THURBER ENGINEERING LTD.

PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 TWINNING, RENFREW AREA
LITTLE HALLIDAY CREEK TRIBUTARY CULVERTS
STA.17+570 EBL AND WBL, HORTON TOWNSHIP
SITE NO. 29X-0404/C0
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009

Geocres No.: 31F-227

Report to:

Ministry of Transportation Ontario

Latitude: 45.505544°
Longitude: -76.675363°

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Thurber File No.: 24726

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

Thurber Engineering Ltd. (Thurber) has been engaged by the Ministry of Transportation Ontario (MTO) to carry out Foundation Investigations to support the design of the Highway 17 Twinning Project which extends from Scheel Drive westerly to 3 km west of Bruce Street in the Renfrew area.

This report addresses the unnamed Little Halliday Creek tributary crossing of Highway 17, located near Station 17+570 in Horton Township just west of Renfrew, Ontario. The existing Highway 17 alignment at this site will become the future Highway 17 westbound lanes and new eastbound lanes will be constructed to the southwest of the existing alignment. Rehabilitation or replacement of the culvert currently present under the existing Highway 17 lanes is proposed, while a new culvert will be required under the proposed eastbound lanes.

This section of the report presents the factual findings obtained from foundation investigations completed for the new and existing culvert structures at Station 17+570. Thurber carried out the investigation under Ministry of Transportation of Ontario (MTO) Assignment No. 4018-E-0009.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work.

2 SITE DESCRIPTION

2.1 General

The site is located on Highway 17 approximately one kilometre northwest of the existing intersection with Bruce Street. At the site, Highway 17 runs roughly north-south and the tributary creek, east-west. However, the travelled lanes of Highway 17 will be described herein as eastbound and westbound to maintain continuity with convention of the overall highway.

The land adjacent to the site is generally flat-lying and consists of agricultural fields. Residential homes are located along Garden of Eden Road which runs roughly parallel to the existing highway, approximately 250 m west of the site. The terrain is relatively flat with a slight downward slope towards the tributary creek. Occasional trees and shrubs are present along the existing highway right-of-way and the tributary creek.

The existing Highway 17 in the vicinity of the site is an undivided highway with two travelled lanes and a westbound passing lane, gravel shoulders, and a posted speed limit of 90 km/hr. The AADT for this existing section of Highway 17 near the site had a reported AADT of 12,300 in 2016.

The existing culvert present beneath Highway 17 is a 1.8 m diameter, 33.7 m long corrugated steel pipe (CSP) culvert and has about 2.6 m of cover. The culvert facilitates the flow of the tributary creek under the highway embankment from east to west where it meets Little Halliday Creek. The existing culvert has an invert elevation of approximately 146.3 m. It is noted that the tributary runs in a small, incised valley which was noted to be approximately 1.0 m wide. The depth of water in the creek was approximately 0.2 m on April 27, 2021.

The embankment sides are sloped at approximately 2.5H:1V and did not show any visible signs of distress at the time of the investigation.

Photographs showing the existing conditions in the area of the site at the time of the field investigation are included in Appendix D for reference.

2.2 Site Geology

Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as the Ottawa Valley Clay Plains. The Ottawa Valley Clay Plains are characterized primarily by clay plains deposited by the Champlain Sea (Leda Clay) interrupted by ridges of rock or sand.

Ontario Geological Survey Map 2460 for Precambrian Geology for the Cobden Area suggests the bedrock comprises calcitic carbonate metasedimentary bedrock including calcitic and siliceous marble.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation was carried out between April 27, 2021 and May 14, 2021, as part of an overall field-testing program to address several project structures. The field investigation consisted of advancing four boreholes identified as Boreholes CV-1, CV-2, CV-3, and CV-28. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The locations and elevations of the boreholes were surveyed by Thurber with a Trimble Catalyst DA1 antenna with centimeter accuracy. The northing, easting and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A, the individual Record of Borehole sheets in Appendix B, and in Table 3-1 below. The site is located within MTM Zone 9.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (Latitude)	Easting (Longitude)	Ground Surface Elevation (m)	Termination Depth (m)
CV-1	Proposed Eastbound Lanes Culvert Outlet	5 040 609.4 (45.505270)	291 050.3 (-76.675956)	146.8	11.9
CV-2	Proposed Eastbound Lanes Embankment	5 040 622.6 (45.505389)	291 062.8 (-76.675796)	146.8	11.9
CV-3	Proposed Westbound Lanes Culvert Outlet / Proposed Eastbound Lanes Culvert Inlet	5 040 631.1 (45.505466)	291 074.8 (-76.675642)	146.9	11.9
CV-28	Proposed Westbound Lanes Culvert Inlet (Existing Hwy 17)	5 040 650.8 (45.505644)	291 113.9 (-76.675142)	147.0	5.8

A track-mounted CME 45 drill rig equipped with hollow stem augers was used to put down the boreholes at the site.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). In situ vane shear testing was completed in cohesive soils with an MTO ‘N’ sized vane.

Monitoring wells, 50 mm in diameter, were installed in Boreholes CV-1 and CV-28. The installation details are illustrated on the respective Record of Borehole sheets provided in Appendix B. The boreholes were backfilled in accordance with MOE requirements (O.Reg 903, as amended). The monitoring wells will be decommissioned by Thurber, as outlined in the Hydrogeological Investigation and Design Report.

In addition, four pavement boreholes were advanced through the existing highway embankment nearby at Station 17+600 to depths ranging from 1.5 m to 2.1 m. The boreholes were drilled with a solid stem auger and representative samples acquired from the augers. In situ vane shear tests were carried out in cohesive deposits.

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The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's geotechnical staff. The drilling supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's Ottawa geotechnical laboratory for further examination and testing.

4 LABORATORY TESTING

Laboratory testing was selected in accordance with the current MTO Guideline for Foundation Engineering Services, Section 5. Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. At least 25% of the recovered soil samples were subjected to testing for grain size distribution and, where, appropriate, Atterberg Limits in accordance with MTO and ASTM standards. Chemical analysis for determination of pH, conductivity, resistivity, sulphide, sulphate and chloride was carried out on a sample of the soil.

The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and all laboratory results are presented on the figures included in Appendix C.

5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in the following sections. However, the factual data presented on the Borehole Records takes precedence over the Soil Strata Drawing and the general description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations. Soil classification is in accordance with ASTM D2487. Cohesive soils are described per current MTO protocols.

In general, the site stratigraphy consists of embankment fill over native deposits of silty clay to clayey silt, weathered to a crust in the upper several metres. Topsoil was encountered at the ground surface at all off-road borehole locations. All boreholes were terminated in the silty clay to clayey silt deposit.

5.1 Embankment Material

An asphalt layer ranging in thickness from 220 mm to 360 mm was encountered at ground surface in three of the four pavement boreholes drilled at 17+600. Granular fill was observed in all four boreholes and extended to depths ranging from 0.9 m to 1.5 m below ground surface. The granular fill ranged from silty gravel with sand to poorly graded sand.

The moisture content of the two samples tested was 5% and 6%. The results of grain size analyses conducted on two samples of the embankment fill are summarized below.

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Summary of Grain Size Distribution Testing – Embankment Fill

Soil Particle	Percentage (%)
Gravel	5 to 44
Sand	43 to 91
Silt and Clay	4 to 13

5.2 Topsoil

A layer of topsoil was encountered at the ground surface in all boreholes. It is noted that the boreholes were put down adjacent to farmland and the extent of the topsoil may reflect the depth of the tilled layer. The topsoil was observed to range in thickness from 300 mm, in the boreholes put down west of the existing Highway 17 alignment, to 610 mm, in Borehole CV-28 put down east of the existing Highway 17 alignment. One complete sample of topsoil obtained in Borehole CV-28 had a natural moisture content of 52%.

5.3 Weathered Silty Clay (CI) Crust

A deposit of silty clay weathered to a grey-brown crust was identified below the topsoil in Boreholes CV-1, CV-2, and CV-3 and three of the pavement boreholes. The thickness of this layer ranged from 1.2 m to 2.0 m with base depths ranging from 1.5 m to 2.3 m (base elevations ranging from 144.5 m to 145.4 m).

SPT N-values ranged from 2 to 3 blows per 0.3 m of penetration, indicating a stiff consistency.

The moisture content of the samples tested ranges from 32% to 59%. The results of grain size analyses conducted on three samples of the weathered silty clay crust are summarized below and two from the foundations boreholes are illustrated on Figure C1 in Appendix C.

Summary of Grain Size Distribution Testing – Weathered Silty Clay Crust

Soil Particle	Percentage (%)
Gravel	0
Sand	0 – 9
Silt	24 – 48
Clay	44 – 67

The results of Atterberg Limits testing carried out on three samples of this material are summarized below and two from the foundations boreholes are illustrated on Figure C4 in Appendix C. The laboratory results indicate that the material is a silty clay of intermediate plasticity (CI).

Summary of Atterberg Limit Testing – Weathered Silty Clay Crust

Parameter	Value
Liquid Limit	43 – 50
Plastic Limit	18 – 21
Plasticity Index	25 – 29

5.4 Silty Clay (CI) to Clayey Silt (CL)

Unweathered silty clay to clayey silt was encountered below the weathered crust in Boreholes CV-1, CV-2, and CV-3, and below the topsoil in Borehole CV-28. All boreholes were terminated in this deposit at base depths ranging from 5.8 m to 11.9 m (base elevations ranging from 134.9 m to 141.2 m). Sand partings were noted throughout this layer in Boreholes CV-1, CV-2, and CV-3.

SPTs conducted in this unit gave N-values ranging from weight of hammer to 3 blows per 0.3 m of penetration. In-situ shear vane tests indicated undrained shear strengths decreasing with increasing depth, ranging from greater than 100 to 41 kPa indicating a very stiff to firm consistency. Sensitivity values ranged from 4 to 18 but were generally between about 5 and 10.

The moisture content of the samples tested ranged from 26 to 52%. The results of nine grain size analysis tests conducted on samples of this material are summarized below and are illustrated on Figures C2 and C3 in Appendix C.

Summary of Grain Size Distribution Testing – Silty Clay to Clayey Silt

Soil Particle	Percentage (%)
Gravel	0
Sand	0 – 3
Silt	44 – 60
Clay	40 – 56

The results of Atterberg Limits testing carried out on five samples of this material are summarized below and are illustrated on Figure C5 in Appendix C. The laboratory results generally indicate that the material is a silty clay of intermediate plasticity (CI), with one test indicating a clayey silt of low plasticity (CL).

Summary of Atterberg Limit Testing – Silty Clay to Clayey Silt

Parameter	Value
Liquid Limit	25 – 47
Plastic Limit	17 – 22
Plasticity Index	8 – 28

5.5 Groundwater

Monitoring wells with diameters of 50 mm were installed in Boreholes CV-1 and CV-28. Groundwater levels recorded in the wells are presented in Table 5-1 below:

Table 5-1: Summary of Groundwater Levels

Borehole No.	Bottom of Screen Elevation (m)	Groundwater Depth (m)	Groundwater Elevation (m)	Date of Measurement
CV-1	142.2	0.3	146.5	August 4, 2021
		0.3	146.5	September 22, 2021
		0.4	146.4	October 5, 2021
		0.4	146.4	October 22, 2021
		0.6	146.2	January 19, 2022
CV-28	142.4	0.1	146.9	August 4, 2021
		0.1	146.9	September 22, 2021
		0	147.0	October 5, 2021
		0.3	146.7	January 19, 2022

The creek water elevation was noted to be approximately 146.4 m on April 27, 2021.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

5.6 Analytical Testing

One sample of the native silty clay was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate, sulphide and chloride concentrations, resistivity and conductivity. The analysis results are summarized in Table 5-2. Copies of the test results are provided in Appendix C.

Table 5-2: Results of Chemical Analysis

Borehole	Sample	Depth (m)	Chloride (μg/g)	Sulphate (μg/g)	Sulphide (%)	pH (-)	Resistivity (Ohm-cm)
CV-2	SS2	0.8 – 1.4	192	30	< 0.04	7.66	2,140

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features. The as-drilled locations and ground surface elevation of the boreholes were surveyed by Thurber following completion of the field program. The elevation survey was carried out with reference to geodetic elevation benchmarks provided by the MTO.

Marathon Underground of Greely, Ontario supplied and operated the drilling equipment and carried out the drilling, soil sampling, in-situ testing, monitoring well installation and borehole decommissioning. The field investigation was supervised on a full-time basis by Anderson de Oliveira of Thurber. Overall supervision of the investigation program was provided by Justin Gray, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa.

Overall project management and direction of the field program was provided by Fred Griffiths, P.Eng. Interpretation of the factual data and preparation of this report were carried out by Matt Kennedy, P.Eng. and Fred Griffiths, P.Eng. The report was reviewed by P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

Part 2 of the report provides an interpretation of the factual data from Part 1 and presents geotechnical recommendations to assist the project team in designing the foundations for a culvert crossing to be located at approximate Station 17+570 on Highway 17, about one kilometre northwest of Bruce Street in Horton Township, Renfrew County. At the site, the existing Highway 17 will become the future westbound lanes while the new future eastbound alignment will be located approximately 45 m southwest of the existing alignment. The existing culvert under the current Highway 17 lanes will be rehabilitated or replaced, while a new culvert will be required under the proposed eastbound lanes. The culverts will convey an unnamed tributary creek to Little Halliday Creek under the existing and proposed highway embankments.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation and shall not be used or relied upon for any other purposes or by any other parties including design-build contractors. It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work. The Preferred Proponent must make their own interpretation based on the factual data in Part 1 of the report. The information included in Part 2 is not to be relied upon for design purposes and foundation design is the sole responsibility of the Preferred Proponent. No use shall be made of Part 2 or any part thereof. The Preferred Proponent must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The following sections provide preliminary geotechnical recommendations for the construction of foundation elements for the proposed culverts. The discussions and recommendations presented in this report are based on the information provided by the Ministry of Transportation of Ontario (MTO) and on the factual data obtained during the course of this investigation.

At the site, Highway 17 runs roughly north-south and the tributary creek, east-west. However, the travelled lanes of Highway 17 will be described herein as eastbound and westbound to maintain continuity with convention of the overall highway.

The ground surface elevation outside the existing highway embankment footprint ranges from 146.8 m to 147.0 m. The elevation of the existing Highway 17 centreline (proposed westbound lanes) at the culvert crossing is about 150.0 m.

The native soils at the site are silty clay/clayey silt. All boreholes were terminated in the lower, unweathered portion of the silty clay layer. The water level in the two monitoring wells were measured to be at elevations 146.5 m and 147.9 m on August 4, 2021.

The 2003 Stormwater Management and Drainage Report by National Capital Engineering (NCE) in support of the Preliminary Design Report for this project indicates a culvert is present beneath the existing highway (proposed westbound lanes) at approximately Sta. 17+570. The NCE report describes the existing culvert as a 1.6 m diameter CSP, approximately 33.7 m long.

A survey report from Callon Dietz Inc. under Assignment 4014-E-0034 from November 2019 indicates that the existing culvert is 1.8 m diameter with obvert elevations ranging from 148.1 m (inlet) to 147.7 m (outlet) and invert elevations ranging from 146.25 m (inlet) and 145.87 m (outlet).

7.1 Proposed Structures

At the time of planning the field investigation, it was understood that the existing 1.8 m diameter CSP under the existing Highway 17 lanes was to be rehabilitated with a 1.2 m diameter conventional liner as part of Contract 2020-4092 (Sheet Nos. 10 and 13, Appendix F). However, the most recent General Arrangement drawing (dated June 16, 2021, Appendix F) indicates that the existing culvert is to be replaced.

The replacement culvert beneath the existing Highway 17 lanes (future westbound lanes) and the new culvert beneath the proposed eastbound lanes are to each consist of a closed bottom concrete box culvert with an external span of 3.5 m and height of 2.6 m. It is anticipated that the new culverts will be constructed with invert elevations similar to that of the existing Highway 17 culvert (approximate Elevation 146.0 m).

The road surface centreline of the proposed eastbound lanes is about Elevation 150.7 m. It has been assumed that the elevation of the roadway surface of the existing Highway 17, approximately 150.0 m, will be maintained for the new westbound lanes.

7.2 Applicable Codes and Design Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC, version CSA S6:19).

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In accordance with the CHBDC, the analysis and design of the structure takes into consideration the importance of the structure and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority, which, in this case, is the Ministry of Transportation, Ontario (MTO).

It is understood that the new culvert structure is being designed to the "Major Route" importance category.

This project has been assigned a "Typical" Consequence Classification, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances.

The degree of site and prediction model understanding for this site has been assessed to be typical understanding (Section 6.5.3 of CHBDC).

8 SEISMIC CONSIDERATIONS

8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). The seismic hazard for this site has been obtained from the GSC online calculator. The data include a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values (Sa(T)) for the *reference* ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix E.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA). The PGA at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.23g. This value is to be scaled by the F(PGA) based on the site-specific Site Class.

8.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the average undrained shear strengths measured below the anticipated culvert foundation elevation, the site is classified as a Seismic Site Class D in accordance with Table 4.1 of the CHBDC.

As per Table 4.8 of the CHBDC, Site Class D yields a PGA_{ref} of 0.18 and F(PGA) of 1.13 for the site. These values give a site-adjusted PGA of 0.26 g.

8.3 Seismic Liquefaction Potential

The susceptibility of the cohesive soils at this site to experience liquefaction/cyclic softening was assessed following the Boulanger and Idriss (2007)[i] criteria using measured undrained shear strengths. The results of the analysis indicate the clayey silt to silty clay is not susceptible to cyclic mobility.

Cohesionless soils were not encountered at the borehole locations. Based on the results of pavement boreholes put down through the existing highway embankment about 30 m south at approximate Station 17+600, it is anticipated that the existing Highway 17 embankment fill at the site comprises cohesionless soils. However, it is anticipated that any existing loose granular material will be removed and replaced with compacted granular engineered fill as part of the proposed culvert replacement.

9 STRUCTURE FOUNDATION ALTERNATIVES

9.1 Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, depth to suitable bearing stratum and post-construction settlement criteria. From a geotechnical perspective, the following culvert types were considered:

- Circular Pipes (Concrete, HDPE, Steel)

  From a foundation engineering perspective, a pipe culvert is a technically feasible alternative. The size of the pipe culvert would depend on the required hydraulic capacity. Multiple smaller pipes may be required to carry the flow.

- Open-Bottom Culvert (Box, Arch)

  The construction of an open-bottom culvert will have greater construction concerns due to the high water table and requirement for greater excavation depths to construct the culvert footings to satisfy frost depth requirements. The use of an open-bottom culvert would require greater dewatering efforts and has the potential for larger settlement following construction when compared to other culvert options.

- Closed-Bottom Box Culvert

  A precast, segmental, closed-bottom, box culvert is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix F. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report.

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9.2 Construction Methodology

Temporary excavations will extend below the water level of the creek. An adequate and effective dewatering plan including surface water management, cofferdams, creek diversion and excavation dewatering will be required to enable excavation to the required founding elevation and construction of the foundations in the dry (See Section 11.3).

At the time of preparation of this report, a construction staging plan has not yet been developed. The foundation recommendations presented herein have been prepared based on the assumption that culvert beneath the proposed eastbound lanes will be constructed prior to the roadway, and construction of the replacement culvert beneath the existing Highway 17 lanes will be carried out either under full road closure using a detour on to the new eastbound lanes alignment or with the use of temporary roadway protection allowing one lane of traffic through the construction zone.

9.3 Recommended Approach

From a geotechnical perspective, a closed-bottom, box culvert is recommended at this site. It is anticipated that construction for the eastbound lanes would be carried out while traffic remains on the existing alignment. Once the new lanes are open, all traffic would be rerouted onto the new lanes, while the culvert structure under the existing lanes is replaced.

Multiple pipe culverts would also be considered a feasible alternative. Construction staging would be similar to that for the closed bottom box culvert option.

10 FOUNDATION DESIGN RECOMMENDATIONS

From a foundation engineering perspective, a concrete, closed-bottom, box culvert is recommended. Relevant elevations obtained from the available preliminary design information are as follows:

- Proposed top of pavement eastbound / westbound lanes 150.7 m / 150.0 m
- Low point of stream bed in proposed culvert 146.2 m
- Proposed elevation of underside of base slab of culvert 145.9 m
- Groundwater elevation 146.9 m

10.1 Culvert Foundation Bearing Resistances

It is assumed that the dimensions of the existing Highway 17 embankment (proposed westbound lanes) will be maintained following culvert replacement, however, the existing three lanes will be reduced to two with a 3.0 m wide outside shoulder. It is not anticipated that the subgrade soils within the proposed westbound lanes culvert footprint will be subjected to any additional loads when compared to the existing embankment footprint. It is assumed the proposed eastbound lanes embankment will have a similar geometry to the existing Highway 17. The construction of the new embankment will add additional loads within and beyond the culvert footprint. Further discussion on the potential settlement of the subgrade soils is provided in Section 10.6.

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The subgrade should be prepared as described in Section 10.3. Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (Section 11.3).

The recommended geotechnical resistances for a 3.5 m wide (exterior) pre-cast, closed-bottom, box culvert with the underside of culvert base slab at or below approximate elevation 145.9 m, installed on a bedding layer as described in Section 10.3 placed on an undisturbed native silty clay crust subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Factored Geotechnical Resistance at SLS* of 100 kPa

  Note (*): The SLS value provided is for settlements up to 25 mm. It should be noted that the placement of new fill will cause up to about 160 mm of settlement for the new eastbound lane as noted in Section 10.6. The eastbound culvert site will need to be pre-loaded to satisfy the 25 mm limitation.

It is noted that the westbound lanes replacement culvert opening will be substantially larger than the existing pipe culvert under the existing embankment, thus the result of the construction will be a net unloading.

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
  - ϕ_{gu} = 0.5 (static analysis; typical degree of understanding)
  - ϕ_{gs} = 0.8 (static analysis; typical degree of understanding)

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 10.3) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. A reduction factor of 0.8 (as per CHBDC Table 6.2) should be used to estimate the sliding resistance between the culvert and Granular A. An unfactored coefficient of friction of 0.35 can be assumed for the interface between the Granular 'A' and the clayey subgrade. A reduction factor of 0.6 (as per CHBDC Table 6.2) should be used to estimate the sliding resistance between the Granular A and the clayey subgrade.

10.2 Wingwalls / Retaining Walls

Based on General Arrangement drawing dated June 16, 2021 (See Appendix F), no retaining walls or wingwalls are proposed at this location. If required, concrete retaining walls or wingwalls could be supported on spread footings. It is noted that wingwalls are not required if the culvert structure length is sufficient to allow the sloped embankment fill recommended in Section 10.6.

Footings for wingwalls or retaining walls should be founded at a depth greater than the depth of frost (see Section 10.4), measured perpendicular to the ground surface. The subgrade and granular pad shall be prepared based on the recommendations provided in Section 10.3.

The geotechnical resistance values provided in Section 10.1 are applicable for shallow footings up to 3 m wide and 10 m long. It should be noted that the placement of new eastbound embankment fill will cause up to about 160 mm of settlement as noted in Section 10.6. If the wingwall/retaining wall structures for the eastbound lanes cannot accommodate that amount of settlement, the site will have to be pre-loaded or the culvert should be lengthened to eliminate the need for wingwalls / retaining walls.

A retained soil system (RSS) for a culvert wingwall or retaining wall is not recommended at this site as it is located within a watercourse and could be affected by fluctuating water levels.

10.3 Subgrade Preparation, Bedding and Backfilling

“Granular A” and “Granular B Type II” in this section refer to OPSS Granular A or Granular B Type II meeting the specifications of OPSS.PROV 1010 and SP110S06. “Granular A” is further defined as “Quarry-Source Granular A” unless specifically described as “Pit-Source Granular A”.

10.3.1 Culverts

The foundation subgrade should be prepared as per OPSS.PROV 422.07.06 using Granular A material as backfill of over-excavated areas, where required. The granular material shall be compacted as per OPSS.PROV 501. Non-native or otherwise deleterious soil encountered at the subgrade level during excavation of the existing embankment are considered to be unsuitable and should be removed.

In order to provide a more uniform foundation subgrade condition for the culvert foundations, a bedding layer and levelling course shall be provided as per OPSD 803.010 (not-withstanding culvert span) and OPSS.PROV 422. A minimum bedding thickness of 0.3 m of Granular A is recommended.

Given the sensitive subgrade clay soils anticipated at the founding level of the culverts, construction equipment should not be permitted to travel on the exposed subgrade. The compaction of granular bedding directly above the subgrade may result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. After inspection and approval of the subgrade, protection of the subgrade should include installation of a Class II, non-woven geotextile with a maximum FOS of 150 μm (OPSS.PROV 1860) installed beneath the Granular A material. The geotextile should be placed as soon as possible after preparation of the final subgrade level. Alternately, the geotextile and bedding material could be replaced with a 200 mm thick, concrete working slab placed on the prepared subgrade prior to placement of the levelling course. The working slab should extend at least 0.5 m beyond the outside dimensions of the culvert. An NSSP is provided in Appendix H to include in the contract documents to alert the Contractor of the sensitive nature of the foundation soils.

It is noted that construction will extend below groundwater elevation. Creek diversion and dewatering will be required to prepare the subgrade in the dry. Please refer to Section 11.3 for additional comments on groundwater and surface water control.

The limits of structural backfill should be in accordance with OPSD 3101.150. Structural backfill adjacent to the culvert should consist of Granular A or Granular B Type II placed and compacted in accordance with OPSS.PROV 501. Heavy compaction equipment used adjacent to the culvert must be restricted in accordance with OPSS.PROV 501.07.02a.

10.3.2 Wingwalls / Retaining Walls

The foundation subgrade should be prepared as per OPSS.PROV 902 using Granular A material as backfill of over-excavated areas, where required. Non-native or otherwise deleterious soil encountered at the subgrade level during excavation of the existing embankment are considered to be unsuitable and should be removed.

The walls should be founded on a granular pad with a minimum thickness of 0.3 m consisting of Granular A material. The top of the Granular A pad must extend to 0.5 m beyond the outside edge of all sides of the footing and sloped away from the footing at 1H:1V, or flatter. The granular shall be compacted as per OPSS.PROV 501.

Given the sensitive subgrade clay soils anticipated at the founding level of the wingwalls/retaining walls, construction equipment should not be permitted to travel on the exposed subgrade. The compaction of granular directly above the subgrade may result in disturbance of the material with pumping of fines into the granular and difficulty achieving the specified degree of compaction. After inspection and approval of the subgrade, protection of the subgrade should include installation of a Class II, non-woven geotextile with a maximum FOS of 150 μm (OPSS.PROV 1860) installed beneath the Granular A material. The geotextile should be placed as soon as possible after preparation of the final subgrade level. Alternately, the geotextile and granular pad could be replaced with a 200 mm thick, concrete working slab placed on the prepared subgrade. The working slab should extend at least 0.5 m beyond the outside dimensions of the footing. An NSSP is provided in Appendix H to include in the contract documents to alert the Contractor of the sensitive nature of the foundation soils.

It is noted that construction will extend below groundwater elevation. Creek diversion and dewatering will be required to prepare the subgrade in the dry. Please refer to Section 11.3 for additional comments on groundwater and surface water control.

The limits of structural backfill should be in accordance with OPSD 3101.150. Structural backfill adjacent to the wingwalls/retaining walls should consist of OPSS Granular A or Granular B Type II placed and compacted in accordance with OPSS.PROV 501. Heavy compaction equipment used adjacent to the retaining walls must be restricted in accordance with OPSS.PROV 501.07.02a.

10.4 Frost Penetration Depth

The depth of frost penetration at this site is estimated to be 1.9 m (as per OPSD 3090.101). Shallow foundations should be founded at or below this depth or provided with equivalent insulation. Closed-bottom, box culverts are not typically provided with frost protection.

Please refer to the pavement design report for frost taper recommendations for the pavement.

10.5 Backfill and Lateral Earth Pressures

Structural backfill material should consist of Granular A or Granular B Type II meeting the OPSS.PROV 1010 and SP110S06 specifications. Large scale direct shear box testing on samples of Granular A and Granular B Type II from numerous nearby aggregate sources was completed for this project. The results indicate that for design of structural backfill for this project, an internal angle of friction of 40 degrees and 42 degrees can be used for quarry-sourced Granular A and Granular B Type II, respectively, in this area provided the effective vertical pressure on the material is less than 150 kPa (Geocres Memorandum 31F-213). An Operational Constraint will be required in the contract restricting the source of Granular A to quarries. Throughout this report, the term “Granular A” is defined as “Quarry-Source Granular A” unless specifically described as “Pit-Source Granular A”.

The backfill must be in accordance with OPSS 902 and placed to the extents shown on OPSD 3101.150 for the culvert and wingwalls/retaining walls. The design of the wingwalls/retaining walls, where required, must incorporate a subdrain as shown in OPSD 3101.150.

Lateral earth pressure parameters provided in Table 10-1 and Table 10-2 in the sections below are based on the assumptions that the wall is vertical and the backfill is fully drained so that there are no unbalanced hydrostatic pressures above the permanent groundwater level. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design.

Where back slopes are horizontal, the corresponding coefficients provided in Table 10-1 and Table 10-2 should be used. For other backfill and wall geometries, Thurber will need to calculate the appropriate earth pressure coefficients once the final geometry is confirmed.

10.5.1 Static Lateral Earth Pressure

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC. Under drained conditions the lateral earth pressure is generally given by the following expression:

$$\sigma_h = K * (\gamma h + q)$$

where:

σ_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below)

		(K_a for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil (see table below), use submerged unit weight below groundwater level
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for OPSS Granular A and OPSS Granular B Type II backfill are shown in Table 10-1.

Table 10-1: Static Earth Pressure Coefficients

Condition	Quarry Sourced OPSS Granular A ϕ = 40°, γ = 22.8 kN/m³	Pit Sourced OPSS Granular A ϕ = 35°, γ = 22.8 kN/m³	Quarry Sourced OPSS Granular B Type II ϕ = 42°, γ = 22.8 kN/m³
Coefficient of at Rest Earth Pressure, K_o (Restrained Wall)	0.36	0.43	0.33
Coefficient of Active Earth Pressure, K_A (Unrestrained Wall)	0.22	0.27	0.20

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The movement required can be assessed from Table C6.12 of the Commentary to the CHBDC. Active earth pressures should be used for any wingwalls or unrestrained walls. For rigid structures, at-rest horizontal earth pressures would apply for design.

10.5.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 6.14 of the current version of CHBDC, retaining structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

- k_h = ½ * F(PGA) * PGA, for structures that allow 25 to 50 mm of movement, and
- k_h = F(PGA) * PGA, for non-yielding walls

Table 10-2: Combined Static and Seismic Earth Pressure Coefficients

Condition	Quarry Sourced OPSS Granular A ϕ = 40°, γ = 22.8 kN/m³	Pit Sourced OPSS Granular A ϕ = 35°, γ = 22.8 kN/m³	Quarry Sourced OPSS Granular B Type II ϕ = 42°, γ = 22.8 kN/m³
Coefficient of Active Earth Pressure, K_{AE} (Restrained Wall)	0.37	0.44	0.34
Coefficient of Active Earth Pressure, K_{AE} (Unrestrained Wall)	0.29	0.35	0.26

The coefficients of horizontal earth pressure for combined static and seismic loading presented in Table 10-2 may be used. The provided earth pressure coefficients are calculated using a site-adjusted PGA of 0.26 g, based on a Seismic Site Class D, a reference (Site Class C) PGA with a 2% probability of exceedance in 50 years of 0.23 g (Geological Survey of Canada – Fifth Generation), and a F(PGA) of 1.135 as per Table 4.8 of the current version of CHBDC.

The total pressure due to combined static and seismic loads acting at a specific depth below the top of the wall may be determined using the following equation that includes consideration of material properties and the soils profile.

$$\sigma_h \quad = \quad K * \gamma * d + (K_{AE} - K_A) * \gamma * (H - d)$$

where:

σ_h = lateral earth pressure at depth d (kPa)
d = depth below the top of the wall (m)
K = static earth pressure coefficient
(K_A for yielding walls, K_o for non-yielding walls)
γ = unit weight of retained soil, use submerged unit weight below groundwater level
K_{AE} = combined static and seismic earth pressure coefficient
H = total height of the wall (m)

10.6 Embankment Fill

Embankments should be constructed in accordance with OPSS.PROV 206. Local marine clay must not be used as embankment fill.

10.6.1 Embankment Stability

Embankment stability has been assessed perpendicular to the highway alignment. Analyses were completed for the proposed eastbound embankment and the reinstatement of the existing highway embankment (proposed westbound).

The slope stability analyses were carried out using GeoStudio 2020 Slope/W software for limit equilibrium analysis. Input parameters for the analyses are based on the SPT N values, undrained shear strength and the results of laboratory testing and are summarized on the stability analyses outputs provided in Appendix G. The following additional parameters and assumptions were used in the analysis:

- The soil stratigraphy is based on the nearest boreholes.
- A maximum fill height of 3.9 m outside of 1 m wide incised stream valley
- Eastbound embankment: options for conventional 2H:1V SSM/Granular B Type I, 1.25H:1V rockfill or retaining wall.
- Westbound embankment: reinstatement of conventional 2H:1V SSM/Granular B Type I and retaining wall.
- Retaining walls: concrete retaining walls must be founded at or below the frost depth outlined in Section 10.4 on a granular pad as outlined in Section 10.2. The recommendations provided retaining walls are based on the strength parameters of quarry-source Granular A material.
- A site adjusted PGA value of 0.13 g, equal to ½ of the site adjusted PGA value (0.26 g), was used for seismic analysis, as per Section 4.4.3.3, of the CHBDC and outlined in Section 8.2 above.
- A traffic surcharge of 17 kPa has been applied as a temporary load.

Copies of the output from the stability analyses are provided in Appendix G. Each output figure shows the slope geometry, groundwater conditions, soil stratigraphy and soil strength parameters utilized in the analysis.

The stability analyses generated the factor of safety values shown below in Table 10-3 and Table 10-4 for the proposed eastbound and westbound embankment designs, respectively.

Table 6.2 of the CHBDC for embankment fills with a typical degree of understanding and a Ψ of 1.0 generates minimum Factors of Safety of 1.5 and 1.3 for permanent and temporary conditions respectively**.** All of the static results presented in Table 10-3 and Table 10-4 meet or exceed the target Factors of Safety.

Table 6.3 in Section 6.14.4.1 of the CHBDC indicates a minimum seismic resistance factor of 0.95 for force-based design and 1.0 for performance-based design. Based on these values and Ψ of 1.0, a target Factor of Safety of 1.1 for this temporary condition with a typical degree of understanding is appropriate for the pseudo-static seismic analysis. The pseudo-static results presented in Table 10-3 and Table 10-4, exceed the target Factor of Safety for seismic design. It is noted that some displacement of the embankment can occur where the pseudo-static Factor of Safety is less than 1.3. However, as noted in Table 10-3 and Table 10-4 this criterion has also been satisfied for all cases.

Table 10-3 Slope Stability Analysis Results for Eastbound Embankment

Condition	Case	Factor of Safety		
		2H:1V [SSM/Granular BI]	**1.25H:1V** [Rockfill]	**Retaining Wall** [Granular A*]
Temporary (traffic loading)	Short Term (Undrained)	2.0 (Fig G1-1)	1.8 (Fig G2-1)	4.2 (Fig G3-1)
Permanent (no traffic loading)	Long Term (Drained)	1.6 (Fig G1-2)	1.5 (Fig G2-2)	1.9 (Fig G3-2)
Temporary (includes seismic)	Pseudo-Static Seismic (Undrained)	1.5 (Fig G1-3)	1.7 (Fig G2-3)	2.7 (Fig G3-3)

Note: * Quarry Sourced Granular A

Table 10-4 Slope Stability Analysis Results for Westbound Embankment

Condition	Case	Factor of Safety [GBI]	
		2H:1V [SSM/Granular BI]	**Retaining Wall** [Granular A*]
Temporary (traffic loading)	Short Term (Undrained)	2.1 (Fig G4-1)	4.9 (Fig G5-1)
Permanent (no traffic loading)	Long Term (Drained)	1.7 (Fig G4-2)	2.1 (Fig G5-2)
Temporary (includes seismic)	Pseudo-Static Seismic (Undrained)	1.5 (Fig G4-3)	3.1 (Fig G5-3)

Note: * Quarry Sourced Granular A

The proposed embankment slopes satisfy all of the static and pseudo-static slope stability requirements.

Should slope flattening of the rock fill embankments be used onsite with surplus excavated material, slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes, see Section 11.4. Slope flattening should meet the requirements of OPSD 202.010 and OPSD 202.020.

10.6.2 Embankment Settlement

The reinstated westbound embankment will have a similar height and footprint to the existing. The proposed culvert opening is greater than the existing, thus, the construction represents a net unloading. No additional settlement is expected along the existing alignment. However, settlement should be reviewed if the embankments are widened or reinstated to design grades greater than the existing grades.

The proposed eastbound lanes will result in a fill height of about 3.9 m across the proposed culvert. Settlement of the future highway embankment needs to be considered not only in terms of pavement performance on the approaches but also in selection and design of the culvert foundations.

An assessment of the time dependent settlement that would result from construction of the proposed Highway 17 eastbound lanes embankment was carried out using Rocscience's Settle3 modelling software with a Boussinesq stress distribution. The soil stratigraphy was defined based on borehole data and the water table was defined based on piezometer readings. It is noted that engineering judgment and experience were used to select the material properties based on the stress range anticipated due to loading.

The following has been assumed for the embankment geometry:

- Height = 3.9 m
- Length = 100 m
- Platform Width = 11.5 m
- Side slopes (Granular) = 2H:1V
- Side Slopes (Rockfill) = 1.25H:1V

It is recommended that slope flattening not be used in the area within 50 m of the culvert to reduce the culvert length and to reduce the magnitude of settlement.

The geotechnical parameters used in the settlement analysis were based on an average of the borehole stratigraphies and consolidation test results from similar soils at the Bruce Street site, approximately one kilometre southeast of Culvert at 17+570 (Gecores Report No. 31F-234).

The clay stratum was separated into two sub-layers: upper silty clay and lower silty clay. Table 10-5 presents the properties used in the Settle3 analysis for the various sub-layers.

Table 10-5: Settle3 Inputs

<table>
<tr><th>Clay Layer</th><th>Elevation (m)</th><th>C_c (-)</th><th>c_v (cm^2/s)</th><th>C_r (-)</th><th>c_{vr} (cm^2/s)</th><th>P_c' (kPa)</th><th>e_o (-)</th></tr>
<tr><td>Upper Silt/Clay</td><td>147 to 141</td><td>0.7</td><td>0.0009</td><td>0.04</td><td>0.009</td><td>400</td><td>1.2</td></tr>
<tr><td rowspan="2">Lower Silt/Clay</td><td>141 to 136</td><td rowspan="2">0.5</td><td rowspan="2">0.006</td><td rowspan="2">0.04</td><td rowspan="2">0.03</td><td>400 to 190</td><td rowspan="2">1.1</td></tr>
<tr><td>136 to 110</td><td>190 to 400</td></tr>
</table>

At the proposed eastbound embankment, the following settlement magnitude and durations are expected:

- Granular: 160 mm of settlement with substantial completion in 23 months
- Rockfill: 150 mm of settlement with substantial completion in 23 months

The magnitude of the embankment compression constructed with rockfill and granular materials is in the order of 0.5% of the embankment height and is expected to occur following fill placement.

Settlement of the existing highway (proposed westbound lanes) due to the construction of the new eastbound embankment is expected to be less than 25 mm.

MTO guidelines for settlement of freeway approach embankments within structure transition zones over a period of 20 years after paving is outlined below:

- 25 mm within 20 m of the structure;
- 50 mm from 20 to 50 m from the structure;
- 75 mm from 50 to 75 m from the structure; and
- 100 mm greater than 75 m from the structure.

Based on these guidelines, the total embankment settlement of the proposed eastbound embankment exceed these criteria. Therefore, it is recommended that a full height preload and a temporary CSP culvert be constructed and left in place for a duration of 23 months to ensure that post-construction settlement meets the above guidelines. The end of preload will need to be confirmed with a settlement monitoring program. The preload material would then be excavated to remove the temporary CSP and construct the permanent highway culvert.

A pre-load will also be required to facilitate the construction of retaining walls and/or wingwalls, if required.

10.7 Cement Type and Corrosion Potential

Chemical analysis for determination of pH, water soluble sulphate, sulphides, chloride concentrations, resistivity and electrical conductivity was carried out on samples of the native materials. The analysis results are summarized in Section 5.6 and a copy of the test results is provided in Appendix C.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Section 5.6 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and indicate a severe corrosive environment. The test results provided in Section 5.6 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with the soil and groundwater at the site. The sulphate results in were compared with Table 3 of Canadian Standards Association Standards A23.1-19 (CSA A23.1) and indicate a low degree of sulphate attack potential on concrete structures at this site.

The corrosive effects of road de-icing salts should also be considered.

11 CONSTRUCTION CONSIDERATIONS

11.1 Temporary Excavations

All temporary excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the stiff to very stiff silty clay to clayey silt soils are considered to be Type 3. Side slopes for excavations through more than one soil type must be entirely based on the highest soil type number. Unsupported excavations made in Type 3 soils must have side slopes no steeper than 1H:1V from the base of the excavation.

Excavation should be carried out in accordance with OPSS 902. The management and disposal of excess material shall be in accordance with OPSS.PROV 180. Excavations will extend into the underlying native deposits (silty clay). Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Stockpiling or surface surcharge should not be allowed on the embankment or side slopes.

Although not anticipated, at locations where there are space restrictions, the excavations could be carried out within a protection system. Further discussion on temporary protection systems (TPS) is presented in Section 11.2.

11.2 Temporary Protection Systems

Temporary protection systems (TPS) could be used for excavation support or groundwater control and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. The protection system should be installed at a suitable distance away from the new structures to limit the disturbance to subgrade associated with removal of the protection system following completing of construction. Alternatively, the protection system near the structures could be left in place and cut off in accordance with OPSS.PROV 903 to limit the disturbance of subgrade during removal of the TPS.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through the embankment fill and culvert backfill are provided in Table 10-1. The lateral earth pressure coefficients for the underlying native soils are given below for a vertical wall and a horizontal backslope:

Existing Fill:

γ = 20.0 (kN/m^3 bulk unit weight of soil, to be adjusted below water)
K_A = 0.33
K_P = 3.0

Native silty clay:

γ	=	17.0 (kN/m^3 bulk unit weight of soil, to be adjusted below water)
K_A	=	0.36
K_P	=	2.8

The design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations.

When designing roadway protection systems, the Contractor should consider the potential for obstructions such as cobbles and boulders in the existing embankment. Although no on-road boreholes were put down at this site, rockfill embankments have been noted along Highway 17 within the project limits. Installation of interlocking sheet piles should be feasible at this site given the contractor has the equipment necessary to deal with the potential obstructions. A soldier pile lagging system is also a feasible option. Lateral support for either alternative can be enhanced by using bracing or rakers. Suggested wording for an NSSP for obstructions is included in Appendix H.

11.3 Surface and Groundwater Control

Culvert and wingwall/retaining wall construction (if required), subgrade preparation and placement and compaction of granular bedding must be carried out in the dry. Based on the groundwater elevation at the time of the investigation, it is anticipated that the site will require dewatering to lower the groundwater to below the final excavation or footing level. Furthermore, surface runoff will tend to seep into and accumulate in the excavations. The Contractor must control groundwater, perched groundwater and surface water flow at the site to permit construction in a dry and stable excavation.

Subgrade preparation, placement and compaction of granular bedding, culvert and retaining wall construction must be carried out with a properly designed dewatering system to control groundwater and creek/surface water and may include cofferdams, creek diversion, pumping etc. The temporary flow diversion pipe should be placed outside the construction area. The dewatering system will be required to remain operational and effective until the temporary excavations are backfilled and then should be decommissioned and removed.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP No. FOUN0003 which amends OPSS 902 and SP517F01 which amends OPSS.PROV 517. Given the site conditions and anticipated works, the Designer Fill-In ***** in SP517F01 Table A should be “No”; the design Engineer and design-checking Engineer do not need a minimum of 5 years of experience in designing similar dewatering systems. A preconstruction survey is not required, thus Designer Fill-In ** in this SP should be “NA”.

The water level will fluctuate and the minimum groundwater elevation for the site at the time of the excavation should be taken as the expected high water level defined in SP517F01 and SP FOUN0003.

It is anticipated that sump pumps will likely be sufficient to extract water from the excavations for the culverts. Pumping from within a sandbag cofferdam system is a feasible option. A sheet pile cofferdam enclosure driven into the foundation soils (silty clay) may also be considered (see Section 11.2, above). The groundwater level within the work zone should be lowered by pumping from sumps to a minimum of 0.5 m below the underside of the planned excavation base prior to each stage of excavation.

Further assessment of dewatering requirements and the need for a Permit to take Water (PTTW) should be carried out by specialists experienced in this field.

It is noted that a Hydrogeological Investigation and Design Report is under preparation for the Highway 17 Twinning Project. Please refer to that document for additional discussion on dewatering with respect to this assignment.

11.4 Erosion and Scour Control

The Contractor should provide silt fences and erosion control blankets as per OPSS 805 throughout the duration of construction to prevent transport of silt/sediment into the creek.

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the earth and granular embankment slopes. A vegetation cover should be established on exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804. Slope vegetation should be established as soon as possible after completion of the embankment fills to limit surficial erosion.

Particle size analysis on samples of the existing embankment materials obtained from a nearby Highway 17 site and the native silty clay indicate that the soils have a low and moderate potential for soil erodibility respectively (Wischmeier Nomograph factor, K of 0.15 and 0.2, respectively).

Scour protection shall be provided at the culvert inlet and outlet areas. Effective scour and erosion protection should be provided along the waterline, ditches and around footings. Design of the erosion protection measures must consider hydrologic and hydraulic factors and shall be carried out by specialists experienced in this field. Typically, rock protection as per OPSS.PROV 511 should be provided over all surfaces with which creek water is likely to be in contact. Treatment at the inlet and outlet of culverts should be in accordance with OPSD 810.010.

Liaison between the Foundations Consultant, Structural Engineer and Hydraulic/Drainage Engineer will be required in design to ensure that scour protections, if required, is adequately addressed.

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12 CONSTRUCTION CONCERNS

The likely construction methodology includes open cut excavations for the installation of foundation elements of the new culverts. Potential construction concerns may include, but are not necessarily limited to:

- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the culverts and wingwall/retaining wall foundations in the dry.
- The native soil which will be exposed beneath culvert bedding layers or wing wall/retaining wall spread footings is sensitive and readily disturbed. A suggested Notice to Contractor is provided in Appendix H.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing soils to support the proposed construction equipment and supplies.
- Obstructions could be encountered in the existing embankment fill and may limit choice of equipment and methods.
- Mitigation of the settlement induced by the new eastbound embankment will require a preload or a structure designed to accommodate the movements. If preloading is employed, an instrumentation and monitoring program will be required to assess the progress of the preload. Given the limited project length, the monitoring program would include approximately six settlement rods located on the new alignment with a nominal spacing of 25 m. The base plates should be installed prior to fill placement and the rods will require extension as fill is placed around them. The top of the settlement rods should be surveyed every week during preload construction, then every two weeks for four months, then every month for the duration of the anticipated preload period (see Section 10.6.2). The installation of the monitoring equipment and surveying would typically be carried out by the Contractor, with the results evaluated by the Contract Administration team.

The successful performance of the structure installations will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per OPSS 902 during construction to confirm that the foundation recommendations are correctly implemented, and material specifications are met.

13 CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Matt Kennedy, P.Eng. and Dr. Fred Griffiths, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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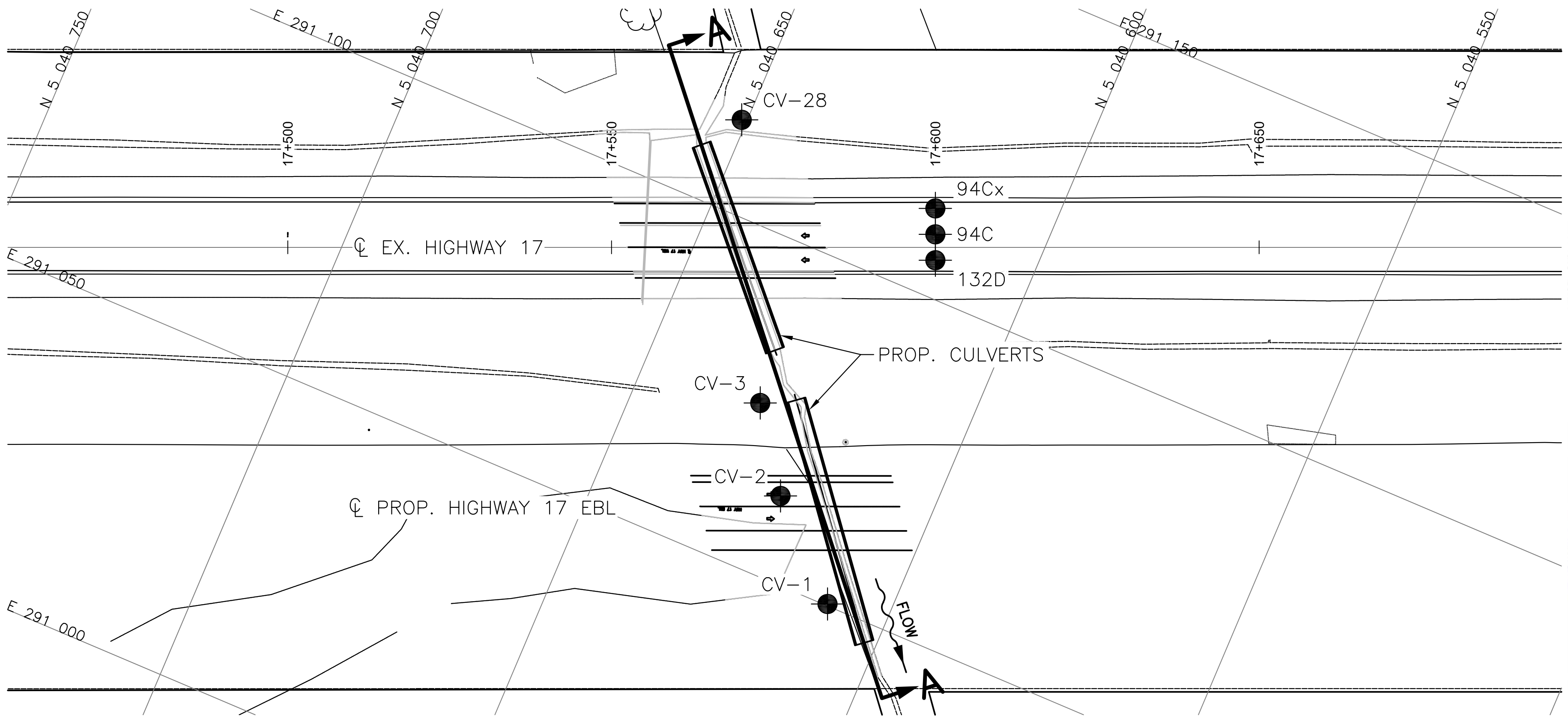
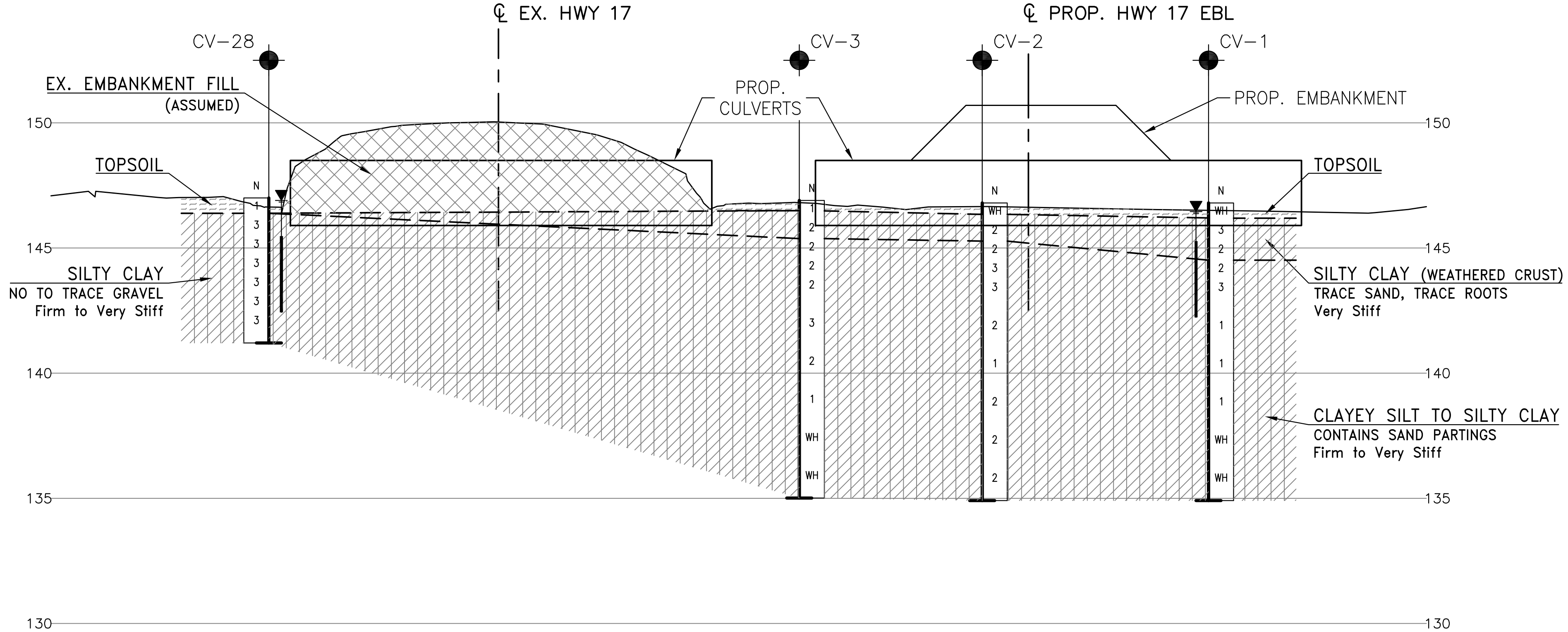
Appendix A.

Borehole Location Plan and Stratigraphic Drawings



PLAN



SECTION ALONG A–A

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

LICENSED PROFESSIONAL ENGINEER
M. J. KENNEDY
100188946
July 15, 2022
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
July 15, 2022
PROVINCE OF ONTARIO

CONT No
WP No

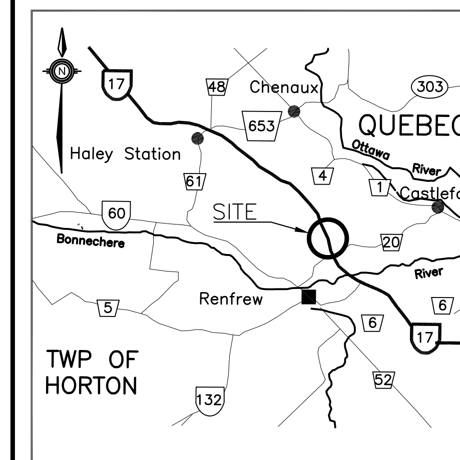
SHEET

HIGHWAY 17 TWINNING
CULVERT STA. 17+570

BOREHOLE LOCATIONS AND SOIL STRATA

Ontario

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

Symbol	Description
●	Borehole
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
CV-1	146.8	5 040 609.4	291 050.3
CV-2	146.8	5 040 622.6	291 062.8
CV-28	147.0	5 040 650.8	291 113.9
CV-3	146.9	5 040 631.1	291 074.8
132D	149.7	5 040 614.8	291 105.6
94C	149.7	5 040 616.4	291 109.3
94Cx	149.7	5 040 617.9	291 113.0

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Structural elements, surface details and features are for conceptual illustration.
3) Coordinate system is MTM NAD 83 Zone 9.

GEOCRES No. 31F-227

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN MJK	CHK PKC	CODE	LOAD	DATE JUL 2022	
DRAWN MFA	CHK MJK	SITE	STRUCT	DWG 1	

MINISTRY OF TRANSPORTATION, ONTARIO

FILENAME: H:\Drafting\24000\24726\TED-24726-BHPP-Cul Sta 17+570.dwg
PLOTDATE: 7/13/2022 8:54 AM

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Appendix B.

Record of Borehole Sheets

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SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an “A” size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

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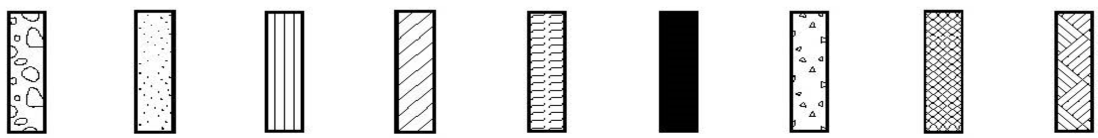
STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT "N" Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

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MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clayey silts of low plasticity, gravelly clays, sandy clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L= Liquid Limit

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EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No CV-1

METRIC

WP# 4068-09-00	LOCATION Lat: 45.50527°, Long: -76.675956° Culvert 17+570 MTM Zone 9: N 5 040 609.4 E 291 050.3	ORIGINATED BY AO
HWY 17	BOREHOLE TYPE CME45 Trackmount, HSA	COMPILED BY AO
DATUM Geodetic	DATE 2021.05.13 - 2021.05.14	CHECKED BY FG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
146.8	Ground Surface							
0.0 / 146.5	**TOP SOIL (300 mm)**	1	SS	WH				
0.3	**SILTY CLAY** Trace roots Grey-brown with yellow mottles Very stiff Homogeneous structure **[WEATHERED CRUST]**	2	SS	3	0	0	48	52
		3	SS	2				
144.5 / 2.3	**CLAYEY SILT to SILTY CLAY** Contains sand partings Grey-brown to grey Firm to very stiff Homogeneous structure	4	SS	2				
		5	SS	3	0	3	55	42
		6	SS	1				
		7	SS	1				
		8	SS	1	0	0	48	52
		9	SS	WH				

Elevation scale: 146, 145, 144, 143, 142, 141, 140, 139, 138, 137

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

Field vane sensitivity annotations: 10.0, 8.0

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

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No CV-1

METRIC

WP#	4068-09-00	LOCATION	Lat: 45.50527°, Long: -76.675956° Culvert 17+570 MTM Zone 9: N 5 040 609.4 E 291 050.3	ORIGINATED BY	AO
HWY	17	BOREHOLE TYPE	CME45 Trackmount, HSA	COMPILED BY	AO
DATUM	Geodetic	DATE	2021.05.13 - 2021.05.14	CHECKED BY	FG

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	CLAYEY SILT to SILTY CLAY Contains sand partings Grey-brown to grey Firm to very stiff Homogeneous structure							Field vane + 16.0; + 18.0			
			10	SS	WH		136		o		
								Field vane + 10.0			
134.9							135	Field vane + 18.0			
11.9	End of Borehole Monitoring well installation consists of 50-mm diameter Schedule 40 PVC pipe with a 3-m slotted screen										

DATE	DEPTH (m)	ELEV. (m)
2021.08.04	0.3	146.5
2021.09.22	0.3	146.5
2021.10.05	0.4	146.4
2021.10.22	0.4	146.4
2022.01.19	0.6	146.4

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. Plastic limit w_P, natural moisture content w, liquid limit w_L.

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

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No CV-2

METRIC

WP# 4068-09-00	LOCATION Lat: 45.505389°, Long: -76.675796° Culvert 17+570 MTM Zone 9: N 5 040 622.6 E 291 062.8	ORIGINATED BY AO
HWY 17	BOREHOLE TYPE CME45 Trackmount, HSA	COMPILED BY AO
DATUM Geodetic	DATE 2021.05.13 - 2021.05.13	CHECKED BY FG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa (Field Vane)	WATER CONTENT (%)	GR	SA	SI	CL
146.8	Ground Surface										
0.0	**TOP SOIL (300 mm)**	1	SS	WH							
146.5 / 0.3	**SILTY CLAY** Trace sand Trace roots Grey-brown with yellow mottles Very stiff Homogeneous structure **[WEATHERED CRUST]**	2	SS	2	146						
145.3 / 1.5	**SILTY CLAY** Contains sand partings Grey-brown to grey Firm to very stiff Homogeneous structure	3	SS	2	145			0	0	52	48
		4	SS	3	144						
		5	SS	3	143						
						+ ; +					
		6	SS	2	142			0	0	51	49
					141	+ ; +					
		7	SS	1	140						
						8.5 ; 9.0					
		8	SS	2	139						
					138	9.0 ; 8.6					
		9	SS	2	137			0	1	58	41

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

15 -⊕- 5 (20 above, 10 below) (%) STRAIN AT FAILURE

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; UNIT WEIGHT γ kN/m3; REMARKS & GRAIN SIZE DISTRIBUTION (%); GROUND WATER CONDITIONS; STRAT PLOT

RECORD OF BOREHOLE No CV-2

METRIC

WP#	4068-09-00	LOCATION	Lat: 45.505389°, Long: -76.675796° Culvert 17+570 MTM Zone 9: N 5 040 622.6 E 291 062.8	ORIGINATED BY	AO
HWY	17	BOREHOLE TYPE	CME45 Trackmount, HSA	COMPILED BY	AO
DATUM	Geodetic	DATE	2021.05.13 - 2021.05.13	CHECKED BY	FG

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (+ FIELD VANE)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY Contains sand partings Grey-brown to grey Firm to very stiff Homogeneous structure							+ 5.0; + 6.0			
			10	SS	2		136		○		
								+ 4.0			
134.9 / 11.9	End of Borehole						135				

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60)

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

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No CV-3

METRIC

WP# 4068-09-00	LOCATION Lat: 45.505466°, Long: -76.675642° Culvert 17+570 MTM Zone 9: N 5 040 631.1 E 291 074.8	ORIGINATED BY AO
HWY 17	BOREHOLE TYPE CME45 Trackmount, HSA	COMPILED BY AO
DATUM Geodetic	DATE 2021.05.12 - 2021.05.13	CHECKED BY FG

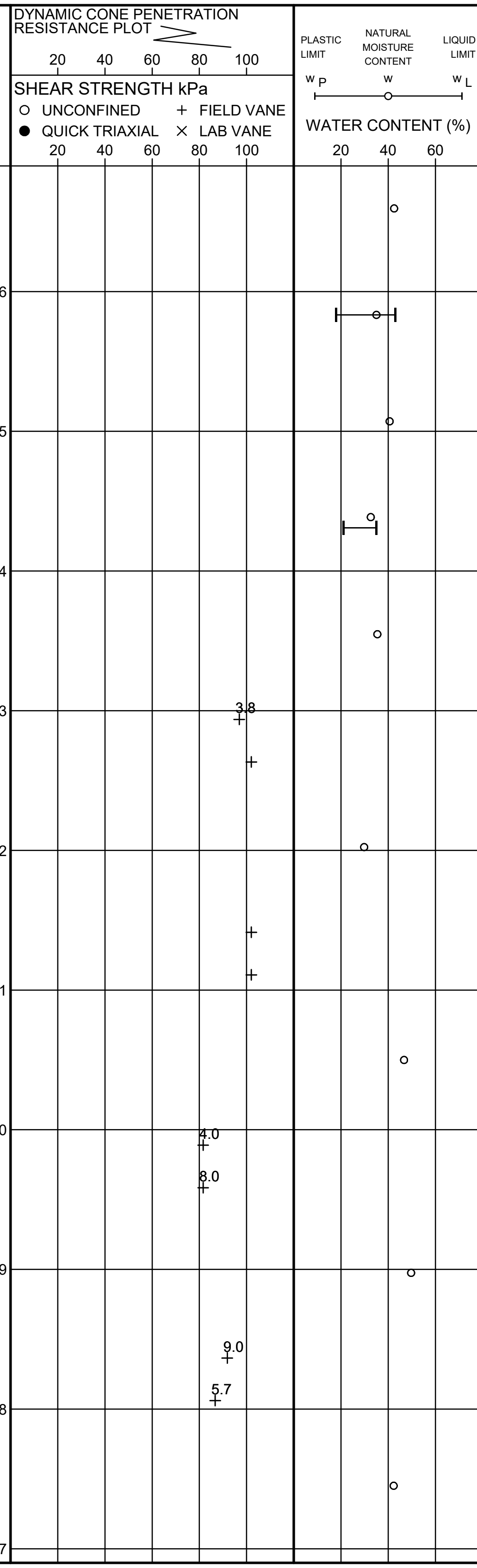
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
146.9	Ground Surface
146.9 / 0.0	**TOP SOIL (300 mm)**
146.6 / 0.3	**SILTY CLAY** Trace sand Trace roots Grey with yellow mottles Very stiff Homogeneous structure **[WEATHERED CRUST]**
145.4 / 1.5	**CLAYEY SILT to SILTY CLAY** Contains sand partings Grey Firm to very stiff Homogeneous structure

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	1				
2	SS	2	0	9	47	44
3	SS	2				
4	SS	2	0	0	50	50
5	SS	2				
6	SS	3				
7	SS	2	0	0	60	40
8	SS	1				
9	SS	WH				

GROUND WATER CONDITIONS | ELEVATION SCALE | UNIT WEIGHT γ kN/m³



Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No CV-3

METRIC

WP# 4068-09-00
LOCATION Lat: 45.505466°, Long: -76.675642° Culvert 17+570 MTM Zone 9: N 5 040 631.1 E 291 074.8
ORIGINATED BY AO

HWY 17
BOREHOLE TYPE CME45 Trackmount, HSA
COMPILED BY AO

DATUM Geodetic
DATE 2021.05.12 - 2021.05.13
CHECKED BY FG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	CLAYEY SILT to SILTY CLAY Contains sand partings Grey Firm to very stiff Homogeneous structure							+ 6.0 (≈60); + 7.0 (≈65)			
			10	SS	WH		136		○ (≈40)		
								+ 5.0 (≈50); + 5.0 (≈50)			
135.0 11.9	End of Borehole										

+³, ×³: Numbers refer to Sensitivity

15-⌖-5 (20 above, 10 below) (%) STRAIN AT FAILURE

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Ontario

THURBER

RECORD OF BOREHOLE No CV-28

METRIC

WP# 4068-09-00
LOCATION Lat: 45.505644°, Long: -76.675142° Culvert 17+570 MTM Zone 9: N 5 040 650.8 E 291 113.9
ORIGINATED BY AO

HWY 17
BOREHOLE TYPE CME45 Trackmount, HSA
COMPILED BY AO

DATUM Geodetic
DATE 2021.04.27 - 2021.04.27
CHECKED BY FG

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
147.0	Ground Surface					
0.0	**TOP SOIL (610 mm)**	1	SS	1		
146.4 / 0.6	**SILTY CLAY** No to trace gravel Grey Firm to very stiff Homogeneous structure					
		2	SS	3	146	0 0 49 51
		3	SS	3	145	
		4	SS	3	144	
		5	SS	3		
		6	SS	3	143	0 0 44 56
		7	SS	3	142	
141.2 / 5.8	End of Borehole					

End of Borehole
Monitoring well installation consists of 50-mm diameter Schedule 40 PVC pipe with a 3-m slotted screen

DATE	DEPTH (m)	ELEV. (m)
2021.08.04	0.1	146.9
2021.09.22	0.1	146.9
2021.10.05	0.0	147.0
2022.01.19	0.3	146.7

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3

+ 3, × 3: Numbers refer to Sensitivity
15 20 5 10 (%) STRAIN AT FAILURE

TWINNING OF HIGHWAY 17 - PART 1B FROM 1 KM WEST OF MILLER / ANDERSON RD TO 3KM WEST OF BRUCE ST
COUNTY OF RENFREW

THURBER

94Cx Station 17+600 — 6m LT CL — D 0

0-220 Asph
220-1 Br Sa and Gr Tr Si — Moist
1-1.8 Br Si(y) Cl Tr Sa — Moist *
w @ 1.4m = 32%
Percent Passing 4.75 mm = 100%
75 µm = 91%
5 µm = 67%
Frost Susceptibility = LSFH
W_L = 50%
W_P = 21%
P_I = 28%
MTC Soil Classification = CI
Existing WB Lane 2. Partially Paved OSH Asphalt Thickness = 75mm. Firm @ 2.1 m
PH

94C Station 17+600 — 2m LT CL — D 0

0-360 Asph
360-1 Br Sa and Gr Tr Si — Moist
1-1.3 Br Sa W Gr Tr Si — Moist
1.3-1.8 Br Si(y) Cl — Moist
Existing WB Lane. Firm @ 2.0 m
PH

132D Station 17+600 — 2m RT CL — D 0

0-350 Asph
350-700 Br Sa and Gr Some Si — Moist *
w @ 0.5m = 6%
Percent Passing 4.75 mm = 56%
75 µm = 13%
700-1.5 Br Sa Tr Si Tr Gr — Moist *
w @ 1.1m = 5%
Percent Passing 4.75 mm = 95%
75 µm = 4%
Existing EB Lane
PH

93Cx Station 17+800 — 2m LT CL — D 0

0-320 Asph
320-770 Br Sa and Gr Tr Si — Moist
770-2 Br Si(y) Cl — Moist
Existing WB Lane
PH

92B Station 18+000 — 8m LT CL — D-0.2

0-350 Br Sa and Gr Tr Si — Moist
350-1.5 Br Sa W Gr Tr Si Occ Cob — Moist
Existing WB OSH
PH

92Cx Station 18+000 — 2m LT CL — D 0

0-275 Asph
275-750 Br Sa and Gr Tr Si — Moist
750-1.5 Br Sa W Gr Tr Si — Moist
Existing WB Lane 1
PH

92C Station 18+000 — 1.5m LT CL — D 0

0-225 Asph
225-650 Br Sa and Gr Tr Si — Moist
650-1.5 Br Sa W Gr Tr Si Occ Cob — Moist
Existing WB Lane 2. Partially Paved OSH Asphalt Thickness = 55mm
PH

134D Station 18+000 — 2m RT CL — D 0

0-350 Asph
350-600 Br Sa and Gr Tr Si — Moist
600-1.5 Br Sa Tr Si — Moist
Existing EB Lane. Partially Paved OSH Asphalt Thickness = 90mm
PH

136D Station 18+300 — 2m RT CL — D 0

0-340 Asph
340-600 Br Sa and Gr Tr Si — Moist
600-1.5 Br Sa Tr Si — Moist
Existing EB Lane. Partially Paved OSH Asphalt Thickness = 80mm
PH

99B Station 18+400 — 11m LT CL — D-0.2

0-400 Br Sa and Gr Tr Si — Moist
400-1.6 Br Sa Some Gr Tr Si Occ Cob — Moist
1.6- Gry Sa(y) Si — Moist
Existing WB OSH. Firm @ 1.7 m
PH

90Cx Station 18+400 — 2m LT CL — D 0

0-330 Asph
330-850 Br Sa and Gr Tr Si — Moist *
850-1.5 Br Sa W Gr Tr Si — Moist *
Existing WB Lane
PH

90C Station 18+400 — 1.5m LT CL — D 0

0-300 Asph
300-500 Br Sa and Gr Tr Si — Moist
500-1.5 Br Sa W Gr Tr Si Occ Cob — Moist
Existing WB Lane 2
PH

Note: Boreholes offsets referenced from staked centreline.

THURBER

Appendix C.

Laboratory Testing

THURBER

Appendix C.1

Particle Size Analysis Figures

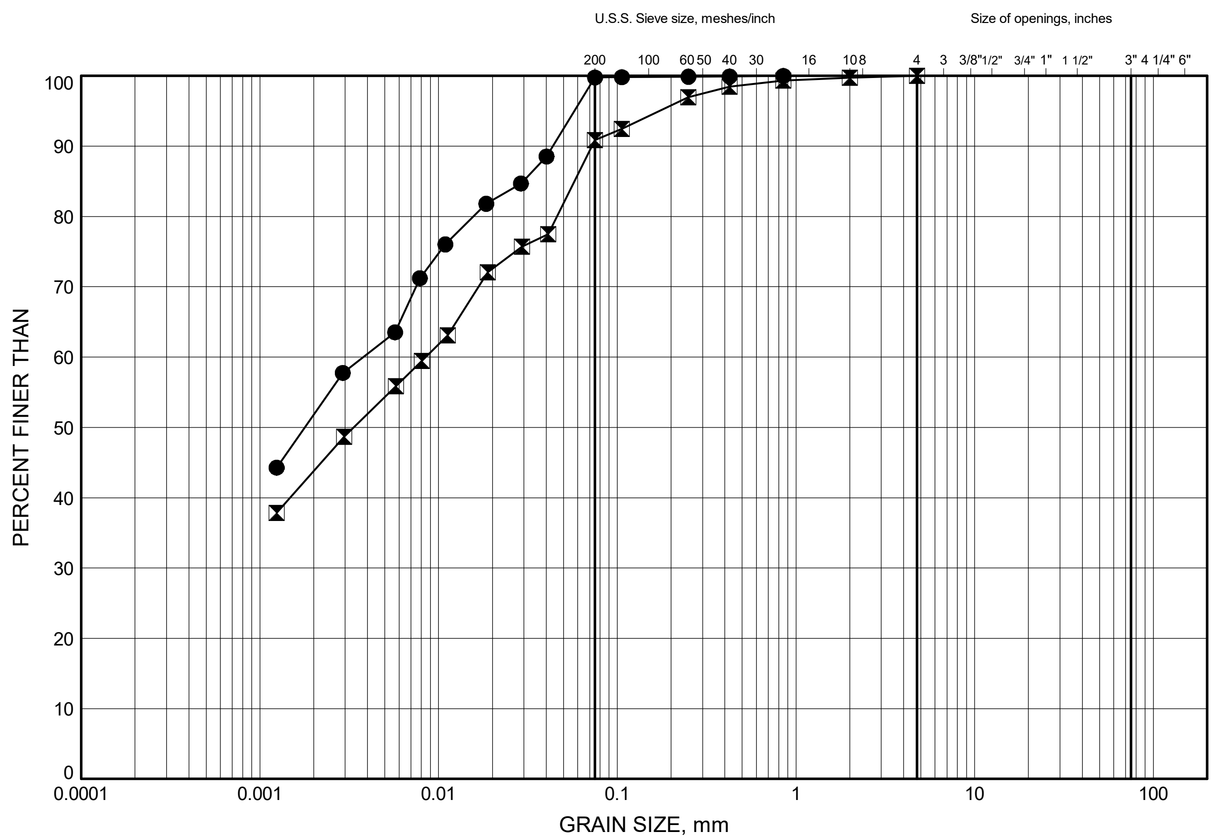
Atterberg Limit Test Results

Highway 17 Twinning

GRAIN SIZE DISTRIBUTION

FIGURE C1

Weathered Silty Clay (CI) Crust



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-1	1.1	145.7
⧗	CV-3	1.1	145.8

Date August 2021

WP# 4068-09-00

THURBER

Prep'd MJK

Chkd. FG

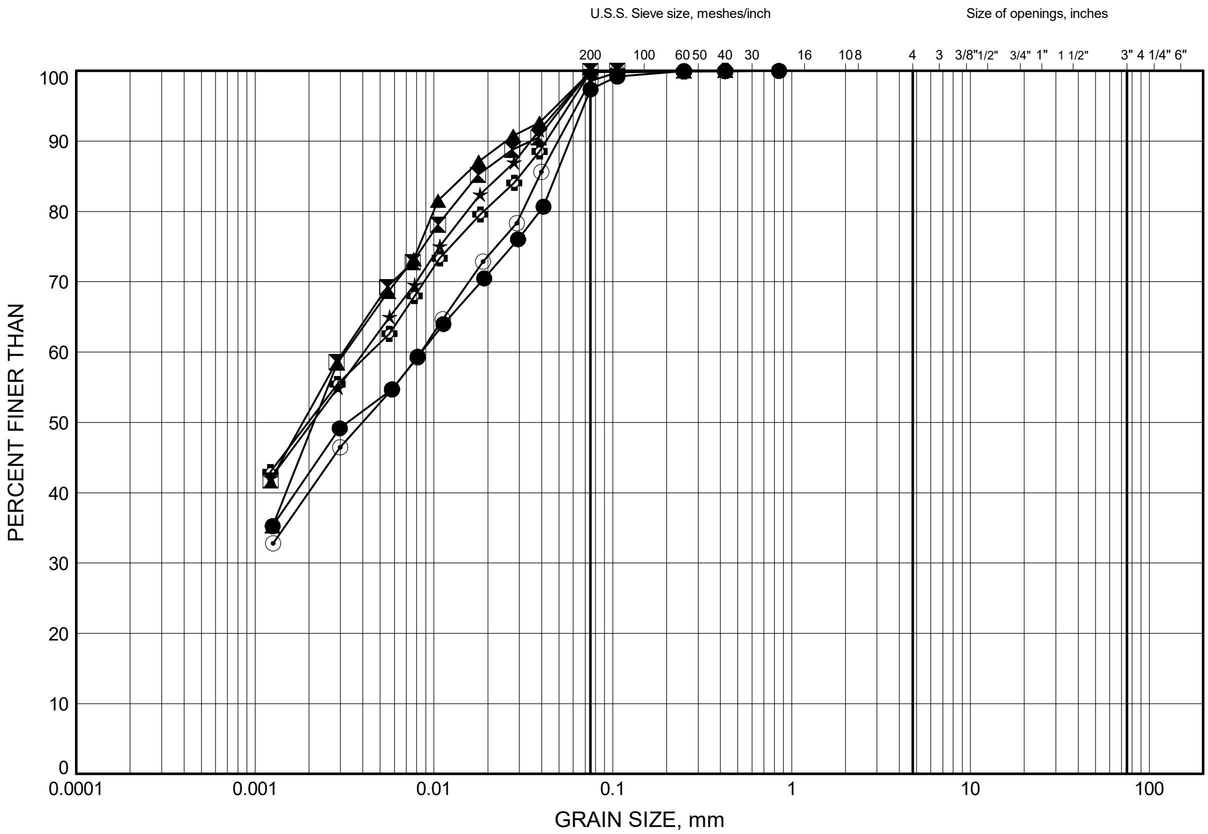
GRAIN SIZE DISTRIBUTION - THURBER 24726 CULVERT 17+570 GINT.GPJ 30/8/21

Highway 17 Twinning

GRAIN SIZE DISTRIBUTION

FIGURE C2

Clayey Silt (CL) to Silty Clay (CI)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-1	3.4	143.4
⧗	CV-1	7.9	138.9
▲	CV-2	1.8	145.0
★	CV-2	4.9	141.9
⊙	CV-2	9.4	137.4
✿	CV-3	2.6	144.3

Date August 2021

WP# 4068-09-00

THURBER

Prep'd MJK

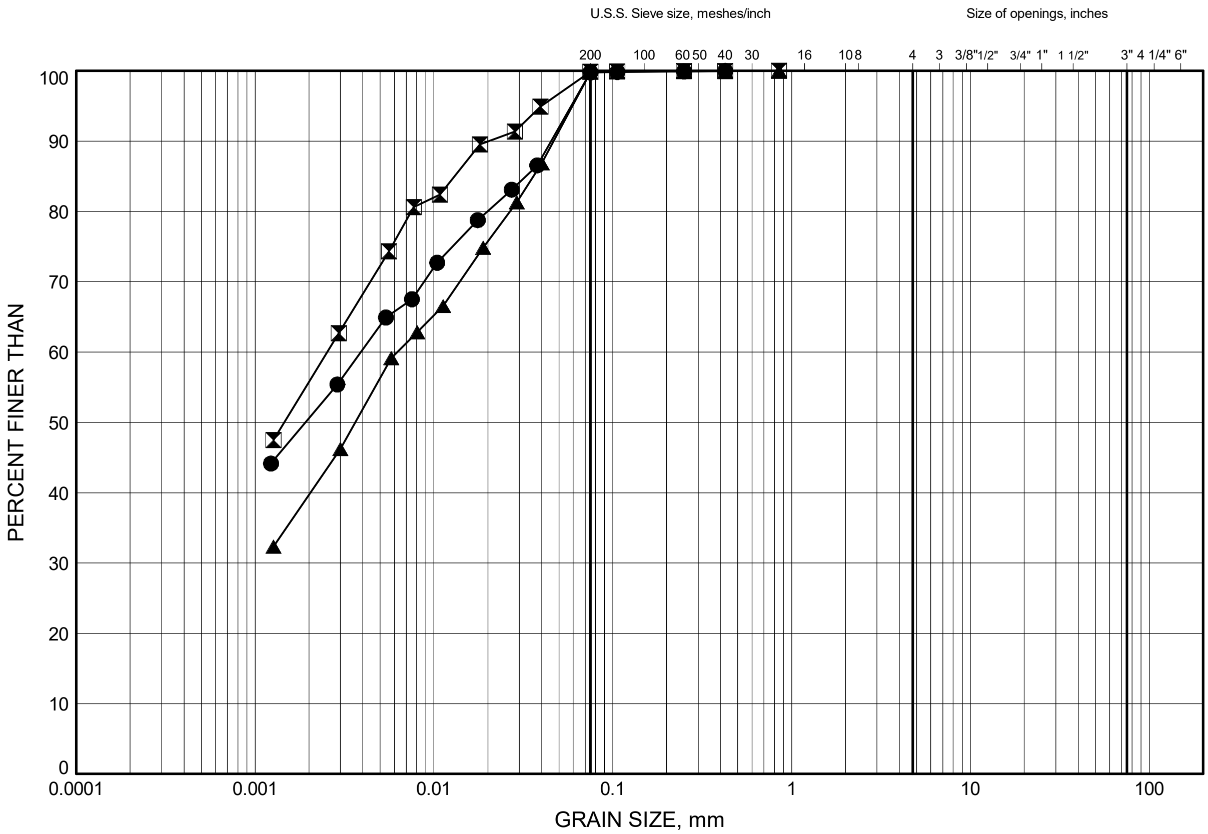
Chkd. FG

Highway 17 Twinning

GRAIN SIZE DISTRIBUTION

FIGURE C3

Silty Clay (CI)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-28	1.1	145.9
⧗	CV-28	4.1	142.9
▲	CV-3	6.4	140.5

GRAIN SIZE DISTRIBUTION - THURBER 24726 CULVERT 17+570 GINT.GPJ 30/8/21

Date August 2021

WP# 4068-09-00

THURBER

Prep'd MJK

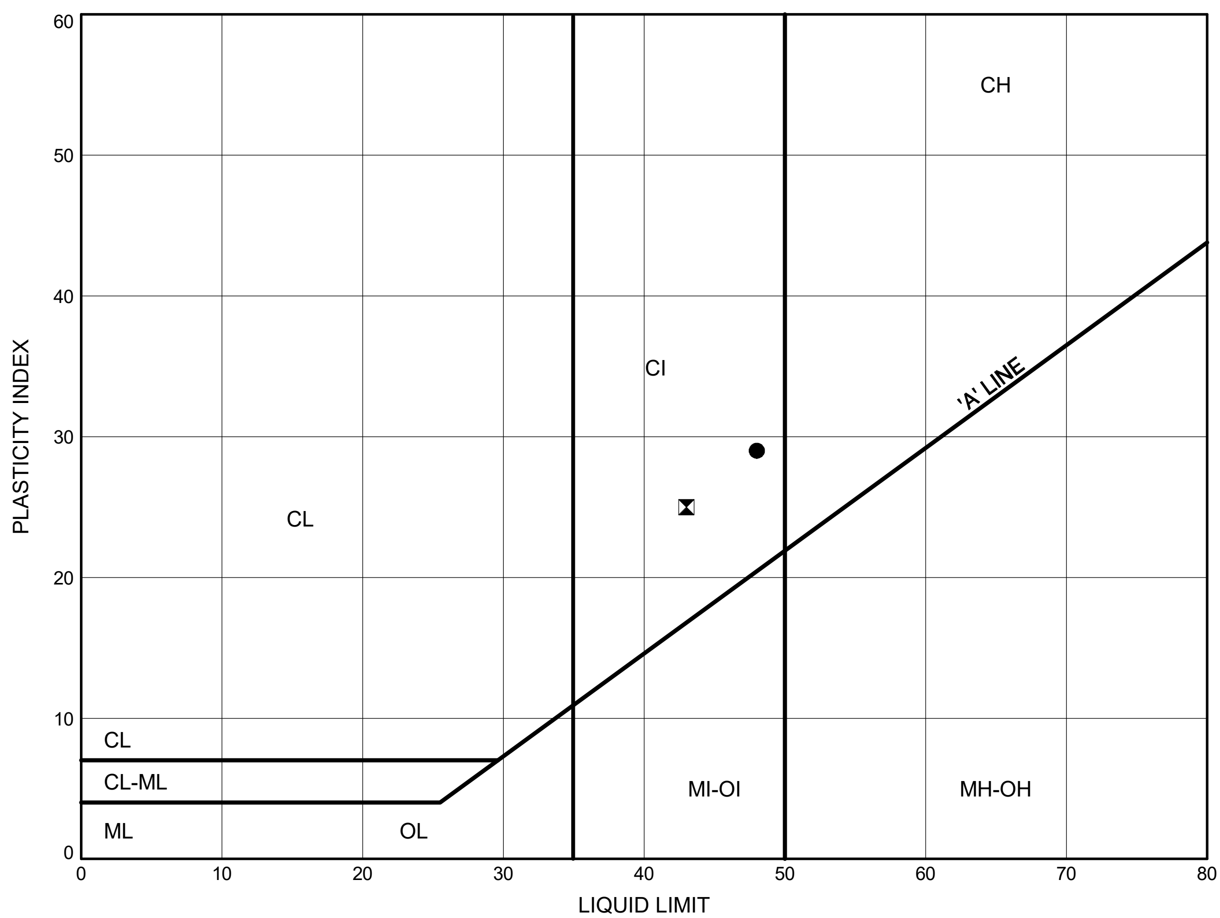
Chkd. FG

Highway 17 Twinning

ATTERBERG LIMITS TEST RESULTS

FIGURE C4

Weathered Silty Clay (CI) Crust



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-1	1.1	145.7
⧗	CV-3	1.1	145.8

THURBALT 24726 CULVERT 17+570 GINT.GPJ 30/8/21

Date August 2021

WP# 4068-09-00

THURBER

Prep'd MJK

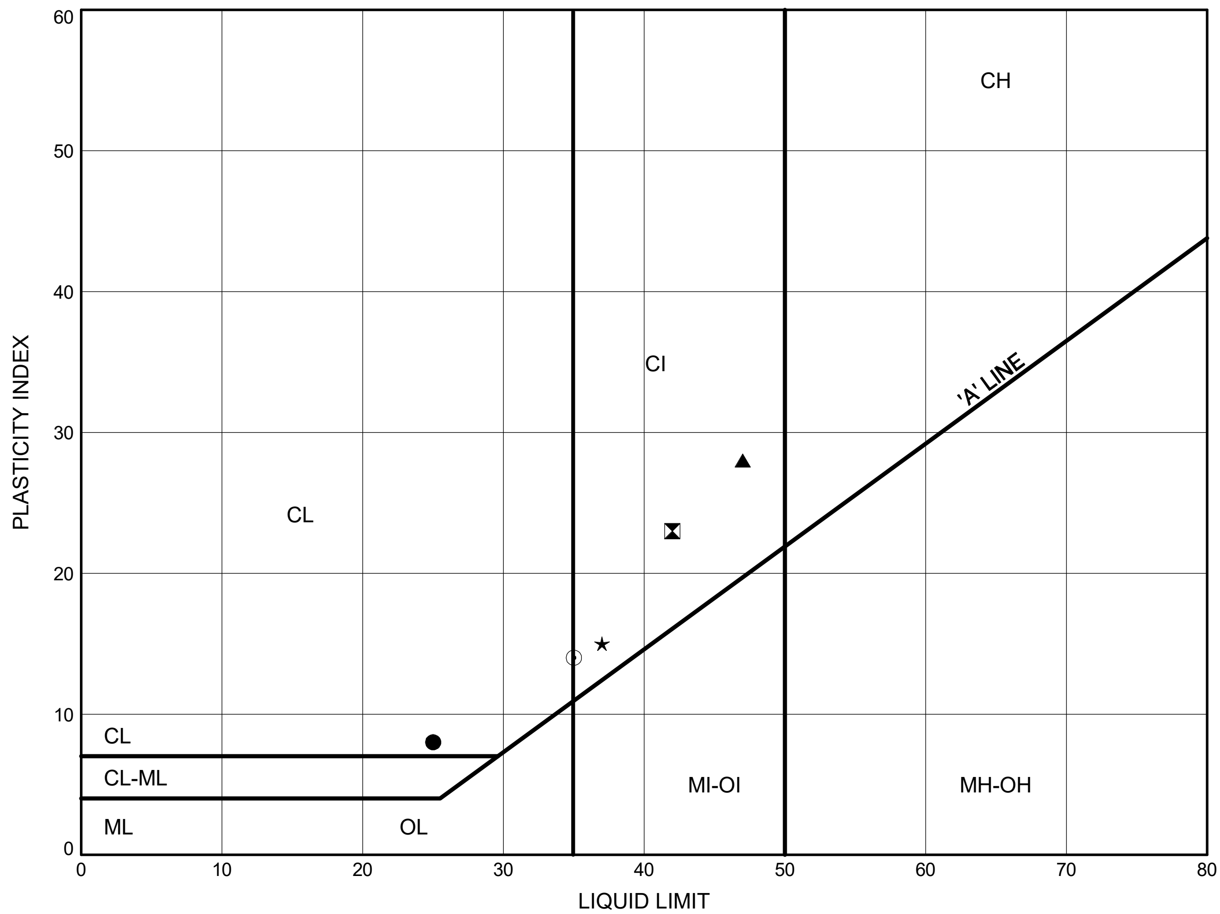
Chkd. FG

Highway 17 Twinning

ATTERBERG LIMITS TEST RESULTS

FIGURE C5

Clayey Silt (CL) to Silty Clay (CI)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-1	3.4	143.4
⧗	CV-2	1.8	145.0
▲	CV-28	1.1	145.9
★	CV-28	4.1	142.9
⊙	CV-3	2.6	144.3

THURBALT 24726 CULVERT 17+570 GINT.GPJ 30/8/21

Date August 2021

WP# 4068-09-00

THURBER

Prep'd MJK

Chkd. FG

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Appendix C.2

Analytical Testing Results

PARACEL LABORATORIES LTD.
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300 - 2319 St. Laurent Blvd
Ottawa, ON, K1G 4J8
1-800-749-1947
www.paracellabs.com

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Justin Gray

Client PO: 24726
Project: Culverts 17+570 and 17+893
Custody: 48670

Report Date: 21-May-2021
Order Date: 17-May-2021

Order #: 2121164

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
2121164-01	CV2 SS2 2'6"-4'6"
2121164-02	CV6 SS3 5'-7'

Approved By: Mark Foto

Mark Foto, M.Sc.
Lab Supervisor

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	21-May-21	21-May-21
Conductivity	MOE E3138 - probe @25 °C, water ext	20-May-21	21-May-21
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	18-May-21	19-May-21
Resistivity	EPA 120.1 - probe, water extraction	20-May-21	21-May-21
Solids, %	Gravimetric, calculation	18-May-21	19-May-21

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO: 24726

Report Date: 21-May-2021

Order Date: 17-May-2021

Project Description: Culverts 17+570 and 17+893

	MDL/Units				
Client ID:		CV2 SS2 2'6"-4'6"	CV6 SS3 5'-7'	-	-
Sample Date:		13-May-21 09:00	14-May-21 14:00	-	-
Sample ID:		2121164-01	2121164-02	-	-
		Soil	Soil	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	67.3	70.5	-	-
General Inorganics					
Conductivity	5 uS/cm	468	504	-	-
pH	0.05 pH Units	7.66	7.73	-	-
Resistivity	0.10 Ohm.m	21.4	19.8	-	-
Anions					
Chloride	5 ug/g dry	192	168	-	-
Sulphate	5 ug/g dry	30	63	-	-

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	53.7	5	ug/g dry	51.6			4.1	20	
Sulphate	79.3	5	ug/g dry	77.9			1.8	20	
General Inorganics									
Conductivity	467	5	uS/cm	468			0.2	5	
pH	7.20	0.05	pH Units	7.23			0.4	2.3	
Resistivity	21.4	0.10	Ohm.m	21.4			0.2	20	
Physical Characteristics									
% Solids	93.4	0.1	% by Wt.	94.2			0.9	25	

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	142	5	ug/g	51.6	90.2	82-118			
Sulphate	165	5	ug/g	77.9	87.0	80-120			

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.
NC: Not Calculated

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Subcontracted Analysis

Thurber Engineering Ltd.
2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Justin Gray

Tel: (613) 408-6795
Fax: (613) 247-2185

Paracel Report No	**2121164**
Client Project(s):	**Culverts 17+570 and 17+893**
Client PO:	**24726**
Reference:	**Standing Offer**
CoC Number:	**48670**

Order Date: 17-May-21
Report Date: 21-May-21

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
2121164-01	CV2 SS2 2'6"-4'6"	Sulphide, solid
2121164-02	CV6 SS3 5'-7'	Sulphide, solid

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

27-May-2021

Paracel Laboratories
Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

Date Rec. : 19 May 2021
LR Report: **CA13681-MAY21**
Reference: Project#: 2121164

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide (Na2CO3) %
1: Analysis Start Date		26-May-21
2: Analysis Start Time		15:06
3: Analysis Completed Date		26-May-21
4: Analysis Completed Time		17:03
5: QC - Blank		< 0.04
6: QC - STD % Recovery		111%
7: QC - DUP % RPD		ND
8: RL		0.02
9: CV2 SS2 2'6"-4'6"	13-May-21 09:00	< 0.04
10: CV6 SS3 5'-7'	14-May-21 14:00	0.05

RL - SGS Reporting Limit
ND - Not Detected

Kimberley Didsbury,
Project Specialist,
Environment, Health & Safety

OnLine LIMS

0002507973

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Appendix D.

Site Photographs

Photo 1. Existing embankment, westbound lanes, looking north at culvert inlet (2021/04/27)

Photo 2. Existing culvert inlet, looking northwest (2021/04/27)

Photo 3. Existing culvert outlet, looking west towards location of proposed eastbound lanes (2021/04/27)

Photo 4. Existing culvert outlet, looking west (2021/04/27)


Photo 5. Highway 17 looking northwest (2021/04/27)

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Appendix E.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Site: 45.505N 76.676W **User File Reference:** Culvert 17+570 2021-08-10 21:12 UT

Requested by: Thurber Engineering Ltd.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.362	0.185	0.106	0.031
Sa (0.1)	0.429	0.230	0.138	0.045
Sa (0.2)	0.358	0.199	0.124	0.043
Sa (0.3)	0.272	0.155	0.098	0.035
Sa (0.5)	0.193	0.113	0.072	0.026
Sa (1.0)	0.098	0.059	0.038	0.013
Sa (2.0)	0.048	0.028	0.018	0.005
Sa (5.0)	0.013	0.007	0.004	0.001
Sa (10.0)	0.005	0.003	0.002	0.001
PGA (g)	0.230	0.126	0.076	0.025
PGV (m/s)	0.161	0.091	0.056	0.018

Notes: Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

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Appendix F.

Foundation Comparison
Preliminary General Arrangement Drawings

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COMPARISON OF ALTERNATIVE FOUNDATION TYPES

	Pipe Culverts	Open-Bottom Box Culvert	Closed-Bottom Box Culvert
Advantages	• Relatively expedient installation • Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade	• Relatively expedient installation if precast units are used • Possibility to maintain work zone outside of existing waterway	• Relatively expedient installation if precast units are used • Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade
Disadvantages	• Requires a temporary by-pass to maintain waterflow • Several parallel pipes required to provide hydraulic opening equivalent to box culvert	• May require protection system for construction of foundations • Deepest excavation, increases quantities and dewatering concerns • Lower geotechnical resistances. • Potential for post construction settlement	• Requires a temporary by-pass to maintain waterflow.
Risks/ Consequences	• Potential for damage due to settlement	• Increased risk of basal instability of footing excavation due to depth of excavation below water table • Potential for damage due to settlement	• Potential for damage due to settlement
Relative Cost	Low to Moderate	Moderate	Moderate
Recommendation	**Feasible**	**Not Recommended**	**Recommended**

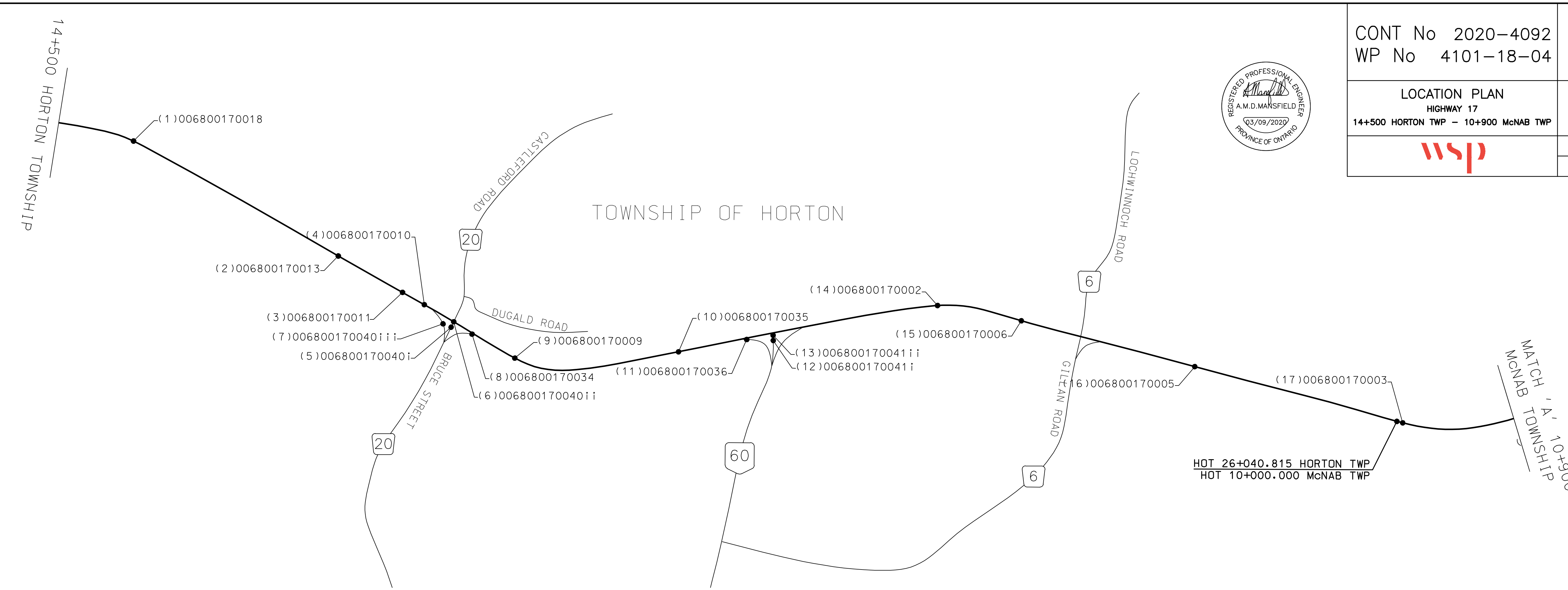
CONT No 2020–4092
WP No 4101–18–04

LOCATION PLAN
HIGHWAY 17
14+500 HORTON TWP – 10+900 McNAB TWP

SHEET 10

wsp

REGISTERED PROFESSIONAL ENGINEER
A.M.D. MANSFIELD
03/09/2020
PROVINCE OF ONTARIO



CULVERT									LOCATION				REMEDIATION	CONTRACT DETAIL SHEET
CONTRACT CULVERT ID	MTO CULVERT ID	EXISTING PIPE DIAMETER	EXISTING LENGTH	DEPTH OF COVER	TYPE	ASBESTOS PRESENT	FISHERIES HABITAT	TIMING WINDOW	TOWNSHIP	CHAINAGE Hwy 17	LATITUDE	LONGITUDE		
1	006800170018	1500	38.6	2.0	SPCSP	NO	INDIRECT	YES	HORTON	15+830	45.51997	-76.68414	TRENCHLESS - CONVENTIONAL	12,33
2	006800170013	1800	33.7	2.0	SPCSP	NO	DIRECT	YES	HORTON	17+570	45.50557	-76.67538	TRENCHLESS - CONVENTIONAL	13,33
3	006800170011	1600	32.1	3.0	SPCSP	NO	INDIRECT	YES	HORTON	18+126	45.50098	-76.67256	REPAIR - OPEN CUT	14,33
4	006800170010	900	39.9	3.0	CSP	NO	NO	NO	HORTON	18+326	45.49930	-76.67162	TRENCHLESS - FOLD AND FORM	15
5	006800170040i	-	19.5	1.0	CB TO CB	NO	NO	NO	HORTON	BRUCE ST. 10+023	45.49707	-76.67075	CLEANOUT AND CCTV	15
6	006800170040ii	-	16.7	1.0	CB TO CB	NO	NO	NO	HORTON	BRUCE ST. 10+013	45.49720	-76.67070	CLEANOUT AND CCTV	15
7	006800170040iii	300	21.9	1.0	CB OUTLET	NO	NO	NO	HORTON	17 TO BRUCE RAMP 20+108	45.49735	-76.67091	REPLACEMENT - OPEN CUT	15,33,37
8	006800170034	300	12.8	1.0	CB OUTLET	NO	NO	NO	HORTON	BRUCE TO 17 RAMP 30+157	45.49665	-76.67027	REPLACEMENT - OPEN CUT	15,33,37
9	006800170009	900	36.6	5.0	CSP	NO	NO	NO	HORTON	19+191	45.49206	-76.66757	TRENCHLESS - CONVENTIONAL	16,33
10	006800170035	1200	33.9	3.0	CSP	NO	NO	NO	HORTON	20+483	45.48555	-76.65420	ABANDONMENT	17,33
11	006800170036	300	-	1.0	CSP	NO	NO	NO	HORTON	21+120 RAMP	45.48280	-76.64713	CLEANOUT	18
12	006800170041i	-	9.1	-	CB TO CB	NO	NO	NO	HORTON	O'BRIEN RD. 10+044	45.48243	-76.64597	CLEANOUT AND CCTV	18
13	006800170041ii	-	43.5	-	CB TO CB	NO	NO	NO	HORTON	O'BRIEN RD. 10+023	45.48243	-76.64594	CLEANOUT AND CCTV	18
14	006800170002	1400	49.8	9.0	CSP	NO	DIRECT	YES	HORTON	22+474	45.47688	-76.63170	TRENCHLESS - CONVENTIONAL	19,33
15	006800170006	900	25.9	0.6	CSP	NO	INDIRECT	YES	HORTON	23+150	45.47227	-76.62628	REPLACEMENT - OPEN CUT	20,33,35
16	006800170005	900	25.8	1.0	CSP	NO	NO	NO	HORTON	24+523	45.46238	-76.61587	TRENCHLESS - FOLD AND FORM	21

N.T.S.

DRAWN LOCATION: P:\181-02689-00 MTO RETAINER\ASSIGNMENT 2\3.7 CAD
DRAWING NAME: HWY 17 COVER AND KEY PLAN.DWG
DRAWN BY: Howe, Jordan MODIFIED: 10/22/2020 1:35 PM PLOTTED: 11/25/2020 11:20 AM

MINISTRY OF TRANSPORTATION, ONTARIO PH-D-707 88-05

NOTES:

1. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE STABILITY OF THE ROADWAY AND PROTECTION OF PERSONNEL.
2. ALL PROVINCIAL SPECIFICATIONS AND REGULATIONS INCLUDING THE ONTARIO OCCUPATIONAL HEALTH AND SAFETY ACT AND O.T.M BOOK 7 SHALL APPLY.
3. THE CONTRACTOR SHALL LIMIT DISTURBED AREAS TO THE MINIMUM REQUIRED TO COMPLETE THE WORK.
4. ALL DISTURBED AREAS OUTSIDE THE EDGE OF SHOULDER ARE TO BE RESTORED WITH 50mm TOPSOIL, SEED & MULCH UNLESS SPECIFIED ELSEWHERE.
5. ALL WORK SHALL BE COMPLETED WITHIN THE MTO ROW LIMITS.
6. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE LOCATE AND PROTECTION OF ANY AND ALL UTILITIES WITHIN THE LIMIT OF CONSTRUCTION.
7. ACCESS TO SIDE ROADS TO BE MAINTAINED AND FLAGGED DURING CONSTRUCTION.

METRIC

DAID: 006800170013

CONT No 2020-4092

WP No 4101-18-04

SHEET 13

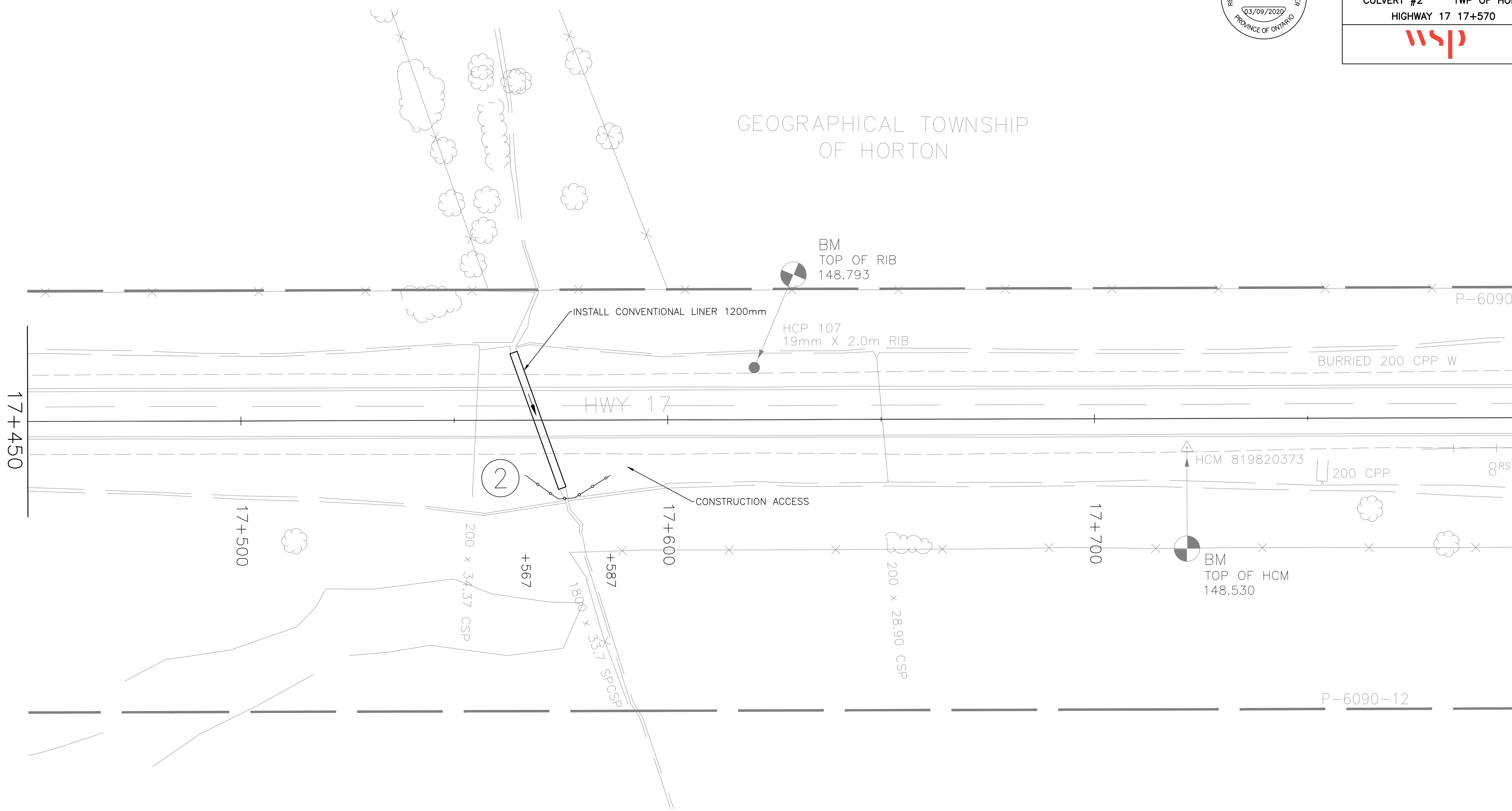
CULVERT REMEDIATION

CULVERT #2 TWP OF HORTON

HIGHWAY 17 17+570

wsp

REGISTERED PROFESSIONAL ENGINEER A.M.D.MANSFIELD 03/09/2020 PROVINCE OF ONTARIO



LEGEND

(#) CONTRACT CULVERT ID

SILT FENCE (OPSD 219.110)

SCALE

10 0 20

Horizontal

DRAWN LOCATION: P:\181-02689-00 MTO RETAINER\ASSIGNMENT 2\3.7 CAD
DRAWING NAME: HWY 17 DESIGN.DWG
DRAWN BY: Howe, Jordan
MODIFIED: 10/22/2020 10:23 AM PLOTTED: 10/22/2020 11:25 AM
MINISTRY OF TRANSPORTATION, ONTARIO PH-D-707 88-05

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN
DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

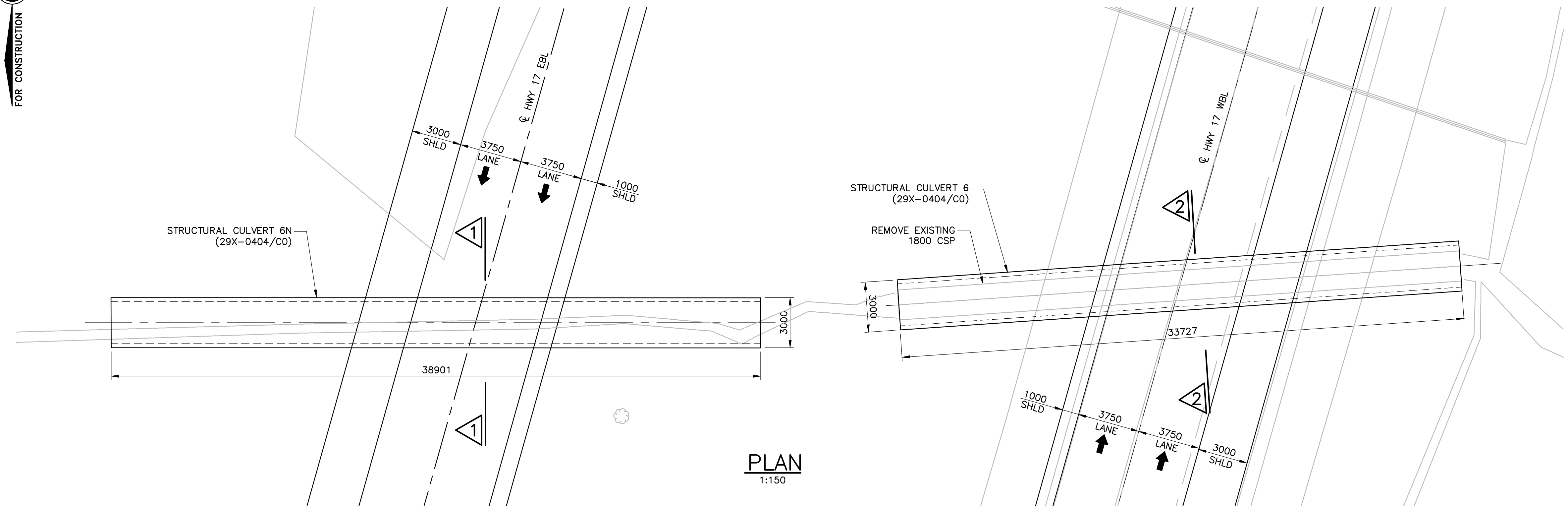
PARSONS

CONT No —
WP —

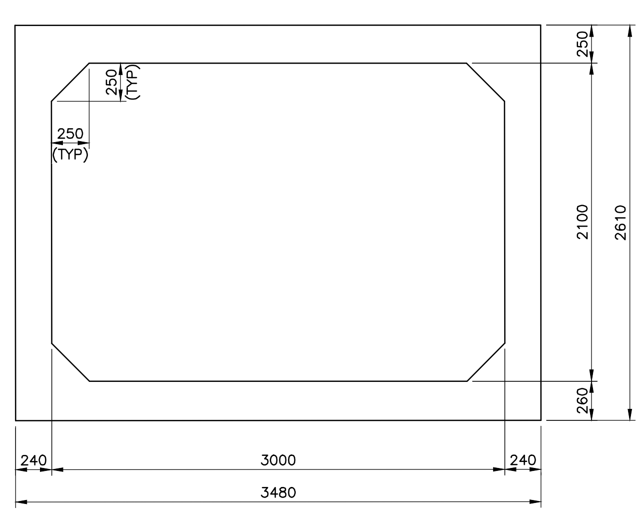
HWY 17 TWINNING
LITTLE HALLIDAY CREEK
TRIBUTARY CULVERT
GENERAL ARRANGEMENT

SHEET —

FOR CONSTRUCTION



PLAN
1:150



1
1:25

REVISIONS NO	DATE	BY	DESCRIPTION

DESIGN	AL	CHK		CODE CAN/CSA S6-14	LOAD CL-625-ONT	DATE	
DRAWN	FP	CHK	AL	SITE 29x-0404/C0		DWG	

DOCUMENT CODE:

MINISTRY OF TRANSPORTATION, ONTARIO ANS-D 2017-08

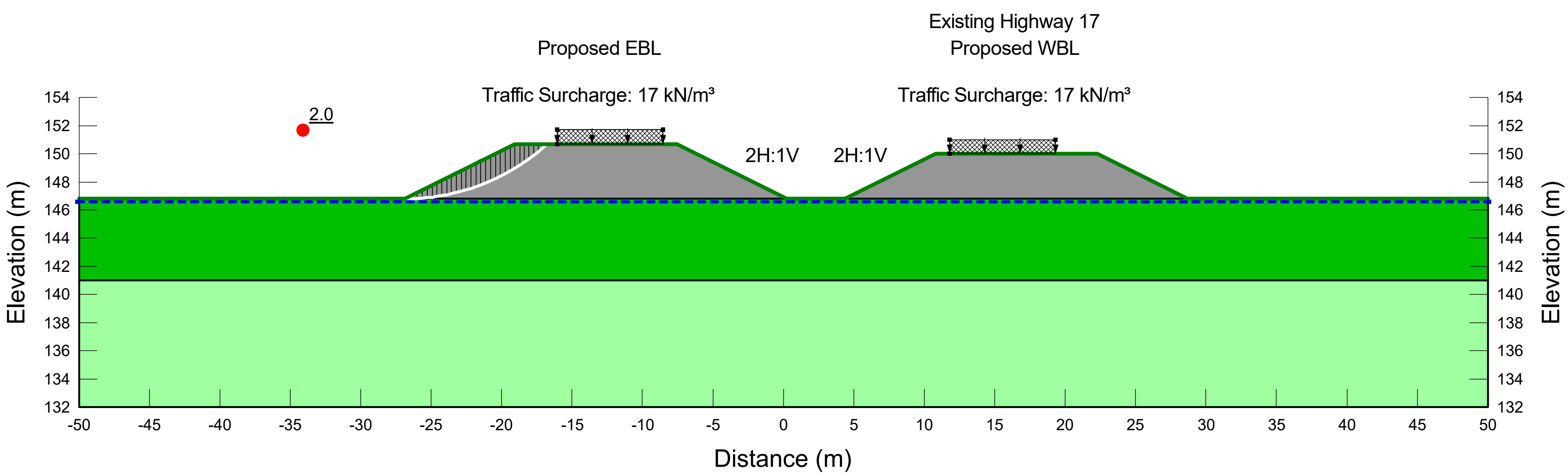
FILE NAME: J:\TOR\477796 WO#24-P-3 Hwy 17 Twinning\5 General\8 Structural\1-CAD\STA 17+570_ Culvert_GA.dwg
MODIFIED: 2021-06-16 13:27

THURBER

Appendix G.

Slope Stability Analysis Figures

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



THURBER

Project
Highway 17 Twinning - Culvert 17+570

Analysis
G1.1 EB Temporary - Static (Undrained)

Seismic Coefficient
H: 0g, V: 0g

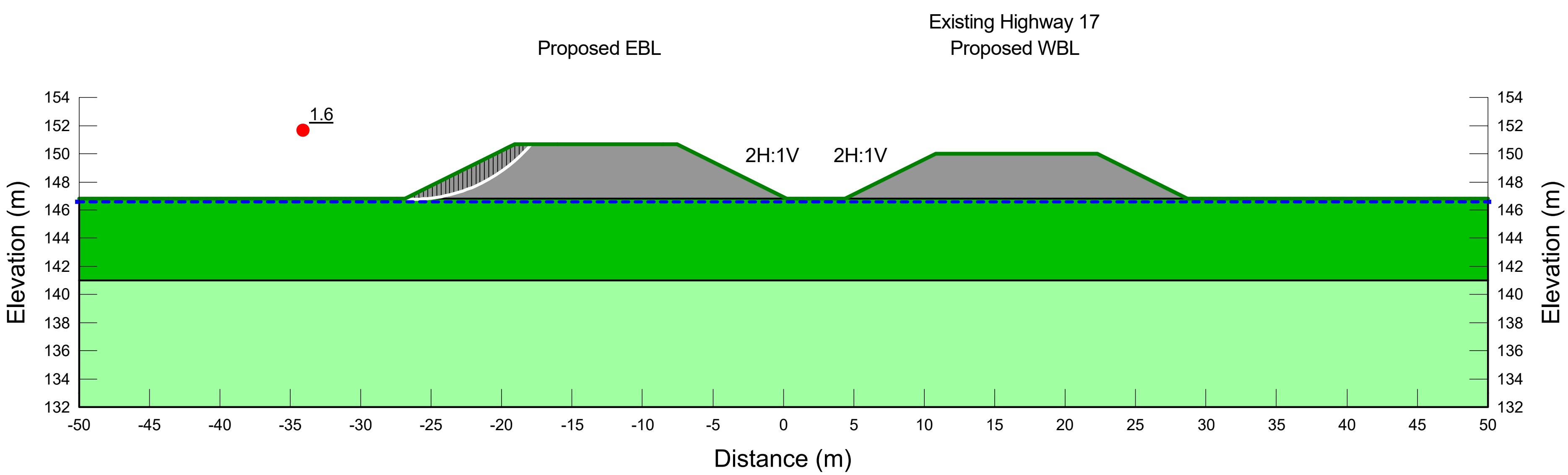
Last Run
2022/06/24, 01:29:26 PM

Scale
1:450

Additional Details
Name: 1. EB Embankment (2H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-16.75, 150.7) m, Exit: (-27, 146.8) m
Center: (-26.832566, 161.7795) m, Radius: 14.980435 m
Surcharge Load: 17 kN/m³

Figure G1-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
(grey)	00: FILL: Gran. B I	Mohr-Coulomb	21	0	32
(green)	02: Upper SILTY CLAY Crust (ESA)	Mohr-Coulomb	17	5	28
(light green)	03: Lower SILTY CLAY (ESA)	Mohr-Coulomb	17	5	28

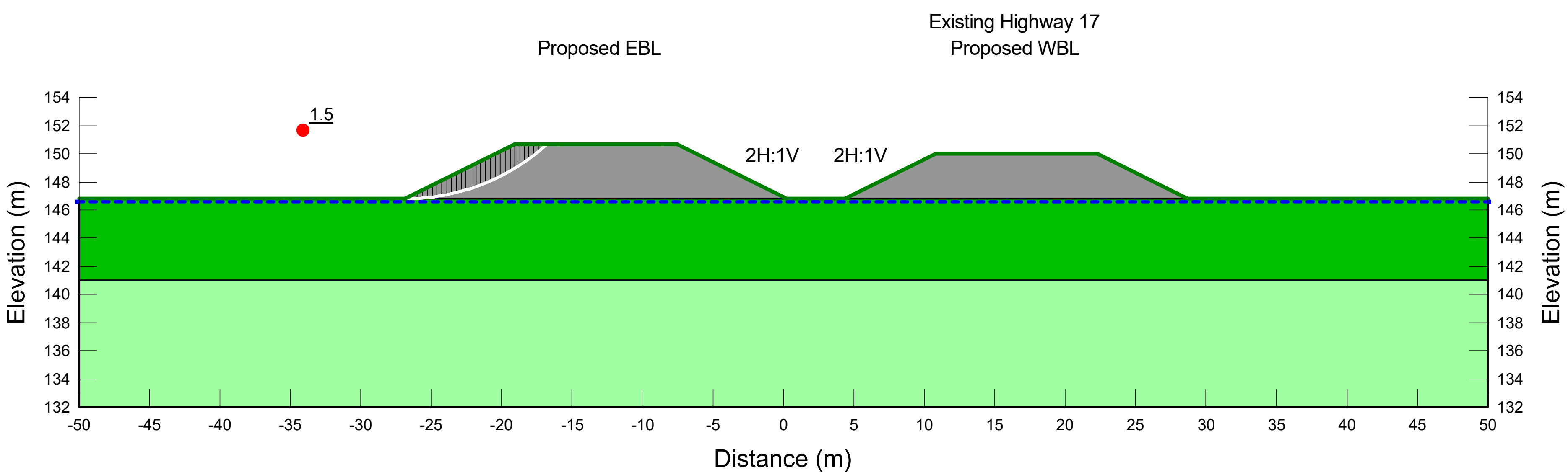


Project	Additional Details
Highway 17 Twinning - Culvert 17+570	Name: 1. EB Embankment (2H:1V)
Analysis: G1.2 EB Permanent - Static (Drained)	Method: Morgenstern-Price, Half-Sine
Seismic Coefficient: H: 0g, V: 0g	Minimum Slip Surface Depth: 1.52 m
Last Run: 2022/06/24, 01:29:30 PM	Entry: (-17.9, 150.7) m, Exit: (-27, 146.8) m
Scale: 1:450	Center: (-26.266366, 157.65485) m, Radius: 10.879618 m

THURBER

Figure G1-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



THURBER

Project
Highway 17 Twinning - Culvert 17+570

Analysis
G1.3 EB Temporary - Seismic (Undrained)

Seismic Coefficient	Last Run	Scale
H: 0.13g, V: 0g	2022/06/24, 01:29:34 PM	1:450

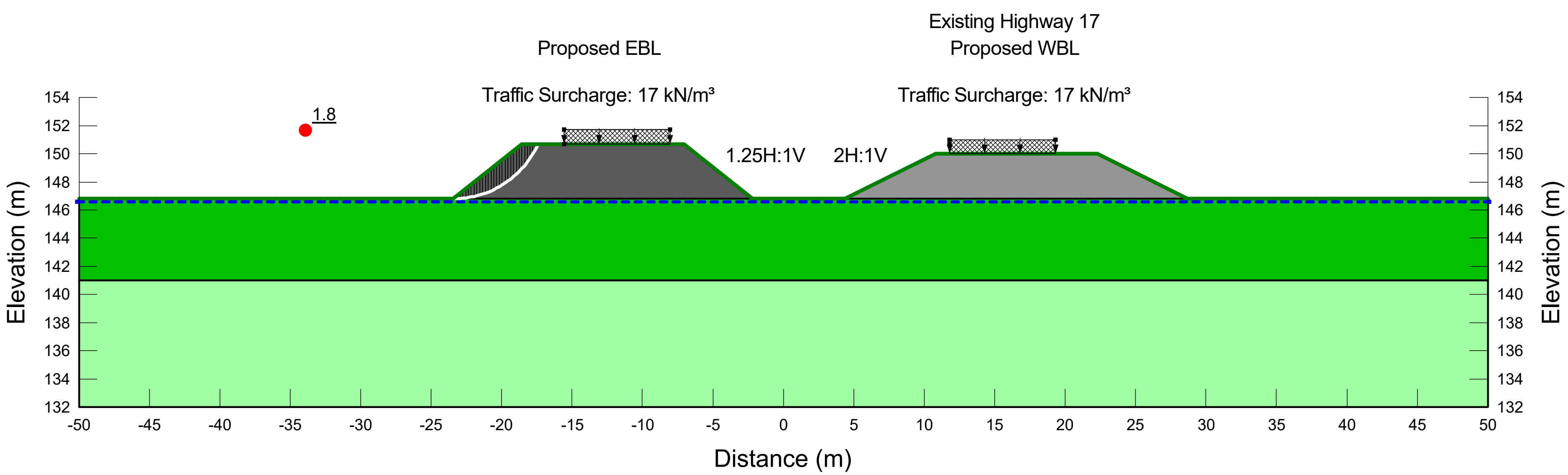
Additional Details
Name: 1. EB Embankment (2H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-16.75, 150.7) m, Exit: (-27, 146.8) m
Center: (-26.832566, 161.7795) m, Radius: 14.980435 m

Figure G1-3

H:\Projects\20001 to 30000\24726 - Hwy 17 Arnprior to Haley Station\PART 1B\Foundations\Culvert 17+570\Analysis\Culvert 17+570_2022 06 24.gsz

Tool Version: 11.3.1.23726

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
	01: FILL: Rock Fill	Mohr-Coulomb	20					0	42
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



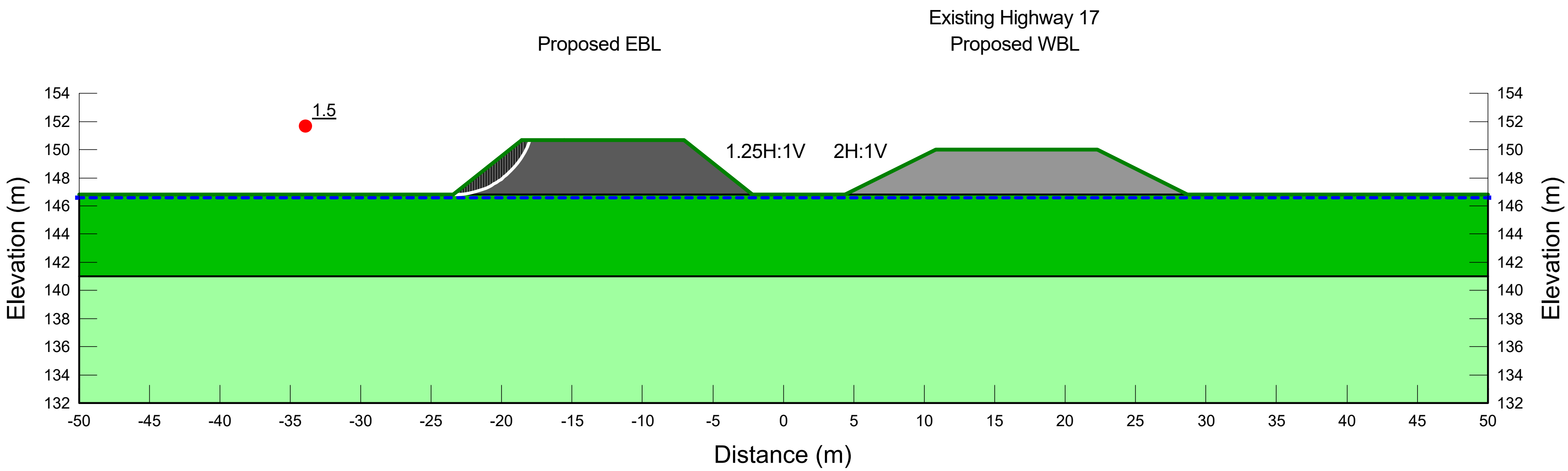
Project	Highway 17 Twinning - Culvert 17+570	
Analysis	G2.1 EB Temporary - Static (Undrained)	
Seismic Coefficient: H: 0g, V: 0g	Last Run: 2022/06/24, 01:29:39 PM	Scale: 1:450

THURBER

Additional Details
Name: 2. EB Embankment (1.25H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-17.4, 150.7) m, Exit: (-23.5, 146.8) m
Center: (-23.426192, 153.40507) m, Radius: 6.6054826 m
Surcharge Load: 17 kN/m³

Figure G2-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21	0	32
	01: FILL: Rock Fill	Mohr-Coulomb	20	0	42
	02: Upper SILTY CLAY Crust (ESA)	Mohr-Coulomb	17	5	28
	03: Lower SILTY CLAY (ESA)	Mohr-Coulomb	17	5	28



Project	Highway 17 Twinning - Culvert 17+570
Analysis	G2.2 EB Permanent - Static (Drained)
Seismic Coefficient	H: 0g, V: 0g
Last Run	2022/06/24, 01:29:43 PM
Scale	1:450

Additional Details
Name: 2. EB Embankment (1.25H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-17.975, 150.7) m, Exit: (-23.5, 146.8) m
Center: (-23.379961, 152.49349) m, Radius: 5.6947513 m

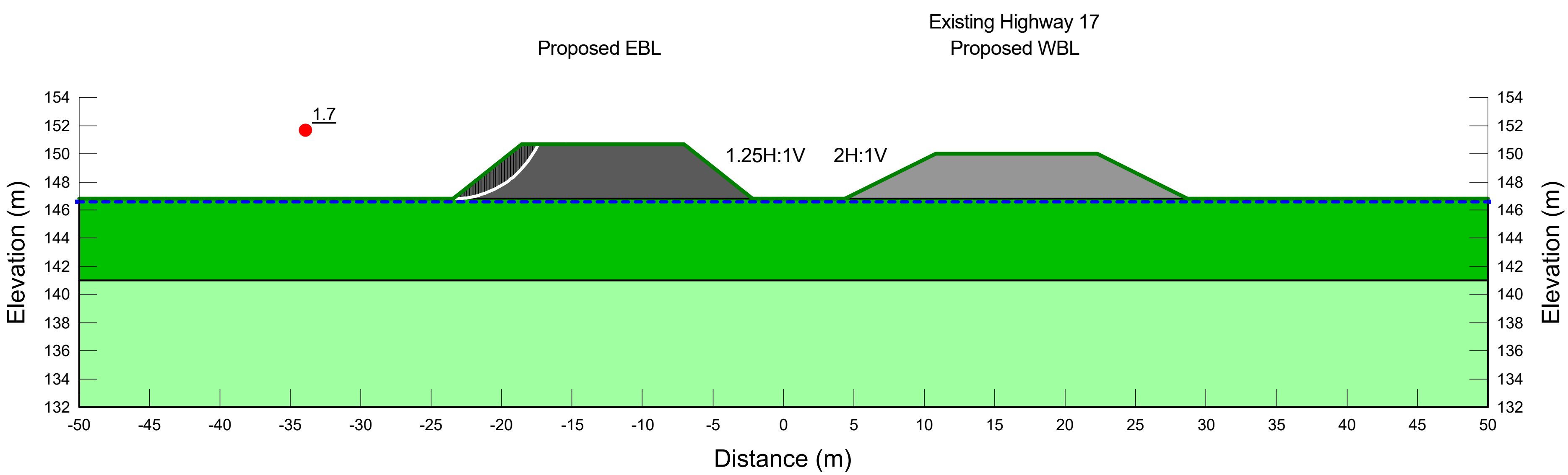
THURBER

Figure G2-2

H:\Projects\20001 to 30000\24726 - Hwy 17 Arnprior to Haley Station\PART 1B\Foundations\Culvert 17+570\Analysis\Culvert 17+570_2022 06 24.gsz

Tool Version: 11.3.1.23726

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
	01: FILL: Rock Fill	Mohr-Coulomb	20					0	42
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



THURBER

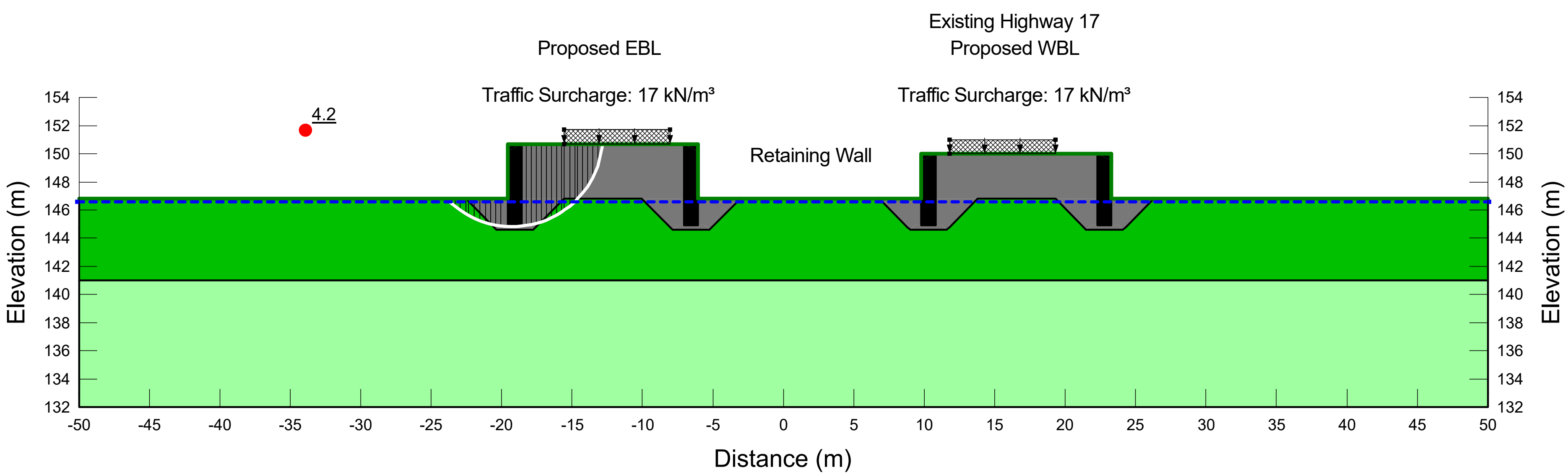
Project	Analysis
Highway 17 Twinning - Culvert 17+570	G2.3 EB Temporary - Seismic (Undrained)

Seismic Coefficient	Last Run	Scale
H: 0.13g, V: 0g	2022/06/24, 01:29:47 PM	1:450

Additional Details
Name: 2. EB Embankment (1.25H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-17.4, 150.7) m, Exit: (-23.6, 146.8) m
Center: (-23.445319, 153.4323) m, Radius: 6.634106 m

Figure G2-3

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: Concrete	High Strength	24						
	00: FILL: Gran. A	Mohr-Coulomb	21					0	40
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



Project	Additional Details
Highway 17 Twinning - Culvert 17+570	Name: 3. EB Embankment (Retaining Wall)
Analysis: G3.1 EB Temporary - Static (Undrained)	Method: Morgenstern-Price, Half-Sine
Seismic Coefficient: H: 0g, V: 0g	Minimum Slip Surface Depth: 1.52 m
Last Run: 2022/06/24, 01:30:00 PM	Entry: (-12.8, 150.7) m, Exit: (-23.9, 146.8) m
Scale: 1:450	Center: (-19.245209, 151.2979) m, Radius: 6.4728821 m
	Surcharge Load: 17 kN/m³

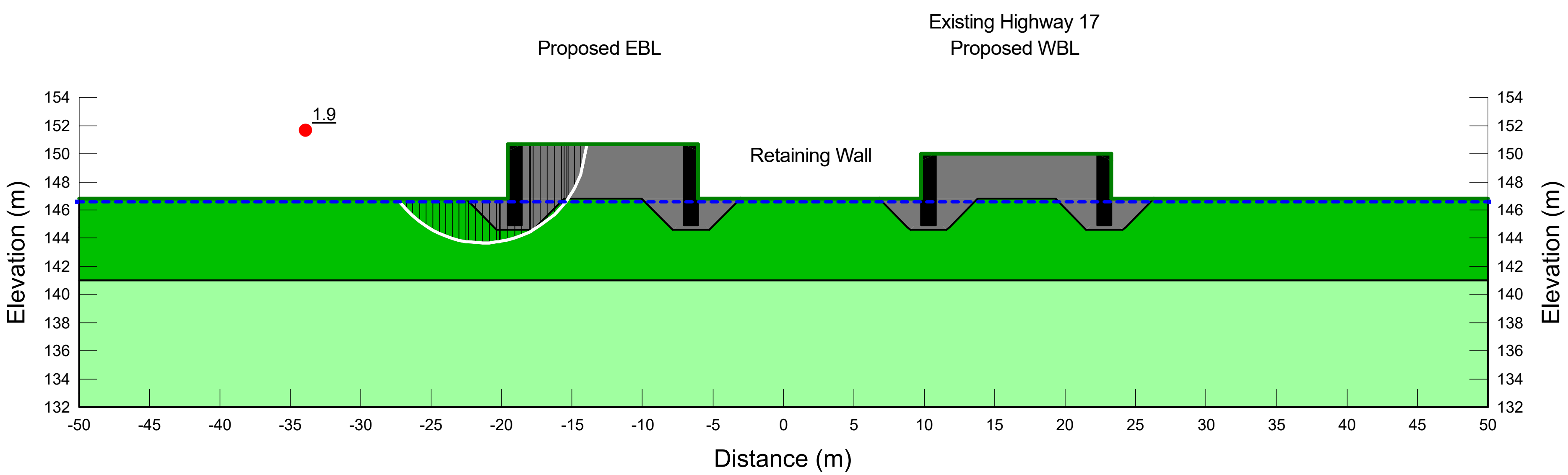
THURBER

Figure G3-1

H:\Projects\20001 to 30000\24726 - Hwy 17 Arnprior to Haley Station\PART 1B\Foundations\Culvert 17+570\Analysis\Culvert 17+570_2022 06 24.gsz

Tool Version: 11.3.1.23726

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: Concrete	High Strength	24		
■	00: FILL: Gran. A	Mohr-Coulomb	21	0	40
■	02: Upper SILTY CLAY Crust (ESA)	Mohr-Coulomb	17	5	28
■	03: Lower SILTY CLAY (ESA)	Mohr-Coulomb	17	5	28



THURBER

Project
Highway 17 Twinning - Culvert 17+570

Analysis
G3.2 EB Permanent - Static (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2022/06/24, 01:30:03 PM	1:450

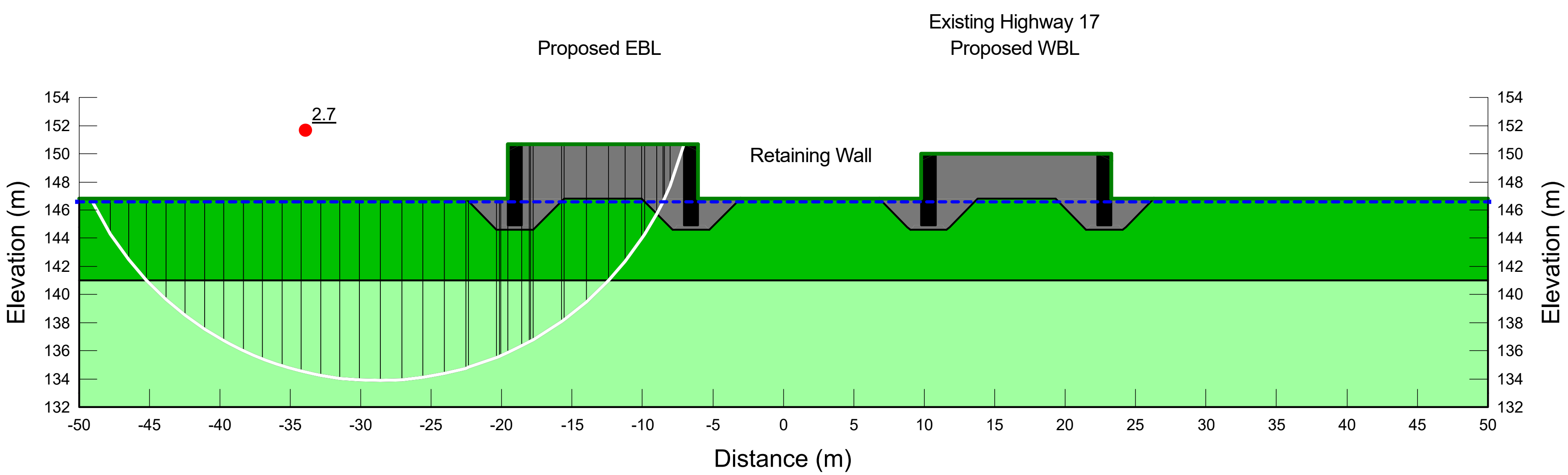
Additional Details
Name: 3. EB Embankment (Retaining Wall)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-13.95, 150.7) m, Exit: (-27.38, 146.8) m
Center: (-21.336214, 151.06139) m, Radius: 7.3950498 m

Figure G3-2

H:\Projects\20001 to 30000\24726 - Hwy 17 Arnprior to Haley Station\PART 1B\Foundations\Culvert 17+570\Analysis\Culvert 17+570_2022 06 24.gsz

Tool Version: 11.3.1.23726

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■ (black)	00: Concrete	High Strength	24						
■ (grey)	00: FILL: Gran. A	Mohr-Coulomb	21					0	40
■ (green)	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
■ (light green)	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



THURBER

Project
Highway 17 Twinning - Culvert 17+570

Analysis
G3.3 EB Temporary - Seismic (Undrained)

Seismic Coefficient
H: 0.13g, V: 0g

Last Run
2022/06/24, 01:30:06 PM

Scale
1:450

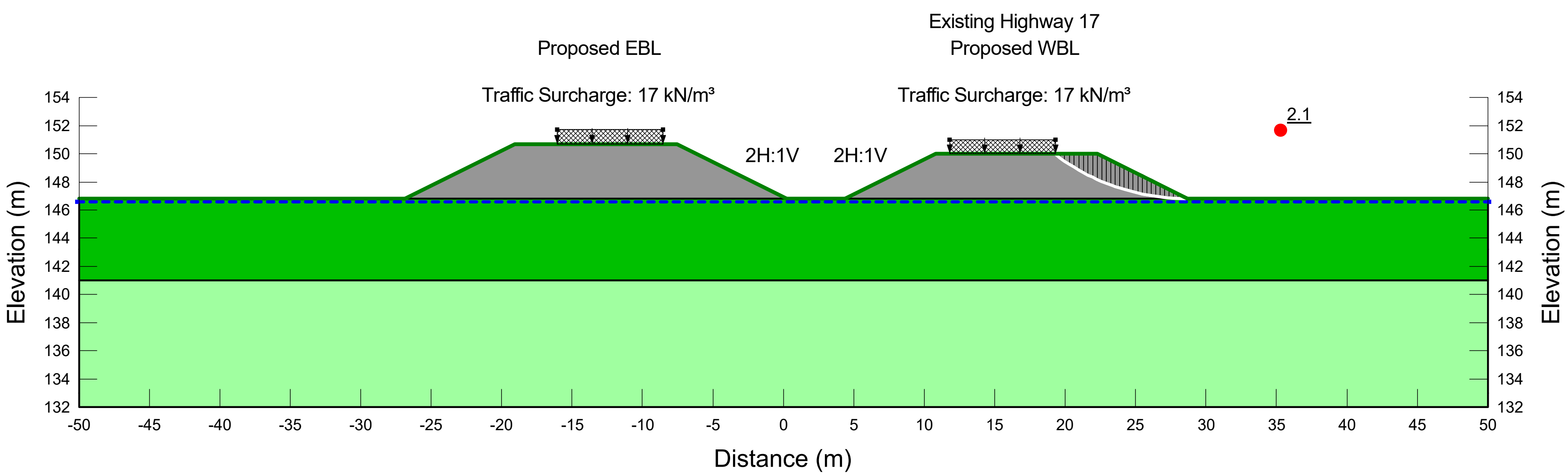
Additional Details
Name: 3. EB Embankment (Retaining Wall)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-7.05, 150.7) m, Exit: (-49.13, 146.8) m
Center: (-28.794628, 156.35276) m, Radius: 22.467366 m

Figure G3-3

H:\Projects\20001 to 30000\24726 - Hwy 17 Arnprior to Haley Station\PART 1B\Foundations\Culvert 17+570\Analysis\Culvert 17+570_2022 06 24.gsz

Tool Version: 11.3.1.23726

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



THURBER

Project
Highway 17 Twinning - Culvert 17+570

Analysis
G4.1 WB Temporary - Static (Undrained)

Seismic Coefficient
H: 0g, V: 0g

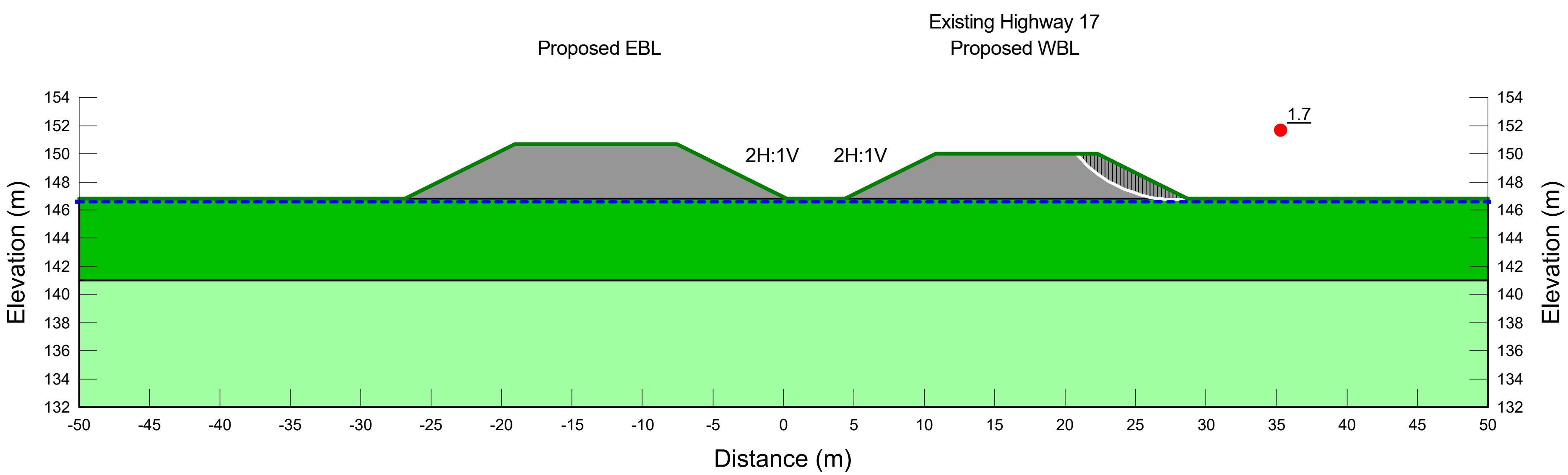
Last Run
2022/06/24, 01:29:50 PM

Scale
1:450

Additional Details
Name: 4. WB Embankment (2H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (19.233333, 150) m, Exit: (28.8, 146.8) m
Center: (28.715341, 162.44708) m, Radius: 15.647309 m
Surcharge Load: 17 kN/m³

Figure G4-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
(grey)	00: FILL: Gran. B I	Mohr-Coulomb	21	0	32
(green)	02: Upper SILTY CLAY Crust (ESA)	Mohr-Coulomb	17	5	28
(light green)	03: Lower SILTY CLAY (ESA)	Mohr-Coulomb	17	5	28



Project	Analysis	Seismic Coefficient	Last Run	Scale
Highway 17 Twinning - Culvert 17+570	G4.2 WB Permanent - Static (Drained)	H: 0g, V: 0g	2022/06/24, 01:29:53 PM	1:450

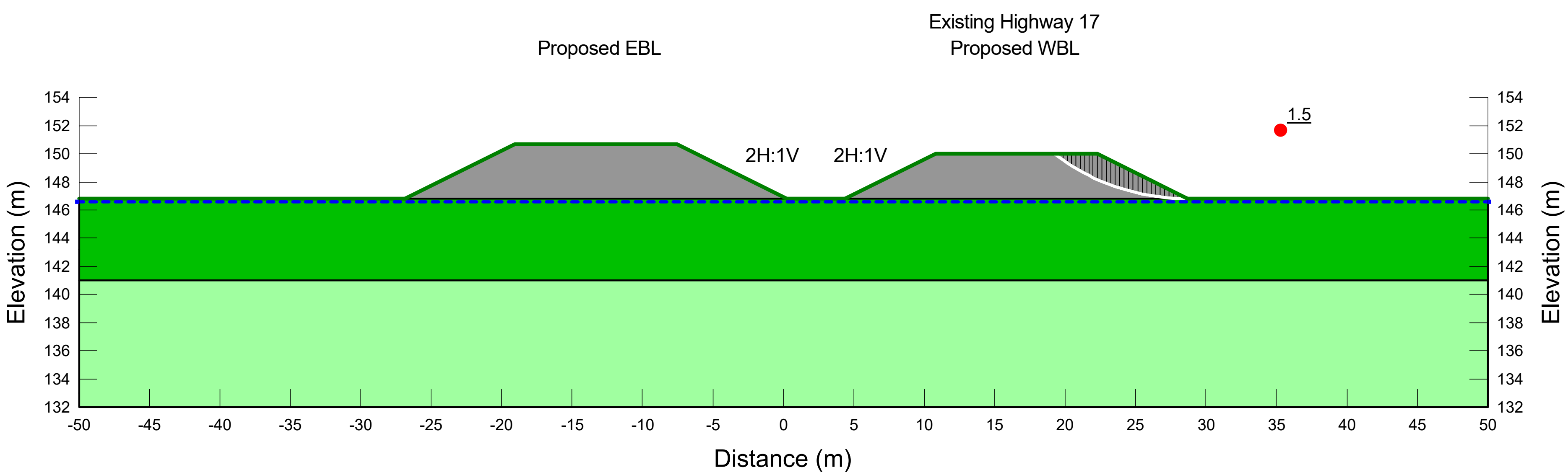
THURBER

Additional Details

Name: 4. WB Embankment (2H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (20.766667, 150) m, Exit: (28.8, 146.8) m
Center: (27.817681, 156.01748) m, Radius: 9.2696722 m

Figure G4-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			

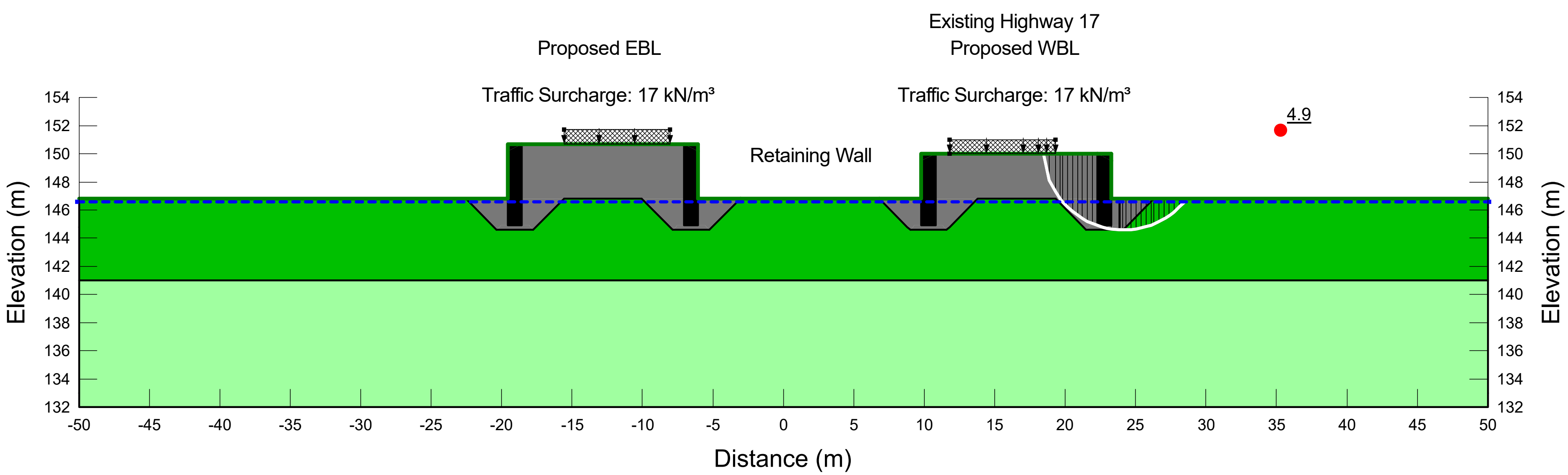


Project	Additional Details
Highway 17 Twinning - Culvert 17+570	Name: 4. WB Embankment (2H:1V) Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 1.52 m Entry: (19.233333, 150) m, Exit: (28.8, 146.8) m Center: (28.715341, 162.44708) m, Radius: 15.647309 m
Analysis: G4.3 WB Temporary - Seismic (Undrained)	
Seismic Coefficient: H: 0.13g, V: 0g; Last Run: 2022/06/24, 01:29:56 PM; Scale: 1:450	

THURBER

Figure G4-3

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: Concrete	High Strength	24						
	00: FILL: Gran. A	Mohr-Coulomb	21					0	40
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



Project	Highway 17 Twinning - Culvert 17+570
Analysis	G5.1 EB Temporary - Static (Undrained)
Seismic Coefficient	H: 0g, V: 0g
Last Run	2022/06/24, 01:30:10 PM
Scale	1:450

THURBER

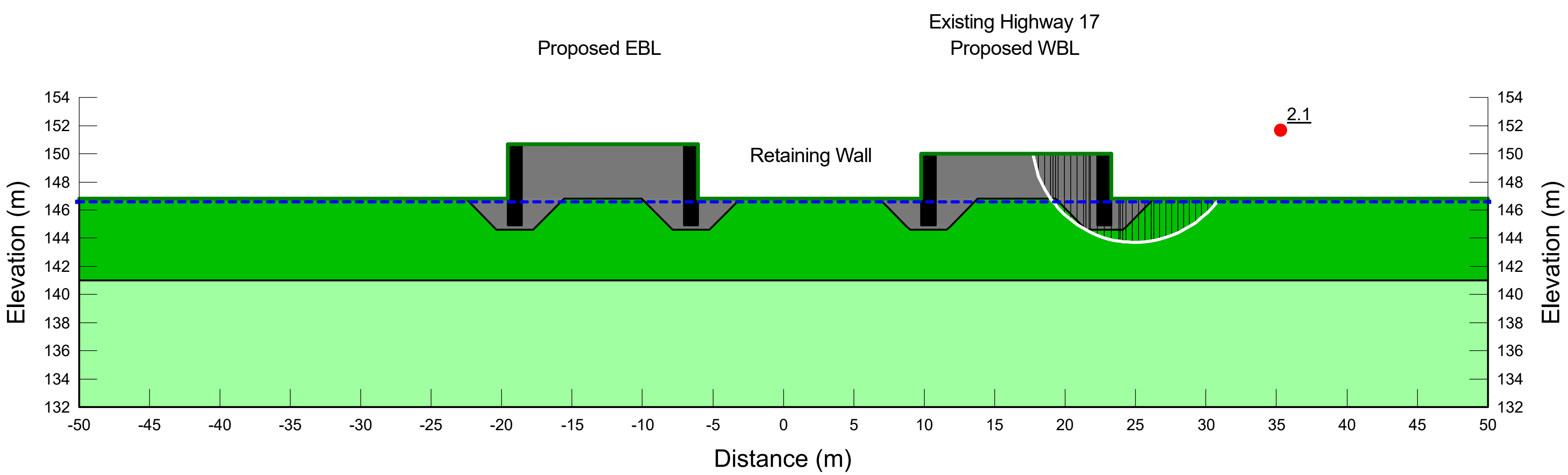
Additional Details
Name: 5. WB Embankment (Retaining Wall)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (18.466667, 150) m, Exit: (28.64, 146.8) m
Center: (24.143343, 150.27574) m, Radius: 5.6833696 m
Surcharge Load: 17 kN/m³

Figure G5-1

H:\Projects\20001 to 30000\24726 - Hwy 17 Arnprior to Haley Station\PART 1B\Foundations\Culvert 17+570\Analysis\Culvert 17+570_2022 06 24.gsz

Tool Version: 11.3.1.23726

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: Concrete	High Strength	24		
	00: FILL: Gran. A	Mohr-Coulomb	21	0	40
	02: Upper SILTY CLAY Crust (ESA)	Mohr-Coulomb	17	5	28
	03: Lower SILTY CLAY (ESA)	Mohr-Coulomb	17	5	28



THURBER

Project
Highway 17 Twinning - Culvert 17+570

Analysis
G5.2 EB Permanent - Static (Drained)

Seismic Coefficient
H: 0g, V: 0g

Last Run
2022/06/24, 01:30:13 PM

Scale
1:450

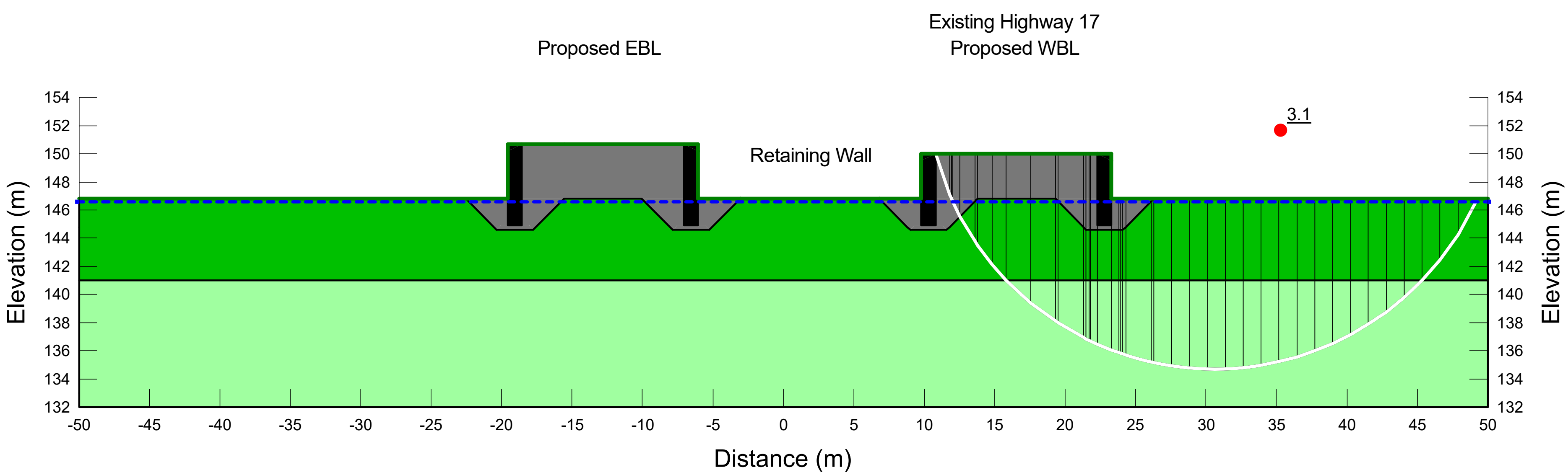
Additional Details
Name: 5. WB Embankment (Retaining Wall)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (17.7, 150) m, Exit: (30.928571, 146.8) m
Center: (24.954956, 151.04849) m, Radius: 7.3303283 m

Figure G5-2

H:\Projects\20001 to 30000\24726 - Hwy 17 Arnprior to Haley Station\PART 1B\Foundations\Culvert 17+570\Analysis\Culvert 17+570_2022 06 24.gsz

Tool Version: 11.3.1.23726

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: Concrete	High Strength	24						
	00: FILL: Gran. A	Mohr-Coulomb	21					0	40
	02: Upper SILTY CLAY Crust (TSA)	Undrained (Phi=0)	17				100		
	03: Lower SILTY CLAY (TSA)	S=f(depth)	17	100	-10	40			



Project	Additional Details
Highway 17 Twinning - Culvert 17+570	Name: 5. WB Embankment (Retaining Wall) Method: Morgenstern-Price, Half-Sine Minimum Slip Surface Depth: 1.52 m Entry: (10.8, 150) m, Exit: (49.237143, 146.8) m Center: (30.580776, 155.15298) m, Radius: 20.440946 m

Analysis: G5.3 EB Temporary - Seismic (Undrained)

Seismic Coefficient	Last Run	Scale
H: 0.13g, V: 0g	2022/06/24, 01:30:16 PM	1:450

THURBER

Figure G5-3

H:\Projects\20001 to 30000\24726 - Hwy 17 Arnprior to Haley Station\PART 1B\Foundations\Culvert 17+570\Analysis\Culvert 17+570_2022 06 24.gsz

Tool Version: 11.3.1.23726

Appendix H.

List of Referenced Specifications
Non-Standard Special Provisions

1. The following Special Provisions and OPSS Documents are referenced in this report:

OPSS 422	Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 903	Construction Specification for Deep Foundations
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1860	Material Specification for Geotextiles
OPSD 202.010	Slope Flattening Using Surplus Excavated Material on Earth or Rock Embankment
OPSD 202.020	Drainage Gap for Slope Flattening on Rock or Granular Embankment
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less than or Equal to 3.0M
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSD 3101.150	Walls Abutment, Backfill Minimum Granular Requirement
SP FOUN0003	Amendment to OPSS 902 – Dewatering Structure Excavations
SP 517F01	Amendment to OPSS 517 - Construction Specification for Dewatering
SP110S06	Amendment to OPSS 1010, April 2013

THURBER

2. Suggested wording for NSSPs

Notice to Contractor: "Protection of Sensitive Foundation Soils"

The Contractor is advised that the native silty and clayey soils that will be exposed at the subgrade are moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for selecting appropriate construction equipment, implementing adequate groundwater control measures and to minimize construction and personnel traffic on the founding subgrade.

"Structural Backfill"

Structural backfill for the culvert and retaining walls shall consist of OPSS Granular B Type II or Quarry Sourced OPSS Granular A material.

Notice to Contractor: "Obstructions"

The Contractor is hereby notified that the existing embankments within the overall project limits have been constructed with rock fill. Considerations of these potential obstructions must be made in the selection of appropriate equipment and procedures for excavations, installations of cofferdams and temporary protection systems.