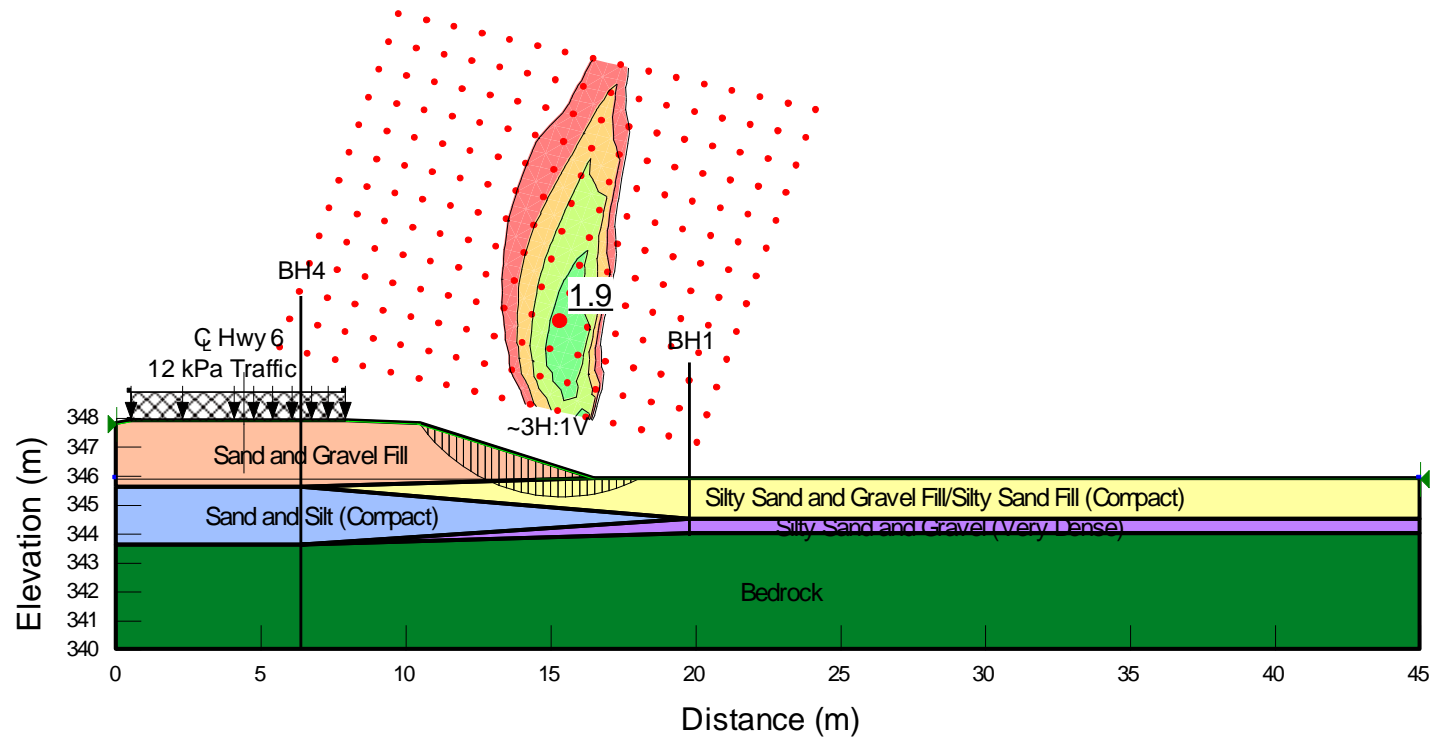


Figure 1: Slope stability analysis for embankment slope – drained static conditions



# Culvert on Hwy 6 Stability of Embankment Slope Drained Static Condition

Name: Engineered Fill Model: Mohr-Coulomb Unit Weight: 21 kN/m<sup>3</sup> Cohesion': 0 kPa Phi': 32 °  
 Name: Silty Sand and Gravel Fill/Silty Sand Fill (Compact) Model: Mohr-Coulomb Unit Weight: 19 kN/m<sup>3</sup> Cohesion': 0 kPa Phi': 30 °  
 Name: Sand and Silt (Compact) Model: Mohr-Coulomb Unit Weight: 19 kN/m<sup>3</sup> Cohesion': 0 kPa Phi': 29 °  
 Name: Silty Sand and Gravel (Very Dense) Model: Mohr-Coulomb Unit Weight: 20 kN/m<sup>3</sup> Cohesion': 0 kPa Phi': 30 °  
 Name: Bedrock Model: Bedrock (Impenetrable)

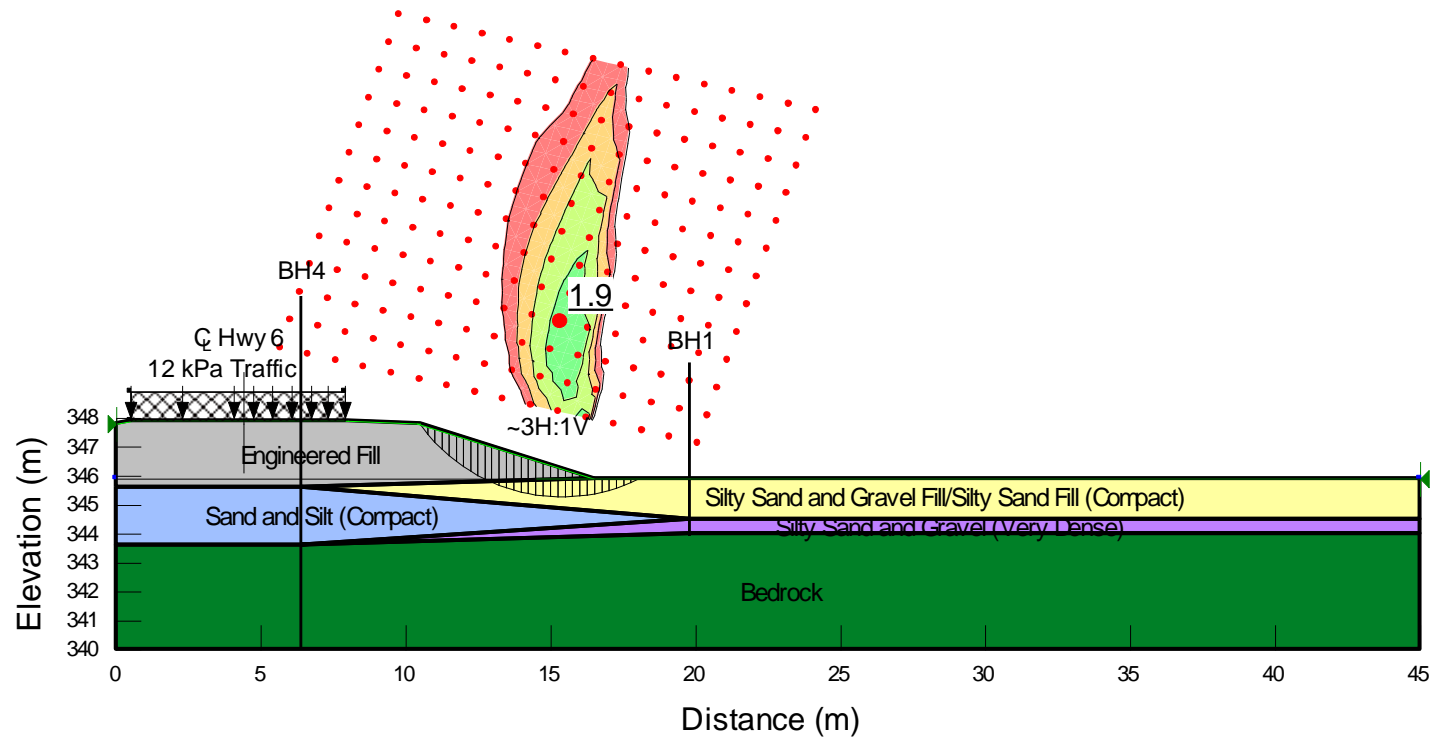


Figure 2: Slope stability analysis for embankment slope after culvert replacement with 3H:1V slope – drained static conditions

# Culvert on Hwy 6 Stability of Embankment Slope Drained Static Condition

Name: Engineered Fill Model: Mohr-Coulomb Unit Weight: 21 kN/m<sup>3</sup> Cohesion': 0 kPa Phi': 32 °  
 Name: Silty Sand and Gravel Fill/ Silty Sand Fill (Compact) Model: Mohr-Coulomb Unit Weight: 19 kN/m<sup>3</sup> Cohesion': 0 kPa Phi': 30 °  
 Name: Sand and Silt (Compact) Model: Mohr-Coulomb Unit Weight: 19 kN/m<sup>3</sup> Cohesion': 0 kPa Phi': 29 °  
 Name: Silty Sand and Gravel (Very Dense) Model: Mohr-Coulomb Unit Weight: 20 kN/m<sup>3</sup> Cohesion': 0 kPa Phi': 30 °  
 Name: Bedrock Model: Bedrock (Impenetrable)

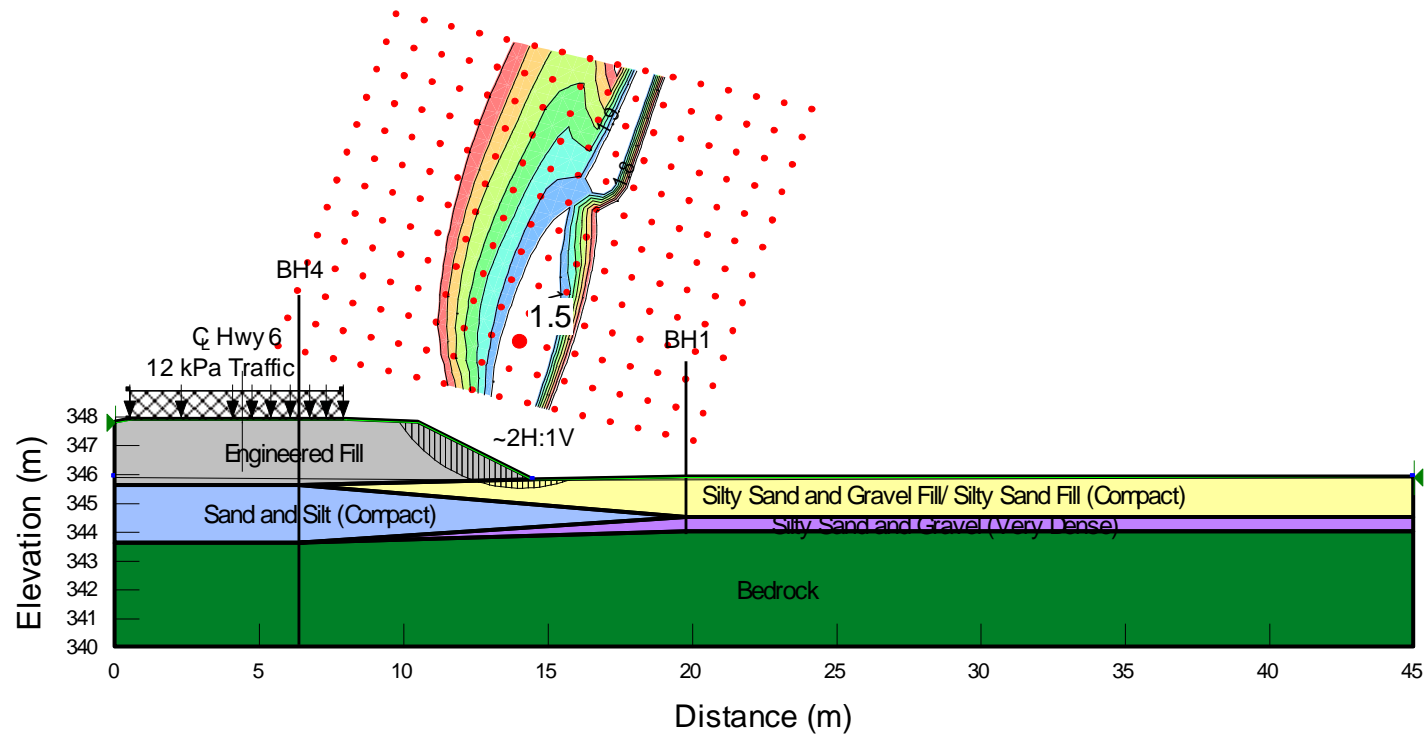
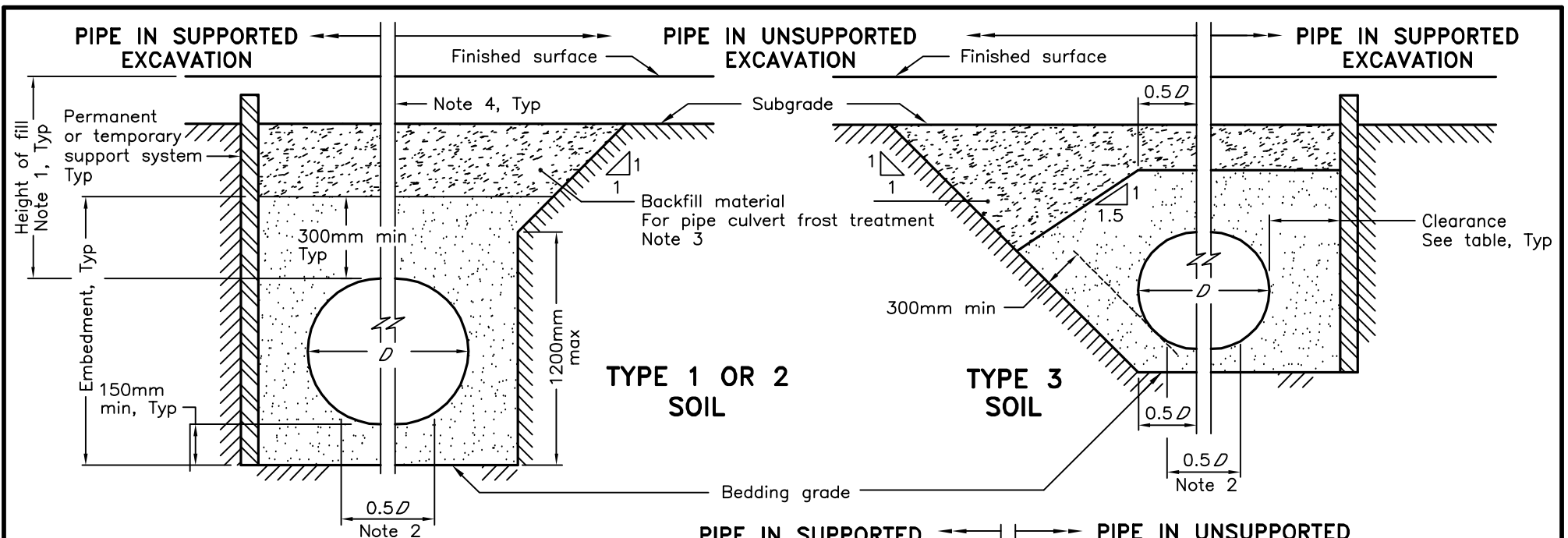


Figure 3: Slope stability analysis for embankment slope after culvert replacement with 2H:1V slope – drained static conditions

## **Appendix G – Ontario Provincial Standard Drawings**

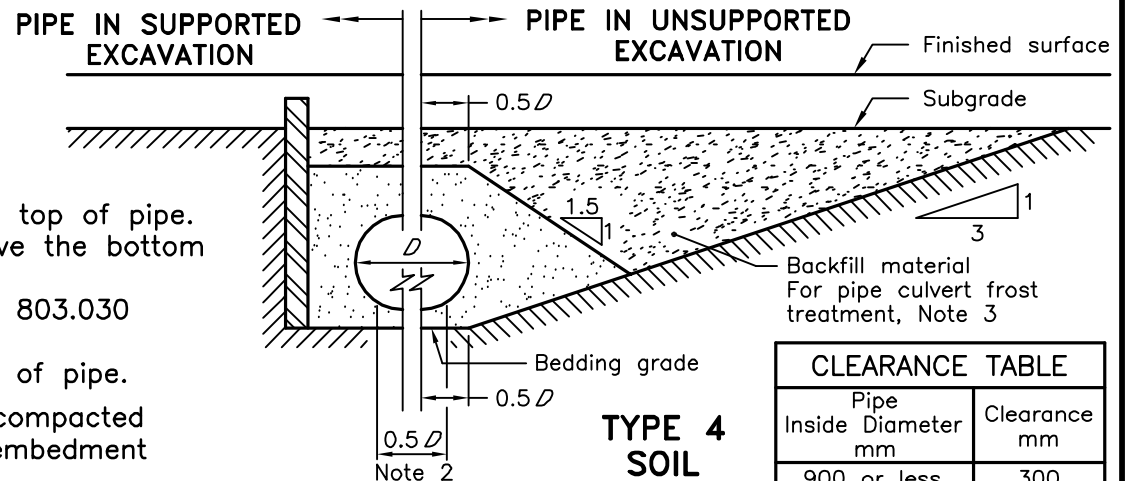


# LEGEND:

$D$  - Inside diameter

# NOTES:

- 1 Height of fill is measured from the finished surface to top of pipe.
  - 2 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
  - 3 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.
  - 4 Condition of excavation is symmetrical about centreline of pipe.
- A Granular material placed in the haunch area shall be compacted prior to placing and compacting the remainder of the embedment material.
- B Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.
- C All dimensions are in metres unless otherwise shown.



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

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2010

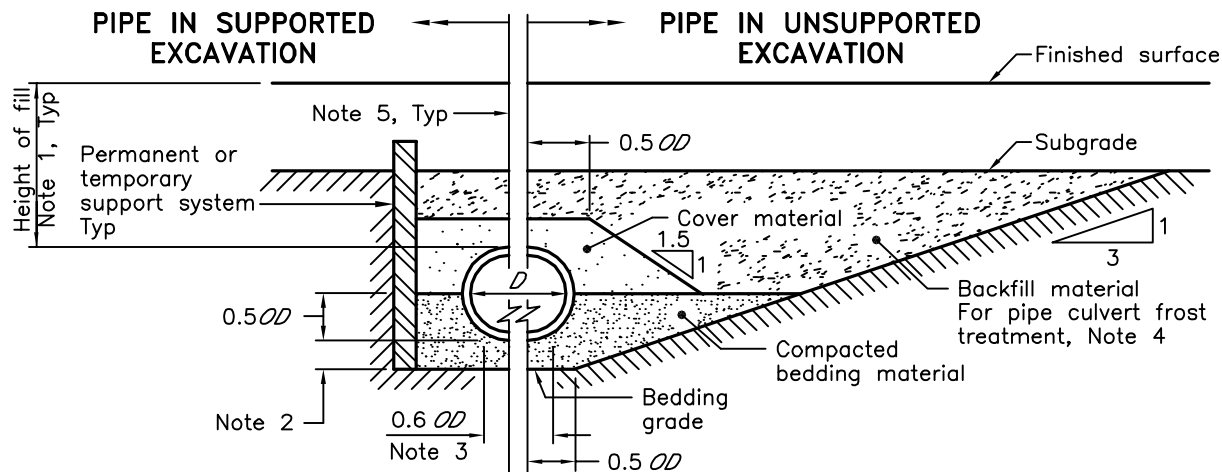
Rev 2

FLEXIBLE PIPE  
EMBEDMENT AND BACKFILL  
EARTH EXCAVATION

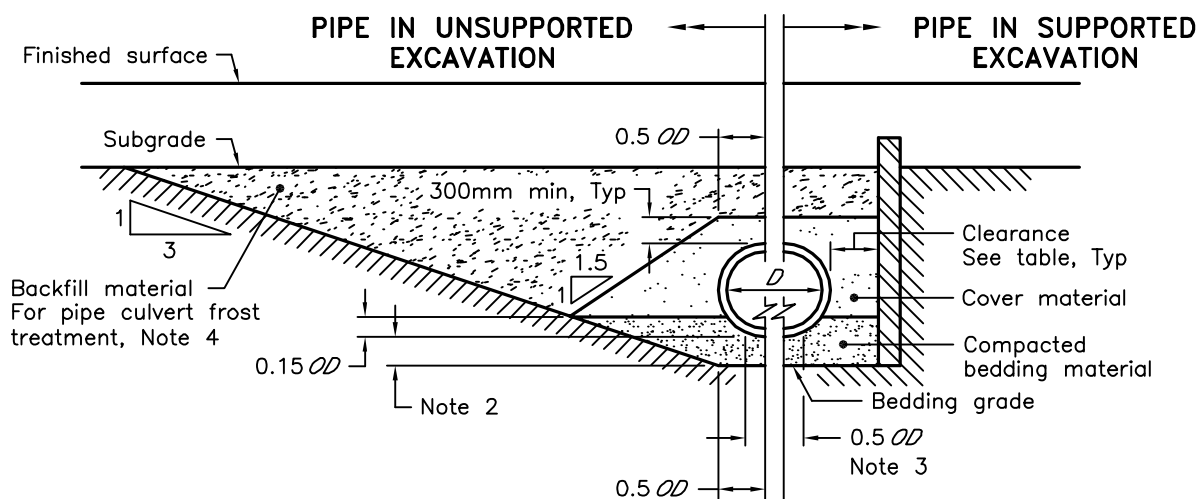
OPSD 802.010







### CLASS B BEDDING



### CLASS C BEDDING

#### 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  $0.15D$ .  
 In no case shall this dimension be less than 150mm or greater than 300mm.
  - 3 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
  - 4 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.
  - 5 Condition of excavation is symmetrical about centreline of pipe.
- A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.
- B All dimensions are in metres unless otherwise shown.

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

ONTARIO PROVINCIAL STANDARD DRAWING

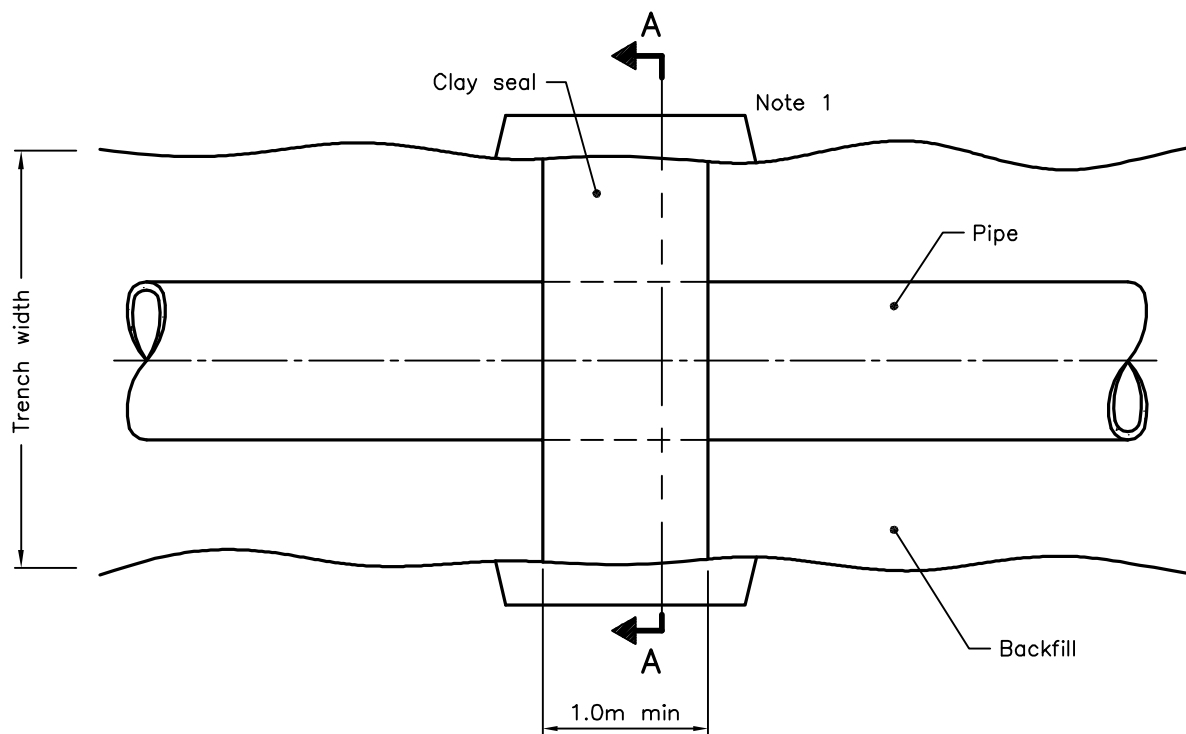
Nov 2010 Rev 2

RIGID PIPE BEDDING,  
 COVER, AND BACKFILL  
 TYPE 4 SOIL – EARTH EXCAVATION

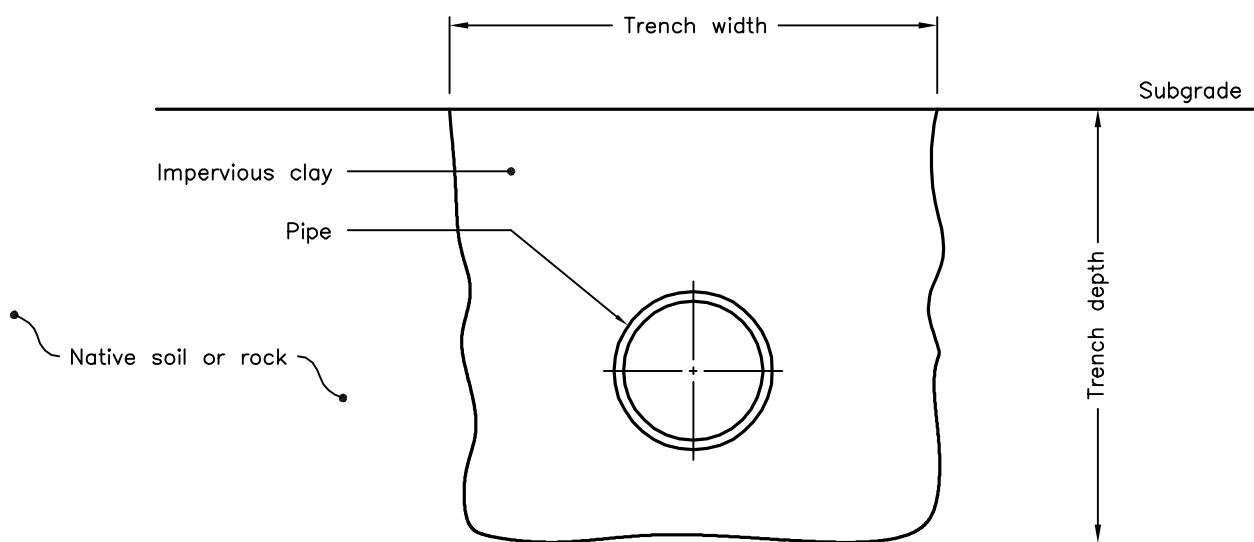
OPSD 802.032







**PLAN**



**SECTION A-A**

**NOTES:**

1. Key into undisturbed trench soil.

A Clay seal shall extend from bottom of trench excavation to the subgrade.

B Clay seal shall be located so that no pipe joints are within the clay seal material.

C All dimensions are in metres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2011

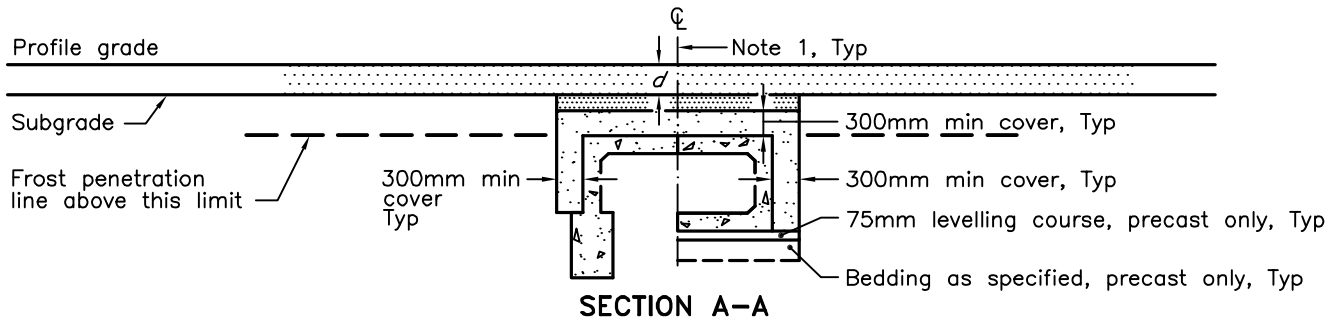
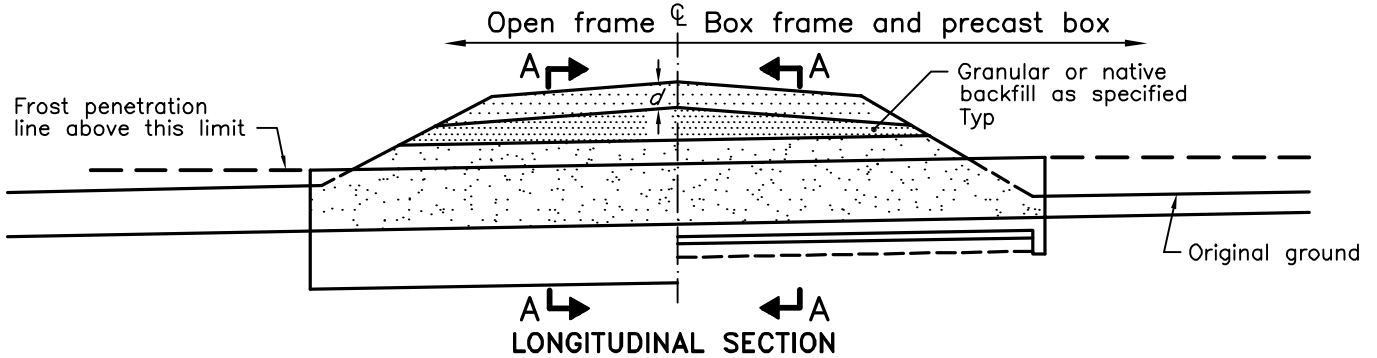
Rev 1

**CLAY SEAL FOR PIPE TRENCHES**

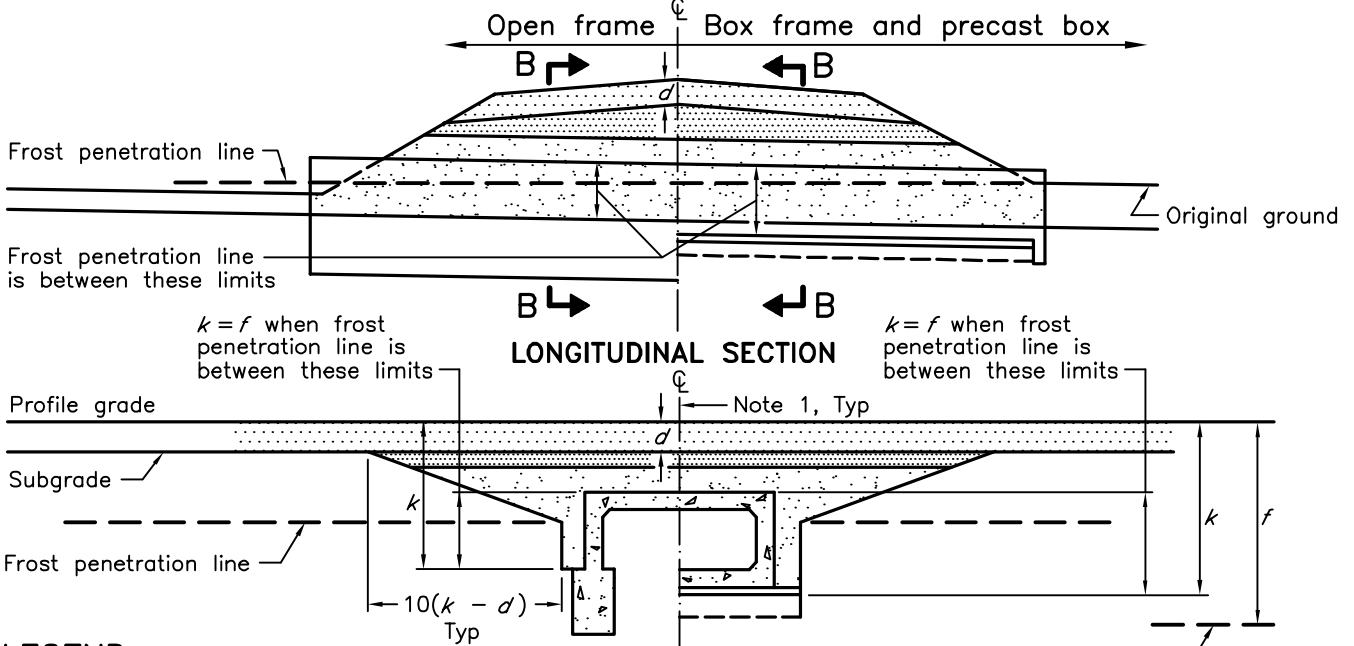
**OPSD 802.095**



## FROST PENETRATION LINE AT OR ABOVE TOP OF CULVERT



## 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.

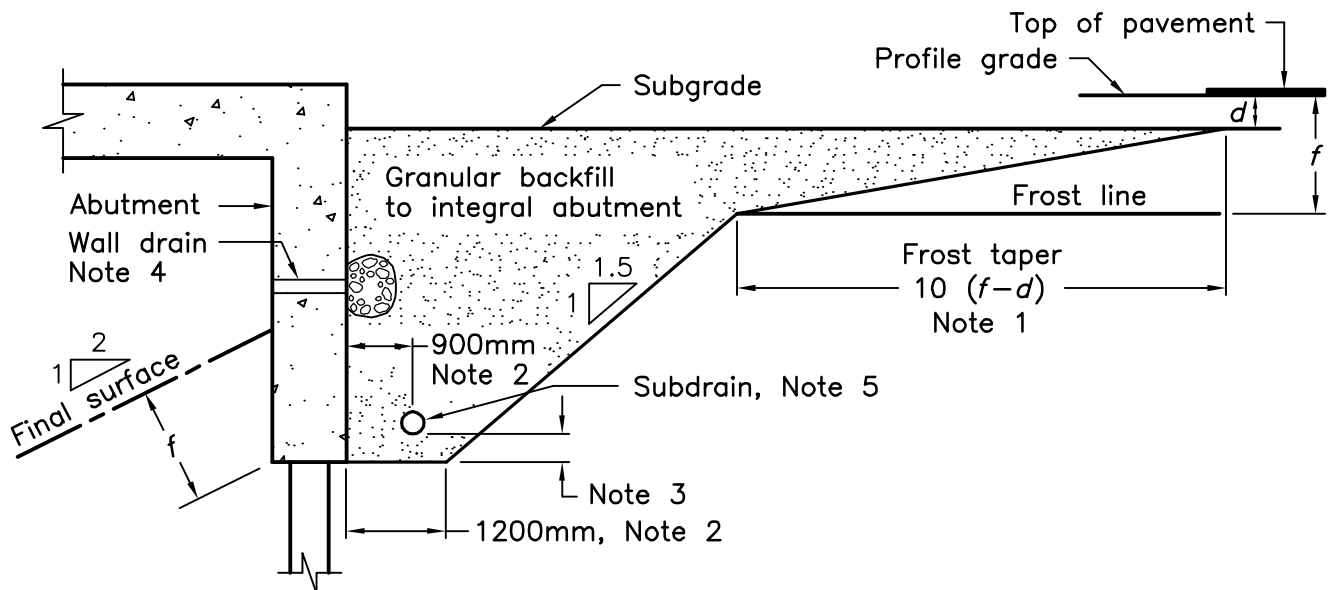
ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2010    Rev    2

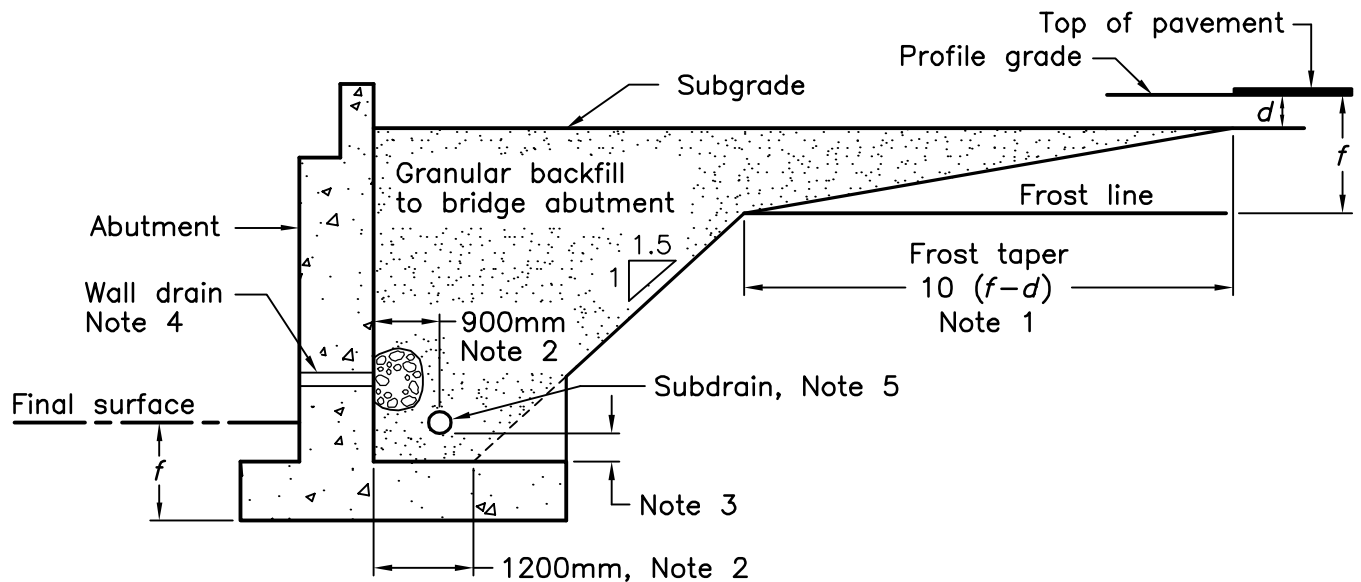
**BACKFILL AND COVER FOR  
CONCRETE CULVERTS WITH SPANS  
LESS THAN OR EQUAL TO 3.0M**

**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

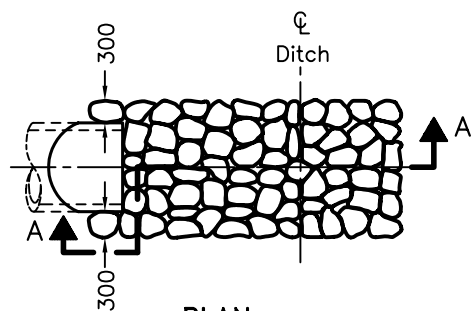
Nov 2010

Rev 1

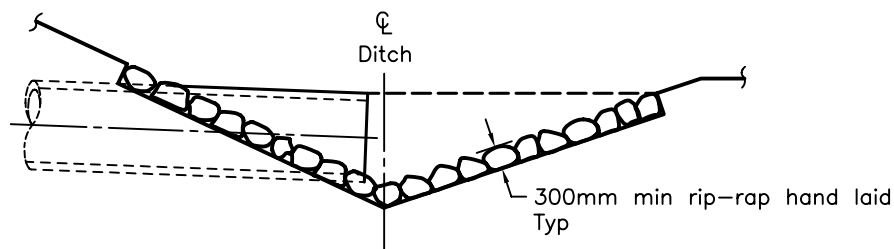


**WALLS**  
**ABUTMENT, BACKFILL**  
**MINIMUM GRANULAR REQUIREMENT**

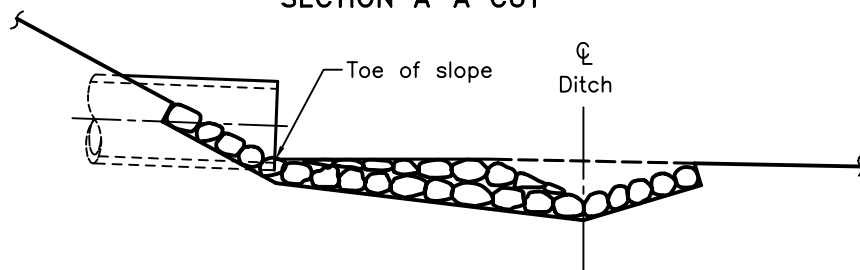
**OPSD 3101.150**



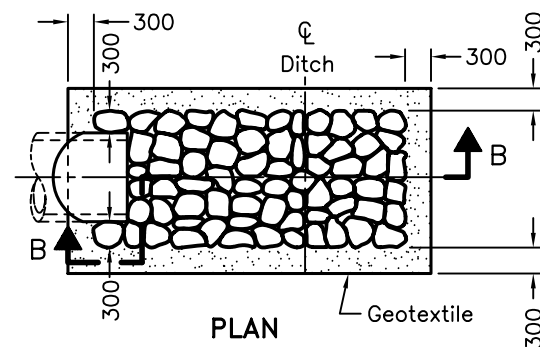
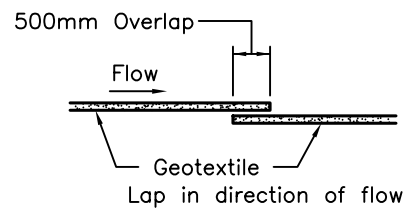
PLAN  
CUT OR FILL



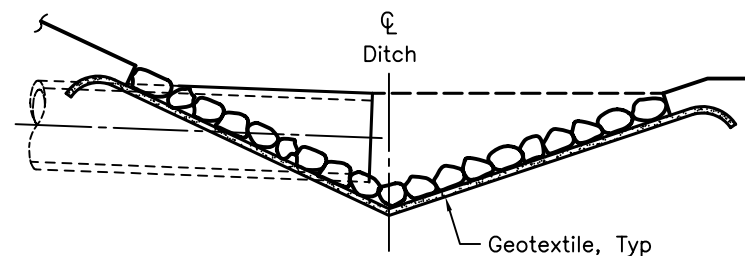
SECTION A-A CUT



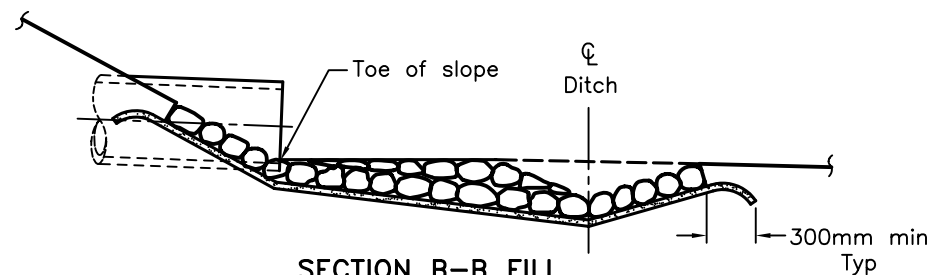
SECTION A-A FILL  
TYPE A – WITHOUT GEOTEXTILE



PLAN  
CUT OR FILL



SECTION B-B CUT



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**

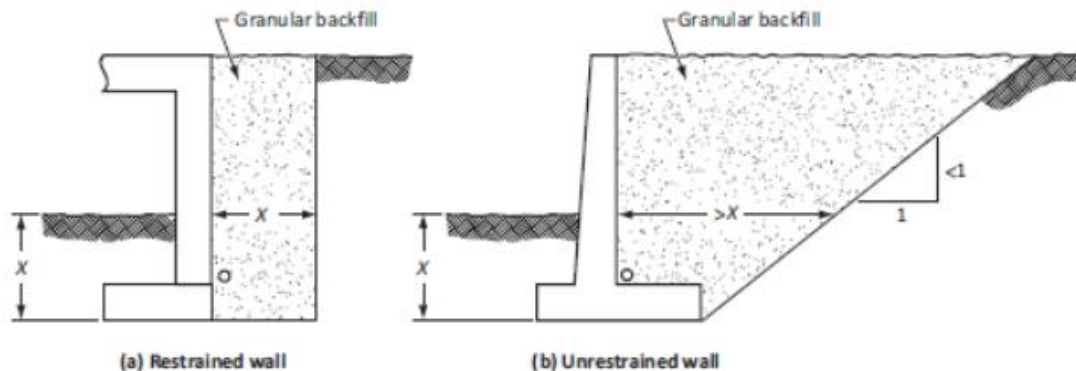
- A drainage system behind a retaining structure should ensure that a groundwater table does not exist above the footing level. Preferably, the ground water level is controlled by the use of free-draining granular backfill and a collection system such as weep holes or perforated drains at the footing level. These weep holes and drains should be inspected and maintained to ensure that they do not become blocked. If free-draining, granular backfill is not employed, the permeability of the backfill and the hydrostatic head will control the extent to which the groundwater table can be depressed locally by seepage towards a footing drain. In practice, design for frost protection is best done using free-draining backfill.

The design should also consider the risk of unusually large inflows of water creating a temporary hydrostatic head of water behind the wall. An example is the overtopping of a retaining wall, adjoining a large body of water, by storm waves. Measures such as the use of quarried rock backfill, design for full hydrostatic pressure, or provision of a sloped impermeable surface layer should be considered.

Measurements have shown that earth pressures can vary seasonally, but the effects have normally been neglected in design, except for winter frost pressures. These latter can be very large if the backfill is frost susceptible and for this reason free-draining granular backfill is recommended.
- Figure C6.20 shows examples of minimum backfill requirements.

The distance,  $x$ , should be equal to or greater than the estimated vertical frost penetration. This distance may be reduced if the wall abuts a vertical face of bedrock that is not susceptible to frost. The frost penetration may be reduced by the use of suitable insulation, in which case a thermal analysis should be performed by a Geotechnical Engineer.

If rock fill is used as a backfill material, consideration should be given to the possible deterioration of the rockfill with time, which could result in the reduction or even the total loss of free-draining properties and, hence, increased frost susceptibility.



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

## C6.12.2 Lateral ground pressures

### C6.12.2.1 General

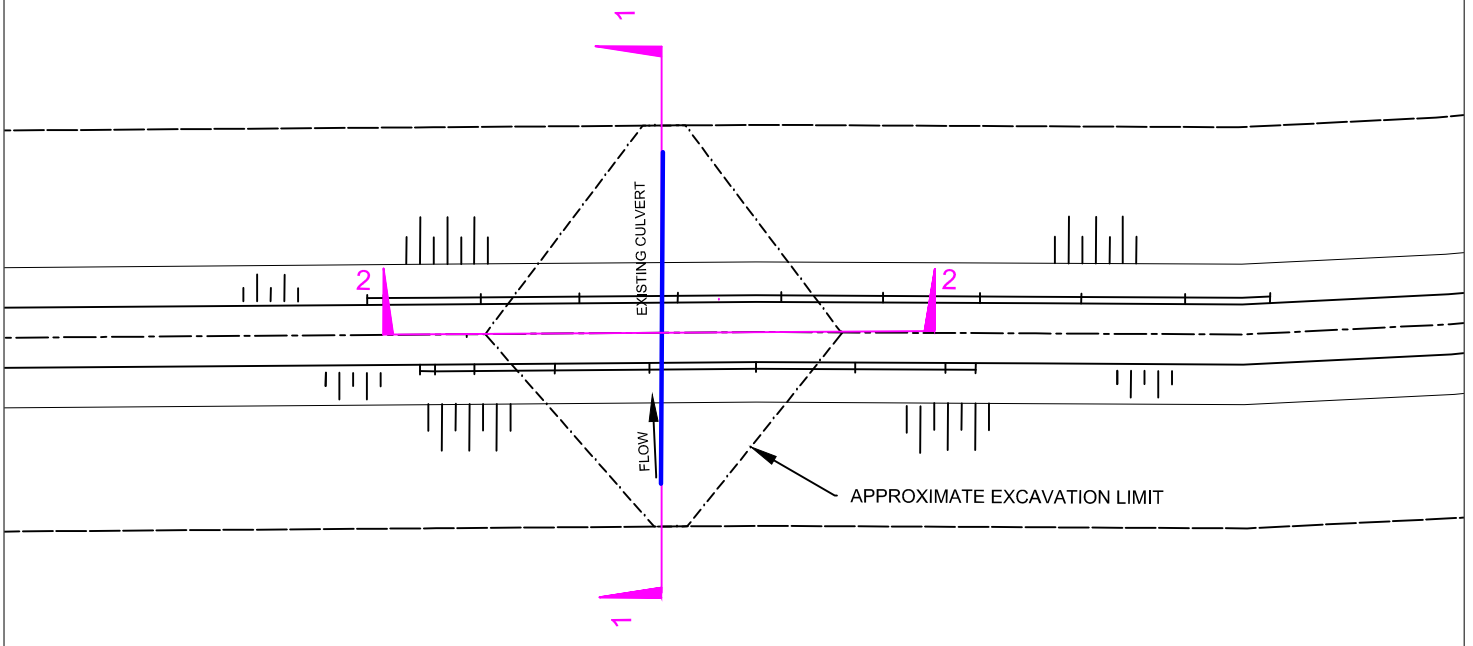
Earth pressure acting on a structure depends on the relative movement of the structure, the backfill, the type of soil adjacent to the backfill, and the soil below the footing or supporting piles. Appropriate geotechnical parameters should be chosen for the calculation of lateral pressures based on recognized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

## **Appendix H – Schematic Sketches for Construction Alternatives**

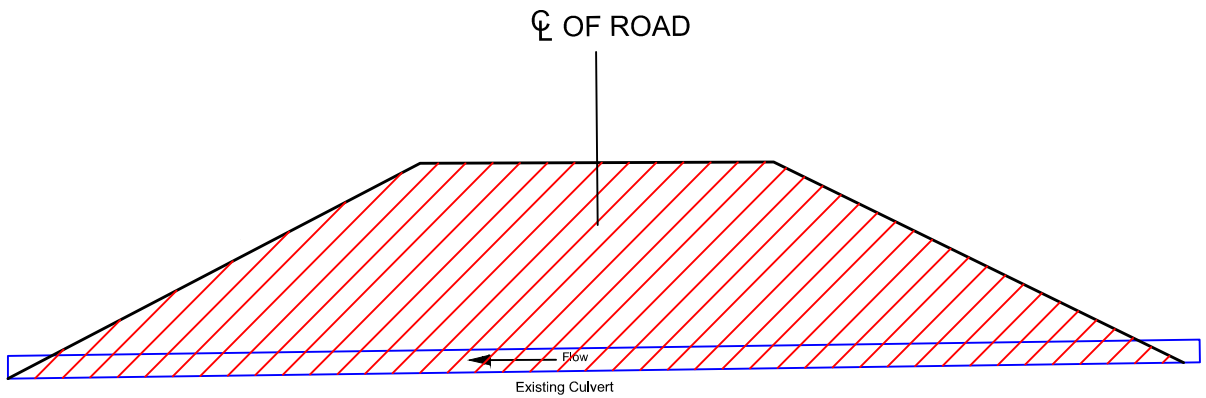


**FIGURE H.1: FULL ROAD CLOSURE USING EXISTING ROADWAYS AND OPEN CUT  
UNSUPPORTED EXCAVATION OPTION1**

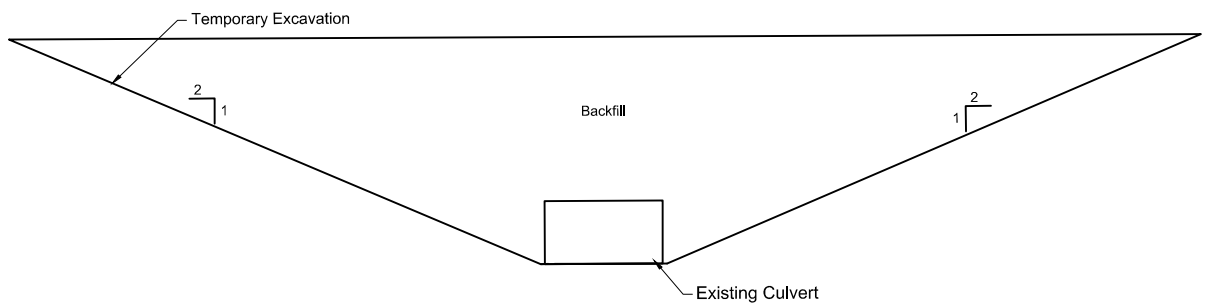
**SCHEMATIC DIAGRAMS (NTS)**



**PLAN**



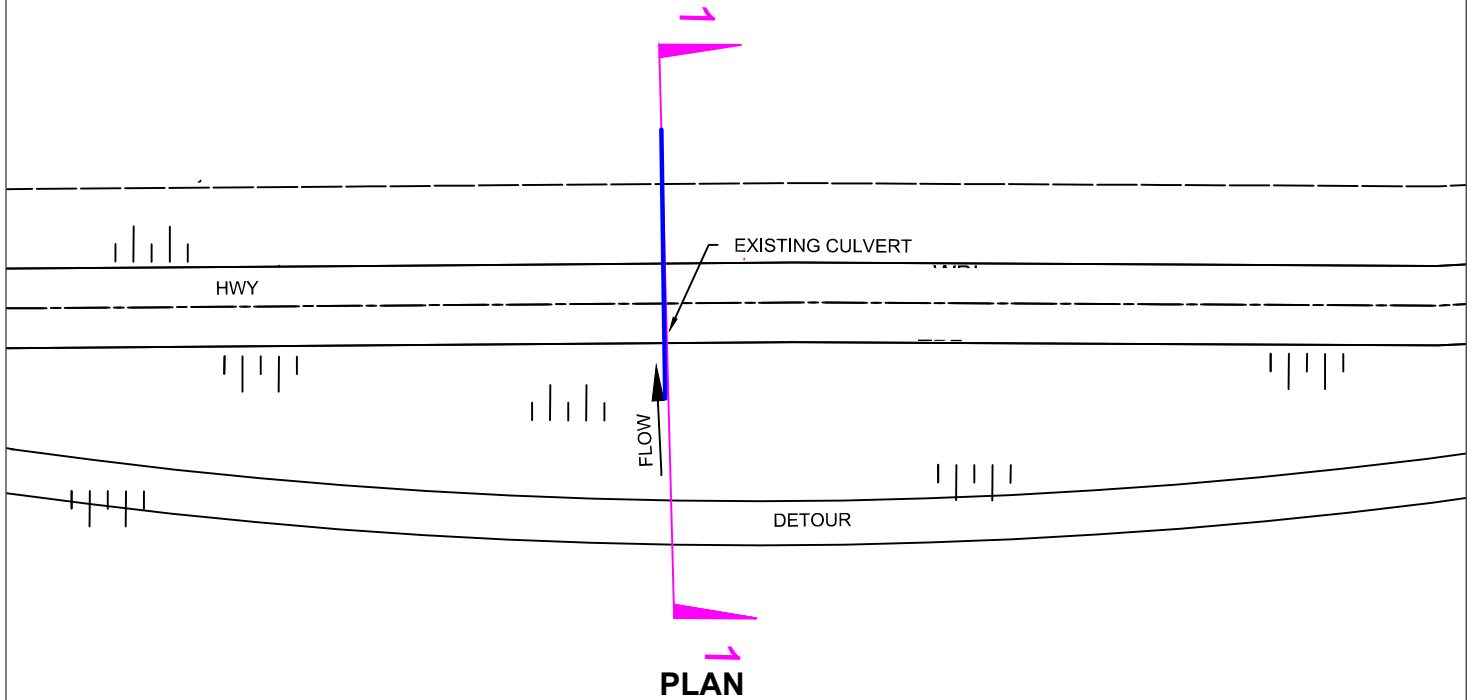
**SECTION 1-1**



**SECTION 2-2**

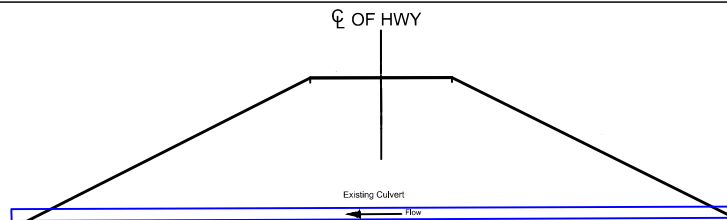
# FIGURE H.2: TEMPORARY LOCAL DETOUR AND OPEN CUT UNSUPPORTED EXCAVATION (OPTION 2)

## SCHEMATIC DIAGRAMS (NTS)

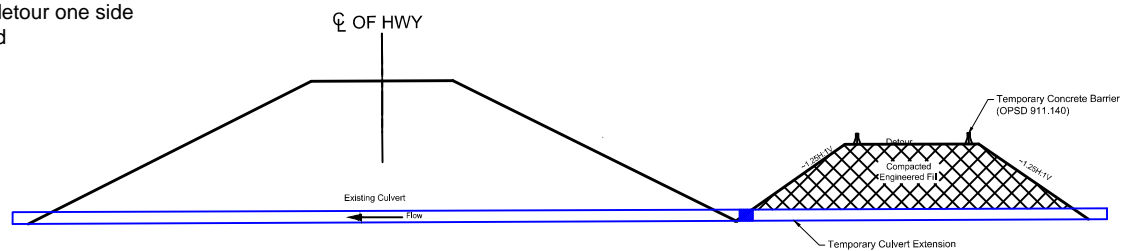


### RECOMMENDED STAGES

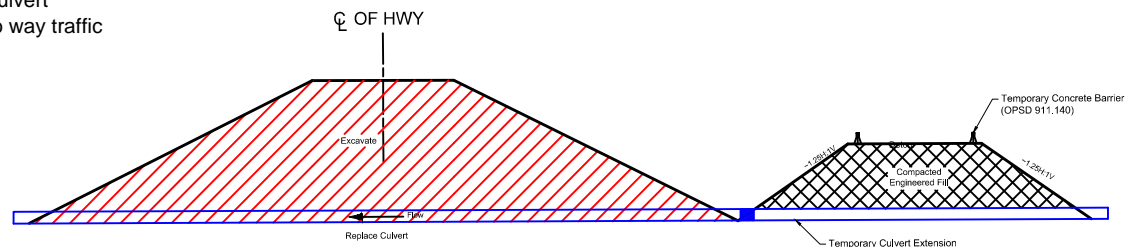
1.0 Stage 1 - Current condition



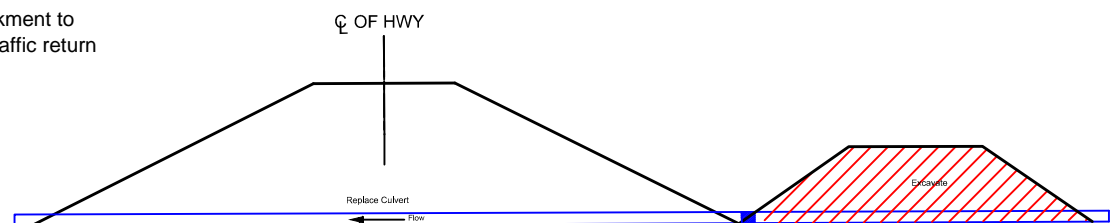
2.0 Stage 2 - Build temporary detour one side  
Two-way traffic on existing road



3.0 Stage 3 - Excavation and culvert construction on other side; Two way traffic shifted to detour

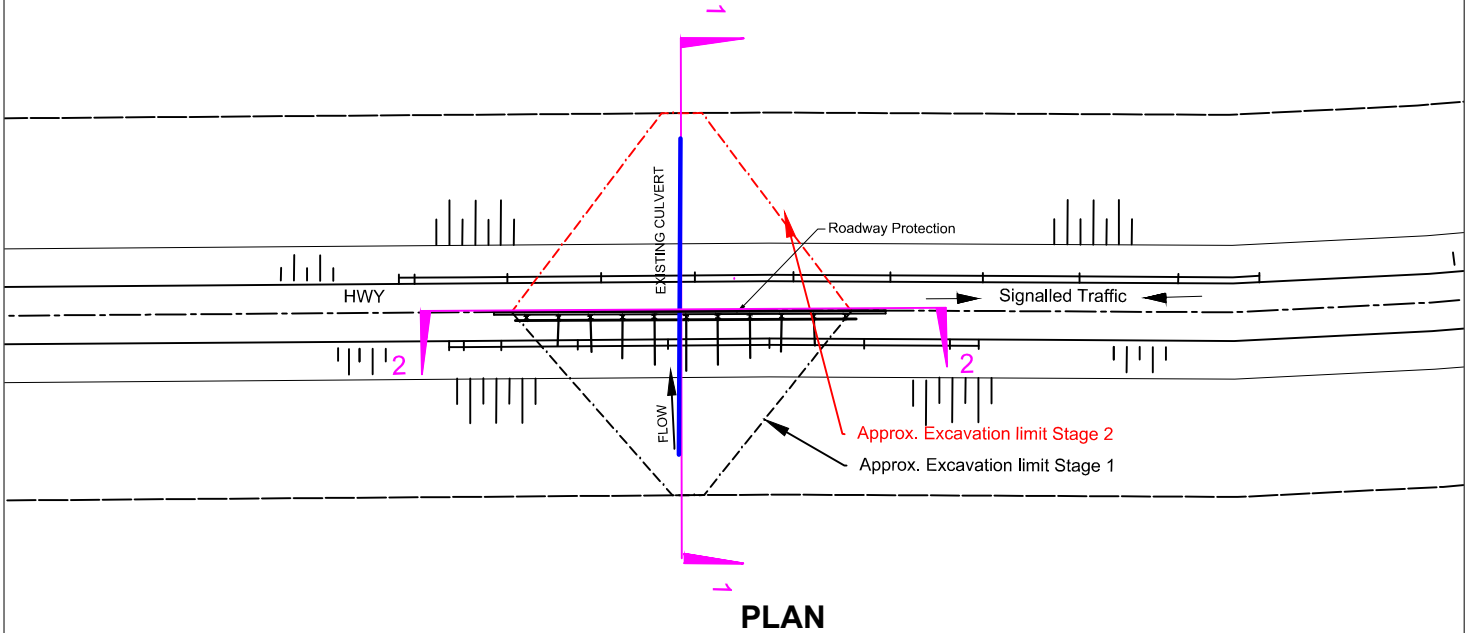


4.0 Stage 4 - Build the embankment to existing alignment; Two-way traffic return

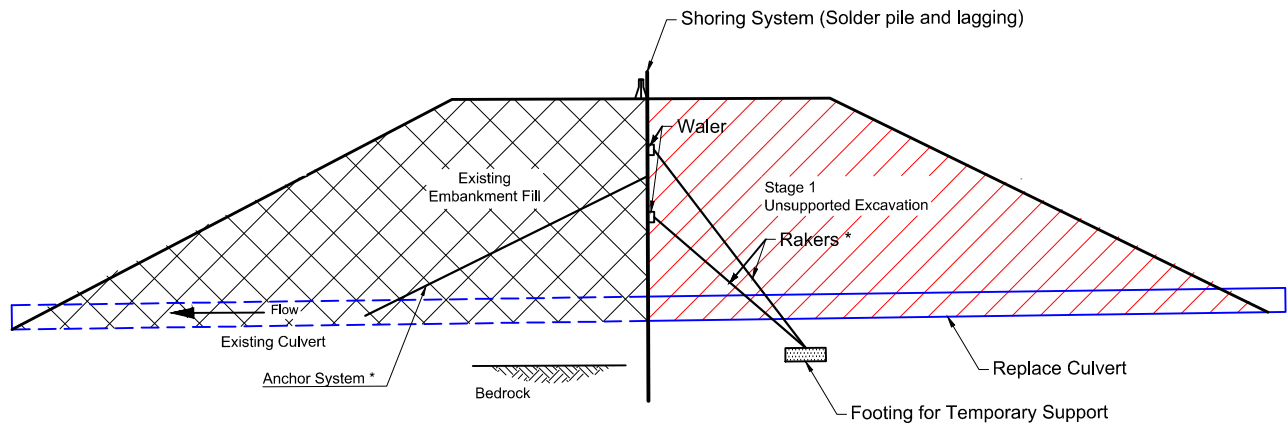


### SECTION 1-1

## SCHEMATIC DIAGRAMS (NTS)

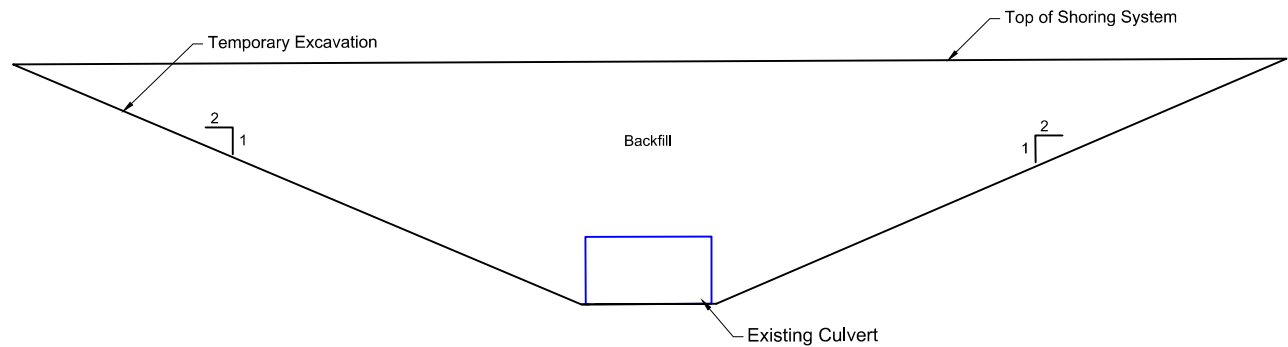


Half and Half Construction, Shoring system with either rakers or anchor system - Unsupported Excavation



\* Rakers or Anchor System

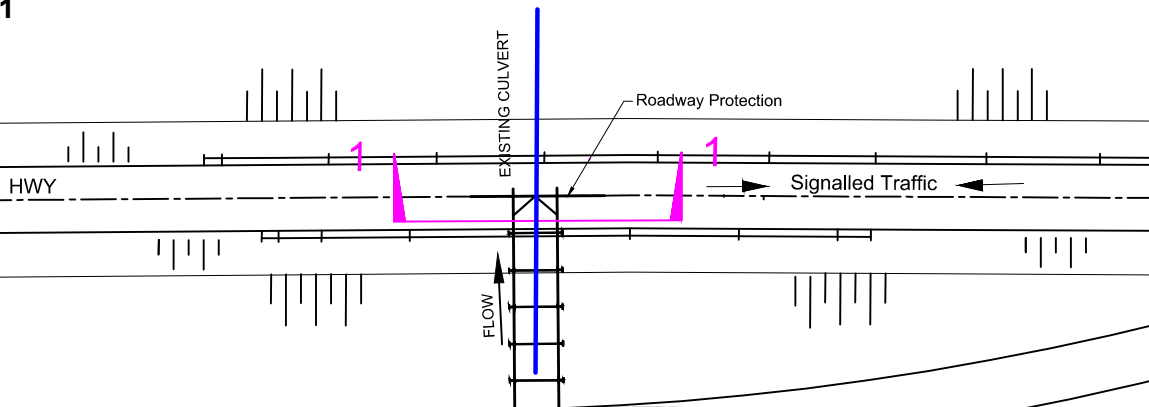
## SECTION 1-1



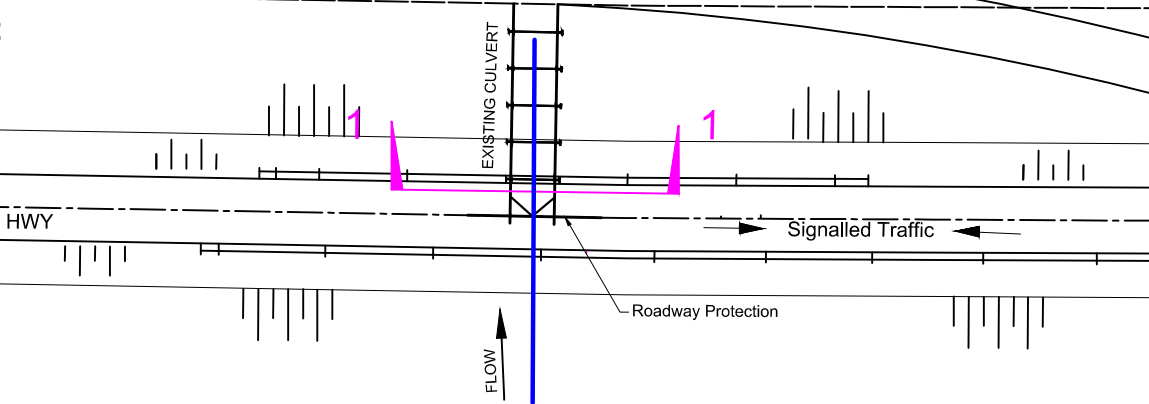
## SECTION 2-2

**FIGURE H.3.B: HALF AND HALF CONSTRUCTION WITH BRACED CUT SIDES  
OR ANCHOR SYSTEM OPTION 3.B  
SCHEMATIC DIAGRAMS (NTS)**

**Stage 1**

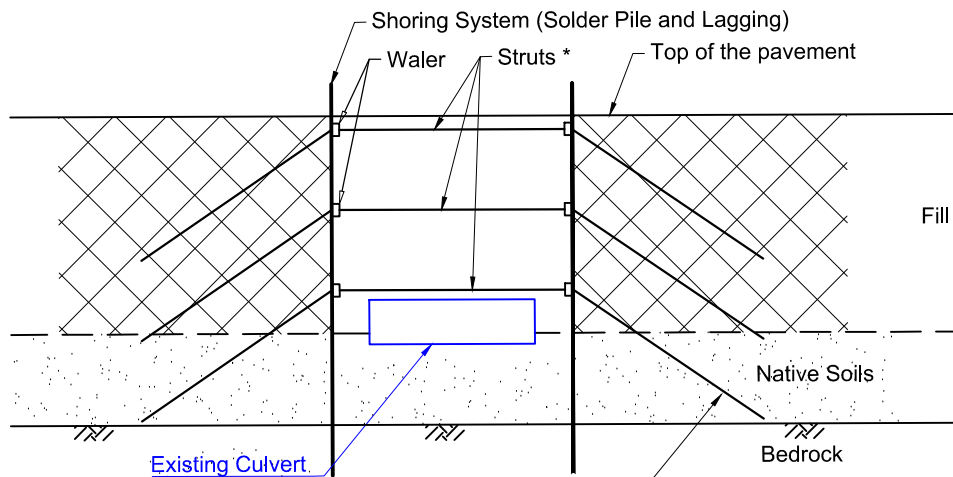


**Stage 2**



**PLAN**

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



\* Struts or Anchor System

**SECTION 1-1**

## **Appendix I – Non-Standard Special Provisions (NSSP)**

## **NSSP FOR GROUNDWATER CONTROL**

### **Scope of Work**

The contractor should be aware that construction of the new culvert will require excavations to extend below the groundwater level at the site. The loose to compact cohesionless soils comprising silty sand to sand and silt that are present below the groundwater table will slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The contractor should propose a suitable dewatering system based on the time of construction, water levels and flow conditions for prior approval to the MTO to enable construction in dry conditions, to prevent disturbance to the founding soils.

### **Basis of Payment**

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

END OF SECTION