



**Foundation Investigation and Design Report**  
**Culvert Replacement, Unnamed Creek**  
**Station 20+210, Township of Vasiloff, Algoma District**  
**Highway 17**

**GWP 5119-06-00**

**Geocres No: 42C-42**  
**Site No: 38C-155/C**

**Prepared for**  
**MTO Northeastern Region**

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## Table of Contents

### PART A - FOUNDATION INVESTIGATION REPORT

1	Introduction .....	1
2	Site Description .....	2
2.1	Surficial Geology .....	3
3	Investigation Procedures .....	4
4	Laboratory Testing .....	4
5	Subsurface Conditions .....	5
5.1	Asphalt .....	5
5.2	Organic Material .....	5
5.3	Embankment Fill .....	5
5.4	Gravel (Possible Fill) .....	5
5.5	Silt and Sand .....	6
5.6	Sand .....	6
5.7	Bedrock .....	6
6	Ground Water .....	9
7	Miscellaneous .....	9

### PART B - FOUNDATION DESIGN RECOMMENDATIONS

8	Introduction .....	10
9	Structure Foundations .....	10
9.1	Initial Review of Foundation Options .....	11
9.2	Closed Bottom Culverts .....	13
9.3	Spread Footings .....	14
9.3.1	Spread Footings on Rock Fill .....	14
9.3.2	Spread Footings on Native Sand .....	15
9.4	Resistance to Lateral Loads .....	16
9.5	Driven Piles .....	17
10	Culvert Camber .....	17
11	Culvert Replacement – Staging .....	17
11.1	Staging – General .....	17
11.2	Staging - Geotechnical Model .....	17
11.3	Stability Analysis Results and Recommendations .....	18
12	Permanent Embankment .....	22
13	Temporary Roadway Protection .....	24
14	Backfill and Lateral Earth Pressures .....	25
15	Dewatering, Excavations and Channel Diversion .....	25
15.1	Preliminary Considerations for Cofferdams .....	26
16	Estimated Frost Depth and Frost Protection .....	27
17	Seismic Considerations .....	27
18	Corrosion and Sulphate Attack Potential .....	28
19	Scour and Erosion Protection .....	28
20	Potential Construction Issues .....	28
21	Limitations .....	30
22	Closure .....	31

## **APPENDICIES**

Appendix A, Borehole and Core Logs  
Appendix B, Laboratory Test Data  
Appendix C, Borehole Locations and Soil Strata Drawing  
Appendix D, Non Standard Special Provisions

## **Part A - FOUNDATION INVESTIGATION REPORT**

### **1 Introduction**

TBT Engineering Limited (TBTE) has been retained by the Ministry of Transportation Northeastern Region (MTO) to provide a foundation investigation and design services for the proposed culvert replacement at Station 20+210, Township of Vasiloff, district of Algoma. The site is located approximately 20 km east of the junction of Highway 17 and Highway 631 (White River), and roughly 12 km west of Obatanga Provincial Park boundaries. The site coordinates are as follows:

- Latitude: 48.464629°
- Longitude: -85.116777°

This project has been assigned Geocres No. 42C-42 and structural site number 38C-155/C.

The foundation investigation was conducted to provide subsurface data to for stability analysis of finished grade and safe excavation slopes, provide commentary on conceptual cofferdam design and roadway protection measures, and for replacement recommendations including but not limited to lateral earth pressures, foundation types (deep and shallow as applicable) and associated ULS resistances and SLS reactions.

A total of 8 boreholes were advanced for this investigation. Two boreholes were advanced through the embankment at the culvert location, three at the inlet and three at the outlet (two of the boreholes at each end of the culvert were at potential cofferdam locations). All borehole locations were determined through consultation with the MTO. This report (Part A) describes the subsurface conditions encountered during the investigation.

## 2 Site Description

The foundation investigation was conducted to investigate subsurface conditions at the culvert located at Station 20+210 Township of Vasiloff, Algoma District. The culvert is located beneath an embankment that crosses low lying terrain where the unnamed creek (Tributary to the South White River) flows from an area of low lying terrain towards a small lake to the north.

The culvert is a 3 m x 35 m structural plate corrugated steel arch pipe with an invert at approximately 406.8 m. Native sand and gravel deposits were observed at the ground surface, within borrow areas approximately 100 m south and 200 m north of the site. The maximum height of the embankment is approximately 6 m with side slopes of approximately 1.5(H) to 1(V). The original ground elevation near the culvert is approximately 408.6 m (BH 3). The water level in the creek was measured at 408.0 m in October 2016.

**Photo 2.1 – Near Station 20+210 Facing South**





**Photo 2.2 – Near Station 20+210 Facing North**



## **2.1 Surficial Geology**

Available surficial geology mapping (OGS NOEGTS Map 5096 – Pukaskwa River) indicates the site is located in a predominantly sand and gravel glaciofluvial outwash plain. Peat organic terrain, alluvial plain and rock knob terrains are also found within this area. Topography in the area has low local relief in plains and channels. Drainage is described as dry with mixed wet and dry areas. An esker is located south of the site, and multiple sand and gravel pits are nearby.

### **3 Investigation Procedures**

A geotechnical site investigation was undertaken between October 12 and 23, 2016. A total of 8 boreholes were advanced during the field investigation. The borehole locations and depths were determined through conversations with the MTO and are illustrated on the Borehole Location Plan found in Appendix C.

The borehole locations were identified in the field by TBTE personnel and service clearances were completed prior to mobilizing the drill rig to site. The boreholes were advanced using a track mounted drill rig, equipped with hollow stem augers and a cat head used to carry out Standard Penetration Testing (SPT). Soil samples were obtained at the boreholes from the auger flights and using a split spoon sampler as a part of the SPT.

All aspects of implementation of geotechnical test holes were completed in accordance with the Ministry of Environment Regulation 903, as amended by Regulation 128/03. Boreholes on the road surface were capped with cold mix asphalt upon decommissioning.

Borehole locations were surveyed by TBTE and were referenced to elevations provided on MTO Plate No. 980-17/19-0 Station 19+700 to 20+400 Surveyed October 1993 TWP of Vasiloff. The provided MTO Plate drawing is based on NAD 83 CSRS MTM Zone 13, and Canadian Geodetic Vertical Datum CGVD28.

### **4 Laboratory Testing**

Samples which were obtained during the field investigation were subjected to routine laboratory testing. The routine testing included moisture content, liquid and plastic limit tests, and grain size analysis. The results of this testing are shown on the Borehole Logs (Appendix A and on the laboratory data reports Appendix B). In order to classify the bedrock with respect to strength, point load tests were carried out on select rock core.

In addition to routine testing, a single sample (BH1, SS3) was selected for analytical laboratory testing. Analytical tests performed included conductivity, moisture content, pH, Redox Potential,

resistivity, chloride, sulphide and sulphate testing. Test results are included in Section 5 and Appendix B.

## **5 Subsurface Conditions**

Details of the subsurface conditions are provided on the test hole logs (Appendix A), and on the Soil Strata Drawings (Appendix C).

The subsurface soils at this site typically consist of sands and gravels overlying bedrock. All boreholes were terminated in bedrock.

### **5.1 Asphalt**

Asphalt was encountered at the surface Boreholes 2 and 6 (elevation 413.9 m at both locations). The asphalt was approximately 100 mm thick.

### **5.2 Organic Material**

A layer of organics was encountered at the surface of Borehole 5 (elevation 408.4 m) and beneath the fill at Borehole 7 (elevation 409.0 m). The organic material thickness ranged from 0.7 to 0.9 m, with natural moisture contents ranging from 109 to 280 %.

### **5.3 Embankment Fill**

Granular embankment fills, with occasional cobbles, were identified beneath the asphalt at Boreholes 2 and 6. The embankment fill thickness ranged from 5.5 to 5.7 m, and extended to elevations ranging from 408.1 to 408.3 m. A 0.5 m thick layer of fill was encountered at the toe of the embankment slope at Borehole 7. Three samples were selected for grain size distribution testing. The test results indicated a grain size distribution of 2 to 30 % gravel, 59 to 83 % sand, and 11 to 17 % silt/clay sized particles. The fill is in a loose to dense condition as indicated by “N” values of 6 to 39 blows/0.3 m.

### **5.4 Gravel (Possible Fill)**

Gravel (possible fill) was encountered beneath the embankment fill at Borehole 2. The gravel has a thickness of 1.4 m, and extended to an elevation of 406.7 m. The gravel is in a dense condition as indicated by an “N” value of 44 blows/0.3 m.



### 5.5 Silt and Sand

Sand and silt was encountered beneath the organics in Borehole 7. The silt and sand has a thickness of 4.9 m, and extended to an elevation of 402.9 m. A single sample was selected for grain size distribution testing. The test result indicated a grain size distribution of 1 % gravel, 44 % sand, and 55 % silt/clay sized particles. The material is in a loose to compact condition as indicated by “N” values of 9 and 17 blows/0.3 m.

### 5.6 Sand

Sand with trace gravel, and some silt to silty, gravelly sand was encountered beneath the fill at Boreholes 2 and 6, beneath the organics at Borehole 5, beneath the silt and sand at Borehole 7, and from the surface of Boreholes 1 and 8, ranging in elevation from 406.1 to 409.0 m. This layer ranged in thickness from 1.4 to 7.6 m extending to elevations 401.4 to 406.6 m).

Occasional cobbles were also encountered within this stratum. Thirteen samples were selected for grain size distribution testing. The test results indicated a grain size distribution of 1 to 30 % gravel, 44 to 88 % sand, and 3 to 32 % silt/clay sized particles. The condition of this material ranges from very loose to very dense as indicated by “N” values of 4 to 62 blows/0.3 m.

A sample of this material from Borehole 1 was submitted for corrosivity and conductivity testing, detailed results are provided in Appendix B. The results are summarized as follows:

**Table 5.1: Analytical Testing Results**

Test	Unit	Result
Conductivity	mS/cm	0.428
Moisture	%	14.7
Acidity/Basicity	pH	7.8
Redox Potential	mV	126
Resistivity	ohm*cm	2340
Chloride	ppm	109
Sulphide (as S)	mg/kg	<0.2
Sulphate	ppm	<20

### 5.7 Bedrock

Bedrock was confirmed below the sand at all borehole locations at depths ranging from 3.7 to 7.6 m (Elevations 401.4 to 406.6). The bedrock elevations are provided in the following table.

**Table 5.2: Bedrock Depths and Elevations**

Borehole	Surface Elevation (m)	Bedrock depth from ground surface (m)	Bedrock Elevation (m)
1	408.3	6.1	402.2
2	413.9	8.6	405.3
3	408.6	3.7	404.9
4	408.4	4.6	403.8
5	408.4	4.6	403.8
6	413.9	7.3	406.6
7	409.0	6.1	402.9
8	409.0	7.6	401.4

Generally, the bedrock encountered was pink and grey gneiss, with moderate to high weathering at the top of the core with decreased weathering with depth. Detailed bedrock core logs and photos are provided as Appendix D.

In order to classify the bedrock with respect to strength, 24 point load tests were completed on selected core samples. The test results are tabulated below:

**Table 5.3: Estimated Uniaxial Compressive Strength of Bedrock**

Borehole	Test depth from ground surface (m)	Test Elevation (m)	*Estimated Uniaxial Compressive Strength (MPa)
1	8.4	399.9	511
2	9.2	404.7	353
2	13.2	400.7	422
2	14.1	399.8	381
2	15.0	398.9	389
3	6.5	402.1	452
3	7.6	401.0	467
3	8.3	400.3	527
3	8.9	399.7	582
4	4.7	403.7	493
4	5.9	402.5	501
5	8.0	400.4	529

5	9.7	398.7	291
5	10.4	398.0	356
6	7.7	406.2	437
6	9.9	404.0	434
6	11.0	402.9	516
6	12.1	401.8	393
7	7.9	401.1	563
7	9.3	399.7	540
7	10.2	398.8	531
8	8.2	400.8	629
8	9.2	399.8	586
8	10.4	398.6	491

*\* Estimated based on published correlations with point load testing*

Based on the estimated uniaxial compressive strength of the intact rock, the bedrock is extremely strong (uniaxial compressive strengths greater than 250 MPa).

The rock quality designation (RQD) is an indirect measure of the number of fractures and the amount of jointing in the rock mass. The RQD is expressed as a percentage of the ratio of the summed core lengths (greater than 100 mm) to the total length cored. The RQD index is used to provide a classification for the rock quality according to the following limits.

**Table 5.4: RQD / Rock Quality Designation**

RQD (%)	Rock Quality	Total Number of Samples of Each Designation
0 – 25	Very Poor	6
25 – 50	Poor	5
50 – 75	Fair	3
75 – 90	Good	1
90 – 100	Excellent	11

The RQD measured over the core lengths ranged from 0 to 100% indicating the rock quality varies from very poor to excellent.

## 6 Ground Water

Groundwater levels were measured upon completion of drilling operations and are summarized in the table below. Groundwater levels will vary from season to season and from the effects of heavy precipitation events. At the time of the investigation the water level in the creek was near elevation 407.3 m.

**Table 6.1: Groundwater Levels**

-Borehole	Groundwater Depth (m)	Groundwater Elevation (m)	Date Measured
1	1.0	407.3	Oct 12, 2016
2	7.0	406.9	Oct 14, 2016
3	0.8	407.8	Oct 15, 2016
4	0.8	407.6	Oct 17, 2016
5	0.1	408.3	Oct 22, 2016
6	4.8	409.1	Oct 20, 2016
7	0.4	408.6	Oct 21, 2016
8	0.2	408.8	Oct 23, 2016

## 7 Miscellaneous

Laboratory testing was carried out at the TBT Engineering laboratory in Thunder Bay. The drill equipment for this investigation was operated by TBT Engineering Limited. The field operations were supervised by Walter Mainville. Laboratory testing was supervised by T. Fummerton C.E.T. This report was prepared by Steven Seller, P.Eng, and reviewed by W. Hurley, P.Eng (TBTE designated principal contact identified for MTO Foundation Engineering projects).



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## **Part B - FOUNDATION DESIGN RECOMMENDATIONS**

### **8 Introduction**

TBT Engineering Limited (TBTE) has been retained by the Ministry of Transportation Northwestern Region (MTO) to provide a foundation investigation and design services for the proposed culvert replacement at Station 20+210, Township of Vasiloff, district of Algoma. The site is located approximately 20 km east of the junction of Highway 17 and Highway 631 (White River), and roughly 12 km west of Obatanga Provincial Park boundaries. The site coordinates are as follows:

- Latitude: 48.464629°
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The foundation investigation was conducted to provide subsurface data to for stability analysis of finished grade and safe excavation slopes, provide commentary on conceptual cofferdam design and roadway protection measures, and for replacement recommendations including but not limited to lateral earth pressures, foundation types (deep and shallow as applicable and associated ULS resistances and SLS reactions.

The foundation investigations as described in Part A, were carried out to investigate subsurface conditions at this site. The investigations consisted of 8 boreholes, laboratory testing and geotechnical analysis. The Part A report describes the subsurface conditions encountered during the investigation. The foundation soils at this consists of granular embankment overlying sands, silts and gravels over bedrock outside of the highway embankment the sand is overlain by organic material at some locations.

The purpose of this section of the report (Part B) is to provide embankment design recommendations for staging and culvert replacement. These are based on the conditions encountered at the borehole locations, TBTE's interpretation of the subsurface conditions at the site and analyses of embankment stability.

### **9 Structure Foundations**

Multiple foundation systems have been considered for the proposed culvert replacement. The foundation systems considered were:

- Closed Bottom Culverts
- Spread Footings on Native Soil

- Spread Footings on Rock Fill
- Driven Piles

Preliminary design recommendations for viable foundation systems are presented below in Table 9.1 based on the subsurface conditions encountered on site and the existing embankment profile.

Unless noted otherwise, foundation design parameters are given for static, vertically and concentrically loaded foundations in compression.

### **9.1 Initial Review of Foundation Options**

Several options for the proposed culvert replacement were reviewed from a foundations perspective and are presented below. Options reviewed address closed bottom culverts, and open footing culverts.

**Table 9.1: Foundation Options**

Option		Advantages	Disadvantages	Comments
Closed Bottom Culvert	Typical, steel or concrete culvert with appropriate bedding. Similar to existing culvert.	<ul style="list-style-type: none"> <li>- least costly option</li> <li>- less excavation required than open footing culvert options</li> <li>- least construction time required</li> </ul>	<ul style="list-style-type: none"> <li>- requires construction within the creek</li> </ul>	Preferred Geotechnical Option
Open Footing Culvert	Footings on Native Sand	<ul style="list-style-type: none"> <li>- longer spans may be considered to minimize construction within the existing channel</li> <li>- least excavation required of footing options</li> <li>- least costly footing option</li> <li>- no rock fill required below the footing</li> </ul>	<ul style="list-style-type: none"> <li>- excavation below ground and surface water is required, complete dewatering will be required</li> <li>- low geotechnical resistance and reactions</li> <li>- highest risk footing option for frost effects unless extensive fill cover or deep bury footings are provided</li> <li>- rock excavation may be required</li> </ul>	Not Preferred
	Footing on Rock Fill	<ul style="list-style-type: none"> <li>- longer spans may be considered to minimize construction within the existing channel</li> <li>- highest geotechnical capacities for footings</li> <li>- precast footings may be considered</li> <li>- rock fill cover and pad below footing can be considered to reduce / limit frost effects</li> </ul>	<ul style="list-style-type: none"> <li>- excavation below ground and surface water is required, although less dewatering than for footings on native soil</li> <li>- additional cost of rock fill</li> <li>- rock fill cannot be compacted below water, as such verification of a level of compaction measurement is challenging</li> <li>- minor rock excavation may be required</li> </ul>	Not Preferred
	Driven Piles	<ul style="list-style-type: none"> <li>- typically high capacities can be achieved</li> <li>- excavation below water level may be reduced or eliminated</li> <li>- longer spans may be considered to minimize construction within the existing channel</li> </ul>	<ul style="list-style-type: none"> <li>- inadequate pile lengths to achieve lateral capacity may occur.</li> <li>- high bedrock line directly beneath the embankment may result in piles less than 2 m in length</li> </ul>	Not Recommended

## 9.2 Closed Bottom Culverts

Closed bottom culvert(s) can be placed on and in compacted granular material in an earth excavation or embankment. Either steel pipe/arch or concrete box culverts may be considered. The culvert shall be placed on bedding fill material and backfilled in accordance with the appropriate OPSD 802 series drawings. Possible applicable OPSD drawings include; 802.020, 802.024, 802.031, 802.034, 802.051, and 802.054. The designer should choose which is the most appropriate drawing for the actual culvert chosen.

A resistance factor of 0.5 has been applied for the estimation of the factored geotechnical resistance at ULS. Settlements for SLS have been estimated assuming a uniform pressure distribution over the entire base of the foundation, with an allowance for potential of some disturbance of the founding surface during construction. A resistance factor of 0.8 has been applied.

Geotechnical resistances at ULS and geotechnical reactions at SLS for closed bottom culverts founded on native silt are provided below, and are subject to the following conditions:

- A minimum depth of cover 0.3 m (depth of soil to the underside of the foundation) must be provided.
- Footings are to be placed on loose native sands, silts or gravels.
- Vertically and concentrically loaded foundations in compression
- Assumed elevation of 406.8 m at underside of footing.

**Table 9.2: Geotechnical Resistances and Reactions  
Closed Bottom Culvert**

Effective Footing Width (m)	Depth of Cover to Underside of Footing (m)	Factored Geotechnical Resistance, ULS (kPa)	Factored Geotechnical Reaction, SLS (kPa) for 25 mm settlement	Factored Geotechnical Reaction, SLS (kPa) for 50 mm settlement
5	0.3	150	73	145



### **9.3 Spread Footings**

Spread footings are considered to be appropriate for open footing culverts. A resistance factor of 0.5 has been applied for the estimation of the factored geotechnical resistance at ULS. Settlements for SLS have been estimated assuming a uniform pressure distribution over the entire base of the foundation, with an allowance for some potential of some disturbance of the founding surface during construction, and a resistance factor of 0.8 has been applied.

Any divergence from the conditions described herein could result in the reduction of ULS values presented. For example if the foundation is placed shallower (less depth of cover to the underside of footing) and/or the ground is sloping away from the foundation, a reduction in the ULS values may be realized.

To eliminate the effects of frost, footings must be placed below the depth of frost penetration or placed over/within non-frost susceptible fills (such as rock fill) which extend from the top of creek low water level or backfill (which ever will govern) to the depth of frost penetration. Volumetric expansion of the water (when frozen) within the pore space of the rock needs to be considered by the designer. This expansion (heave) can be estimated at 1 % of the height of the rock fill pad which is subjected to frozen condition.

#### **9.3.1 Spread Footings on Rock Fill**

Geotechnical resistances at ULS and geotechnical reactions at SLS for typical footings founded on rock fill are provided below, and are subject to the following conditions:

- A minimum depth of cover 0.3 m (depth of soil to the underside of the foundation) must be provided over a distance of at least 5 times the footing width from the edge of footing. Cover material should consist of Granular B Type II or rock fill.
- Foundations shall be placed on a minimum 2.0 m thick compacted graded rock fill pad founded on loose native sand, or a minimum 0.4 m thick compacted graded rock fill pad founded on bedrock, which must extend to the estimated frost penetration depth.
- Single foundation elements should not be founded on both soil and rock.
- Vertically and concentrically loaded foundations in compression.
- Assumed elevation of 406.5 m at underside of footing.

**Table 9.2: Geotechnical Resistances and Reactions  
 Strip Footings on Rock Fill**

Effective Footing Width (m)	Thickness of Rock Fill Below Footing (m)	Depth of Cover to Underside of Footing (m)	Factored Geotechnical Resistance, ULS (kPa)	Factored Geotechnical Reaction, SLS (kPa) for 25 mm settlement	Factored Geotechnical Reaction, SLS (kPa) for 50 mm settlement
1.2	2.0	0.3	160	Exceeds ULS	Exceeds ULS
1.5	2.0	0.3	180	Exceeds ULS	Exceeds ULS
1.8	2.0	0.3	205	185	Exceeds ULS
2.0	2.0	0.3	220	170	Exceeds ULS

For the values presented above a resistance factor of 0.5 and 0.8 has been applied for the calculation of factored geotechnical resistance at ULS and the geotechnical reactions at SLS, respectively. The SLS reactions have been computed for settlements of up to 25 mm and 50 mm under foundation loading. Differential settlements up to 100 % of the estimated settlement can be realized where footings are constructed over shallow excavated bedrock (with a thin pad). The resistance factors are as provided in the 2014 Canadian Highway Bridge Code (CHBC).

If the provide ULS resistances are insufficient, additional configurations can be examined (e.g. Increasing the depth of cover) to increase the ULS resistances.

The rock fill pad should consist of graded rock fill. The upper 150 mm of the rock fill pad should be constructed with 19 mm clear stone. The base of the pad should extend horizontally beyond the edge of the footings by a distance at least equal to the thickness of the rock fill pad provided.

The excavations required for construction of the rock fill pad should be considered when planning for the locations of the footings especially if construction within the existing channel is not permitted.

### **9.3.2 Spread Footings on Native Sand**

Geotechnical resistances at ULS and geotechnical reactions at SLS for typical footings founded on native sand are provided below, and are subject to the following conditions:

- A minimum depth of cover of 2.3 m (depth of soil to the underside of the foundation) must be provided over a distance of at least 5 times the footing width from the edge of footing. Cover material should consist of Granular B Type II.
- Where bedrock is encountered it shall be excavated or shattered to a minimum depth of 0.3 m below the underside of the footing. The excavated material shall be replaced with compacted granular material such as Granular B Type 1 or Type II compacted to at least 95 % SPMDD. Construction shall take place in the "dry". Dewatering may prove challenging.
- Single foundation elements should not be founded on both soil and rock.
- The depth of cover is taken as the depth of frost penetration to protect the foundation from frost action.
- Footings are to be placed on loose native sands, silts or gravels.
- Vertically and concentrically loaded foundations in compression
- Assumed elevation of 404.5 m at underside of footing.

**Table 9.3: Geotechnical Resistances and Reactions  
Strip Footings on Native Sands**

Effective Footing Width (m)	Depth of Cover to Underside of Footing (m)	Factored Geotechnical Resistance, ULS (kPa)	Factored Geotechnical Reaction, SLS (kPa) for 25 mm settlement	Factored Geotechnical Reaction, SLS (kPa) for 50 mm settlement
1.2	2.3	300	205	Exceeds ULS
1.5	2.3	310	185	Exceeds ULS
1.8	2.3	315	170	Exceeds ULS
2.0	2.3	320	165	Exceeds ULS

For the values presented above a resistance factor of 0.5 and 0.8 has been applied for the calculation of factored geotechnical resistance at ULS and the geotechnical reactions at SLS, respectively. The SLS reactions have been computed for settlements of up to 25 mm and 50 mm under foundation loading. Differential settlements up to 100 % of the estimated settlement can be realized where footings are constructed over shallow excavated bedrock (with a thin pad) and native sand. The resistance factors are as provided in the 2014 Canadian Highway Bridge Code (CHBC).

#### 9.4 Resistance to Lateral Loads

Resistance to lateral forces (sliding) shall be calculated in accordance with Section 6.10.5 of the CHBDC using the following unfactored parameters and appropriate resistance factor from Section 6.9.1 of the CHBDC be applied:

- Between granular pads and pre -cast concrete
  - Co-efficient of friction of 0.5
- Between cast in place concrete and sand subgrade
  - Co-efficient of friction of 0.4

## **9.5 Driven Piles**

The shallow bedrock line indicated in Boreholes 2 and 6 would result in piles with lengths of 1.7 and 0.4 m, respectively, based on an estimated top of pile elevation of 407 m. The use of driven steel piles is not recommended in these conditions and this alternative has not been further developed.

## **10 Culvert Camber**

It is understood that the existing embankment will not be raised and no appreciable settlements are expected. Culverts will not require camber.

## **11 Culvert Replacement – Staging**

### **11.1 Staging – General**

The replacement of the culvert can be completed utilizing a staged construction methodology. To provide a single trafficable lane (during construction) and expose sufficient length of existing culverts, and attempt to avoid utility poles (both sides of the highway) the vertical profile of the roadway will need to be temporarily lowered (1.0 m) and a temporary widening with a culvert extension will also be required. The temporary widening can be expected to experience approximately 30 mm of total settlement. However due to the temporary nature of this widening it is anticipated that only a portion of this total settlement will occur

### **11.2 Staging - Geotechnical Model**

Stability modeling was completed out using Slope/W software and limit equilibrium analysis using the Morgenstern-Price method.



The soil properties established for the embankment are presented below.

Stability analyses have been completed to investigate potential configurations for the proposed embankment during construction for the proposed culvert replacement. The design was based on providing a minimum calculated factor of safety (FoS) of 1.33 (resistance factor of 0.75) during construction (staging embankments) and a (FoS) of 1.54 (resistance factor of 0.65) for final configuration. The resistance factors are as provided in the 2014 Canadian Highway Bridge Code. A uniformly distributed traffic load of 12 kPa over the traversable lane(s) was applied in all cases.

**Table 11.1: Stability Analyses Soil Properties**

Soil	Effective Shear Strength Properties		Unit Weight, $\gamma$ (kN/m <sup>3</sup> )
	Effective Angle of Internal Friction, $\phi'$ (degrees)	Effective Cohesion Intercept, $C'$ (kPa)	
Granular B Type II	35	0	20
Native Silty Sand	29	0	20
Existing Granular Fill	32	0	20
Compacted Granular Fill	35	0	20
Rock Fill	40	0	18

### 11.3 Stability Analysis Results and Recommendations

The culvert can be replaced in two stages, with traffic maintained over alternating widened sections (Stage 1 and 2). The final roadway embankment will then be restored at its current location (Stage 3).

Various slope configurations were analyzed to determine sections which would meet the design stability requirements.

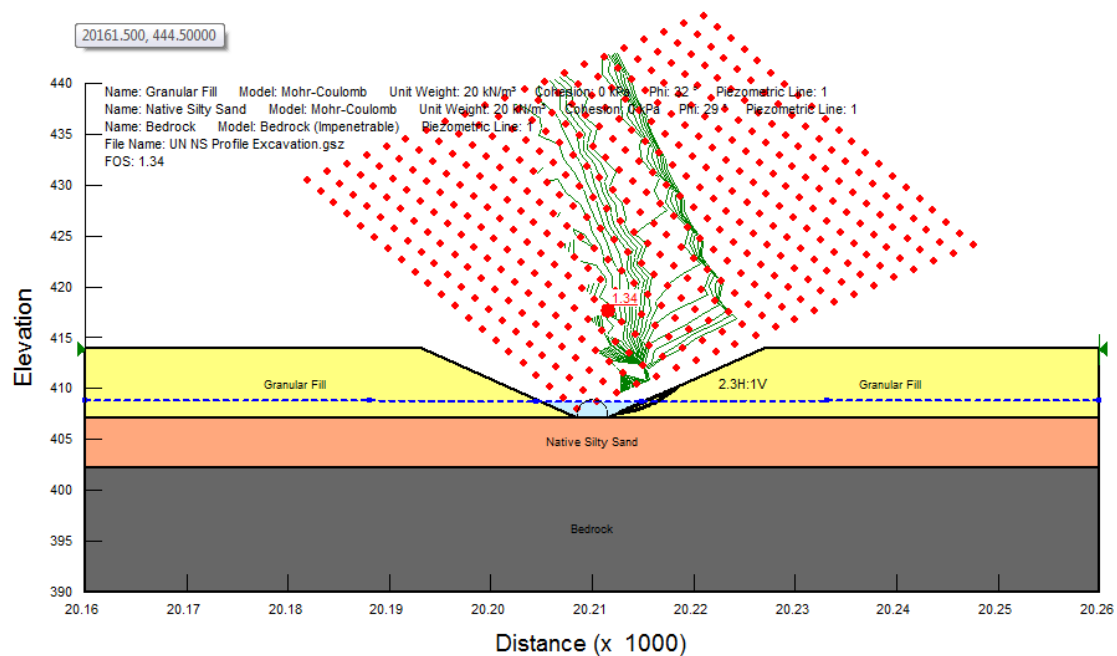
The following assumptions were made for the analysis:

- Assumed water levels to be maintained at natural levels for profile excavation and removal of culverts (Figures 11.1 and 11.2)
- All organic material shall be removed from beneath the footprint of the widened section.
- Temporary lowering of the vertical alignment for staging of 1.0 m.

The following recommendations have been derived from the analysis:

- Cut slopes through existing granular fill shall be constructed at 2.3(H):1(V), or flatter. (Figures 11.1 and 11.2)
- Temporary slopes constructed using Granular B, Type II shall be constructed at 2(H):1(V), or flatter. (Figure 11.2)
- For construction in the wet the rock fill pad can be constructed below water. (Figure 11.3, 11.4, and 11.5)
- For construction in the dry the ground water must be maintained a minimum of 0.3 m below the base of the excavation. (Figure 11.6)

**Figure 11.1 – Culvert Excavation, Profile Section**



File Name: UN NS Staging Right - Gran BII right - AN - 2.3H:1V.gsd  
 FOS: 1.35

Name	Model	Unit Weight	Cohesion	Phi	Piezometric Line
Granular Fill	Mohr-Coulomb	20 kN/m <sup>3</sup>	0 kPa	32°	1
Native Silty Sand	Mohr-Coulomb	20 kN/m <sup>3</sup>	0 kPa	29°	1
Bedrock	Bedrock (Impenetrable)	20 kN/m <sup>3</sup>	0 kPa	33°	1
Gran B II	Mohr-Coulomb	20 kN/m <sup>3</sup>	0 kPa	33°	1

The plot shows a cross-section of a slope with a failure surface defined by a green line. The failure surface is labeled with 'Q1 1.35' and '2.3H:1V'. The slope is composed of 'Native Silty Sand' (orange) and 'Bedrock' (grey). A 'Gran B II' structure is shown on the right side of the slope. The plot includes a grid of red dots representing the failure surface and green lines representing the failure surface. The x-axis is 'Distance' from -55 to 55, and the y-axis is 'Elevation' from 390 to 440. A table of material properties is provided at the top left.

Name: Granular Fill Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 32° Piezometric Line: 1  
 Name: Native Silty Sand Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 29° Piezometric Line: 1  
 Name: Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1  
 File Name: UN NS Profile Excavation, Shallow Foundations, WL High, AN.gsz  
 FOS: 1.34

20160.400, 427.70000

1.34

2.5H:1V

2.0 m

Native Silty Sand

Bedrock

Granular Fill

Granular Fill

Elevation

Distance (x 1000)

Name: Granular Fill    Model: Mohr-Coulomb    Unit Weight: 20 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 32°    Piezometric Line: 1  
 Name: Native Silty Sand    Model: Mohr-Coulomb    Unit Weight: 20 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 29°    Piezometric Line: 1  
 Name: Bedrock    Model: Bedrock (Impenetrable)    Piezometric Line: 1  
 Name: Rock Fill    Model: Mohr-Coulomb    Unit Weight: 18 kN/m<sup>3</sup>    Cohesion: 0 kPa    Phi: 40°    Piezometric Line: 1  
 File Name: UN NS Profile Excavation, Shallow Foundations, WL High - 2.0 m Pads.s2  
 FOS: 1.39

Elevation

Granular Fill

Rock Fill

Native Silty Sand

Bedrock

2.0 m

0.3 m

2.5H:1V

413.9

Piezometric Line: 1

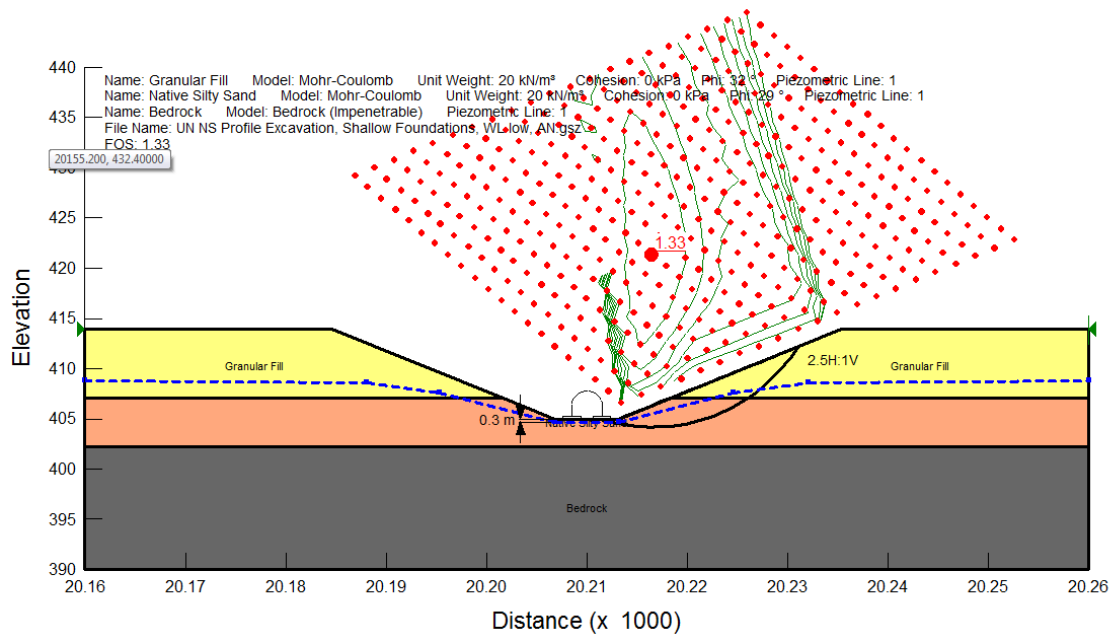
Piezometric Line: 1

Piezometric Line: 1

Distance (x 1000)



**Figure 11.6 – Profile, Shallow Foundations on Native Silty Sand  
 Dewatered to 0.3 m Below the Base of the Excavation**



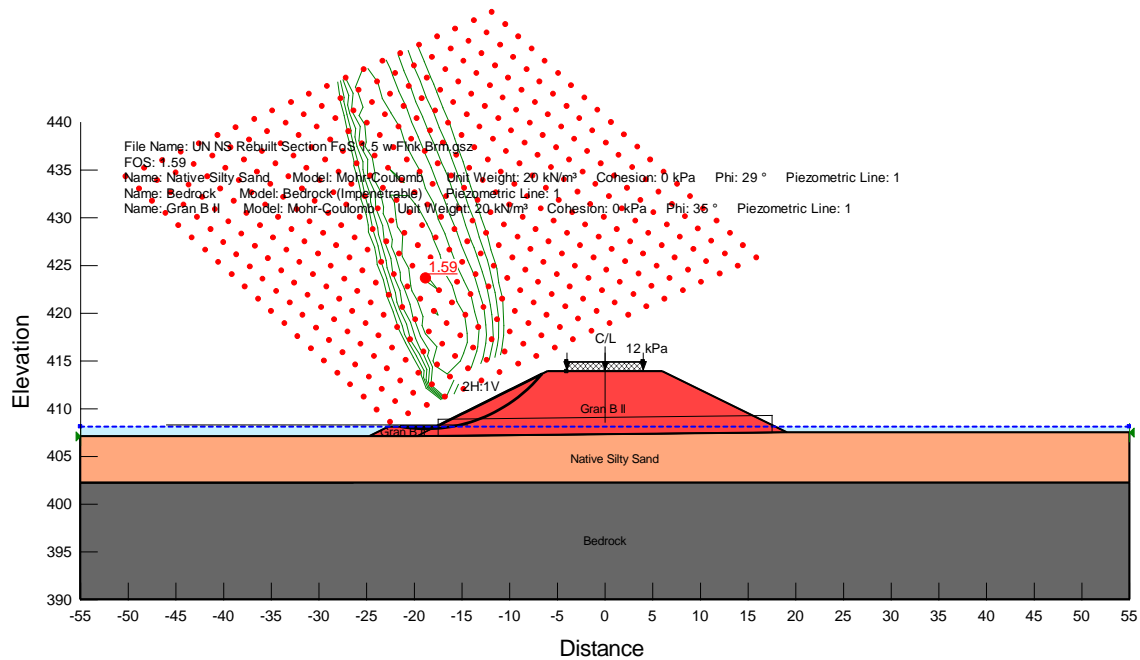
## 12 Permanent Embankment

Stability analyses have been completed to determine the final embankment configuration for the proposed culvert replacement. The design was based on providing a minimum calculated factor of safety (FoS) of 1.54 (resistance factor of 0.65 as provided in the CHBDC) and FoS of 1.3 for final configuration outside of approach embankment. A uniformly distributed traffic load of 12 kPa over the traversable lane(s) was applied.

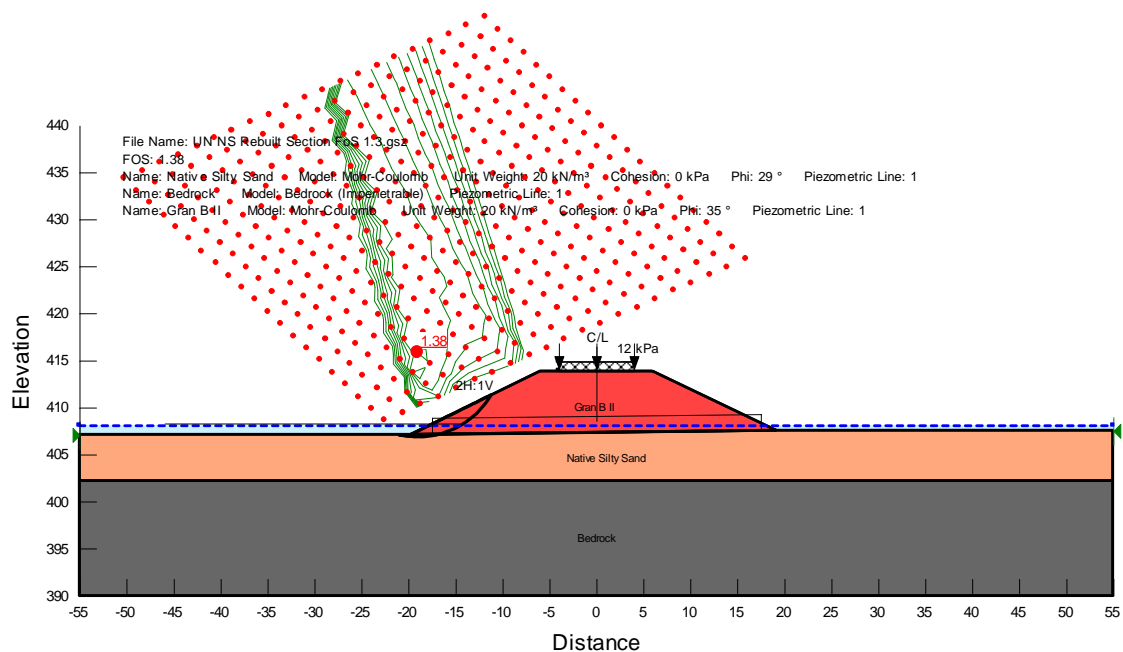
Permanent slopes constructed of compacted Granular B, Type II shall be constructed at:

- 2(H):1(V) or flatter with a 1 m high 5m long flanking berm for a FoS of 1.54 or greater as per Figure 12.1
- 2(H):1(V) or flatter for a FoS of 1.3 or greater as per Figure 12.2.

**Figure 12.1 – Re-Built Cross Section Minimum FoS 1.54**



**Figure 12.2 – Re-Built Cross Section Minimum FoS 1.3**



It is understood that there will be no grade raise and no appreciable settlements are anticipated. Any settlement experienced from a temporary widening to facility staging

will be minimal and will not affect overall performance of the roadway. Settlement from the flanking berm will be minimal and will be less than a 25 mm, assuming all organics are removed from beneath the flanking berm.

### **13 Temporary Roadway Protection**

The implementation of temporary roadway protection is not anticipated for this culvert replacement. Traversable lanes can be provided through stable embankment construction and the temporary lowering of the vertical alignment. Temporary roadway protection will likely prove cost prohibitive. The use of driven piles (sheet or H piles for lagging) are not recommended due to the lack of potential embedment from the shallow bedrock line.

However, where a sheet pile cofferdam system is utilized, roadway protection using driven piles may be cost effective. Traffic protection systems, if considered, can consist of interlocking sheet piles, or soldier piles and lagging. Due to shallow bedrock at some locations, relative to the current culvert inverts, simple cantilevered systems may not prove feasible and socketing of the piles into the bedrock may be required. Additional to socketing of the piles temporary shoring of the traffic protection system may be required to provide lateral resistance. Shoring measures could consist of grouted anchors, rakers, tiebacks and/or deadmans. Design of any shoring should consider the geometry of the embankment and its ability to provide adequate embedment, and/or cover, and lateral spacing to ensure no overlap of the active wedge of any anchors and the passive wedge of the traffic protection.

All roadway protection systems should be designed in accordance to OPSS 539 to Performance Level 2, by engineers with a minimum of five years of experience designing similar systems. Design should also include the global stability of the chosen traffic protection system. Design of roadway protection systems is the responsibility of the contractor. Material properties as used in stability analyses may be utilized.

## 14 Backfill and Lateral Earth Pressures

The existing site materials are not suitable for use as structural backfill. Structural backfill should consist of Granular “B” Type I, or II. Granular “A” may be specified as structural backfill in specific zones.

Lateral earth pressure coefficients for potential granular backfill and level ground conditions have been provided below.

**Table 13.1: Lateral Earth Pressure Coefficients**

Lateral Earth Pressure Coefficients (K)					
Compacted Granular Backfill	$\phi'$ (°)	Bulk Unit Weight of Soil, $\gamma$ (kN/m <sup>3</sup> )	Active Ka	At Rest Ko	Passive Kp
OPSS Granular A, or Granular B Type II	35	20	0.27	0.43	3.7
OPSS Granular B Type I	32	20	0.47	0.31	3.3
Native Silty Sand	29	20	0.35	0.52	2.9

No factor of safety or resistance factor has been included in the above coefficients. A compaction surcharge should be added in accordance with the CHDBC s6-14 Section 6.12.3. The culvert must also be designed to resist hydrostatic pressures where applicable.

## 15 Dewatering, Excavations and Channel Diversion

Excavations should be excavated and sloped in accordance with the requirements of the Occupational Health and Safety act. Dewatering systems should be designed in accordance to OPSS 517 and SP 517F01 (July 2017), and it is recommended that any dewatering system be designed and checked by engineers with a minimum of five years of experience designing similar systems.

The current creek level is approximately 1.2 m above the existing inlet invert. The soils below the ground water level consist of permeable native sands. Excavations for culvert construction and/or placement of fill are expected to extend below the ground and surface water level.

To facilitate construction in the dry, control of surface and ground water will be required. Dewatering of the site will likely require the use of coffer dams constructed across the water course. The complexity of the dewatering system will be governed by the depth of the excavation and any requirements for working in the dry. Well points should be considered for working in the dry, as ground water needs to be lowered below the base excavation. Groundwater flows into open excavations below the ground water level may be rapid and difficult to control.

The soil through the embankment and the native sand can be preliminarily classified as Type 2 soils, as defined by the Occupational Health and Safety Act and Regulations for Construction Projects. Cut slopes for unsupported excavations shall be no steeper than those provided in Section 11.3. The soil types must be reassessed as excavations proceed and adjustments to construction methodologies should be taken as required.

Channel diversion options are limited without the construction of a diversion and subsequent temporary culvert. The use of temporary cofferdams utilizing either controlled flow or pumping should be considered the best option for channel diversion.

Cobbles were noted during drilling operations in the native and fill material which could affect the installation of roadway protection measures. An NSSP should be included within the contract to inform the contractor of the presence of these potential obstructions. An example of the wording for the NSSP has been included in Appendix D.

### **15.1 Preliminary Considerations for Cofferdams**

The potential use of cofferdams to control inlet and outlet water conditions can be considered at this location. Cofferdam systems to be considered can vary from earthen structures to sheet piles. Sheet piles alone may not obtain sufficient embedment to provide suitable cut off or lateral support.

Subsurface investigations were completed near potential cofferdam locations (Boreholes 1, 4, 5, and 7). Boreholes 1 and 4 are on the right side of the highway and Boreholes 5 and 7 are on the left side of the highway. Bedrock was encountered at Boreholes 1 and 4 at depths of 6.1 and 4.6 m (elev. 402.2 and 403.8m), respectively. Bedrock was encountered at Boreholes 5 and 7 at depths of 4.6 and 6.1 m (elev. 403.8 and 402.9m), respectively. It should be noted that cobbles and boulders were noted within Boreholes 1 and 4.

Cofferdam design should be completed by the contractor's designer and consider, but not limited to, the following potential issues:

- Requirement for bracing and/or tie backs;
- Global and internal stability;
- Sufficient seepage cut off measures be employed to avoid piping of the soil. The native silts encountered at Borehole 7 are of low permeability and may pipe if sufficient seepage exit gradients develop on the downstream side of the cofferdam.
- Potential loss of soil adjacent to the cofferdam.
- Flow through the native sands may be rapid and difficult to control.
- Potential sheet pile refusal on cobbles, or shallow bedrock.

## **16 Estimated Frost Depth and Frost Protection**

Based on OPSD 3090.100 Foundation Frost Penetration Depths for Northern Ontario; the estimated frost depth penetration within the expected embankment fill is 2.3 m. The embankment soils anticipated within the frost depth are considered to be of low frost susceptibility (MTO Pavement Design and Rehabilitation Manual).

## **17 Seismic Considerations**

Seismic analysis for the culvert will not be required based on the following rationale as per the 2014 Canadian Highway Design Bridge Code (CHBDC). In accordance with Section 4.4.3.1 spectral ground acceleration data for the sites was obtained from



www.earthquakescanada.nrcan.gc.ca. In accordance with Section 4.4.4, Table 4.10 and assuming the culverts have a Seismic Importance Category of “Major-route and other bridges”, the site is classified as Seismic Performance Category 1. As per Section 4.4.5.1, no seismic analyses are required for structures located in Seismic Performance Category 1.

## **18 Corrosion and Sulphate Attack Potential**

Corrosivity and sulphate content testing was conducted on a sample of the native soil, and the results are provided in Appendix B. The results of the test indicate the following conditions at the test location:

- Sulphate was measured at less than 20 ppm (less than 0.002%) and does not require sulphate resistant concrete since it is less than 0.1 %.
- The pH of the soil was measured at 7.8, with resistivity of 2340 ohm-cm, and sulphide content less than 0.2 mg/kg. Considering these factors, the native soils are not considered to be aggressively corrosive.

## **19 Scour and Erosion Protection**

Erosion/scour protection should be provided at culvert inlet and outlet, and for any foundation element. The ultimate design of erosion protection measures should be provided by designers with sufficient experience. Where appropriate, foundation elements should be provided with sufficient scour protection in the event of elevated creek levels. Scour protection should be designed in accordance with Section 1.9.5 of the 2014 Canadian Highway Bridge Design Code, where clay seals are considered OPSS 1205 should be reviewed and OPSD 810.010 for rip rap placement should be reviewed.

## **20 Potential Construction Issues**

With the exception of dewatering issues, major construction difficulties are not foreseen at this site. Issues which may require consideration include:

- Staging Requirements.
- Nearby Utility Lines may interfere with staging design.

Groundwater levels are near the ground surface. The in situ soils are permeable.

Dewatering efforts may prove challenging and will increase in complexity with the depth of dewatering required. Some of the issues involved can include:

- Dewatering of the site to facilitate construction in the dry may be subject to high flow from native sand.
- Control of surface and groundwater during shallower excavations below the creek/groundwater level will require careful design and construction.
- Potential for construction 'in the wet' may be required
- The potential for piping or ground loss should be monitored.

## **21 Limitations**

Conclusions and recommendations presented in this report are based on the information determined at a limited number of test hole locations. Subsurface and groundwater conditions between and beyond these locations may differ from those encountered. Conditions may become apparent during construction that were not detected and could not be anticipated at the time of the site investigation.

The comments given in this report on potential construction problems and possible methods of construction are intended only for the guidance of the designer.

Groundwater levels indicated are based on the information described within the report. The presence of all conditions that could affect the type and scope of dewatering procedures which may be considered cannot readily be determined from boreholes. These include local and seasonal fluctuations of the groundwater level, changes in soil conditions between test locations, thin and/or discontinuous layers of highly permeable soils, etc.

The information contained within this report in no way reflects any environmental aspect of the site or soil.

## 22 Closure

We trust the above addresses your project requirements at this time. Should you have any questions or comments, please do not hesitate to contact us at your convenience.

Yours truly,

For TBT ENGINEERING



Steven Seller, P.Eng.  
Senior Project Engineer



Wayne Hurley, P.Eng.  
Principal Contact for MTO Foundations

## **APPENDIX A**

### **Borehole Logs**

## EXPLANATION OF TERMS USED IN REPORT

**N VALUE:** THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m, N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS  $\bar{N}$ .

**DYNAMIC CONE PENETRATION TEST:** CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

**CONSISTENCY:** COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ( $c_u$ ) AS FOLLOWS:

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	>200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

**DENSENESS:** COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

**RECOVERY:** SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

**MODIFIED RECOVERY:** SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

**JOINTING AND BEDDING:**

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	>3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$u$	l	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
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
$E$	kPa	MODULUS OF LINEAR DEFORMATION
$G$	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	l	COEFFICIENT OF FRICTION

### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	l	COMPRESSION INDEX
$C_s$	l	SWELLING INDEX
$C_a$	l	RATE OF SECONDARY CONSOLIDATION
$C_v$	m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
$H$	m	DRAINAGE PATH
$T_v$	l	TIME FACTOR
$U$	%	DEGREE OF CONSOLIDATION
$\sigma'_{v0}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$T_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$T_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_r$	l	SENSITIVITY = $\frac{c_v}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	$e$	l, %	VOID RATIO	$e_{min}$	l, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	$n$	l, %	POROSITY	$I_D$	l	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\rho_w$	kg/m <sup>3</sup>	DENSITY OF WATER	$w$	l, %	WATER CONTENT	$D$	mm	GRAIN DIAMETER
$\gamma_w$	kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	kg/m <sup>3</sup>	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	l	UNIFORMITY COEFFICIENT
$\gamma$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	$h$	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	$q$	m <sup>3</sup> /s	RATE OF DISCHARGE
$\gamma_d$	kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	$v$	m/s	DISCHARGE VELOCITY
$\rho_{sat}$	kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_L$	l	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	$i$	l	HYDRAULIC GRADIENT
$\gamma_{sat}$	kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	$I_C$	l	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	$k$	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	$e_{max}$	l, %	VOID RATIO IN LOOSEST STATE	$j$	kN/m <sup>2</sup>	SEEPAGE FORCE
$\gamma'$	kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL						


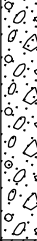
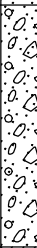


# RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 5119-06-00 LOCATION Unnamed Creek N:5370169; E:222247 MTM Zone:13 ORIGINATED BY W.M.  
 DIST NER HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY S.W.  
 DATUM Geodetic DATE 2016.10.10 - 2016.10.10 LATITUDE 48.464736 LONGITUDE -85.11642 CHECKED BY S.S.

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 (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE														
408.3							20	40	60	80	100						GR	SA	SI	CL		
0.0	SAND - trace silt, trace gravel, brown, loose to compact		1	AS		▽	408											Water level @ 1.0m on completion. 6 88 (6)				
	----- - occasional cobbles		2	SS	4		407												Flowing sand @ 1.5m.			
			3	SS	26		406															
405.4			4	SS	10		405												25 49 (26) Auger refusal @ 3.2m. Advanced with casing.			
2.9	SAND - Gravelly, Silty, occasional cobbles & boulders, compact to very dense		5	SS	62		404															
			6	SS	19		403															
402.2							402											RC #1 REC 100% RQD 73.3%				
6.1	BEDROCK - Gneiss, pink & grey		1	RC		401											RC #2 REC 100% RQD 100%					
			2	RC		400																
399.2																						
9.1	End of Borehole @ 9.1m.																					

# RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 5119-06-00 LOCATION Unnamed Creek N:5370147; E:222229 MTM Zone:13 ORIGINATED BY W.M.  
 DIST NER HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY S.W.  
 DATUM Geodetic DATE 2016.10.14 - 2016.10.14 LATITUDE 48.464535 LONGITUDE -85.11666 CHECKED BY S.S.

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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE										○		
								● QUICK TRIAXIAL      × LAB VANE												
413.9							20	40	60	80	100					GR SA SI CL				
413.3	ASPHALT - 100mm FILL - GRAVEL		1	AS												Water level @ 7.0m on completion.				
0.6	FILL - SAND - some silt, trace gravel, grey/brown, loose to very dense		2	SS	60											2 83 (15)				
			3	SS	20															
			4	SS	8															
			5	SS	34															
	----- - occasional cobbles		6	SS	39															
407.9			7	SS	44															
6.0	GRAVEL (possible fill) - grey, dense															Auger refusal @ 6.2m. Advanced with casing.				
406.7																				
7.2	SAND - Gravelly, some silt, compact		8	SS	22											30 58 (12)				
405.3																				
8.6	BEDROCK - Gneiss, pink & grey		1	RC												RC #1 REC 68% RQD 22% RC #2 REC 47.7% RQD 36.6%				
			2	RC																
			3	RC												RC #3 REC 33.3% RQD 0%				
			4	RC												RC #4 REC 56% RQD 40%				
			5	RC												RC #5 REC 100% RQD 85.3%				
398.8																				
15.1	End of Borehole @ 15.1m.																			

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

# RECORD OF BOREHOLE No 3

1 OF 1

**METRIC**

W.P. 5119-06-00 LOCATION Unnamed Creek N:5370173; E:222237 MTM Zone:13 ORIGINATED BY W.M.  
 DIST NER HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY S.W.  
 DATUM Geodetic DATE 2016.10.15 - 2016.10.15 LATITUDE 48.464767 LONGITUDE -85.116555 CHECKED BY S.S.

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	20						40	60	80
408.6																				
0.0	SAND - Silty, some gravel, brown, compact to dense		1	AS		▽	408										13 64 (23)			
			2	SS	21													Water level @ 0.8m on completion.		
	----- - numerous cobbles		3	SS	46			407												
406.5																				
2.1	SAND - Gravelly, some silt, occasional cobbles, grey, compact		4	SS	24			406										27 54 (19)		
			5	SS	13												Auger refusal @ 3.7m. Continued with casing.			
404.9	BEDROCK - Gneiss, pink & grey		1	RC			405										RC #1 REC 92.2% RQD 74.4%			
3.7			2	RC			404										RC #2 REC 66.6% RQD 18%			
			3	RC			403													
			4	RC			402										RC #3 REC 72% RQD 56%			
400.5							401										RC #4 REC 100% RQD 100%			
8.1	End of Borehole @ 8.1m.																			

# RECORD OF BOREHOLE No 4

1 OF 1

**METRIC**

W.P. 5119-06-00 LOCATION Unnamed Creek N:5370175; E:222242 MTM Zone:13 ORIGINATED BY W.M.  
 DIST NER HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY S.W.  
 DATUM Geodetic DATE 2016.10.17 - 2016.10.17 LATITUDE 48.464787 LONGITUDE -85.116485 CHECKED BY S.S.




SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE					WATER CONTENT (%) W <sub>P</sub> W                      W <sub>L</sub>				GR	SA	SI	CL
408.4						▽	408								○				5 92 (3)	
0.0	SAND - trace silt, trace gravel, brown		1	AS			407									○			23 71 (6) Water level @ 0.8m on completion. On cobble.	
407.8			2	SS	12		406												On cobble.	
0.6	SAND - Gravelly, trace silt, trace organics, occasional cobbles, grey, loose to compact		3	SS	100+		405									○				
			4	SS	100+		404													
			5	SS	7		403												RC #1 REC 98.7% RQD 90.7%	
							402												RC #2 REC 100% RQD 48%	
403.8							401													
4.6	BEDROCK - Gneiss, pink & grey		1	RC																
			2	RC																
400.8																				
7.6	End of Borehole @ 7.6m.																			

# RECORD OF BOREHOLE No 5

1 OF 1

METRIC

W.P. 5119-06-00 LOCATION Unnamed Creek N:5370152; E:222197 MTM Zone:13 ORIGINATED BY W.M.  
 DIST NER HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY S.W.  
 DATUM Geodetic DATE 2016.10.19 - 2016.10.22 LATITUDE 48.464576 LONGITUDE -85.1170909 CHECKED BY S.S.

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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	20						40	60	80
408.4																				
0.0	ORGANICS - black		1	AS												280.2	Water level @ 0.1m on completion.			
407.5																109.5				
0.9	SAND - some gravel, trace silt, very loose to dense		2	SS	2															
			3	SS	5															
			4	SS	8															
			5	SS	49															
403.8	BEDROCK - Gneiss, pink & grey																			
4.6																				
			1	RC														RC #1 REC 42% RQD 13.3%		
			2	RC														RC #2 REC 61.3% RQD 32%		
			3	RC														RC #3 REC 82.7% RQD 44%		
			4	RC													RC #4 REC 100% RQD 92%			
397.8	End of Borehole @ 10.6m.																			
10.6																				

# RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. 5119-06-00 LOCATION Unnamed Creek N:5370168; E:222216 MTM Zone:13 ORIGINATED BY W.M.  
 DIST NER HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY S.W.  
 DATUM Geodetic DATE 2016.10.20 - 2016.10.20 LATITUDE 48.46472 LONGITUDE -85.116832 CHECKED BY S.S.

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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)								
413.9							20	40	60	80	100						GR	SA	SI	CL
413.9	ASPHALT - 100mm		1	AS																
413.9	FILL - SAND - trace gravel to Gravelly, some silt, occasional cobbles, brown, compact to dense		2	SS	34															Water level @ 4.8m on completion.
			3	SS	11															
			4	SS	6															
			5	SS	33															5 79 (16)
			6	SS	23															
408.3	SAND - Gravelly, Silty, occasional cobbles & boulders		7	SS	100+															On cobble.
406.6	BEDROCK - Gneiss, pink & grey		1	RC																RC #1 REC 100% RQD 100%
			2	RC																RC #2 REC 37.7% RQD 0%
			3	RC																RC #3 REC 100% RQD 90.9%
			4	RC																RC #4 REC 98% RQD 98%
401.8	End of Borehole @ 12.1m.																			
12.1																				



# RECORD OF BOREHOLE No 7

1 OF 1

METRIC

W.P. 5119-06-00 LOCATION Unnamed Creek N:5370140; E:222206 MTM Zone:13 ORIGINATED BY W.M.  
 DIST NER HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY S.W.  
 DATUM Geodetic DATE 2016.10.21 - 2016.10.21 LATITUDE 48.464473 LONGITUDE -85.116962 CHECKED BY S.S.

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									
								20	40	60	80	100					
409.0																	
0.0	FILL - SAND - trace organics, brown		1	AS													Water level @ 0.4m on completion.
408.5																	
0.5	ORGANICS - some sand, trace wood		2	SS	4												
407.8																	
1.2	SILT & SAND - trace gravel, grey, loose to compact		3	SS	9												1 44 (55)
			4	SS	17												
406.1																	
3.0	SAND - some gravel, some silt, grey, compact		5	SS	14												
			6	SS	25												17 66 (17)
402.9																	
6.1	BEDROCK - Gneiss, Gravelly, pink & grey		1	RC													RC #1 REC 37% RQD 0%
			2	RC													RC #2 REC 100% RQD 96.6%
			3	RC													RC #3 REC 100% RQD 100%
398.4																	
10.6	End of Borehole @ 10.6m.																

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

# RECORD OF BOREHOLE No 8

1 OF 1

METRIC

W.P. 5119-06-00 LOCATION Unnamed Creek N:5370158; E:222204 MTM Zone:13 ORIGINATED BY W.M.  
 DIST NER HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY S.W.  
 DATUM Geodetic DATE 2016.10.23 - 2016.10.23 LATITUDE 48.464633 LONGITUDE -85.116999 CHECKED BY S.S.

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												
409.0							20	40	60	80	100									
0.0	SAND - Silty, trace gravel, brown, loose to compact ----- - grey		1	AS													Water level @ 0.2m on completion. 1 67 (32)			
			2	SS	20															
			3	SS	5															
			4	SS	29															
			5	SS	25															
			6	SS	18															
			7	SS	23															
	- gravelly, some silt																21 67 (12)			
	- occasional cobbles																			
401.4																				
7.6	BEDROCK - Gneiss, grey & white		1	RC													RC #1 REC 100% RQD 95.3%			
			2	RC																
398.4																	RC #2 REC 100% RQD 98.6%			
10.6	End of Borehole @ 10.6m.																			

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

### ROCK CORE LOG

Page 1 of 1

Project #: 16-138

Borehole #1

Lab# 16-16517

Client: MTO NER

Logger: Larry Wells

Site: Sta.20+210 Vasiloff Twp.

Date: Oct. 26/16

DEPTH FROM SURFACE (m)		DEPTH (m)	BOX/RUN	% REC (m)	% RQD (m)	GENERAL DESCRIPTION (Rock type(s), %, colour, texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES							OCCASIONAL FEATURES	
									# OF SETS	TYPE(S)	Orientation	SPACING	Roughness	APERTURE	FILLING		
From		From 6.10	1	100.0%	73.3%	Pink and Grey Gneiss		S									
To		To 7.60															
From		7.6	1	100.0%	100.0%	Pink and Grey Gneiss		S									
To		7.60															
		To 9.10															
From		From															
		To															
From		From															
To		To															

**Strength (MPa)**  
 VH = Very High = >200  
 H = High = 50-200  
 M = Medium = 15-50  
 L = Low = 4-15  
 VL = Very Low = 1-4

**Discontinuity type**  
 B = Bedding joint  
 J = Cross joint  
 F = Fault  
 S = Shear Plane

**Orientation**  
 F = Flat (0-20°)  
 D = Dipping (20-50°)  
 V = Near Vertical (>50°)

**Spacing**  
 VW = Very wide = >3m  
 W = Wide = 1-3m  
 M = Moderate = 0.3-1m  
 C = Close = 5-30cm  
 VC = Very close = <5cm

**Roughness**  
 RU = Rough undulating  
 RP = Rough planar  
 SU = Smooth undulating  
 SP = Smooth planar  
 LU = Slickensided undulating  
 LP = Slickensided planar

**Aperture**  
 O = Open  
 C = Closed  
 F = Filled

**Filling**  
 T = Tight, hard  
 O = Oxidized  
 SA = Slightly altered, clay free  
 S = Sandy, Clay free  
 SI = Sandy, silty, minor clay  
 NC = Non-softening clay  
 SC = Swelling, softening clay  
 N = No filling

## Full Rock Core Dry



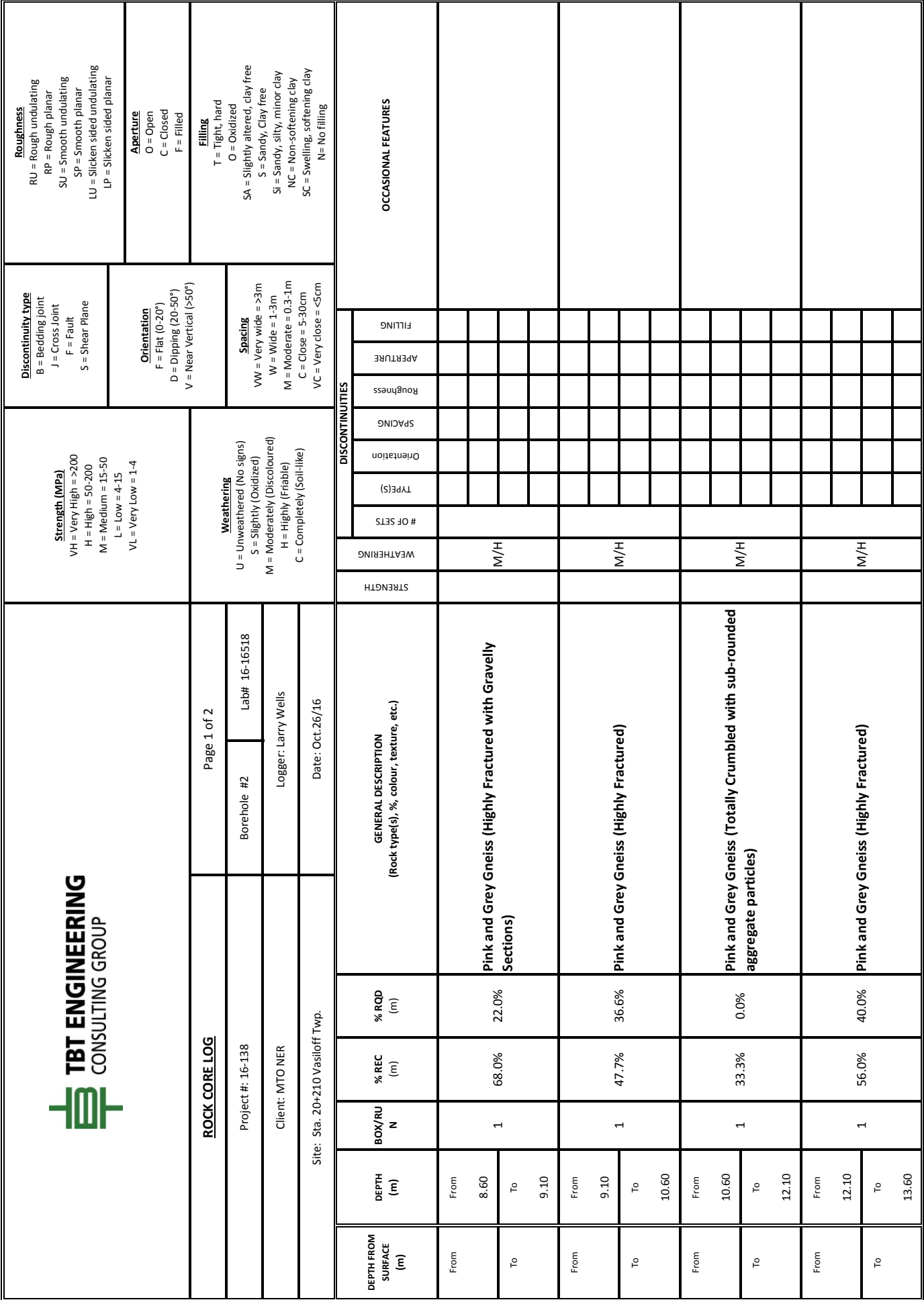
## Full Rock Core Wet





## Rock Core Detail





### ROCK CORE LOG

Page 2 of 2

Project #: 16-138

Borehole #2

Lab# 16-16518

Client: MTO NER

Logger: Larry Wells

Site: Sta. 20+210 Vasiloff Twp.

Date: Oct.26/16

#### Strength (MPa)

VH = Very High = >200  
H = High = 50-200  
M = Medium = 15-50  
L = Low = 4-15  
VL = Very Low = 1-4

#### Weathering

U = Unweathered (No signs)  
S = Slightly (Oxidized)  
M = Moderately (Discoloured)  
H = Highly (Friable)  
C = Completely (Soil-like)

#### Discontinuity type

B = Bedding joint  
J = Cross joint  
F = Fault  
S = Shear Plane

#### Orientation

F = Flat (0-20°)  
D = Dipping (20-50°)  
V = Near Vertical (>50°)

#### Spacing

VW = Very wide = >3m  
W = Wide = 1-3m  
M = Moderate = 0.3-1m  
C = Close = 5-30cm  
VC = Very close = <5cm

#### Roughness

RU = Rough undulating  
RP = Rough planar  
SU = Smooth undulating  
SP = Smooth planar  
LU = Slickensided undulating  
LP = Slickensided planar

#### Aperture

O = Open  
C = Closed  
F = Filled

#### Filling

T = Tight, hard  
O = Oxidized  
SA = Slightly altered, clay free  
S = Sandy, Clay free  
SI = Sandy, silty, minor clay  
NC = Non-softening clay  
SC = Swelling, softening clay  
N = No filling

#### DISCONTINUITIES

STRENGTH

WEATHERING

# OF SETS

TYPE(S)

Orientation

SPACING

Roughness

APERTURE

FILLING

#### OCCASIONAL FEATURES



## Full Rock Core Dry



## Full Rock Core Wet





## Rock Core Detail



### ROCK CORE LOG

Page 1 of 1

Project #: 16-138

Borehole #3

Lab# 16-16519

Client: MTO NER

Logger: Larry Wells

Site: Sta. 20+210 Vasiloff Twp.

Date: Oct.26/16

DEPTH FROM SURFACE (m)		DEPTH (m)	BOX/RU N	% REC (m)	% RQD (m)	GENERAL DESCRIPTION (Rock type(s), %, colour, texture, etc.)		STRENGTH		WEATHERING	DISCONTINUITIES						OCCASIONAL FEATURES			
From	To										# OF SETS	TYPE(S)	Orientation	SPACING	Roughness	APERTURE	FILLING			
From	To		1	92.2%	74.4%	Pink and Grey Gneiss (Fractured)				S										
From	To		1	66.6%	18.0%	Pink and Grey Gneiss (Highly Fractured, Crumbly)				S/M										
From	To		1	72.0%	56.0%	Pink and Grey Gneiss (Highly Fractured)				S										
From	To		1	100.0%	100.0%	Pink and Grey Gneiss				S										

**Strength (MPa)**  
 VH = Very High = >200  
 H = High = 50-200  
 M = Medium = 15-50  
 L = Low = 4-15  
 VL = Very Low = 1-4

**Discontinuity type**  
 B = Bedding joint  
 J = Cross joint  
 F = Fault  
 S = Shear Plane

**Orientation**  
 F = Flat (0-20°)  
 D = Dipping (20-50°)  
 V = Near Vertical (>50°)

**Spacing**  
 VW = Very wide = >3m  
 W = Wide = 1-3m  
 M = Moderate = 0.3-1m  
 C = Close = 5-30cm  
 VC = Very close = <5cm

**Weathering**  
 U = Unweathered (No signs)  
 S = Slightly (Oxidized)  
 M = Moderately (Discoloured)  
 H = Highly (Friable)  
 C = Completely (Soil-like)

**Roughness**  
 RU = Rough undulating  
 RP = Rough planar  
 SU = Smooth undulating  
 SP = Smooth planar  
 LU = Slickensided undulating  
 LP = Slickensided planar

**Aperture**  
 O = Open  
 C = Closed  
 F = Filled

**Filling**  
 T = Tight, hard  
 O = Oxidized  
 SA = Slightly altered, clay free  
 S = Sandy, Clay free  
 SI = Sandy, silty, minor clay  
 NC = Non-softening clay  
 SC = Swelling, softening clay  
 N = No filling



## Full Rock Core Dry



## Full Rock Core Wet



## Rock Core Detail





### ROCK CORE LOG

Page 1 of 1

Project #: 16-138

Borehole #4

Lab# 16-16520

Client: MTO NER

Logger: Larry Wells

Site: Sta. 20+210 Vasiloff Twp.

Date: Oct 28/16

DEPTH FROM SURFACE (m)		DEPTH (m)	BOX/RU N	% REC (m)	% RQD (m)	GENERAL DESCRIPTION (Rock type(s), %, colour, texture, etc.)		STRENGTH	WEATHERING	# OF SETS	TYPE(S)	Orientation	SPACING	Roughness	APERTURE	FILLING	OCCASIONAL FEATURES	
From		From																
To		4.60	1	98.7%	90.7%	Pink and Grey Gneiss			S									
		To																
		6.10																
From		From																
		6.10	1	100.0%	48.0%	Pink and Grey Gneiss (Fractured)			S									
To		To																
		7.60																
From		From																
		To																
From		From																
To		To																
From		From																
To		To																

**Strength (MPa)**  
 VH = Very High = >200  
 H = High = 50-200  
 M = Medium = 15-50  
 L = Low = 4-15  
 VL = Very Low = 1-4

**Discontinuity type**  
 B = Bedding joint  
 J = Cross joint  
 F = Fault  
 S = Shear Plane

**Orientation**  
 F = Flat (0-20°)  
 D = Dipping (20-50°)  
 V = Near Vertical (>50°)

**Spacing**  
 VW = Very wide = >3m  
 W = Wide = 1-3m  
 M = Moderate = 0.3-1m  
 C = Close = 5-30cm  
 VC = Very close = <5cm

**Weathering**  
 U = Unweathered (No signs)  
 S = Slightly (Oxidized)  
 M = Moderately (Discoloured)  
 H = Highly (Friable)  
 C = Completely (Soil-like)

**Roughness**  
 RU = Rough undulating  
 RP = Rough planar  
 SU = Smooth undulating  
 SP = Smooth planar  
 LU = Slickensided undulating  
 LP = Slickensided planar

**Aperture**  
 O = Open  
 C = Closed  
 F = Filled

**Filling**  
 T = Tight, hard  
 O = Oxidized  
 SA = Slightly altered, clay free  
 S = Sandy, Clay free  
 SI = Sandy, silty, minor clay  
 NC = Non-softening clay  
 SC = Swelling, softening clay  
 N = No filling

## Full Rock Core Dry



## Full Rock Core Wet





## Rock Core Detail





### ROCK CORE LOG

Page 1 of 1

Project #: 16-138

Borehole #5

Lab# 16-16521

Client: MTO NER

Logger: Larry Wells

Site: Sta. 20+210 Vasiloff Twp.

Date: Oct 28/16

#### Strength (MPa)

VH = Very High = >200  
H = High = 50-200  
M = Medium = 15-50  
L = Low = 4-15  
VL = Very Low = 1-4

#### Weathering

U = Unweathered (No signs)  
S = Slightly (Oxidized)  
M = Moderately (Discoloured)  
H = Highly (Friable)  
C = Completely (Soil-like)

#### Discontinuity type

B = Bedding joint  
J = Cross joint  
F = Fault  
S = Shear Plane

#### Orientation

F = Flat (0-20°)  
D = Dipping (20-50°)  
V = Near Vertical (>50°)

#### Spacing

VW = Very wide = >3m  
W = Wide = 1-3m  
M = Moderate = 0.3-1m  
C = Close = 5-30cm  
VC = Very close = <5cm

#### Roughness

RU = Rough undulating  
RP = Rough planar  
SU = Smooth undulating  
SP = Smooth planar  
LU = Slickensided undulating  
LP = Slickensided planar

#### Aperture

O = Open  
C = Closed  
F = Filled

#### Filling

T = Tight, hard  
O = Oxidized  
SA = Slightly altered, clay free  
S = Sandy, Clay free  
SI = Sandy, silty, minor clay  
NC = Non-softening clay  
SC = Swelling, softening clay  
N = No filling

#### DISCONTINUITIES

STRENGTH

WEATHERING

# OF SETS

TYPE(S)

Orientation

SPACING

Roughness

APERTURE

FILLING

#### OCCASIONAL FEATURES

## Full Rock Core Dry



## Full Rock Core Wet





## Rock Core Detail



### ROCK CORE LOG

Page 1 of 1

Project #: 16-138

Borehole #6

Lab# 16-16522

Client: MTO NER

Logger: Larry Wells

Site: Sta. 20+210 Vasiloff Twp.

Date: Oct. 31/16

#### Strength (MPa)

VH = Very High = >200  
H = High = 50-200  
M = Medium = 15-50  
L = Low = 4-15  
VL = Very Low = 1-4

#### Weathering

U = Unweathered (No signs)  
S = Slightly (Oxidized)  
M = Moderately (Discoloured)  
H = Highly (Friable)  
C = Completely (Soil-like)

#### Discontinuity type

B = Bedding joint  
J = Cross joint  
F = Fault  
S = Shear Plane

#### Orientation

F = Flat (0-20°)  
D = Dipping (20-50°)  
V = Near Vertical (>50°)

#### Spacing

VW = Very wide = >3m  
W = Wide = 1-3m  
M = Moderate = 0.3-1m  
C = Close = 5-30cm  
VC = Very close = <5cm

#### Roughness

RU = Rough undulating  
RP = Rough planar  
SU = Smooth undulating  
SP = Smooth planar  
LU = Slickened undulating  
LP = Slickened planar

#### Aperture

O = Open  
C = Closed  
F = Filled

#### Filling

T = Tight, hard  
O = Oxidized  
SA = Slightly altered, clay free  
S = Sandy, Clay free  
SI = Sandy, silty, minor clay  
NC = Non-softening clay  
SC = Swelling, softening clay  
N = No filling

#### DISCONTINUITIES

STRENGTH

WEATHERING

# OF SETS

TYPE(S)

Orientation

SPACING

Roughness

APERTURE

FILLING

#### OCCASIONAL FEATURES



## Full Rock Core Dry



## Full Rock Core Wet





## Rock Core Detail



### ROCK CORE LOG

Page 1 of 1

Project #: 16-138

Borehole #7

Lab# 16-16523

Client: MTO NER

Logger: Larry Wells

Site: Sta. 20+210 Vasiloff Twp.

Date: Oct. 31/16

#### Strength (MPa)

VH = Very High = >200  
H = High = 50-200  
M = Medium = 15-50  
L = Low = 4-15  
VL = Very Low = 1-4

#### Discontinuity type

B = Bedding joint  
J = Cross joint  
F = Fault  
S = Shear Plane

#### Orientation

F = Flat (0-20°)  
D = Dipping (20-50°)  
V = Near Vertical (>50°)

#### Weathering

U = Unweathered (No signs)  
S = Slightly (Oxidized)  
M = Moderately (Discoloured)  
H = Highly (Friable)  
C = Completely (Soil-like)

#### Spacing

VW = Very wide = >3m  
W = Wide = 1-3m  
M = Moderate = 0.3-1m  
C = Close = 5-30cm  
VC = Very close = <5cm

#### Aperture

O = Open  
C = Closed  
F = Filled

#### Filling

T = Tight, hard  
O = Oxidized  
SA = Slightly altered, clay free  
S = Sandy, Clay free  
SI = Sandy, silty, minor clay  
NC = Non-softening clay  
SC = Swelling, softening clay  
N = No filling

#### DISCONTINUITIES

##### STRENGTH

##### WEATHERING

##### # OF SETS

##### TYPE(S)

##### Orientation

##### SPACING

##### Roughness

##### APERTURE

##### FILLING

#### OCCASIONAL FEATURES

GENERAL DESCRIPTION  
(Rock type(s), %, colour, texture, etc.)

% RQD  
(m)

% REC  
(m)

BOX/RU  
N

DEPTH  
(m)

DEPTH FROM  
SURFACE  
(m)

Pink and Grey Gneiss (Highly Fractured, Gravelly)

0.0%

37.0%

1

From  
6.10  
To  
7.60

From  
7.60  
To  
9.10

Pink and Grey Gneiss

96.6%

100.0%

1

From  
9.10  
To  
10.60

From  
10.60  
To  
12.10

Pink and Grey Gneiss

100.0%

100.0%

1

From  
12.10  
To  
13.60

From  
13.60  
To  
15.10

1

From  
15.10  
To  
16.60

From  
16.60  
To  
18.10



## Full Rock Core Dry



## Full Rock Core Wet





## Rock Core Detail



### ROCK CORE LOG

Page 1 of 1

Project #: 16-138

Borehole #8

Lab# 16-16524

Client: MTO NER

Logger: Larry Wells

Site: Sta. 20+210 Vasiloff Twp.

Date: Oct. 31/16

DISCONTINUITIES															OCCASIONAL FEATURES
# OF SETS	TYPE(S)	Orientation	SPACING	Roughness	APERTURE	FILLING									
DEPTH FROM SURFACE (m)	DEPTH (m)	BOX/RUN	% REC (m)	% RQD (m)	GENERAL DESCRIPTION (Rock type(s), %, colour, texture, etc.)	STRENGTH	WEATHERING								
From	From	1	100.0%	95.3%	Grey and White Gneiss		S								
To	To														
From	From	1	100.0%	98.6%	Grey and White Gneiss		S								
To	To														
From	From														
To	To														
From	From														
To	To														
From	From														
To	To														

**Strength (MPa)**  
VH = Very High = >200  
H = High = 50-200  
M = Medium = 15-50  
L = Low = 4-15  
VL = Very Low = 1-4

**Discontinuity type**  
B = Bedding joint  
J = Cross joint  
F = Fault  
S = Shear Plane

**Orientation**  
F = Flat (0-20°)  
D = Dipping (20-50°)  
V = Near Vertical (>50°)

**Weathering**  
U = Unweathered (No signs)  
S = Slightly (Oxidized)  
M = Moderately (Discoloured)  
H = Highly (Friable)  
C = Completely (Soil-like)

**Spacing**  
VW = Very wide = >3m  
W = Wide = 1-3m  
M = Moderate = 0.3-1m  
C = Close = 5-30cm  
VC = Very close = <5cm

**Roughness**  
RU = Rough undulating  
RP = Rough planar  
SU = Smooth undulating  
SP = Smooth planar  
LU = Slickened undulating  
LP = Slickened planar

**Aperture**  
O = Open  
C = Closed  
F = Filled

**Filling**  
T = Tight, hard  
O = Oxidized  
SA = Slightly altered, clay free  
S = Sandy, Clay free  
SI = Sandy, silty, minor clay  
NC = Non-softening clay  
SC = Swelling, softening clay  
N = No filling



## Full Rock Core Dry



## Full Rock Core Wet



## Rock Core Detail

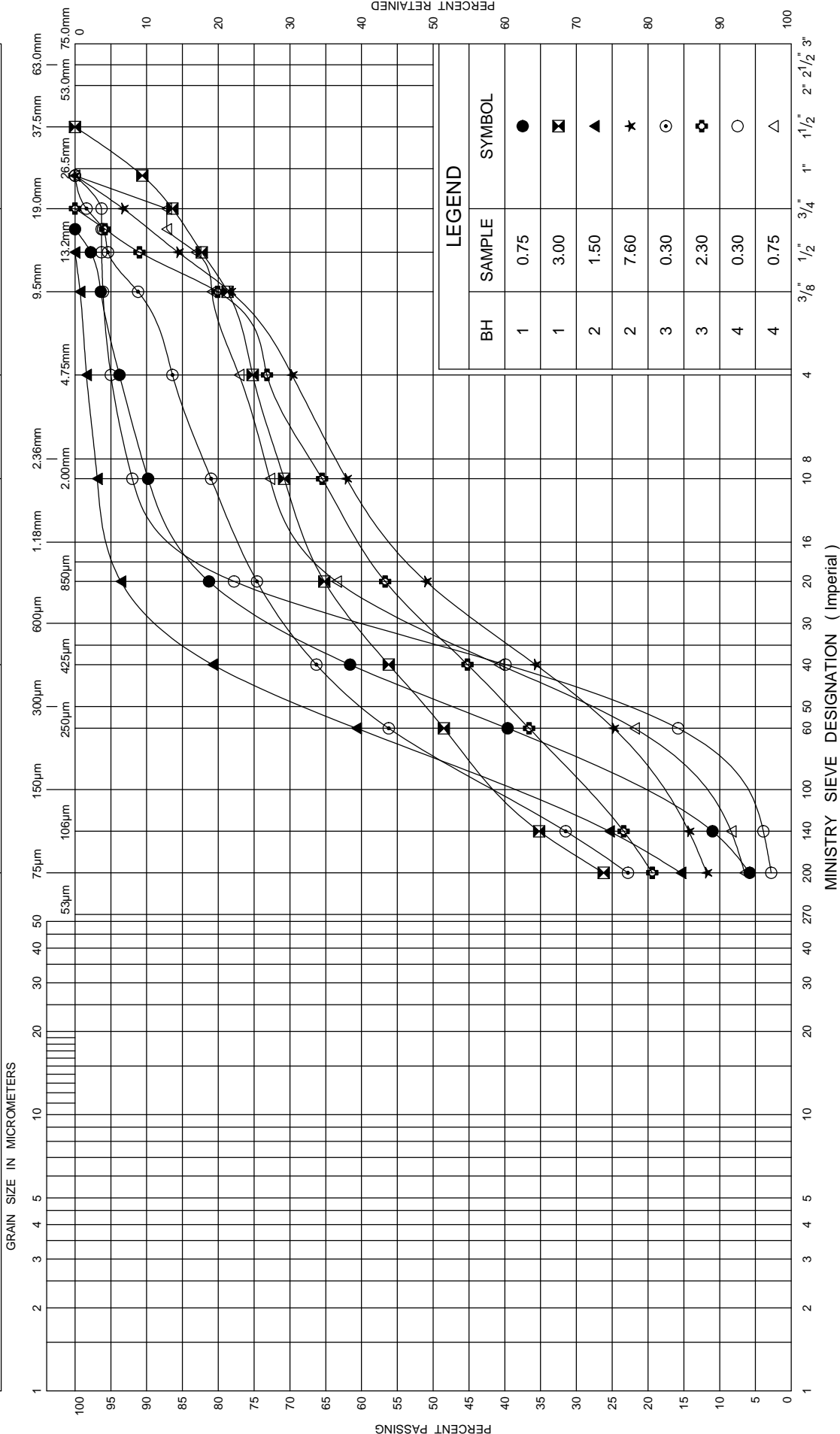


## **APPENDIX B**

### **Laboratory Test Data**

UNIFIED SOIL CLASSIFICATION SYSTEM

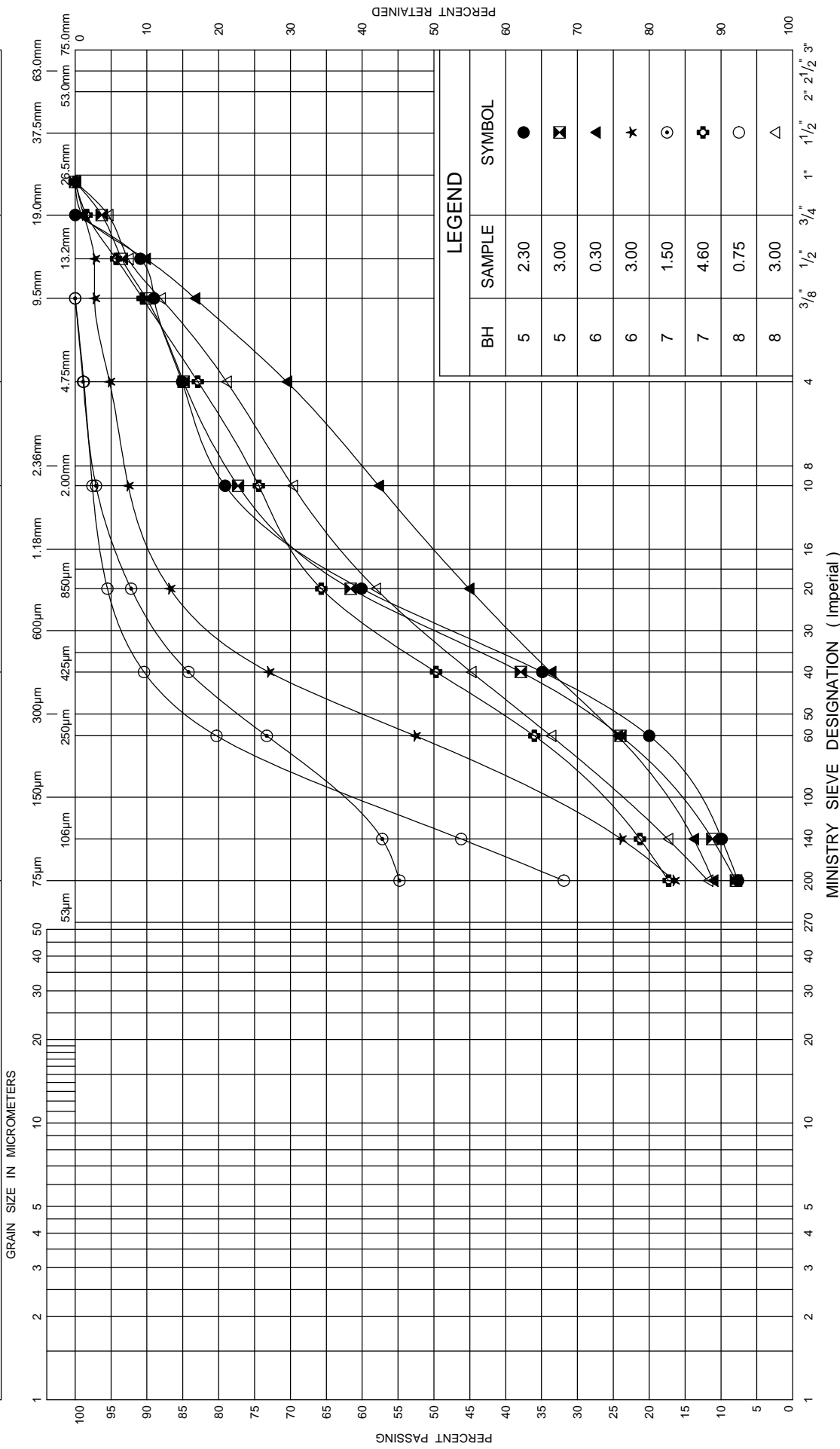
CLAY & SILT		SAND			GRAVEL	
		Fine		Medium	Fine	Coarse





UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine		Medium	Fine	Coarse





TBTE Engineering Group  
ATTN: Doug Steele  
1918 Young St.  
Thunder Bay ON P7E 6T9

Date Received: 01-NOV-16  
Report Date: 10-NOV-16 14:42 (MT)  
Version: FINAL

Client Phone: 807-624-5160

## Certificate of Analysis

Lab Work Order #: L1851596  
Project P.O. #: NOT SUBMITTED  
Job Reference: 16-138  
C of C Numbers:  
Legal Site Desc:

Christine Paradis  
Project Manager

[This report shall not be reproduced except in full without the written authority of the Laboratory.]

ADDRESS: 1081 Barton Street, Thunder Bay, ON P7B 5N3 Canada | Phone: +1 807 623 6463 | Fax: +1 807 623 7598  
ALS CANADA LTD Part of the ALS Group A Campbell Brothers Limited Company



# ALS ENVIRONMENTAL ANALYTICAL REPORT

<b>Sample ID</b> <b>Description</b> <b>Sampled Date</b> <b>Sampled Time</b> <b>Client ID</b>		L1851596-1 Soil 12-OCT-16 09:30 UNNAMED CREEK BH1 SS3				
Grouping	Analyte					
<b>SOIL</b>						
<b>Physical Tests</b>	Conductivity (mS/cm)	0.428				
	% Moisture (%)	14.7				
	pH (pH units)	7.80				
	Redox Potential (mV)	126				
	Resistivity (ohm*cm)	2340				
<b>Leachable Anions &amp; Nutrients</b>	Chloride (ppm)	109				
	Sulphide (as S) (mg/kg)	<0.20				
<b>Anions and Nutrients</b>	Sulphate (ppm)	<20				

## Reference Information

### Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
<b>CL-R511-WT</b>	Soil	Chloride-O.Reg 153/04 (July 2011)	EPA 300.0
5 grams of dried soil is mixed with 10 grams of distilled water for a minimum of 30 minutes. The extract is filtered and analyzed by ion chromatography.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).			
<b>EC-WT</b>	Soil	Conductivity (EC)	MOEE E3138
A representative subsample is tumbled with de-ionized (DI) water. The ratio of water to soil is 2:1 v/w. After tumbling the sample is then analyzed by a conductivity meter.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).			
<b>MOISTURE-WT</b>	Soil	% Moisture	Gravimetric: Oven Dried
<b>PH-WT</b>	Soil	pH	MOEE E3137A
A minimum 10g portion of the sample is extracted with 20mL of 0.01M calcium chloride solution by shaking for at least 30 minutes. The aqueous layer is separated from the soil and then analyzed using a pH meter and electrode.			
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).			
<b>REDOX-POTENTIAL-WT</b>	Soil	Redox Potential	APHA 2580
This analysis is carried out in accordance with the procedure described in the "APHA" method 2580 "Oxidation-Reduction Potential" 2012. Samples are extracted at a fixed ratio with DI water. Results are reported as observed oxidation-reduction potential of the platinum metal-reference electrode employed, in mV.			
<b>RESISTIVITY-CALC-WT</b>	Soil	Resistivity Calculation	APHA 2510 B
Resistivity are calculated based on the conductivity using APHA 2510B where Conductivity is the inverse of Resistivity.			
<b>RESISTIVITY-CALC-WT</b>	Soil	Resistivity Calculation	MOECC E3138
Resistivity are calculated based on the conductivity using APHA 2510B where Conductivity is the inverse of Resistivity.			
<b>SO4-WT</b>	Soil	Sulphate	EPA 300.0
<b>SULPHIDE-WT</b>	Soil	Sulphide (as S)	APHA 4500S2D
Sulphide in Soil analysis is based on APHA 4500 S2D. A sub-sample of the soil sample is distilled, sulphuric acid and sodium hydroxide are added to the distillate. The sample is then analyzed on a spectrophotometer.			

\*\* ALS test methods may incorporate modifications from specified reference methods to improve performance.

*The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:*

Laboratory Definition Code	Laboratory Location
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA

### Chain of Custody Numbers:

#### GLOSSARY OF REPORT TERMS

*Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.*

*mg/kg - milligrams per kilogram based on dry weight of sample.*

*mg/kg ww - milligrams per kilogram based on wet weight of sample.*

*mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.*

*mg/L - milligrams per litre.*

*< - Less than.*

*D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).*

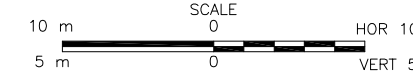
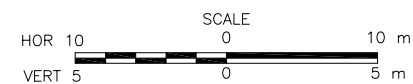
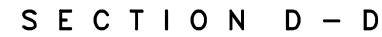
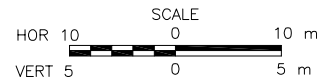
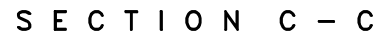
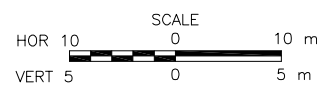
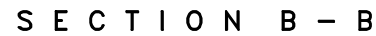
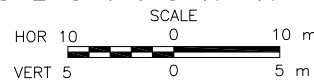
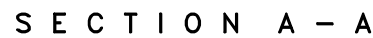
*N/A - Result not available. Refer to qualifier code and definition for explanation.*

*Test results reported relate only to the samples as received by the laboratory.*

*UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.*

*Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.*

**APPENDIX C**  
**Borehole Locations and Soil Strata Drawing**



KEY PLAN



2.0 km 2.0 km

No	ELEVATION	CO-ORDINATES (MTM)	
		NORTH	EAST
BH 1	408.3	13 5 370 169	222 247
BH 2	413.9	13 5 370 147	222 229
BH 3	408.6	13 5 370 173	222 237
BH 4	408.4	13 5 370 175	222 242
BH 5	408.4	13 5 370 152	222 197
BH 6	413.9	13 5 370 168	222 216
BH 7	409.0	13 5 370 140	222 206
BH 8	409.0	13 5 370 158	222 204

REVIEWS							
	170929	TB	ISSUED				
	170621	TB	DRAFT				
	DESCRIPTION						
CO—ORDINATES		Lat	48.464629°	Long	-85.116777°		
DESIGN	CHK	CODE	XXXX-XX	LOAD XX-XXX-XXX	DATE	20161224	
DRAWN	TB	CHK	GM SITE	38C-155/C	APPENDIX		

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

Sep 29, 2017, 1:02pm  
 Login name: tblunden  
 Drawing Name: Y:\Projects\2016\16-138 MTO NER Hwy 17 Part Eng\Foundations\2\_Unnamed Creek\Drawings\Unnamed Creek FNDN\_FINAL.dwg

**APPENDIX D**  
**Non Standard Special Provisions**



## **OBSTRUCTIONS**

Non Standard Special Provision:

The Contractor is notified that the soils at the site of Un-named Creek at Station 20+210 in the Township of Vasiloff Hwy 17. are expected to contain cobbles and possibly boulders which could affect the installation of temporary cofferdams, temporary shoring and/or temporary roadway protection measures. Consideration of these obstructions must be taken in selecting appropriate methodologies, equipment for excavations and installation of temporary cofferdams, temporary shoring and/or temporary roadway protection measures

End of Section