



## REPORT

# Foundation Investigation and Design Raisin River Bridge Replacements Structure Sites No. 31-231/1&2

*WP 4083-13-01 & WP 4087-13-01 under GWP 4013-11-00*

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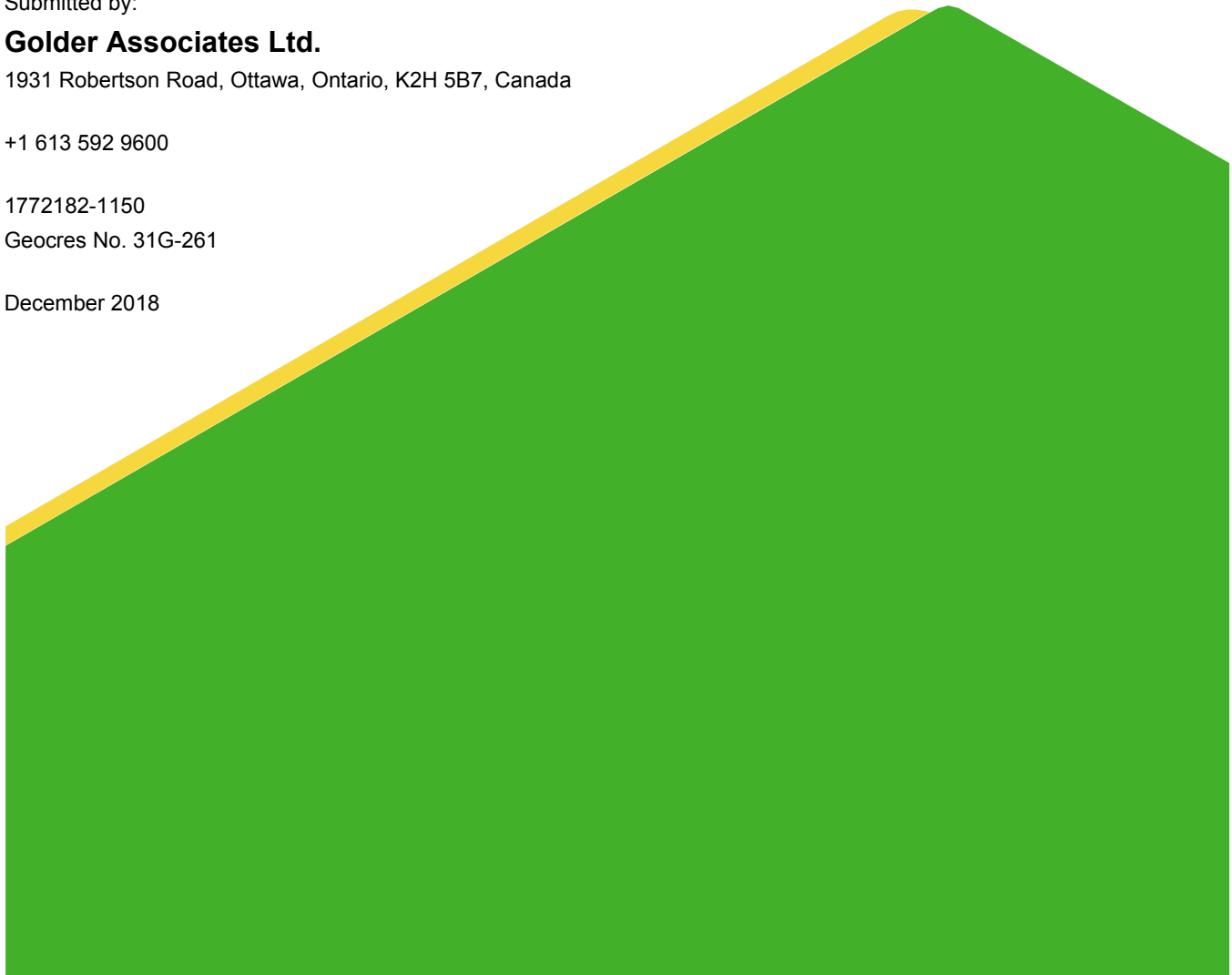
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# Table of Contents

## PART A – FOUNDATION INVESTIGATION REPORT

<b>1.0 INTRODUCTION .....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION AND GEOLOGY .....</b>	<b>1</b>
2.1 General.....	1
2.2 Regional Geology and Seismicity .....	1
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>2</b>
3.1 Current (2017) Investigation.....	2
3.2 Previous Investigation .....	4
3.3 Vertical Seismic Profiling.....	4
<b>4.0 SUBSURFACE CONDITIONS .....</b>	<b>4</b>
4.1 General.....	4
4.2 Westbound Structure, Site No. 31-231/2 .....	5
4.2.1 Topsoil.....	5
4.2.2 Pavement Structure and Fill.....	5
4.2.3 Silt, Sand and Gravel Riverbed Deposits .....	5
4.2.4 Organic Silt to Silt and Organic Silt to Clayey Silt.....	6
4.2.5 Silty Clay to Clay .....	6
4.2.6 Till.....	7
4.2.7 Bedrock .....	7
4.2.8 Groundwater .....	8
4.3 Eastbound Structure, Site No. 31-231/1 .....	9
4.3.1 Topsoil.....	9
4.3.2 Pavement Structure and Fill.....	9
4.3.3 Silt, Sand and Gravel Riverbed Deposits .....	9
4.3.4 Sand, Silty Sand and Silty Sand and Gravel .....	10
4.3.5 Organic Silt to Silt .....	10
4.3.6 Silty Clay to Clay .....	10

4.3.7	Till .....	11
4.3.8	Bedrock .....	11
4.3.9	Groundwater .....	12
4.4	Corrosion and Cement Type Testing .....	13
<b>5.0</b>	<b>CLOSURE .....</b>	<b>13</b>

## **PART B – FOUNDATION DESIGN REPORT**

<b>6.0</b>	<b>DISCUSSION AND ENGINEERING RECOMMENDATIONS .....</b>	<b>14</b>
6.1	Seismic Design .....	14
6.1.1	Seismic Site Classification .....	14
6.1.2	Spectral Response Values and Seismic Performance Category .....	15
6.1.3	Site-Specific Ground Response Analyses .....	16
6.1.3.1	Spectrum-Compatible Time Histories .....	16
6.1.3.2	One-Dimensional Ground Response Analyses .....	17
6.1.3.3	Shake Analysis Models .....	18
6.1.3.4	Analysis Results .....	18
6.1.4	Liquefaction Assessment .....	18
6.1.5	Seismic Loading on Abutment Walls .....	19
6.2	Existing Foundations .....	20
6.3	Foundation Options for Replacement Structures .....	21
6.3.1	Consequence and Site Understanding Classification .....	22
6.3.2	Feasibility of Integral and Semi-Integral Abutments .....	22
6.3.3	Driven Steel H-Pile or Steel Pile Foundations .....	23
6.3.3.1	Founding Elevations .....	23
6.3.3.2	Axial Geotechnical Resistance/Reaction .....	24
6.3.3.3	Downdrag Load and Uplift Resistance .....	24
6.3.3.4	Lateral Geotechnical Resistance .....	25
6.3.3.5	Lateral Soil-Structure Interaction Springs .....	25
6.3.4	Drilled Steel Casings .....	26
6.3.4.1	Founding Elevations .....	26



6.3.4.2	Axial Geotechnical Resistance/Reaction .....	27
6.3.4.3	Downdrag Load and Uplift Resistance .....	27
6.3.4.4	Resistance to Lateral Loads .....	27
6.3.4.5	Lateral Soil-Structure Interaction Springs .....	27
6.3.5	Concrete Caissons .....	27
6.3.5.1	Founding Elevations .....	28
6.3.5.2	Axial Geotechnical Resistance/Reaction .....	29
6.3.5.3	Downdrag Load and Uplift Resistance .....	29
6.3.5.4	Resistance to Lateral Loads .....	29
6.3.5.5	Lateral Soil-Structure Interaction Springs .....	29
6.4	Lateral Earth Pressures for Design .....	29
6.4.1.1	Static Lateral Earth Pressures for Design .....	30
6.4.1.2	Seismic Lateral Earth Pressures for Design .....	31
6.5	Approach Embankments .....	32
6.5.1	Subgrade Preparation and Embankment Construction .....	32
6.5.2	Global Stability .....	33
6.5.3	Settlement .....	34
6.6	Construction Considerations .....	35
6.6.1	Excavation and Temporary Protection Systems .....	35
6.6.2	Groundwater Control .....	36
6.6.3	Vibration Monitoring During Deep Foundation Installation .....	36
6.6.4	Bedrock Excavation and Obstructions .....	37
6.6.5	Erosion and Scour Protection .....	37
6.6.6	Corrosion and Cement Type .....	37
<b>7.0</b>	<b>CLOSURE .....</b>	<b>38</b>

## TABLES

Table 1 Comparison of Foundation Alternatives

## DRAWINGS

Drawings 1 to 3 Raisin River Overpass WBL – Highway 401 Borehole Locations and Soil Strata

Drawings 4 to 6 Raisin River Overpass EBL – Highway 401 Borehole Locations and Soil Strata

## **APPENDICES**

### **APPENDIX A**

#### **Borehole and Drillhole Records, 2017 Investigation**

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 17-01 to 17-08 and 17-101 to 17-112

### **APPENDIX B**

#### **Laboratory Test Results, 2017 Investigation**

### **APPENDIX C**

#### **Record of Boreholes - Previous Investigation (Geocres No. 31G-143)**

### **APPENDIX D**

#### **Vertical Seismic Profiling Test Results**

### **APPENDIX E**

#### **Seismic Analysis Results**

### **APPENDIX F**

#### **Static and Cyclic P-Y Curves**

### **APPENDIX G**

#### **Non Standard Special Provisions**

**PART A**

Foundation Investigation Report  
Replacement of Raisin River Bridges  
Structure Sties No. 31-231/1&2  
Highway 401, Lancaster, Ontario  
GWP 4013-11-00

## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with the detailed design of the replacement of the twin Raisin River Bridges, Site No. 31-231/1 (eastbound) and Site No. 31-231/2 (westbound), in Lancaster, Ontario.

The Terms of Reference for this assignment are outlined in MTO's Work Order for 4016-E-0012 provided to Golder by Dillon on March 20, 2017. The scope of work for the foundation engineering services is presented in Golder's proposal for services related to the replacement of the Raisin River Bridges dated March 24, 2017, and the scope change for additional services dated April 17, 2018.

## 2.0 SITE DESCRIPTION AND GEOLOGY

### 2.1 General

The site is located on Highway 401 approximately 780 metres (m) west of County Road 2/34 and southwest of Lancaster, Ontario, as shown on the Key Plan on Drawings 1 to 6. Each of the existing twin bridges consists of a two-lane, three-span structure that was originally constructed in 1958.

The Raisin River flows from north to south beneath Highway 401 and outlets into the St. Lawrence River near South Lancaster. The structures are twin bridges, each consisting of three-span structures that carry two lanes of traffic each over the Raisin River. The bridges are situated in a rural section of Highway 401 which is wooded, particularly to the west of the bridges. Highway 401 in this area is aligned east-west and is a dual carriageway with a grassed median.

The topography of the lands adjacent to the bridge is relatively flat with man-made channels extending east of the Raisin River, north and south of Highway 401. Elevations of the adjacent lands generally range between 47 and 48 m. The Raisin River flows in a fairly shallow, low gradient channel. The river bed elevations at the bridge locations are understood to range between elevations 42 and 46 m.

### 2.2 Regional Geology and Seismicity

The site is situated in a physiographic region known as the Lancaster Flats, a till plain buried under water-laid deposits. In this area, the stony crest of a few drumlins and ridges are exposed. The water-laid deposits are expected to consist primarily of clay and very fine sand. The Raisin River channel cuts through beds of marine clay.<sup>1</sup>

The surficial soils are deltaic and estuarine deposits consisting of medium to fine gravelly sand sometimes containing fossils. This deltaic sandy plain developed as water levels fell and is generally less than 4 m thick.<sup>2</sup> The underlying bedrock is mapped as limestone, dolostone, shale, arkose and sandstone of the Ottawa and Simcoe Groups of the Shadow Lake Formation. A northwest to southeast trending fault line (traceable on the surface) has been mapped northeast of Lancaster.<sup>3</sup>

<sup>1</sup> Chapman, L.J. and D.F. Putnam, 1984. *The Physiography of Southern Ontario*. Ontario Geological Survey Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.

<sup>2</sup> St. Onge, D.A. 2006. *Quaternary Geology of the Cornwall Area, Ontario*, Geological Survey of Canada, Open File 5013, Scale 1:50,000.

<sup>3</sup> Ontario Geological Survey, 1991. *Bedrock Geology of Ontario, Southern Sheet*, Ontario Geological Survey, Map 2544, Scale 1:1,000,000.

The site falls within the Western Québec Seismic Zone (WQSZ) according to the Geological Survey of Canada. The WQSZ constitutes a large area that extends from Montréal to Témiscaming. Within the WQSZ, recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montréal-Maniwaki axis. Historical seismicity within the WQSZ includes the 1935 Témiscaming event which had a magnitude (i.e., a measure of the intensity of the earthquake,  $M_{bLg}$  or MN) of 6.2 and the 1944 Cornwall-Massena event which had a magnitude of 5.6. In comparison to other seismically active areas in the world (e.g., California, Japan, New Zealand), the frequency of earthquake activity within the WQSZ is significantly lower but there still exists the potential for significant earthquake events to be generated.

## 3.0 INVESTIGATION PROCEDURES

### 3.1 Current (2017) Investigation

The subsurface investigation for the proposed bridge replacements was carried out between April 11 and May 20, 2017. During that time, twenty boreholes (numbered 17-01 to 17-08 and 17-101 to 17-112, inclusive) were advanced at the locations shown on Drawings 1 to 6; the records for these boreholes are contained in Appendix A. Twelve boreholes were drilled for each structure (i.e., two boreholes at each proposed foundation element and one single borehole for each of the approach embankments).

Boreholes 17-01 to 17-08, inclusive, were advanced by wash boring in NW casing size using a drill rig mounted to a barge, supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. Boreholes 17-101 to 17-104, 17-106, 17-107, 17-110 and 17-111 were drilled through the Highway 401 pavement surface using 200 mm inside diameter continuous-flight hollow-stem augers and a truck-mounted drill rig, supplied and operated by George Downing Estate Drilling (Downing) of Hawkesbury, Ontario. Boreholes 17-105, 17-108 and 17-109 were drilled off the highway using a track-mounted drill rig supplied and operated by Downing. Borehole 17-112 was drilled off the highway advanced using portable/manual drilling equipment supplied and operated by OGS Drilling Services of Appleton, Ontario.

The boreholes were advanced to total depths between about 8.3 m and 18.9 m below the existing pavement/ground surface. Soil samples in the boreholes were obtained at vertical intervals of about 0.60 to 1.52 m, using a 50 mm outer diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures. In-situ vane testing, using an MTO “N”-size vane, was carried out to measure the undrained shear strength of the cohesive soils encountered at the site. Bedrock was proven in Boreholes 17-02, 17-03, 17-06, 17-07, 17-106, 17-108, 17-109 and 17-111 by obtaining cores between about 2.8 and 5.5 m in length using both NQ and HQ size coring equipment.

Monitoring wells were installed in Boreholes 17-105 and 17-112 to monitor the groundwater levels at the site. The monitoring wells consist of a 32 mm diameter rigid PVC pipe with a 1.5 m long slotted screen section, installed within silica sand backfill and sealed by a section of bentonite pellet backfill. Groundwater measurements were taken within the monitoring wells on May 26 and July 29, 2017.

PVC casings were installed and grouted in boreholes 17-108 and 17-109 to allow for Vertical Seismic Profiling (VSP) testing (discussed below in Section 3.3).

The remaining boreholes were backfilled with bentonite pellets mixed with native soils in the overburden, and bentonite pellets in the bedrock. The site conditions were restored following completion of work.

The field work was supervised by a member of Golder's technical staff, who located the boreholes, supervised the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled, and transported to Golder's laboratory facility in Ottawa for further examination. Index and classification tests consisting of grain size distributions, Atterberg limits, organic contents and water contents were carried out on selected soil samples at the Ottawa laboratory. Unconfined compressive strength tests were carried out on selected rock core samples in Golder's Mississauga laboratory. All of the laboratory tests were carried out to MTO and/or ASTM standards as appropriate. Details of the subsurface soil, rock and groundwater conditions encountered in each borehole are summarized in the Record of Boreholes in Appendix A. The results of the laboratory testing are summarized in Appendix B.

The borehole locations and ground surface elevations were surveyed by Golder Associates Ltd. using a Trimble R8 GPS unit. The borehole locations, including MTM NAD83 (Zone 9) northing and easting coordinates, and ground surface elevations referenced to Geodetic datum are summarized in the following table and are shown on Drawings 1 to 4.

Borehole Number	Borehole Location	Northing (m)	Easting (m)	Ground/Riverbed Surface Elevation (m)
<b>Highway 401 Raisin River Bridge, EBL, Site No. 31-231/1</b>				
17-01	West Pier	4 999 645.2	225 749.4	44.0
17-02	West Pier	4 999 659.0	225 736.9	45.5
17-03	East Pier	4 999 659.7	225 772.5	45.8
17-04	East Pier	4 999 673.8	225 759.9	45.3
17-102	West Approach	4 999 625.8	225 705.2	50.2
17-104	East Approach	4 999 688.3	225 806.5	49.9
17-107	West Abutment	4 999 643.6	225 721.2	50.1
17-108	West Abutment	4 999 628.6	225 728.2	48.2
17-111	East Abutment	4 999 682.5	225 782.7	50.0
17-112	East Abutment	4 999 668.4	225 790.4	47.5
<b>Highway 401 Raisin River Bridge, WBL, Site No. 31-231/2</b>				
17-05	West Pier	4 999 667.1	225 731.8	45.1
17-06	West Pier	4 999 681.5	225 719.3	45.0
17-07	East Pier	4 999 682.5	225 754.5	45.6
17-08	East Pier	4 999 697.5	225 741.9	45.6
17-101	West Approach	4 999 650.6	225 685.8	50.2
17-103	East Approach	4 999 715.5	225 786.8	49.9
17-105	West Abutment	4 999 671.6	225 699.6	47.3
17-106	West Abutment	4 999 658.0	225 708.3	50.1
17-109	East Abutment	4 999 710.9	225 761.3	47.7
17-110	East Abutment	4 999 967.3	225 770.6	50.0

## 3.2 Previous Investigation

The subsurface conditions for the existing Raisin River Bridges are described in the Geocres No. 31G-143 report. The investigation for Geocres No. 31G-143 was carried out in 1957/1958 and consisted of 15 boreholes drilled to depths of about 3.0 to 15.2 m.<sup>4</sup> The borehole locations are shown on Drawings 1 to 6 and the Records of Boreholes are presented in Appendix C. Review of the information presented in the Geocres No. 31G-143 report indicates that the subsurface soil, rock and groundwater conditions described in the report are similar to those encountered during the 2017 investigation. However, apart from information on the location of the bedrock surface, groundwater levels and river water levels, the results of the 1957/1958 investigation were not relied upon for this report since they do not meet current MTO standards, particularly with respect to the level of laboratory testing. In addition, the 1957/1958 investigation pre-dated construction of this section of Highway 401 and its crossing of the Raisin River. Surficial materials at the ground surface may have been stripped and/or additional materials placed to construct the approach embankments.

## 3.3 Vertical Seismic Profiling

Vertical Seismic Profiling (VSP) testing was carried out in Boreholes 17-108 and 17-109, located in the southwest quadrant of the EBL structure (Site No. 31-231/1) and the northeast quadrant of the WBL structure (Site-31-231/2), respectively. The VSP testing was carried out on May 9, 2017 to provide information on the average shear wave velocity ( $V_s$ ) to enable seismic site classification.

The VSP testing involves generating seismic energy at the ground surface from an active seismic source and recording the waves generated with a geophone (receiver) situated at a known depth in an adjacent borehole. The active seismic source can be either a compression or a shear wave. The velocity of the average compression or shear wave is determined by measuring the time for the energy generated to travel from the source to the receiver. Data obtained from different geophone depths are used to calculate a detailed vertical seismic velocity profile of the subsurface in the immediate vicinity of the test borehole. A summary of the VSP testing and the results are presented in the technical memorandum in Appendix D.

## 4.0 SUBSURFACE CONDITIONS

### 4.1 General

The detailed subsurface soil, rock and groundwater conditions encountered in the boreholes drilled as part of the current investigation and the results of related in situ and laboratory testing are given on the Record of Borehole and Drillhole sheets contained in Appendix A. The results of geotechnical laboratory testing carried out as part of the current investigation are included in Appendix B. The borehole logs and geotechnical test results from the previous investigation, carried out in 1958 (prior to construction of the bridges), are included in Appendix C.

The interpreted stratigraphic conditions along the centreline of the existing bridges and at the proposed abutment and pier and locations are shown on Drawings 1 to 4. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic sections included on Drawings 1 to 4 are inferred from non-continuous sampling and, therefore, represent transitions between soil and rock types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

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<sup>4</sup> E.M. Peto Associates Limited 1958. Report of Soil Site Investigation for Raisin River – Highway 401 Bridge, Job Number 57147 dated February 10, 1958.

In general, the subsurface conditions at the site consist of topsoil, pavement structure, embankment or grade fill overlying in sequence: loose to compact granular deposits (silty gravel, sandy silt, sand and gravel and silty sand) to elevations ranging from approximate 41 to 45 m, stiff to firm silty clay and clayey silt to elevations ranging from approximate 40 to 47 m, and loose to very dense glacial till and/or compact sand and gravel. The overburden deposits are underlain by limestone bedrock at elevations ranging from about 34 to 40 m. Organic layers (organic silt and peat) or soils containing organic matter were encountered in the deposits above the clay or glacial till. The Raisin River substrate comprises sand, silty gravel, sand and gravel, and silty sand and contains shells, cobbles and boulders. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

## **4.2 Westbound Structure, Site No. 31-231/2**

Boreholes 17-05 to 17-08, 17-101, 17-103, 17-105, 17-106, 17-109 and 17-110 were advanced for the westbound structure. The stratigraphic centreline profile is shown on Drawing 1 and the stratigraphic profiles for the piers and abutments are presented on Drawings 2 and 3.

### **4.2.1 Topsoil**

Surficial layers of topsoil, about 0.2 m in thickness, were encountered at boreholes 17-105 and 17-109. Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

### **4.2.2 Pavement Structure and Fill**

Boreholes 17-101, 17-103, 17-106 and 17-110 encountered the Highway 401 pavement structure. The asphaltic concrete pavement was between 0.1 and 0.4 m in thickness. At all locations except at Borehole 17-103, the asphaltic concrete was underlain by concrete about 0.3 to 0.4 m in thickness.

Fill materials were found underlying the topsoil fill at Borehole 17-105 and beneath the pavement structure at Boreholes 17-101, 17-103, 17-106 and 17-110. The fill consists of silty sand to sandy silt, silt, silty gravel and gravelly sand and extends to depths of 0.8 to 3.8 m below the existing ground surface (i.e., Elevations 46.1 to 46.6 m). The fill is very loose to very dense based on SPT 'N' values ranging from 3 to 63 blows per 0.3 m of penetration.

Water contents measured in the fill samples ranged from about 10 to 19 percent. The organic content of a single fill sample from Borehole 17-101 was 3 per cent. The results of grain size analyses carried out on three samples of the fill materials are presented on Figure B1 in Appendix B.

### **4.2.3 Silt, Sand and Gravel Riverbed Deposits**

Layers of silt, sand and gravel were encountered at the surface of the riverbed at Boreholes 17-05 to 17-08, inclusive. The shallow deposits varied in composition from sand and gravel, sandy gravel, silty gravel, silty sand, clayey silty sand, clayey sandy silt to silty sand and gravel.

The silt, sand, and gravel layers were about 1.1 to 2.6 m in thickness, extending down to Elevations of 42.4 to 43.9 m. Standard Penetration Test (SPT) "N" values measured within the shallow riverbed deposits generally ranged from 'weight of hammer' to 6 blows per 0.3 m of penetration, indicating these layers are very loose to loose. Higher N-values of 16 and 21 were obtained in the lower portion of these deposits at Borehole 17-05, the deposit is compact in that localized area.



Water contents measured in three samples of the silt, sand and gravel layers ranged from about 9 to 22 percent. The organic content of one sample from these shallow layers was 3 percent. The results of the grain size analyses for one sample of the sand and gravel and two samples of the silty sand and gravel are presented on Figures B2 and B3, respectively.

#### 4.2.4 Organic Silt to Silt and Organic Silt to Clayey Silt

Organic silt to silt layers were encountered near the west pier (Borehole 17-05), west abutment (Boreholes 17-105 and 17-106) and west approach (17-101). The upper portion of the deposit at Borehole 17-101 consisted of organic silt to clayey silt. The lower portion of the organic silt in Borehole 17-106 was observed to contain peat. The organic silt to silt layers were about 0.9 to 3.1 m in thickness, extending down to Elevation 41.5 m at Borehole 17-05 (i.e., in the river) and Elevations 43.2 to 43.5 m below the west abutment and approach.

Measured SPT “N” values in the organic deposits ranged from ‘weight of rods’ to 6 blows per 0.3 m of penetration. The measured shear strengths within the organic silt to clayey silt at Borehole 17-101 were 52 and 82 kPa. These test results indicate that the organic deposits are generally loose to very loose, with the cohesive portions being generally stiff; however, the shear strength values may not be representative since the wood and gravel can affect the field vane test results (i.e., result in higher shear strength values than exist).

The measured water content of the organic silt to silt ranged from about 35 to 108 percent. The organic content of five samples from these organic layers were between 8 and 23 percent. The results of Atterberg limit testing on six selected samples of the organic deposits are shown on Figure B4 and indicate a plasticity index ranging from about 3 to 15 percent and a liquid limit ranging from about 44 to 58 percent, indicating a clayey silt to organic silt.

#### 4.2.5 Silty Clay to Clay

A deposit of silty clay to clay was encountered beneath the topsoil at Borehole 17-109 (north of the east abutment) and beneath the organic deposits at Boreholes 17-101, 17-105, and 17-106 (on the west side of the river).

The deposit at Borehole 17-109 has been weathered to a grey-brown colour and is about 0.8 m thick, extending down to Elevation 46.7 m. One measured SPT “N” value in this weathered zone was 3 blows per 0.3 m of penetration, indicating a stiff to very stiff consistency.

The silty clay to clay encountered below the organic deposits is grey in colour, unweathered, and extends to depths of about 7.6 to 9.3 m below the existing ground surface (i.e., extending to Elevations of 39.7 to 41.6 m). In situ vane testing carried out within this unweathered deposit measured undrained shear strengths ranging between 28 and 58 kPa. These test results indicate that the unweathered silty clay to clay has a firm to stiff consistency. In situ vane testing carried out on remoulded grey silty clay to clay gave undrained shear strengths ranging from 5 to 10 kPa, reflecting a sensitive material (sensitivities ranging from 6 to 8).

Measured water contents of the unweathered silty clay to clay samples ranged from about 77 to 80 per cent. The results of Atterberg limit testing on three selected samples of the unweathered silty clay to clay indicate plasticity index values of 37 to 44 percent and liquid limit values of 61 to 68 percent. These results, also shown on the plasticity chart on Figure B5, indicate that this material is a clay of high plasticity. The results of one grain size distribution test carried out on a select sample of the unweathered silty clay to clay from Borehole 17-105 are shown on Figure B6.

#### 4.2.6 Till

Glacial till was encountered at all of the borehole locations beneath the fill, riverbed layers, organic deposits and/or clay to silty clay. The gradation of the till was variable and consisted of silty sand, sand and gravel and gravelly sand till with cobbles and boulders. At borehole 17-05, the upper 0.7 m of glacial till consists of silty sand without any gravel. Where fully penetrated, the glacial till layers were about 3.9 to 11.0 m thick (i.e., extending down to Elevations 36.9 to 34.4 m). Where the boreholes were terminated due to refusal, the till was at least 2.1 to 7.4 m in thickness.

The very loose to very dense glacial till had N values ranging from 2 to over 100 blows per 0.3 m of penetration. In Boreholes 17-06, 17-07, 17-106 and 17-109, rotary diamond drilling techniques were required to penetrate the cobbles and boulders. The presence of cobbles and boulders should therefore be expected throughout the glacial till deposit. Water contents within the glacial till ranged from 6 to 12 percent. The results of grain size analyses carried out on seven samples of the till are presented on Figure B7. It is noted that the samples were retrieved using a 50 mm diameter sampler and therefore the samples do not reflect the cobble and boulder portions of the deposit.

Samples of the glacial till from Boreholes 17-05, 17-106, and 17-110 had measured water contents ranging from about 5 to 7 percent, liquid limits ranging from about 12 to 16 percent, and plasticity indices ranging from about 1 to 3 percent. The results of the Atterberg limit testing are shown on Figure B7b.

The result of one unconfined compressive strength (UCS) testing of a cored cobble/boulder from the glacial till gave a strength of 107 MPa.

#### 4.2.7 Bedrock

Bedrock was encountered in Boreholes 17-06, 17-07, 17-106, 17-109 and proven by coring for 1.8 to 4.7 m using NQ and HQ-sized equipment.

Boreholes 17-05, 17-08, 17-101, 17-103, 17-105 and 17-110 experienced refusal to sampler or auger advancement. Refusals could reflect cobbles/boulders in the till or the bedrock surface.

The following table summarizes the refusal and bedrock surface depths and elevations as encountered at the borehole locations.

Location	Borehole Number	Ground/River Surface Elevation <sup>3</sup> (m)	Depth to Bedrock Surface/Refusal (m)	Bedrock Surface/Refusal Elevation (m)
West Approach	17-101	50.2	10.7	39.5 <sup>1</sup>
West Abutment	17-105	47.3	10.1	37.2 <sup>1</sup>
	17-106	50.1	13.2	36.9
	1 <sup>2</sup>	46.5	7.8	38.7 <sup>1</sup>
	2 <sup>2</sup>	46.4	7.6	38.8
West Pier	17-05	46.6	10.1	36.5 <sup>1</sup>
	17-06	46.6	11.7	34.9
	4 <sup>2</sup>	46.4	7.9	38.5 <sup>1</sup>
	5 <sup>2</sup>	46.4	7.9	38.5

Location	Borehole Number	Ground/River Surface Elevation <sup>3</sup> (m)	Depth to Bedrock Surface/Refusal (m)	Bedrock Surface/Refusal Elevation (m)
East Pier	17-07	46.6	11.5	35.1
	17-08	46.6	8.8	37.8 <sup>1</sup>
	7 <sup>2</sup>	46.4	9.1	37.3
	8 <sup>2</sup>	46.4	9.3	37.1
East Abutment	17-109	47.7	13.3	34.5
	17-110	50.0	11.2	38.8 <sup>1</sup>
	10 <sup>2</sup>	46.5	6.7	39.8 <sup>1</sup>
	11 <sup>2</sup>	46.5	11.9	34.6
East Approach	17-103	49.9	10.3	39.6 <sup>1</sup>

**Notes:**

1. Split-spoon, auger or casing refusal encountered within the borehole.
2. Borehole records from 1958 Geocres report No. 31G-143.
3. Ground/river surface elevation measured at the time of investigation.

The bedrock consists of interbedded shale, dolostone and limestone. The dolostone is generally fresh, thinly to medium bedded and strong. The shale is generally slightly weathered to fresh, thinly to medium bedded, and weak to medium strong. The limestone generally is thinly to medium bedded and strong.

The RQD values measured on the recovered bedrock core samples typically ranged from about 70 to 100 percent, indicating fair to excellent quality rock.

Laboratory unconfined compressive strength testing was carried out on selected specimens of the bedrock core from Boreholes 17-06, 17-07, 17-106 and 17-109. The results of the testing indicate unconfined compressive strengths ranging from about 64 to 107 MPa, which correspond to strong to very strong rock. The results of the testing are shown on Figure B8 in Appendix B. Photographs of the bedrock core are also presented in Appendix B.

#### 4.2.8 Groundwater

The groundwater levels measured in the piezometer in Borehole 17-105 is summarized in the table below:

Borehole	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
17-105	47.7	0.6	47.1	May 26, 2017
		0.6	47.1	July 29, 2017

The water levels measured at the Raisin River during the field investigations are summarized below:

Date	River Surface Elevation (m)
December 1957 and January 1958	46.4-46.61
May, 2017	46.6

**Notes:**

1. Surface of the ice during the investigation in 1957/1958

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.

### **4.3 Eastbound Structure, Site No. 31-231/1**

Boreholes 17-01 to 17-04, 17-102, 17-104, 17-107, 17-108, 17-111, and 17-112 were advanced for the eastbound structure. The stratigraphic centreline profiles are shown on Drawing 4 and the stratigraphic profiles for the piers and abutments are presented on Drawings 5 and 6.

#### **4.3.1 Topsoil**

A surficial layer of topsoil, about 0.3 m in thickness, was encountered at borehole 17-108. Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

#### **4.3.2 Pavement Structure and Fill**

Boreholes 17-102, 17-104, 17-107 and 17-111 encountered the Highway 401 pavement structure. The asphaltic concrete was found to be 0.1 to 0.3 metres thick. Concrete, about 0.4 m in thickness, was found underlying the asphaltic concrete in Boreholes 17-107 and 17-111.

Fill materials were encountered at the ground surface at Borehole 17-112 and beneath the topsoil fill at Borehole 17-108 and the pavement structure at Boreholes 17-102, 17-104, 17-107 and 17-111. The fill was primarily granular in nature and consists of sandy silt to silty sand and gravelly sand to sandy gravel. Cobbles were encountered in the fill in Boreholes 17-102, 17-104, 17-107 and 17-108. The fill in Boreholes 17-111 and 17-112 contained organic matter. The fill layers were 0.6 to 4.3 m in thickness, extending down to elevations ranging from about 46.9 to 45.4 m.

The fill is very loose to very dense based on SPT 'N' values ranging from 2 to 62 blows per 0.3 m of penetration. Measured water contents ranged from about 4 to 10 percent. The results of grain size analyses carried out on four samples of the embankment fill are presented on Figure B9 in Appendix B.

#### **4.3.3 Silt, Sand and Gravel Riverbed Deposits**

Layers of silt, sand and gravel were encountered at the surface of the riverbed at Boreholes 17-01 to 17-04, inclusive. The shallow deposits varied in composition from sand, sand and gravel, silty sand, sandy silt to silty gravel. The silt, sand, and gravel layers were about 0.2 to 4.2 m thick, extending down to Elevations of 41.3 to 45.1 m. Standard Penetration Test (SPT) "N" values measured within the shallow riverbed deposits ranged from 2 to 49 blows per 0.3 m of penetration, indicating these layers to be very loose to dense. Some cobbles, boulders and organic matter were encountered within the shallow riverbed deposits. Rotary diamond drilling techniques were required to penetrate the cobbles and boulders in the sand and gravel at Borehole 17-02.

Water contents measured in three samples of the silt, sand and gravel layers ranged from about 8 to 67 percent. The organic content of two samples from these shallow layers were about 1 and 4 percent. The results of the grain size analyses for three samples of the river bed deposits from Boreholes 17-01 and 17-02 are presented on Figure B10.

#### 4.3.4 Sand, Silty Sand and Silty Sand and Gravel

Deposits of sand, silty sand and silty sand and gravel were encountered below the embankment fill at Boreholes 17-102 and 17-107, on the west side of the structure, extending to Elevations of 44.1 and 43.3 m, respectively. At Borehole 17-102, about 1.5 m of silty sand was encountered. At Borehole 17-107, about 0.7 m of silty sand and gravel was encountered underlain by about 1.6 m of sand. The sand and gravel deposits were noted to contain shells.

Standard Penetration Test (SPT) “N” values measured within the sand and gravel deposits below the embankment fill ranged from about 8 to 16 blows per 0.3 m of penetration, indicating loose to compact state of packing.

The results of the grain size analysis for samples of the sand and gravel from Boreholes 17-102 and 17-107 are presented on Figure B10.

A sample of the sandy silt from Borehole 17-107 had a measured water content of about 17 percent and a measured liquid limit of about 25 percent and a plasticity index of about 8 percent. The results of the Atterberg limit testing are shown on Figure B11b.

#### 4.3.5 Organic Silt to Silt

The fill at Borehole 17-108 (west abutment) was underlain by a 1.6 m thick layer of organic silt to silt. A sample of the organic silt to silt had a measured water content of about 106 percent and an organic content of about 21 percent. The organic silt is of high plasticity based on a measured liquid limit of about 68 percent and a plasticity index of about 4 percent. The results of the Atterberg limit testing are shown on Figure B11.

#### 4.3.6 Silty Clay to Clay

All boreholes advanced for the eastbound structure contained layers of silty clay to clay. The silty clay to clay deposits were found beneath the fill in Boreholes 17-104, 17-111 and 17-112 (extending down to Elevations ranging from 44.4 to 43.2 m), beneath the granular deposits in Boreholes 17-01 to 17-04, 17-102, and 17-107 (extending down to elevations ranging from 43.3 to 42.7 m), and below the organic silt to silt at Borehole 17-108 (extending down to about Elevation 41.2 m). The thickness of the silty clay to clay varied from about 0.7 to 3.9 m at the borehole locations.

The full depth of the deposit at Boreholes 17-104 and 17-112 has been weathered to a grey-brown colour. Measured SPT “N” values in this weathered zone were between 3 and 24 blows per 0.3 m of penetration and two measured shear strengths of about 60 and 110 kPa, indicate a stiff to very stiff consistency.

The silty clay to clay at the other borehole locations is grey in colour and unweathered. The unweathered silty clay to clay was very soft to stiff based on measured SPT “N” values generally ranging from about 1 to 3 blows per 0.3 m and measured shear strengths ranging from about 27 to 65 kPa. The sensitivity of the clay ranged from about 4 to 7, indicating a sensitive material.

Measured water contents of samples of the silty clay ranged from about 28 to 83 percent. A sample of the silty clay to clay from Borehole 17-04 was noted to contain organic matter and had a measured organic content of about 3 percent. The results of Atterberg limit testing on seven selected samples of the unweathered silty clay to clay indicate plasticity index values ranging from 15 to 50 percent and liquid limit values ranging from 31 to 76 percent. These results, also shown on the plasticity chart on Figure B12, indicate that this material is a silty clay to clay of intermediate to high plasticity. The results of a grain size distribution test carried out on a select sample of the weathered silty clay to clay from Borehole 17-104 are shown on Figure B13.

### 4.3.7 Till

Glacial till was encountered beneath the silty clay to clay at all of the borehole locations. The gradation of the till was variable and consisted of silty sand, sandy silt, silty sand and gravel to gravelly silty sand till with cobbles and boulders. Where fully penetrated, the glacial till layers were about 1.2 to 9.6 m in thickness (i.e., extending down to Elevations 40.0 to 34.8 m). Where the boreholes were terminated due to refusal, the till was at least 1.8 to 5.5 m in thickness.

The very loose to very dense glacial till had N values ranging from 3 to greater than 100 blows per 0.3 m of penetration. In Boreholes 17-02 and 17-111, rotary diamond drilling techniques were required to penetrate the cobbles and boulders. The presence of cobbles and boulders should therefore be expected throughout the glacial till deposit. Water contents within the glacial till ranged from 5 to 11 percent. The results of grain size analyses carried out on six samples of the till are presented on Figure B14. It is noted that the samples were retrieved using a 50 mm diameter sampler and therefore the samples do not reflect the cobble and boulder portions of the deposit.

Atterberg Limit tests were carried out on three samples of the portion of the till that passed the number 40 sieve. The sample from Borehole 17-111 was non-plastic and the two samples from Boreholes 17-108 and 17-112 measured liquid limits of about 16 and 15 percent and plasticity indices of about 4 and 3 percent, respectively. The results of the Atterberg limit testing are shown on Figure B14b.

### 4.3.8 Bedrock

Bedrock was proven in Boreholes 17-02, 17-03, 17-108, 17-111 and by coring for 2.8 to 5.5 m using NQ and HQ-sized equipment.

Boreholes 17-01, 17-04, 17-102, 17-104, 17-107, and 17-112 experienced refusal to sampler or auger advancement. Refusals could reflect cobbles/boulders in the till or the bedrock surface.

The following table summarizes the refusal and bedrock surface depths and elevations as encountered at the borehole locations.

Location	Borehole Number	Ground/River Surface Elevation <sup>3</sup> (m)	Depth to Bedrock Surface/Refusal (m)	Bedrock Surface/Refusal Elevation (m)
West Approach	17-102	50.2	10.9	39.3 <sup>1</sup>
West Abutment	17-107	50.1	11.7	38.4 <sup>1</sup>
	17-108	48.2	8.2	40.0
	2 <sup>2</sup>	46.4	7.6	38.8 <sup>1</sup>
	3 <sup>2</sup>	46.6	8.8	37.8
West Pier	17-01	46.6	8.8	37.8 <sup>1</sup>
	17-02	46.6	9.3	37.3
	5 <sup>2</sup>	46.4	7.9	38.5
	6 <sup>2</sup>	46.4	7.6	38.8
East Pier	17-03	46.6	8.2	38.4
	17-04	46.6	8.9	37.7 <sup>1</sup>
	8 <sup>2</sup>	46.4	9.3	37.1
	9 <sup>2</sup>	46.4	10.1	36.3

Location	Borehole Number	Ground/River Surface Elevation <sup>3</sup> (m)	Depth to Bedrock Surface/Refusal (m)	Bedrock Surface/Refusal Elevation (m)
East Abutment	17-111	50.0	15.2	34.8
	17-112	47.5	8.3	39.2 <sup>1</sup>
	11 <sup>2</sup>	46.5	11.9	34.6
	12 <sup>2</sup>	46.5	8.8	37.7 <sup>1</sup>
East Approach	17-104	49.9	10.4	39.6 <sup>1</sup>

**Notes:**

1. Split-spoon, auger or casing refusal encountered within the borehole.
2. Borehole records from 1958 Geocres report No. 31G-143.
3. Ground/river surface elevation measured at the time of investigation.

The bedrock consists of interbedded shale, dolostone and limestone. The dolostone is generally fresh, thinly to medium bedded and medium strong to strong. The shale is generally slightly weathered to fresh, porous, and weak. The limestone is thinly to medium bedded, fresh, and strong to very strong.

The RQD values measured on the recovered bedrock core samples typically ranged from about 40 to 100 percent, indicating poor to excellent quality rock.

Laboratory unconfined compressive strength testing was carried out on selected specimens of the bedrock core from Boreholes 17-02, 17-03, 17-108 and 17-111. The results of the testing indicate unconfined compressive strengths ranging from about 80 to 103 MPa, which correspond to strong to very strong rock. The results of the testing are shown on Figure B15 in Appendix B. Photographs of the bedrock core are also presented in Appendix B.

#### 4.3.9 Groundwater

The groundwater levels measured in the piezometer in Borehole 17-112 is summarized in the table below:

Borehole	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
17-112	47.5	0.5	47.0	May 26, 2017
		0.5	47.0	July 29, 2017

The water levels measured at the Raisin River during the field investigations are summarized below:

Date	River Surface Elevation (m)
December 1957 and January 1958	46.4-46.6 <sup>1</sup>
May, 2017	46.6

**Notes:**

1. Surface of the ice during the investigation in 1957/1958

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.



## 4.4 Corrosion and Cement Type Testing

Samples of soil from one borehole at each foundation element (i.e., Boreholes 17-02, 17-03, 17-06, 17-07, 17-106, 17-108, 17-109 and 17-111) were submitted to Eurofins for basic chemical analysis related to potential corrosion of buried steel elements and potential sulphate attack on buried concrete elements. The results of this testing are provided in Appendix B and are summarized below.

Borehole and Sample Number	pH	SO <sub>4</sub> (%)	Chloride (%)	Resistivity (ohm-cm)	Sulphides (ug/g)
17-02B Sample #3	8.8	<0.01	<0.002	8330	5
17-03B Sample #4	8.8	0.05	0.008	1490	2
17-06B Sample #5	8.1	0.06	0.005	1190	2
17-07B Sample #4	8.0	0.06	0.004	1240	4
17-106 Sample #4	8.1	<0.01	0.042	662	4
17-108 Sample #3	7.3	0.13	0.066	500	6
17-109 Sample #2	8.6	<0.01	0.028	1150	3
17-111 Sample #4	9.1	<0.01	0.017	1050	2

## 5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Kim Lesage, P.Eng. and Mr. Matt Kennedy, P.Eng. It was reviewed by Mr. Michael Snow, P.Eng., a Principal and senior geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., the Designated MTO Foundations Contact for this assignment, conducted an independent quality review of this report.

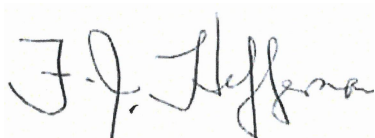
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**PART B**

Foundation Design Report  
Replacement of Raisin River Bridges  
Structure Sties No. 31-231/1&2  
Highway 401, Lancaster, Ontario  
GWP 4013-11-00

## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the existing Raisin River bridges on Highway 401. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives to carry out the detail design of the foundations for the replacement structure. It is understood that the bridge is to be designed in accordance with the current Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC). In accordance with Section 4.4.2 of the CHBDC, we understand that the proposed bridge structure has an importance category of *major route* bridge.

Where comments are made on construction, they are provided to highlight those aspects that could affect the detail design of the project, and for which special provisions may be required in the contract documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, and scheduling.

It is understood that the existing structures are to be replaced with bridges that each have 2 lanes plus a speed change lane, with substructures designed for three lanes plus a speed change lane, along the same alignment. The bridge decks and approach embankments are to be widened to the north and south of the existing westbound and eastbound structures, respectively. A slight grade raise, of up to approximately 500 mm, is proposed for the approach embankments.

### 6.1 Seismic Design

#### 6.1.1 Seismic Site Classification

Vertical Seismic Profiling (VSP) geophysical testing was carried out near the east and west abutment areas (one on each side of the river) to evaluate the average shear wave velocity of the upper 30 m of soil at the site. The shear wave velocities measured are presented in a technical memorandum (see results in Appendix D) and indicate that the average shear wave velocity in the upper 30 m of the subsurface stratigraphy is about 287 m/s at Borehole 17-108 on the west side of the river and about 689 m/s at Borehole 17-109 on the east side of the river. The measured shear wave velocity in the upper 30 m below the proposed foundations is about 350 m/s at Borehole 17-108 on the west side of the river and about 825 m/s at Borehole 17-109 on the east side of the river. Based on the shear wave velocities measured at the site, a Site Class D designation would be appropriate.

However, table 4.1 of the CHBDC specifies circumstances for which a Site Class of F is applicable and a site-specific response evaluation must be carried out; the presence of more than 3 m of peat and/or highly organic clays greater than 3 m thick is one of those conditions, as is the presence of liquefiable soils. During the preliminary design stage, the liquefaction potential at the site was assessed using the “simplified” method outlined in the CHBDC. The results of the simplified liquefaction analyses indicated that there were potentially liquefiable soil strata present at all proposed foundation elements. Therefore, site-specific ground response analyses were carried out to better define the liquefaction potential at the site and to develop a site-specific design spectrum.

The site-specific ground response analysis methodology, and the site-specific design spectrum that was developed based on the results of the analyses, are described in further detail below in Section 6.1.3.

### 6.1.2 Spectral Response Values and Seismic Performance Category

In accordance with Section 4.4.3.1 of the CHBDC and based on the location of the bridge (latitude 45.132 and longitude 74.505), the following are the reference Site Class C (reference) peak seismic hazard values based on the 5<sup>th</sup> generation seismic hazard maps published by the GSC.

**Seismic Hazard Values for Reference Ground Condition Site Class C**

Seismic Hazard Values	10% Exceedance in 50 years (475-year return period)	5% Exceedance in 50 years (975-year return period)	2% Exceedance in 50 years (2,475 return period)
<b>PGA (g)</b>	0.138	0.223	0.379
<b>PGV (m/s)</b>	0.085	0.143	0.258
<b>Sa (0.2) (g)</b>	0.215	0.346	0.596
<b>Sa (0.5) (g)</b>	0.111	0.180	0.313
<b>Sa (1.0) (g)</b>	0.053	0.085	0.150
<b>Sa (2.0) (g)</b>	0.024	0.039	0.069
<b>Sa (5.0) (g)</b>	0.0054	0.0095	0.018
<b>Sa (10.0) (g)</b>	0.0021	0.0035	0.0061

The values given above are for the reference ground condition Site Class C and must be modified for other seismic site classifications, in accordance with Section 4.4.3.3 of the CHBDC. For comparison purposes, the Site Class D seismic hazard values are presented in the table below. As indicated in Section 4.4.3.3 of the CHBDC the value of  $PGA_{ref}$  for use with Tables 4.2 to 4.9 were taken as 80 percent of the PGA for Site Class C where  $Sa(0.2)/PGA$  is less than 2.0. Based on this requirement a  $PGA_{ref}$  values of 0.303, 0.178 and 0.110 for the 2,475, 975 and 475 year return periods, respectively, were used.

**Seismic Hazard Values for Reference Ground Condition Site Class D**

Seismic Hazard Values	10% Exceedance in 50 years (475-year return period)	5% Exceedance in 50 years (975-year return period)	2% Exceedance in 50 years (2,475 return period)
<b>PGA (g)</b>	0.175	0.254	0.374
<b>PGV (m/s)</b>	0.124	0.191	0.309
<b>S(0.2) (g)</b>	0.263	0.388	0.595
<b>S(0.5) (g)</b>	0.161	0.241	0.375
<b>S(1.0) (g)</b>	0.081	0.121	0.196
<b>S(2.0) (g)</b>	0.037	0.057	0.094
<b>S(5.0) (g)</b>	0.008	0.014	0.025
<b>S(10.0) (g)</b>	0.003	0.005	0.008

It is understood that the fundamental period of the structure will be less than 0.5 s, which, in consideration of its *major route* importance category and the site-specific seismic hazard values given above, would indicate that the bridge structure falls in Seismic Performance Category 3 in accordance with Table 4.10 of the CHBDC. Based on this Seismic Performance Category and the *regular* geometry of the bridge, it is understood that the structure will be designed using a “force-based approach” as defined in the CHBDC, however the Regulatory Authority may require a “performance-based approach”.

### 6.1.3 Site-Specific Ground Response Analyses

The site-specific seismic assessment was carried out to model the dynamic ground response at the site as input to the updated liquefaction assessment and to develop site-specific design spectra, as required. The assessment was based on the ground motion hazard parameters defined in Section 6.1.2. Further details on the development of the spectrum-compatible input acceleration time histories, and the one-dimensional ground response analyses are included in the following sections.

#### 6.1.3.1 Spectrum-Compatible Time Histories

The CHBDC describes two approaches to scaling input time histories to match a target spectrum: linear scaling and spectral matching. Linear scaling involves simply scaling the ordinates of the record to achieve the best fit to the target response spectrum over the period range of interest. Linear scaling provides input time histories that are more representative of the original records of ground shaking (i.e. less modification), but can be difficult to match the target spectrum over a large period range. Spectral matching involves changing the frequency and phase contents of the record to match the target spectrum. Spectral matching allows for development of input records that provide a closer match to the target spectrum over a broad range of periods, but involves more modification of the original records since no real earthquake spectrum will match the entire target spectrum.

The target spectra used to scale the input time histories was developed using the 5<sup>th</sup> generation seismic hazard values given in Section 6.1.2 for Site Class C and modified to the site-specific seismic site classification of Site Class B, representative of the bedrock conditions in accordance with Section 4.4.3.3 of the CHBDC.

#### Target Seismic Hazard Values for Ground Motion Scaling for Site Class B (bedrock)

Seismic Hazard Values	10% Exceedance in 50 years (475-year return period)	5% Exceedance in 50 years (975-year return period)	2% Exceedance in 50 years (2,475 return period)
PGA (g)	0.120	0.194	0.330
PGV (m/s)	0.057	0.096	0.173
Sa (0.2) (g)	0.166	0.266	0.459
Sa (0.5) (g)	0.072	0.117	0.203
Sa (1.0) (g)	0.033	0.054	0.095
Sa (2.0) (g)	0.015	0.025	0.043
Sa (5.0) (g)	0.003	0.006	0.012
Sa (10.0) (g)	0.001	0.002	0.003

Both linearly-scaled and spectrally matched time histories were used in the site-specific ground response analysis to develop the minimum of 11 sets horizontal ground motions as required by Section 4.4.3.6 of the CHBDC.

As part of site-specific ground response analyses previously carried out at a site with a similar seismic hazard, orthogonal pairs of records from five earthquakes retrieved from the Pacific Earthquake Engineering Research (PEER) Center NGA-West2 database were spectrally matched to a target spectrum for Site Class B ground motions similar to that at the Raisin River bridges site. An additional five simulated time histories were selected from the Engineering Seismology Toolbox (EST) database as outlined in Section C4.4.3.6 of the Commentary to the CHBDC. All time histories were then linearly scaled to achieve the best fit to the Site Class B target response spectrum for the site.

A summary of the earthquake records used in the site-specific ground response analyses for each design earthquake are provided in the tables below. Plots of the Site Class B scaled spectral accelerations of the input time histories, along with the target Site Class B spectra, for each of the 2,475-year and 975-year design earthquakes are shown on Figures E1 and E2, respectively, in Appendix E.

#### Summary of Input Time History Earthquake Events

Database	Event Name	Event Year	Station / Suite Name	Mag.	Dist. (km)	Scaling Method
PEER	San Fernando	1971	Lake Hughes #4 (H1)	6.6	19.5	Spectral Matching
PEER	San Fernando	1971	Lake Hughes #4 (H2)	6.6	19.5	Spectral Matching
PEER	N. Palm Springs	1986	Winchester Bergman (H1)	6.1	48.9	Spectral Matching
PEER	N. Palm Springs	1986	Winchester Bergman (H2)	6.1	48.9	Spectral Matching
PEER	Coyote Lake	1979	Gilroy Array #1 (H1)	5.7	10.2	Spectral Matching
PEER	Coyote Lake	1979	Gilroy Array #1 (H2)	5.7	10.2	Spectral Matching
PEER	Northridge	1994	LA - Wonderland Ave (H1)	6.7	15.1	Spectral Matching
PEER	Northridge	1994	LA – Wonderland Ave (H2)	6.7	15.1	Spectral Matching
PEER	Nahanni	1985	Site 3 (H1)	6.8	4.9	Spectral Matching
PEER	Nahanni	1985	Site 3 (H2)	6.8	4.9	Spectral Matching
EST	Motion #09	-	East6a2 Suite	6.0	16.9	Linear Scaling
EST	Motion #11	-	East6a2 Suite	6.0	21.1	Linear Scaling
EST	Motion #22	-	East6a2 Suite	6.0	26.1	Linear Scaling
EST	Motion #35	-	East6a2 Suite	6.0	24.8	Linear Scaling
EST	Motion #36	-	East6a2 Suite	6.0	24.8	Linear Scaling

#### 6.1.3.2 One-Dimensional Ground Response Analyses

One-dimensional ground response analyses were undertaken to assess the ground response at the site. Two stratigraphic profiles were selected for analysis: a “stiffer” profile that is representative of the ground conditions at the abutments and a “softer” profile representative of the ground conditions in the river at the pier locations. The ground response analyses were carried out for each of the two profiles, for each of the 2,475-year and 975-year design earthquakes.

Based on the results of the field investigation, and an average shear wave velocity of 1,000 m/s for the bedrock, representative index properties and shear wave velocity variations of overburden soil and rock encountered were developed for each design soil profile, and are summarized in the table below.

#### Summary of Representative Stratigraphy and Material Properties

Soil Unit	$\gamma$ (kN/m <sup>3</sup> )	Abutment Profile		Pier Profile	
		Depth (m)	$V_s$ (m/s)	Depth (m)	$V_s$ (m/s)
Granular Fill	18	0 – 2.3	150 – 190	-	-
Sand and Gravel	20	-	-	0 – 4.4	150
Silty Sand	18	-	-	4.4 – 5.3	115 – 135
Silty Clay	16	2.3 – 3.3	205 – 220	5.3 – 5.9	100
Glacial Till	22	3.3 – 15.6	250 – 720	5.9 – 9.3	135 – 200
Bedrock	26	> 15.6	1,000	> 9.3	1,000

Where required for analysis, the small-strain shear modulus ( $G_{\max}$ ) for the site soils encountered within the depth of investigation were estimated using the site-specific shear wave velocity ( $V_s$ ) measurements obtained from the results of the VSP testing. The values of  $G_{\max}$  and  $V_s$  are related through the following expression:

$$G_{\max} = \rho (V_s)^2, \text{ where } \rho = \text{material density.}$$

### 6.1.3.3 *Shake Analysis Models*

The one-dimensional soil columns and soil parameters described above were used for the ground response analyses. For all soil columns, the input motions established for the site were applied at the top of the bedrock as outcropping motions to account for the overburden effects. All ground response analyses were carried out using the software Shake2000 (Version 99.99.93, released June 2015, part of the Professional Suite of ground response software by GeoMotions, LLC).

The modulus reduction and damping verses shear strain curves used for the main soil strata are as follows:

- Granular Fill: Seed and Idriss (1970) average curves for shear modulus and damping;
- Sand and Gravel: Seed and Idriss (1970) average curves for shear modulus and damping;
- Silty Sand: Seed and Idriss (1970) average curves for shear modulus and damping;
- Silty Clay: Vucetic and Dobry (1991) for  $I_p = 30\%$ ;
- Glacial Till: Vucetic and Dobry (1991) for  $I_p = 30\%$ ; and,
- Bedrock: EPRI, 1993.

### 6.1.3.4 *Analysis Results*

The ground response analyses were carried out to quantify the site-specific ground response to develop a site-specific design spectrum, as well as input to the updated liquefaction assessment.

The acceleration time histories at the ground surface were obtained from the site-specific ground response analyses. The averages of the time history response spectra at the ground surface for the profile modeled at the pier location, the profile modeled at the abutment location, and the geomean of both profiles combined (to provide an average, representative response spectrum for the overall site) are shown on Figures E3 and E4 for the 2,475-year and 975-year design earthquakes, respectively. Based on the average site response, recommended site-specific response spectra were developed for the 2,475-year and 975-year design earthquakes and are included on Figures E3 and E4, respectively. For comparison, the average modeled time history spectra are plotted relative to the Site Class D design response spectrum defined in the CHBDC, along with the recommended design spectra.

The Cyclic Stress Ratio (CSR) values with depth were calculated as part of the site-specific ground response analyses and used in the updated liquefaction assessment described below.

## 6.1.4 *Liquefaction Assessment*

Liquefaction is a phenomenon whereby seismically-induced shaking generates shear stresses within the soil under undrained conditions. These stresses tend to densify the soil (i.e., leading to potentially large surface settlements) and under undrained conditions generate excess pore pressures. The excess pore pressures also lead to sudden temporary losses in strength. Where existing static shear stresses are present, the loss of strength can lead to significant lateral movements (i.e., analogous to a slope failure) often referred to as “lateral spreading”

or under certain conditions even catastrophic failure of the slope often referred to as “flow slides”. Lateral spreading and flow slides often accompany liquefaction along rivers and other shorelines.

The liquefaction susceptibility of organic and granular soils was evaluated by comparing the penetration resistance required to trigger liquefaction with the available penetration resistance. Liquefaction is predicted to occur when the available penetration resistance is less than the resistance required.

The methodology used to assess liquefaction potential at the site is consistent with that presented in the CHBDC Commentary. It involves comparing the cyclic shear stresses applied to the soil by the design earthquake, represented as the cyclic stress ratio (CSR), to the cyclic shear strength, represented as the cyclic resistance ratio (CRR) provided by the soil. The site-specific CSR values with depth for each design earthquake were calculated as part of the ground-response analyses.

The liquefaction analysis was carried out using the in-situ testing data collected at all of the borehole locations. The design groundwater level was determined based on the measured groundwater level in the monitoring wells installed in Boreholes 17-105 and 17-112. The CRR with depth was calculated at each borehole location using the parameter,  $(N_1)_{60cs}$ , that is based on the SPT N blow counts obtained in the field and corrected for overburden stress, rod length during sampling, hammer energy efficiencies, and fines content. A summary of the calculated CSR and CRR values are presented on Figures E5 to E18 in Appendix E, and present both the “simplified” CSR profiles, calculated based on the “simplified” methodology outlined in the CHBDC using an estimate of the ground surface response, and the site-specific CSR profiles, based on the ground response analyses carried out using the program, Shake2000. The liquefaction analyses were carried out assuming that the undersides of pile caps at the abutments and piers would be at about Elevations 46.1 m and 41.9 m, respectively.

The results of the updated liquefaction analyses indicate that isolated and discontinuous areas of the glacial till were potentially liquefiable under the 2,475-year ground motions. These included two SPTs carried out in the upper portion of the till at borehole 17-05, and one SPT carried out in borehole 17-111. Review of the nearby GEOCREs boreholes and the liquefaction analyses at current boreholes put down in between 17-05 and 17-111 indicate no adjacent inferred potential for liquefaction.

Further, the results of the updated liquefaction analyses indicate that similarly isolated and discontinuous layers of the sand and gravel deposits underlying the river bed are potentially liquefiable under the 2,475-year ground motions. These included three SPTs in borehole 17-01 and three SPTs in borehole 17-107.

Based on the limited and isolated extent of potentially liquefiable zones in the sands and gravels or glacial till during the 2,475-year design earthquake, liquefaction is *not* considered to have a significant influence on the overall site response and is not expected to develop liquefaction-induced settlements. However, the behaviour of the soil under cyclic loading is complex and it is recommended that a post-seismic strength reduced by 25% in these localized, potentially liquefiable zones be considered in design to account for potential cyclic softening.

### 6.1.5 Seismic Loading on Abutment Walls

Section C4.6.4 of the Commentary to the CHBDC provides guidance on appropriate methods to represent the backfill passive pressure force resisting movement at the abutments during seismic loading. For vertical bridge abutment walls up to about 1.7 m high, a spring stiffness based on the near-field conditions immediately behind the abutment wall is recommended (Caltrans, 2013). For abutment walls that are taller than 1.7 m, consideration of the influence of the far field conditions on the backfill stiffness is recommended (Carvajal, 2011). It is



understood that the proposed abutment walls at the Raisin River site will be about 4.5 m high (from underside of approach slab to the underside of the abutment “pile cap”).

An evaluation of methods was previously carried out at a nearby, similar highway overpass site comparing the Carvajal approach (near-field + far field), a limit equilibrium approach (Mononobe-Okabe), and Caltrans (2013) to a Soil Structure Interaction model of the bridge and abutments. The results of that evaluation indicated that the force vs. displacement was best represented by the Carvajal approach (near field + far field), followed by the Caltrans approach.

However, the Carvajal approach considers that the bridge abutment is within an embankment of finite length and height above the existing ground surface (i.e. a typical highway underpass bridge that goes “up and over” the relatively level highway alignment). At the Raisin River site, the river valley is below the general ground surface elevation and highway grade, resulting in embankments that may be considered to have negligible height and, therefore, the far-field response calculated as part of the Carvajal methodology is not considered applicable.

Based on the results of the methodological evaluation carried out at a nearby site, and the geometry of the Raisin River site, it is recommended that the Caltrans approach be considered to represent the soil reaction at the abutments using the relationship below. The soil spring should be applied at mid-height of the wall.

$$K = (K_i)(w)(h)/1.7$$

Where: K is the soil stiffness (kN/mm, up to a maximum passive pressure of 239 kPa);

$K_i$  is the initial soil stiffness (taken as 29 kN/mm per metre width);

w is the effective width of the pile cap (taken as 20 m); and,

h is the embedded height of pile cap (taken as 4.5 m).

## 6.2 Existing Foundations

Each of the existing twin bridges consists of a two-lane, three-span structure that was originally constructed in 1958. The middle span is about 24.4 m long, and the two outer spans are about 16.8 m long. The width of the bridge deck of each twin structure is about 11.1 m wide. Based on the original General Arrangement drawings, dated April 30, 1958 (Drawings TWP #32-231-1A and TWP #32-231-1B), the piers, abutments and wingwalls are founded on driven steel H-piles, size HP250 x 63 (BP 10 x 42), driven to a design capacity of 445 kN (i.e., 50 tons).

Because the existing piles were driven to a much lower capacity than what the new piles will have (even if the new piles hang up in the glacial till as discussed further in Section 6.3.3.2) the existing piles will not be suitable for support of the new structures.

There is some risk associated with extraction of existing piles because the integrity of the existing piles is unknown, which may result in the piles breaking during extraction. In addition, the method the contractor will use for extraction is also unknown, which could impact the state of compaction and/or strength of the surrounding soils and reduce the lateral soil resistance, particularly where cobbles and boulders surround the existing piles.

The new foundations will likely be driven to a lower elevation than the current piles and therefore the risk of pile extraction impacting the axial capacity is low. The current design considers these risks and the layout of the new foundations is generally planned to minimize the need for pile extraction.



### 6.3 Foundation Options for Replacement Structures

It is understood that the preferred alternative for the proposed replacement consists of twin three-span structures on the same highway alignment, with a bridge deck width increase of about 6 m at each structure to accommodate four lanes and one speed change lane at each structure (i.e., a total of four lanes plus two speed change lanes across both structures for a total bridge deck width increase of about 12 m). The new bridge substructure widths will be increased by about 10 m at each bridge to accommodate an additional lane in the future. The new bridge structures are to have slightly longer span lengths than the existing, with the new abutments constructed behind the footprints of the existing abutments, one pier per structure constructed in the existing pier location and one pier per structure offset approximately 3 m from the existing pier location. The proposed Highway 401 pavement grades at the new structure will be up to about 500 mm higher than the existing pavement grades.

Based on the subsurface conditions at the site, several foundation options have been considered for the replacement of the Raisin River Bridges. A summary of the advantages and disadvantages associated with each option is provided below, and a comparison of the alternative foundation options based on advantages, disadvantages, risks and approximate costs is provided in Table 1 following the text of this report.

- **Shallow foundations (spread/strip footings):** Shallow foundations are not considered suitable for this site due to the presence of low strength, compressible clay and organic soils within 10 m of the ground surface or within 5 m of the river bed surface. In addition, the very loose to loose glacial till and granular deposits at depth are expected to provide relatively low bearing resistances. For these reasons, shallow foundations are considered unsuitable for this site.
- **Driven steel piles:** Driven steel H-piles driven to refusal on bedrock is considered feasible for this site for support of the piers and abutment. This option would provide high geotechnical resistances and minimal post-construction settlements. The existing structure is supported on driven steel H-piles and this foundation system has performed adequately to date. Some of the piles could have difficulty penetrating through cobbles and/or boulders in the glacial till. This option would also require construction of pier pile caps in the water, inside a cofferdam (which is anticipated to be challenging) or above the water level.
- **Driven steel pipe (tube) piles:** Closed-ended steel tube (pipe) piles could also be considered as a deep foundation option for support of the abutments and central pier. This foundation option would have similar advantages to steel H-piles in terms of high geotechnical resistances and minimal settlements. Cobbles and/or boulders were encountered at the borehole locations. Pipe piles are considered to have a higher risk than H-piles for “hanging up” or being deflected away from their vertical or battered orientation if cobbles and/or boulders are encountered within the till deposit during driving. Construction of a pile cap for this type of foundation may be challenging at the pier locations due to dewatering and temporary protection requirements.
- **Concrete caissons:** Caissons deriving their support from bearing within the bedrock are also feasible for this site. Their key advantage lies in the fact that the structure columns could be designed at each caisson to eliminate the need for caisson cap construction, thereby minimizing the need for cofferdams and minimizing environmental impacts at the pier locations. Caissons would require the use of temporary or permanent liners to mitigate the potential risks of ground loss from potential water-bearing cohesionless soil layers during construction. In addition, the caissons would have to be socketed at least nominally into the bedrock

to permit cleaning of the caisson bases, and such sockets would have to be advanced by rock coring and/or chisel drilling into the strong to very strong bedrock.

- **Drilled Steel Casings:** Deep foundations consisting of drilled steel casings socketed into bedrock are feasible for support of the replacement bridge structure. These larger diameter installations (in the order of 450 to 750 mm diameter) can handle obstructions within the glacial till and granular deposits at depth and penetrate the strong bedrock. In addition, this type of steel casing is suitable for abrasive and stepped bedrock. Construction of a pile cap for this type of foundation may be challenging at the pier locations; similar to piles and micropiles as described above.

Based on the above considerations, the preferred option from a geotechnical/foundations perspective would be to support the abutments and piers on steel H-piles driven to found on the bedrock or to meet refusal on boulders within the till.

The piles or casings for the new abutments and piers may need to be driven in close proximity to the piles supporting the existing structures. Where new piles/casings may be in proximity to existing piles, consideration should be given to installing the new piles/caissons either in front of, behind or adjacent to (or in between) the existing piles following removal of the existing pile cap and exposure of the existing piles. Consideration could also be given to extracting the existing piles that are in conflict with the new foundations. However, as discussed in Section 6.2, it is recommended to minimize the extraction of piles where possible.

### 6.3.1 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the Canadian Highway Bridge Design Code (CHBDC version S6-14) and its Commentary, a classification of 'typical' consequence has been assumed for this site. This consequence classification should be confirmed by Dillon in consultation with the MTO.

The degree of understanding, based on the scope of the foundation investigation and proximity of the boreholes to the structure, is considered 'typical' as described in Clause 6.5.3.2 of the 2014 CHBDC. The appropriate Ultimate Limit States (ULS) and Serviceability Limit States (SLS) consequence factors,  $\Psi$ , geotechnical resistance factors at ULS ( $\phi_{gu}$ ) and SLS ( $\phi_{gs}$ ), respectively, from Tables 6.1 and 6.2 of the CHBDC should be used for design.

### 6.3.2 Feasibility of Integral and Semi-Integral Abutments

As outlined in MTO's report SO-96-01, integral abutment bridges are single span or multiple span continuous deck type bridges with a movement system composed primarily of abutments on flexible integral foundations and approach slabs, in lieu of movable deck expansion joints and bearings at abutments. The feasibility of integral abutments is influenced by a number of factors considering geometry and subsurface conditions. The primary criterion is the need to support the abutments on relatively flexible piles. Where the load bearing stratum is near the surface or where the use of short piles or caissons (less than 5 m in length) is planned, the site is not considered suitable for integral abutment bridges. Geometric constraints on the use of integral abutments are also applicable and include: overall bridge length less than 150 m; skew angle less than 35°; and abutment wall heights less than 6 m without a retained soil system.

Section 6.17.3.1 of the CHBDC also indicates that integral abutments shall not be used where the soils are susceptible to liquefaction. As outlined in Section 6.1.4, isolated and discontinuous areas at this site are potentially liquefiable but are *not* considered to have a significant influence on the overall site response or foundation performance. As such, an integral abutment arrangement using a deep foundation option described

above is considered feasible at this site since the flexible pile-supported abutment foundations would meet MTO's foundation criteria for integral abutments.

### 6.3.3 Driven Steel H-Pile or Steel Pipe Foundations

The abutments and piers for the replacement structure may be supported on steel H-piles or closed-ended steel pipe piles driven to refusal on the bedrock. Pipe piles would however have a higher risk than H-piles for "hanging up" on cobbles and boulders or being deflected away from their vertical or battered orientation, and therefore H-piles would be preferred at this site.

Pile installation should be in accordance with OPSS.PROV 903 (*Deep Foundations*).

#### 6.3.3.1 Founding Elevations

Based on the borehole results from the investigation, the bedrock elevations provided in the table below are recommended for design of steel H-piles or pipe piles. A review of the Record of Boreholes for the current and 1957/1958 investigations reveal that there may be nests of cobbles or boulders within the glacial till above the overburden/bedrock interface that could impede the advance of driven piles. Reference should also be made to the interpreted stratigraphic cross-sections provided for each of the foundation elements on Drawings 2, 3, 5 and 6 to assess the variability in pile length along the foundation unit.

Foundation Element	Borehole Numbers	Bedrock Surface Elevation, as Cored (m)	Reference Drawing No.
<b>Eastbound Structure, Site No. 31-231/1</b>			
West Abutment	17-107, 17-108 & 3IG-143: 2 & 3	37.3 to 40.0	5
West Pier	17-01, 17-02 & 3IG-143: 5 & 6	37.3 to 38.8	5
East Pier	17-03, 17-04 & 3IG-143: 8 & 9	36.4 to 38.4	6
East Abutment	17-111, 17-112 & 3IG-143: 11 & 12	34.7 to 34.8	6
<b>Westbound Structure, Site No. 31-231/2</b>			
West Abutment	17-105, 17-106 & 3IG-143: 1 & 2	36.9 to 37.3	2
West Pier	17-05, 17-06 & 3IG-143: 4 & 5	34.9 to 37.0	2
East Pier	17-07, 17-08 & 3IG-143: 7 & 8	35.1 to 37.9	3
East Abutment	17-109, 17-110 & 3IG-143: 10 & 11	34.4 to 34.7	3

If socketing the piles into bedrock is required for axial resistance considerations, the use of temporary liners would be necessary to maintain an open hole through the embankment fill and overburden soils during bedrock socket formation.

The abutment pile caps should be constructed at a minimum depth of 1.7 m below the ground surface for frost protection purposes, per OPSPD 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*).

Cobbles and boulders are expected in the till deposits. Therefore, each pile should be reinforced at the tip with suitable driving points (such as Titus Standard 'H' Points for H-piles or Titus Open Cutting Shoe for pipe piles, or equivalent) to reduce the potential for damage to the piles during driving through soils that may contain boulders, in accordance with OPSS.PROV 903 (*Deep Foundations*). For steel pipe piles the driving shoes should be in accordance with OPSPD 3001.100 Type II (*Steel Tube Pile Driving Shoe*).

The borehole logs indicate that there are dense to very dense portions of the glacial till, generally below about Elevation 40 metres, when encountered. Most of the boreholes did penetrate these zones by augering, requiring diamond drill coring in a few locations. Steel H-piles reinforced at the tip with a driving shoe (as recommended above) should penetrate these layers; however, it is recommended that a contingency item be provided to pre-auger, if needed. The auger size should be chosen to loosen the soil within a diameter smaller than the size of the pile. For example, pre-augering for a 310x110 H-pile should be carried out using an auger with a cutting diameter no larger than about 300 mm. The loosened soil is to be left in place following augering.

Vibration monitoring should be carried out during pile installation to ensure that the vibration levels at the adjacent bridge structure are maintained below tolerable levels. Further discussion of the recommended vibration monitoring requirements is included in Section 6.6.3.

### **6.3.3.2 Axial Geotechnical Resistance/Reaction**

For design of HP 310x110 piles driven to found on the dolostone or limestone bedrock at the estimated tip elevations provided in Section 6.3.3.1, the factored axial geotechnical resistance at Ultimate Limit States (ULS) may be taken as 2,000 kN, which considers the structural limitations of the H-pile. Serviceability Limit States (SLS) resistances do not apply to piles founded on bedrock, since the SLS resistance for 25 mm of settlement is greater than the factored axial geotechnical resistance at ULS. The same axial resistances may be used in the design of closed-end, concrete-filled, 324 mm diameter steel pipe piles having a minimum wall thickness of 13 mm.

There is the potential for piles to meet refusal on boulders within the till. For piles meeting resistance in the glacial till overburden near the bedrock surface, the factored axial geotechnical resistance at ULS should be taken as 1,600 kN. The axial resistance at SLS for 25 millimetres of settlement would likely be in the order of 1,300 kN. Should this situation occur, of a reduced capacity needing to be used, additional piles could be driven to achieve the required combined overall foundation capacity. Consideration could also be given to using this lower capacity for general design purposes, and thereby limit the potential need for additional piles should refusal in the till occur during construction.

For piles driven to refusal on bedrock, it is a generally accepted practice to reduce the hammer energy after abrupt peaking is met on the bedrock surface, and to then gradually increase the energy over a series of blows to seat the pile.

### **6.3.3.3 Downdrag Load and Uplift Resistance**

Downdrag forces on the piles at this site could be generated from either of the following:

- The grade raise and widening of the embankments which will raise the effective stress level in the underlying silty clay to clay; and,
- The grade raise and widening of the embankments which would lead to compression of the very loose to loose existing embankment fill, organic materials and till layers.

As discussed further in Section 6.5.3, the proposed grade raise and widening of the embankments is not expected to overstress the clay deposit encountered at the site. Where organic soils are present at the west abutments, the proposed underside of pile cap elevations (i.e. Elevation 46.1 m) are below the overlying soil (i.e. within the organic deposit) and therefore the soil above the compressible organic deposit will not impose any downdrag loads on the abutment piles. Downdrag loads are expected to be negligible at the piers, where no grade raise is proposed.

The site soils will provide uplift resistance to the piles. The factored uplift of a single HP 310x110 pile may be taken as 35 kN at the west piers, and 30 kN at the east piers.

#### 6.3.3.4 Lateral Geotechnical Resistance

The ULS *geotechnical* resistance to lateral loading may be calculated using passive earth pressure theory as outlined in Section C6.11.2.2.1 of the *Commentary to the CHBDC*.

The ULS lateral resistance of a pile group may be estimated as the sum of the individual pile resistances across the face of the pile group, perpendicular to the direction of the applied lateral force, and to a depth of six pile diameters below the underside of the pile cap.

The ULS resistances obtained using the above parameters represent unfactored values; in accordance with Section 6.9.1 of the CHBDC, a resistance factor of 0.5 is to be applied in calculating the horizontal resistance under static loading conditions.

#### 6.3.3.5 Lateral Soil-Structure Interaction Springs

An assessment of the lateral performance of the proposed bridge abutments and pier foundations may be carried out considering the effects of lateral loading on the structure. The lateral response of the pile foundations can be analysed considering the soil-structure interaction between the pile(s) and the surrounding soils using the load transfer method. From a geotechnical perspective, the lateral load-displacement behaviour of the soils can be modeled using P-y curves (CFEM, 2006).

P-y curves representing the non-linear response of the soils and bedrock under lateral loading from the pile foundations have been generated using the commercially available program LPILE (version 2016) produced by ENSOFT Inc. The P-y curves have been calculated considering both static and cyclic loading options for the lateral soil models. The strength of localized soil zones (See Section 6.1.4) was reduced by 25% to account for cyclic softening under the cyclical loading condition. At the abutments, the strength parameters of the soil in the upper 3 m were modified to represent loose sand within the Corrugated Steel Pipes (CSPs) to be installed with each pile as part of the integral abutment configuration.

The families of static and cyclic P-y curves calculated at 0.5 to 1.0 m depth increments for a single, vertical HP310x110 pile at the abutments and piers are presented in tabular format and shown graphically in the Appendix F.

The ground would provide greater resistance to the lateral deflection of a pile with a larger face width (flange and section depth), such as an HP310x152, resulting in increased stiffness when compared to the response of an HP310x110 pile. The increase in stiffness can be approximated by the percentage increase in face width (i.e. the P-values for an HP310x110 pile could be increased by about 4-5% to provide an approximation of the response of an HP310x152 pile.

The P-y curves presented in Appendix F are for a single pile and do not include any effects of group action. Group action for lateral loading must be considered when the pile spacing in a group in the direction of loading is less than seven (7) pile diameters. These 'Group Effects' can be incorporated into the analysis using a method that modifies the single pile P-y curve(s) by a reduction factor termed a 'P-Multiplier'. Generalized P-Multipliers (or reduction factors) for a range of pile spacing's and loading directions are provided in Section C6.11.3.4 of the CHBDC.

### 6.3.4 Drilled Steel Casings

Alternatively, the abutments and piers for the replacement structures may be supported on drilled steel casings socketed into bedrock.

The drilled steel casings are installed by rotary duplex drilling using a sacrificial ring bit on the bottom of a permanent steel casing. A drag bit using a water or polymer flush (discharging to a storage vessel/tank for off-site disposal) is employed to advance and clean out the casing within the overburden. A DTH hammer utilizing water/surfactant flush (discharging to a storage vessel/tank for off-site disposal) is employed to advance and seat the casing within the rock and also to create an uncased rock socket within the bedrock below the bottom of the casing.

Information from product suppliers indicates that this type of drilling system allows accurate and straight penetration in steeply sloping bedrock surfaces and can also readily penetrate cobbles and boulders. In addition, based on discussions with local piling contractors, this type of system has been successfully used to drill rock sockets in very strong and very steeply sloping (60° to 70°, and in some extreme cases up to 80°) granitic bedrock in northern Ontario.

The permanent steel casing must be embedded at least 1 m below the lowest point of contact with the bedrock surface and a minimum of 1 m into fair quality bedrock, but additional casing embedment length may be required to satisfy the lateral loads on the piers, and also to achieve a proper seal in the bedrock prior to socket construction, if the upper bedrock at the pile location is of poor or very poor quality.

The pile is designed to develop the majority of its axial capacity based on the shear resistance along the rock socket wall (i.e., between the concrete and bedrock interface) rather than on end-bearing at the base of the socket. As such, the requirement to thoroughly clean and inspect the base of the socket will be lessened, however a thorough and proper flushing of the side walls of the rock socket is required. A reinforcing bar cage would have to be lowered through the casing and into the rock socket prior to placement of concrete by tremie methods.

The installation of the drilled steel casings should be in accordance with OPSS.PROV 903 (*Deep Foundations*).

Vibration monitoring should be carried out during casing installation to ensure that the vibration levels at the existing structure are maintained below tolerable levels, in accordance with Section 6.6.3.

#### 6.3.4.1 Founding Elevations

Ultimately, the founding elevation for drilled steel casings will depend on the required depth of rock socket at the abutments and at the piers. The following table summarizes the range in bedrock surface elevation as encountered in the boreholes at/near each of the foundation elements, from which the total length for each drilled steel casing can be assessed based on the required rock socket length. It is noted that reference should also be made to the interpreted stratigraphic cross-sections provided for each of the foundation elements on Drawings 2, 3, 5, and 6, to assess the variability in the founding elevation and length of each caisson along the foundation unit.

Foundation Element	Borehole Numbers	Bedrock Surface Elevation, as Cored (m)	Reference Drawing No.
<b>Eastbound Structure, Site No. 31-231/1</b>			
West Abutment	17-107, 17-108 & 3IG-143: 2 & 3	37.3 to 40.0	5
West Pier	17-01, 17-02 & 3IG-143: 5 & 6	37.3 to 38.8	5



Foundation Element	Borehole Numbers	Bedrock Surface Elevation, as Cored (m)	Reference Drawing No.
East Pier	17-03, 17-04 & 3IG-143: 8 & 9	36.4 to 38.4	6
East Abutment	17-111, 17-112 & 3IG-143: 11 & 12	34.7 to 34.8	6
<b>Westbound Structure, Site No. 31-231/2</b>			
West Abutment	17-105, 17-106 & 3IG-143: 1 & 2	36.9 to 37.3	2
West Pier	17-05, 17-06 & 3IG-143: 4 & 5	34.9 to 37.0	2
East Pier	17-07, 17-08 & 3IG-143: 7 & 8	35.1 to 37.9	3
East Abutment	17-109, 17-111 & 3IG-143: 10 & 11	34.4 to 34.7	3

#### 6.3.4.2 Axial Geotechnical Resistance/Reaction

This foundation type develops its axial capacity based on the shear resistance in the rock socket wall. For design purposes, the factored axial geotechnical resistance at ULS for 600 mm diameter drilled steel casing rock sockets may be taken as 1,700 kN/m length of socket. The ULS resistance considers the RQD values recorded for the bedrock as well as the compressive strength data for the rock core. This value is applicable provided that the socket is within competent bedrock and that the side wall of the socket is cleaned of any smeared material.

Serviceability Limit States (SLS) resistances do not apply to piles socketed in the granitic bedrock, since it is estimated that the SLS resistance for 25 mm of settlement is greater than the factored axial resistance at ULS.

#### 6.3.4.3 Downdrag Load and Uplift Resistance

As discussed in Section 6.3.3.3, downdrag loads are considered to be negligible at the abutment and pier locations. Drilled steel casings would provide uplift resistance based on the shear resistance in the rock socket wall, as described in Section 6.3.4.2. Further details on the factored uplift resistance can be provided, if required.

#### 6.3.4.4 Resistance to Lateral Loads

The resistance to lateral loading developed by the soil in front of the drilled steel casings may be determined as outlined in Section 6.3.3.4. Where higher lateral resistances are required than can be achieved from the overburden soils alone, lateral resistance can be provided by the bedrock sockets.

Further detail on passive resistance of the portion of the foundation element socketed into the bedrock can be provided, if required.

#### 6.3.4.5 Lateral Soil-Structure Interaction Springs

Further detail on lateral soil-structure interaction springs for drilled steel casings can be provided, if required.

### 6.3.5 Concrete Caissons

Support of the replacement bridges may alternatively be provided by drilled concrete caisson foundations extending to or into the bedrock. At the piers in particular, the structure columns could be designed at each

caisson to eliminate the need for pier cap construction; this option would therefore minimize the need for cofferdams at the pier locations and the associated construction challenges and environmental impacts.

Due to the presence of saturated granular layers, temporary or permanent liners would be required for caisson construction through the overburden soils, to minimize ground loss and to provide groundwater control. It may also be necessary to use a rock core barrel to penetrate the glacial till as cobbles and boulders are known to be present in the overburden material just above the bedrock surface. Installation of liners would therefore be difficult and may not be practical at this site.

Caisson installation should be in accordance with OPSS.PROV 903 (*Deep Foundations*).

### 6.3.5.1 Founding Elevations

It is recommended that the caissons be socketed a minimum of 0.5 m into the bedrock to allow for some weathering/fracturing of the upper portion of the bedrock, and to minimize the potential for loss of soils at the soil-bedrock interface during caisson construction. However, deeper sockets may be required to satisfy lateral/seismic loading requirements (as discussed further below). The table below summarizes the range in bedrock surface elevation as encountered in the boreholes at/near each of the foundation elements, from which the founding elevation and total length for each caisson can be assessed. It is noted that reference should also be made to the interpreted stratigraphic cross-sections provided for each of the foundation elements on Drawings 2, 3, 5, and 6, to assess the variability in the founding elevation and length of each caisson along the foundation unit.

Foundation Element	Borehole Numbers	Bedrock Surface Elevation, as Cored (m)	Reference Drawing No.
<b>Eastbound Structure, Site No. 31-231/1</b>			
West Abutment	17-107, 17-108 & 3IG-143: 2 & 3	37.3 to 40.0	5
West Pier	17-01, 17-02 & 3IG-143: 5 & 6	37.3 to 38.8	5
East Pier	17-03, 17-04 & 3IG-143: 8 & 9	36.4 to 38.4	6
East Abutment	17-111, 17-112 & 3IG-143: 11 & 12	34.7 to 34.8	6
<b>Westbound Structure, Site No. 31-231/2</b>			
West Abutment	17-105, 17-106 & 3IG-143: 1 & 2	36.9 to 37.3	2
West Pier	17-05, 17-06 & 3IG-143: 4 & 5	34.9 to 37.0	2
East Pier	17-07, 17-08 & 3IG-143: 7 & 8	35.1 to 37.9	3
East Abutment	17-109, 17-111 & 3IG-143: 10 & 11	34.4 to 34.7	3

Given the ground conditions, it will be difficult to clean the bedrock surface, even with the use of liners, unless the liner is nominally socketed into the bedrock. The casing should be extended so that it is “seated” a minimum of 300 mm into the bedrock. Alternatively, the caisson excavations could be cleaned using methods such as airlifting prior to concreting, and tremie concreting techniques may be required for placing concrete. A minimum caisson diameter of 0.9 m is recommended, to facilitate inspection.

For caissons that are socketed nominally into the bedrock (i.e., approximately 0.5 m), tremie concrete should be placed to further seal the caisson/rock interface on the bedrock surface.



If caisson caps are to be included as part of the design, they should be constructed at a minimum depth of 1.7 m for frost protection purposes, per OPSD 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*).

Similar to pile installation, vibration monitoring should be carried out during caisson installation to ensure that the vibration levels at the existing structure are maintained below tolerable levels. Further discussion of the recommended vibration monitoring requirements is included in Section 6.6.3.

#### **6.3.5.2 Axial Geotechnical Resistance/Reaction**

Caissons socketed at least 0.5 m into the limestone/dolostone bedrock should be designed based on end-bearing resistance, using a factored axial geotechnical resistance at ULS of 8 MPa; for a 0.9 m diameter caisson, this would equate to a factored axial geotechnical resistance at ULS of about 5,000 kN.

End-bearing resistance may be considered in design provided that the base of each caisson is thoroughly cleaned of any cuttings or other material. End bearing for the caisson relies solely on the quality of the rock surface at the base of the excavation. As such, it is imperative that the rock surface be adequately cleaned of loose soils, rock, and debris prior to construction of the caisson.

Serviceability Limit States (SLS) resistances for 25 mm of settlement will not apply to caissons founded within the bedrock at this site, as the required loading would exceed the ULS resistance. SLS resistances do not apply to caissons founded within the limestone bedrock, because the SLS resistance for 25 mm of settlement will be greater than the factored axial geotechnical resistance at ULS.

#### **6.3.5.3 Downdrag Load and Uplift Resistance**

As discussed in Section 6.3.3.3, downdrag loads are considered to be negligible at the abutment and pier locations. Concrete caissons would provide uplift resistance based on the shear resistance in the rock socket wall, as described in Section 6.3.4.2. Further details on the factored uplift resistance can be provided, if required.

#### **6.3.5.4 Resistance to Lateral Loads**

The ULS geotechnical resistance to lateral loading may be calculated using passive earth pressure theory as outlined in Section C6.11.2.2.1 of the Commentary to the CHBDC.

The ULS lateral resistance of a caisson group may be estimated as the sum of the individual caisson resistance across the force of a caisson group, perpendicular to the direction of the applied lateral force.

#### **6.3.5.5 Lateral Soil-Structure Interaction Springs**

Further detail on lateral soil-structure interaction springs for drilled concrete caissons can be provided, if required.

### **6.4 Lateral Earth Pressures for Design**

The lateral earth pressures acting on the abutment walls will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls. Seismic (earthquake) loading must also be taken into account in the design.

The following recommendations are made concerning the design of the walls if granular backfill is used:

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (*Aggregates*) Granular A or Granular B Type II, should be used as backfill behind the walls. Longitudinal drains or weep holes should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target

densities, etc.) should be carried out in accordance with OPSS.PROV 501 (*Compacting*). Other aspects of the granular backfill requirements with respect to sub-drains and frost taper should be in accordance with OPSD 3101.150 (*Walls, Abutment, Backfill, Minimum Granular Requirement*), OPSD 3121.150 (*Walls, Retaining, Backfill, Minimum Granular Requirement*), and 3190.100 (*Walls, Retaining and Abutment, Wall Drain*).

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with CHBDC Section 6.12.3 and Figure 6.6. Care must be taken during the compaction operation not to overstress the wall. Heavy construction equipment should be maintained at a distance of at least 1 m away from the walls while the backfill soils are being placed. Hand-operated compaction equipment should be used to compact the backfill soils within a 1 m wide zone adjacent to the walls. Other surcharge loadings should be accounted for in the design, as required.
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.7 m behind the back of the wall (Case (a) on Figure C6.20 of the *Commentary* to the CHBDC). For unrestrained walls, fill should be placed within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing or pile cap (Case (b) on Figure C6.20 of the *Commentary* to the CHBDC).

#### 6.4.1.1 Static Lateral Earth Pressures for Design

The following guidelines and recommendations are provided regarding the lateral earth pressures for static (i.e., not earthquake) loading conditions. These lateral earth pressures assume that the ground above the wall will be flat, not sloping. If the inclination of the slope above the wall changes then new lateral earth pressures will need to be calculated.

- For Case (a), the pressures are based on the proposed embankment fill and the following parameters (unfactored) may be used assuming the use of earth fill or Select Subgrade Material (SSM):

Material	Earth Fill or SSM
Soil Unit Weight:	19 kN/m <sup>3</sup>
Coefficients of static lateral earth pressure:	
Active, $K_a$	0.33
At rest, $K_o$	0.50

- For Case (b), the pressures are based on using engineered granular fill and the following parameters (unfactored) may be used:

Material	Granular A	Granular B Type II
Soil Unit Weight:	22 kN/m <sup>3</sup>	21 kN/m <sup>3</sup>
Coefficients of static lateral earth pressure:		
Active, $K_a$	0.27	0.27
At rest, $K_o$	0.43	0.43

- If the wall support and superstructure allow lateral yielding, active earth pressures may be used in the geotechnical design of the structure. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as:
  - Rotation of approximately 0.002 about the base of a vertical wall (where the rotation is calculated as the horizontal displacement divided by the height of the wall);
  - Horizontal translation of 0.001 times the height of the wall; or,
  - A combination of both.
- If the wall does not allow lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design.

#### 6.4.1.2 Seismic Lateral Earth Pressures for Design

Seismic (earthquake) loading must be taken into account in the design in accordance with Section 4.6 of the CHBDC. In this regard, the following should be included in the assessment of lateral earth pressures:

- Seismic loading will result in increased lateral earth pressures acting on the wall. The wall should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given in Section 6.4.1.1, above, plus the earthquake-induced dynamic earth pressure.
- In accordance with Sections 4.6.5 and C.4.6.5 of the CHBDC and its *Commentary*, for structures which do not allow lateral yielding, the horizontal seismic coefficient ( $k_h$ ) used in the calculation of the seismic active pressure coefficient is taken as 1.0 times the PGA. For structures which allow lateral yielding, ( $k_h$ ) is taken as 0.5 times the PGA.
- The following seismic active pressure coefficients ( $K_{AE}$ ) for unrestrained walls (in accordance with Section C.4.6.5 of the *Commentary* to the CHBDC) may be used in design; these coefficients reflect the maximum  $K_{AE}$  obtained for each of the earthquake design periods and backfill conditions. It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is flat. Where sloping backfill is present above the top of the wall, the lateral earth pressures under seismic loading conditions should be calculated by treating the weight of the backfill located above the top of the wall as a surcharge.

**Seismic Active Pressure Coefficients,  $K_{AE}$**

	Design Earthquake	Site PGA	Granular A	Granular B Type II	SSM
Yielding Wall	475 Year	0.175	0.32	0.32	0.39
	975 Year	0.254	0.34	0.34	0.42
	2,475 Year	0.374	0.39	0.39	0.46
Non-Yielding Wall	475 Year	0.175	0.38	0.38	0.45
	975 Year	0.254	0.44	0.44	0.52
	2,475 Year	0.374	0.55	0.55	0.66

- The K<sub>AE</sub> value for a yielding wall is applicable provided that the wall can move up to 250PGA mm, where the site specific PGA may be taken from the table above. This corresponds to displacements of 45, 65, and 95 mm for the 475-year, 975-year, and 2,475-year design earthquakes at this site.
- The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e., an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined as follows:

$$\sigma_h(d) = K_a \gamma d + (K_{AE} - K_a) \gamma (H-d), \text{ yielding walls}$$

$$\sigma_h(d) = K_o \gamma d + (K_{AE} - K_a) \gamma (H-d), \text{ non-yielding walls}$$

Where:  $\sigma_h(d)$  is the (static plus seismic) lateral earth pressure at depth,  $d$ , (kPa);

$K_a$  is the static active earth pressure coefficient;

$K_o$  is the static at-rest earth pressure coefficient;

$K_{AE}$  is the seismic active earth pressure coefficient;

$\gamma$  is the unit weight of the backfill soil (kN/m<sup>3</sup>), as given previously;

$d$  is the depth below the top of the wall (m); and,

$H$  is the total height of the wall (m).

## 6.5 Approach Embankments

It is understood that the overall grade of Highway 401 may be raised up to 500 mm to accommodate the new bridge structures and that about a 6 m widening is proposed for both the eastbound (widening to the south) and westbound (widening to the north) structures.

The subsurface conditions at the site are variable from one side of the river to the other, but generally consist of embankment fill and organic deposits underlain by a compressible silty clay to clay over bouldery glacial till underlain by bedrock. The organic deposits were encountered in boreholes on the west side of the river, with the thickest layer (3.1 m) below the existing roadway of the westbound structure, near the west abutment. Silty clay to clay was encountered beneath the fill and/or organic deposits at most of the borehole locations.

### 6.5.1 Subgrade Preparation and Embankment Construction

The topsoil and organic deposits are compressible soils that are expected to experience settlement under increased load. Full removal of the existing embankment and underlying organic deposits would materially reduce the potential for additional settlement of these deposits due to grade raise fill and widening. However, given that these organic soils have been buried beneath the existing fills for almost 60 years, the additional potential compression from these soils is considered to be modest and removal of the organic material is generally not justified. The fill subgrade should nonetheless be proof-rolled to identify any particularly compressible subgrade areas and to compact the remaining soils. However, partial removal of the compressible organic deposit present at the west approach embankment is recommended for acceptable slope stability performance in this area, as discussed further in Section 6.5.2.

It is also recommended that any topsoil present within the footprint of the embankment widening be stripped prior to placement of the new embankment fill. To limit settlements, as discussed further in Section 6.5.3, new embankment fill should consist of Select Subgrade Material with a unit weight of 19 kPa or less.

The new embankment fill associated with the grade raise and widening for the bridge replacement should be placed and compacted in accordance with OPSS.PROV 206 (*Earth Excavation and Grading*) and OPSS.PROV 501 (*Compacting*). Benching of the existing Highway 401 embankment side slopes should be carried out to “key in” the new fill materials in areas where the embankment is widened, in accordance with OPSS 208.010 (*Benching of Earth Slopes*).

To reduce erosion of the embankment side slopes due to surface water runoff, placement of topsoil (*OPSS 802 – Topsoil*) and seeding (*OPSS.PROV 804 – Seed and Cover*) or pegged sod (*OPSS 803 – Sodding*) is recommended as soon as practicable after construction of the embankments.

### 6.5.2 Global Stability

Slopes for the widening are currently planned at 3 horizontal to 1 vertical (3H:1V). Static and seismic slope stability analyses of the embankments with the proposed grade raise and widening were carried out with the commercially available slope stability analysis software, SlopeW (part of the software package, Geo-Studio 2007 Version 7, produced by Geo-Slope International Ltd.), to verify that a minimum factor of safety of 1.3 is achieved under static conditions and 1.1 under seismic conditions. These minimum factors of safety are considered appropriate for the proposed bridge approach embankments, considering the design requirements and the available field and laboratory testing data. A Morgenstern-Price method was used to determine the factor of safety. The analyses were based on the cross sections provided by the design team and the available subsurface information.

The soil and bedrock stratigraphy between the borehole locations is based on our interpretation of the geological conditions of the area and consequently the actual conditions may vary from that used in our model. The soil parameters used in the analyses were based on in situ and laboratory testing data as well as published correlations and are given in the following table:

Soil Stratum	Bulk Unit Weight (kN/m <sup>3</sup> )	Static <sup>1</sup> Effective Friction Angle, $\phi$ (°)	Static <sup>1</sup> Cohesion (kPa)	Static <sup>1</sup> Undrained Shear Strength (kPa)
Existing Embankment Fill	20	30	-	-
New Embankment Fill	19	30	-	-
Organic Deposits	15	26 <sup>2</sup>	-	-
Sand and Gravel	19	30 <sup>2</sup>	-	-
Weathered Silty Clay to Clay	17.5	35	5	60
Grey Silty Clay to Clay	16	31	7.5	40
Glacial Till	21.5	32 <sup>2</sup>	-	-
Bedrock	-	-	-	-

**Notes:**

<sup>1</sup> For pseudo-static analyses  $\tan \phi$  was increased by 10 percent for strain rate effects.

<sup>2</sup> For the post-earthquake analyses residual friction angles of 4° and 7° was used to account for the reduced shear strength of the liquefied organic silt and till/sand and gravel layers, respectively.

Provided that the approach embankment side slopes are maintained no steeper than 3H:1V, and the existing embankment side slopes are benched in accordance with OPSD 208.010 (*Benching of Earth Slopes*), to “key in” any new fill materials placed on the slopes to accommodate the overall grade, the embankments should have an adequate minimum factor of safety of at least 1.3 under static conditions.

The stability of the embankments was also evaluated under seismic loading conditions. The minimum factor of safety value that is typically required against instability during a seismic event is 1.1. A horizontal seismic coefficient of 0.187 (i.e., 50% of the PGA for the 2,475 year event) was used for the pseudo-static analyses. Furthermore, the static soil shear strengths were increased by 10 percent under seismic loading conditions to account for strain-rate effects. Under these loading conditions the factor of safety of the proposed 4 to 5 m high embankments was in excess of 1.1.

The stability of the embankments towards Highway 401, through the abutments, were also analysed and found to have an adequate factor of safety for the east and west approaches to the eastbound structure and for the east approach to the westbound structure, in consideration of the modest active earth pressure resistance offered by the abutment wall. Thus, no lateral forces are expected to be applied on the piles (e.g., no flow slide) at those locations. However, the factor of safety is less than 1.1 for the west approach to the westbound structure under seismic conditions. It is therefore recommended to remove the organic material that is present under the abutment/pile cap of the west approach to the westbound structure to a depth of at least 1.5 m below the underside of the abutment wall (i.e. Elevation 44.6 m), or to the underlying silty clay deposit, whichever is higher, at an angle of 1H:1V extending down and out from the edges of the pile cap.

### 6.5.3 Settlement

Negligible additional settlement is expected of the native soils underlying the existing roadway due to the proposed 500 mm grade raise. For the widening, provided any organic matter encountered within the footprint of the widened embankments is removed prior to placement of any fill, negligible settlement would be expected of the underlying soils. Some settlements could be expected where the organic silt is left in place. It is therefore recommended that new embankment fill consist of Select Subgrade Material with a unit weight of 19 kPa or less, placed at least 20 m beyond the abutments where there will be a significant thickness of new fill placed for embankment construction. Furthermore, given the material's low plasticity, the settlement would likely be elastic in nature and occur quickly. Long term settlements are similarly not expected from the underlying clay deposits because the proposed grade raise and widening will not bring the stresses in the clay close to (or over) its apparent preconsolidation pressure. The settlement of the native soils encountered at the site should therefore generally be elastic in nature and occur during construction, and therefore be within tolerable limits prior to final paving.

Settlement of the existing embankments has likely occurred over time since the original bridge construction. Additional settlement of the embankments will occur as a result of compression of the new and existing embankment fill. The magnitude of compression of the new fill may range from 0.5 to 1 percent of its thickness, assuming approximately 95 percent compaction of the embankment fill is achieved, relative to the material's standard Proctor maximum dry density. Some nominal compression of the existing fill (less than 0.5 percent of its thickness) is expected to occur under the increased loading. Provided that SSM is used to raise the grade, settlement of the new fill is expected to occur essentially during embankment construction. Similarly, settlement of the existing embankment fill will be elastic in nature and should occur essentially immediately following placement of the new fill.



Seismic settlements as discussed in Section 6.1.4 would be in addition to these values.

## 6.6 Construction Considerations

The following sections identify future construction issues that should be considered during the design stage, and for which appropriate provisions should be made in the Contract Documents.

### 6.6.1 Excavation and Temporary Protection Systems

Depending on the foundation type adopted, excavation for the pile caps at the abutments and piers are expected to extend through the existing granular embankment fill and into the underlying native granular deposits, organic material, and potentially into the silty clay to clay and till. The excavations are expected to extend up to about 5 m below the existing Highway 401 grade at the abutments. Depending on the foundation option adopted at the piers, excavations within cofferdams are expected to extend approximately 3 m below the surface of the riverbed.

Where space permits, open-cut excavations at the abutments into these materials should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) for Construction Activities. The existing embankment fill above the water table would be classified as Type 3 soil, based on the OHSA. According to OHSA excavations that extend to, or into, Type 3 soils should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). Excavations in the embankment fill or native materials below the water table would be classified as Type 4 soil, based on OSHA, and excavations in these materials should be sloped no steeper than 3H:1V. However, excavations for abutment construction immediately adjacent to the river will extend below the river level and it is likely that cofferdams and/or relatively lower permeability excavation support (e.g., sheetpiles, with or without joint sealing) will be required along three sides (i.e., the along the river and extending back from the river's edge parallel to the roadway). With adequate dewatering and cut-offs, it is anticipated that temporary excavation slopes at the backs of the excavations (i.e. farthest from and parallel to the river edge) could be maintained at 1H:1V.

Excavations for below-grade pile caps at the piers will extend below the groundwater level and the Raisin River water level. Use of cofferdams is recommended to minimize unwatering requirements and potential environmental impacts. The cut-off/cofferdams could consist of interlocking steel sheetpiles driven to the bedrock surface or into the glacial till. The bedrock surface elevation is variable (refer to the interpreted stratigraphic cross-sections on Drawings 2, 3, 5 and 6).

A Non-Standard Special Provision (NSSP) has been provided in Appendix G for inclusion in the Contract Documents, to address water control/cofferdams for the abutment and pier foundations at this site.

If the open-cut excavation side slopes at the abutments, where feasible, cannot be accommodated, then a temporary protection system will be required. At this stage, it is anticipated that temporary protection systems will be required in the vicinity of the existing abutments to permit their removal or partial removal. Where required, the protection system should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.

The selection and design of the protection systems will be the responsibility of the Contractor. For conceptual planning and costing purposes, it is considered that either a driven, interlocking sheetpile system or a soldier pile and timber lagging system would be suitable for the temporary excavation support at the abutments. At the piers, an interlocking sheetpile system would contribute to both ground and groundwater/surface water control.

## 6.6.2 Groundwater Control

Based on the groundwater level encountered in the standpipe piezometers and the river level elevation at the time of the investigation, the groundwater level is expected to be between about Elevation 46.6 and 47.0 m.

The excavations for the bridge replacement will extend into the fill, organic silt, silty clay to clay, sand and gravel and potentially into the glacial till (at the piers). Excavations will therefore require groundwater control for the construction of the pile/pier caps and for the removal of the organic deposits below the footprint of the new embankments. Excavations would also need to deal with flow from the river and therefore significant groundwater inflow to the excavations should be expected.

It is therefore recommended that the excavations will need to be separated from the river using a sheetpile cofferdam. The sheet piling should extend into the glacial till. However, penetration of interlocking sheetpile walls into the glacial till may be difficult due to the density of the till and presence of cobbles and boulders, and therefore significant embedment into the glacial till, as required to effectively cut-off the flow, may not be feasible at some locations. It should however be possible for the contractor to handle the groundwater inflow from the till by pumping from well filtered sumps in the floor of the excavation, using suitably sized pumps.

For the construction of the piers, the sheet piling should fully surround the excavation.

The selection, design, and construction of the dewatering system is the responsibility of the contractor and should be carried out in accordance with OPSS.PROV 517 (*Dewatering*) with amendments as per SSP 517F01. Given the groundwater and soil conditions at this site, a preconstruction survey is not considered to be required, but the dewatering is expected to be of high complexity and therefore the dewatering Design Engineer and design-checking Engineer should have a minimum of 5 years of experience in designing systems of similar nature and scope to this work, as per Table A of SP 517F01 (*Dewatering System*).

Dewatering should be carried out in accordance with NSSP FOUND003 (*Dewatering Structure Excavations*), which is an amendment to OPSS 902 (*Excavation and Backfill – Structures*).

According to Ontario Regulation 63/16 and Ontario Regulation 387/04, a Permit to Take Water (PTTW) is required from the Ministry of the Environment and Climate Change (MOECC) if a volume of water greater than 400,000 L/day is pumped from the excavations. If the volume of water to be pumped will be less than 400,000 L/day, but more than 50,000 L/day, the water taking will not require a PTTW, but will need to be registered in the Environmental Activity and Sector Registry (EASR) as a prescribed activity.

Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the subgrade.

## 6.6.3 Vibration Monitoring During Deep Foundation Installation

Each bridge will be replaced over a single construction season, with no staging required. Median crossovers will be used to maintain traffic flow on Highway 401. It is recommended that vibration monitoring be carried out during any deep foundation installation (driving piles, drilled steel casings, drilled micropiles or drilled caissons) to assist in maintaining vibration levels within tolerable ranges at the adjacent bridge structure. A maximum peak particle velocity of 100 mm per second is recommended at the adjacent structure's piers and abutments. An NSSP has been provided in Appendix G to address vibration monitoring, for inclusion in the Contract Documents.



#### **6.6.4 Bedrock Excavation and Obstructions**

The bedrock at this site is strong to very strong. If excavation/socketing into the bedrock is required, it is recommended that an NSSP be included in the Contract Documents to warn the contractor of the bedrock strength and that excavation into the bedrock will require appropriate equipment and construction procedures.

The presence of cobbles and boulders in the glacial till could affect the installation of deep foundations or protection system elements. If caissons or drilled steel casings are to be used, appropriate drilling techniques will be required to advance the caissons or casings through the glacial till. A NSSP is provided in Appendix G, for inclusion in the Contract Documents to alert the Contractor to this condition.

#### **6.6.5 Erosion and Scour Protection**

The near-surface soils in the vicinity of the piers and at the river's edge are expected to be susceptible to erosion and scour under the design flood/flow velocities. The requirements for design of erosion/scour protection should be assessed by the hydraulic design engineer. As a minimum, it is recommended that erosion protection (e.g., rip-rap or granular sheeting) be provided on the river banks and adjacent to the piers to protect the foundations/pile caps from being exposed. The rip-rap should be consistent with the standard R-10 classification or granular sheeting classification in accordance with OPSS 1004 (Aggregates) but should be approved by the hydraulic design engineer.

#### **6.6.6 Corrosion and Cement Type**

Samples of soil from one borehole at each foundation element (i.e., Boreholes 17-02, 17-03, 17-06, 17-07, 17-106, 17-108, 17-109 and 17-111) were submitted to Eurofins for basic chemical analysis related to potential corrosion of buried steel elements and potential sulphate attack on buried concrete elements. The results of this testing are provided in Appendix B and are summarized in Section 4.4. The results indicate that concrete made with Type GU Portland cement should generally be acceptable for substructures. However, one sample from Borehole 17-108 (i.e., at the west abutment of the eastbound structure) measured a sulphate content of 0.13 percent, which is considered a moderate degree of exposure to sulphate and therefore moderate sulphate resistant hydraulic cement (i.e., Type MS) would be recommended. The results also indicate a high potential for corrosion of exposed ferrous metal.

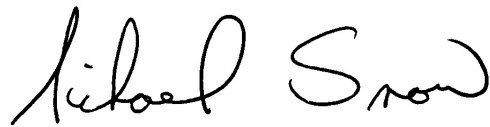
## 7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Kim Lesage, P.Eng. and Mr. Matt Kennedy and reviewed by Mr. Michael Snow, P.Eng., a geotechnical engineer and Principal with Golder. Mr. Fin Heffernan, P.Eng., the Designated MTO Foundations Contact for this assignment, conducted an independent quality review of this report.

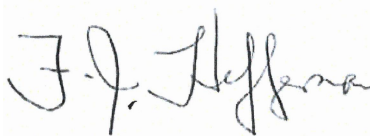
### Golder Associates Ltd.



Matt Kennedy, P.Eng.  
*Senior Geotechnical Engineer*



Michael Snow, P.Eng.  
*Principal, Senior Geotechnical Engineer*



Fintan Heffernan, P.Eng.  
*Designated MTO Foundations Contact*



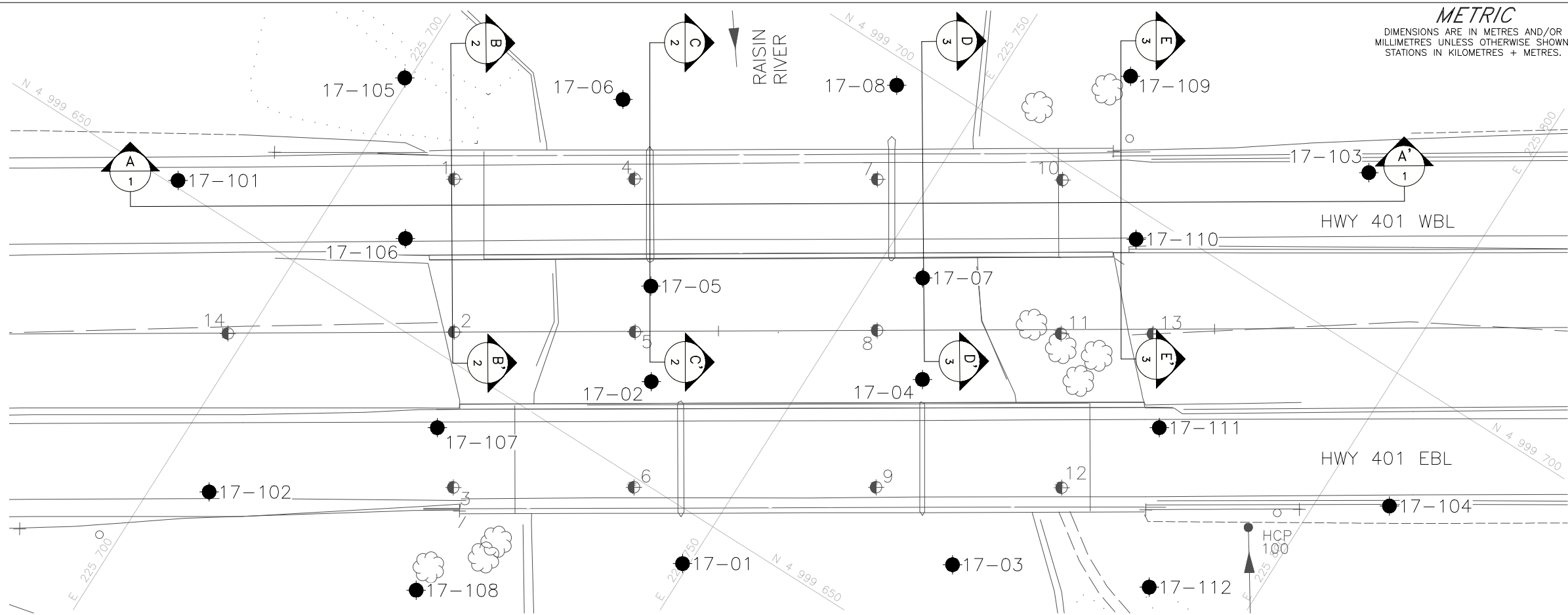
KSL/MJK/FJN/MSS/mvrd

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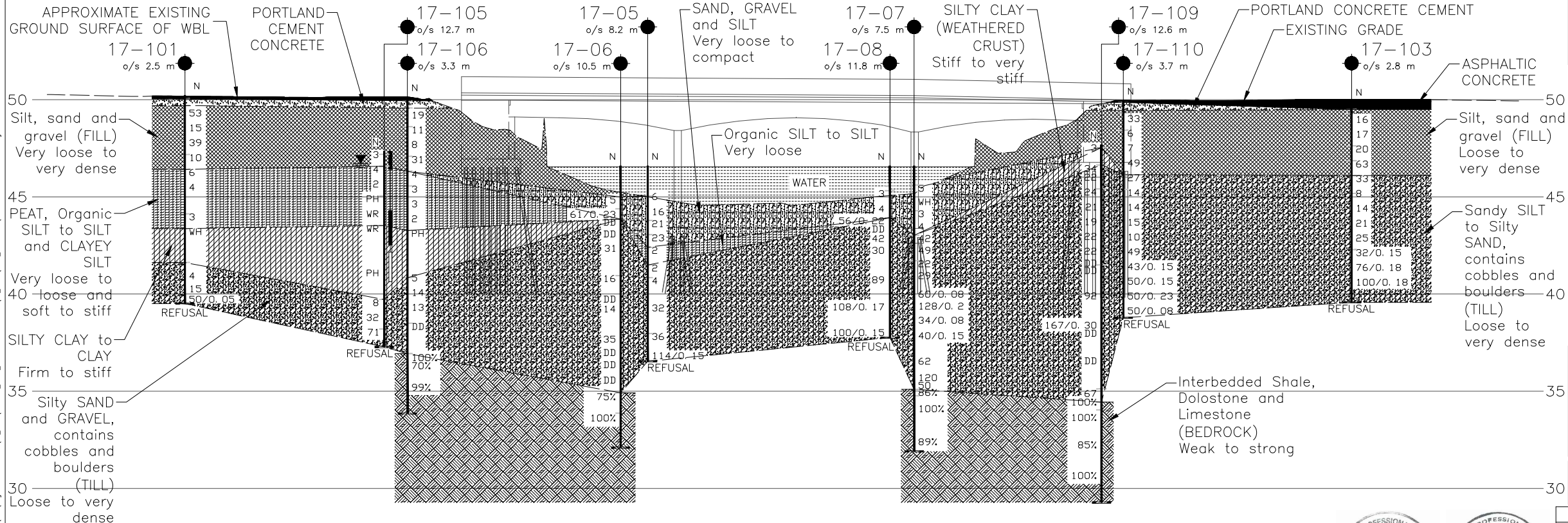
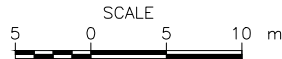
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Table 1: Comparison of Foundation Alternative

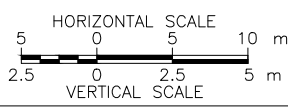
Foundation Option	Feasibility	Advantages	Disadvantages	Constructability/Risks	Relative Costs
Driven steel H-piles driven to refusal in the glacial till or on the bedrock, or installed in pre-cored socket holes in bedrock	<ul style="list-style-type: none"><li>Feasible, Preferred</li></ul>	<ul style="list-style-type: none"><li>Conventional construction technique for abutment and pier locations</li><li>Pile tips can be reinforced with driving points to minimize damage during pile driving and aid in seating pile onto the sloping bedrock</li><li>Preferred foundation option for integral abutment configuration</li></ul>	<ul style="list-style-type: none"><li>At piers, this option will require construction of a pier pile cap in the water, with excavation inside a cofferdam</li><li>Potential for encountering obstructions (cobbles and/or boulders) during pile driving that could result in some piles “hanging up” in the glacial till deposits and lower geotechnical resistances</li><li>Pre-augering or additional piles may be required</li></ul>	<ul style="list-style-type: none"><li>Some risk of difficulty in seating driven piles on stepped bedrock; Titus driving points and careful driving onto bedrock would aid in controlling this risk at the abutments, based on interpreted bedrock surface from the borehole results</li><li>Environmental protection considerations for construction of in-water pile cap;</li><li>Moderate to high risk of encountering cobbles or boulders during installation of driven sheetpiling for cofferdams</li><li>Higher risk for pipe piles to meet refusal in the cobbles and boulders (as opposed to h-piles)</li></ul>	<ul style="list-style-type: none"><li>Typically least expensive option</li></ul>
Drilled steel casings socketed into bedrock	<ul style="list-style-type: none"><li>Feasible</li></ul>	<ul style="list-style-type: none"><li>Reasonably conventional construction technique for abutment and pier locations</li><li>Access at abutments is good throughout construction staging; access to pier locations for heavy rig reasonable via rock fill access roadway</li><li>Effective where rock sockets are required, whether at the abutments or piers; this relatively smaller option will be more constructible than larger diameter caissons since it is better able to handle abrasive/strong rock conditions and stepped bedrock conditions</li><li>Cleaning of base of rock socket not as critical because axial capacity developed based on shaft resistance in socket</li><li>Drilled steel casings can handle obstructions (i.e., cobbles and boulders)</li></ul>	<ul style="list-style-type: none"><li>At piers, would require construction of a pier pile cap in the water, with excavation inside a cofferdam</li><li>A special working platform may need to be constructed for installation of the casings at the pier locations</li><li>Not compatible with integral abutment configuration</li></ul>	<ul style="list-style-type: none"><li>Drilled steel casings with diameters of 450 mm to 750 mm are considered to be the most readily constructible of rock socket options (similar to micropiles)</li><li>Environmental protection considerations for construction of in-water pile cap</li><li>Moderate to high risk of encountering cobbles or boulders during installation of driven sheetpiling for cofferdams</li></ul>	<ul style="list-style-type: none"><li>More expensive than driven steel H-piles or pipe piles</li></ul>
Caissons socketed into bedrock	<ul style="list-style-type: none"><li>Feasible</li></ul>	<ul style="list-style-type: none"><li>A single large diameter caisson may be able to support each pier column, eliminating the need for a pile cap and cofferdam at the piers, and thereby minimizing environmental impacts in the river and associated constructability challenges</li></ul>	<ul style="list-style-type: none"><li>Depending on the results of structural analysis, the caisson size may need to be larger than the pier columns thereby increasing construction complexity and costs</li><li>Temporary casings required to construct caissons</li><li>Not compatible with integral abutment configuration</li></ul>	<ul style="list-style-type: none"><li>Possibility of encountering cobbles or boulders in the overburden during augering would make for difficult construction using conventional caisson construction methods</li><li>Lower environmental and constructability risk for to in-water work because pile cap/ cofferdam can be eliminated; liners would be required through water and overburden soils to support caisson sides during excavation and construction</li><li>If caisson diameter must be larger than column, then significant constructability issues associated with forming deep socket in bedrock may arise</li><li>Difficulties associated with seating large diameter caissons where bedrock surface is sloping or stepped; more challenging than smaller diameter drilled steel casings or micropiles</li></ul>	<ul style="list-style-type: none"><li>Likely most expensive option</li></ul>
Spread footings founded on the bedrock surface	<ul style="list-style-type: none"><li>Not feasible (lack of competent overburden within 3 m of ground/pavement surface or riverbed and high groundwater level)</li></ul>				



PLAN



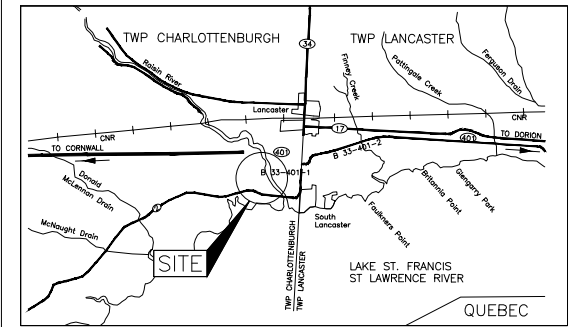
PROFILE A-A'



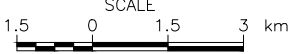
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DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. 4084-11-00  
GWP No. 4084-11-00

RAISIN RIVER BRIDGE WBL  
HIGHWAY 401  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 45.132590 LONG. -74.505061



KEY PLAN



LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation  
Geocres No. 31G-143
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated  
(Std. Pen. Test, 475 j/blow)
- DD Diamond Drilling
- 100% Rock Quality Designation (RQD)
- WL in piezometer, measured on MAY 26, 2017
- WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM ZONE 8)

No.	ELEVATION	NORTHING	EASTING
17-01	46.6	4999645.2	225749.4
17-02	46.6	4999659.0	225736.9
17-03	46.6	4999659.7	225772.5
17-04	46.6	4999673.8	225759.9
17-05	46.6	4999667.1	225731.8
17-06	46.6	4999681.5	225719.3
17-07	46.6	4999682.5	225754.5
17-08	46.6	4999697.5	225741.9
17-101	50.2	4999650.6	225685.8
17-102	50.2	4999625.8	225705.2
17-103	49.9	4999715.5	225786.8
17-104	49.9	4999688.3	225806.5
17-105	47.3	4999671.6	225699.6
17-106	50.1	4999658.0	225708.3
17-107	50.1	4999643.6	225721.2
17-108	48.2	4999628.6	225728.2
17-109	47.7	4999710.9	225761.3
17-110	50.0	4999697.3	225770.6
17-111	50.0	4999682.5	225782.7
17-112	47.5	4999668.4	225790.4

NOTES

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

REFERENCE

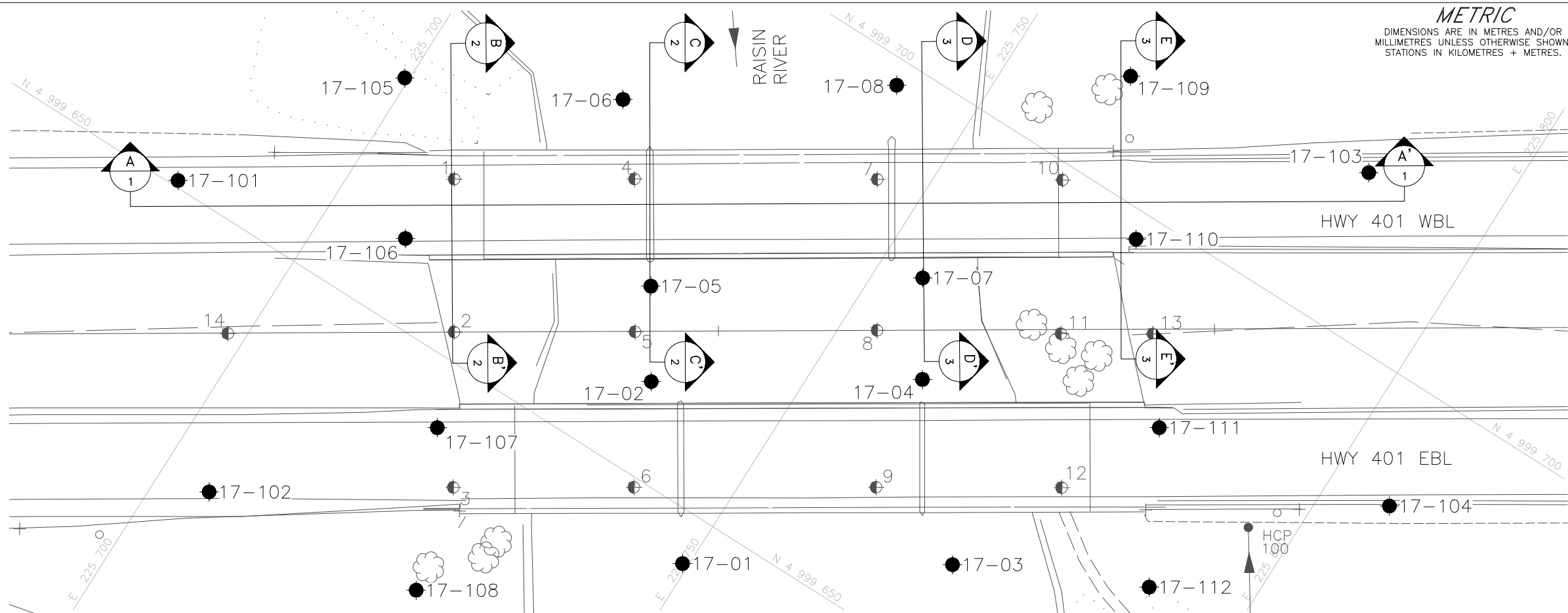
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NO.	DATE	BY	REVISION
1	11/13/2018	J.M.	Initial Design
2	11/13/2018	M.J.K.	Check Design
3	11/13/2018	F.J.H.	Approve Design

Geocres No. 31G-261	PROJECT No. 1772182	DIST. EASTERN
HWY. 401	CHKD. KSL	DATE: 11/13/2018
SUBM'D. KSL	CHKD. MJK	SITE: 31-231/1&2
DRAWN: JM	APPD. FJH	DWG. 1





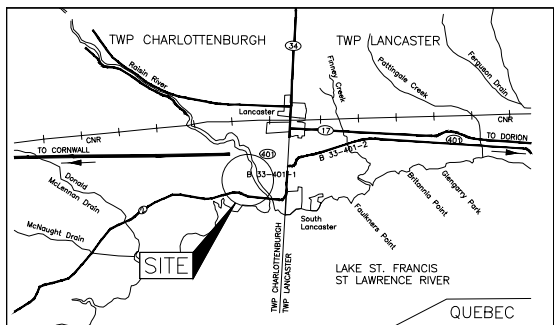


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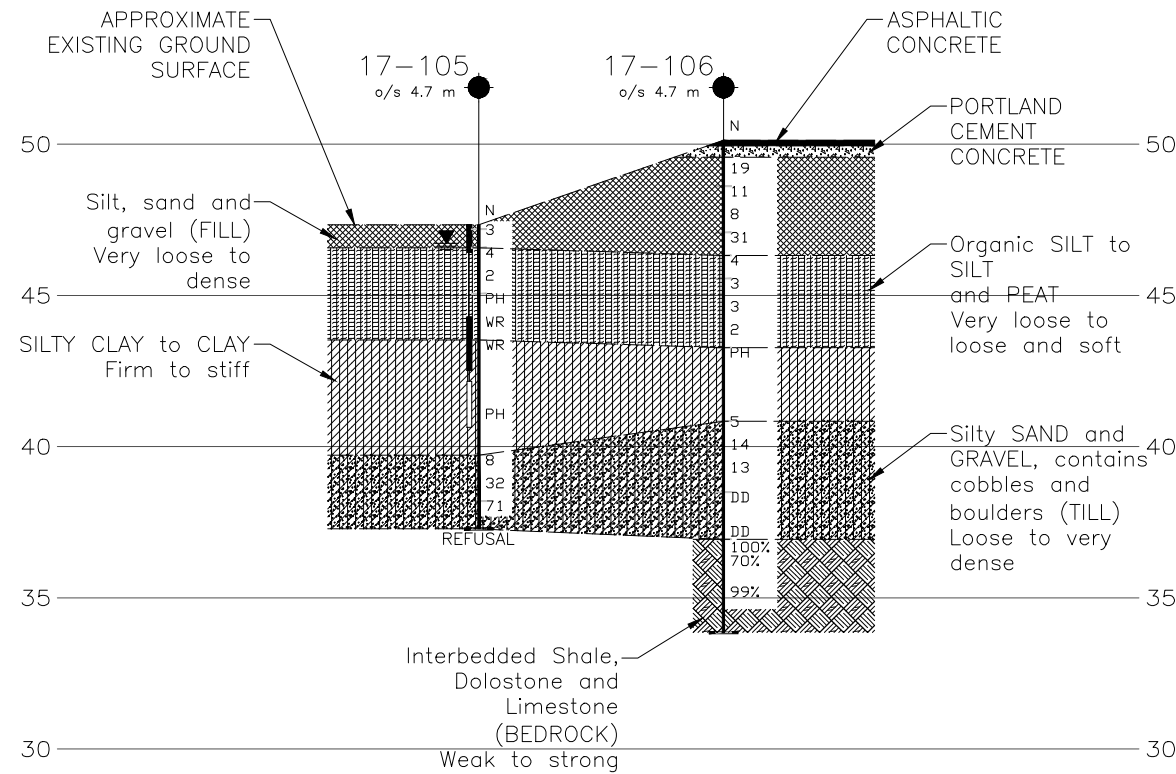
CONT No.  
GWP No. 4084-11-00

RAISIN RIVER BRIDGE WBL  
HIGHWAY 401  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 45.132590 LONG. -74.505061

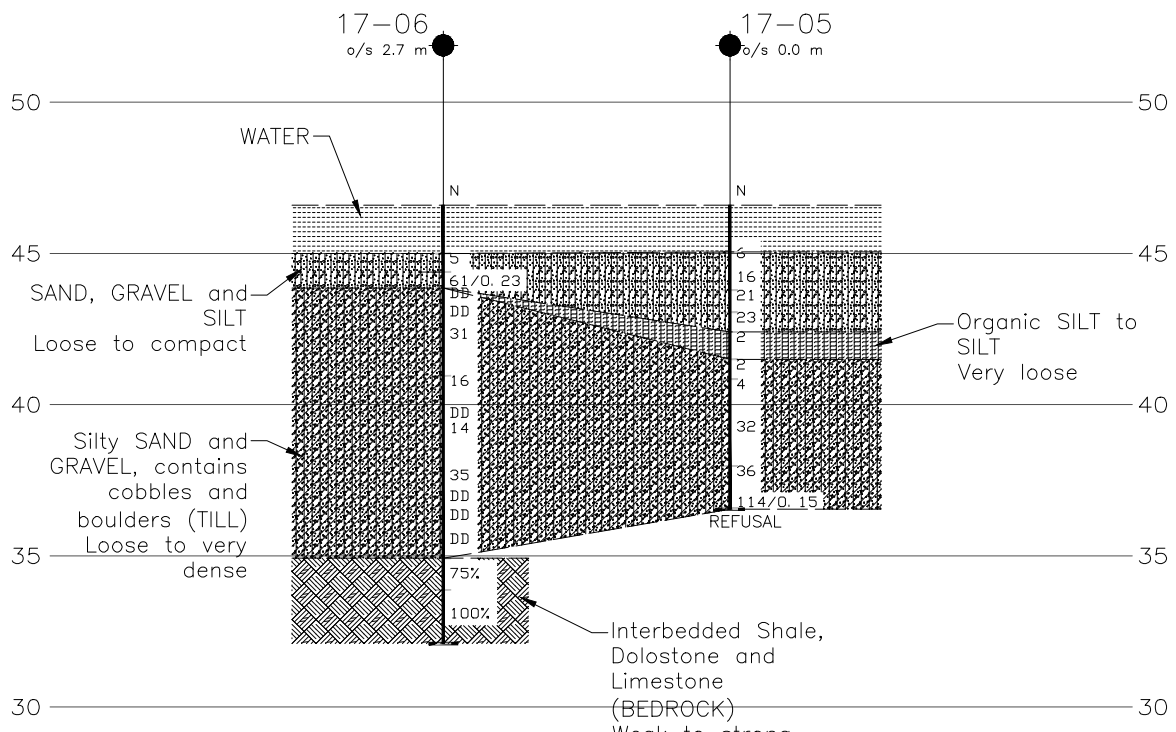
SHEET



- LEGEND**
- Borehole - Current Investigation
  - Borehole - Previous Investigation  
Geocres No. 31G-143
  - ⊞ Seal
  - ⊞ Piezometer
  - N Standard Penetration Test Value
  - 16 Blows/0.3m unless otherwise stated  
(Std. Pen. Test, 475 j/blow)
  - DD Diamond Drilling
  - 100% Rock Quality Designation (RQD)
  - ≡ WL in piezometer, measured on MAY 26, 2017
  - ≡ WL upon completion of drilling



CROSS-SECTION B-B'



CROSS-SECTION C-C'

BOREHOLE CO-ORDINATES (MTM ZONE 8)			
No.	ELEVATION	NORTHING	EASTING
17-01	46.6	4999645.2	225749.4
17-02	46.6	4999659.0	225736.9
17-03	46.6	4999659.7	225772.5
17-04	46.6	4999673.8	225759.9
17-05	46.6	4999667.1	225731.8
17-06	46.6	4999681.5	225719.3
17-07	46.6	4999682.5	225754.5
17-08	46.6	4999697.5	225741.9
17-101	50.2	4999650.6	225685.8
17-102	50.2	4999625.8	225705.2
17-103	49.9	4999715.5	225786.8
17-104	49.9	4999688.3	225806.5
17-105	47.3	4999671.6	225699.6
17-106	50.1	4999658.0	225708.3
17-107	50.1	4999643.6	225721.2
17-108	48.2	4999628.6	225728.2
17-109	47.7	4999710.9	225761.3
17-110	50.0	4999697.3	225770.6
17-111	50.0	4999682.5	225782.7
17-112	47.5	4999668.4	225790.4

**NOTES**

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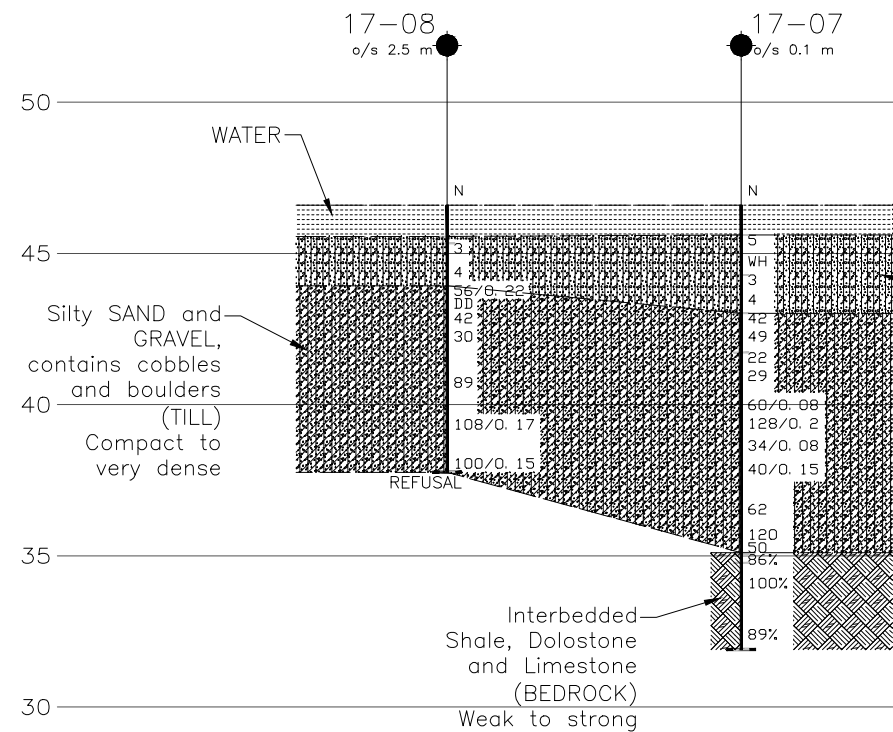
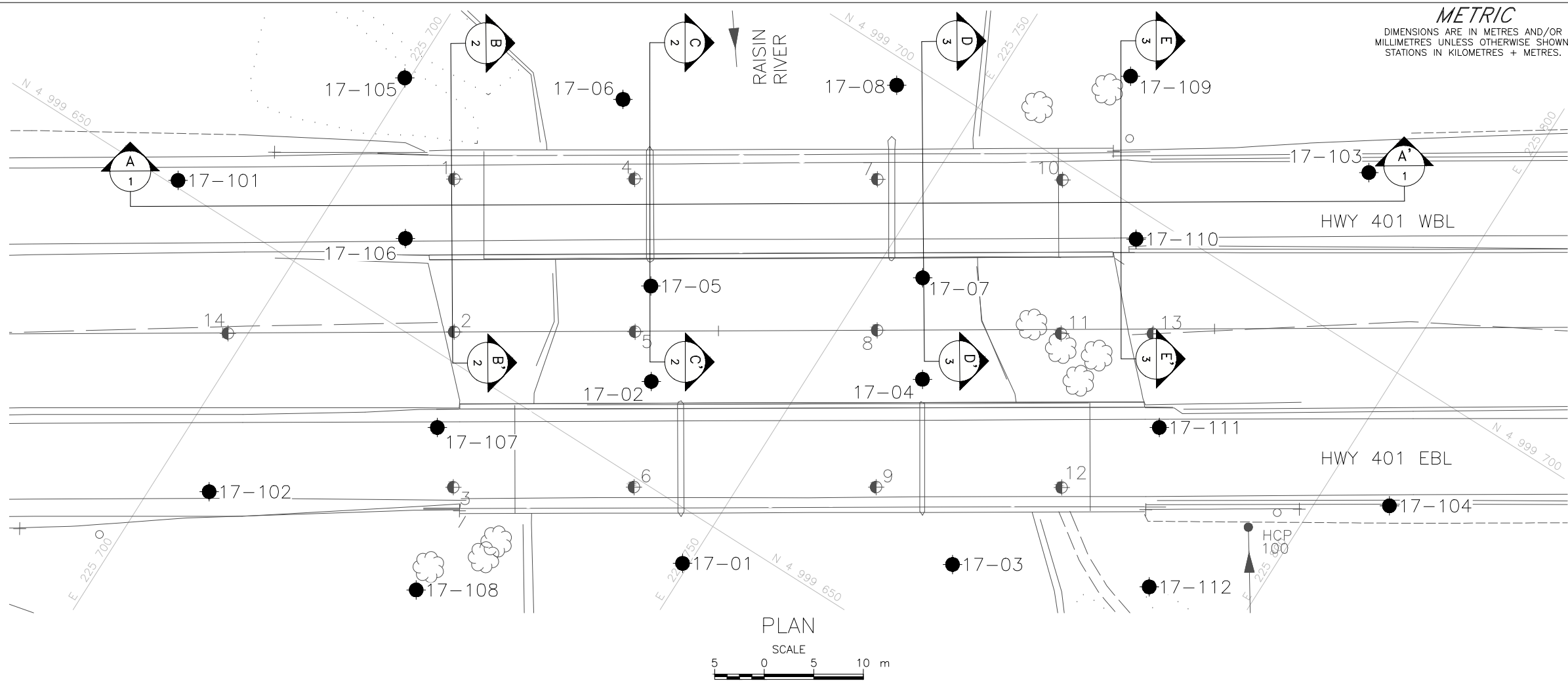
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**REFERENCE**

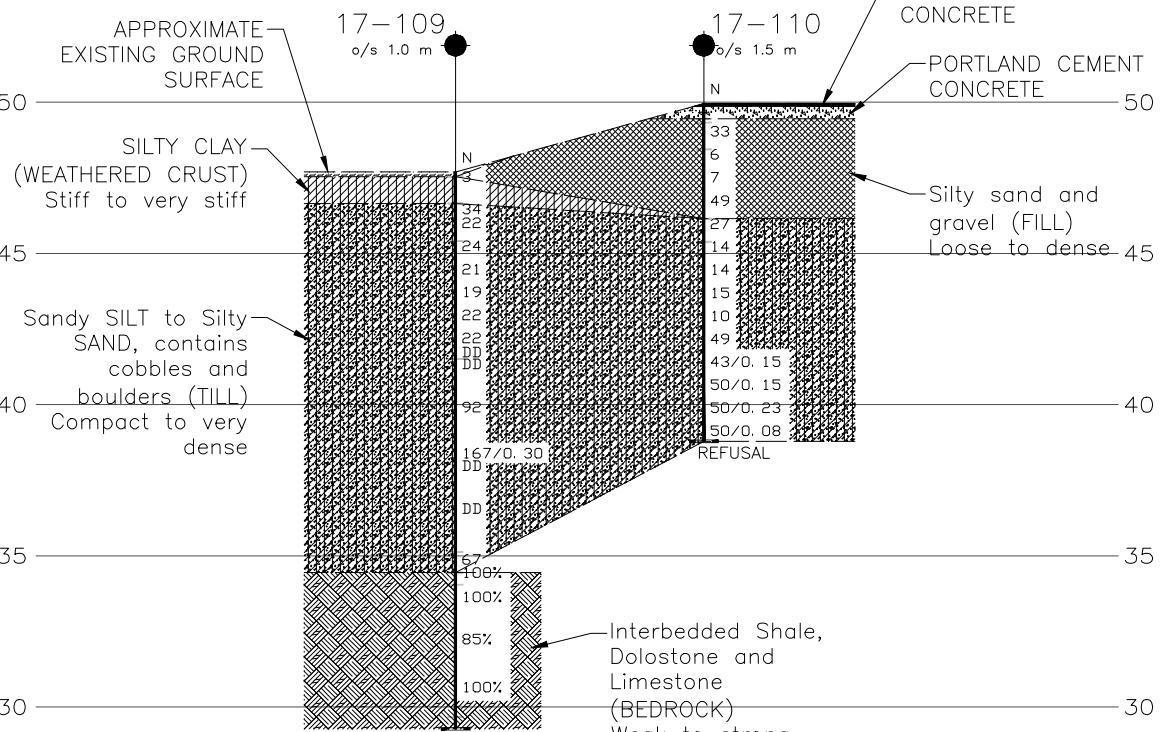
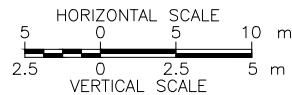
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A			
NO.	DATE	BY	REVISION
Geocres No. 31G-261			
HWY. 401		PROJECT NO. 1772182	
SUBM'D. KSL	CHKD. KSL	DATE: 11/13/2018	SITE: 31-231/1&2
DRAWN: JM	CHKD. MJK	APPD. FJH	DWG. 2

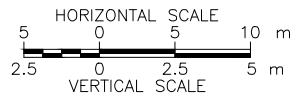




CROSS-SECTION D-D'



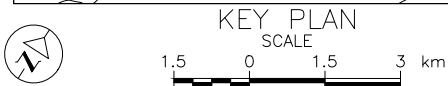
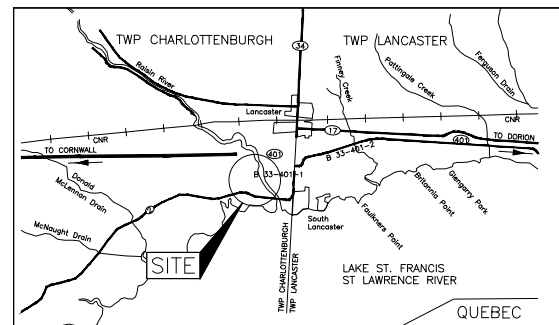
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METRIC  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
GWP No4084-11-00

RAISIN RIVER BRIDGE WBL  
HIGHWAY 401  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 45.132590 LONG. -74.505061



LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation Geocres No. 31G-143
- ⊞ Seal
- ⊞ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- DD Diamond Drilling
- 100% Rock Quality Designation (RQD)
- WL in piezometer, measured on MAY 26, 2017
- WL upon completion of drilling

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No.	ELEVATION	NORTHING	EASTING
17-01	46.6	4999645.2	225749.4
17-02	46.6	4999659.0	225736.9
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17-06	46.6	4999681.5	225719.3
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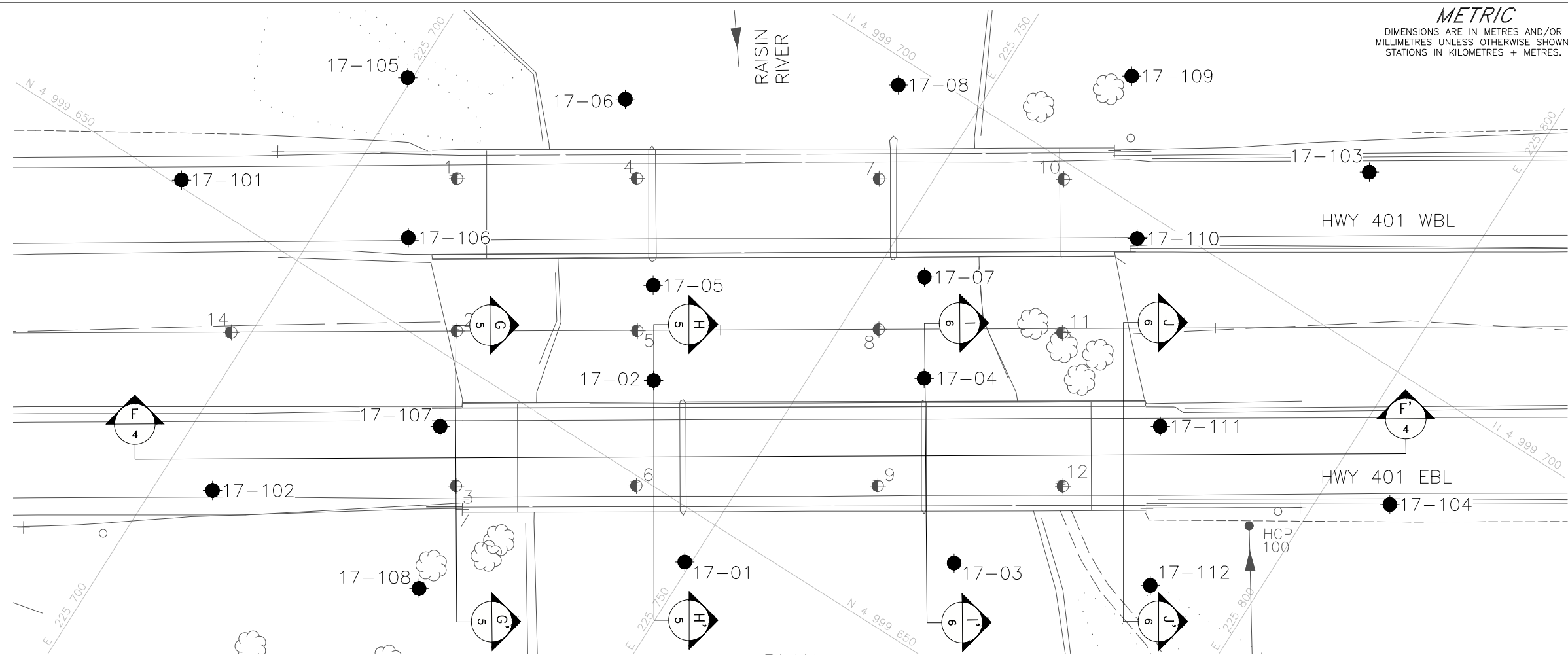
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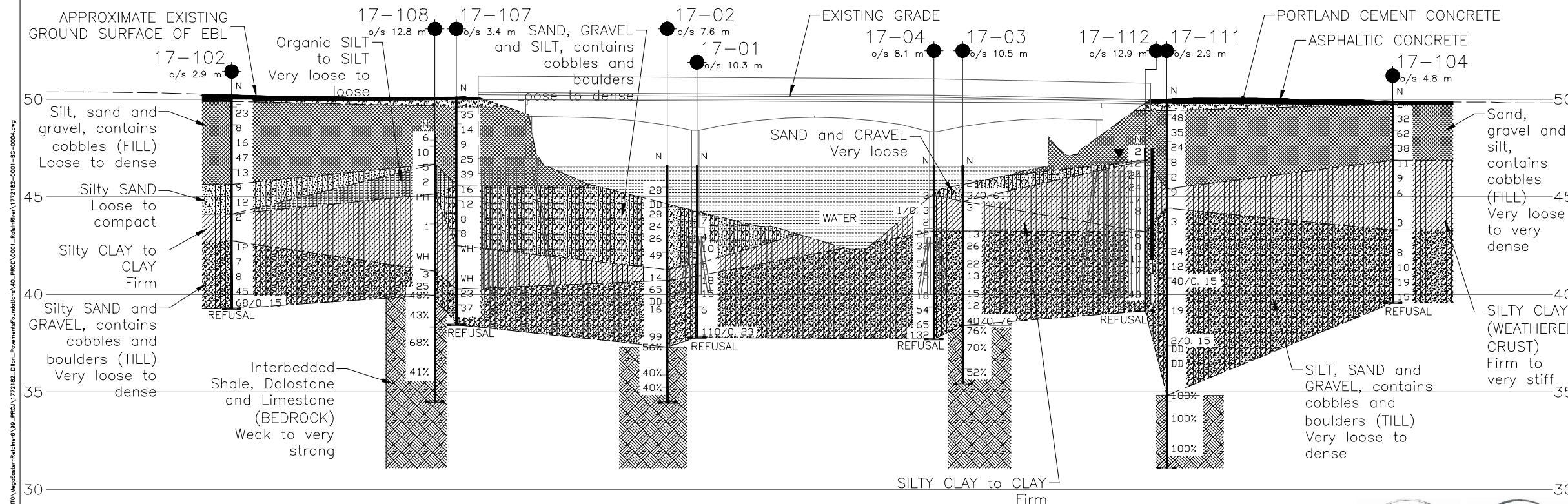
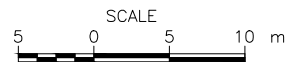
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A			
NO.	DATE	BY	REVISION
1			
Geocres No. 31G-261		PROJECT NO. 1772182	DIST. EASTERN
HWY. 401			
SUBM'D. KSL	CHKD. KSL	DATE: 11/13/2018	SITE: 31-231/1&2
DRAWN: JM	CHKD. MJK	APPD. FJH	DWG. 3

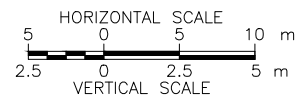




PLAN



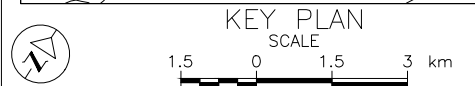
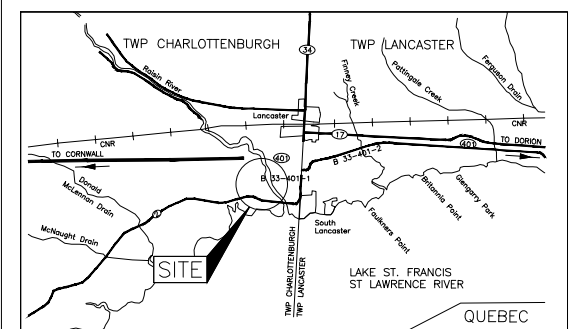
CROSS-SECTION F-F'



**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
GWP No. 4084-11-00

RAISIN RIVER BRIDGE EBL  
HIGHWAY 401  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 45.132590 LONG. -74.505061



LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation  
Geocres No. 31G-143
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
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(Std. Pen. Test, 475 j/blow)
- DD Diamond Drilling
- 100% Rock Quality Designation (RQD)
- ≡ WL in piezometer, measured on MAY 26, 2017
- ≡ WL upon completion of drilling

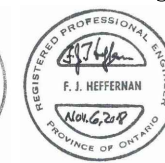
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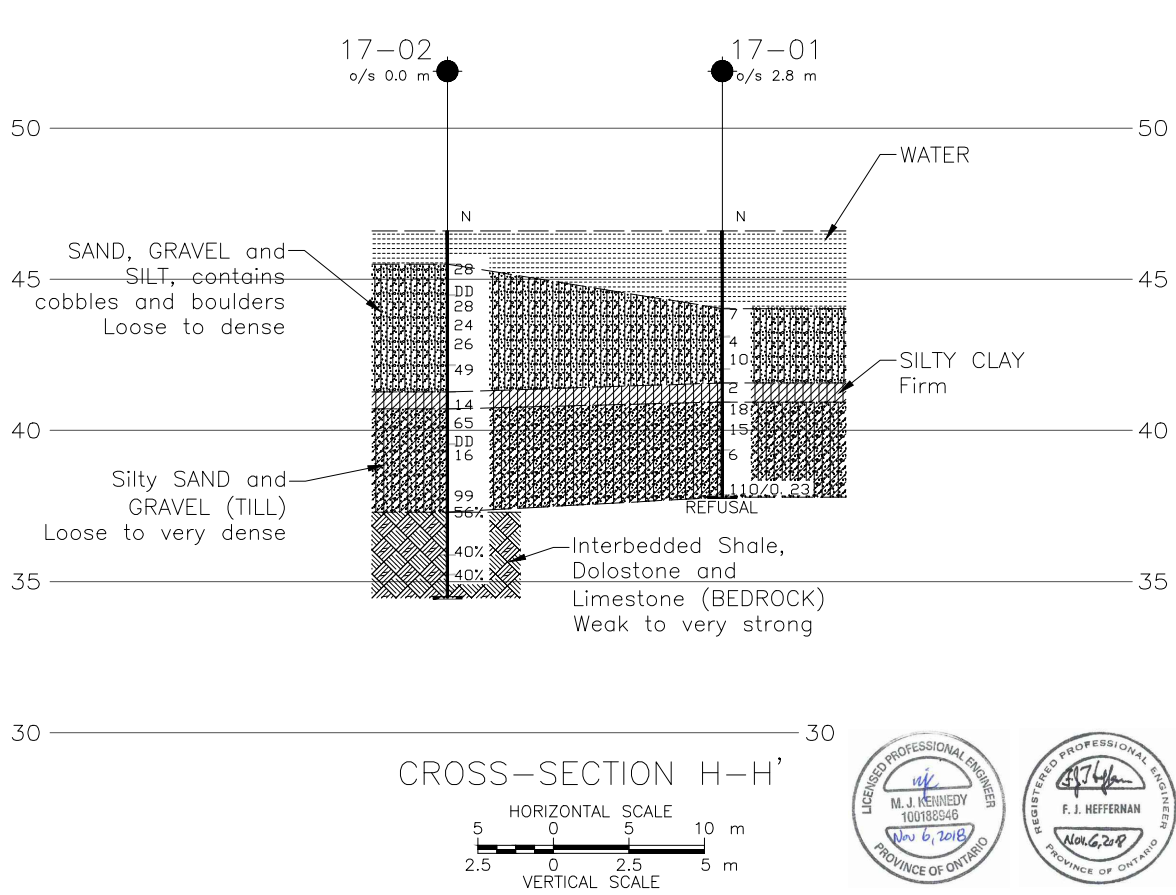
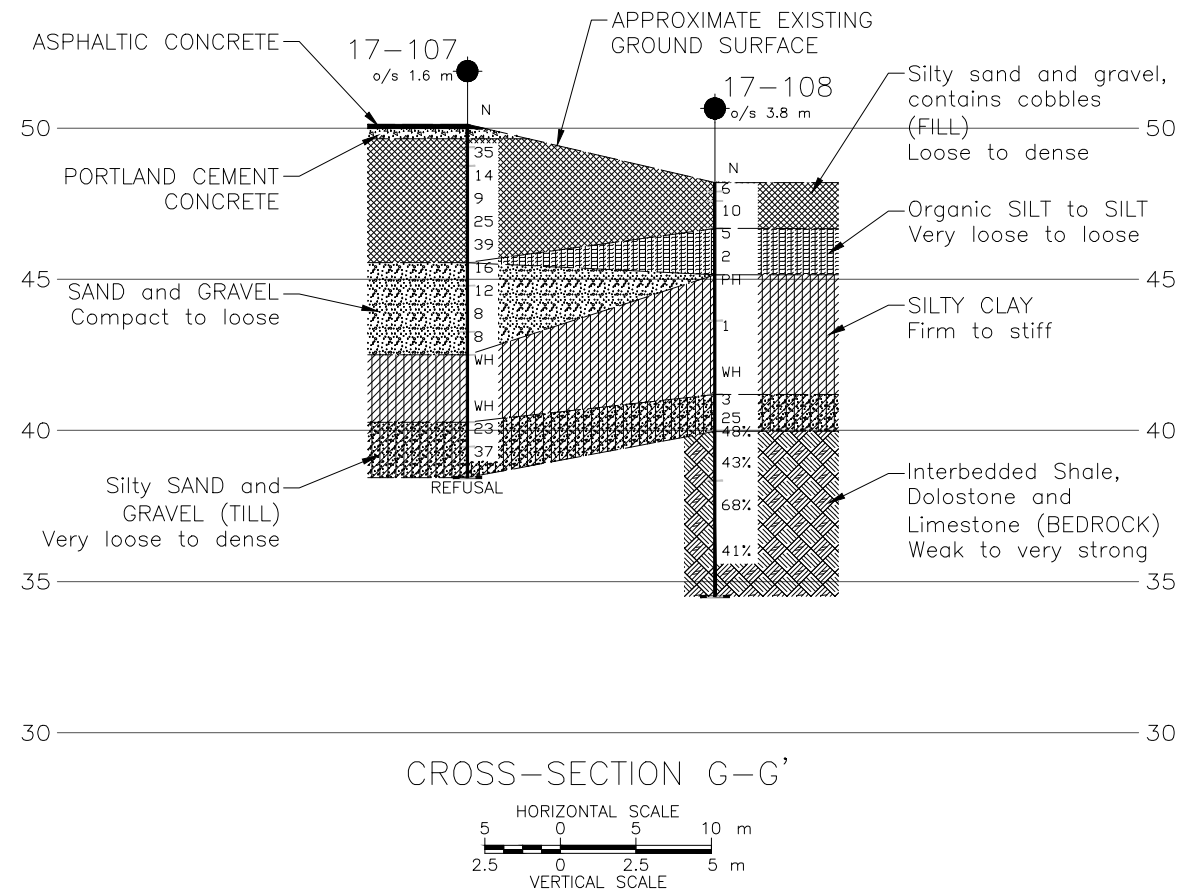
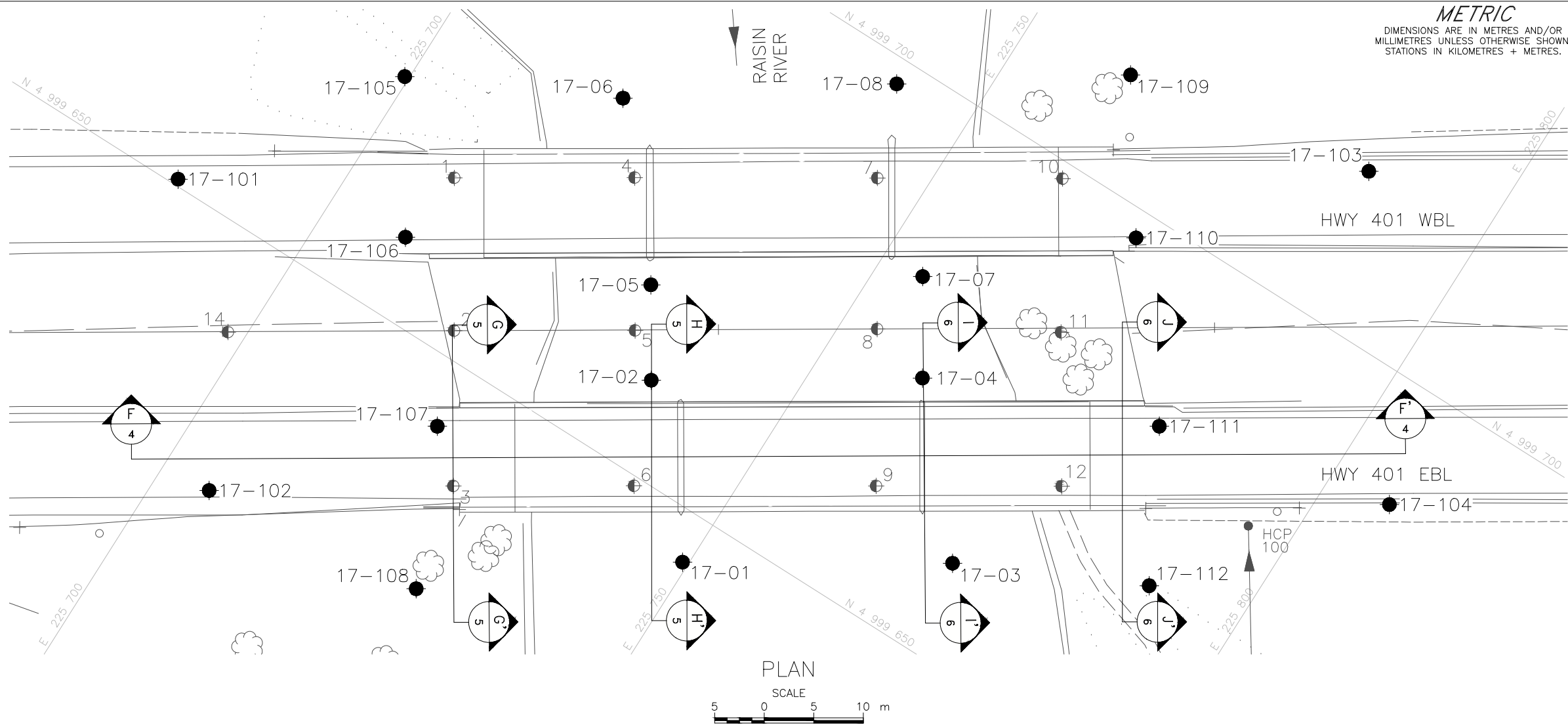
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A			
NO.	DATE	BY	REVISION
Geocres No. 31G-261			
HWY. 401		PROJECT NO. 1772182	
SUBM'D. KSL		DATE: 11/13/2018	
DRAWN: JM		APPD. FJH	
CHKD. MJK		SITE: 31-231/1&2	
		DWG. 4	



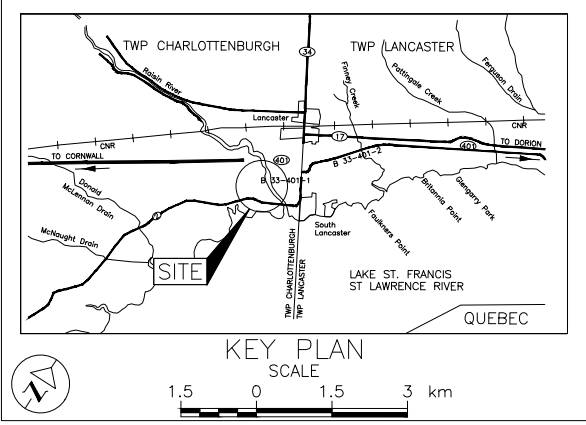


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CONT No.  
GWP No. 4084-11-00

RAISIN RIVER BRIDGE EBL  
HIGHWAY 401  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 45.132590 LONG. -74.505061

SHEET



LEGEND

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- Borehole - Previous Investigation Geocres No. 31G-143
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- Piezometer
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17-05	46.6	4999667.1	225731.8
17-06	46.6	4999681.5	225719.3
17-07	46.6	4999682.5	225754.5
17-08	46.6	4999697.5	225741.9
17-101	50.2	4999650.6	225685.8
17-102	50.2	4999625.8	225705.2
17-103	49.9	4999715.5	225786.8
17-104	49.9	4999688.3	225806.5
17-105	47.3	4999671.6	225699.6
17-106	50.1	4999658.0	225708.3
17-107	50.1	4999643.6	225721.2
17-108	48.2	4999628.6	225728.2
17-109	47.7	4999710.9	225761.3
17-110	50.0	4999697.3	225770.6
17-111	50.0	4999682.5	225782.7
17-112	47.5	4999668.4	225790.4

NOTES

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

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

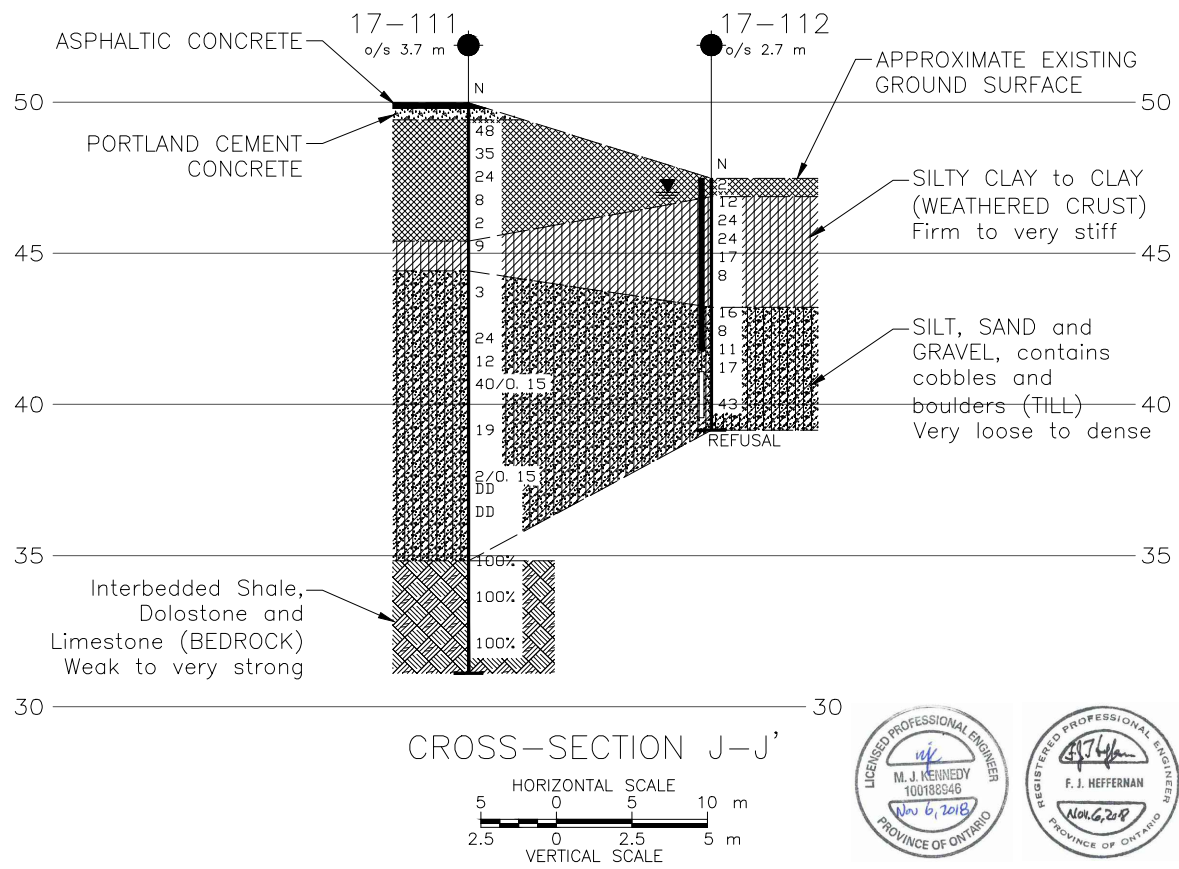
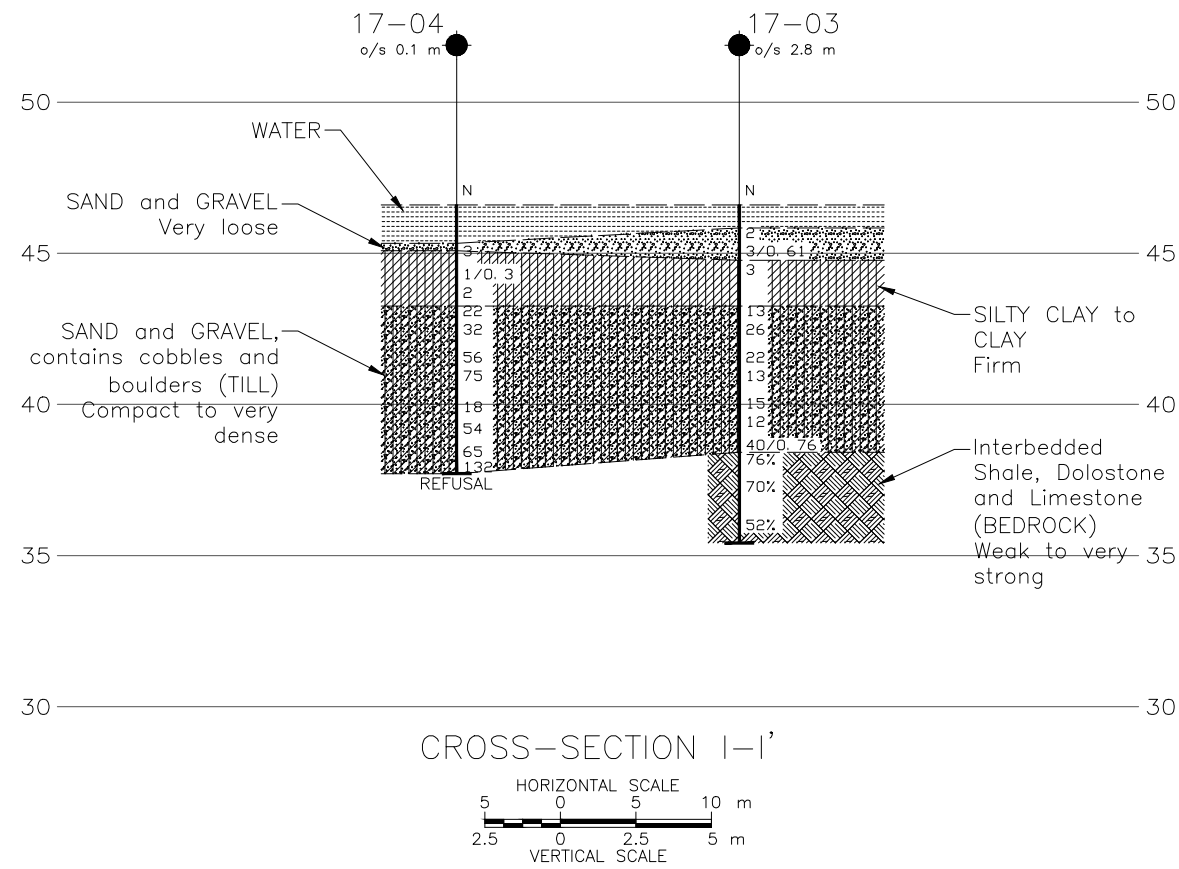
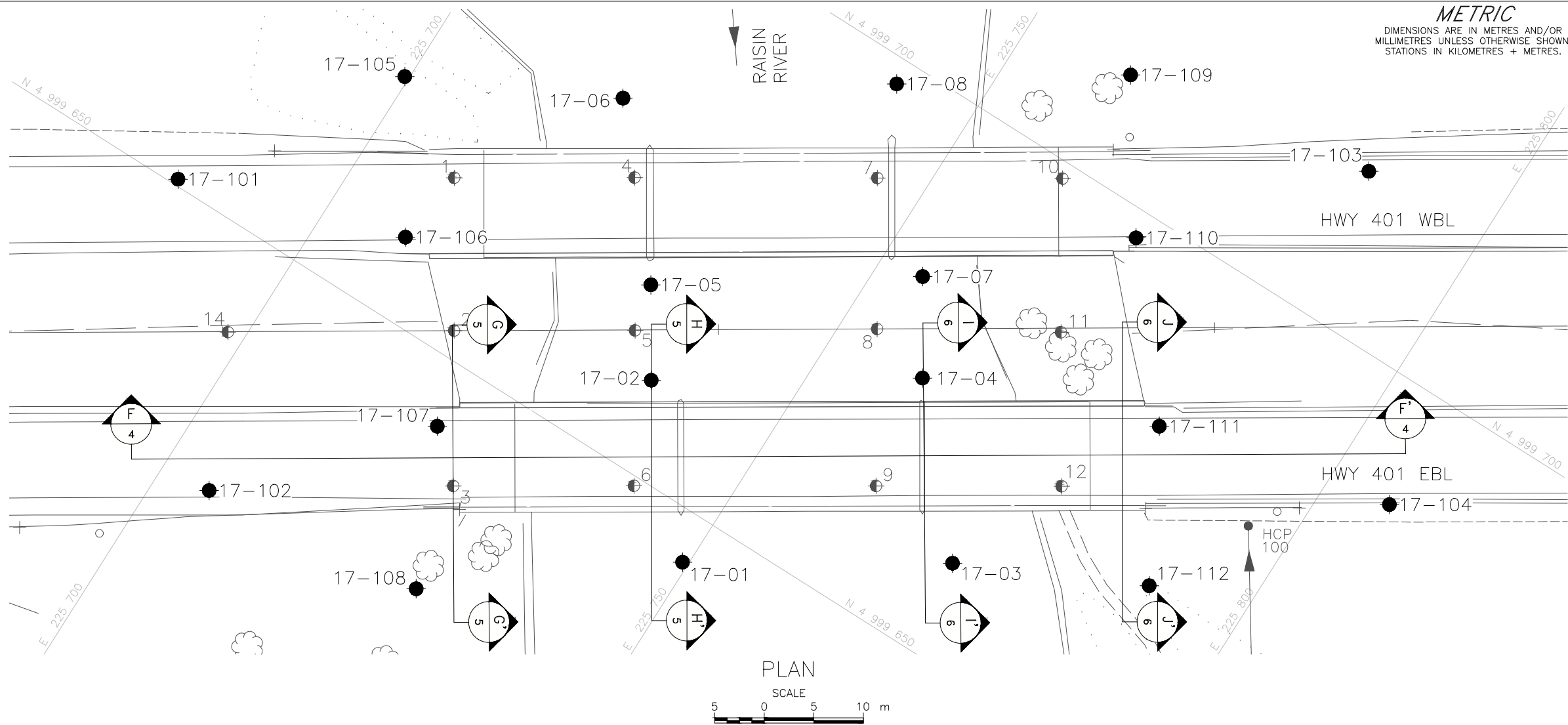
REFERENCE

Base plans provided in digital format by Dillon, drawing file nos. Base.dwg and 31-231-09-GA.dwg, received SEPTEMBER 19, 2017.



A			
NO.	DATE	BY	REVISION
Geocres No. 31G-261			
HWY. 401	PROJECT NO. 1772182		DIST. EASTERN
SUBM'D. KSL	CHKD. KSL	DATE: 11/13/2018	SITE: 31-231/1&2
DRAWN: JM	CHKD. MJK	APPD. FJH	DWG. 5

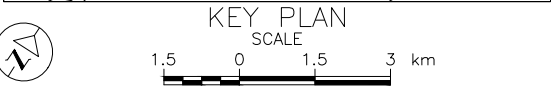
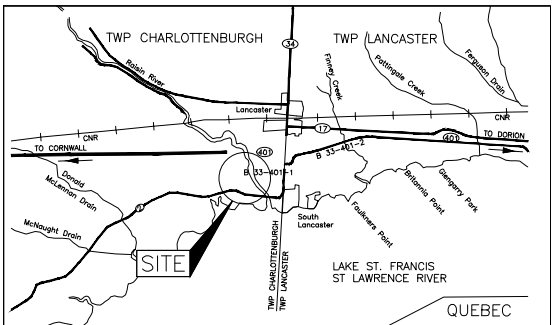




CONT No.  
GWP No. 4084-11-00

RAISIN RIVER BRIDGE EBL  
HIGHWAY 401  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 45.132590 LONG. -74.505061

SHEET



- LEGEND**
- Borehole - Current Investigation
  - Borehole - Previous Investigation  
Geocres No. 31G-143
  - Seal
  - Piezometer
  - N Standard Penetration Test Value
  - 16 Blows/0.3m unless otherwise stated  
(Std. Pen. Test, 475 j/blow)
  - DD Diamond Drilling
  - 100% Rock Quality Designation (RQD)
  - WL in piezometer, measured on MAY 26, 2017
  - WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM ZONE 8)			
No.	ELEVATION	NORTHING	EASTING
17-01	46.6	4999645.2	225749.4
17-02	46.6	4999659.0	225736.9
17-03	46.6	4999659.7	225772.5
17-04	46.6	4999673.8	225759.9
17-05	46.6	4999667.1	225731.8
17-06	46.6	4999681.5	225719.3
17-07	46.6	4999682.5	225754.5
17-08	46.6	4999697.5	225741.9
17-101	50.2	4999650.6	225685.8
17-102	50.2	4999625.8	225705.2
17-103	49.9	4999715.5	225786.8
17-104	49.9	4999688.3	225806.5
17-105	47.3	4999671.6	225699.6
17-106	50.1	4999658.0	225708.3
17-107	50.1	4999643.6	225721.2
17-108	48.2	4999628.6	225728.2
17-109	47.7	4999710.9	225761.3
17-110	50.0	4999697.3	225770.6
17-111	50.0	4999682.5	225782.7
17-112	47.5	4999668.4	225790.4

**NOTES**

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

**REFERENCE**

Base plans provided in digital format by Dillon, drawing file nos. Base.dwg and 31-231-09-GA.dwg, received SEPTEMBER 19, 2017.

A			
NO.	DATE	BY	REVISION
Geocres No. 31G-261			
HWY. 401	PROJECT NO. 1772182		DIST. EASTERN
SUBM'D. KSL	CHKD. KSL	DATE: 11/13/2018	SITE: 31-231/1&2
DRAWN: JM	CHKD. MJK	APPD. FJH	DWG. 6

**APPENDIX A**

**Borehole and Drillhole Records, 2017 Investigation**

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 17-01 to 17-08 and 17-101 to 17-112

## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

<b>I. GENERAL</b>		<b>(a) Index Properties (continued)</b>	
$\pi$	3.1416	w	water content
$\ln x$ ,	natural logarithm of x	$w_l$ or LL	liquid limit
$\log_{10}$	x or log x, logarithm of x to base 10	$w_p$ or PL	plastic limit
g	acceleration due to gravity	$I_p$ or PI	plasticity index = $(w_l - w_p)$
t	time	$w_s$	shrinkage limit
FoS	factor of safety	$I_L$	liquidity index = $(w - w_p) / I_p$
		$I_C$	consistency index = $(w_l - w) / I_p$
		$e_{max}$	void ratio in loosest state
		$e_{min}$	void ratio in densest state
		$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)
<b>II. STRESS AND STRAIN</b>		<b>(b) Hydraulic Properties</b>	
$\gamma$	shear strain	h	hydraulic head or potential
$\Delta$	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
$\varepsilon$	linear strain	v	velocity of flow
$\varepsilon_v$	volumetric strain	i	hydraulic gradient
$\eta$	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
$\nu$	Poisson's ratio	j	seepage force per unit volume
	total stress		
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )	<b>(c) Consolidation (one-dimensional)</b>	
$\sigma'_{vo}$	initial effective overburden stress	C	compression index (normally consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, minor)	$C_r$	recompression index (over-consolidated range)
$\sigma_{oct}$	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$	$C_s$	swelling index
$\tau$	shear stress	$C_{\alpha}$	secondary compression index
u	porewater pressure	$m_v$	coefficient of volume change
E	modulus of deformation	$c_v$	coefficient of consolidation (vertical direction)
G	shear modulus of deformation	$C_h$	coefficient of consolidation (horizontal direction)
K	bulk modulus of compressibility	$T_v$	time factor (vertical direction)
		U	degree of consolidation
<b>III. SOIL PROPERTIES</b>		$\sigma'_p$	pre-consolidation stress
<b>(a) Index Properties</b>		OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$
$\rho(\gamma)$	bulk density (bulk unit weight)*	<b>(d) Shear Strength</b>	
$\rho_d(\gamma_d)$	dry density (dry unit weight)	$\tau_p, \tau_r$	peak and residual shear strength
$\rho_w(\gamma_w)$	density (unit weight) of water	$\phi'$	effective angle of internal friction
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	$\delta$	angle of interface friction
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )	$\mu$	coefficient of friction = $\tan \delta$
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )	$c'$	effective cohesion
e	void ratio	$C_u, S_u$	undrained shear strength ( $\phi = 0$ analysis)
n	porosity	p	mean total stress $(\sigma_1 + \sigma_3)/2$
S	degree of saturation	$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
		q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
		$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
		$S_t$	sensitivity

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$\tau = c' + \sigma' \tan \phi'$   
shear strength = (compressive strength)/2

## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### Dynamic Cone Penetration Resistance; N<sub>d</sub>:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q<sub>t</sub>), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

Condition	N Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

	kPa	Cu, Su psf
Very soft	0 to 12	0 to 250
Firm Stiff	12 to 25	250 to 500
Very stiff	25 to 50	500 to 1,000
Hard	50 to 100	1,000 to 2,000
	100 to 200	2,000 to 4,000
	over 200	over 4,000

### IV. SOIL TESTS

w	water content
w <sub>p</sub>	plastic limit
w <sub>l</sub>	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
D <sub>R</sub>	relative density (specific gravity, G <sub>s</sub> )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

**Note:** 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

## LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

### WEATHERINGS STATE

**Fresh:** no visible sign of weathering

**Faintly weathered:** weathering limited to the surface of major discontinuities.

**Slightly weathered:** penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

**Moderately weathered:** weathering extends throughout the rock mass but the rock material is not friable.

**Highly weathered:** weathering extends throughout rock mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

### BEDDING THICKNESS

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

### JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

### GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: \* Grains greater than 60 microns diameter are visible to the naked eye.

### CORE CONDITION

#### Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

#### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

#### Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

### DISCONTINUITY DATA

#### Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

#### Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

#### Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

#### Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT		1772182-1040		RECORD OF BOREHOLE No 17-01		SHEET 1 OF 1		METRIC								
G.W.P.		4013-11-00		LOCATION		N 4999645.2; E 225749.4 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY								
DIST		Eastern HWY 401		BOREHOLE TYPE		Wash Boring, NW Casing		COMPILED BY								
DATUM		Geodetic		DATE		April 24, 2017		CHECKED BY								
KSL																
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
46.6	DECK SURFACE															
0.0	WATER															
44.0																
2.6	(GM) Silty GRAVEL, some sand, contains white shells Loose Brown Wet		1	SS	7											
43.1																
3.5	(SM) Silty SAND, some gravel Loose Brown Wet		2	SS	4											
42.0																
4.6	(ML) Sandy SILT, contains organic matter (wood)		3	SS	10											
41.6																
5.0	(CI) SILTY CLAY, contains silt seams Grey Wet		4	SS	2											
40.9																
5.7	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Compact Grey Wet		5	SS	18											
			6	SS	15											
39.4																
7.2	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Loose Grey Wet		7	SS	6											
37.9																
8.8	Probable Bedrock END OF BOREHOLE SAMPLER REFUSAL		8	SS	110/0.23											

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGAEASTERN\RETAINER6\02\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT		1772182-1040		RECORD OF BOREHOLE No 17-02		SHEET 1 OF 3		METRIC								
G.W.P.		4013-11-00		LOCATION		N 4999659.0; E 225736.9 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY								
DIST		Eastern HWY 401		BOREHOLE TYPE		Wash Boring, NW Casing		COMPILED BY								
DATUM		Geodetic		DATE		April 23, 2017		CHECKED BY								
								KSL								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
46.6 0.0	DECK SURFACE WATER							20 40 60 80 100								
45.5 1.1	(SP/GP) SAND and GRAVEL, contains cobbles, boulders and shells Compact Brown Wet		1	SS	28											
44.5 2.1	(SP/GP) SAND and GRAVEL, some silt Compact Grey-brown Wet		2	RC	DD											
			3	SS	28											
			4	SS	24											
			5	SS	26											
42.2 4.4	(SM) Silty SAND, contains organic matter (wood) Dense		6	SS	49											
41.3 5.3	(CI) SILTY CLAY, trace gravel Grey Wet															
40.7 5.9	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Very dense Grey Wet		7	SS	14											
			8	SS	65											
39.5 7.1	(ML) Sandy SILT, some gravel, contains cobbles and boulders (TILL) Compact to very dense Grey Wet		9	RC	DD											
			10	SS	16											
			11	SS	99											
37.3 9.3			1	RC	REC 100%											

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMITO\MEGAEASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT <u>1772182-1040</u>		<b>RECORD OF BOREHOLE No 17-02</b>		SHEET 2 OF 3		<b>METRIC</b>	
G.W.P. <u>4013-11-00</u>		LOCATION <u>N 4999659.0; E 225736.9 MTM ZONE (LAT. ; LONG. )</u>		ORIGINATED BY <u>DWM</u>			
DIST <u>Eastern</u> HWY <u>401</u>		BOREHOLE TYPE <u>Wash Boring, NW Casing</u>		COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>April 23, 2017</u>		CHECKED BY <u>KSL</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL LIMIT   MOISTURE   CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								○ UNCONFINED   + FIELD VANE	● QUICK TRIAXIAL   × REMOULDED												
	--- CONTINUED FROM PREVIOUS PAGE ---																				
	Dolostone (BEDROCK)																				
35.9	Bedrock cored from depths 9.3 m to 12.1 m		1	RC	REC 100%													RQD = 56%			
10.7	For bedrock coring detail refer to Record of Drillhole 17-02																				
	Shale (BEDROCK)		2	RC	REC 87%													RQD = 40%			
35.2																					
11.4	Interbedded Shale and Dolostone (BEDROCK)																				
			3	RC	REC 50%													RQD = 40%			
34.7																					
	Limestone (BEDROCK)																				
34.5																					
12.1	END OF BOREHOLE																				

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGAEASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS



PROJECT: 1772182-1040

**RECORD OF DRILLHOLE: 17-02**

SHEET 3 OF 3

LOCATION: N 4999659.0 ;E 225736.9

DRILLING DATE: April 23, 2017

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D-25

DRILLING CONTRACTOR: Walker Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS °	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr		Js	10 <sup>-5</sup> 10 <sup>-4</sup> 10 <sup>-3</sup> 10 <sup>-2</sup>	W1 W2 W3 W4 W5 W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
		BEDROCK SURFACE		37.30																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						

DEPTH SCALE

1 : 50

**GOLDER**

LOGGED: DWM

CHECKED: KSL


GTA-RCK 031 N:\ACTIVE\SPATIAL\_IMMTO\MEGA\EASTERN\RETRAINER\02\_DATA\GINT\1772182-1040.GPJ GAL-MISS.GDT 7/30/18 ZS

PROJECT 1772182-1040			RECORD OF BOREHOLE No 17-03			SHEET 1 OF 3			METRIC							
G.W.P. 4013-11-00			LOCATION N 4999659.7; E 225772.5 MTM ZONE (LAT. ; LONG. )			ORIGINATED BY DWM										
DIST Eastern HWY 401			BOREHOLE TYPE Wash Boring, NW Casing			COMPILED BY ZS										
DATUM Geodetic			DATE April 11, 2017			CHECKED BY KSL										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
46.6	DECK SURFACE															
0.0	WATER															
45.8	(SM/GM) SILTY SAND and GRAVEL Very loose Grey Wet		1	SS	2											
45.2	(SM) Silty SAND Very loose Grey		2	SS	1											
44.8	(CH) CLAY Firm Grey Wet		3	SS	3											
43.3	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Compact Grey Wet		4	SS	13											
3.4			5	SS	26											
			6	SS	22											
			7	SS	13											
			8	SS	15											
			9	SS	12											
			10	SS	40/0.20											
38.4	Dolostone (BEDROCK)															
8.2	Bedrock cored from depths 8.2 m to 11.2 m  For bedrock coring detail refer to Record of Drillhole 17-03		1	RC	REC 100%											RQD = 76%
			2	RC	REC 100%											RQD = 70%

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTOMEGA\EASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT		RECORD OF BOREHOLE No 17-03				SHEET 2 OF 3		METRIC									
G.W.P. 1772182-1040		LOCATION N 4999659.7; E 225772.5 MTM ZONE (LAT. ; LONG. )				ORIGINATED BY DWM											
DIST Eastern HWY 401		BOREHOLE TYPE Wash Boring, NW Casing				COMPILED BY ZS											
DATUM Geodetic		DATE April 11, 2017				CHECKED BY KSL											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					25 50 75				GR SA SI CL	
36.2	Shale (BEDROCK)		2	RC	REC 100%	36											RQD = 70%
10.4			3	RC	REC 87%												
35.4	END OF BOREHOLE																
11.2																	

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGAEASTERNRETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

SHEET 3 OF 3

DATUM: Geodetic

DRILLING CONTRACTOR: Walker Drilling

[illegible]

CHECKED: KSL

GTA-RCK 031 N:ACTIVE|SPATIAL\_IMMTO|MEGA|EASTERN|RETAINER6|02\_DATA|GINT|1772182-1040.GPJ GAL-MISS.GDT 7/30/18 ZS

PROJECT 1772182-1040		RECORD OF BOREHOLE No 17-04		SHEET 1 OF 1		METRIC											
G.W.P. 4013-11-00		LOCATION N 4999673.8; E 225759.9 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY DWM													
DIST Eastern HWY 401		BOREHOLE TYPE Wash Boring, NW Casing		COMPILED BY ZS													
DATUM Geodetic		DATE April 12, 2017		CHECKED BY KSL													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL
								20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>	25 50 75				
46.6 0.0	DECK SURFACE WATER																
45.3							46										
45.1 1.5	(SP) SAND, some silt, trace gravel Black Wet		1	SS	3		45										
44.5 2.1	(CI/CH) SILTY CLAY to CLAY, trace sand, contains organic matter Grey Wet		2	SS	1		44										
43.9 2.7	(CI/CH) SILTY CLAY to CLAY, contains silty sand seams and organic matter Grey Wet		3	SS	2												
43.3 3.4	(CI/CH) SILTY CLAY to CLAY Firm Grey Wet		4	SS	22		43										
	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Compact to very dense Grey Wet		5	SS	32		42										
			6	SS	56		41										
			7	SS	75		40										
			8	SS	18		39										
39.4 7.2	(SM) Gravelly Silty SAND, contains cobbles and boulders (TILL) Very dense Grey Wet		9	SS	54												
			10	SS	65		38										
37.7 8.9	END OF BOREHOLE SAMPLER REFUSAL		11	SS	132												

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTOMEGA\EASTERNRETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS



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



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

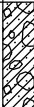


PROJECT 1772182-1040		RECORD OF BOREHOLE No 17-06		SHEET 1 OF 3		METRIC											
G.W.P. 4013-11-00		LOCATION N 4999681.5; E 225719.3 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY DWM													
DIST Eastern HWY 401		BOREHOLE TYPE Wash Boring, NW Casing		COMPILED BY ZS													
DATUM Geodetic		DATE April 20, 2017		CHECKED BY KSL													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	WATER CONTENT (%)	25 50 75	γ	GR SA SI CL			
46.6 0.0	DECK SURFACE WATER																
45.0 1.6	(SM/GM) Silty SAND and GRAVEL, contains shells and clayey silt seams Loose Grey Wet		1	SS	5								OC = 3.2%	36 38 21 5			
44.4 2.2	(ML) CLAYEY Sandy SILT, some gravel, contains clayey sandy shells Grey Wet		2	SS	61/0.23												
43.9 2.7	(SM) Gravelly SAND, contains cobbles and boulders (TILL) Dense Grey Wet		3	RC	DD												
			4	RC	DD												
			5	SS	31												
41.0 5.6	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Compact to dense Grey Wet		6	SS	16									42 37 19 2			
			7	RC	DD												
			8	SS	14												
			9	SS	35												
			10	RC	DD												

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGAEASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS



PROJECT <u>1772182-1040</u>			RECORD OF BOREHOLE <b>No 17-06</b>			SHEET 2 OF 3			<b>METRIC</b>								
G.W.P. <u>4013-11-00</u>			LOCATION <u>N 4999681.5; E 225719.3 MTM ZONE (LAT. ; LONG. )</u>			ORIGINATED BY <u>DWM</u>											
DIST <u>Eastern</u> HWY <u>401</u>			BOREHOLE TYPE <u>Wash Boring, NW Casing</u>			COMPILED BY <u>ZS</u>											
DATUM <u>Geodetic</u>			DATE <u>April 20, 2017</u>			CHECKED BY <u>KSL</u>											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Compact to dense Grey Wet		11	RC	DD												
34.9																	
11.7	Dolostone (BEDROCK)  Bedrock cored from depths 11.7 m to 14.5 m  For bedrock coring details refer to Record of Drillhole 17-06		12	RC	DD												
33.9			13	RC	DD												
12.7	Limestone (BEDROCK)		1	RC	REC 89%												RQD = 75%
32.1																	
14.5	END OF BOREHOLE		2	RC	REC 100%												RQD = 100%

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGAEASTERN\RETAINER6\02\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT: 1772182-1040

**RECORD OF DRILLHOLE: 17-06**

SHEET 3 OF 3

LOCATION: N 4999681.5 ;E 225719.3

DRILLING DATE: April 20, 2017

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D-25

DRILLING CONTRACTOR: Walker Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS °	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr		Js	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>	10 <sup>-2</sup>	W1		W2	W3	W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
		BEDROCK SURFACE		34.92																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			

DEPTH SCALE

1 : 50

**GOLDER**

LOGGED: DWM

CHECKED: KSL

GTA-RCK 031 N:\ACTIVE\SPATIAL\_IMMTO\MEGA\EASTERN\RETRAINER\02\_DATA\GINT\1772182-1040.GPJ GAL-MISS.GDT 7/30/18 ZS



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

GTA-MTO 001 N:\ACTIVE\SPATIAL IM\MTO\MEGAEAST\RETAINER6\02 DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

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

SHEET 3 OF 3

DATUM: Geodetic

DRILLING CONTRACTOR: Walker Drilling

[illegible]

DEPTH SCALE

1 : 50



# GOLDER

LOGGED: DWM

CHECKED: KSL

GTARCK 031 N:ACTIVE|SPATIAL IMMTO|MEGA|EASTER|RETAINER6|02 DATA\GINT\1772182-1040.GPJ GAL-MISS.GDT 7/30/18 ZS

PROJECT		1772182-1040		RECORD OF BOREHOLE No 17-08		SHEET 1 OF 1		METRIC									
G.W.P.		4013-11-00		LOCATION		N 4999697.5; E 225741.9 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY									
DIST		Eastern HWY 401		BOREHOLE TYPE		Wash Boring, NW Casing		COMPILED BY									
DATUM		Geodetic		DATE		April 18, 2017		CHECKED BY									
KSL																	
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
46.6 0.0	DECK SURFACE WATER							20	40	60	80	100					
45.6	(SM) Silty SAND, some gravel																
45.3 1.3	(SM/GM) Silty SAND and GRAVEL, contains silty clay layers Very loose Grey Wet		1	SS	3												35 32 25 8
43.9 2.7	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Dense to very dense Grey Wet		2	SS	4												
			3	SS	56/0.22												
			4	RC	DD												
			5	SS	42												
			6	SS	30												
			7	SS	89												
			8	SS	108/0.17												
			9	SS	100/0.15												
37.8 8.8	END OF BOREHOLE SAMPLER REFUSAL																32 48 18 2

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMITO\MEGAEASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

GTA-MTO 001 N:\ACTIVE\SPATIAL IMMTO\MEGAEASTERNRETAINER6\02 DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

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



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



PROJECT <u>1772182-1040</u>		<b>RECORD OF BOREHOLE No 17-102</b>		SHEET 1 OF 2		<b>METRIC</b>	
G.W.P. <u>4013-11-00</u>		LOCATION <u>N 4999625.8; E 225705.2 MTM ZONE (LAT. ; LONG. )</u>		ORIGINATED BY <u>DWM</u>			
DIST <u>Eastern</u> HWY <u>401</u>		BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>		COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>May 09, 2017</u>		CHECKED BY <u>KSL</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE   LIQUID CONTENT   CONTENT   LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED   + FIELD VANE	● QUICK TRIAXIAL   × REMOULDED											
50.2	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALTIC CONCRETE																			
49.9																				
0.3	(SP) Gravelly sand (FILL)		1	GRAB	-															
49.6	Brown Dry																			
0.6	(SM/ML) Sandy silt to silty sand, contains cobbles (FILL)		2	SS	23															
	Compact Brown Dry																			
48.7																				
1.5	(SM) Silty sand, some gravel, trace clay, contains cobbles (FILL)		3	SS	8									○				27	44	
	Loose to dense Brown Moist																	22	7	
			4	SS	16															
			5	SS	47															
46.4																				
3.8	(SM) Gravelly silty sand (FILL)		6	SS	13															
	Compact Brown Moist																			
45.6																				
4.6	(SW/GW) SAND and GRAVEL, contains shells		7	SS	9													35	57	
	Loose to compact Brown Wet																	(8)		
			8	SS	12															
44.1																				
6.1	(CI/CH) SILTY CLAY to CLAY		9	SS	2															
	Firm Grey with black organic mottling Wet																			
42.7																				
7.5	(SM) Gravelly Silty SAND (TILL)		10	SS	12															
	Loose to dense Grey Wet																			
			11	SS	7															
			12	SS	8															


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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTOMEGA\EASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT <u>1772182-1040</u>		<b>RECORD OF BOREHOLE No 17-102</b>				SHEET 2 OF 2		<b>METRIC</b>	
G.W.P. <u>4013-11-00</u>		LOCATION <u>N 4999625.8; E 225705.2 MTM ZONE (LAT. ; LONG. )</u>				ORIGINATED BY <u>DWM</u>			
DIST <u>Eastern</u> HWY <u>401</u>		BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>				COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>May 09, 2017</u>				CHECKED BY <u>KSL</u>			

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W <sub>p</sub>	W		
						20	40	60	80	100	WATER CONTENT (%)					
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED										
						20	40	60	80	100	25	50	75			
	--- CONTINUED FROM PREVIOUS PAGE ---															
	(SM) Gravelly Silty SAND (TILL) Loose to dense Grey Wet		13	SS	45											
39.3			14	SS	68/0.15											
10.9	END OF BOREHOLE AUGER REFUSAL															

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTOWMEGAEASTERNRETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS



N:\ACTIVE\SPATIAL IMMTO\MEGAEASTERNRETAINER6\02\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

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



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

PROJECT <u>1772182-1040</u>		<b>RECORD OF BOREHOLE No 17-104</b>		SHEET 1 OF 2		<b>METRIC</b>	
G.W.P. <u>4013-11-00</u>		LOCATION <u>N 4999688.3; E 225806.5 MTM ZONE (LAT. ; LONG. )</u>		ORIGINATED BY <u>DWM</u>			
DIST <u>Eastern</u> HWY <u>401</u>		BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>		COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>May 09, 2017</u>		CHECKED BY <u>KSL</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL LIMIT   MOISTURE   CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED   + FIELD VANE	● QUICK TRIAXIAL   × REMOULDED											
49.9	GROUND SURFACE																			
49.7	ASPHALTIC CONCRETE																			
0.2	(SP) Gravelly sand, some silt (FILL) Dense Brown Dry		1	GRAB	-															
			2	SS	32															
48.4																				
1.5	(SM) Sandy gravel, contains cobbles (FILL) Very dense Brown Dry		3	SS	62															
47.6																				
2.3	(GP) Sandy gravel, some silt (FILL) Dense Brown Moist		4	SS	38															
46.9																				
3.1	(CI/CH) SILTY CLAY to CLAY, trace sand (WEATHERED CRUST) Very stiff to stiff Grey-brown Wet		5	SS	11															
			6	SS	9															
			7	SS	6															
			8	SS	3															
43.3																				
6.6	(ML/SM) Sandy SILT to Silty SAND, some gravel, contains cobbles and boulders (TILL) Loose Grey Wet																			
			9	SS	8															
			10	SS	10															
40.8																				
9.1	(SM) Silty SAND, some gravel, contains cobbles and boulders (TILL) Compact Grey Wet		11	SS	19															
									</											

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IM\MTOMEGA\EA\STERN\RETRAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS



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

PROJECT		1772182-1040		RECORD OF BOREHOLE No 17-105		SHEET 1 OF 2		METRIC														
G.W.P.		4013-11-00		LOCATION		N 4999671.6; E 225699.6 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY														
DIST		Eastern HWY 401		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)		COMPILED BY														
DATUM		Geodetic		DATE		May 02, 2017		CHECKED BY														
								KSL														
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
47.3	0.0	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					25 50 75 W <sub>p</sub> W W <sub>L</sub>			25 50 75					
47.3	0.2	Topsoil (FILL) Brown (ML) Sandy silt, some clay, trace gravel (FILL) Very loose Brown Wet		1	SS	3		47									OC = 8.0%					
46.6	0.8	(OL) Organic SILT, some sand, trace gravel, contains rootlets and decomposed wood Very loose Brown to dark brown Wet		2	SS	4		46														
				3	SS	2																
45.1	2.3	(OL/MH) Organic SILT to SILT, some sand and clay Very loose Dark brown Wet		4	SS	PH		45									107.5 OC = 19.8%					
				5	SS	WR		44									OC = 12.4%					
43.5	3.8	(CI/CH) SILTY CLAY to CLAY Firm to stiff Grey Wet		6	SS	WR		43														
								42														
								41												0 1 26 73		
								40														
39.7	7.6	(SM/GM) Silty SAND and GRAVEL, contains cobbles and boulders (TILL) Loose to dense Grey Wet		8	SS	8		39														
				9	SS	32																
38.2	9.1	(GM) Sandy GRAVEL, some silt (TILL) Very dense Grey to black Wet		10	SS	71		38														

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMITO\MEGAEASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT <u>1772182-1040</u>		<b>RECORD OF BOREHOLE No 17-105</b>				SHEET 2 OF 2		<b>METRIC</b>	
G.W.P. <u>4013-11-00</u>		LOCATION <u>N 4999671.6; E 225699.6 MTM ZONE (LAT. ; LONG. )</u>				ORIGINATED BY <u>DWM</u>			
DIST <u>Eastern</u> HWY <u>401</u>		BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>				COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>May 02, 2017</u>				CHECKED BY <u>KSL</u>			

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W <sub>p</sub>	W		
							20	40	60	80	100					
37.3 10.1	END OF BOREHOLE AUGER REFUSAL  Note:  1. Water level in piezometer at a depth of 0.6 m below ground surface (Elev. 46.7 m) on July 29, 2017.	XXXX				XXXXXX										

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGAEASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS





PROJECT		1772182-1040		RECORD OF BOREHOLE No 17-106		SHEET 1 OF 3		METRIC																
G.W.P.		4013-11-00		LOCATION		N 4999658.0; E 225708.3 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY																
DIST		Eastern HWY 401		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), NQ Casing		COMPILED BY																
DATUM		Geodetic		DATE		May 11, 2017		CHECKED BY																
KSL																								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																		
50.1		GROUND SURFACE																						
50.0		ASPHALTIC CONCRETE																						
0.2		PORTLAND CEMENT CONCRETE																						
49.6		(SP) Gravelly sand, some silt (FILL) Compact Grey-brown		1	SS	19																		
48.6		(SM) Silty sand, some gravel, trace clay (FILL) Compact to loose Grey-brown Moist		2	SS	11																		
1.5				3	SS	8																		
47.1		(GM) Silty gravel, some sand (FILL) Dense Grey-brown Dry		4	SS	31																		
3.1				5	SS	4																		
46.3		(OL/ML) Organic SILT to SILT, some sand, trace gravel, contains organic matter Loose Dark brown Moist		6	SS	3																		
45.6				7	SS	3																		
4.6		(OL) Organic SILT, some sand Very loose Dark brown to black Wet		8	SS	2																		
				9	SS	PH																		
43.3		(CI/CH) SILTY CLAY to CLAY Firm Grey Wet																						
6.9																								
40.8		(SM) Gravelly silty SAND, contains cobbles and boulders (TILL) Loose Grey Wet		10	SS	5																		
9.3																								

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGA\EASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT		RECORD OF BOREHOLE No 17-106				SHEET 2 OF 3		METRIC										
1772182-1040		LOCATION N 4999658.0; E 225708.3 MTM ZONE (LAT. ; LONG. )				ORIGINATED BY DWM												
G.W.P. 4013-11-00		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem), NQ Casing				COMPILED BY ZS												
DIST Eastern HWY 401		DATE May 11, 2017				CHECKED BY KSL												
DATUM Geodetic																		
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100						
	(SM) Gravelly silty SAND, contains cobbles and boulders (TILL) Loose Grey Wet		11	SS	14													
			12	SS	13													
38.5																		
11.6	Probable (SM) Silty SAND, contains cobbles and boulders (TILL) Wet		13	RC	DD													
36.9			14	RC	DD													
13.2	Dolostone (BEDROCK)		1	RC	REC 100%												RQD = 100%	
	Bedrock cored from depths 13.2 m to 16.3 m  For bedrock coring details refer to Record of Drillhole 17-106		2	RC	REC 96%												RQD = 70%	
			3	RC	REC 100%												RQD = 99%	
33.9																		
16.3	END OF BOREHOLE																	

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTOWMEGAEASTERNRETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT: 1772182-1040

## RECORD OF DRILLHOLE: 17-106

SHEET 3 OF 3

LOCATION: N 4999658.0 ;E 225708.3

DRILLING DATE: May 11, 2017

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing Drilling

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY																		FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
					ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY		R.Q.D. %	FRACT INDEX PER	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY K, cm/sec			WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
								TOTAL CORE %	SOLID CORE %			DIP W/L CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	10 <sup>-6</sup> C	10 <sup>-6</sup> C	10 <sup>-6</sup> C	W1	W2	W3	W4		W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
		BEDROCK SURFACE		36.93																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														

UC = 106.6 MPa

DEPTH SCALE

1 : 50

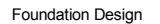


GOLDER

LOGGED: DWM

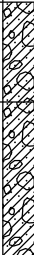
CHECKED: KSL

GTA-RCK 031 N:\ACTIVE\SPATIAL\_IMMTO\MEGA\EASTERN\RETRAINER6\02\_DATA\GINT\1772182-1040.GPJ GAL-MISS.GDT 7/30/18 ZS

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGAEASTERNRETAINER\02\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

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

PROJECT <u>1772182-1040</u>		<b>RECORD OF BOREHOLE No 17-107</b>		SHEET 2 OF 2		<b>METRIC</b>	
G.W.P. <u>4013-11-00</u>		LOCATION <u>N 4999643.6; E 225721.2 MTM ZONE (LAT. ; LONG. )</u>		ORIGINATED BY <u>DWM</u>			
DIST <u>Eastern</u> HWY <u>401</u>		BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>		COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>May 15, 2017</u>		CHECKED BY <u>KSL</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
39.5	(SM/GM) Silty SAND and GRAVEL (TILL) Compact Brown Wet		13	SS	23												
10.7	(SM) Gravelly silty SAND (TILL) Dense Brown Wet		14	SS	37												
38.4																	
11.7	END OF BOREHOLE AUGER REFUSAL																

PROJECT		1772182-1040		RECORD OF BOREHOLE No 17-108		SHEET 1 OF 3		METRIC									
G.W.P.		4013-11-00		LOCATION		N 4999628.6; E 225728.2 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY									
DIST		Eastern HWY 401		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), Wash Boring, HW Casing		COMPILED BY									
DATUM		Geodetic		DATE		May 03, 2017		CHECKED BY									
								KSL									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS		ELEVATION SCALE		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES											
48.2	0.0	GROUND SURFACE															
47.9	0.3	Topsoil (FILL) Brown		1	SS	6											
47.6	0.6	(SP) Gravelly sand, some silt (FILL) Brown Moist		2	SS	10											
46.7	1.5	(SM) Silty sand, some gravel, trace clay, contains cobbles (FILL) Loose Brown Wet		3	SS	5											
45.2	3.1	(OH/ML) Organic SILT to SILT, some sand, trace gravel, contains wood Dark brown		4	SS	2											
43.6	4.6	(CI) SILTY CLAY, trace sand, contains organic matter (decomposed wood) Stiff Grey Wet		5	SS	PH											
41.2	7.0	(CI) SILTY CLAY, contains silt seams Firm Grey Wet		6	SS	1											
40.0	8.2	(ML/SM) Gravelly SILT to Silty SAND, contains cobbles and boulders (TILL) Very loose to compact Grey Wet		7	SS	WH											
38.3	9.9	Limestone (BEDROCK)		8	SS	3											
		Bedrock cored from depths 8.2 m to 13.7 m		9	SS	25											
		For bedrock coring details refer to Record of Drillhole 17-108		1	RC	REC 75%											RQD = 48%
				2	RC	REC 92%											RQD = 43%
		Dolostone (BEDROCK)															




Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IM\MTOMEGA\EASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT <u>1772182-1040</u>		<b>RECORD OF BOREHOLE No 17-108</b>				SHEET 2 OF 3		<b>METRIC</b>	
G.W.P. <u>4013-11-00</u>		LOCATION <u>N 4999628.6; E 225728.2 MTM ZONE (LAT. ; LONG. )</u>				ORIGINATED BY <u>DWM</u>			
DIST <u>Eastern</u> HWY <u>401</u>		BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem), Wash Boring, HW Casing</u>				COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>May 03, 2017</u>				CHECKED BY <u>KSL</u>			

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W <sub>p</sub>	W			W <sub>L</sub>
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)					
							20 40 60 80 100 20 40 60 80 100					25 50 75					
	--- CONTINUED FROM PREVIOUS PAGE ---																
	Dolostone (BEDROCK)		2	RC		REC 92%	38										RQD = 43%
			3	RC		REC 95%	37										RQD = 68%
			4	RC		REC 57%	36										RQD = 41%
34.5 13.7	END OF BOREHOLE						35										

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMITO\MEGAEASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

SHEET 3 OF 3

DATUM: Geodetic

DRILLING CONTRACTOR: Downing Drilling

[illegible]

CHECKED: KSL

GTA-RCK 031 N:ACTIVE|SPATIAL\_IMMTO|MEGA|EASTERN|RETAINER6|02\_DATA|GINT|1772182-1040.GPJ GAL-MISS.GDT 7/30/18 ZS





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

PROJECT 1772182-1040		<b>RECORD OF BOREHOLE No 17-109</b>		SHEET 2 OF 4		<b>METRIC</b>	
G.W.P. 4013-11-00		LOCATION N 4999710.9; E 225761.3 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY DWM			
DIST Eastern HWY 401		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem), Wash Boring, HW Casing		COMPILED BY ZS			
DATUM Geodetic		DATE April 27, 2017		CHECKED BY KSL			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL LIMIT   MOISTURE   CONTENT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	25	50	75					
	--- CONTINUED FROM PREVIOUS PAGE ---																			
	(ML/SM) Sandy SILT to Silty SAND, some gravel, contains cobbles and boulders (TILL) Very dense Grey Wet		13	RC	DD															
			14	RC	DD															
35.1																				
12.6	(ML) Sandy SILT, some gravel, contains cobbles and boulders (TILL) Very dense Grey Wet		15	SS	67															
34.4																				
13.3	Shale (BEDROCK)																			
34.0	Bedrock cored from depths 13.3 m to 18.4 m		1	RC	REC 100%													RQD = 100%		
13.7	For bedrock coring details refer to Record of Drillhole 17-109 Limestone (BEDROCK)																			
			2	RC	REC 100%													RQD = 100%		
			3	RC	REC 100%													RQD = 85%		
			4	RC	REC 100%													RQD = 100%		
29.7																				
18.0	Dolostone (BEDROCK)																			
29.3																				
18.4	END OF BOREHOLE																			

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTOMEGA\EASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

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

SHEET 4 OF 4

DATUM: Geodetic

DRILLING CONTRACTOR: Downing Drilling

[illegible]

CHECKED: KSL

PROJECT 1772182-1040			RECORD OF BOREHOLE No 17-110			SHEET 1 OF 2			METRIC							
G.W.P. 4013-11-00			LOCATION N 4999697.3; E 225770.6 MTM ZONE (LAT. ; LONG. )			ORIGINATED BY DWM										
DIST Eastern HWY 401			BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)			COMPILED BY ZS										
DATUM Geodetic			DATE May 15, 2017			CHECKED BY KSL										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
50.0	GROUND SURFACE															
0.0	ASPHALTIC CONCRETE															
0.1	PORTLAND CEMENT CONCRETE															
49.5																
0.6	(SP) Gravelly sand, some silt (FILL) Brown Dry		1	SS	33											
48.4	(SM-GM) Silty sand and gravel (FILL) Dense Grey-Brown Dry		2	SS	6											
1.5	(SM/ML) Silty sand to sandy silt, some gravel to gravelly, contains clay layers (FILL) Loose to dense Brown Moist		3	SS	7											
			4	SS	49											
46.2	(SM) Silty SAND, some gravel (TILL) Compact Grey-brown Wet		5	SS	27											
45.4	(SM) Silty SAND, some gravel to gravelly, contains cobbles and boulders (TILL) Compact to dense Grey Moist		6	SS	14											
4.6			7	SS	14											
			8	SS	15											
			9	SS	10											
			10	SS	49											
			11	SS	43/0.15											
			12	SS	50/0.15											

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTOMEGA\EASTERNRETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT <u>1772182-1040</u>			<b>RECORD OF BOREHOLE No 17-110</b>				SHEET 2 OF 2		<b>METRIC</b>	
G.W.P. <u>4013-11-00</u>			LOCATION <u>N 4999697.3; E 225770.6 MTM ZONE (LAT. ; LONG. )</u>				ORIGINATED BY <u>DWM</u>			
DIST <u>Eastern</u> HWY <u>401</u>			BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)</u>				COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>			DATE <u>May 15, 2017</u>				CHECKED BY <u>KSL</u>			

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W <sub>p</sub>	W		
	--- CONTINUED FROM PREVIOUS PAGE ---															
	(SM) Silty SAND, some gravel to gravelly, contains cobbles and boulders (TILL) Compact to dense Grey Moist		13	SS	50/0.23											
			14	SS	50/0.08											
38.8						39										
11.2	END OF BOREHOLE AUGER REFUSAL															

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\MEGAEASTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT		1772182-1040		RECORD OF BOREHOLE No 17-111		SHEET 1 OF 3		METRIC								
G.W.P.		4013-11-00		LOCATION		N 4999682.5; E 225782.7 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY								
DIST		Eastern HWY 401		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem), Wash Boring, NW Casing		COMPILED BY								
DATUM		Geodetic		DATE		May 12, 2017		CHECKED BY								
KSL																
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
50.0	GROUND SURFACE															
49.8	ASPHALTIC CONCRETE															
0.2	PORTLAND CEMENT CONCRETE															
49.4																
49.2	(SW) Gravelly SAND (FILL) Brown Dry															
0.8	(SP/GP) Sand and gravel, some silt (FILL) Dense Grey-brown Dry		1	SS	48											
			2	SS	35											
47.9	(SP) Gravelly sand, some silt (FILL) Compact Grey-brown Dry															
2.1			3	SS	24											
46.9	(SM) Silty sand, some gravel (FILL) Loose Grey-brown Wet															
3.1			4	SS	8											
46.2	(ML) Sandy silt, trace clay, contains organic matter (FILL) Very Loose Grey-brown Wet															
3.8			5	SS	2											
45.4	(CI/CH) SILTY CLAY to CLAY, contains sand seams Stiff to firm Grey-brown Wet															
4.6			6	SS	9											
44.4	(SM) Silty SAND, some gravel, contains cobbles and boulders (TILL) Very loose Grey Wet															
5.6			7	SS	3											
42.4	(SM/GM) Silty SAND and GRAVEL (TILL) Compact Grey Wet															
7.6			8	SS	24											
			9	SS	12											
40.8	(SM/GM) Gravelly Silty SAND to Silty GRAVEL, contains cobbles and boulders (TILL) Compact Grey Wet															
9.1			10	SS	40/0.15											

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTOMEGA\EA\ESTERN\RETAINER602\_DATA\GINT\1772182-1040.GPJ GAL-GTA.GDT 7/30/18 ZS

PROJECT		RECORD OF BOREHOLE No 17-111				SHEET 2 OF 3		METRIC									
G.W.P. 4013-11-00		LOCATION N 4999682.5; E 225782.7 MTM ZONE (LAT. ; LONG. )				ORIGINATED BY DWM											
DIST Eastern HWY 401		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem), Wash Boring, NW Casing				COMPILED BY ZS											
DATUM Geodetic		DATE May 12, 2017				CHECKED BY KSL											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---																
37.4	(SM/GM) Gravelly Silty SAND to Silty GRAVEL, contains cobbles and boulders (TILL) Compact Grey Wet		11	SS	19		39										
12.6	(SM) Silty SAND, some gravel, contains cobbles and boulders (TILL)		12	SS	57/0.41		38										
			13	RC	DD		37										
			14	RC	DD		36										
34.8							35										
15.2	Shale (BEDROCK)																
34.5	Bedrock cored from depths 15.2 m to 18.9 m		1	RC	REC 100%		34									RQD = 100%	
15.5	For bedrock coring details refer to Record of Drillhole 17-111 Limestone (BEDROCK)		2	RC	REC 100%		33									RQD = 100%	
			3	RC	REC 100%		32									RQD = 100%	
31.1	END OF BOREHOLE																
18.9																	

SHEET 3 OF 3

DATUM: Geodetic

DRILLING CONTRACTOR: Downing Drilling



**GOLDER**

CHECKED: KSL



PROJECT		1772182-1040		RECORD OF BOREHOLE No 17-112		SHEET 1 OF 1		METRIC									
G.W.P.		4013-11-00		LOCATION		N 4999668.4; E 225790.4 MTM ZONE (LAT. ; LONG. )		ORIGINATED BY									
DIST		Eastern HWY 401		BOREHOLE TYPE		Portable Drill		COMPILED BY									
DATUM		Geodetic		DATE		May 16, 2017		CHECKED BY									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
47.5	GROUND SURFACE																
0.0	(ML) Silt, some sand and clay, trace organics (FILL) Very loose Brown Moist		1	SS	2												
46.9																	
0.6	(ML) SILTY CLAY, trace sand (WEATHERED CRUST) Very stiff Brown Moist		2	SS	12												
			3	SS	24												
			4	SS	24												
45.0																	
2.4	(CI) SILTY CLAY (WEATHERED CRUST), contains silt seams Stiff to very stiff Grey-brown to grey Moist		5	SS	17												
			6	SS	8												
43.2																	
4.3	(SM/ML) Sandy SILT to Silty SAND, some gravel, contains cobbles and boulders (TILL) Compact to loose Grey Wet		7	SS	16												
			8	SS	8												
			9	SS	11												
41.4																	
6.1	(SM) Silty SAND, some gravel, contains cobbles and boulders (TILL) Compact to dense Grey Wet		10	SS	17												
			11	SS	43												
39.2																	
8.3	END OF BOREHOLE CASING REFUSAL																
	Note: 1. Water level in piezometer at a depth of 0.5 m below ground surface (Elev. 47.0 m) on July 29, 2017.																

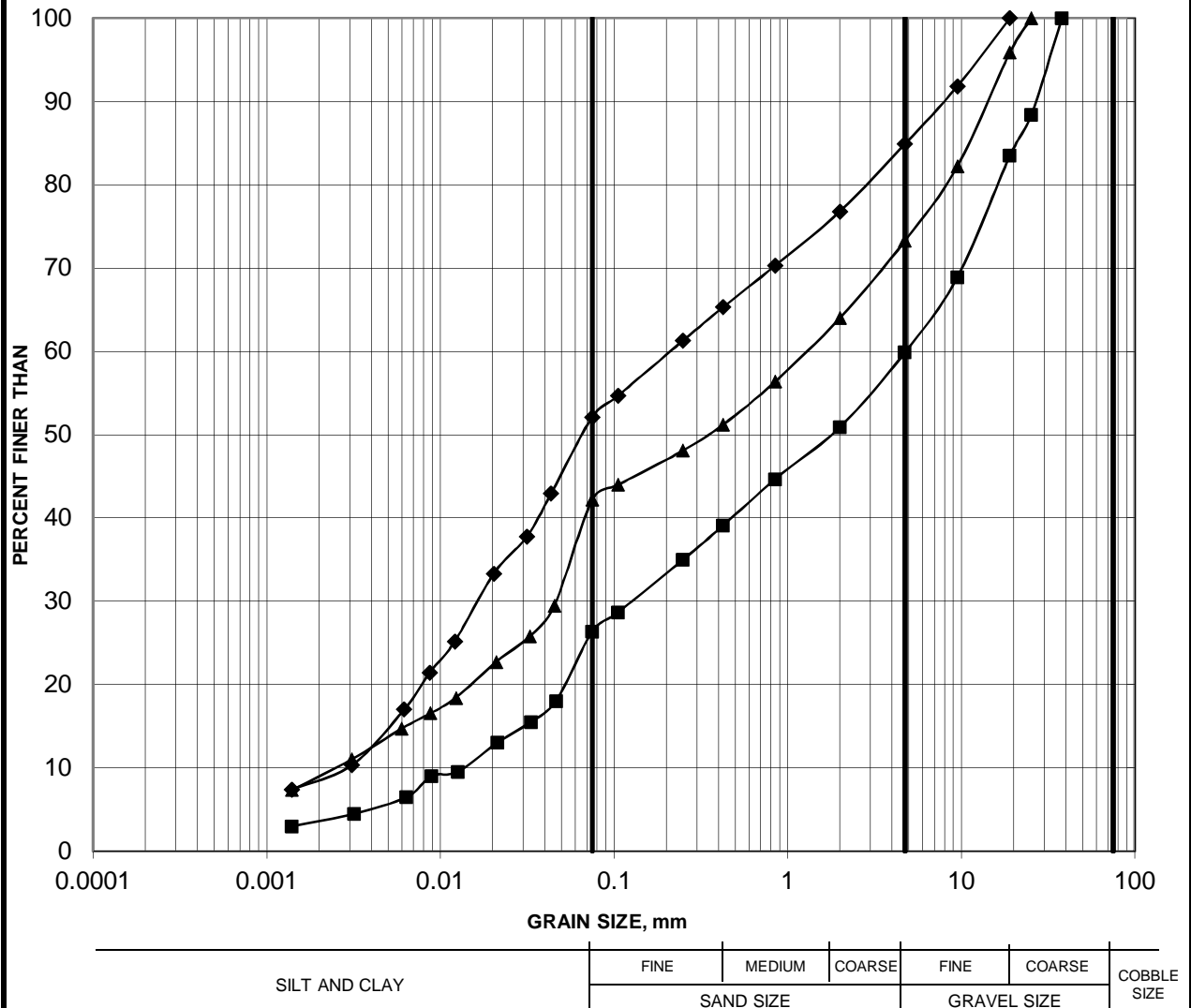
**APPENDIX B**

**Laboratory Test Results, 2017 Investigation**

# GRAIN SIZE DISTRIBUTION

FIGURE B1

## FILL - Westbound Structure

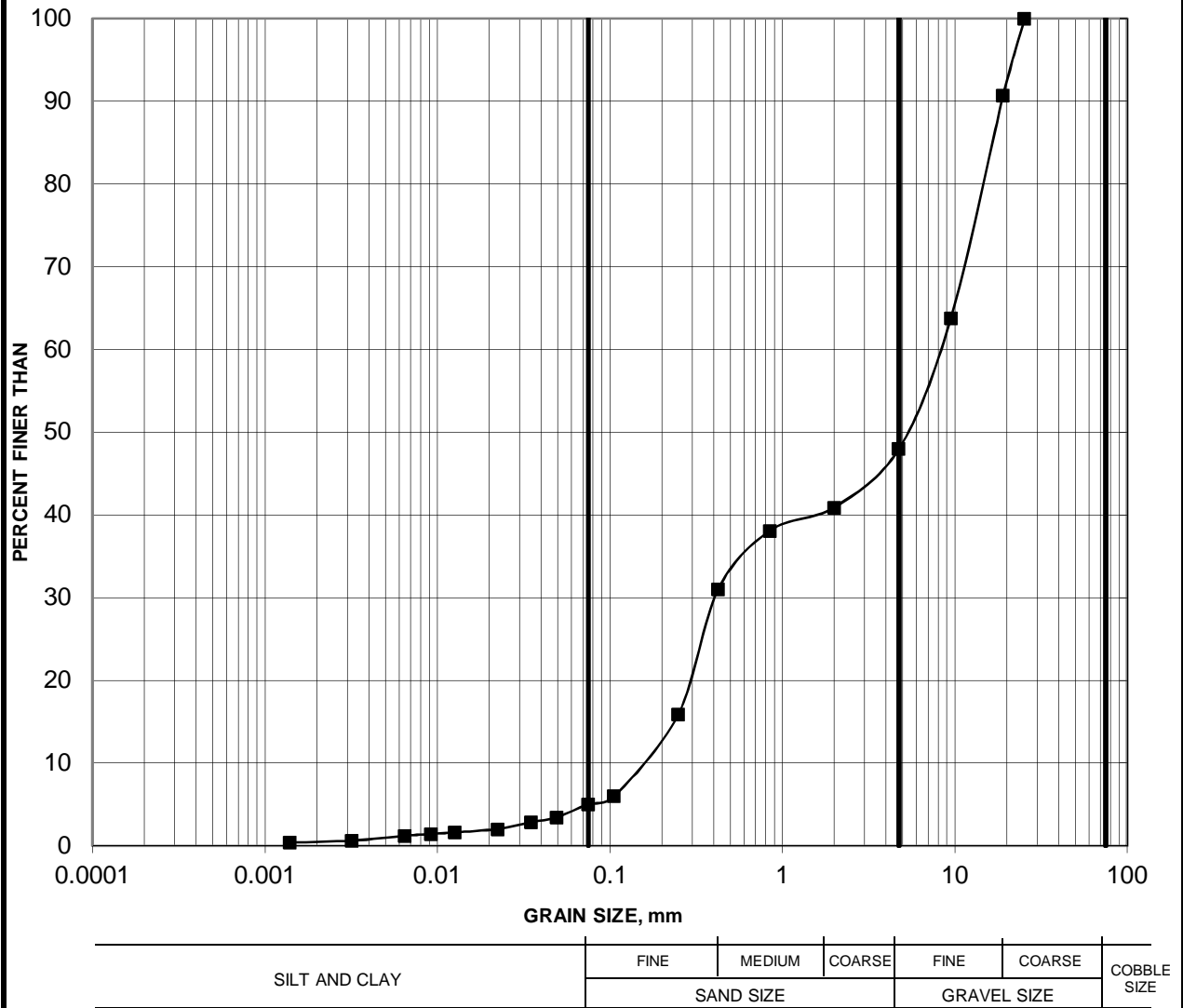


Borehole	Sample	Depth (m)
17-101	2	1.52-2.13
17-103	3	1.52-2.13
17-110	3	2.29-2.90

# GRAIN SIZE DISTRIBUTION

FIGURE B2

## SAND and GRAVEL - Westbound Structure

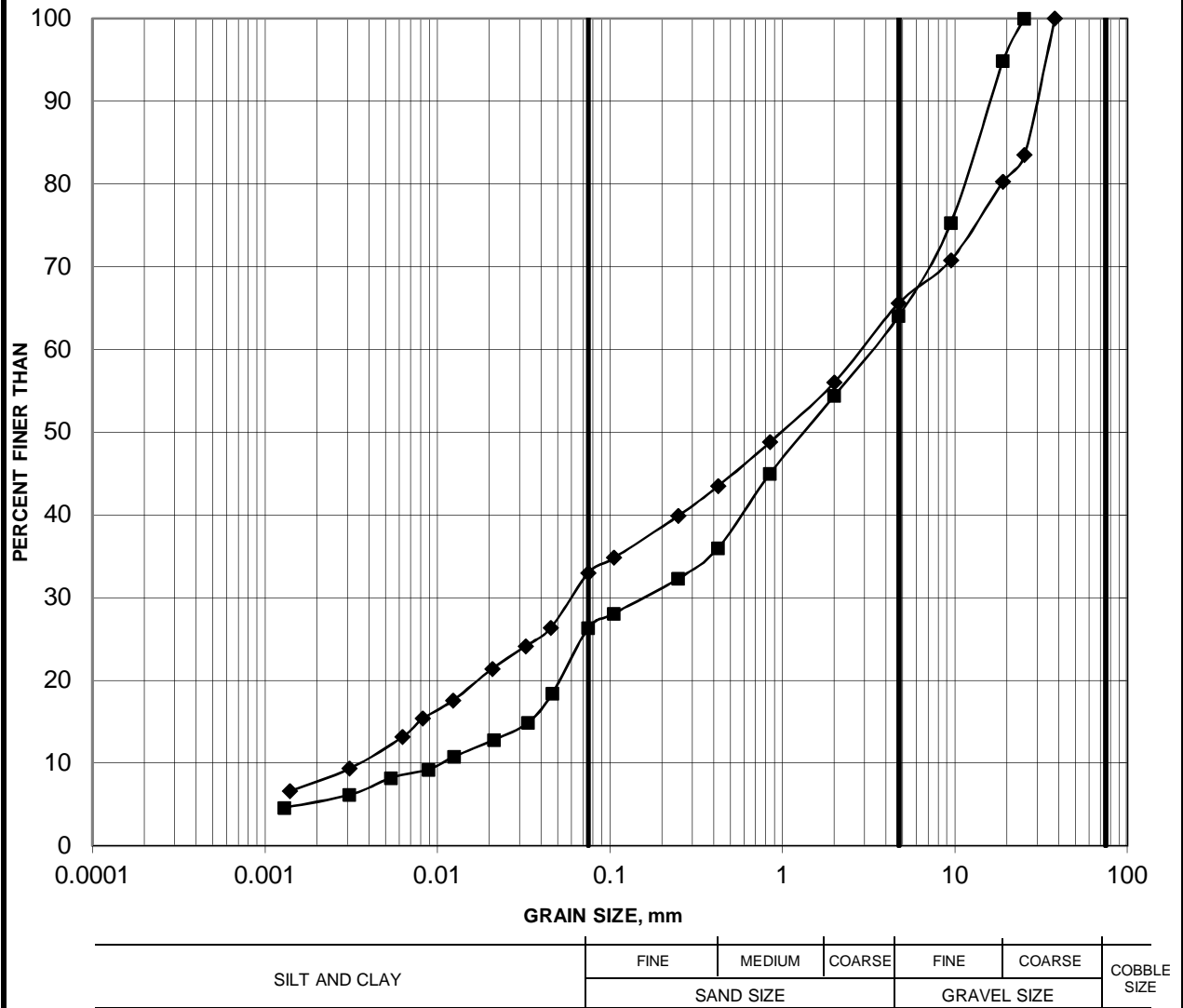


Borehole	Sample	Depth (m)
17-05	3	2.82-3.43

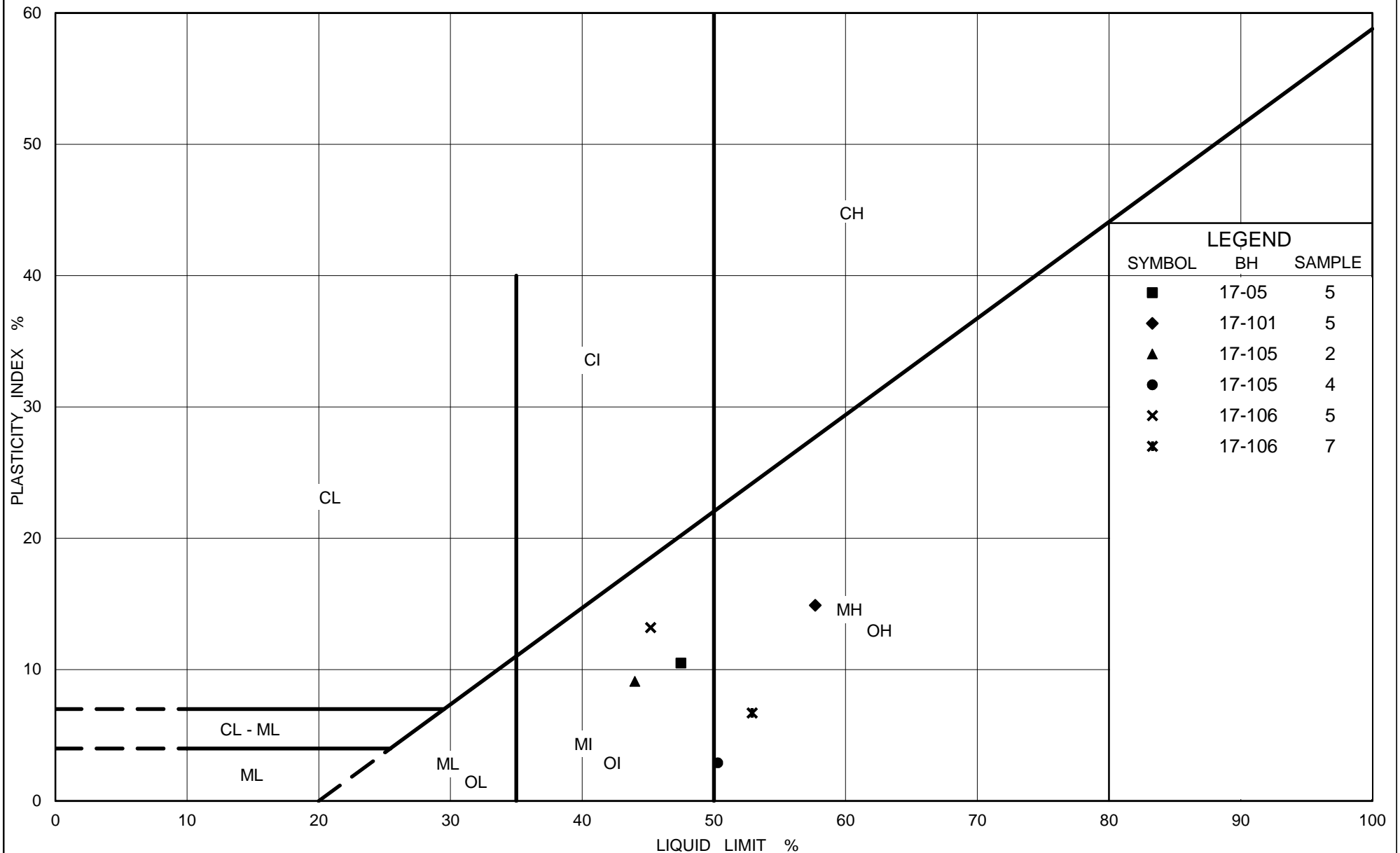
# GRAIN SIZE DISTRIBUTION

FIGURE B3

## Silty SAND and GRAVEL - Westbound Structure



Borehole	Sample	Depth (m)
17-06	1	1.62-2.21
17-08	1	1.27-1.88



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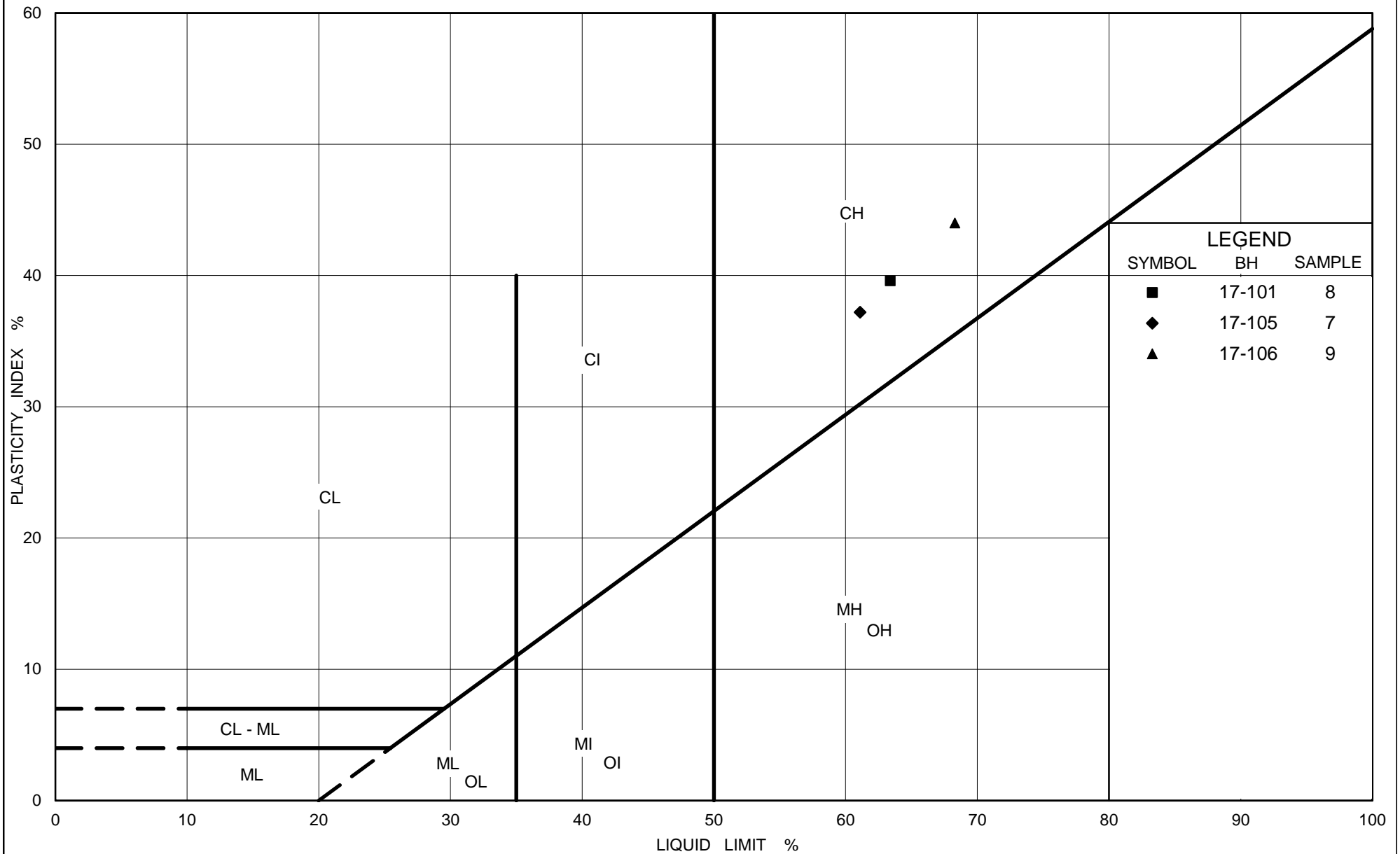
Ministry of Transportation

# PLASTICITY CHART Organic SILT to SILT - Westbound Structure

FIG No. B4

Project No. 1772182 /1040

Compiled By : MI      Checked By : CNM



Ontario

Ministry of Transportation

## PLASTICITY CHART

### CLAY - Westbound Structure

FIG No. B5

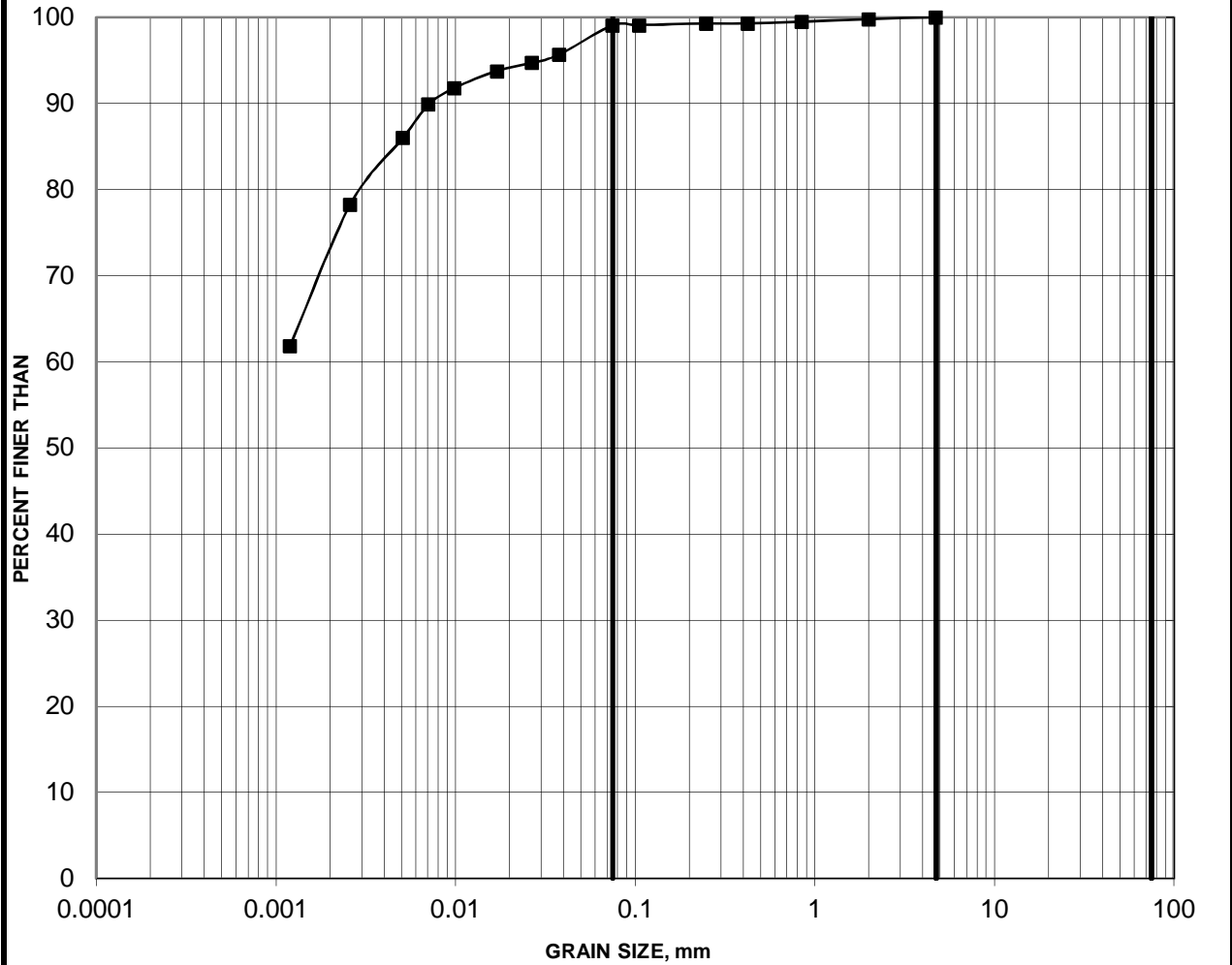
Project No. 1772182 /1040

Compiled By : MI    Checked By : CNM

# GRAIN SIZE DISTRIBUTION

FIGURE B6

## SILTY CLAY to CLAY - Westbound Structure



SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

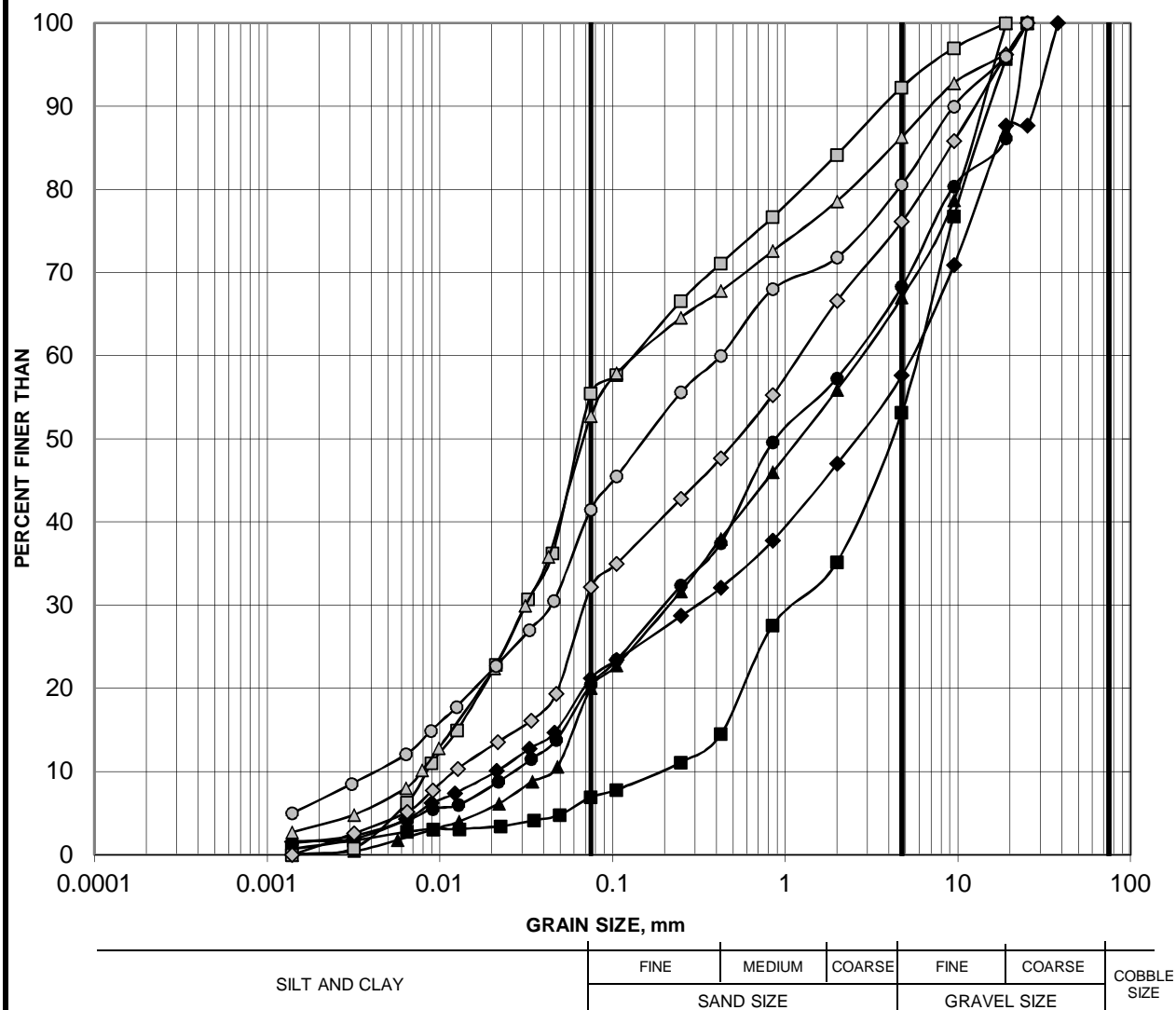
Borehole	Sample	Depth (m)
17-105	7	6.10-6.71



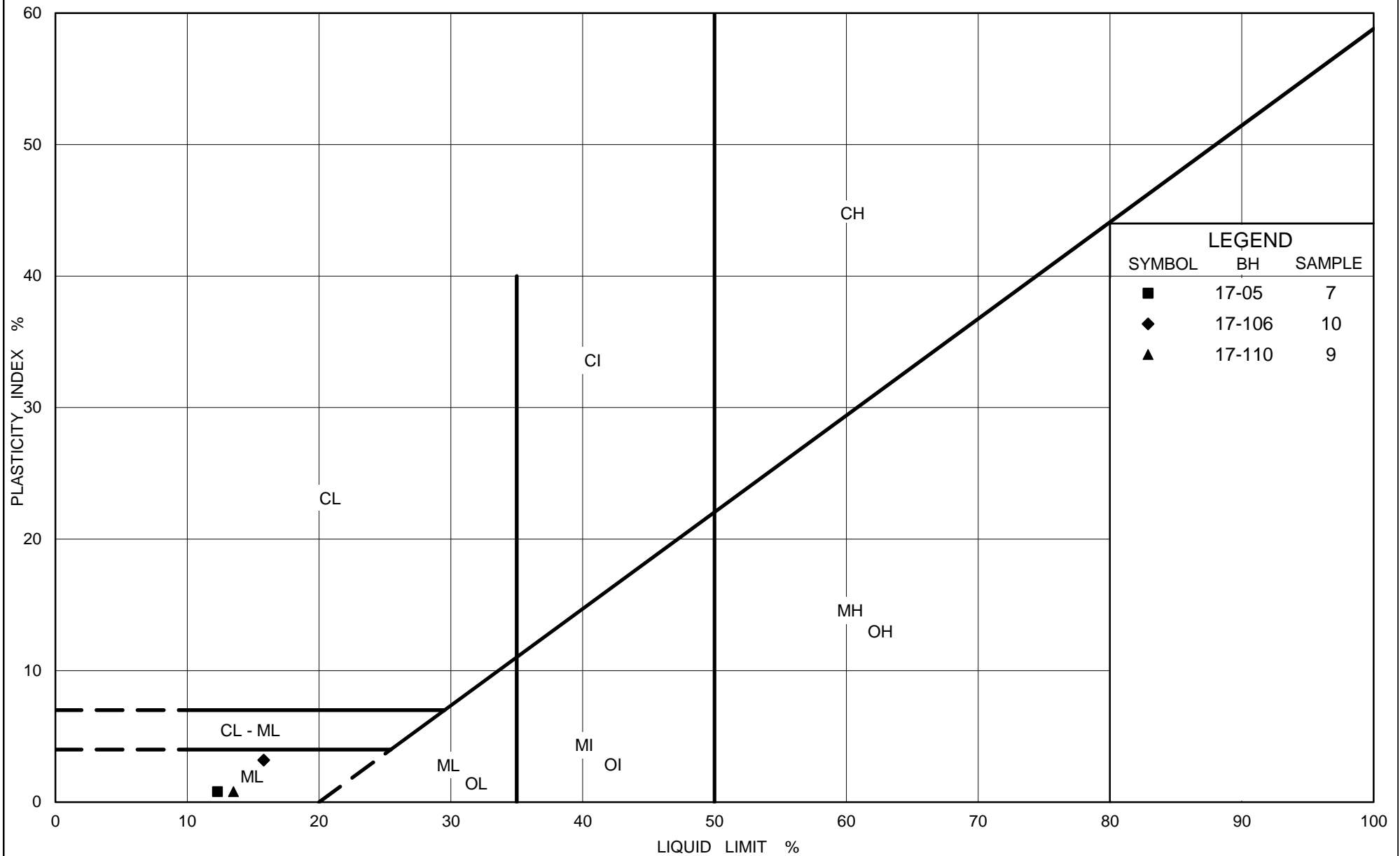
# GRAIN SIZE DISTRIBUTION

FIGURE B7

## TILL - Westbound Structure



Borehole	Sample	Depth (m)
17-05	9	8.63-9.24
17-06	6	5.64-6.25
17-07	9	6.45-6.80
17-08	9	7.01-7.32
17-103	10	6.86-7.47
17-109	3	1.52-2.13
17-109	11	7.62-8.23
17-110	11	8.38-8.99



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# PLASTICITY CHART Till - Westbound Structure

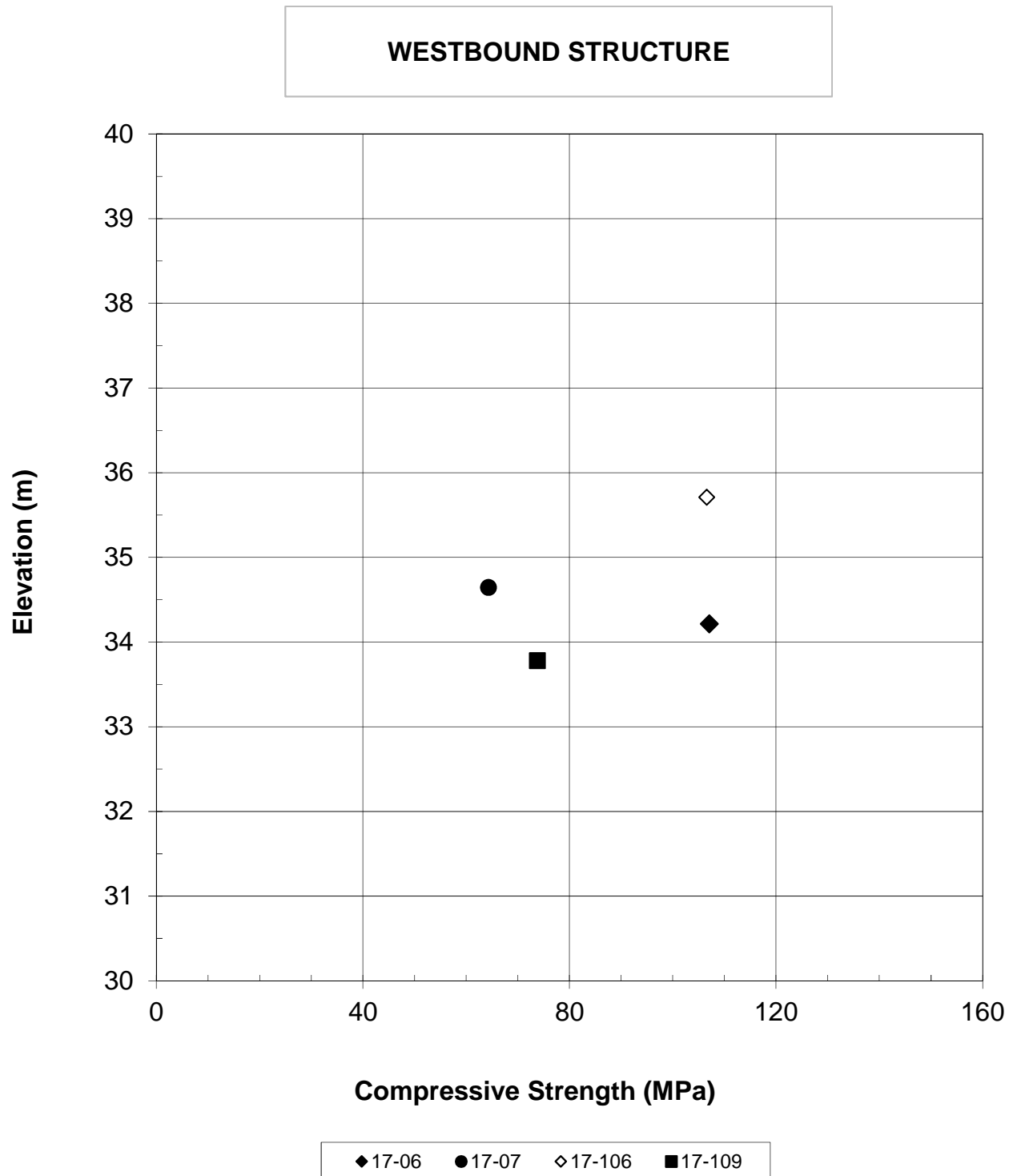
FIG No. B7b

Project No. 1772182 /1040

Compiled By : MI    Checked By : AC

**SUMMARY OF LABORATORY COMPRESSIVE STRENGTH  
UNCONFINED COMPRESSION TESTS**

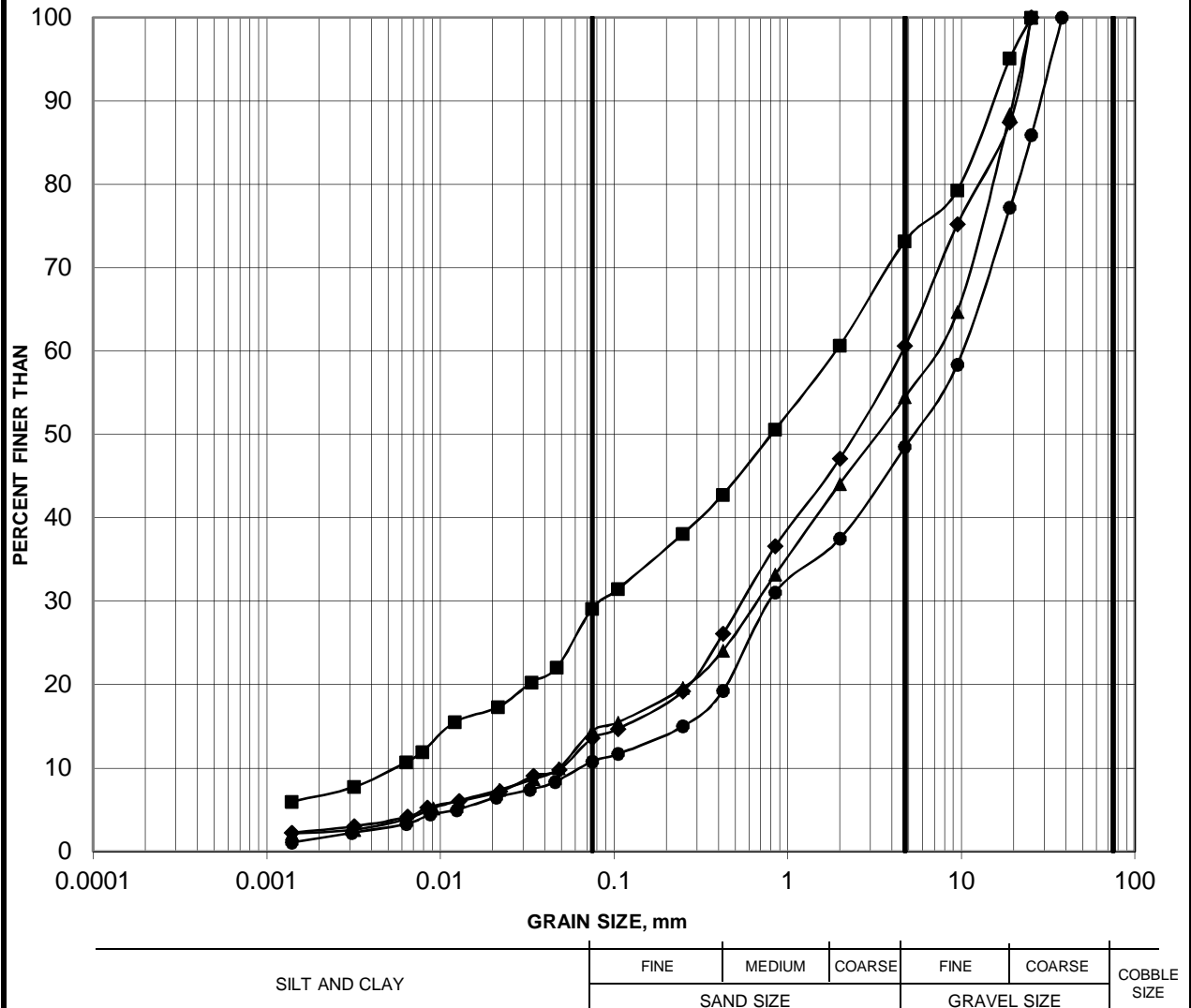
**FIGURE B8**



# GRAIN SIZE DISTRIBUTION

FIGURE B9

## FILL - Eastbound Structure

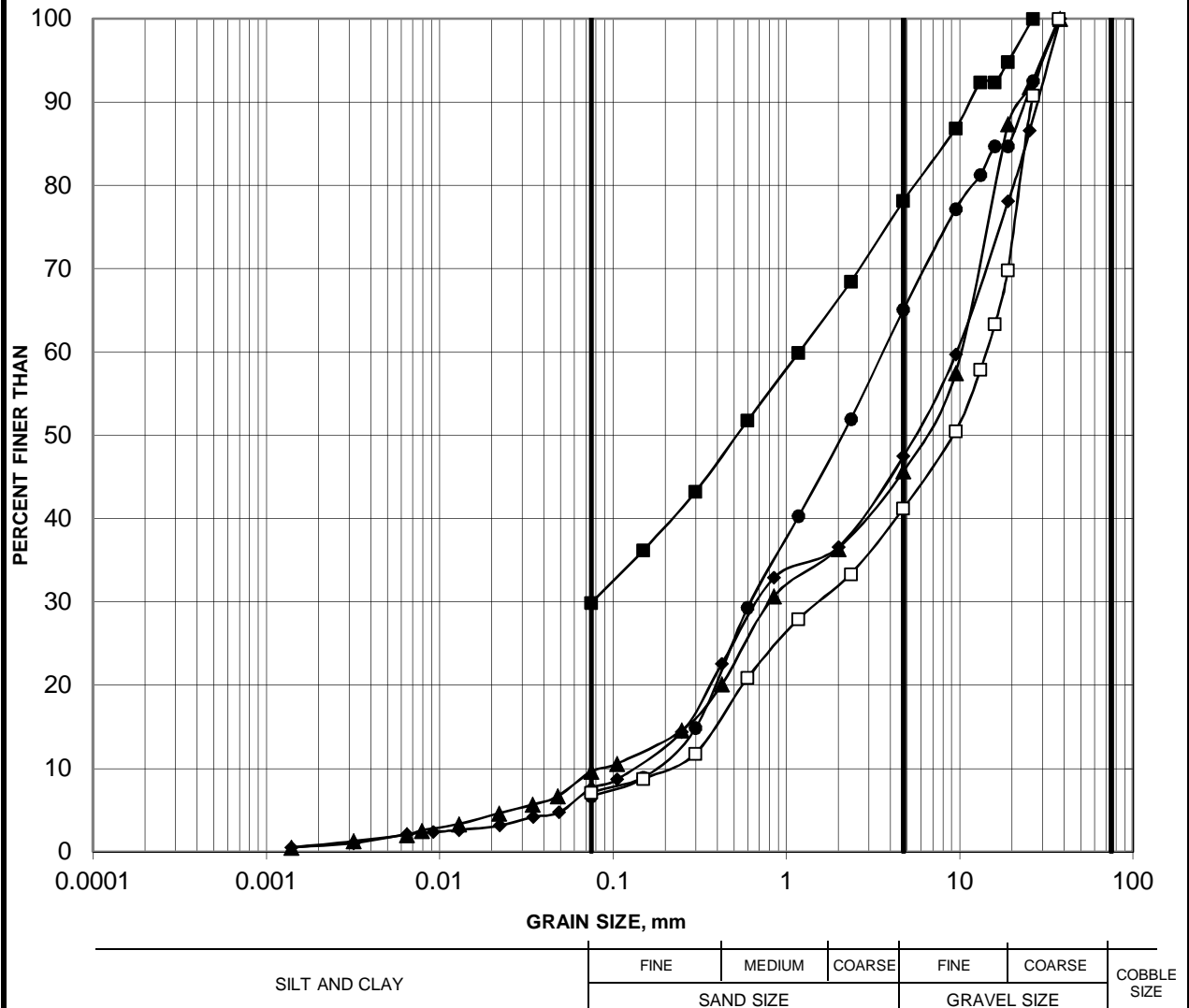


Borehole	Sample	Depth (m)
17-102	3	1.52-2.13
17-104	2	0.61-1.22
17-104	4	1.83-2.44
17-111	2	1.52-2.13

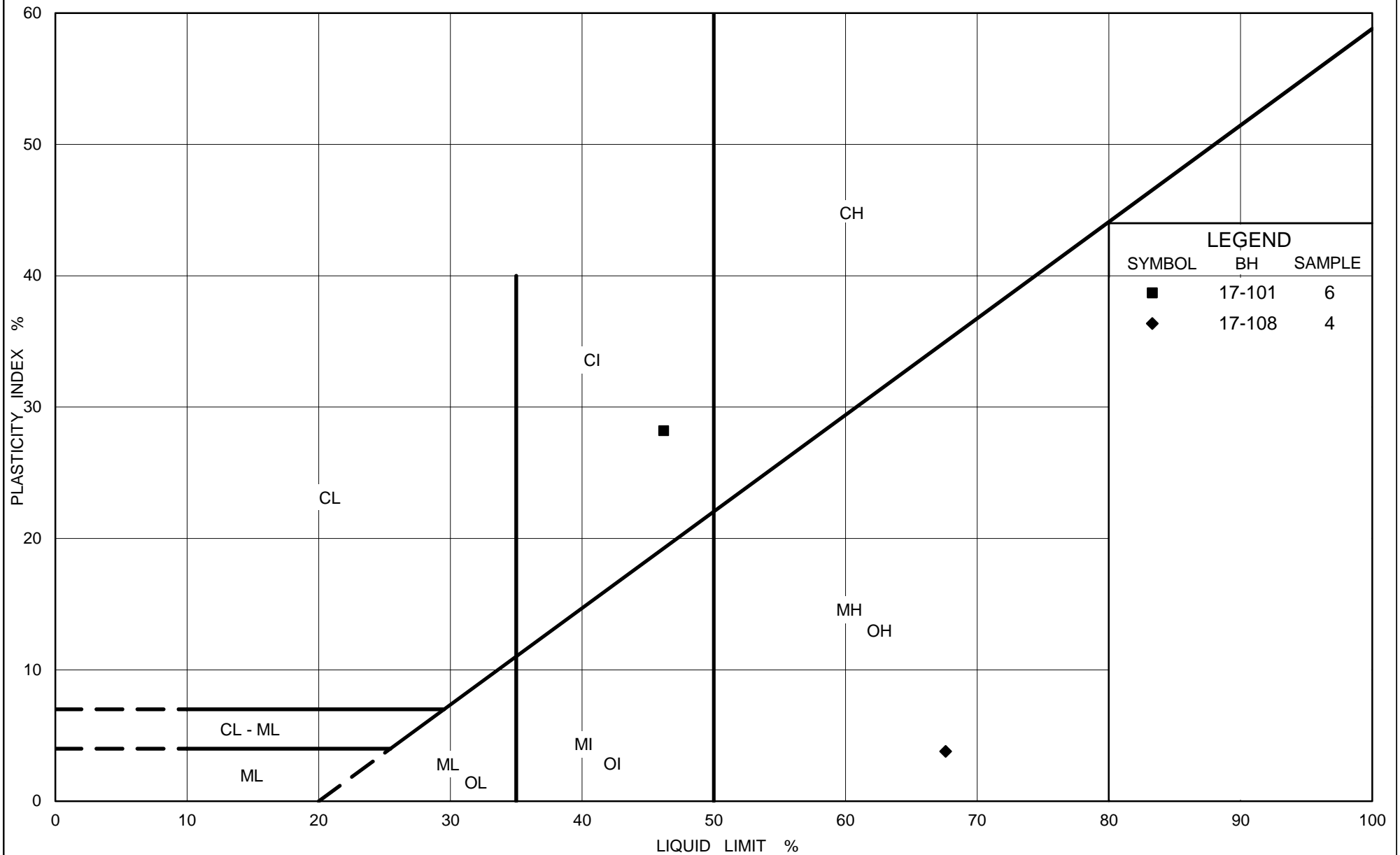
# GRAIN SIZE DISTRIBUTION

FIGURE B10

## SAND and GRAVEL - Eastbound Structure



Borehole	Sample	Depth (m)
■ 17-01	2	3.48-4.09
◆ 17-02	1	1.09-1.70
▲ 17-02	4	2.95-3.54
● 17-102	7	4.57-4.09
□ 17-107	9	6.10-6.71



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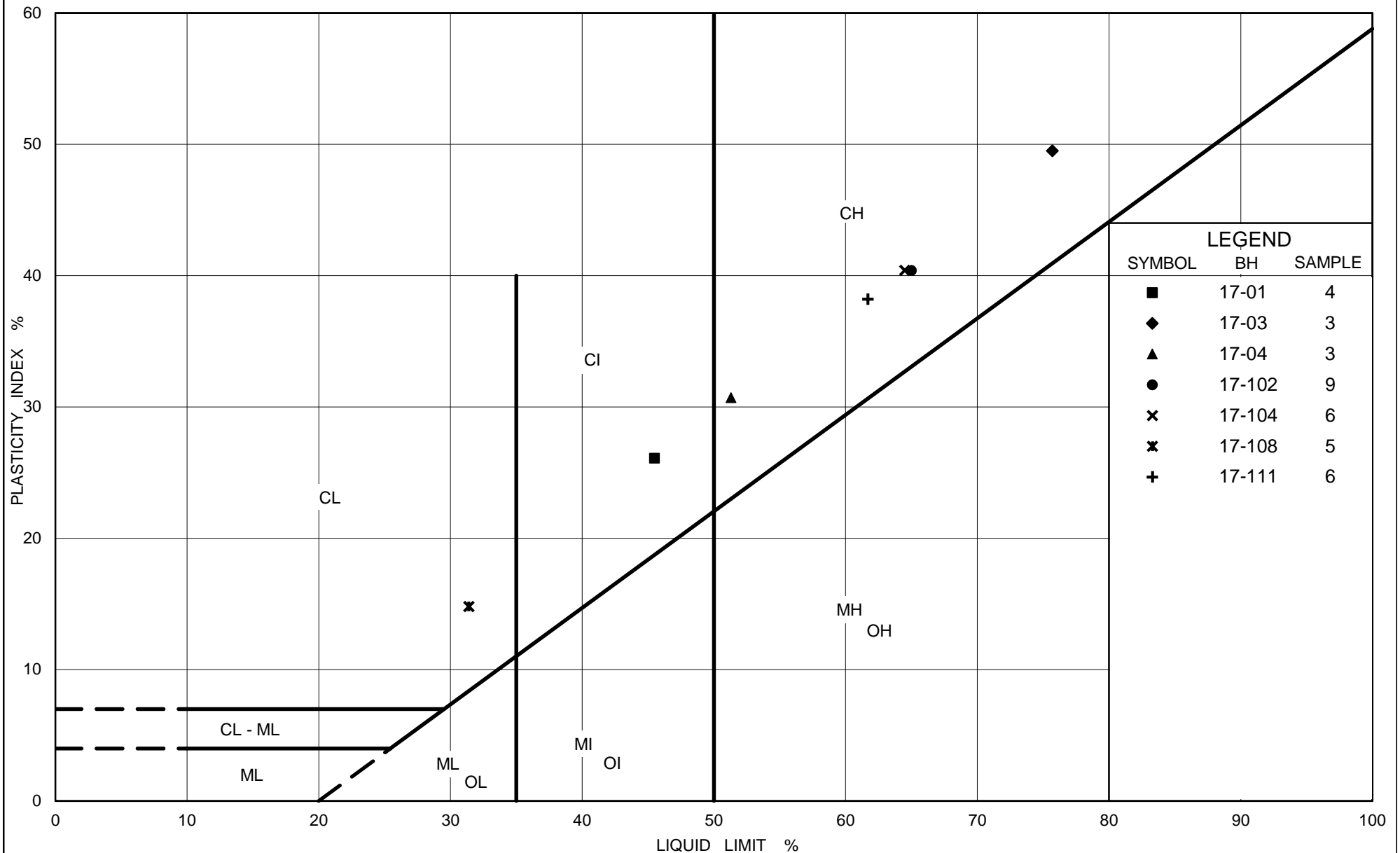
Ontario

# PLASTICITY CHART Organic SILT to SILT - Eastbound Structure

FIG No. B11

Project No. 1772182 /1040

Compiled By : MI    Checked By : AC



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## PLASTICITY CHART

### SILTY CLAY to CLAY - Eastbound Structure

FIG No. B12

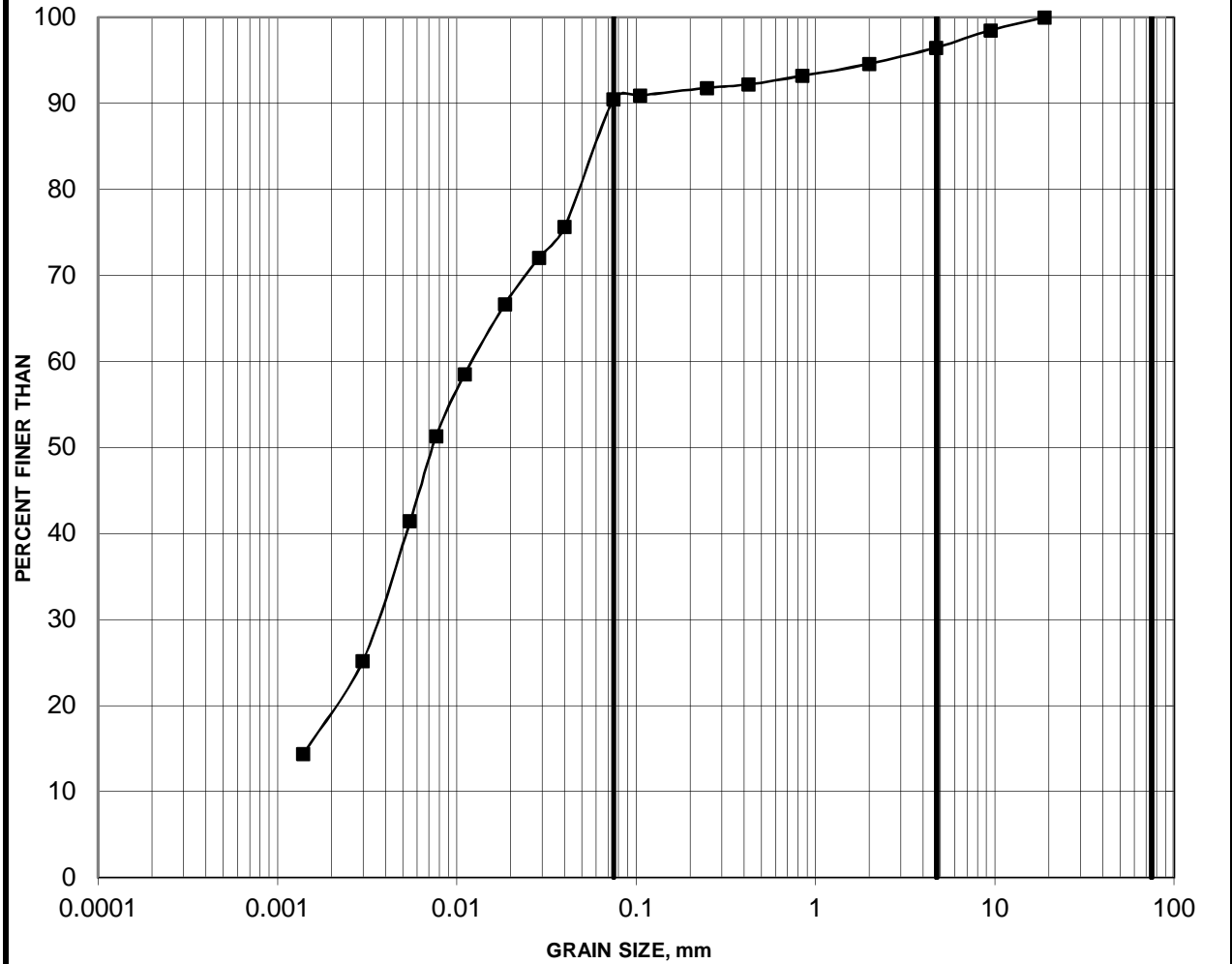
Project No. 1772182 /1040

Compiled By : MI Checked By : CNM

# GRAIN SIZE DISTRIBUTION

FIGURE B13

## SILTY CLAY to CLAY (Weathered Crust) - Eastbound Structure



SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

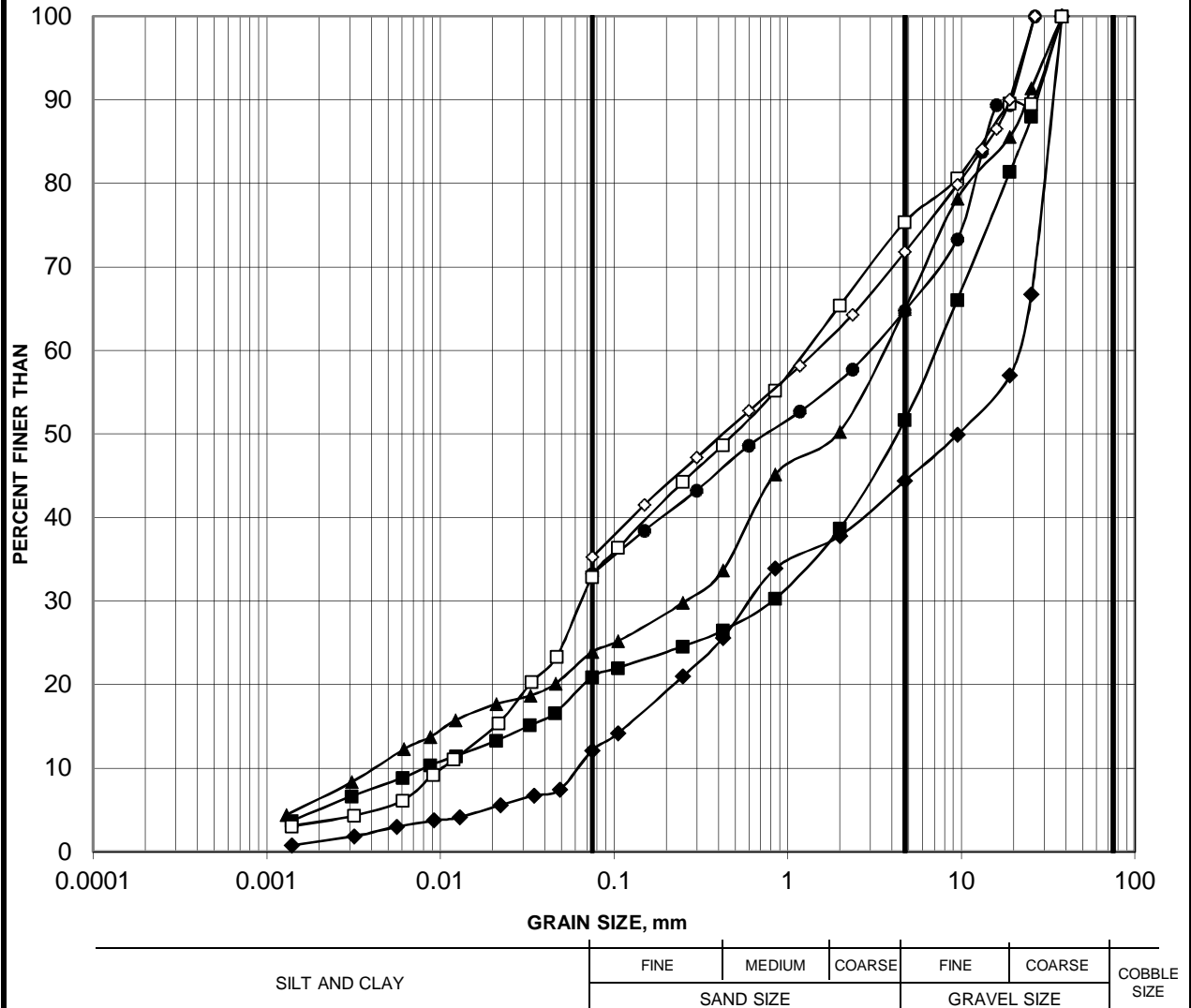
Borehole	Sample	Depth (m)
17-104	8	4.88-5.49



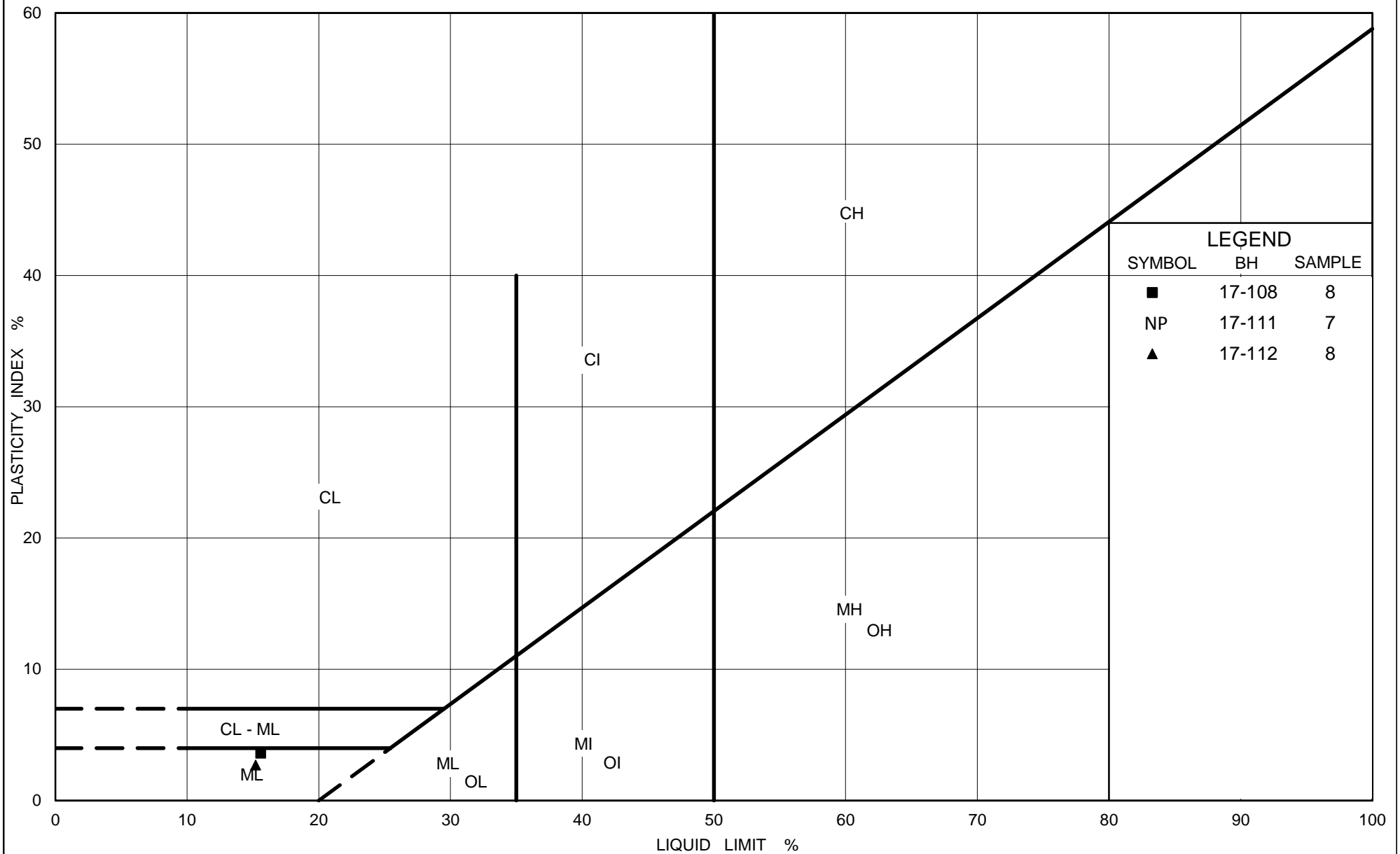
# GRAIN SIZE DISTRIBUTION

FIGURE B14

## TILL - Eastbound Structure



Borehole	Sample	Depth (m)
■ 17-01	5	5.74-6.34
◆ 17-03	8	6.40-7.01
▲ 17-04	9	7.24-7.83
● 17-05	6	5.11-5.72
□ 17-102	13	9.91-10.52
◇ 17-111	9	8.38-8.99



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# PLASTICITY CHART TILL - Eastbound Structure

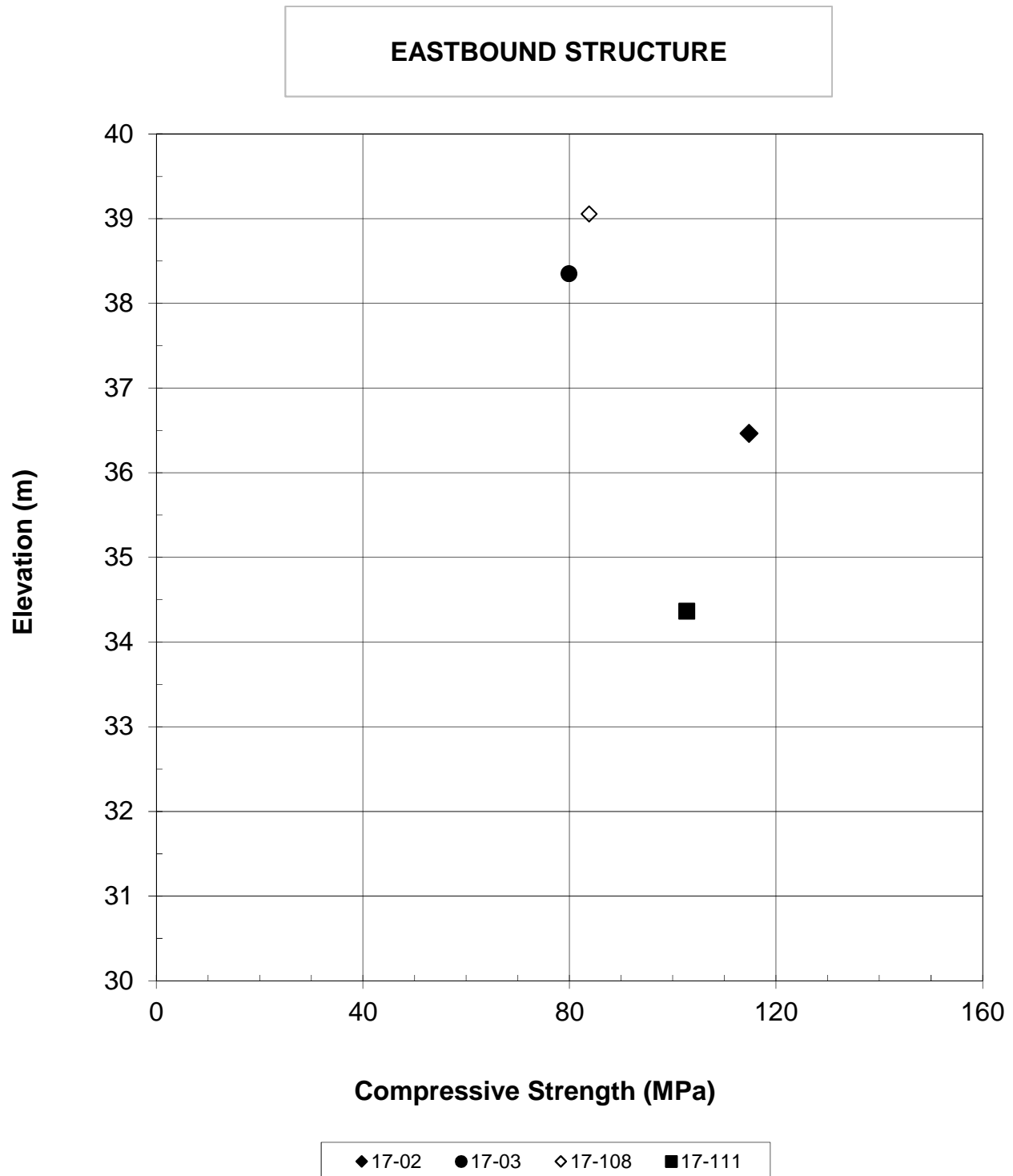
FIG No. B14b

Project No. 1772182 /1040

Compiled By : MI      Checked By : CNM

**SUMMARY OF LABORATORY COMPRESSIVE STRENGTH  
UNCONFINED COMPRESSION TESTS**

**FIGURE B15**



**TABLE 1****SUMMARY OF ORGANIC CONTENT BY PERCENTAGE**

---

**PROJECT NUMBER :** 1772182 /1040**PROJECT NAME :** Dillon - Mega 6 - HWY 401 - Raisin River**DATE TESTED :** June 2017

---

Borehole No.	Sample No.	Depth (m)	Water Content (%)	Organic Content (%)
17-01	3	4.09-4.69	27.6%	4.3%
17-02	1	1.09-1.70	9.3%	1.0%
17-04	2	2.13-2.74	73.9%	2.8%
17-05	5	4.19-4.80	77.4%	14.0%
17-06	1	1.06-2.21	22.4%	3.2%
17-101	4	3.05-3.66	15.6%	3.2%
17-101	5	3.81-4.42	68.8%	22.7%
17-105	2	0.76-1.37	38.8%	8.0%
17-105	4	2.29-2.90	107.5%	19.8%
17-105	5	3.05-3.66	95.7%	12.4%
17-106	7	5.33-5.94	97.2%	14.9%
17-108	4	2.29-2.90	106.1%	20.8%

# Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)  
1931 Robertson Road  
Ottawa, ON  
K2H 5B7  
Attention: Ms. Kim Lesage  
PO#:  
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1709293  
Date Submitted: 2017-06-12  
Date Reported: 2017-06-20  
Project: 1772182/1040  
COC #: 818890

					Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1297547 Soil  2017-04-23 17-02B sa3 7.8-9.8	1297548 Soil  2017-04-11 17-03B sa4 11-13	1297549 Soil  2017-04-20 17-06B sa5 13.5-15.5	1297550 Soil  2017-04-13 17-07B sa4 9.9-11.9
Group	Analyte	MRL	Units	Guideline					
Agri. - Soil	pH	2.0				8.8	8.8	8.1	8.0
	SO4	0.01	%			<0.01	0.05	0.06	0.06
General Chemistry	Cl	0.002	%			<0.002	0.008	0.005	0.004
	Electrical Conductivity	0.05	mS/cm			0.12	0.67	0.84	0.81
	Resistivity	1	ohm-cm			8330	1490	1190	1240
Subcontract	S2-	1	ug/g			5	2	2	4

					Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1297551 Soil  2017-05-11 17-106 sa4 10-12	1297552 Soil  2017-05-03 17-108 sa3 5-7	1297553 Soil  2017-04-27 17-109 sa2 3.5-5.0	1297554 Soil  2017-05-11 17-111 sa4 10-12
Group	Analyte	MRL	Units	Guideline					
Agri. - Soil	pH	2.0				8.1	7.3	8.6	9.1
	SO4	0.01	%			<0.01	0.13	<0.01	<0.01
General Chemistry	Cl	0.002	%			0.042	0.066	0.028	0.017
	Electrical Conductivity	0.05	mS/cm			1.51	2.00	0.87	0.95
	Resistivity	1	ohm-cm			662	500	1150	1050
Subcontract	S2-	1	ug/g			4	6	3	2

**Guideline =**                      **\* = Guideline Exceedence**

All analysis completed in Ottawa, Ontario (unless otherwise indicated by \*\* which indicates analysis was completed in Mississauga, Ontario).  
Results relate only to the parameters tested on the samples submitted.  
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

**APPENDIX C**

**Record of Boreholes - Previous Investigation**  
**(Geocres No. 31G-143)**

## BOREHOLE LOG





Checked By M.M.

[illegible]

**e. m. peto associates ltd.**  
SOIL ENGINEERING SERVICE - TORONTO, ONTARIO  
**BOREHOLE LOG**

Job Name Hwy. 401 Reisin River Bridge Job No. 5747 Borehole No. 2  
Client Dept. of Highways of Ontario Casing BX Boring Date Jan. 20th - 22nd, 1958.  
Datum D.H.O. Compiled By E. M. Peto Checked By M.M.

**SAMPLE CONDITION**

 **UNDISTURBED**  
 **FAIR**  
 **DISTURBED**  
 **LOST**

**SAMPLE TYPE**

S.S. 2" STANDARD SPLIT TUBE SAMPLE  
S.L. SPLIT BARREL WITH LINERS  
S.T. THIN-WALLED SHELBY TUBE SAMPLE  
W.S. WASH SAMPLE  
R.C. ROCK CORE

**ABBREVIATIONS**

V.T. IN SITU VANE SHEAR TEST  
Q.U. UNCONFINED COMPRESSIVE STRENGTH  
W.L. WATER LEVEL IN CASING  
W.T. GROUND WATER TABLE IN SOIL

SOIL DESCRIPTION	COLOUR	Consistency	Depth (Feet)	Sample Type	Remarks
Ice Surface			0.0		
Water			0.0		
Sandy and clayey organic silt.	Olive Grey	Very loose	1.0	S.T. PUSHED	Q/u 127 p.s.f. M.C. 41.0%
Organic silt some sand.	Mixed Brown-Grey	Very loose	1.2	S.S.	M.C. 70.0%
Matrix of clayey silt with numerous rock fragments.	Grey	Compact to Dense	1.6	S.T. PUSHED	M.C. 10.7%
As above with coarse sand (fragments to 1" size).	Grey	Compact to Dense	2.0	S.S.	
Layer of shale 25 - 26 ft.			2.5		
Coarse sand and fine gravel with binder.	Brownish Grey	Extremely Dense	3.0	W.S.	Chopped with open end A rod and chopping bit alternately from 25 to 30 ft.
Fine grained limestone with some fossils	Grey-Black	Hard	3.5	W.S.	
Fine grained shale from 37 ft. to 39 ft.	Black	Hard	3.7		Core recovery 82.4% from 30 ft. to 39 ft.
HOLE TERMINATED					



# e. m. peto associates ltd.

SOIL ENGINEERING SERVICE - TORONTO, ONTARIO

## BOREHOLE LOG

Job Name Hwy. 401 Reisin River Bridge Job No. 5747

Client Dept. of Highways of Ontario Casing BX





Datum D.H.O. Compiled By L. M. Peto

Borehole No. 3

Boring Date Jan. 18th, 1958

Checked By M.M.

### SAMPLE CONDITION

-  UNDISTURBED
-  FAIR
-  DISTURBED
-  LOST

### SAMPLE TYPE

- S.S. 2" STANDARD SPLIT TUBE SAMPLE
- S.L. SPLIT BARREL WITH LINERS
- S.T. THIN-WALLED SHELLY TUBE SAMPLE
- W.S. WASH SAMPLE
- R.C. ROCK CORE

### ABBREVIATIONS

- V.T. IN SITU VANE SHEAR TEST
- Q/u UNCONFINED COMPRESSIVE STRENGTH
- W.L. WATER LEVEL IN CASING
- W.T. GROUND WATER TABLE IN SOIL

SOIL DESCRIPTION	COLOR	Consistency	Depth (Elevation)	Level	Sample No. and Location	Sample Type	No. of blows per ft.	WATER LEVEL AND MOISTURE & REMARKS
Ice Surface			0.0					
Water			1.2					
			3.0					
			5.0					
Sandy and clayey silt, organic content and seam of brown decayed wood.	Olive Grey	Very loose	12.0		1	S.T.	10	Q/u 187 p.s.f. M.C. 36.3%
			15.0		2	S.T.	12	Q/u 173 p.s.f. M.C. 80.3% dropping to 59.1% at 14 ft depth
Silty clay	Grey	Very soft	15.0		3	S.S.	6	M.C. 52.7%
Silty clay, slightly nuggety	Grey	Soft to Firm	22.0		4	S.S.	27	
Very silty clay, coarse sand and fine angular gravel. Some decayed wood.	Grey	Very stiff	25.0		5	S.S.	28	
Medium to coarse sand with fine angular gravel, clayey silt binder.	Grey-Black Light Brownish Grey	Compact to Dense	41.0		6	R.C.	-	Limestone fragment 2-1/4" recovered from tip of casing.

VIRTUAL REFUSAL

**e. m. peto associates ltd.**  
SOIL ENGINEERING SERVICE - TORONTO, ONTARIO  
**BOREHOLE LOG**

Job Name Hwy. 40<sup>th</sup> Raisin River Bridge Job No. 57147

Borehole No. 4





Client Dept. of Highways of Ontario Casing BX

Boring Date Jan. 17th - 18th, 1958.

Datum D.H.O. Compiled By E. M. Peto

Checked By M.M.

**SAMPLE CONDITION**

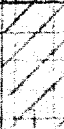




-  UNDISTURBED
-  FAIR
-  DISTURBED
-  LOST

**SAMPLE TYPE**

- S.S. 2" STANDARD SPLIT TUBE SAMPLE
- S.L. SPLIT BARREL WITH LINERS
- S.T. THIN-WALLED SHELBY TUBE SAMPLE
- W.S. WASH SAMPLE
- R.C. ROCK CORE

**ABBREVIATIONS**

- V.T. IN SITU VANE SHEAR TEST
- Q/u UNCONFINED COMPRESSIVE STRENGTH
- W.L. WATER LEVEL IN CASING
- W.T. GROUND WATER TABLE IN SOIL

SOIL DESCRIPTION	COLOR	Density or Consistency	Depth (feet)	Legend	Sample No. and Condition	Sample Type	Water Level (feet)	WATER LEVEL, SOIL MOISTURE & REMARKS
Ice Surface			0.0					
			152.4					
Water			5.0					
			14.0					
Silty clay, slightly nuggety texture.	Gray	Soft	20.0		1 	SS	4	M.C. 82.5% much wetter than Plastic Limit. Approx. Q/u 0.24 tons per sq. ft.
Clayey silt L.L. 33.3 P.L. 19.0 P.I. 14.3	Gray	Loose	22.0		2 	SS	5	M.C. 38.7%. Instantaneous response to shake test. Unable to drive sampler below 25 ft.
		Compact	26.0					
(Casing and chopping bit refused on layer of very hard shale or limestone)								

VIRTUAL REFUSAL

SOIL ENGINEERING SERVICE - TORONTO, ONTARIO  
BOREHOLE LOG

SOIL ENGINEERING SERVICE - TORONTO, ONTARIO

# BOREHOLE LOG

Borehole No. 5

Boring Date Jan. 16th - 17th, 1958

Checked By                                          

SAMPLE CONDITION

 UNDISTURBED

 FAIR

**M** DISTURBED

LGST

SAMPLE TYPE

### 5.5. 2" STANDARD SPLIT TUBE SAMPLE

S.L. SPLIT BARREL WITH LINERS.

### S. T. THIN-WALLED SHELEY TUBE SAMPLE

W. S. WASH SAMPLE

### R.C. ROCK CORE

### ABBREVIATIONS

### V. 7. IN SITU VANE SHEAR TEST

0.4% UNCONFINED COMPRESSIVE STRENGTH

\* L WATER LEVEL IN CASING

W 7 GROUND WATER TABLE IN SOIL

SOIL DESCRIPTION	COLOR	Density or Consistency	Depth Elevation	Legend	Sample No. and Location	Sample Type	No. of Blows per ft.	WATER LEVELS, SOIL MOISTURE & REMARKS
Ice Surface			0 9 152.4					
Water			5 0 10 0 15 0					
Very silty fine to medium sand, some organic matter.	Dark Brownish Grey	Compact	15 0	1	SS	16	M.C. 30.5%	
Medium to coarse sand, grits and small angular stones, some binder.	Dark Grey	Compact to Dense	20 0	2	SS	30		
Layer of hard shale.	Black		25 0	3	WS		Unab'e to drive split spoon more than 3"	
Silty medium to coarse sand and fine angular gravel.	Grey-Brown	Compact to Dense	30 0	4	SS	38	Slight reaction with dilute hydrochloric acid	
As above. Gravel to 1" Fine grained dolomitic limestone.	Grey-Black	Hard	35 0	5	P.C.		Cleavage slight'y inclined from horizontal	
As above with some fossils								
very fine grained shale from 37 to 38 ft.	Black	Hard						
HOLE TERMINATED								

## BOREHOLE LOG

Checked By M.M.

### ABBREVIATIONS

### Y. T. IN SITU VANE SHEAR TEST

### 9.4 UNCONFINED COMPRESSIVE STRENGTH

W T GROUND WATER TABLE IN

W. T. GROUND WATER TABLE IN SOIL





R. C. ROCK CORE

**HOLB TERMINATED**

**e. m. peto associates ltd.**  
SOIL ENGINEERING SERVICE - TORONTO, ONTARIO  
BOREHOLE LOG

Job Name Hwy. 401 Kaisin River Bridge Job No. 57147 Borehole No. 7  
Client Dept of Highways of Ontario Casing BX Boring Date Jan. 14th - 15th, 1958.  
Datum D.H.O. Compiled By E. M. Peto Checked By M.M.

**SAMPLE CONDITION**

 UNDISTURBED  
 FAIR  
 DISTURBED  
 LOST

**SAMPLE TYPE**

S.S. 2" STANDARD SPLIT TUBE SAMPLE  
S.L. SPLIT BARREL WITH LINERS  
S.T. THIN-WALLED SHELBY TUBE SAMPLE  
W.S. WASH SAMPLE  
R.C. ROCK CORE

**ABBREVIATIONS**

V.T. IN SITU VANE SHEAR TEST  
Q.C. UNCONFINED COMPRESSIVE STRENGTH  
W.L. WATER LEVEL IN CASING  
W.T. GROUND WATER TABLE IN SOIL

SOIL DESCRIPTION	COLOUR	Density or Consistency	Depth, Elevation	Legend	Disturb. Condition	Sample Type	No. of Blows per Ft.	WATER LEVEL, SOIL MOISTURE, & REMARKS
Ice Surface			0' 0"					
			162.4					
Water			5' 0"					
			10' 0"					
			15' 0"					
			15' 0"					
Medium to coarse sand many angular rock fragments some binder As above rock fragments up to 1-1/4"	Grey	Compact to Dense			1	S.S.	30	Quite moist.
	Grey	Compact to Dense			2	S.S.	27	Quite moist.
			20' 0"					
Silty coarse sand with considerable angular fine gravel. As above.	Grey-Black	Compact			3	S.S.	19	
	Grey-Black	Dense			4	S.S.	53	Quite moist
			25' 0"					Compact only from 23 ft. to 25 ft.
Silty fine to coarse sand and gravel to 1-1/2"	Grey	Dense			5	S.S.	57	
	Grey	Very dense			6	S.S.	80	
Medium to coarse sand.	Grey-Black	Extremely Dense			7	W.S.	-	Casing refused at 27 ft. Drilled with open end A rod from 27 ft. to 31 ft.
Fragmented shale.	Black	Extremely Dense	31' 0"		8	W.S.	-	





HOSE TERMINATED

**e. m. peto associates ltd.**  
SOIL ENGINEERING SERVICE - TORONTO, ONTARIO  
**BOREHOLE LOG**

Job Name Hwy. 401 Raisin River Bridge Job No. 5747  
Client Dept. of Highways Of Ontario Casing BX  
Datum D.H.O. Compiled By E. M. Peto

Borehole No. 8  
Boring Date Jun. 13th 1958  
Checked By M.M.

**SAMPLE CONDITION**











-  UNDISTURBED
-  FAIR
-  DISTURBED
-  LOST

**SAMPLE TYPE**

- S.S. 2" STANDARD SPLIT TUBE SAMPLE
- S.L. SPLIT SAMREL WITH LINERS
- S.T. THIN-WALLED SHELBY TUBE SAMPLE
- W.S. WASH SAMPLE
- R.C. ROCK CORE

**ABBREVIATIONS**

- V.T. IN SITU VANE SHEAR TEST
- Q.C. UNCONFINED COMPRESSIVE STRENGTH
- W.L. WATER LEVEL IN CASING
- W.T. GROUND WATER TABLE IN SOIL

SOIL DESCRIPTION	COLOR	Consistency	Depth (feet)	Legend	Sample No.	Sample Type	Moisture (%)	WATER LEVELS, SOIL MOISTURE & REMARKS
Ice surface.			0' 0"					
			15' 4"					
Water			5' 0"					
			10' 0"					
			14' 0"					
Very silty clay, many grits and angular pebbles.	Grey	Stiff	18' 0"		1	S.S.	18	Saturated. Fair response to shake test.
Fine to coarse sand, many grits and angular rock fragments, some binder.	Grey	Compact to Dense	20' 0"		2	S.S.	34	
	Grey	Compact to Dense			3	S.	27	quite moist. Stratum of loose to compact coarse to fine sand from 23 ft. to 25 ft.
Medium to coarse sand	Grey-Black	Loose to Compact				S.S.	11	
					4	W.S.	-	
Fine to coarse sand, many grits and stones, considerable binder.	Grey	Dense			5	S.S.	52	
Pulverized shale	Black	Soft			6	S.S.	10	
						R.C.		Chopped to 33 ft.
Fine grained shale with thin bands of limestone	Black	Hard	33' 0"					
Dolomitic limestone	Grey-Black	Hard	35' 0"					
with some fossils 34-1/2 to 36-1/2 ft.	Black							
Fine grained shale	Black							No reaction with weak hydrochloric acid.
36-1/2 to 37-1/2 ft.								73% core recovery. Core very badly broken up. Drift hole did not stand up well.
Medium grained limestone	Grey-Black	Very hard	42' 0"					
Some very thin black layers of fossiliferous limestone	Black		42' 0"					

HOLE TERMINATED

**e. m. peto associates ltd.**  
SOIL ENGINEERING SERVICE - TORONTO, ONTARIO  
**BOREHOLE LOG**

Job Name Hwy. 401 Raisin River Bridge Job No. 57747

Borehole No. 9





Client Dept. of Highways of Ontario Casing B.X.

Boring Date Jan. 12th - 12th, '958

Datum D.H.O. Compiled By E. M. Peto

Checked By M.M.

**SAMPLE CONDITION**

 **UNDISTURBED**  
 **FAIR**  
 **DISTURBED**  
 **LOST**

**SAMPLE TYPE**

S.S. 2" STANDARD SPLIT TUBE SAMPLE  
S.L. SPLIT BARREL WITH LINERS  
S.T. THIN-WALLED SHELLY TUBE SAMPLE  
W.S. WASH SAMPLE  
R.C. ROCK CORE

**ABBREVIATIONS**

V.T. IN SITU VANE SHEAR TEST  
Q.U. UNCONFINED COMPRESSIVE STRENGTH  
W.L. WATER LEVEL IN CASING  
W.T. GROUND WATER TABLE IN SOIL

SOIL DESCRIPTION	COLOR	Consistency	Depth (ft.)	Remarks	Sample Type	Number of Tests	Notes
Ice Surface			0.0				
Water			0.5				
			1.0				
			1.5				
			2.0				
Silty clay, nuggety	Grey	Very soft	17.0		1	SS	3
Sandy and silty clay, many grits and angular rock fragments.	Dark Grey	Firm to Stiff	20.0		2	SS	12
As above	Dark Grey	Very stiff	25.0		3	SS	32
Medium to coarse sand, angular rock fragments	Grey	Dense	26.0		4	SS	45
Coarse sand and fine gravel in matrix of light grey silt.	Grey	Dense	27.0		5	SS	52
As above.	Grey	Very dense	28.0		6	SS	98
As above	Grey	Dense	30.0		7	SS	34 For 6
2" of black shale above fine grained limestone, some fossils.	Grey-Black	Hard	35.0			R.C.	Boulder at 30'6". C hop to 32 ft. Ran rod to 33 f Shale cleavage from 33 ft to 33'3".
7" of black shale at bottom of core.							Lost wash water at 35 ft.
Limestone	Grey-Black	Hard	40.0			R.C.	87.5% core recovery.

HOLE TERMINATED

## BOREHOLE LOG

Checked By M.M.

# 3. GROUND WATER TABLE IN SOIL

[illegible]



# BOREHOLE LOG

Borehole No. 11

Boring Date Dec. 22nd - 23rd, 1957

Checked By M. M.

**SAMPLE TYPE**

## ABBREVIATIONS

 UNDISTURBED

 FAIR

☒ DISTURBED

**LOST**

### 5.5. 2<sup>nd</sup> STANDARD SPLIT TUBE SAMPLE

5.2. SPLIT BARREL WITH LINERS

S. T. THIN-WALLED SHELBY TUBE SAMPLE

W.S. WASH SAMPLE

R. C. ROCK CORE

### V. T. IN SITU VANE SHEAR TEST

Q/V UNCONFINED COMPRESSIVE STRENGTH

W. L. WATER LEVEL IN CASING

W. T. GROUND WATER TABLE IN SOIL

[illegible]

## BOREHOLE LOG

Checked By M.M.

## ABBREVIATIONS

B.C. ROC

SOIL DESCRIPTION	COLOR	Dens Consistency	Geph Elevation	Land	Sample No and Condition	sample Type	No. of Blows per Ft.	WATER LEVELS, SOIL MOISTURE & REMARKS
Ice Surface			0' 6"					Hole remained dry with casing to 14 ft. depth overnight.
Water			4' 2"					
Clay with thin layers of grey brown clay and some decayed wood.	Grey	Soft			1	S.S.	5	Approx. Q/u O.5 t.s.f. M.C. 73.5%. Much wetter than Plastic Limit.
Clay with light grey layers at 1" intervals	Grey	Soft	10' 8"		2	S.S.	2	M.C. 58%
Sandy gravel with clay end silt binder, layers of silt.	Dark Grey	Loose			3	S.S.	6	
Coarse sand and gravel to 1-1/4", some binder	Dark Grey	Compact	15' 0"		4	S.S.	25	
Coarse sand with pebble gravel.	Very dark grey	Compact to Dense			5	S.S.	35	
Pea gravel and coarse sand, minor clay content	Dark grey	Compact	20' 0"		6	S.S.	22*	Odd subrounded 2" stone.
As above with more medium gravel.	Dark Grey	Compact to Dense			7	S.S.	32*	Loose from 21 ft. to 22 ft.
Coarse sand and fine to medium gravel, some binder.	Dark Grey	Compact	25' 1"		9	S.S.	22	
Medium sand and fine gravel, considerable clay binder.	Dark Grey	Dense			9	S.S.	40	
Medium and coarse sand, gravel and stones to 1-1/2", clay binder.	Dark Grey	Dense	29' 0"		10	S.S.	42	
VIRTUAL REFUSAL.								* trap valve in sampler.

## BOREHOLE LOG

Checked By M. M.

SOIL DESCRIPTION	COLOR	Density or Consistency	Depth Elevation	Legend	Sample No. and Condition	Sample Type	No. of Piles per Ft.	WATER LEVELS, SOIL MOISTURE & REMARKS
Ground Surface			0' 0"					
			7.6'					
			5' 0"					
Very silty clay, and luggety texture	Grey- Brown	Stiff			1	S.S.	18	M.C. 40.3%
			10' 0"					
Clayey silt with sand content, numerous angular rock fragments.	Mixed Brown-Grey	Compact			2	S.S.	14	Saturated
			15' 0"					
Medium to Coarse sand with angular rock fragments, some binder.	Gray- Black	Dense			3	S.S.	34	
			20' 0"					
As above.	Grey	Extremely Dense			4	S.S.	134	
			23' 0"					
				VIRTUAL REFUSAL				

## BOREHOLE LOG

Checked By M. M.

### ABBREVIATIONS

W.T. GROUND WATER TABLE IN SOIL

SOIL DESCRIPTION	COLOR	Density or Consistency	Depth Elevation	Legend	Sample No. and Condition	Sample Type	No. of Blows per Ft.	WATER LEVELS, SOIL MOISTURE & REMARKS
Ground Surface			0' 8" 153.6					
-	-	-	5' 9"					
Organic silt. Clay and silty fine sand	Black Grey-Brown	Very loose Loose			X	S.T. PUSHED		Super saturated 50% recovery from tube.
Sandy organic silt								M.C. 28.5%
Silty and sandy clay - Pockets of organic silt	Light Brown Grey-Brown	Very soft	10' 2"  13' 9"		2	S.T. PUSHED		Q/u 104 p.s.f. L.L. 35.5 M.C. 87.5% P.L. 20.6 P.I. 14.9
Sandy silt with considerable angular gravel	b'l Grey	Dense	15' 5" 16' 0" 17' 0"		3 4	S.S. w.s.	39 -	Very moist.
Pulverized shale	Grey-Black							
				VIRTUAL REFUSAL				



**APPENDIX D**

**Vertical Seismic Profiling Test Results**

**DATE** June 5, 2017**PROJECT No.** 1772182/1040**TO** Kim Lesage  
Golder Associates Ltd.**FROM** Stephane Sol, Christopher Phillips**EMAIL** ssol@golder.com, cphillips@golder.com**VERTICAL SEISMIC PROFILING TEST RESULTS  
RAISIN RIVER, LANCASTER, ONTARIO**

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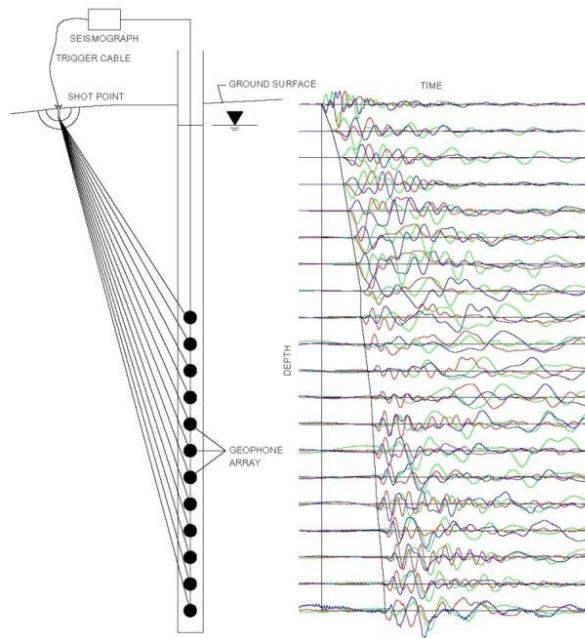
This memorandum presents the results of two Vertical Seismic Profiling (VSP) testing carried out on both sides of the Raisin River along HWY401 southwest of Lancaster, Ontario. VSP testing were completed in Borehole BH17-108 and BH-109. VSP testing was carried out on May 9, 2017. BH17-108 was drilled to an approximate depth of 13.7 m below the existing ground surface and then cased with a PVC pipe grouted in place. The borehole consisted of approximately 8.5 m of overburden consisting of 1.5 m of sand and silty sand overlaying approximately 5.5 m of peat and silty clay, 1.2 m of sand. At BH17-108 the limestone shale bedrock was located at approximately 8.5 mbgs to the bottom of the hole. BH17-109 was drilled to an approximate depth of 18.5 m below the existing ground surface and then cased with a PVC pipe grouted in place. The borehole consisted of approximately 13.25 m of overburden consisting of 1 m of silty clay overlaying approximately 12.25 m of sand and silty sand. At BH17-108 the limestone shale bedrock was located at approximately 13.25 mbgs to the bottom of the hole.

**Methodology**

For the VSP method, seismic energy is generated at the ground surface by an active seismic source and recorded by a geophone located in a nearby borehole at a known depth. The active seismic source can be either compression or shear wave. The time required for the energy to travel from the source to the receiver (geophone) provides a measurement of the average compression or shear wave seismic velocity of the medium between the source and the receiver. Data obtained from different geophone depths are used to calculate a detailed vertical seismic velocity profile of the subsurface in the immediate vicinity of the test borehole.

The high resolution results of a VSP survey are often used for earthquake engineering site classification, as per the 2015 National Building Code of Canada.





*Example 1: Layout and resulting time traces from a VSP survey.*

## Fieldwork

The fieldwork was carried out on May 9, 2017, by personnel from the Golder Mississauga office.

Both compression and shear wave seismic sources were used and both were located 2 m from the borehole. The seismic source for the compression wave test consisted of a 9.9 kg sledge hammer vertically impacted on a metal plate. Because access to the site was not accessible with a truck, the seismic source for the shear wave test consisted of a metallic U-shaped object that was horizontally struck with a 9.9 kg sledge hammer on alternate ends to induce polarized shear waves. Test measurements at BH17-108 started at 0.55 m from ground surface and were recorded in the borehole with a 3-component receiver spaced at 0.5 m intervals below the ground surface to a maximum depth (12.6 m). The top surface of the ground was saturated at the time of the testing. Test measurements at BH17-109 started at 0.5 m from ground surface and were recorded in the borehole with a 3-component receiver spaced at 0.5 m intervals below the ground surface to a maximum depth (17.85 m). The top surface of the ground was saturated at the time of the testing

The seismic records collected for each source location were stacked a minimum of five times to minimize the effects of ambient background seismic noise on the collected data. The data was sampled at 0.020833 millisecond intervals and a total time window of 0.341 seconds was collected for each seismic shot.

## Data Processing

Processing of the VSP test results consisted of the following main steps:

- 1) Combination of seismic records to present seismic traces for all depth intervals on a single plot for each seismic source and for each component;
- 2) Low Pass Filtering of data to remove spurious high frequency noise;



- 3) First break picking of the compression and shear wave arrivals; and,
- 4) Calculation of the average compression and shear wave velocity to each tested depth interval.

Processing of the VSP data was completed using the SeisImager/SW software package (Geometrics Inc.). The seismic records are presented on the following four plots and show the first break picks of the compression wave at BH17-108 and BH17-109 (Figures 1 and 2) and shear wave arrivals at BH17-108 and BH17-109 (Figures 3 and 4) overlaid on the seismic waveform traces recorded at the different geophone depths for each borehole. The arrivals were picked on the vertical component for the compression source and on the two horizontal components for the shear source.

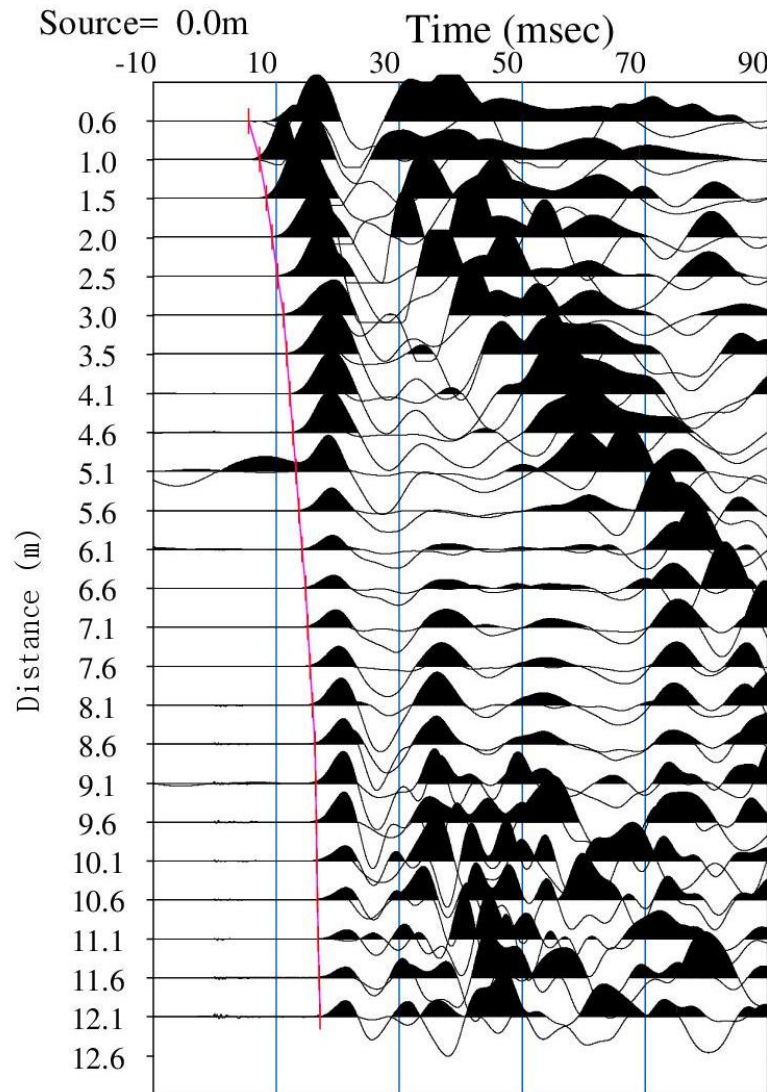


Figure 1: First break picking of compression wave arrivals (red) along the seismic traces recorded at each receiver depth of Borehole 17-108.

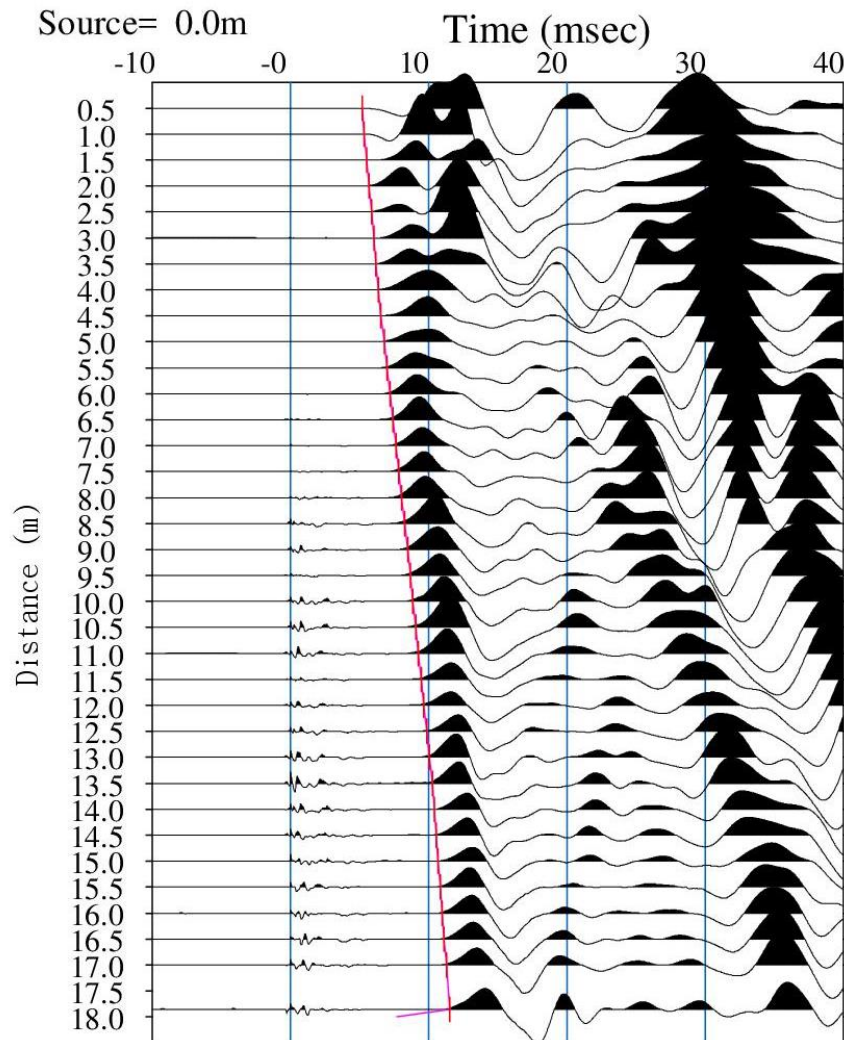


Figure 2: First break picking of compression wave arrivals (red) along the seismic traces recorded at each receiver depth of Borehole 17-109.

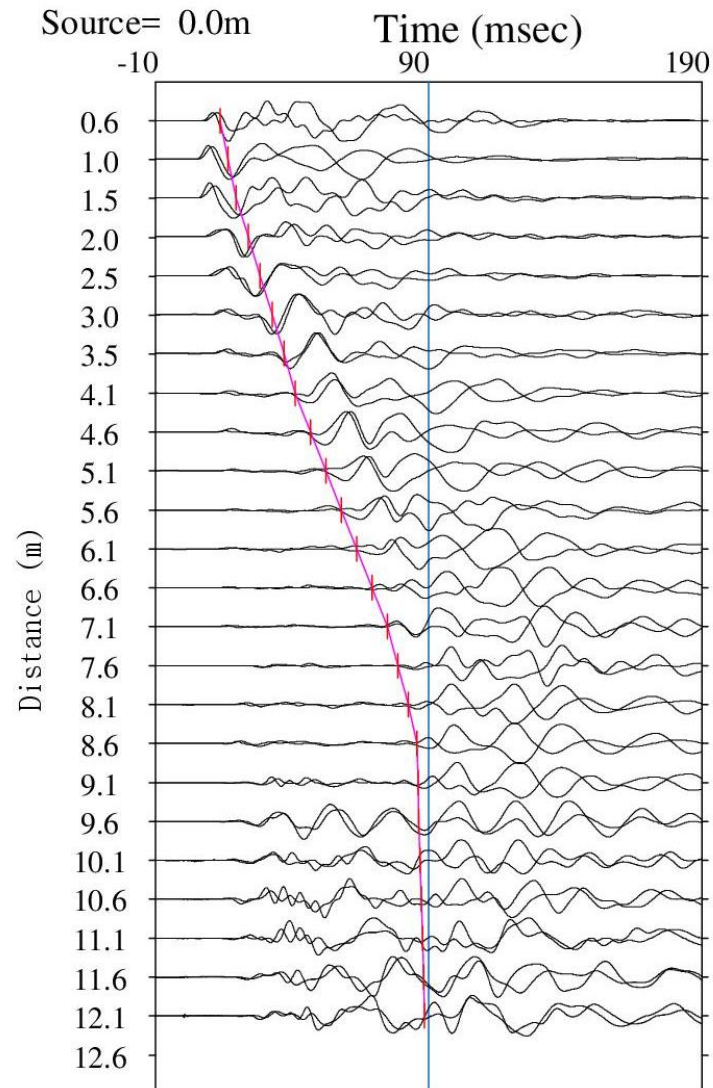


Figure 3: First break picking of shear wave arrivals (red) along the seismic traces recorded at each receiver depth of Borehole 17-108.

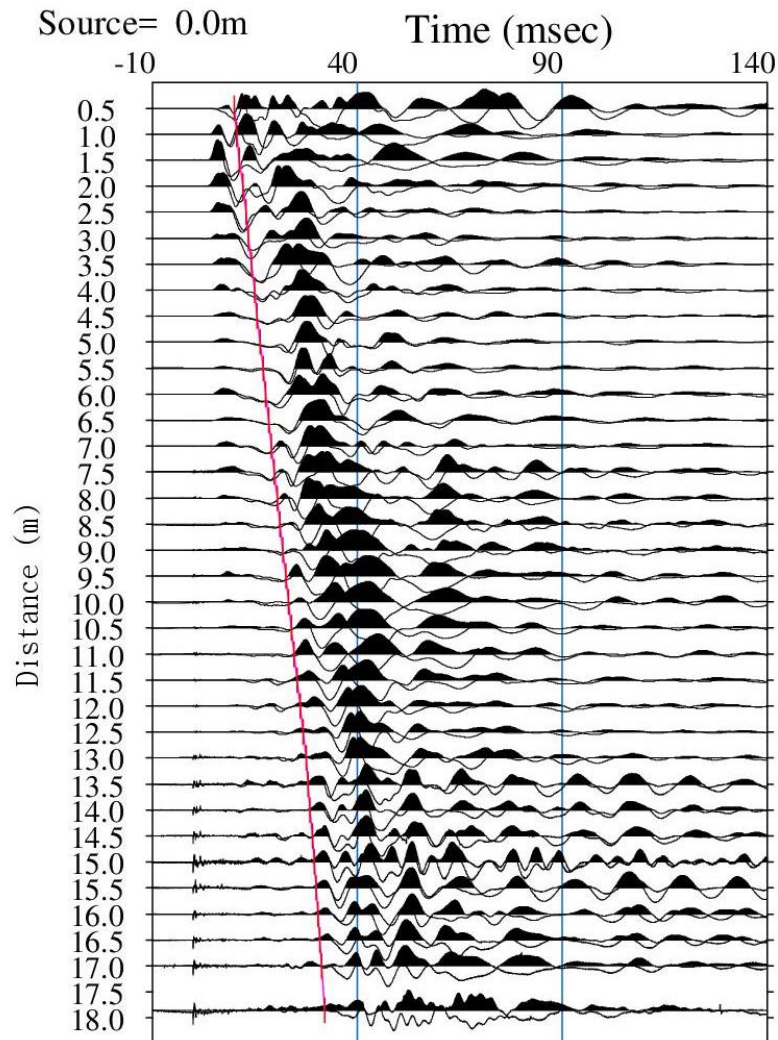


Figure 4: First break picking of shear wave arrivals (red) along the seismic traces recorded at each receiver depth of Borehole 17-109.

## Results

The VSP results at borehole Bh17-108 and BH17-109 are summarized in Tables 1 and 2, respectively. The compression and shear wave layer velocities were calculated by best fitting a theoretical travel time model to the field data. The depths presented on the table are relative to ground surface.

The estimated dynamic engineering moduli, based on the calculated wave velocities, are also presented in Table 1. The engineering moduli were calculated using an estimated bulk density of 1,600 kg/ m<sup>3</sup> for silty clay, 2,200 kg/m<sup>3</sup> for glacial till and an estimated bedrock bulk density of 2,400 kg/ m<sup>3</sup> based on the borehole log.

The average shear wave velocity from ground surface to a depth of 30 m (Vs30) was measured to be 287 m/s at BH17-108. The average velocity was calculated assuming that the velocity from 12.6 m to a depth of 30 m was constant with an average shear wave velocity value of 1,050 m/s which is equal to the velocity of the bedrock at the bottom of the borehole.

The average shear wave velocity from ground surface to a depth of 30 m ( $V_{s30}$ ) was measured to be 689 m/s at BH17-109. The average velocity was calculated assuming that the velocity from 17.85 m to a depth of 30 m was constant with an average shear wave velocity value of 1,050 m/s which is equal to the velocity of the bedrock at the bottom of the borehole.

## Limitations

This technical memorandum is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this memo.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The services performed, as described in this memo, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this memo, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this memo.

The findings and conclusions of this memo are valid only as of the date of this memo. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this memo, and to provide amendments as required.

## Closure

We trust that these results meet your current needs. If you have any questions or require clarification, please contact the undersigned at your convenience.

### GOLDER ASSOCIATES LTD.



Stephane Sol, Ph.D., P.Geo  
Senior Geophysicist



Christopher Phillips, M.Sc., P.Geo  
Principal, Senior Geophysicist

SS/CRP/jl

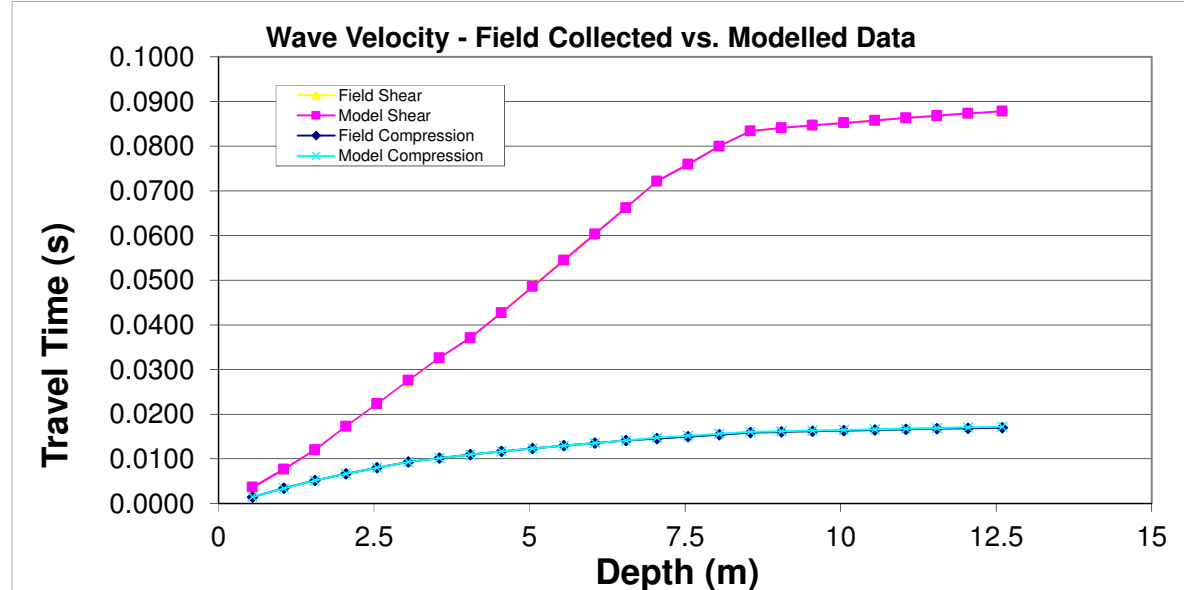
c:\users\jrlee\desktop\current\1772182 tech memo 2017\june05 raisin river.docx

Attachment: Table 1 – Shear Wave Velocity Profile at BH17-108  
Table 2 – Shear Wave Velocity Profile at BH17-109



**TABLE 1**  
**SHEAR WAVE VELOCITY PROFILE AT BH17-108**

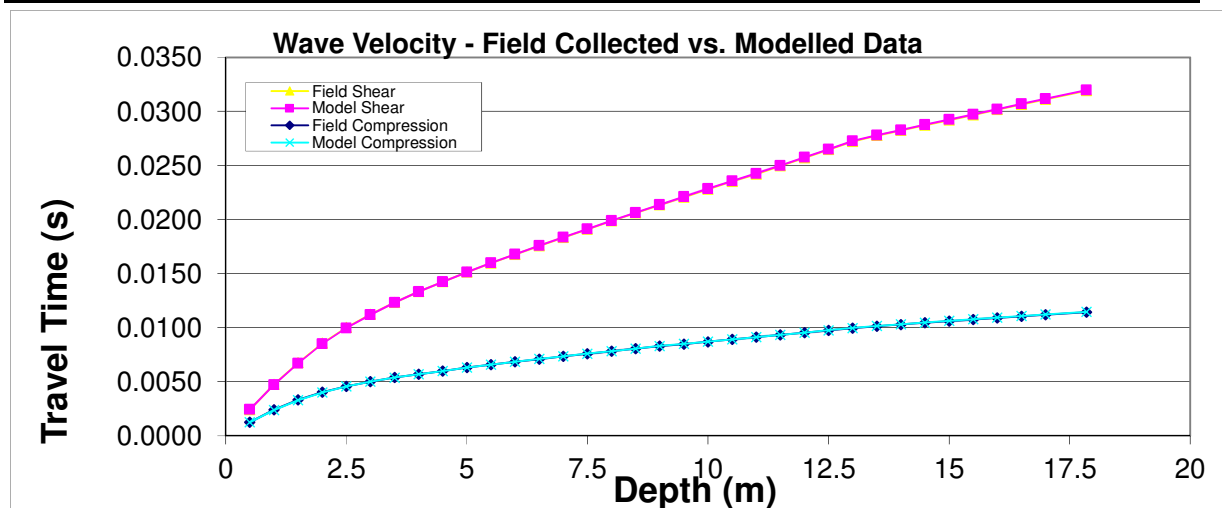
Layer Depth (m)		Velocities (m/s)		Estimated Bulk Density (kg/m <sup>3</sup> )	Dynamic Engineering Properties			
Top	Bottom	Compressional Wave	Shear Wave		Poissons Ratio	Shear Modulus (MPa)	Deformation Modulus (MPa)	Bulk Modulus (MPa)
0.0	0.6	370	150	2200	0.40	50	139	235
0.6	1.1	260	125	2200	0.35	34	93	103
1.1	1.6	285	115	2200	0.40	29	82	140
1.6	2.1	330	95	1600	0.45	14	42	155
2.1	2.6	370	99	1600	0.46	16	46	198
2.6	3.1	380	95	1600	0.47	14	42	212
3.1	3.6	590	100	1600	0.49	16	48	536
3.6	4.1	660	110	1600	0.49	19	58	671
4.1	4.6	700	90	1600	0.49	13	39	767
4.6	5.1	760	85	1600	0.49	12	35	909
5.1	5.6	800	85	1600	0.49	12	35	1009
5.6	6.1	840	85	1600	0.49	12	35	1114
6.1	6.6	840	85	1600	0.49	12	35	1114
6.6	7.1	840	85	1600	0.49	12	35	1114
7.1	7.6	1150	130	2200	0.49	37	111	2860
7.6	8.1	1150	125	2200	0.49	34	103	2864
8.1	8.6	1100	145	2200	0.49	46	138	2600
8.6	9.1	3300	750	2400	0.47	1350	3976	24336
9.1	9.6	3300	850	2400	0.46	1734	5079	23824
9.6	10.1	3450	900	2400	0.46	1944	5690	25974
10.1	10.6	3500	900	2400	0.46	1944	5694	26808
10.6	11.1	3600	950	2400	0.46	2166	6336	28216
11.1	11.6	3600	950	2400	0.46	2166	6336	28216
11.6	12.1	3600	1000	2400	0.46	2400	6999	27904
12.1	12.6	3600	1050	2400	0.45	2646	7692	27576

**Notes**

1. Depth presented relative to ground surface.
2. This Table to be analyzed in conjunction with the accompanying report.

**TABLE 2**  
**SHEAR WAVE VELOCITY PROFILE AT BH17-109**

Layer Depth (m)		Velocities (m/s)		Estimated Bulk Density (kg/m <sup>3</sup> )	Dynamic Engineering Properties			
Top	Bottom	Compressional Wave	Shear Wave		Poissons Ratio	Shear Modulus (MPa)	Deformation Modulus (MPa)	Bulk Modulus (MPa)
0.0	0.5	400	205	1600	0.32	67	178	166
0.5	1.0	445	220	1600	0.34	77	207	214
1.0	1.5	545	250	2200	0.37	138	376	470
1.5	2.0	700	280	2200	0.40	172	485	848
2.0	2.5	900	340	2200	0.42	254	721	1443
2.5	3.0	1120	405	2200	0.42	361	1028	2279
3.0	3.5	1340	450	2200	0.44	446	1280	3356
3.5	4.0	1570	500	2200	0.44	550	1588	4689
4.0	4.5	1750	540	2200	0.45	642	1857	5882
4.5	5.0	1550	560	2200	0.42	690	1966	4366
5.0	5.5	1800	590	2200	0.44	766	2205	6107
5.5	6.0	1850	620	2200	0.44	846	2430	6402
6.0	6.5	2000	630	2200	0.44	873	2523	7636
6.5	7.0	2000	640	2200	0.44	901	2601	7599
7.0	7.5	2050	650	2200	0.44	930	2685	8006
7.5	8.0	2150	660	2200	0.45	958	2775	8892
8.0	8.5	2100	670	2200	0.44	988	2851	8385
8.5	9.0	2100	680	2200	0.44	1017	2933	8346
9.0	9.5	2500	680	2200	0.46	1017	2971	12394
9.5	10.0	2400	680	2200	0.46	1017	2963	11316
10.0	10.5	2400	690	2200	0.45	1047	3048	11275
10.5	11.0	2400	720	2200	0.45	1140	3309	11151
11.0	11.5	2400	690	2200	0.45	1047	3048	11275
11.5	12.0	2400	660	2200	0.46	958	2797	11394
12.0	12.5	2400	660	2200	0.46	958	2797	11394
12.5	13.0	2400	660	2200	0.46	958	2797	11394
13.0	13.5	2500	910	2200	0.42	1822	5187	11321
13.5	14.0	3300	1050	2400	0.44	2646	7640	22608
14.0	14.5	3300	1030	2400	0.45	2546	7364	22741
14.5	15.0	3300	1030	2400	0.45	2546	7364	22741
15.0	15.5	3350	1050	2400	0.45	2646	7650	23406
15.5	16.0	3350	1050	2400	0.45	2646	7650	23406
16.0	16.5	3350	1050	2400	0.45	2646	7650	23406
16.5	17.0	3350	1050	2400	0.45	2646	7650	23406
17.0	17.9	3350	1050	2400	0.45	2646	7650	23406

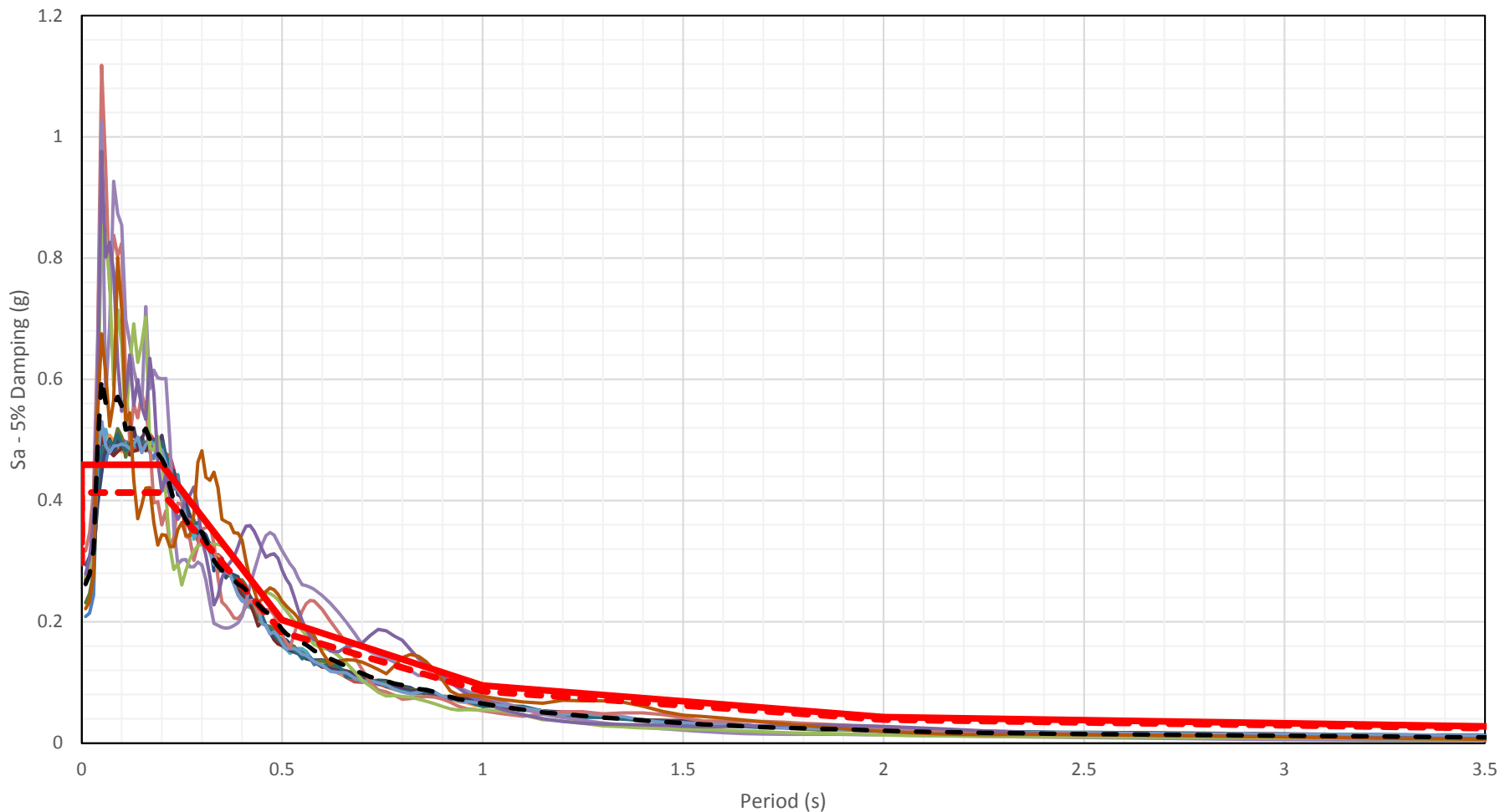
**Notes**

1. Depth presented relative to ground surface.
2. This Table to be analyzed in conjunction with the accompanying report.

**APPENDIX E**

**Seismic Analysis Results**





- |                       |                           |                     |                     |                  |
|-----------------------|---------------------------|---------------------|---------------------|------------------|
| San Fernando (H1)     | San Fernando (H2)         | N.Palm Springs (H1) | N.Palm Springs (H2) | Coyote Lake (H1) |
| Coyote Lake (H2)      | Northridge (H1)           | Northridge (H2)     | Nahanni (H1)        | Nahanni (H2)     |
| M6a2m09               | M6a2m11                   | M6a2m22             | M6a2m35             | M6a2m36          |
| Target (Site Class B) | 90% Target (Site Class B) | Average             |                     |                  |

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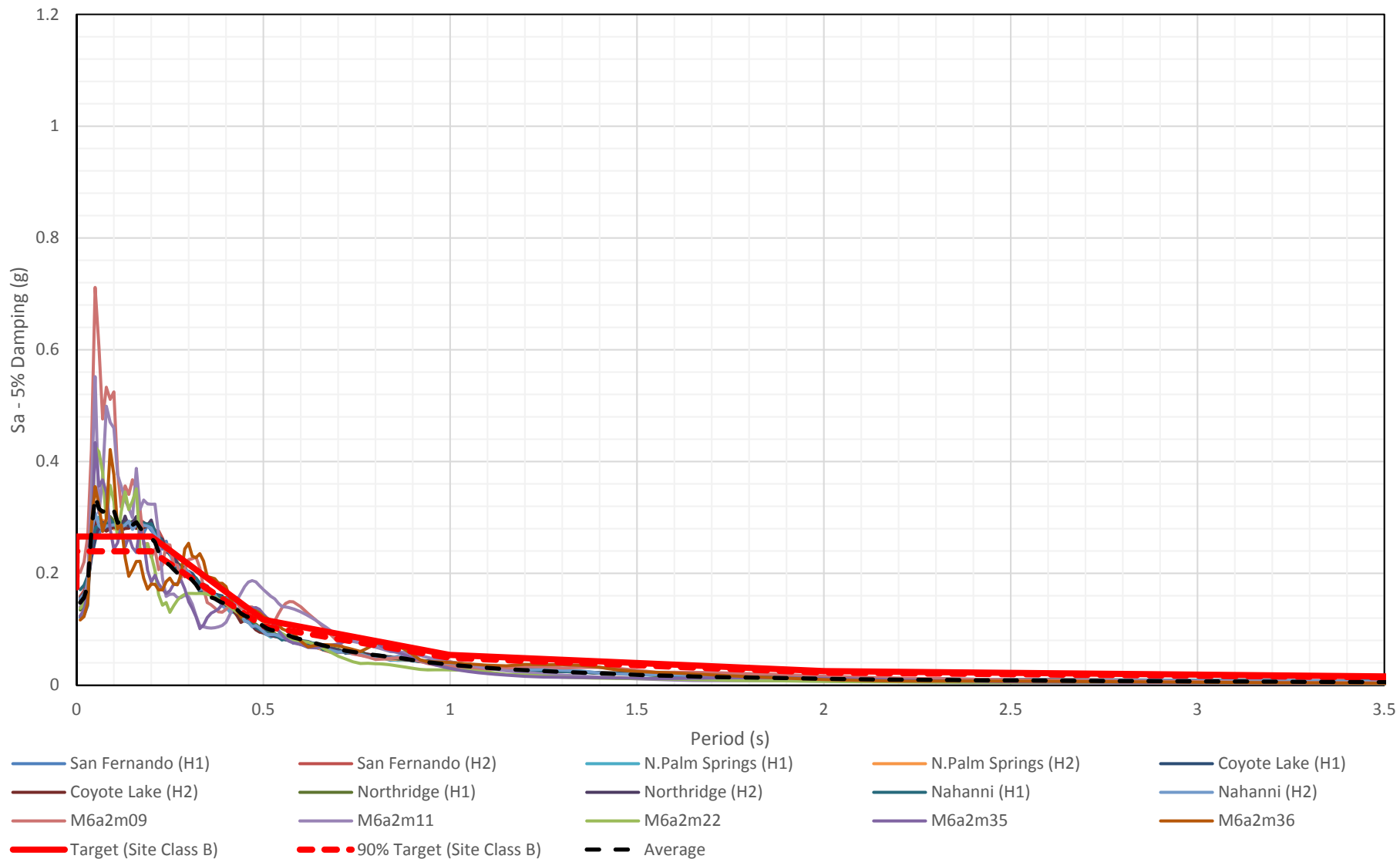
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**SITE CLASS A SCALED INPUT RESPONSE SPECTRA  
2,475-YEAR DESIGN EARTHQUAKE**

PROJECT No.  
**1772182**

Phase  
**1150**

Rev.  
**1**

Figure  
**E1**



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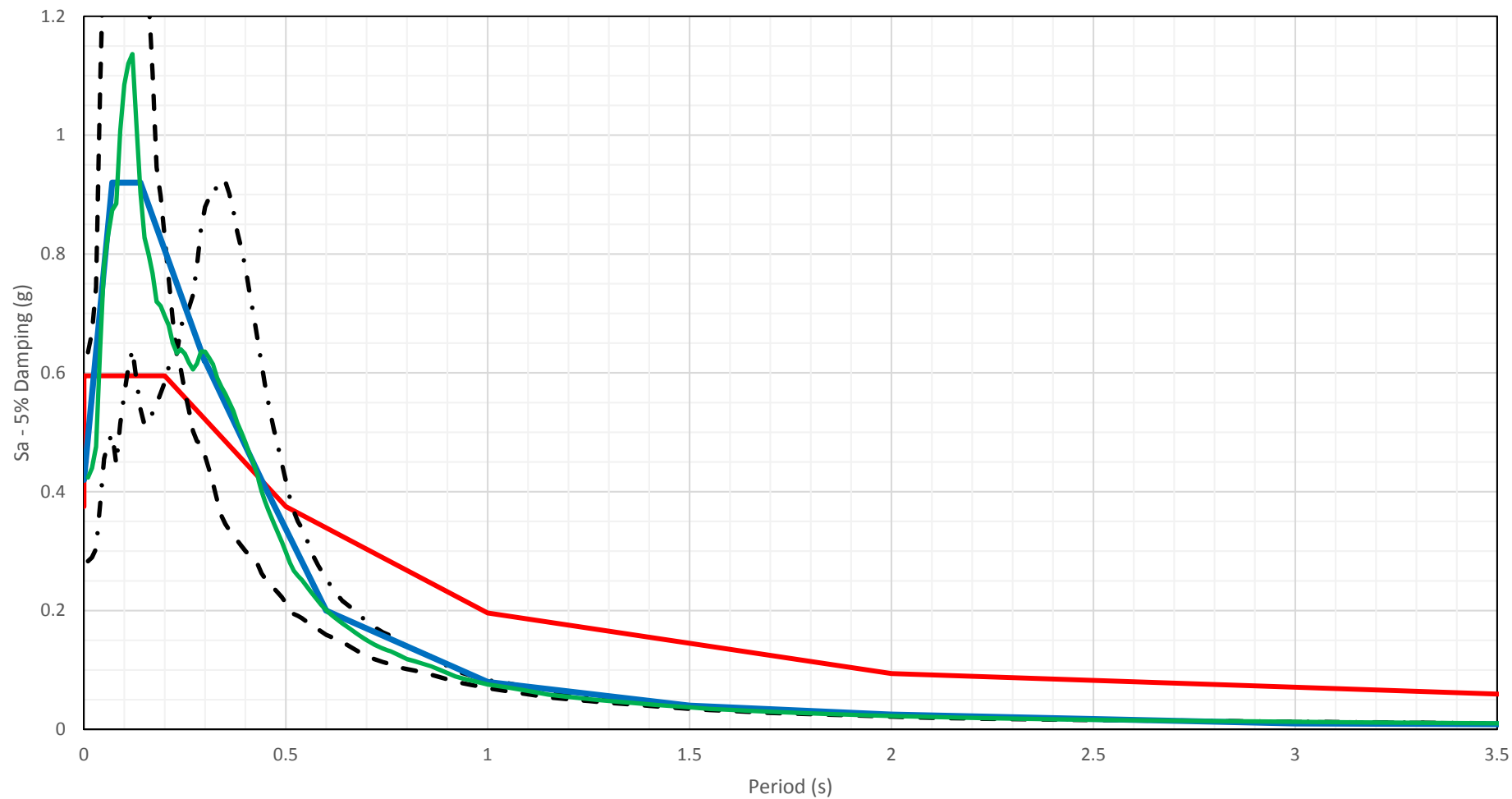
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APPROVED	MSS

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TITLE  
**SITE CLASS A SCALED INPUT RESPONSE SPECTRA  
975-YEAR DESIGN EARTHQUAKE**

PROJECT No.	Phase	Rev.	Figure
1772182	1150	1	E2

1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



— Site Class D (CHBDC)    
 - · - Pier Location    
 --- Abutment Location    
 — Recommended for Design    
 — Geomean of All THs

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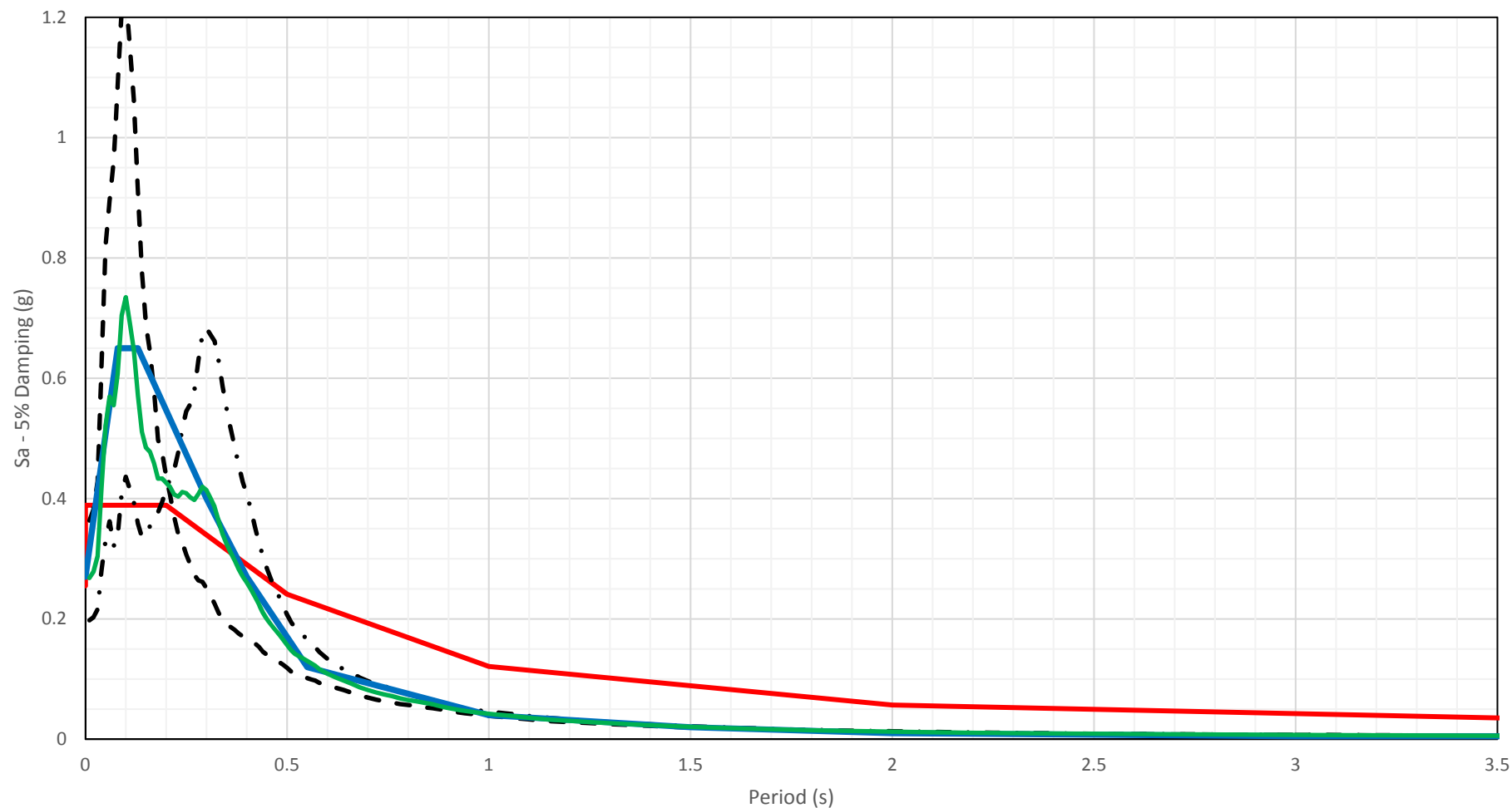
YYYY-MM-DD	2018/10/03
PREPARED	SG
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APPROVED	MSS

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TITLE  
**AVERAGE GROUND SURFACE RESPONSE SPECTRA  
 2,475-YEAR DESIGN EARTHQUAKE**

PROJECT No.	Phase	Rev.	Figure
1772182	1150	1	E3

1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



— Site Class D (CHBDC)    
 - · - Pier Location    
 - - - Abutment Location    
 — Recommended for Design    
 — Geomean of All THs

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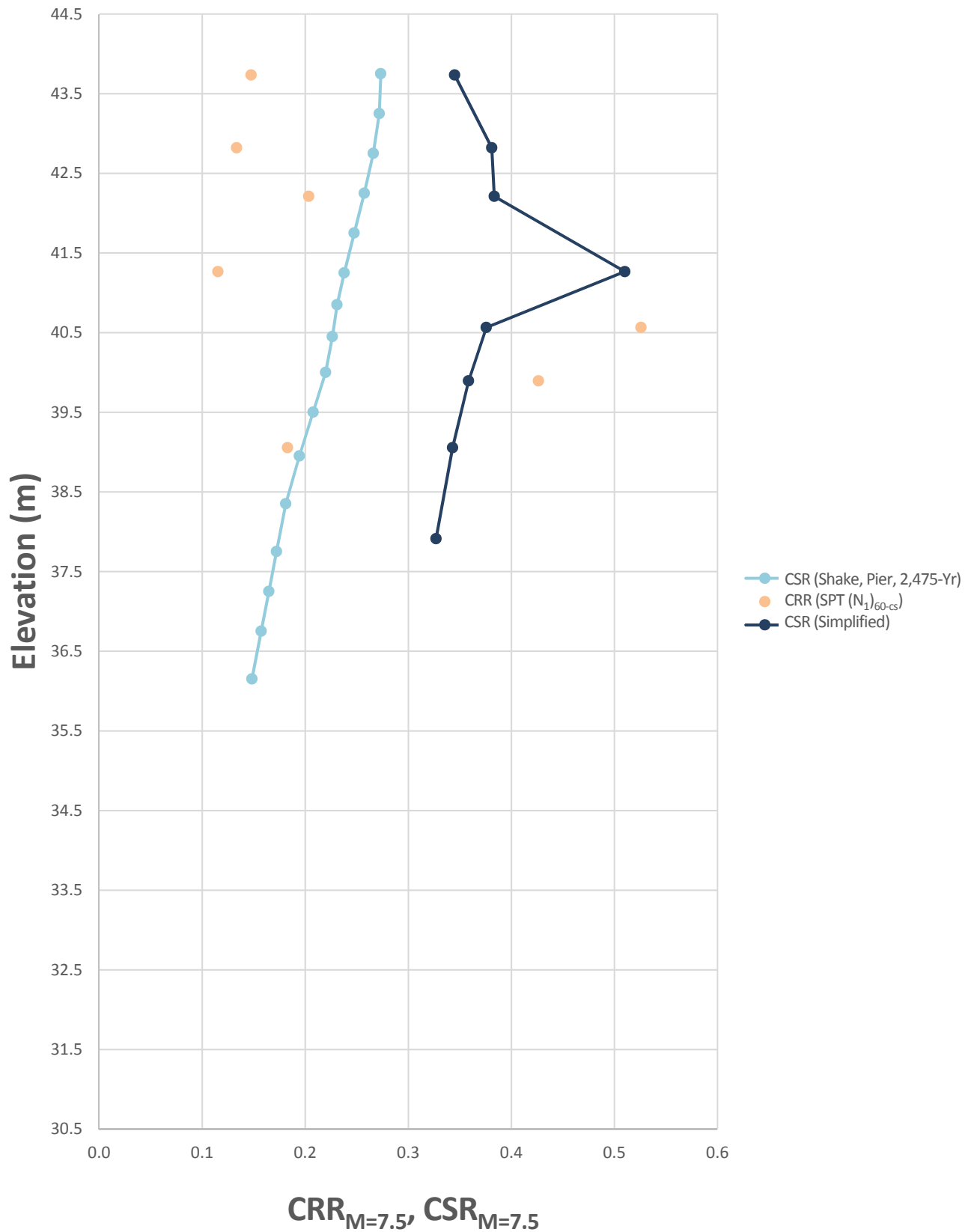
PROJECT  
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SITE NO. 31-231, HIGHWAY 401  
OTTAWA, ONTARIO

TITLE  
**AVERAGE GROUND SURFACE RESPONSE SPECTRA  
975-YEAR DESIGN EARTHQUAKE**

PROJECT No.	Phase	Rev.
1772182	1150	1

Figure  
**E4**

1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



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**CSR vs CRR PROFILES**  
**BOREHOLE 17-01**

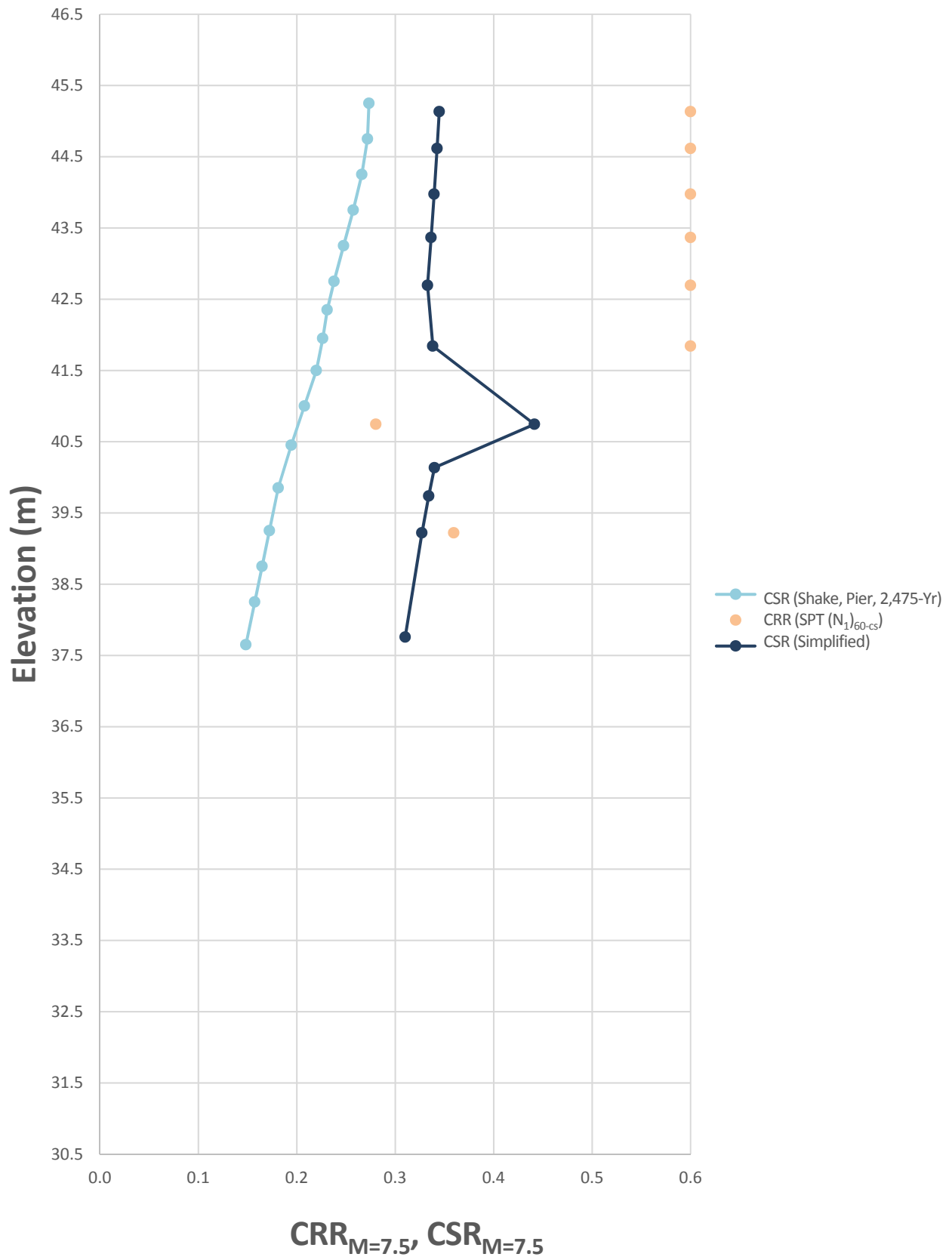
PROJECT No.  
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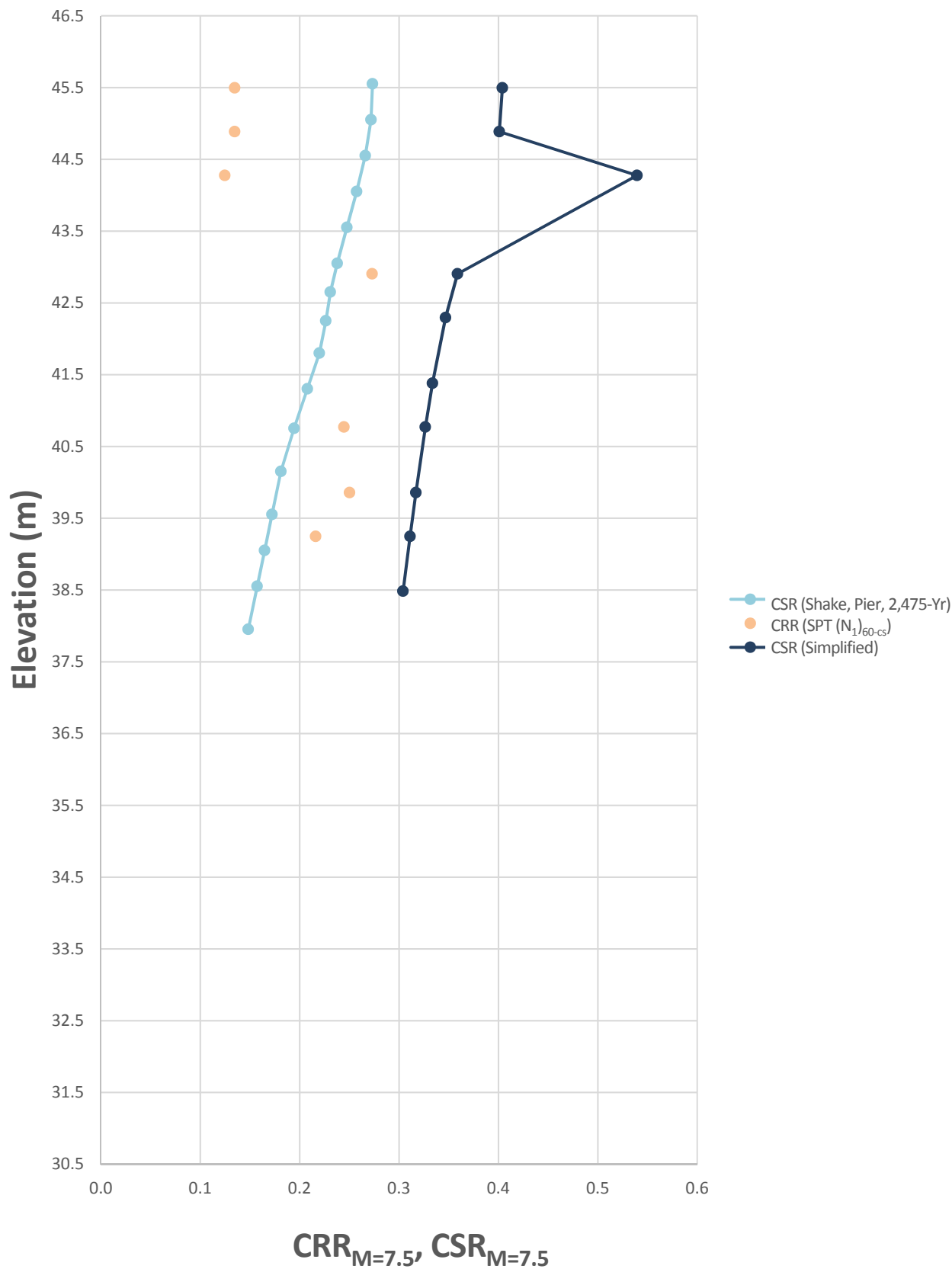
Phase  
**1150**

Rev.  
**1**

Figure  
**E5**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A  
1 in





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**CSR vs CRR PROFILES**  
**BOREHOLE 17-03**

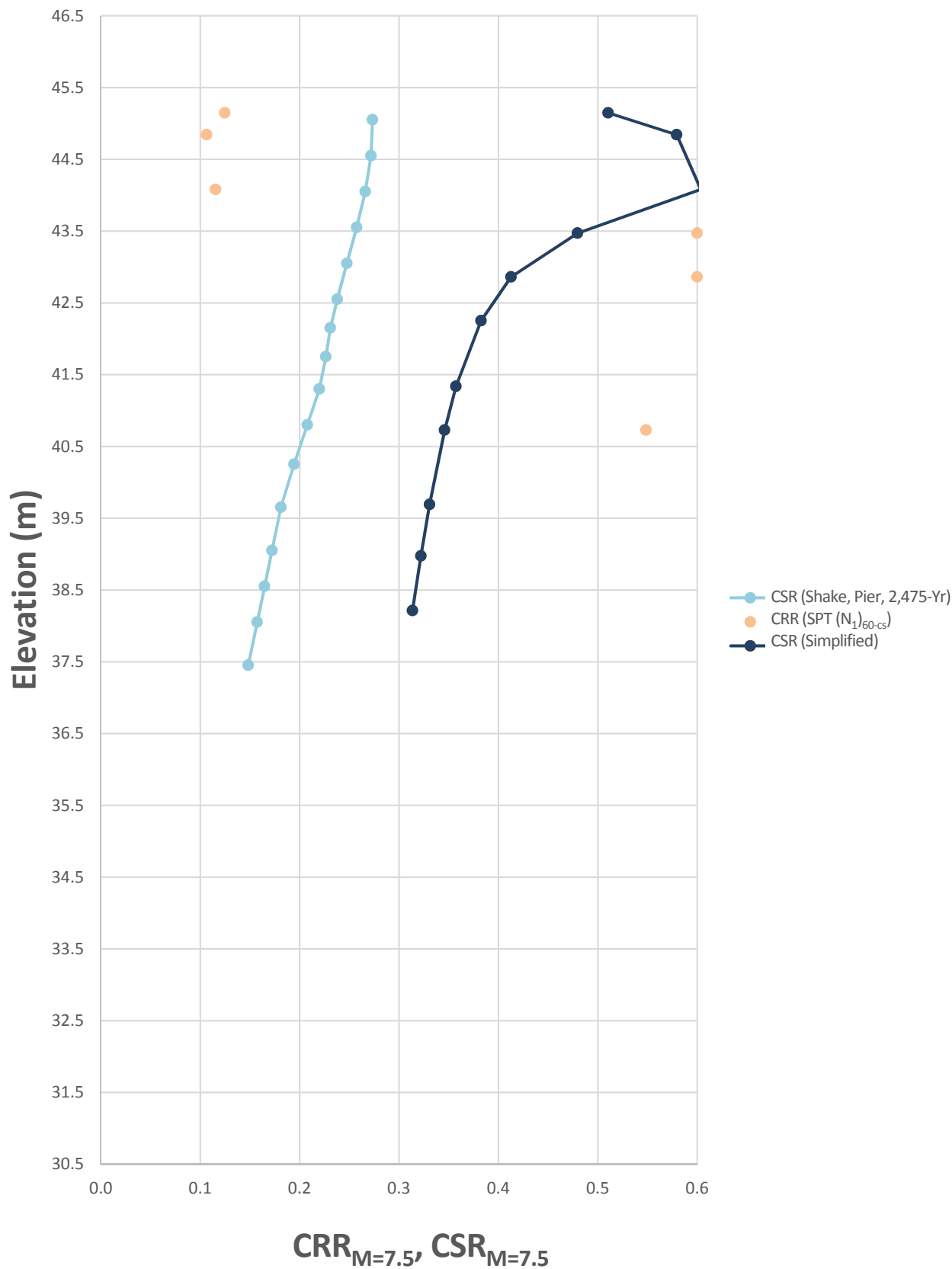
PROJECT No.  
**1772182**

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**1150**

Rev.  
**1**

Figure  
**E7**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



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**CSR vs CRR PROFILES**  
**BOREHOLE 17-04**

PROJECT No.  
**1772182**

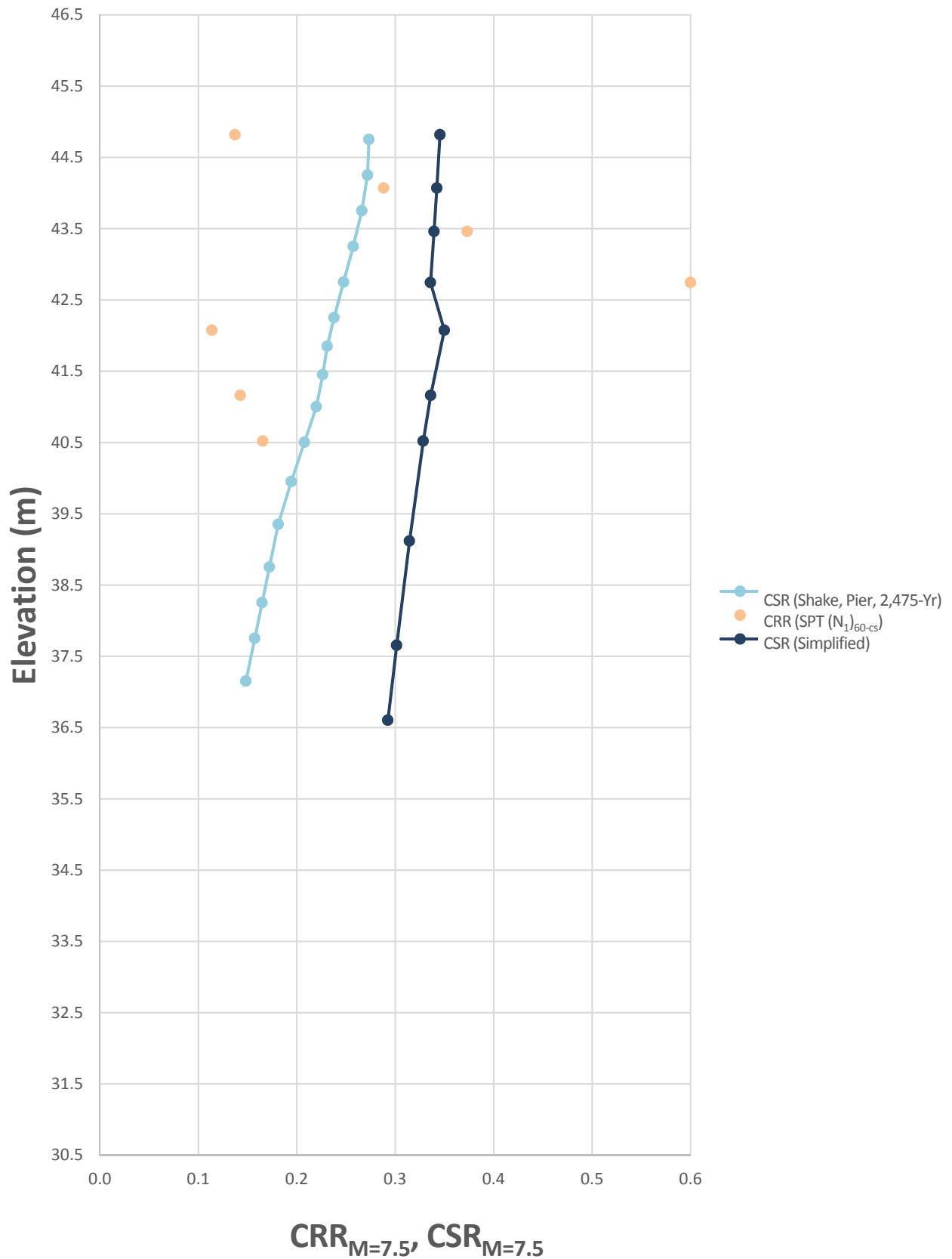
Phase  
**1150**

Rev.  
**1**

Figure  
**E8**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A





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**CSR vs CRR PROFILES**  
**BOREHOLE 17-05**

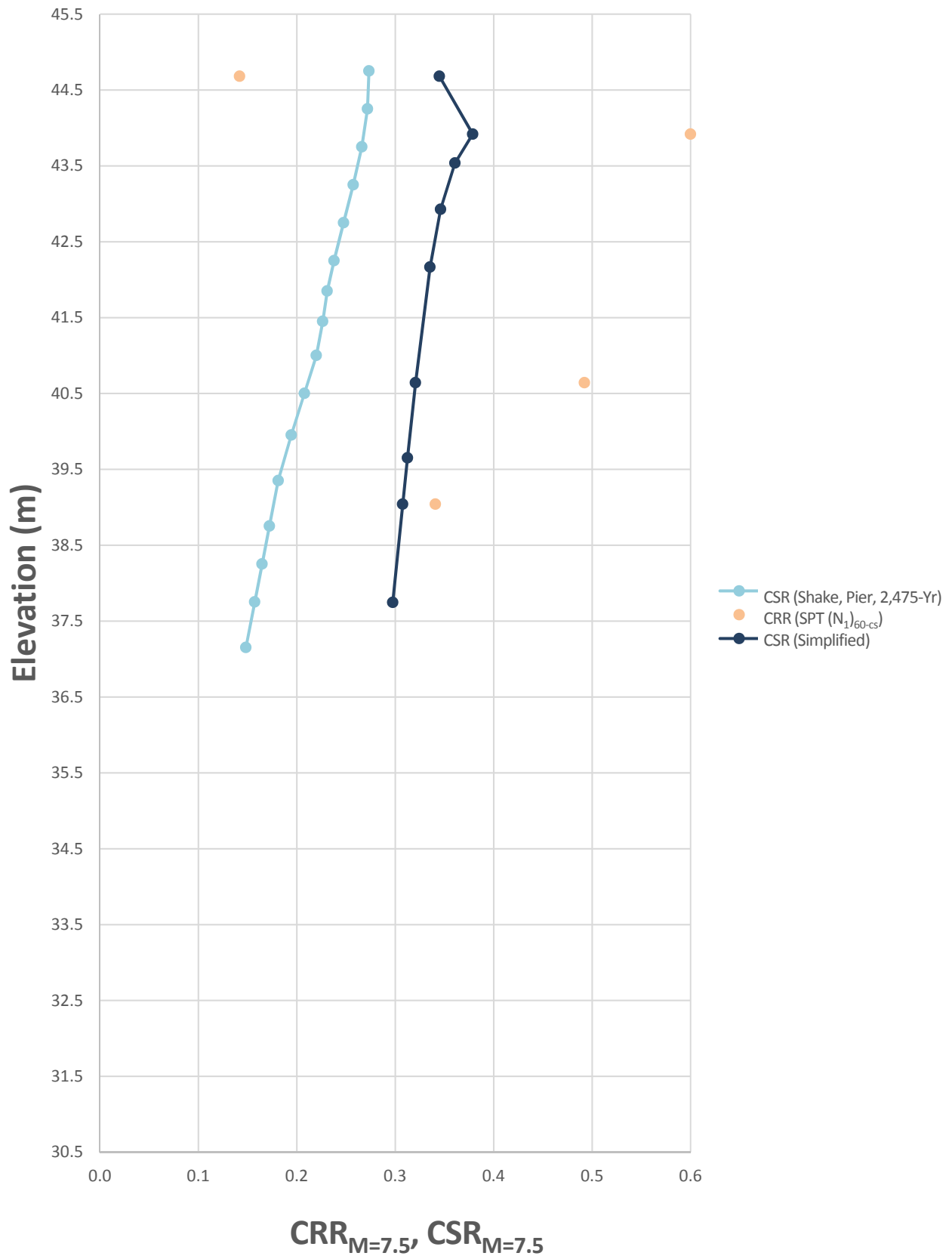
PROJECT No.  
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Phase  
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Rev.  
**1**

Figure  
**E9**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A  
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**CSR vs CRR PROFILES**  
**BOREHOLE 17-06**

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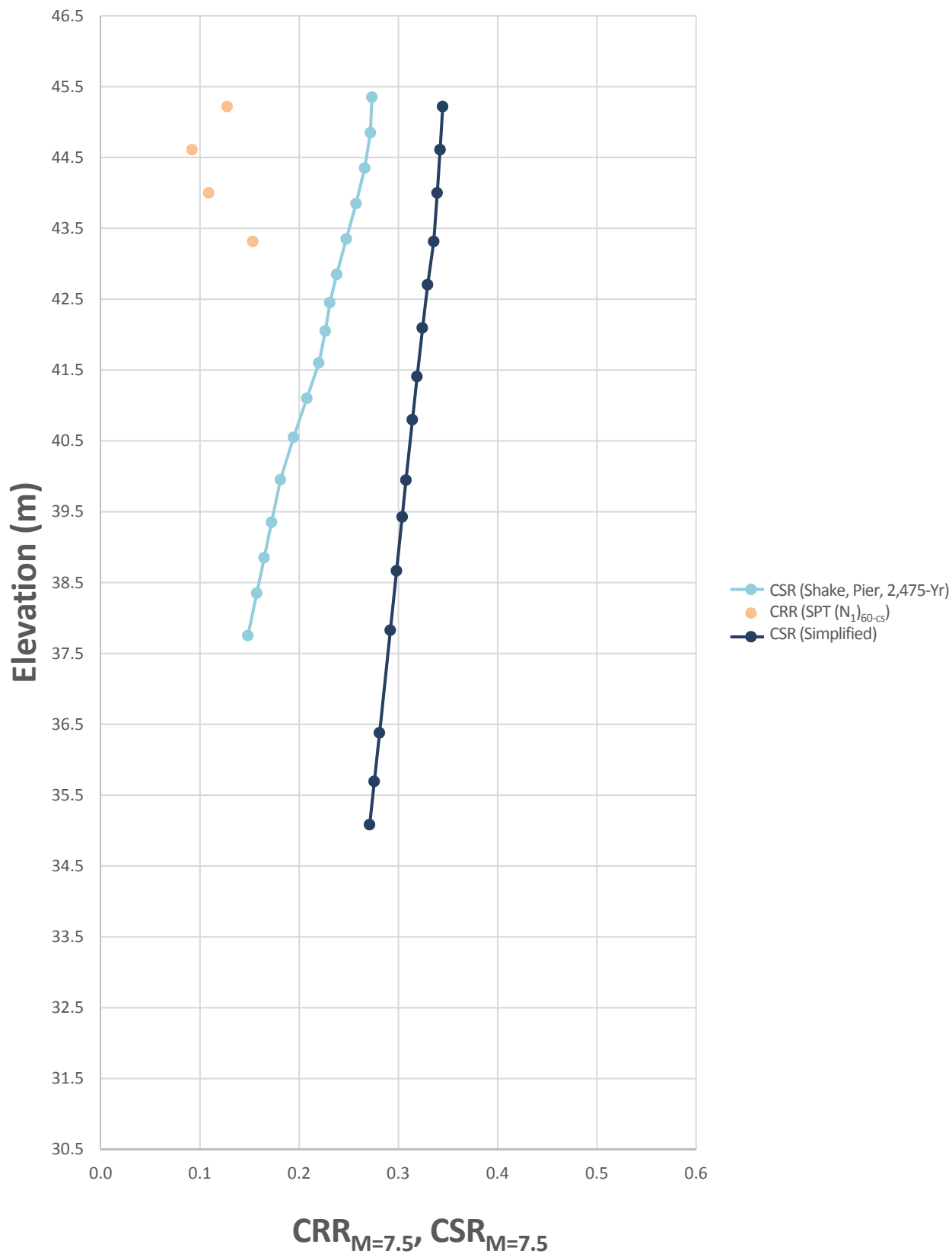
Phase  
**1150**

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Figure  
**E10**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

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**CSR vs CRR PROFILES**  
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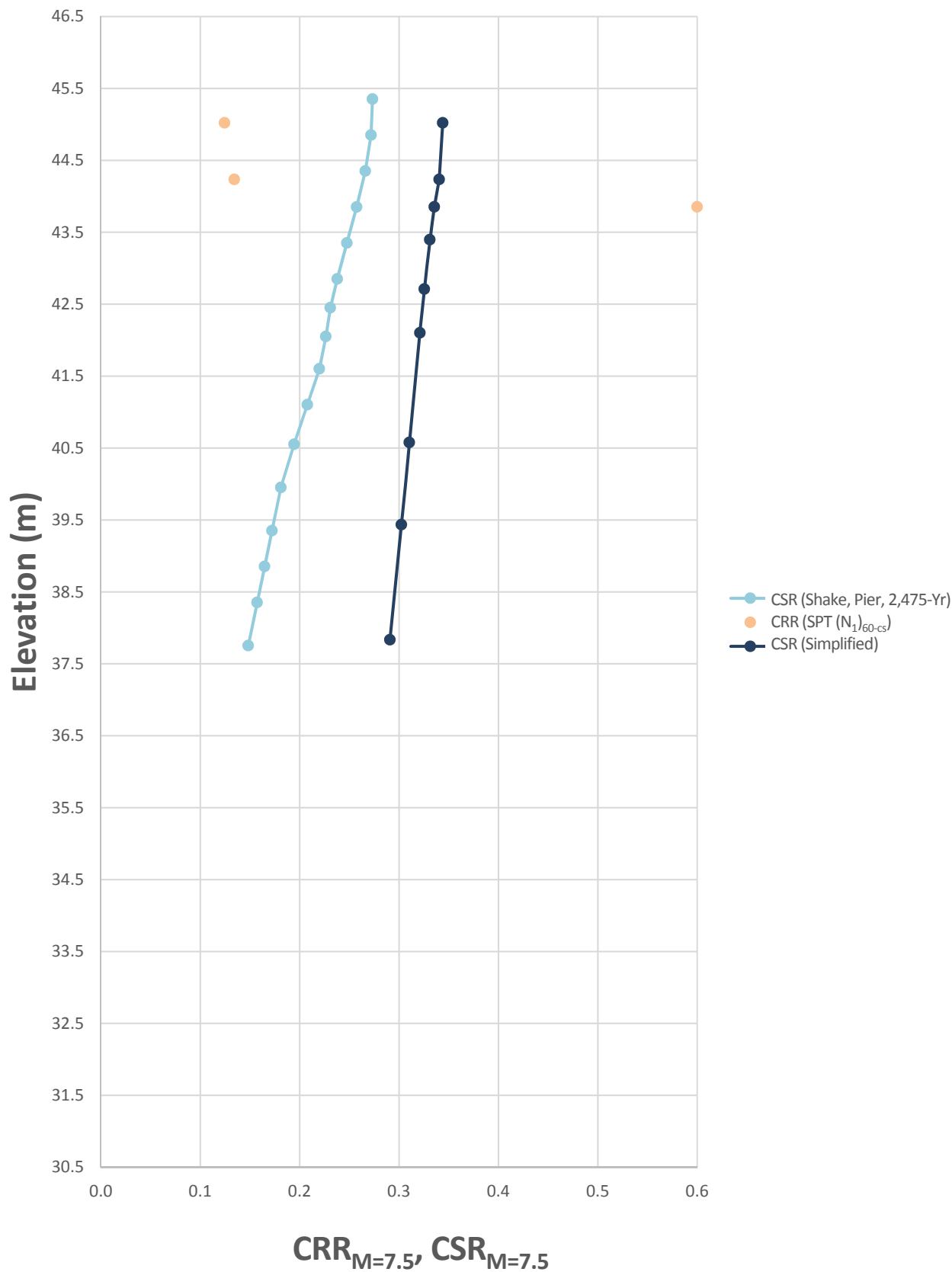
Phase  
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**1**

Figure  
**E11**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

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**CSR vs CRR PROFILES**  
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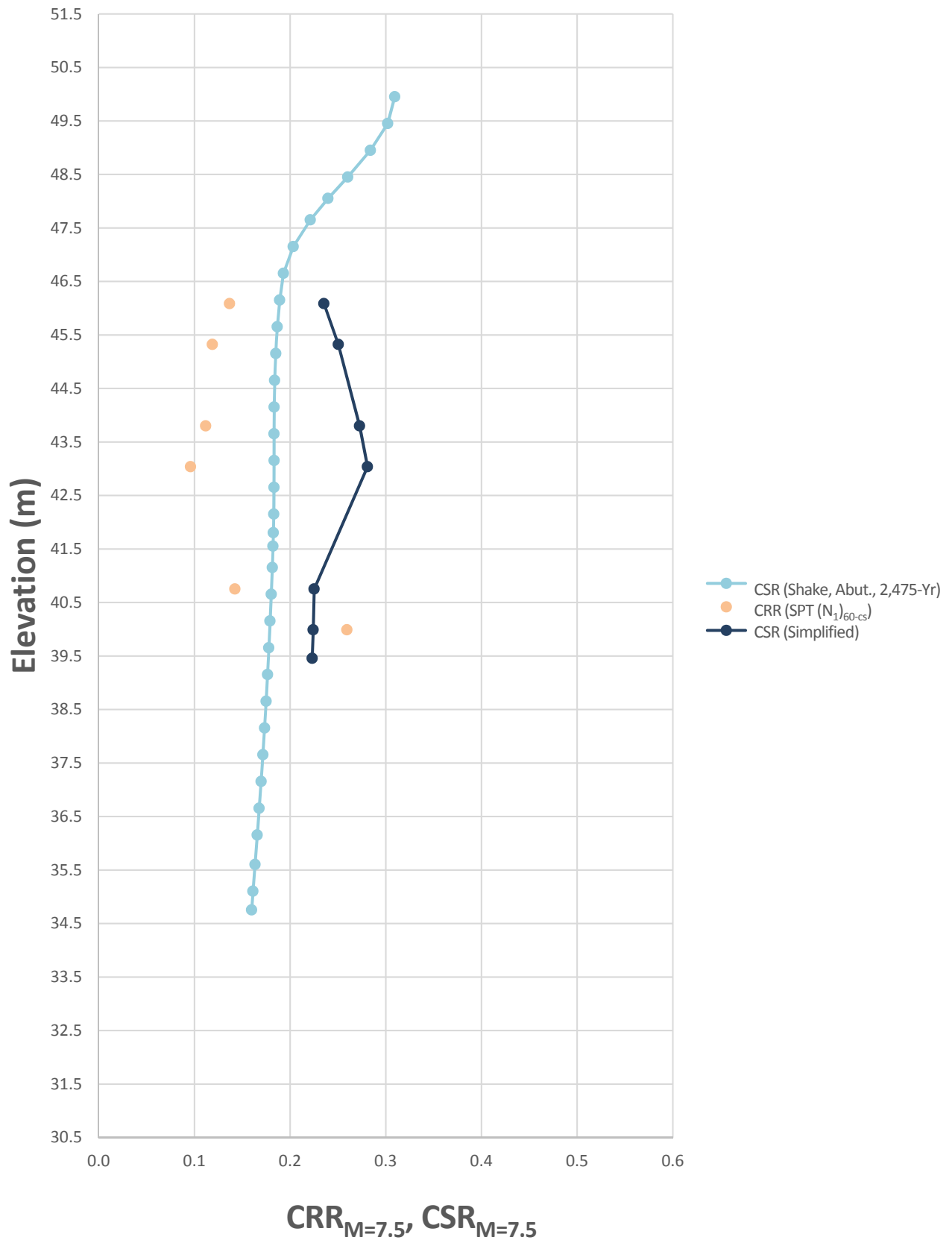
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**1**

Figure  
**E12**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A  
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**RESULTS OF LIQUEFACTION ANALYSIS**  
**CSR vs CRR PROFILES**  
**BOREHOLE 17-101**

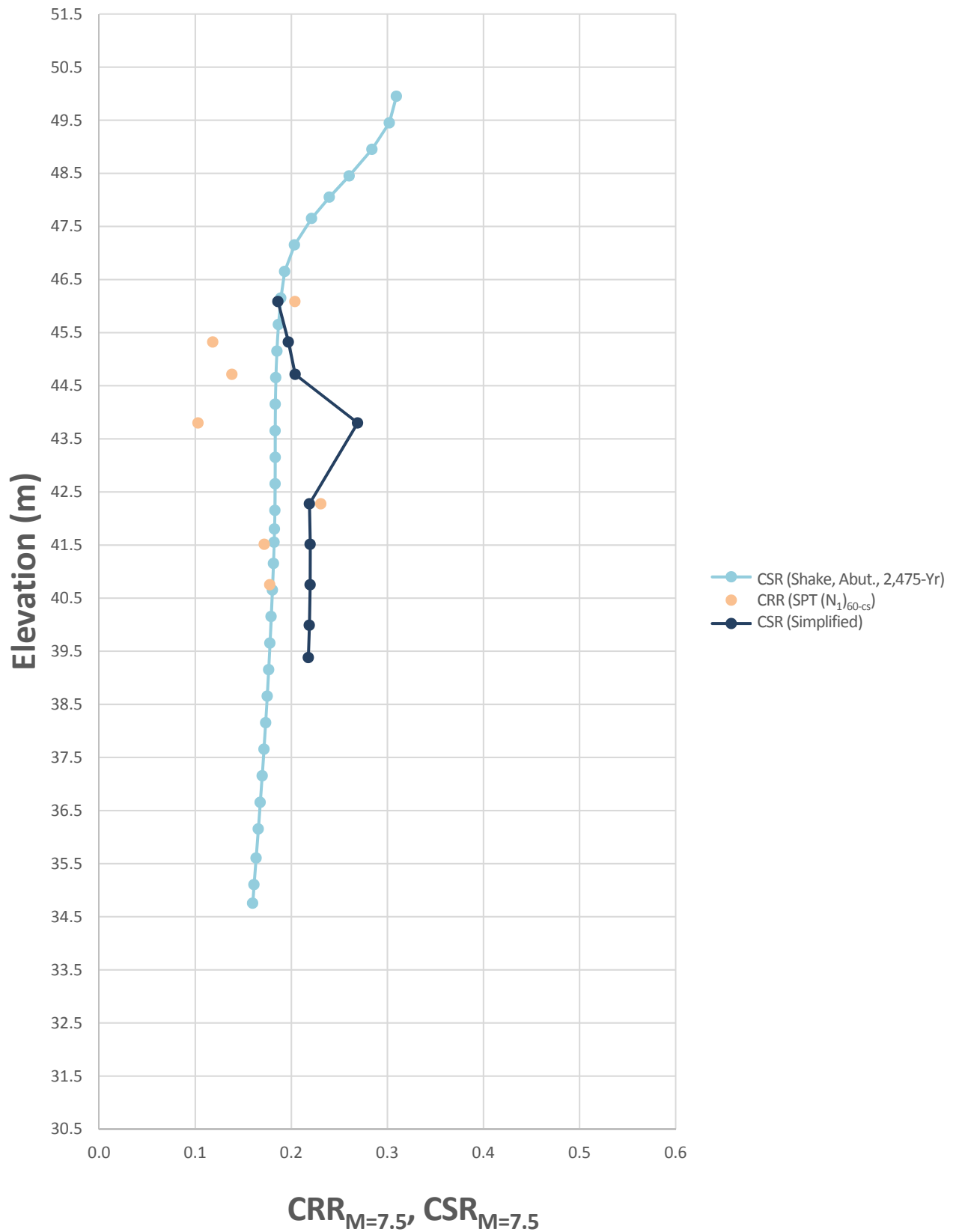
PROJECT No.  
**1772182**

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**1150**

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**1**

Figure  
**E13**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A  
1 in



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**RESULTS OF LIQUEFACTION ANALYSIS**  
**CSR vs CRR PROFILES**  
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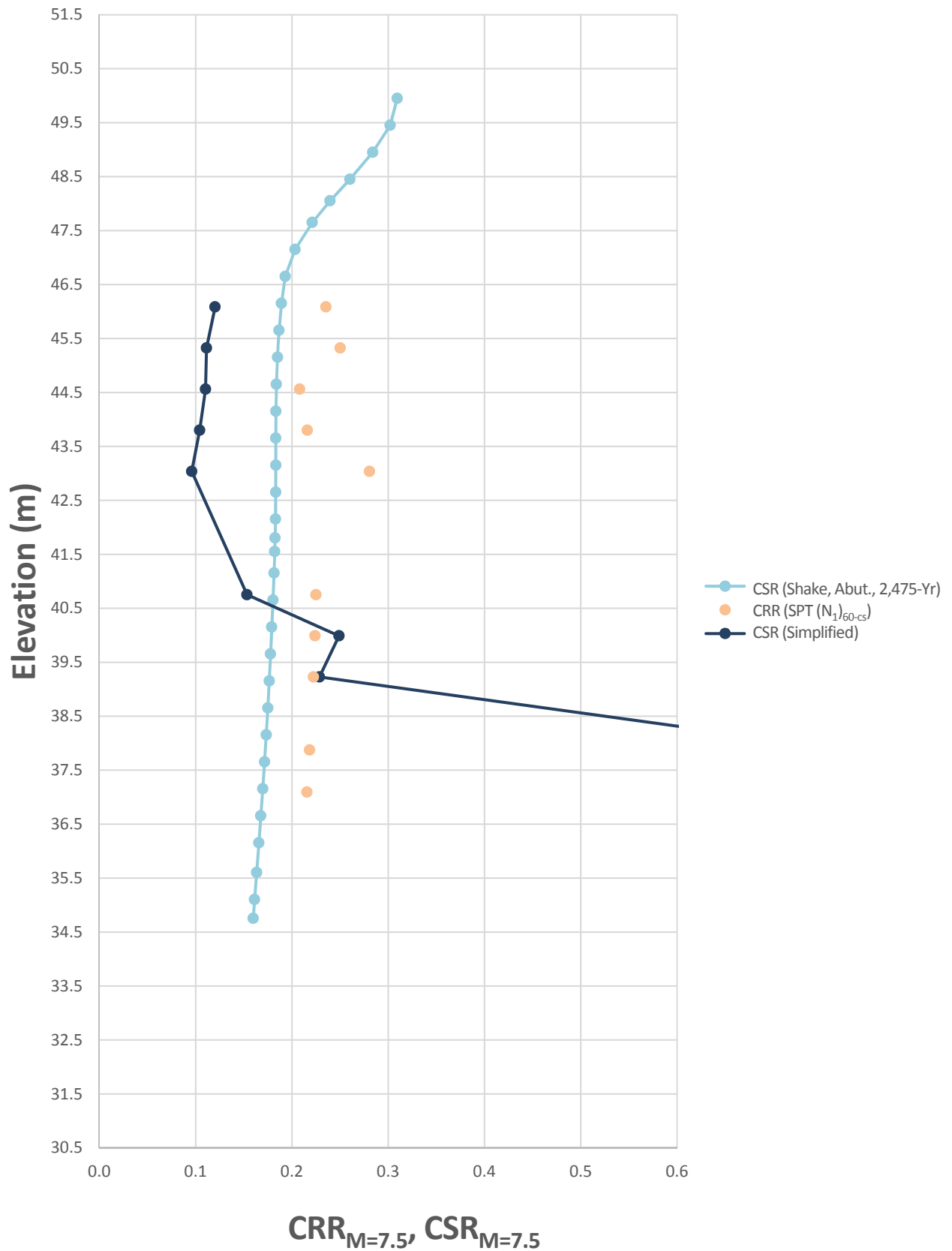
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**1**

Figure  
**E14**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A



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TITLE  
**RESULTS OF LIQUEFACTION ANALYSIS**  
**CSR vs CRR PROFILES**  
**BOREHOLE 17-106**

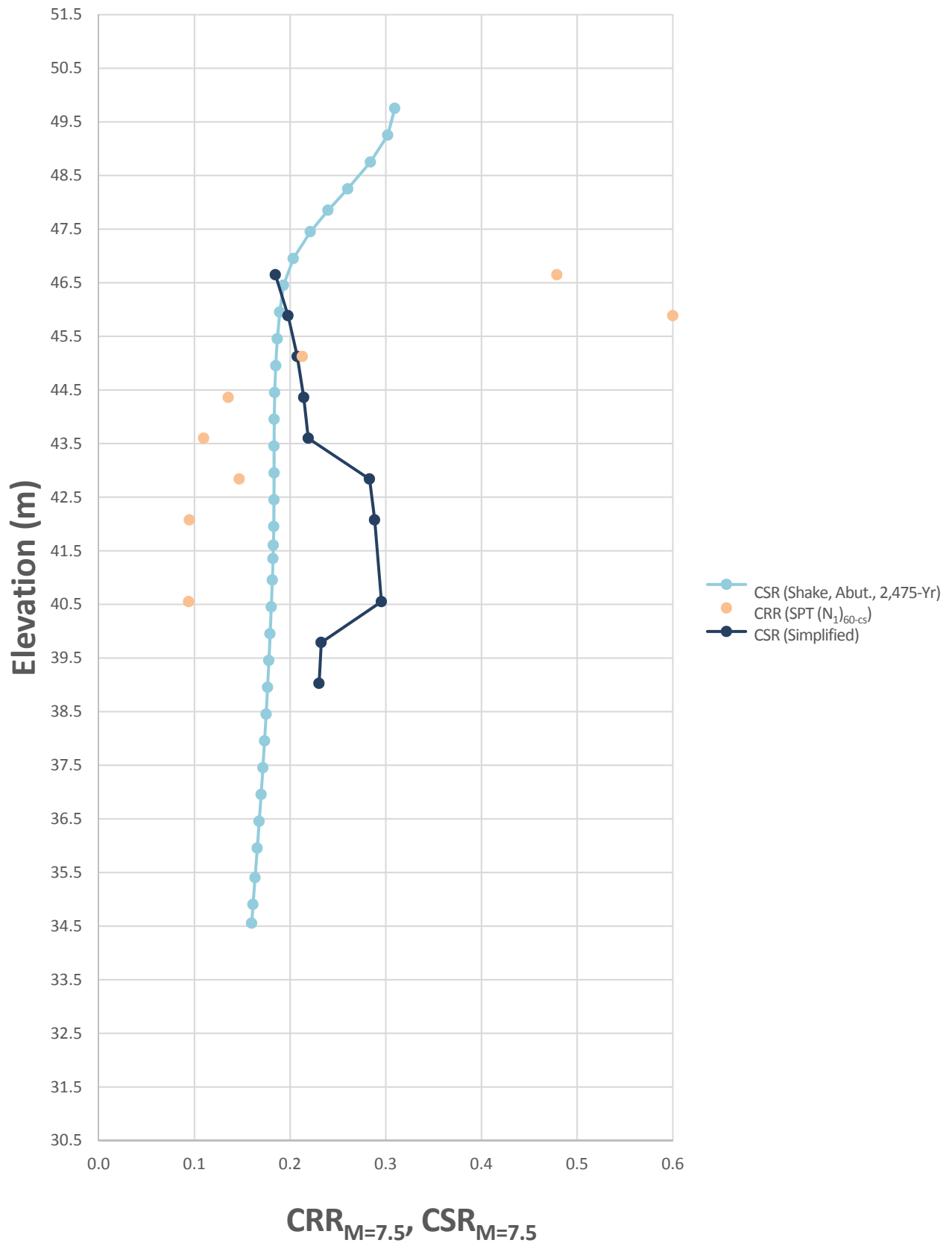
PROJECT No.  
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**1**

Figure  
**E15**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A  
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TITLE  
**RESULTS OF LIQUEFACTION ANALYSIS**  
**CSR vs CRR PROFILES**  
**BOREHOLE 17-107**

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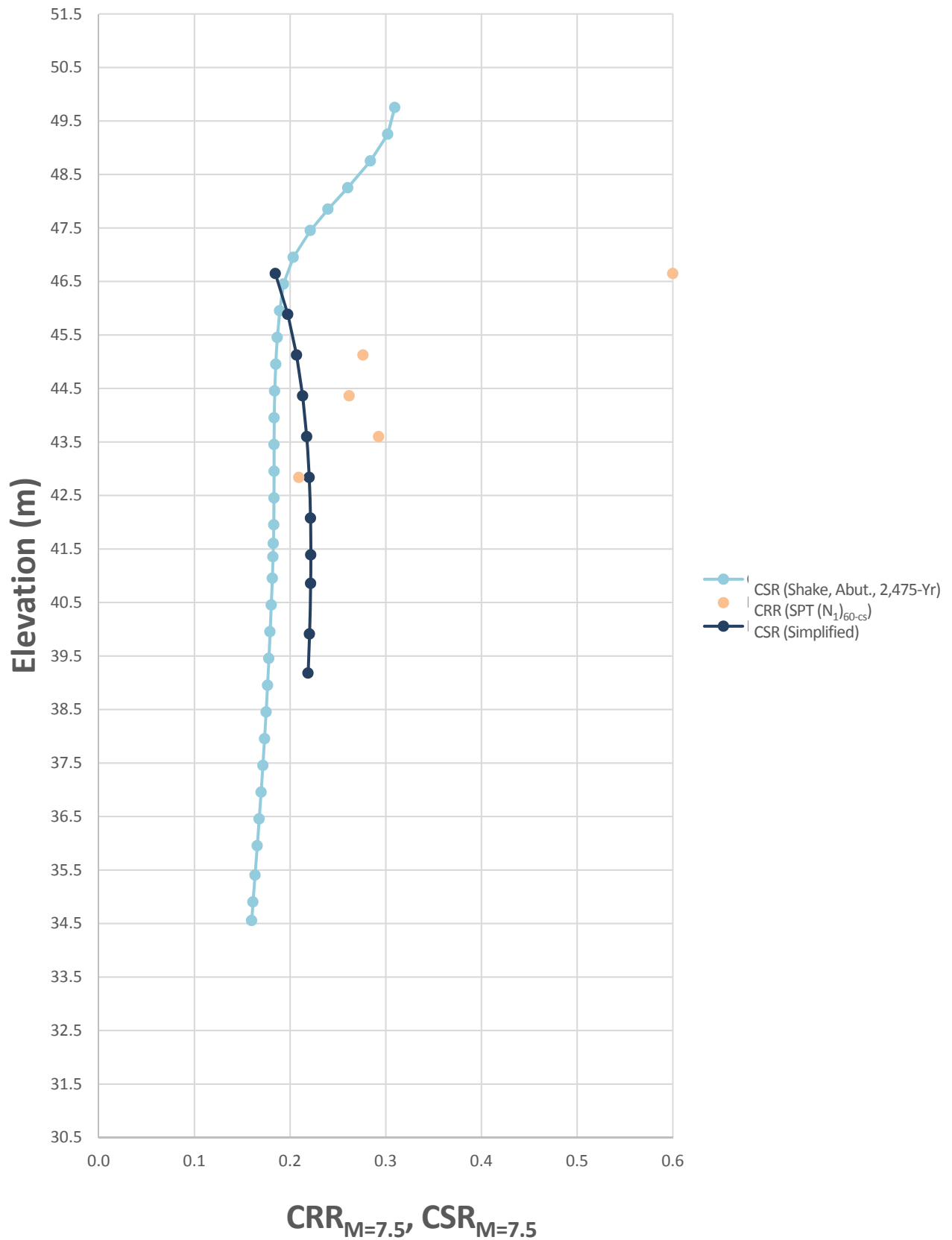
Phase  
**1150**

Rev.  
**1**

Figure  
**E16**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A  
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TITLE  
**RESULTS OF LIQUEFACTION ANALYSIS**  
**CSR vs CRR PROFILES**  
**BOREHOLE 17-110**

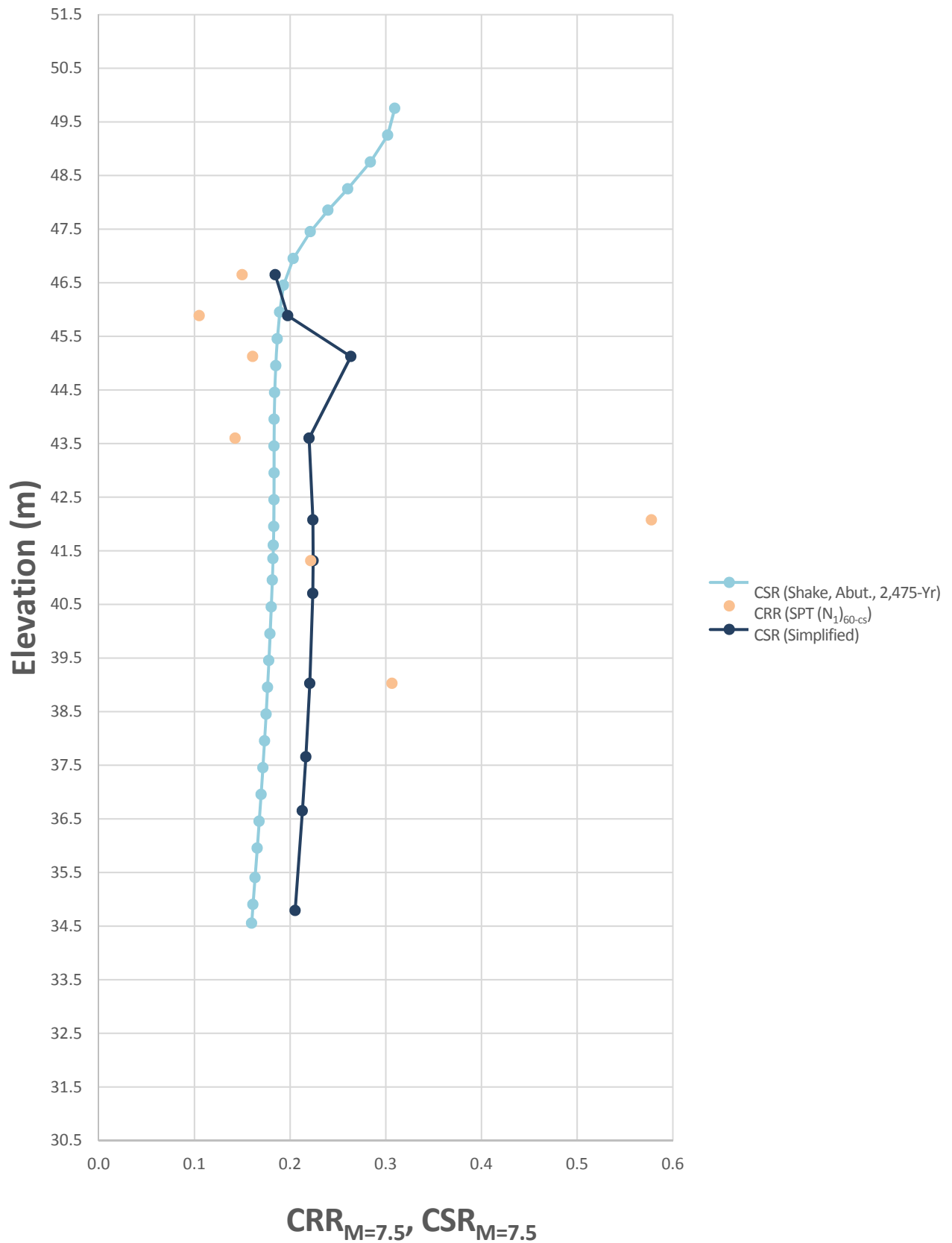
PROJECT No.  
**1772182**

Phase  
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**1**

Figure  
**E17**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A  
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TITLE  
**RESULTS OF LIQUEFACTION ANALYSIS**  
**CSR vs CRR PROFILES**  
**BOREHOLE 17-111**

PROJECT No.  
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Rev.  
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Figure  
**E18**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A  
1 in

## APPENDIX F

# Static and Cyclic P-Y Curves

SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - EBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Grey Silty Clay to Clay											
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m			
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m			
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)		
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	0.012	171.823	0.011	180.628	0.010	189.433	0.010	198.238	0.010	207.043	0.009	215.847	0.000	7.440	0.000	7.440	0.000	7.440	0.000	7.440	0.000	7.440		
	0.024	301.539	0.022	316.991	0.021	332.443	0.020	347.895	0.019	363.347	0.018	378.799	0.000	14.880	0.000	14.880	0.000	14.880	0.000	14.880	0.000	14.880		
	0.036	380.193	0.033	399.675	0.031	419.157	0.030	438.640	0.029	458.122	0.028	477.605	0.000	22.320	0.000	22.320	0.000	22.320	0.000	22.320	0.000	22.320		
	0.048	421.714	0.044	443.324	0.042	464.934	0.040	486.544	0.038	508.154	0.037	529.764	0.001	29.760	0.001	29.760	0.001	29.760	0.001	29.760	0.001	29.760		
	0.059	442.039	0.056	464.691	0.052	487.342	0.050	509.994	0.048	532.645	0.046	555.297	0.002	37.200	0.002	37.200	0.002	37.200	0.002	37.200	0.002	37.200		
	0.071	451.620	0.067	474.763	0.063	497.906	0.060	521.048	0.057	544.191	0.055	567.333	0.004	44.640	0.004	44.640	0.004	44.640	0.004	44.640	0.004	44.640		
	0.083	456.057	0.078	479.427	0.073	502.797	0.070	526.167	0.067	549.537	0.064	572.906	0.006	52.080	0.006	52.080	0.006	52.080	0.006	52.080	0.006	52.080		
	0.095	458.094	0.089	481.568	0.084	505.043	0.080	528.517	0.076	551.991	0.073	575.466	0.009	59.520	0.009	59.520	0.009	59.520	0.009	59.520	0.009	59.520		
	0.107	459.026	0.100	482.548	0.094	506.070	0.090	529.592	0.086	553.114	0.083	576.636	0.013	66.960	0.013	66.960	0.013	66.960	0.013	66.960	0.013	66.960		
	0.119	459.451	0.111	482.995	0.105	506.539	0.100	530.083	0.095	553.627	0.092	577.171	0.018	74.400	0.018	74.400	0.018	74.400	0.018	74.400	0.018	74.400		
	0.131	459.645	0.122	483.199	0.115	506.753	0.110	530.307	0.105	553.861	0.101	577.414	0.024	81.840	0.024	81.840	0.024	81.840	0.024	81.840	0.024	81.840		
	0.143	459.734	0.133	483.292	0.126	506.850	0.120	530.409	0.115	553.967	0.110	577.526	0.032	89.280	0.032	89.280	0.032	89.280	0.032	89.280	0.032	89.280		
	0.154	459.774	0.144	483.335	0.136	506.895	0.130	530.455	0.124	554.016	0.119	577.576	0.040	96.720	0.040	96.720	0.040	96.720	0.040	96.720	0.040	96.720		
	0.166	459.793	0.155	483.354	0.147	506.915	0.140	530.477	0.134	554.038	0.129	577.599	0.050	104.160	0.050	104.160	0.050	104.160	0.050	104.160	0.050	104.160		
	0.178	459.801	0.167	483.363	0.157	506.925	0.150	530.486	0.143	554.048	0.138	577.610	0.062	111.600	0.062	111.600	0.062	111.600	0.062	111.600	0.062	111.600		
	0.190	459.805	0.178	483.367	0.168	506.929	0.159	530.491	0.153	554.053	0.147	577.615	0.066	111.600	0.066	111.600	0.066	111.600	0.066	111.600	0.066	111.600		

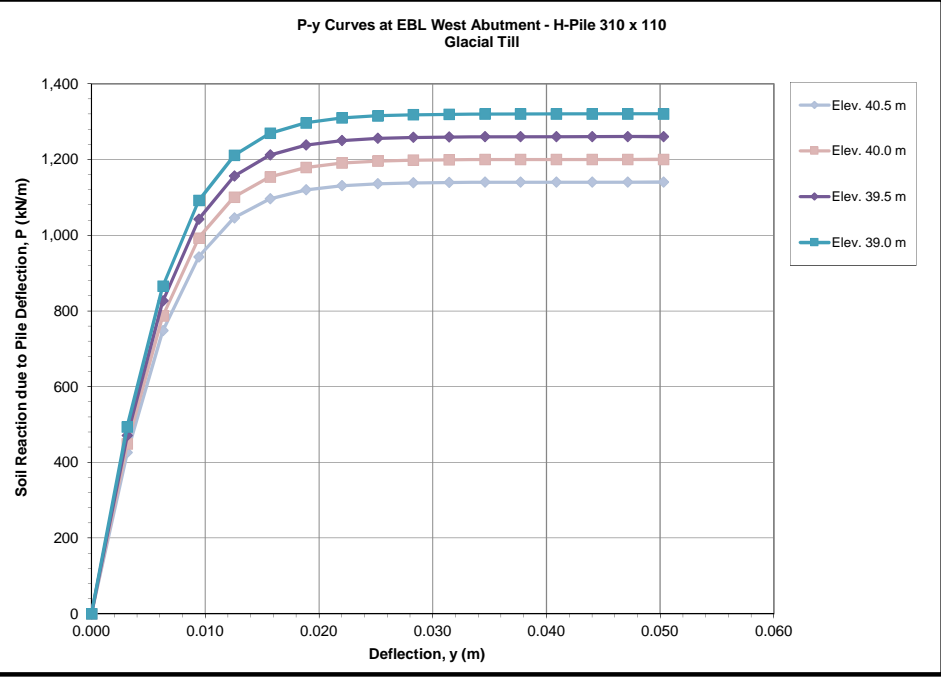
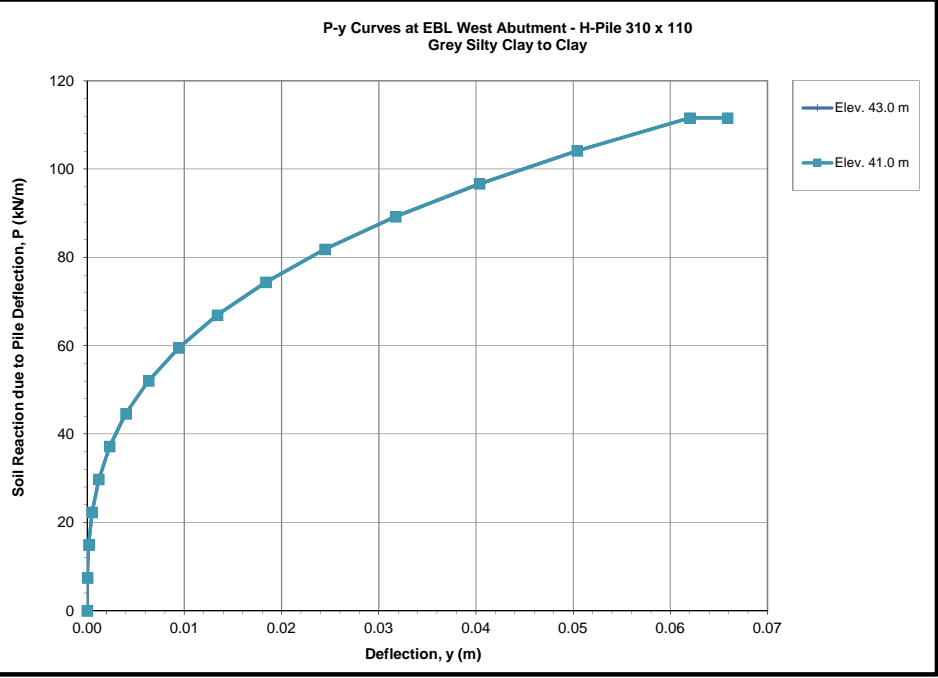
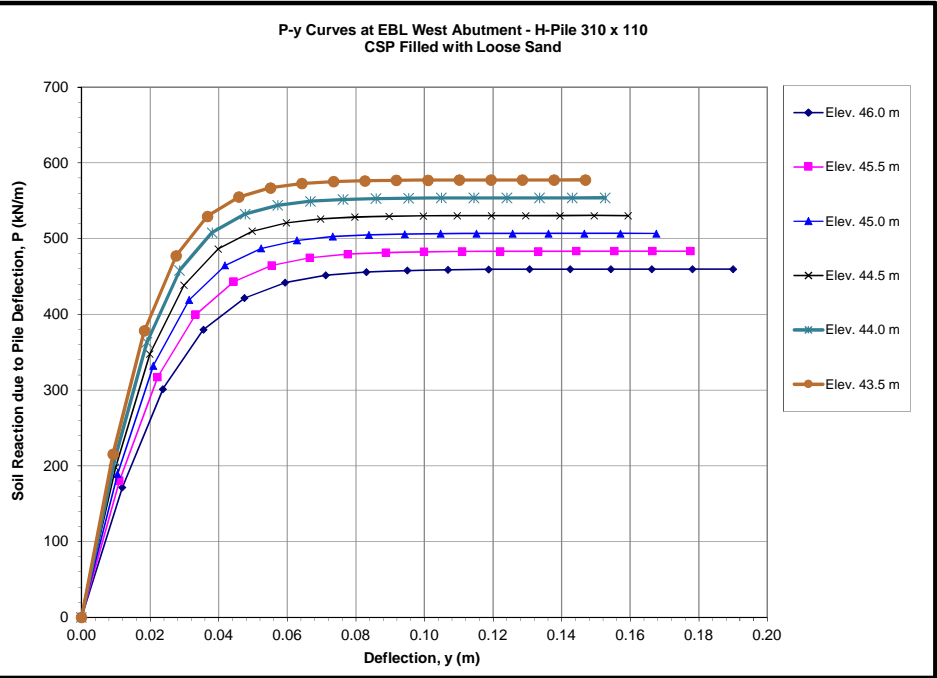
Description Depth (z) * Elevation P-y Curves	Glacial Till							
	z= 9.5 m		z= 10.0 m		z= 10.5 m		z= 11.0 m	
	Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.003	426.227	0.003	448.680	0.003	471.134	0.003	493.587
	0.006	748.003	0.006	787.407	0.006	826.811	0.006	866.215
	0.009	943.111	0.009	992.793	0.009	1042.475	0.009	1092.157
	0.013	1046.110	0.013	1101.218	0.013	1156.326	0.013	1211.434
	0.016	1096.528	0.016	1154.292	0.016	1212.056	0.016	1269.820
	0.019	1120.296	0.019	1179.312	0.019	1238.328	0.019	1297.344
	0.022	1131.301	0.022	1190.897	0.022	1250.492	0.022	1310.088
	0.025	1136.354	0.025	1196.216	0.025	1256.078	0.025	1315.940
	0.028	1138.666	0.028	1198.649	0.028	1258.633	0.028	1318.617
	0.031	1139.721	0.031	1199.760	0.031	1259.800	0.031	1319.839
	0.035	1140.203	0.035	1200.267	0.035	1260.332	0.035	1320.397
	0.038	1140.422	0.038	1200.498	0.038	1260.575	0.038	1320.651
	0.041	1140.522	0.041	1200.604	0.041	1260.685	0.041	1320.767
	0.044	1140.568	0.044	1200.652	0.044	1260.736	0.044	1320.820
	0.047	1140.589	0.047	1200.674	0.047	1260.759	0.047	1320.844
	0.050	1140.598	0.050	1200.684	0.050	1260.769	0.050	1320.855

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Program: Lpile 2016.9.11

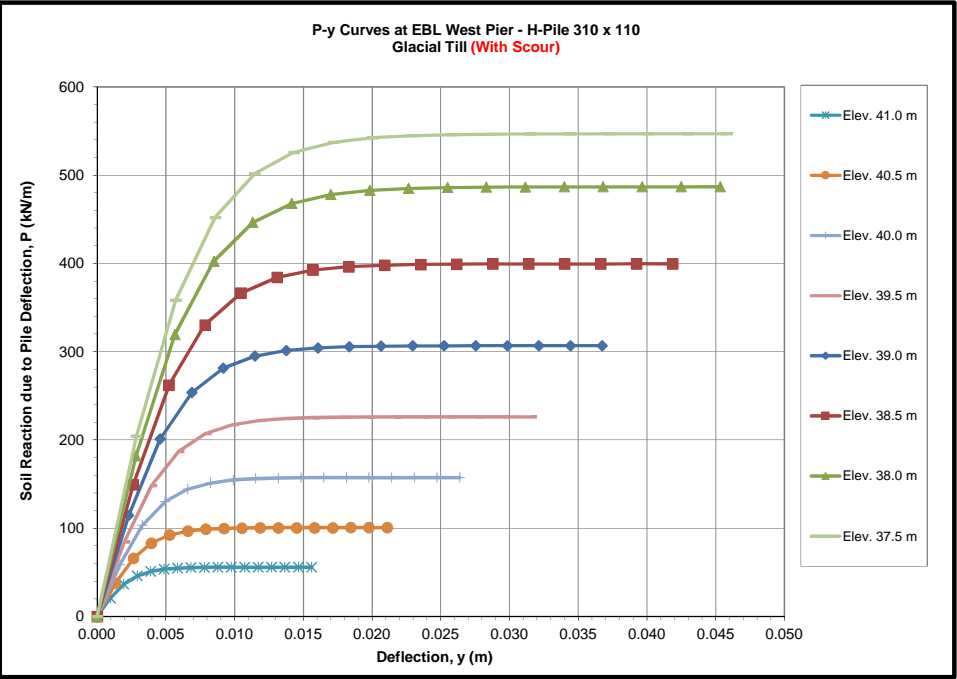
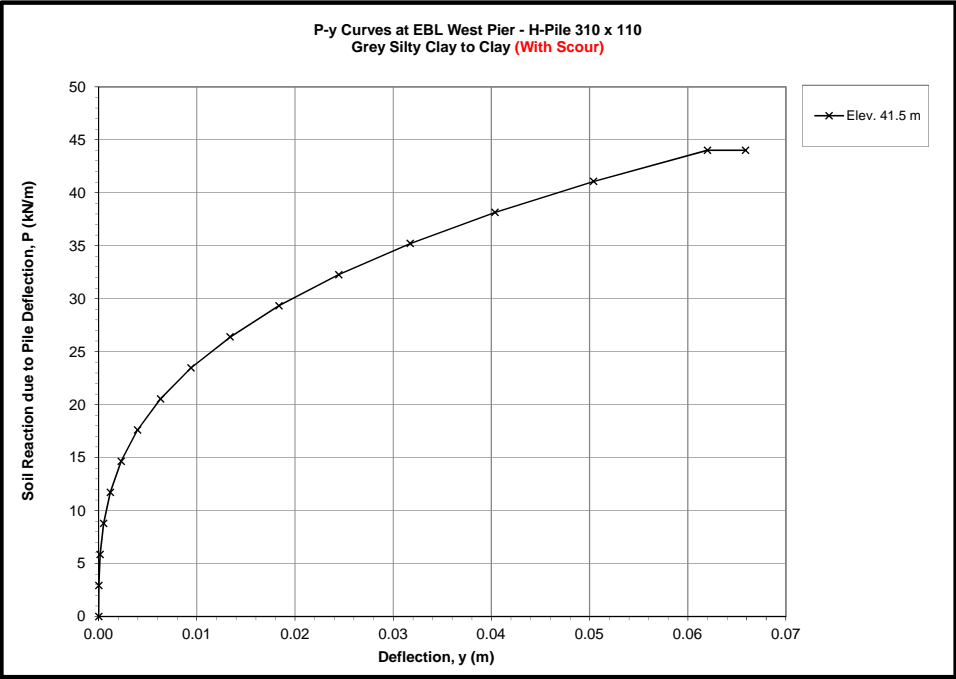


SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - EBL WEST PIER

Description Depth (z) * Elevation P-y Curves	Silty Clay / Clay		Glacial Till													
	z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m	
	Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	2.935	0.001	20.892	0.001	37.627	0.002	58.831	0.002	84.514	0.002	114.680	0.003	149.331	0.003	181.929	0.003
0.000	5.869	0.002	36.665	0.003	66.033	0.003	103.245	0.004	148.317	0.005	201.257	0.005	262.067	0.006	319.274	0.006
0.000	8.804	0.003	46.228	0.004	83.257	0.005	130.175	0.006	187.004	0.007	253.752	0.008	330.424	0.009	402.553	0.009
0.001	11.739	0.004	51.277	0.005	92.350	0.007	144.392	0.008	207.427	0.009	281.465	0.010	366.510	0.011	446.516	0.011
0.002	14.673	0.005	53.748	0.007	96.801	0.008	151.351	0.010	217.424	0.011	295.030	0.013	384.175	0.014	468.036	0.014
0.004	17.608	0.006	54.913	0.008	98.899	0.010	154.632	0.012	222.137	0.014	301.425	0.016	392.502	0.017	478.181	0.017
0.006	20.543	0.007	55.453	0.009	99.871	0.012	156.151	0.014	224.319	0.016	304.386	0.018	396.358	0.020	482.879	0.020
0.009	23.477	0.008	55.701	0.011	100.317	0.013	156.848	0.016	225.321	0.018	305.746	0.021	398.128	0.023	485.035	0.023
0.013	26.412	0.009	55.814	0.012	100.521	0.015	157.167	0.018	225.779	0.021	306.368	0.024	398.938	0.025	486.022	0.026
0.018	29.347	0.010	55.866	0.013	100.614	0.016	157.313	0.020	225.989	0.023	306.652	0.026	399.308	0.028	486.473	0.029
0.024	32.281	0.011	55.889	0.015	100.656	0.018	157.380	0.022	226.084	0.025	306.781	0.029	399.476	0.031	486.678	0.032
0.032	35.216	0.012	55.900	0.016	100.676	0.020	157.410	0.024	226.128	0.028	306.840	0.031	399.553	0.034	486.772	0.034
0.040	38.151	0.013	55.905	0.017	100.685	0.021	157.424	0.026	226.148	0.030	306.867	0.034	399.588	0.037	486.815	0.037
0.050	41.085	0.014	55.907	0.018	100.689	0.023	157.430	0.028	226.157	0.032	306.880	0.037	399.604	0.040	486.834	0.040
0.062	44.020	0.015	55.908	0.020	100.690	0.025	157.433	0.030	226.161	0.034	306.885	0.039	399.612	0.042	486.843	0.043
0.066	44.020	0.016	55.909	0.021	100.691	0.026	157.434	0.032	226.163	0.037	306.888	0.042	399.615	0.045	486.847	0.046

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.  
Please note the following assumptions:  
1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.  
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.  
3. There are no pile group effects (i.e., analysis is based on a single pile).  
4. The effects of construction disturbance are not considered.

5. Pier location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.  
6. Groundwater table assumed above top of pile.  
7. Top of pile assumed at Elevation 41.9 m.  
8. A scour depth of 2.5 m is considered (i.e., scour to Elevation 42.5 m), as per Dillon.  
9. Program: Lpile 2016.9.11

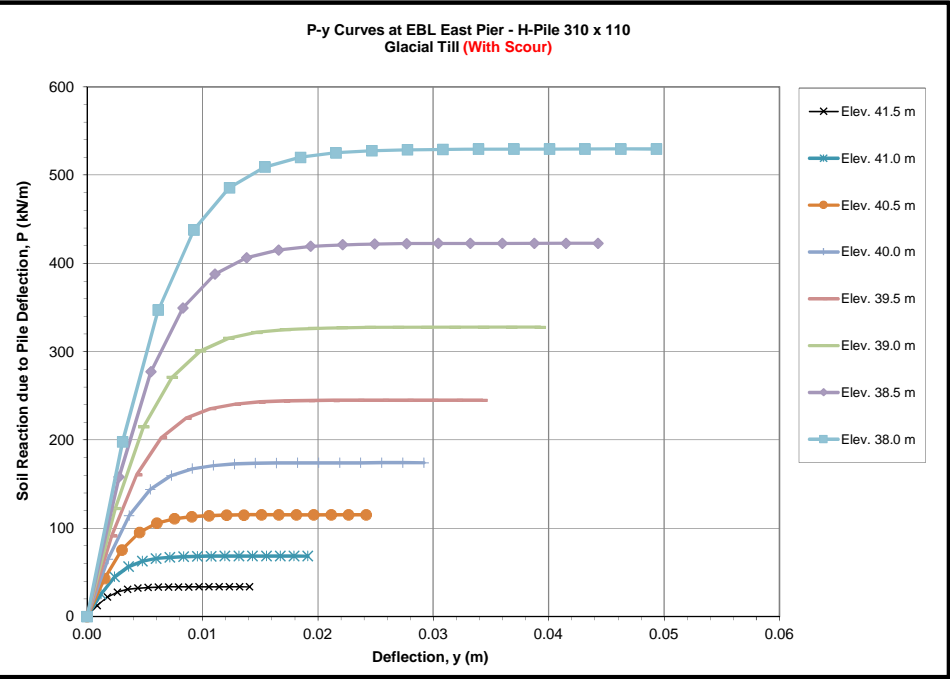


SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - EBL EAST PIER

Description Depth (z) * Elevation P-y Curves	Glacial Till															
	z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m	
	Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.001	12.572	0.001	25.591	0.002	43.098	0.002	65.093	0.002	91.577	0.002	122.550	0.003	158.010	0.003	197.960	
0.002	22.063	0.002	44.910	0.003	75.634	0.004	114.235	0.004	160.713	0.005	215.067	0.006	277.299	0.006	347.407	
0.003	27.818	0.004	56.625	0.005	95.362	0.005	144.032	0.006	202.633	0.007	271.165	0.008	349.629	0.009	438.025	
0.004	30.856	0.005	62.809	0.006	105.777	0.007	159.762	0.009	224.763	0.010	300.780	0.011	387.813	0.012	485.862	
0.004	32.343	0.006	65.836	0.008	110.875	0.009	167.462	0.011	235.595	0.012	315.276	0.014	406.504	0.015	509.279	
0.005	33.044	0.007	67.263	0.009	113.278	0.011	171.091	0.013	240.702	0.015	322.110	0.017	415.315	0.018	520.317	
0.006	33.369	0.008	67.923	0.011	114.391	0.013	172.772	0.015	243.066	0.017	325.274	0.019	419.395	0.022	525.429	
0.007	33.518	0.010	68.227	0.012	114.902	0.015	173.544	0.017	244.152	0.020	326.727	0.022	421.268	0.025	527.776	
0.008	33.586	0.011	68.366	0.014	115.136	0.016	173.897	0.019	244.649	0.022	327.391	0.025	422.125	0.028	528.849	
0.009	33.617	0.012	68.429	0.015	115.243	0.018	174.058	0.021	244.875	0.025	327.695	0.028	422.516	0.031	529.339	
0.010	33.632	0.013	68.458	0.017	115.291	0.020	174.132	0.024	244.979	0.027	327.833	0.030	422.695	0.034	529.563	
0.011	33.638	0.014	68.471	0.018	115.313	0.022	174.165	0.026	245.026	0.029	327.896	0.033	422.776	0.037	529.665	
0.011	33.641	0.016	68.477	0.020	115.324	0.024	174.180	0.028	245.048	0.032	327.925	0.036	422.813	0.040	529.712	
0.012	33.642	0.017	68.480	0.021	115.328	0.026	174.187	0.030	245.057	0.034	327.938	0.039	422.830	0.043	529.733	
0.013	33.643	0.018	68.481	0.023	115.330	0.027	174.191	0.032	245.062	0.037	327.944	0.042	422.838	0.046	529.742	
0.014	33.643	0.019	68.482	0.024	115.331	0.029	174.192	0.034	245.064	0.039	327.947	0.044	422.841	0.049	529.747	

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.  
Please note the following assumptions:  
1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.  
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.  
3. There are no pile group effects (i.e., analysis is based on a single pile).  
4. The effects of construction disturbance are not considered.

5. Pier location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.  
6. Groundwater table assumed above top of pile.  
7. Top of pile assumed at Elevation 41.9 m.  
8. A scour depth of 2.5 m is considered (i.e., scour to Elevation 42.5 m), as per Dillon.  
9. Program: Lpile 2016.9.11



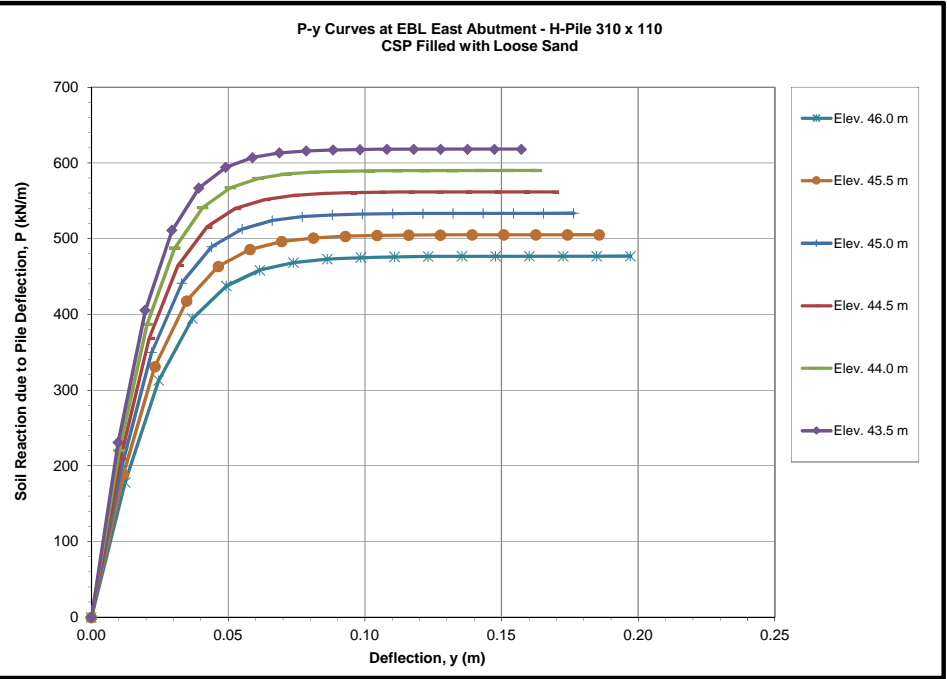
SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - EBL EAST ABUTMENT

Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Glacial Till											
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m		z= 9.5 m	
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.012	178.280	0.012	188.846	0.011	199.412	0.011	209.977	0.010	220.543	0.010	231.109	0.004	396.098	0.004	418.551	0.004	441.004	0.004	463.457	0.004	485.910	0.004	508.364
	0.025	312.871	0.023	331.413	0.022	349.955	0.021	368.498	0.020	387.040	0.020	405.582	0.008	695.127	0.008	734.531	0.008	773.936	0.008	813.340	0.008	852.744	0.008	892.148
	0.037	394.480	0.035	417.858	0.033	441.237	0.032	464.616	0.031	487.995	0.030	511.374	0.012	876.444	0.012	926.126	0.012	975.808	0.011	1025.490	0.011	1075.172	0.011	1124.854
	0.049	437.561	0.046	463.493	0.044	489.426	0.042	515.358	0.041	541.290	0.039	567.222	0.016	972.161	0.016	1027.269	0.015	1082.377	0.015	1137.485	0.015	1192.593	0.015	1247.701
	0.062	458.650	0.058	485.832	0.055	513.014	0.053	540.196	0.051	567.378	0.049	594.560	0.020	1019.016	0.020	1076.780	0.019	1134.544	0.019	1192.308	0.019	1250.072	0.019	1307.836
	0.074	468.592	0.070	496.363	0.066	524.134	0.063	551.905	0.061	579.676	0.059	607.447	0.024	1041.103	0.023	1100.119	0.023	1159.135	0.023	1218.152	0.023	1277.168	0.022	1336.184
	0.086	473.195	0.081	501.239	0.077	529.283	0.074	557.327	0.071	585.370	0.069	613.414	0.028	1051.330	0.027	1110.926	0.027	1170.522	0.027	1230.118	0.026	1289.714	0.026	1349.309
	0.099	475.308	0.093	503.478	0.088	531.647	0.084	559.816	0.081	587.985	0.079	616.154	0.032	1056.027	0.031	1115.888	0.031	1175.750	0.031	1235.612	0.030	1295.474	0.030	1355.336
	0.111	476.275	0.104	504.502	0.099	532.728	0.095	560.955	0.091	589.181	0.088	617.408	0.036	1058.175	0.035	1118.158	0.035	1178.142	0.034	1238.126	0.034	1298.109	0.034	1358.093
	0.123	476.717	0.116	504.969	0.110	533.222	0.106	561.475	0.102	589.727	0.098	617.980	0.040	1059.155	0.039	1119.195	0.039	1179.234	0.038	1239.273	0.038	1299.313	0.037	1359.352
	0.136	476.918	0.128	505.183	0.121	533.447	0.116	561.712	0.112	589.976	0.108	618.241	0.044	1059.603	0.043	1119.668	0.042	1179.732	0.042	1239.797	0.042	1299.862	0.041	1359.926
	0.148	477.010	0.139	505.280	0.132	533.550	0.127	561.820	0.122	590.090	0.118	618.360	0.048	1059.807	0.047	1119.883	0.046	1179.960	0.046	1240.036	0.045	1300.112	0.045	1360.188
	0.160	477.052	0.151	505.324	0.143	533.597	0.137	561.869	0.132	590.142	0.128	618.414	0.052	1059.900	0.051	1119.982	0.050	1180.063	0.050	1240.145	0.049	1300.226	0.049	1360.308
	0.173	477.071	0.162	505.345	0.154	533.618	0.148	561.892	0.142	590.166	0.138	618.439	0.056	1059.942	0.055	1120.026	0.054	1180.110	0.053	1240.194	0.053	1300.278	0.052	1360.362
	0.185	477.080	0.174	505.354	0.165	533.628	0.158	561.902	0.152	590.176	0.147	618.450	0.059	1059.962	0.059	1120.047	0.058	1180.132	0.057	1240.217	0.057	1300.302	0.056	1360.387
	0.197	477.084	0.186	505.358	0.176	533.632	0.169	561.907	0.163	590.181	0.157	618.456	0.063	1059.971	0.063	1120.056	0.062	1180.142	0.061	1240.227	0.061	1300.313	0.060	1360.398
Description Depth (z) * Elevation P-y Curves	Glacial Till (continued)																							
	z= 10.0 m		z= 10.5 m		z= 11.0 m		z= 11.5 m		z= 12.0 m		z= 12.5 m		z= 13.0 m		z= 13.5 m		z= 14.0 m		z= 14.5 m		z= 15.0 m			
	Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m		Elev. 36.5 m		Elev. 36.0 m		Elev. 35.5 m		Elev. 35.0 m			
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)		
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	0.004	530.817	0.004	553.270	0.004	575.723	0.004	598.177	0.004	620.630	0.004	643.083	0.004	665.536	0.004	687.989	0.004	710.443	0.004	732.896	0.004	755.349		
	0.007	931.552	0.007	970.956	0.007	1010.360	0.007	1049.764	0.007	1089.168	0.007	1128.572	0.007	1167.976	0.007	1207.380	0.007	1246.784	0.007	1286.188	0.007	1325.592		
	0.011	1174.536	0.011	1224.218	0.011	1273.901	0.011	1323.583	0.011	1373.265	0.011	1422.947	0.011	1472.629	0.011	1522.311	0.011	1571.993	0.011	1621.675	0.011	1671.357		
	0.015	1302.809	0.015	1357.917	0.015	1413.025	0.015	1468.133	0.014	1523.241	0.014	1578.349	0.014	1633.457	0.014	1688.565	0.014	1743.673	0.014	1798.781	0.014	1853.889		
	0.019	1365.600	0.018	1423.364	0.018	1481.128	0.018	1538.892	0.018	1596.656	0.018	1654.420	0.018	1712.184	0.018	1769.948	0.018	1827.712	0.018	1885.476	0.018	1943.240		
	0.022	1395.200	0.022	1454.216	0.022	1513.232	0.022	1572.248	0.022	1631.264	0.022	1690.280	0.022	1749.296	0.021	1808.312	0.021	1867.328	0.021	1926.344	0.021	1985.360		
	0.026	1408.905	0.026	1468.501	0.026	1528.097	0.026	1587.692	0.025	1647.288	0.025	1706.884	0.025	1766.480	0.025	1826.075	0.025	1885.671	0.025	1945.267	0.025	2004.863		
	0.030	1415.198	0.030	1475.060	0.029	1534.922	0.029	1594.784	0.029	1654.646	0.029	1714.508	0.029	1774.370	0.029	1834.232	0.028	1894.094	0.028	1953.956	0.028	2013.818		
	0.033	1418.077	0.033	1478.061	0.033	1538.044	0.033	1598.028	0.033	1658.012	0.032	1717.996	0.032	1777.979	0.032	1837.963	0.032	1897.947	0.032	1957.931	0.032	2017.914		
	0.037	1419.391	0.037	1479.431	0.037	1539.470	0.036	1599.509	0.036	1659.549	0.036	1719.588	0.036	1779.627	0.036	1839.667	0.036	1899.706	0.035	1959.745	0.035	2019.785		
	0.041	1419.991	0.041	1480.056	0.040	1540.120	0.040	1600.185	0.040	1660.250	0.040	1720.315	0.039	1780.379	0.039	1840.444	0.039	1900.509	0.039	1960.573	0.039	2020.638		
	0.045	1420.265	0.044	1480.341	0.044	1540.417	0.044	1600.493	0.043	1660.570	0.043	1720.646	0.043	1780.722	0.043	1840.798	0.043	1900.875	0.042	1960.951	0.042	2021.027		
	0.048	1420.389	0.048	1480.471	0.048	1540.552	0.047	1600.634	0.047	1660.715	0.047	1720.797	0.047	1780.879	0.046	1840.960	0.046	1901.042	0.046	1961.123	0.046	2021.205		
	0.052	1420.446	0.052	1480.530	0.051	1540.614	0.051	1600.698	0.051	1660.782	0.050	1720.866	0.050	1780.950	0.050	1841.034	0.050	1901.118	0.050	1961.202	0.049	2021.286		
	0.056	1420.472	0.055	1480.557	0.055	1540.642	0.055	1600.727	0.054	1660.812	0.054	1720.897	0.054	1780.982	0.054	1841.067	0.053	1901.152	0.053	1961.238	0.053	2021.323		
	0.060	1420.484	0.059	1480.569	0.059	1540.655	0.058	1600.741	0.058	1660.826	0.058	1720.912	0.057	1780.997	0.057	1841.083	0.057	1901.168	0.057	1961.254	0.056	2021.339		

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.  
Please note the following assumptions:

1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Program: Lpile 2016.9.11



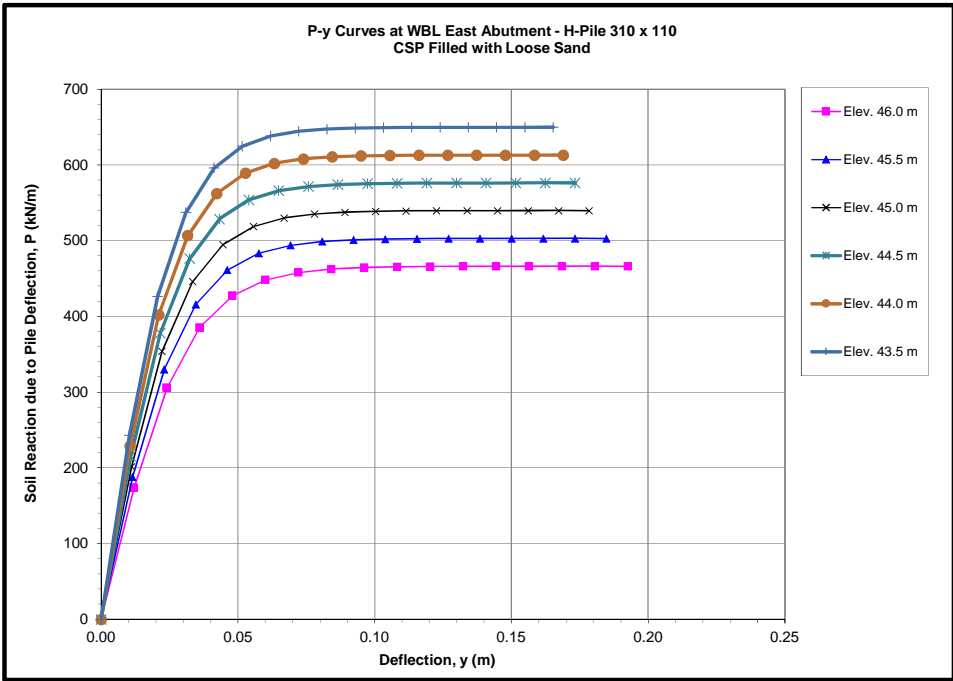
SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - WBL EAST ABUTMENT

Description		CSP Filled with Loose Sand												Glacial Till											
Depth (z) * Elevation P-y Curves	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m		z= 9.5 m		
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	0.012	174.218	0.012	187.954	0.011	201.689	0.011	215.425	0.011	229.160	0.010	242.896	0.004	419.510	0.004	441.964	0.004	464.417	0.004	486.870	0.004	509.323	0.004	531.776	
	0.024	305.742	0.023	329.847	0.022	353.952	0.022	378.057	0.022	402.162	0.021	426.267	0.008	736.215	0.008	775.619	0.008	815.023	0.008	854.427	0.008	893.832	0.008	933.276	
	0.036	385.492	0.035	415.884	0.033	446.277	0.033	476.669	0.032	507.062	0.031	537.454	0.013	928.249	0.012	977.931	0.012	1027.613	0.012	1077.295	0.012	1126.977	0.012	1176.659	
	0.048	427.592	0.046	461.304	0.045	495.015	0.043	528.727	0.042	562.439	0.041	596.151	0.017	1029.624	0.017	1084.732	0.016	1139.840	0.016	1194.948	0.016	1250.056	0.016	1305.164	
	0.060	448.200	0.058	483.537	0.056	518.873	0.054	554.210	0.053	589.546	0.052	624.883	0.021	1079.248	0.021	1137.012	0.020	1194.776	0.020	1252.540	0.020	1310.304	0.020	1368.068	
	0.072	457.915	0.069	494.018	0.067	530.120	0.065	566.223	0.063	602.325	0.062	638.427	0.025	1102.642	0.025	1161.658	0.024	1220.674	0.024	1279.690	0.024	1338.706	0.024	1397.722	
	0.084	462.413	0.081	498.870	0.078	535.328	0.076	571.785	0.074	608.242	0.072	644.699	0.029	1113.473	0.029	1173.069	0.028	1232.665	0.028	1292.260	0.028	1351.856	0.027	1411.452	
	0.096	464.479	0.092	501.099	0.089	537.719	0.087	574.339	0.085	610.959	0.083	647.579	0.034	1118.447	0.033	1178.309	0.033	1238.171	0.032	1298.033	0.032	1357.895	0.031	1417.757	
	0.108	465.424	0.104	502.118	0.100	538.813	0.097	575.507	0.095	612.201	0.093	648.896	0.038	1120.722	0.037	1180.705	0.037	1240.689	0.036	1300.673	0.036	1360.657	0.035	1420.640	
	0.120	465.855	0.116	502.583	0.112	539.312	0.108	576.040	0.106	612.769	0.103	649.497	0.042	1121.761	0.041	1181.800	0.041	1241.839	0.040	1301.878	0.040	1361.918	0.039	1421.957	
	0.132	466.052	0.127	502.796	0.123	539.540	0.119	576.284	0.116	613.028	0.114	649.772	0.046	1122.234	0.045	1182.299	0.045	1242.364	0.044	1302.429	0.044	1362.493	0.043	1422.558	
	0.145	466.142	0.139	502.893	0.134	539.644	0.130	576.395	0.127	613.146	0.124	649.897	0.050	1122.451	0.050	1182.527	0.049	1242.603	0.048	1302.679	0.048	1362.756	0.047	1422.832	
	0.157	466.183	0.150	502.937	0.145	539.691	0.141	576.445	0.137	613.200	0.134	649.954	0.055	1122.549	0.054	1182.631	0.053	1242.712	0.052	1302.794	0.052	1362.875	0.051	1422.957	
	0.169	466.201	0.162	502.957	0.156	539.713	0.152	576.468	0.148	613.224	0.145	649.980	0.059	1122.594	0.058	1182.678	0.057	1242.762	0.056	1302.846	0.056	1362.930	0.055	1423.014	
	0.181	466.210	0.173	502.966	0.167	539.723	0.162	576.479	0.158	613.235	0.155	649.992	0.063	1122.615	0.062	1182.700	0.061	1242.785	0.060	1302.870	0.059	1362.955	0.059	1423.040	
	0.193	466.214	0.185	502.970	0.178	539.727	0.173	576.484	0.169	613.241	0.165	649.997	0.067	1122.624	0.066	1182.709	0.065	1242.795	0.064	1302.881	0.063	1362.966	0.063	1423.052	
Description		Glacial Till (continued)																							
Depth (z) * Elevation P-y Curves	z= 10.0 m		z= 10.5 m		z= 11.0 m		z= 11.5 m		z= 12.0 m		z= 12.5 m		z= 13.0 m		z= 13.5 m		z= 14.0 m		z= 14.5 m		z= 15.0 m		z= 15.5 m		
	Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m		Elev. 36.5 m		Elev. 36.0 m		Elev. 35.5 m		Elev. 35.0 m		Elev. 34.5 m		
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	0.004	554.230	0.004	576.683	0.004	599.136	0.004	621.589	0.004	644.042	0.004	666.496	0.004	688.949	0.004	711.402	0.004	733.855	0.004	756.309	0.004	778.762	0.004	801.215	
	0.008	972.640	0.008	1012.044	0.008	1051.448	0.008	1090.852	0.008	1130.256	0.007	1169.660	0.007	1209.064	0.007	1248.468	0.007	1287.872	0.007	1327.276	0.007	1366.680	0.007	1406.084	
	0.012	1226.342	0.012	1276.024	0.011	1325.706	0.011	1375.388	0.011	1425.070	0.011	1474.752	0.011	1524.434	0.011	1574.116	0.011	1623.799	0.011	1673.481	0.011	1723.163	0.011	1772.845	
	0.016	1360.272	0.015	1415.380	0.015	1470.488	0.015	1525.596	0.015	1580.704	0.015	1635.812	0.015	1690.920	0.015	1746.028	0.015	1801.136	0.015	1856.244	0.015	1911.352	0.015	1966.460	
	0.019	1425.832	0.019	1483.596	0.019	1541.360	0.019	1599.124	0.019	1656.888	0.019	1714.652	0.019	1772.416	0.018	1830.180	0.018	1887.944	0.018	1945.708	0.018	2003.472	0.018	2061.236	
	0.023	1456.738	0.023	1515.754	0.023	1574.770	0.023	1633.786	0.023	1692.802	0.022	1751.818	0.022	1810.834	0.022	1869.850	0.022	1928.866	0.022	1987.882	0.022	2046.898	0.022	2105.914	
	0.027	1471.048	0.027	1530.643	0.027	1590.239	0.027	1649.835	0.026	1709.431	0.026	1769.027	0.026	1828.622	0.026	1888.218	0.026	1947.814	0.026	2007.410	0.025	2067.005	0.025	2126.601	
	0.031	1477.619	0.031	1537.480	0.031	1597.342	0.030	1657.204	0.030	1717.066	0.030	1776.928	0.030	1836.790	0.030	1896.652	0.029	1956.514	0.029	2016.376	0.029	2076.238	0.029	2136.100	
	0.035	1480.624	0.035	1540.608	0.034	1600.592	0.034	1660.575	0.034	1720.559	0.034	1780.543	0.033	1840.526	0.033	1900.510	0.033	1960.494	0.033	2020.478	0.033	2080.461	0.033	2140.445	
	0.039	1481.996	0.038	1542.036	0.038	1602.075	0.038	1662.114	0.038	1722.154	0.037	1782.193	0.037	1842.232	0.037	1902.272	0.037	1962.311	0.037	2022.350	0.036	2082.390	0.036	2142.429	
	0.043	1482.623	0.042	1542.687	0.042	1602.752	0.042	1662.817	0.041	1722.881	0.041	1782.946	0.041	1843.011	0.041	1903.076	0.040	1963.140	0.040	2023.205	0.040	2083.270	0.040	2143.334	
	0.047	1482.908	0.046	1542.984	0.046	1603.061	0.045	1663.137	0.045	1723.213	0.045	1783.290	0.045	1843.366	0.044	1903.442	0.044	1963.518	0.044	2023.595	0.044	2083.671	0.043	2143.747	
	0.050	1483.038	0.050	1543.120	0.050	1603.202	0.049	1663.283	0.049	1723.365	0.049	1783.446	0.048	1843.528	0.048	1903.609	0.048	1963.691	0.048	2023.772	0.047	2083.854	0.047	2143.935	
	0.054	1483.098	0.054	1543.182	0.053	1603.266	0.053	1663.350	0.053	1723.434	0.052	1783.518	0.052	1843.601	0.052	1903.685	0.051	1963.769	0.051	2023.853	0.051	2083.937	0.051	2144.021	
	0.058	1483.125	0.058	1543.210	0.057	1603.295	0.057	1663.380	0.056	1723.465	0.056	1783.550	0.056	1843.635	0.055	1903.720	0.055	1963.805	0.055	2023.890	0.055	2083.975	0.054	2144.060	
	0.062	1483.137	0.062	1543.223	0.061	1603.308	0.061	1663.394	0.060	1723.479	0.060	1783.565	0.059	1843.650	0.059	1903.736	0.059	1963.822	0.058	2023.907	0.058	2083.993	0.058	2144.078	

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.  
Please note the following assumptions:

1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Program: Lpile 2016.9.11





SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - WBL EAST PIER

Description Depth (z) * Elevation P-y Curves	Glacial Till															
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m	
	Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.001	25.591	0.002	43.098	0.002	65.093	0.002	91.577	0.002	122.550	0.003	158.010	0.003	197.960	0.003	224.532	0.003
0.002	44.910	0.003	75.634	0.004	114.235	0.004	160.713	0.005	215.067	0.006	277.299	0.006	347.407	0.006	394.040	0.006
0.004	56.625	0.005	95.362	0.005	144.032	0.006	202.633	0.007	271.165	0.008	349.629	0.009	438.025	0.009	496.821	0.009
0.005	62.809	0.006	105.777	0.007	159.762	0.009	224.763	0.010	300.780	0.011	387.813	0.012	485.862	0.013	551.080	0.013
0.006	65.836	0.008	110.875	0.009	167.462	0.011	235.595	0.012	315.276	0.014	406.504	0.015	509.279	0.016	577.640	0.016
0.007	67.263	0.009	113.278	0.011	171.091	0.013	240.702	0.015	322.110	0.017	415.315	0.018	520.317	0.019	590.160	0.019
0.008	67.923	0.011	114.391	0.013	172.772	0.015	243.066	0.017	325.274	0.019	419.395	0.022	525.429	0.022	595.958	0.022
0.010	68.227	0.012	114.902	0.015	173.544	0.017	244.152	0.020	326.727	0.022	421.268	0.025	527.776	0.025	598.620	0.025
0.011	68.366	0.014	115.136	0.016	173.897	0.019	244.649	0.022	327.391	0.025	422.125	0.028	528.849	0.028	599.837	0.028
0.012	68.429	0.015	115.243	0.018	174.058	0.021	244.875	0.025	327.695	0.028	422.516	0.031	529.339	0.031	600.393	0.031
0.013	68.458	0.017	115.291	0.020	174.132	0.024	244.979	0.027	327.833	0.030	422.695	0.034	529.563	0.035	600.647	0.035
0.014	68.471	0.018	115.313	0.022	174.165	0.026	245.026	0.029	327.896	0.033	422.776	0.037	529.665	0.038	600.763	0.038
0.016	68.477	0.020	115.324	0.024	174.180	0.028	245.048	0.032	327.925	0.036	422.813	0.040	529.712	0.041	600.815	0.041
0.017	68.480	0.021	115.328	0.026	174.187	0.030	245.057	0.034	327.938	0.039	422.830	0.043	529.733	0.044	600.839	0.044
0.018	68.481	0.023	115.330	0.027	174.191	0.032	245.062	0.037	327.944	0.042	422.838	0.046	529.742	0.047	600.850	0.047
0.019	68.482	0.024	115.331	0.029	174.192	0.034	245.064	0.039	327.947	0.044	422.841	0.049	529.747	0.050	600.855	0.050

Description Depth (z) * Elevation P-y Curves	Glacial Till (continued)									
	z= 8.0 m		z= 8.5 m		z= 9.0 m		z= 9.5 m		z= 10.0 m	
	Elev. 37.5 m		Elev. 37.0 m		Elev. 36.5 m		Elev. 36.0 m		Elev. 35.5 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.003	246.985	0.003	269.439	0.003	291.892	0.003	314.345	0.003	336.798	0.003
0.006	433.444	0.006	472.848	0.006	512.252	0.006	551.656	0.006	591.060	0.006
0.009	546.503	0.009	596.185	0.009	645.868	0.009	695.550	0.009	745.232	0.009
0.013	606.188	0.013	661.296	0.013	716.404	0.013	771.512	0.013	826.620	0.013
0.016	635.404	0.016	693.168	0.016	750.932	0.016	808.696	0.016	866.460	0.016
0.019	649.176	0.019	708.192	0.019	767.208	0.019	826.225	0.019	885.241	0.019
0.022	655.553	0.022	715.149	0.022	774.745	0.022	834.341	0.022	893.937	0.022
0.025	658.482	0.025	718.344	0.025	778.206	0.025	838.068	0.025	897.930	0.025
0.028	659.821	0.028	719.805	0.028	779.789	0.028	839.772	0.028	899.756	0.028
0.031	660.433	0.031	720.472	0.031	780.511	0.031	840.551	0.031	900.590	0.031
0.035	660.712	0.035	720.776	0.035	780.841	0.035	840.906	0.035	900.970	0.035
0.038	660.839	0.038	720.915	0.038	780.991	0.038	841.068	0.038	901.144	0.038
0.041	660.897	0.041	720.979	0.041	781.060	0.041	841.142	0.041	901.223	0.041
0.044	660.923	0.044	721.007	0.044	781.091	0.044	841.175	0.044	901.259	0.044
0.047	660.936	0.047	721.021	0.047	781.106	0.047	841.191	0.047	901.276	0.047
0.050	660.941	0.050	721.027	0.050	781.112	0.050	841.198	0.050	901.283	0.050

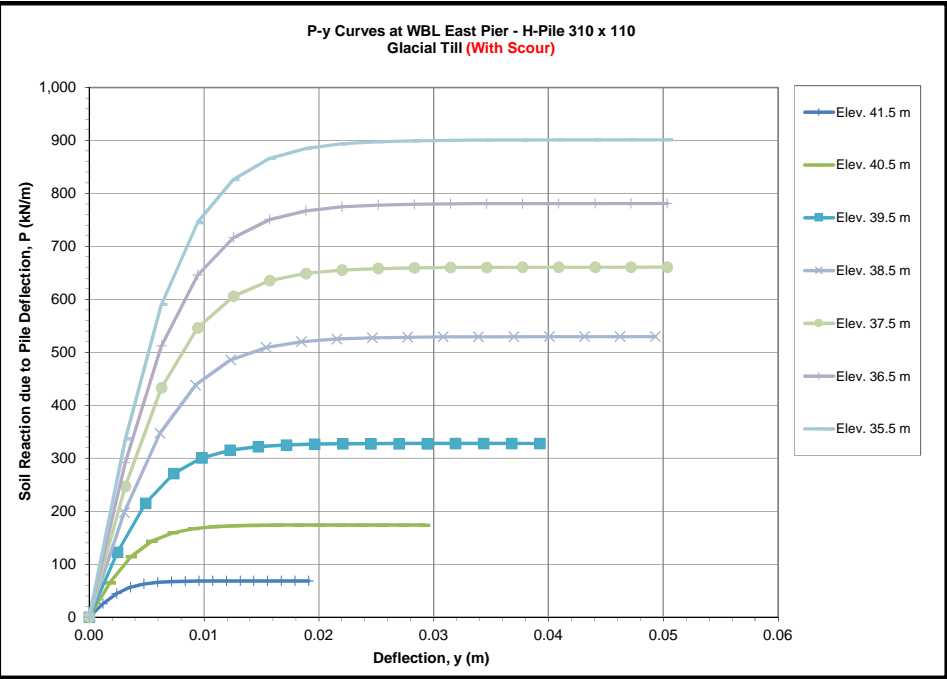
NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Pier location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed above top of pile.
7. Top of pile assumed at Elevation 41.9 m.
8. A scour depth of 2.5 m is considered (i.e., scour to Elevation 43.0 m), as per Dillon.

9. Program: Lpile 2016.9.11



SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - WBL WEST PIER

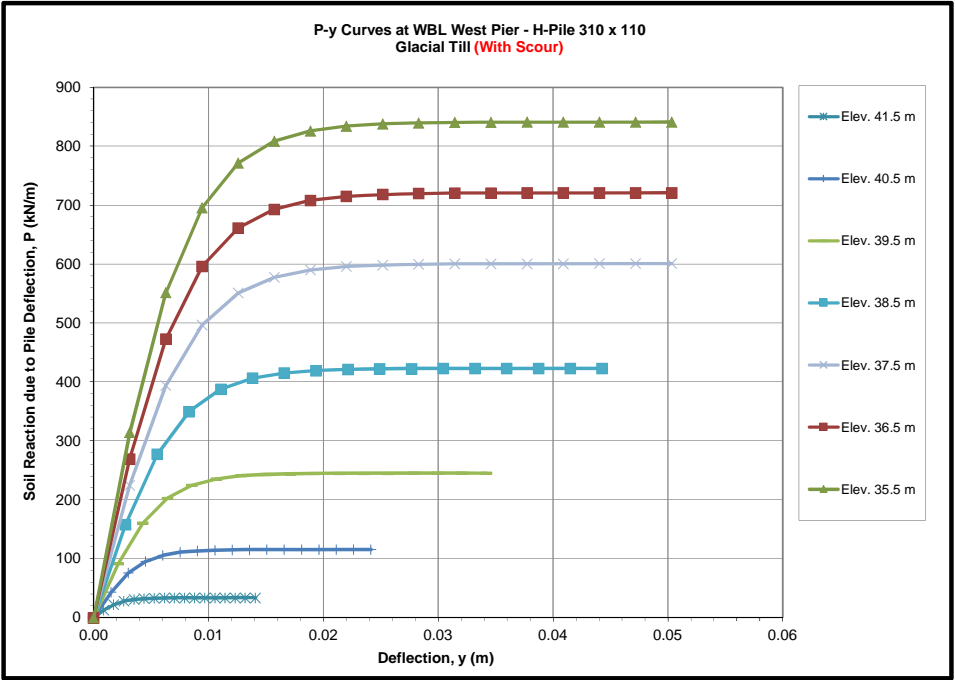
Description Depth (z) * Elevation P-y Curves	Glacial Till															
	z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m	
	Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.001	12.572	0.001	25.591	0.002	43.098	0.002	65.093	0.002	91.577	0.002	122.550	0.003	158.010	0.003	197.960	0.003
0.002	22.063	0.002	44.910	0.003	75.634	0.004	114.235	0.004	160.713	0.005	215.067	0.006	277.299	0.006	347.407	0.006
0.003	27.818	0.004	56.625	0.005	95.362	0.005	144.032	0.006	202.633	0.007	271.165	0.008	349.629	0.009	438.025	0.009
0.004	30.856	0.005	62.809	0.006	105.777	0.007	159.762	0.009	224.763	0.010	300.780	0.011	387.813	0.012	485.862	0.013
0.004	32.343	0.006	65.836	0.008	110.875	0.009	167.462	0.011	235.595	0.012	315.276	0.014	406.504	0.015	509.279	0.016
0.005	33.044	0.007	67.263	0.009	113.278	0.011	171.091	0.013	240.702	0.015	322.110	0.017	415.315	0.018	520.317	0.019
0.006	33.369	0.008	67.923	0.011	114.391	0.013	172.772	0.015	243.066	0.017	325.274	0.019	419.395	0.022	525.429	0.022
0.007	33.518	0.010	68.227	0.012	114.902	0.015	173.544	0.017	244.152	0.020	326.727	0.022	421.268	0.025	527.776	0.025
0.008	33.586	0.011	68.366	0.014	115.136	0.016	173.897	0.019	244.649	0.022	327.391	0.025	422.125	0.028	528.849	0.028
0.009	33.617	0.012	68.429	0.015	115.243	0.018	174.058	0.021	244.875	0.025	327.695	0.028	422.516	0.031	529.339	0.031
0.010	33.632	0.013	68.458	0.017	115.291	0.020	174.132	0.024	244.979	0.027	327.833	0.030	422.695	0.034	529.563	0.035
0.011	33.638	0.014	68.471	0.018	115.313	0.022	174.165	0.026	245.026	0.029	327.896	0.033	422.776	0.037	529.665	0.038
0.011	33.641	0.016	68.477	0.020	115.324	0.024	174.180	0.028	245.048	0.032	327.925	0.036	422.813	0.040	529.712	0.041
0.012	33.642	0.017	68.480	0.021	115.328	0.026	174.187	0.030	245.057	0.034	327.938	0.039	422.830	0.043	529.733	0.044
0.013	33.643	0.018	68.481	0.023	115.330	0.027	174.191	0.032	245.062	0.037	327.944	0.042	422.838	0.046	529.742	0.047
0.014	33.643	0.019	68.482	0.024	115.331	0.029	174.192	0.034	245.064	0.039	327.947	0.044	422.841	0.049	529.747	0.050

Description Depth (z) * Elevation P-y Curves	Glacial Till (continued)					
	z= 8.5 m		z= 9.0 m		z= 9.5 m	
	Elev. 36.5 m		Elev. 36.0 m		Elev. 35.5 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.003	269.439	0.003	291.892	0.003	314.345	0.003
0.006	472.848	0.006	512.252	0.006	551.656	0.006
0.009	596.185	0.009	645.868	0.009	695.550	0.009
0.013	661.296	0.013	716.404	0.013	771.512	0.013
0.016	693.168	0.016	750.932	0.016	808.696	0.016
0.019	708.192	0.019	767.208	0.019	826.225	0.019
0.022	715.149	0.022	774.745	0.022	834.341	0.022
0.025	718.344	0.025	778.206	0.025	838.068	0.025
0.028	719.805	0.028	779.789	0.028	839.772	0.028
0.031	720.472	0.031	780.511	0.031	840.551	0.031
0.035	720.776	0.035	780.841	0.035	840.906	0.035
0.038	720.915	0.038	780.991	0.038	841.068	0.038
0.041	720.979	0.041	781.060	0.041	841.142	0.041
0.044	721.007	0.044	781.091	0.044	841.175	0.044
0.047	721.021	0.047	781.106	0.047	841.191	0.047
0.050	721.027	0.050	781.112	0.050	841.198	0.050

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.  
Please note the following assumptions:  
1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.  
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.  
3. There are no pile group effects (i.e., analysis is based on a single pile).  
4. The effects of construction disturbance are not considered.

5. Pier location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.  
6. Groundwater table assumed above top of pile.  
7. Top of pile assumed at Elevation 41.9 m.  
8. A scour depth of 2.5 m is considered (i.e., scour to Elevation 42.5 m), as per Dillon.

9. Program: Lpile 2016.9.11



SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - WBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Grey Silty Clay to Clay											
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m			
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m			
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)		
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	0.012	171.307	0.011	177.529	0.010	183.751	0.010	189.973	0.009	196.195	0.009	202.417	0.000	7.440	0.000	7.440	0.000	7.440	0.000	7.440	0.000	7.440		
	0.024	300.633	0.022	311.552	0.020	322.472	0.019	333.391	0.018	344.310	0.017	355.230	0.000	14.880	0.000	14.880	0.000	14.880	0.000	14.880	0.000	14.880		
	0.036	379.050	0.033	392.817	0.030	406.585	0.029	420.352	0.027	434.120	0.026	447.887	0.000	22.320	0.000	22.320	0.000	22.320	0.000	22.320	0.000	22.320		
	0.047	420.446	0.044	435.717	0.041	450.988	0.038	466.260	0.036	481.531	0.034	496.802	0.001	29.760	0.001	29.760	0.001	29.760	0.001	29.760	0.001	29.760		
	0.059	440.710	0.055	456.717	0.051	472.724	0.048	488.732	0.045	504.739	0.043	520.746	0.002	37.200	0.002	37.200	0.002	37.200	0.002	37.200	0.002	37.200		
	0.071	450.263	0.065	466.617	0.061	482.971	0.057	499.325	0.054	515.679	0.052	532.033	0.004	44.640	0.004	44.640	0.004	44.640	0.004	44.640	0.004	44.640		
	0.083	454.686	0.076	471.200	0.071	487.715	0.067	504.230	0.063	520.745	0.060	537.260	0.006	52.080	0.006	52.080	0.006	52.080	0.006	52.080	0.006	52.080		
	0.095	456.717	0.087	473.305	0.081	489.894	0.076	506.482	0.072	523.071	0.069	539.659	0.009	59.520	0.009	59.520	0.009	59.520	0.009	59.520	0.009	59.520		
	0.107	457.646	0.098	474.268	0.091	490.890	0.086	507.512	0.081	524.135	0.078	540.757	0.013	66.960	0.013	66.960	0.013	66.960	0.013	66.960	0.013	66.960		
	0.118	458.070	0.109	474.708	0.102	491.345	0.096	507.983	0.090	524.621	0.086	541.258	0.018	74.400	0.018	74.400	0.018	74.400	0.018	74.400	0.018	74.400		
	0.130	458.263	0.120	474.908	0.112	491.553	0.105	508.198	0.099	524.842	0.095	541.487	0.024	81.840	0.024	81.840	0.024	81.840	0.024	81.840	0.024	81.840		
	0.142	458.352	0.131	475.000	0.122	491.647	0.115	508.295	0.109	524.943	0.103	541.591	0.032	89.280	0.032	89.280	0.032	89.280	0.032	89.280	0.032	89.280		
	0.154	458.392	0.142	475.041	0.132	491.691	0.124	508.340	0.118	524.989	0.112	541.639	0.040	96.720	0.040	96.720	0.040	96.720	0.040	96.720	0.040	96.720		
	0.166	458.410	0.153	475.060	0.142	491.710	0.134	508.360	0.127	525.010	0.121	541.660	0.050	104.160	0.050	104.160	0.050	104.160	0.050	104.160	0.050	104.160		
	0.178	458.419	0.164	475.069	0.152	491.719	0.143	508.370	0.136	525.020	0.129	541.670	0.062	111.600	0.062	111.600	0.062	111.600	0.062	111.600	0.062	111.600		
	0.190	458.422	0.175	475.073	0.163	491.723	0.153	508.374	0.145	525.024	0.138	541.675	0.066	111.600	0.066	111.600	0.066	111.600	0.066	111.600	0.066	111.600		
Description Depth (z) * Elevation P-y Curves	Glacial Till																							
	z= 9.5 m		z= 10.0 m		z= 10.5 m		z= 11.0 m		z= 11.5 m		z= 12.0 m		z= 12.5 m		z= 13.0 m									
P-y Curves	Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m									
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)								
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000								
	0.003	400.895	0.003	423.349	0.003	445.802	0.003	468.255	0.003	490.708	0.003	513.161	0.003	535.615	0.003	558.068								
	0.006	703.547	0.006	742.951	0.006	782.355	0.006	821.759	0.006	861.163	0.006	900.567	0.006	939.971	0.006	979.375								
	0.009	887.059	0.009	936.742	0.009	986.424	0.009	1036.106	0.009	1085.788	0.009	1135.470	0.009	1185.152	0.009	1234.834								
	0.012	983.937	0.012	1039.045	0.012	1094.153	0.012	1149.260	0.012	1204.368	0.012	1259.476	0.012	1314.584	0.012	1369.692								
	0.015	1031.359	0.015	1089.123	0.015	1146.887	0.015	1204.651	0.015	1262.415	0.015	1320.179	0.015	1377.943	0.015	1435.706								
	0.018	1053.714	0.018	1112.730	0.018	1171.746	0.018	1230.762	0.018	1289.778	0.018	1348.794	0.018	1407.810	0.018	1466.826								
	0.021	1064.065	0.021	1123.660	0.021	1183.256	0.021	1242.852	0.021	1302.448	0.021	1362.043	0.021	1421.639	0.021	1481.235								
	0.024	1068.818	0.024	1128.680	0.024	1188.541	0.024	1248.403	0.024	1308.265	0.024	1368.127	0.024	1427.989	0.024	1487.851								
	0.027	1070.992	0.027	1130.975	0.027	1190.959	0.027	1250.943	0.027	1310.927	0.027	1370.910	0.027	1430.894	0.027	1490.878								
	0.030	1071.984	0.030	1132.024	0.030	1192.063	0.030	1252.102	0.030	1312.142	0.030	1372.181	0.030	1432.220	0.030	1492.260								
	0.033	1072.437	0.033	1132.502	0.033	1192.567	0.033	1252.631	0.033	1312.696	0.033	1372.761	0.033	1432.825	0.033	1492.890								
	0.035	1072.644	0.036	1132.720	0.036	1192.796	0.036	1252.873	0.036	1312.949	0.036	1373.025	0.036	1433.101	0.036	1493.178								
	0.038	1072.738	0.039	1132.820	0.039	1192.901	0.039	1252.983	0.039	1313.064	0.039	1373.146	0.039	1433.227	0.039	1493.309								
	0.041	1072.781	0.042	1132.865	0.042	1192.949	0.042	1253.033	0.042	1313.117	0.042	1373.201	0.042	1433.285	0.042	1493.369								
	0.044	1072.801	0.044	1132.886	0.045	1192.971	0.045	1253.056	0.045	1313.141	0.045	1373.226	0.045	1433.311	0.045	1493.396								
	0.047	1072.809	0.047	1132.895	0.048	1192.981	0.048	1253.066	0.048	1313.152	0.048	1373.237	0.048	1433.323	0.048	1493.408								

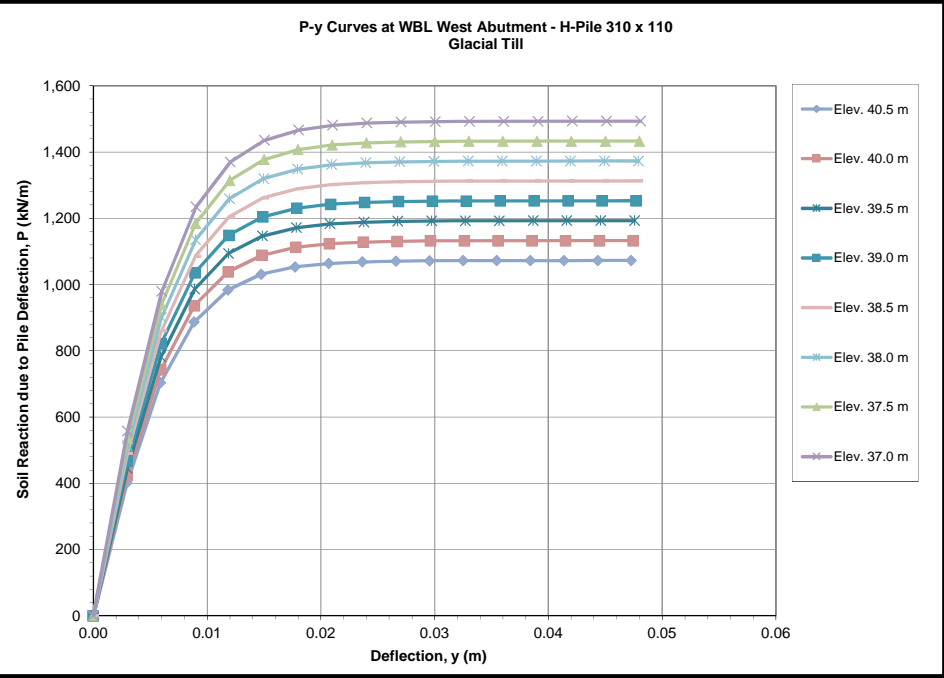
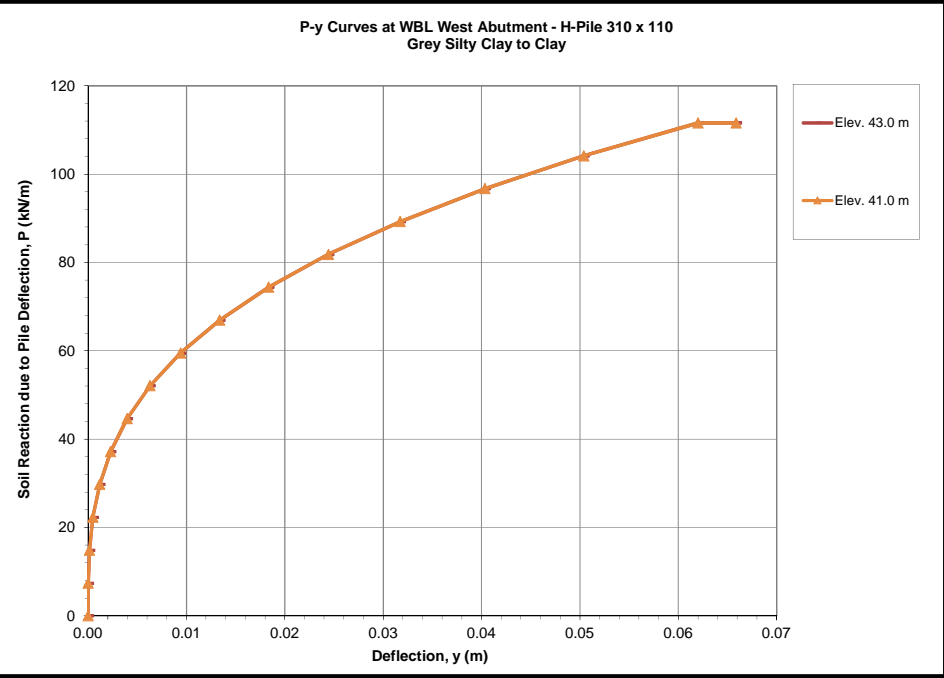
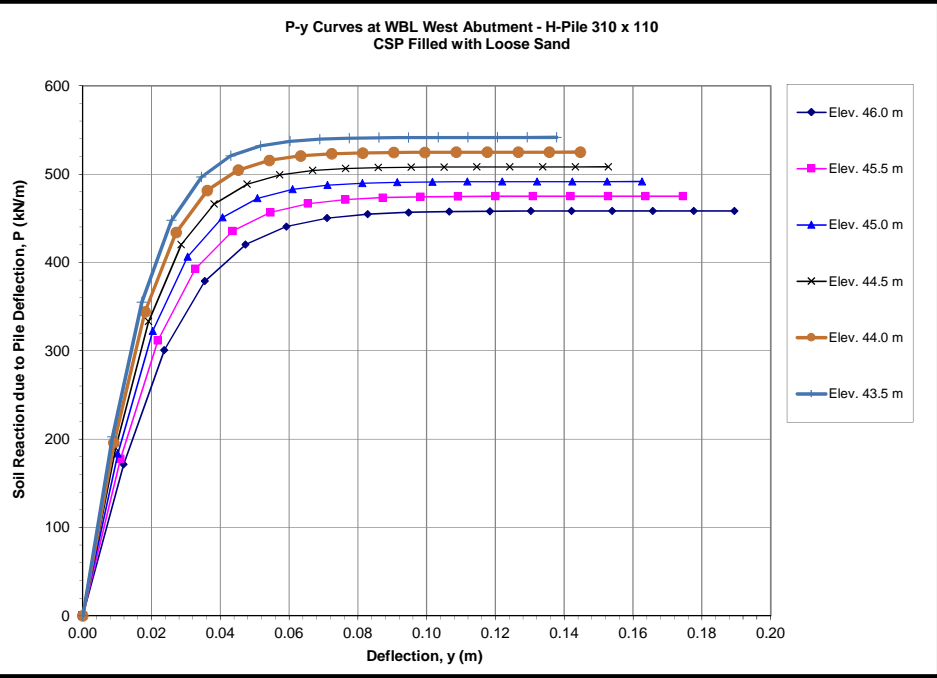
NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Organic deposits layer assumed to remain *in situ*.

9. Program: Lpile 2016.9.11



P-Y CURVES

Raisin River Overpass  
H-Pile 310x110 - WBL West Abutment (Borehole 17-105, 17-106) - Without Organic Deposits

FIGURE F9

SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - WBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Grey Silty Clay to Clay											
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m			
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m			
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)		
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	0.012	178.750	0.012	191.663	0.011	204.577	0.011	217.491	0.011	230.405	0.010	243.318	0.000	7.440	0.000	7.440	0.000	7.440	0.000	7.440	0.000	7.440		
	0.025	313.695	0.024	336.358	0.023	359.021	0.022	381.683	0.021	404.346	0.021	427.009	0.000	14.880	0.000	14.880	0.000	14.880	0.000	14.880	0.000	14.880		
	0.037	395.519	0.035	424.093	0.034	452.667	0.033	481.241	0.032	509.815	0.031	538.390	0.000	22.320	0.000	22.320	0.000	22.320	0.000	22.320	0.000	22.320		
	0.049	438.714	0.047	470.409	0.045	502.104	0.044	533.798	0.042	565.493	0.041	597.188	0.001	29.760	0.001	29.760	0.001	29.760	0.001	29.760	0.001	29.760		
	0.062	459.858	0.059	493.081	0.057	526.303	0.055	559.525	0.053	592.748	0.052	625.970	0.002	37.200	0.002	37.200	0.002	37.200	0.002	37.200	0.002	37.200		
	0.074	469.826	0.071	503.768	0.068	537.711	0.066	571.653	0.064	605.596	0.062	639.538	0.004	44.640	0.004	44.640	0.004	44.640	0.004	44.640	0.004	44.640		
	0.087	474.441	0.082	508.717	0.079	542.993	0.077	577.269	0.074	611.545	0.072	645.821	0.006	52.080	0.006	52.080	0.006	52.080	0.006	52.080	0.006	52.080		
	0.099	476.560	0.094	510.989	0.091	545.418	0.087	579.847	0.085	614.276	0.083	648.705	0.009	59.520	0.009	59.520	0.009	59.520	0.009	59.520	0.009	59.520		
	0.111	477.530	0.106	512.029	0.102	546.528	0.098	581.027	0.096	615.526	0.093	650.025	0.013	66.960	0.013	66.960	0.013	66.960	0.013	66.960	0.013	66.960		
	0.124	477.972	0.118	512.503	0.113	547.034	0.109	581.565	0.106	616.096	0.104	650.627	0.018	74.400	0.018	74.400	0.018	74.400	0.018	74.400	0.018	74.400		
	0.136	478.174	0.130	512.720	0.124	547.265	0.120	581.811	0.117	616.357	0.114	650.902	0.024	81.840	0.024	81.840	0.024	81.840	0.024	81.840	0.024	81.840		
	0.148	478.266	0.141	512.819	0.136	547.371	0.131	581.923	0.127	616.475	0.124	651.028	0.032	89.280	0.032	89.280	0.032	89.280	0.032	89.280	0.032	89.280		
	0.161	478.308	0.153	512.864	0.147	547.419	0.142	581.974	0.138	616.530	0.135	651.085	0.040	96.720	0.040	96.720	0.040	96.720	0.040	96.720	0.040	96.720		
	0.173	478.327	0.165	512.884	0.158	547.441	0.153	581.998	0.149	616.554	0.145	651.111	0.050	104.160	0.050	104.160	0.050	104.160	0.050	104.160	0.050	104.160		
	0.185	478.336	0.177	512.894	0.170	547.451	0.164	582.008	0.159	616.566	0.155	651.123	0.062	111.600	0.062	111.600	0.062	111.600	0.062	111.600	0.062	111.600		
	0.198	478.340	0.188	512.898	0.181	547.455	0.175	582.013	0.170	616.571	0.166	651.128	0.066	111.600	0.066	111.600	0.066	111.600	0.066	111.600	0.066	111.600		
Description Depth (z) * Elevation P-y Curves	Glacial Till																							
	z= 9.5 m		z= 10.0 m		z= 10.5 m		z= 11.0 m		z= 11.5 m		z= 12.0 m		z= 12.5 m		z= 13.0 m									
	Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m									
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)								
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000								
	0.004	476.507	0.004	498.960	0.003	521.413	0.003	543.867	0.003	566.320	0.003	588.773	0.003	611.226	0.003	633.679								
	0.007	836.241	0.007	875.645	0.007	915.049	0.007	954.453	0.007	993.857	0.007	1033.261	0.007	1072.665	0.007	1112.069								
	0.011	1054.365	0.010	1104.047	0.010	1153.729	0.010	1203.411	0.010	1253.093	0.010	1302.776	0.010	1352.458	0.010	1402.140								
	0.014	1169.514	0.014	1224.622	0.014	1279.730	0.014	1334.838	0.014	1389.946	0.014	1445.054	0.014	1500.162	0.014	1555.270								
	0.018	1225.880	0.017	1283.644	0.017	1341.408	0.017	1399.172	0.017	1456.936	0.017	1514.700	0.017	1572.464	0.017	1630.228								
	0.021	1252.451	0.021	1311.467	0.021	1370.484	0.021	1429.500	0.021	1488.516	0.021	1547.532	0.021	1606.548	0.020	1665.564								
	0.025	1264.755	0.024	1324.350	0.024	1383.946	0.024	1443.542	0.024	1503.138	0.024	1562.733	0.024	1622.329	0.024	1681.925								
	0.028	1270.404	0.028	1330.266	0.028	1390.128	0.028	1449.990	0.028	1509.852	0.028	1569.714	0.027	1629.576	0.027	1689.438								
	0.032	1272.988	0.031	1332.972	0.031	1392.956	0.031	1452.939	0.031	1512.923	0.031	1572.907	0.031	1632.890	0.031	1692.874								
	0.035	1274.168	0.035	1334.207	0.035	1394.247	0.035	1454.286	0.035	1514.325	0.034	1574.365	0.034	1634.404	0.034	1694.443								
	0.039	1274.706	0.038	1334.771	0.038	1394.836	0.038	1454.900	0.038	1514.965	0.038	1575.030	0.038	1635.095	0.038	1695.159								
	0.042	1274.952	0.042	1335.028	0.042	1395.104	0.042	1455.181	0.041	1515.257	0.041	1575.333	0.041	1635.410	0.041	1695.486								
	0.046	1275.064	0.045	1335.145	0.045	1395.227	0.045	1455.308	0.045	1515.390	0.045	1575.472	0.045	1635.553	0.044	1695.635								
	0.049	1275.115	0.049	1335.199	0.049	1395.283	0.048	1455.367	0.048	1515.451	0.048	1575.535	0.048	1635.619	0.048	1695.703								
	0.053	1275.138	0.052	1335.223	0.052	1395.308	0.052	1455.393	0.052	1515.478	0.052	1575.563	0.051	1635.648	0.051	1695.733								
	0.056	1275.149	0.056	1335.234	0.056	1395.320	0.055	1455.405	0.055	1515.491	0.055	1575.577	0.055	1635.662	0.055	1695.748								

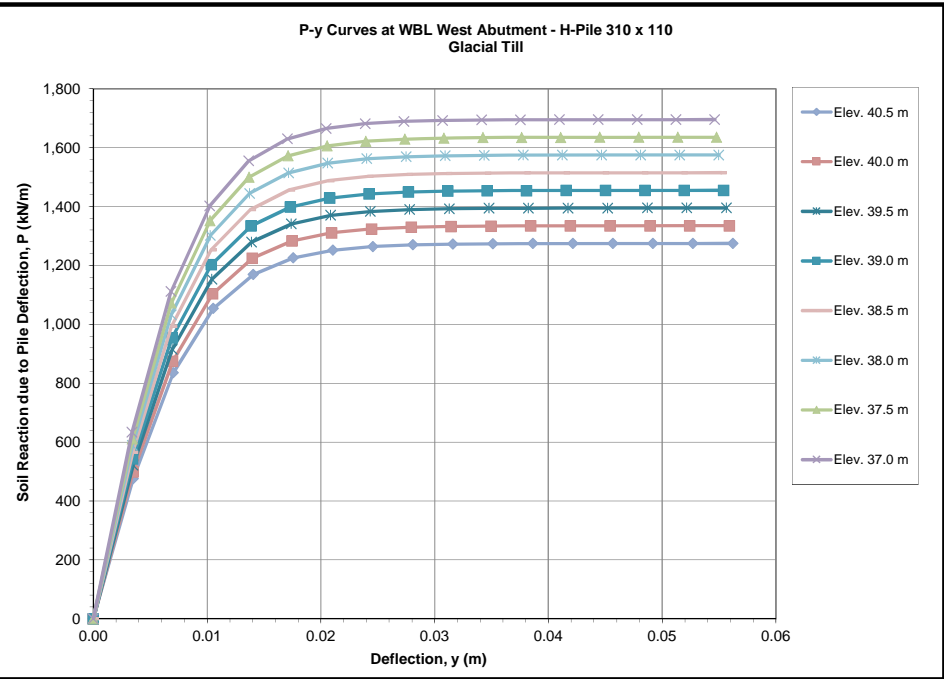
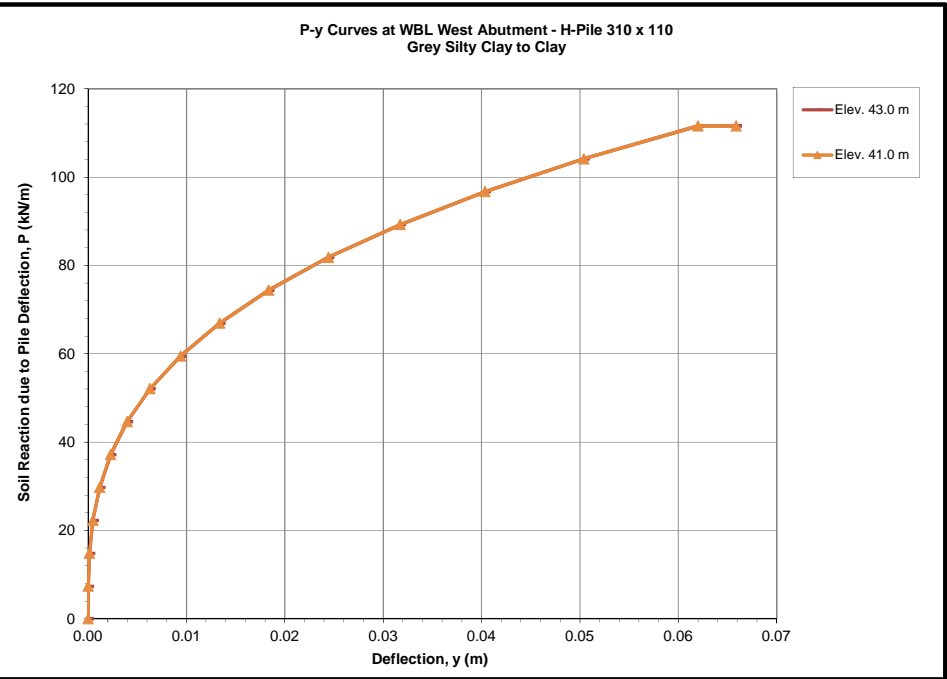
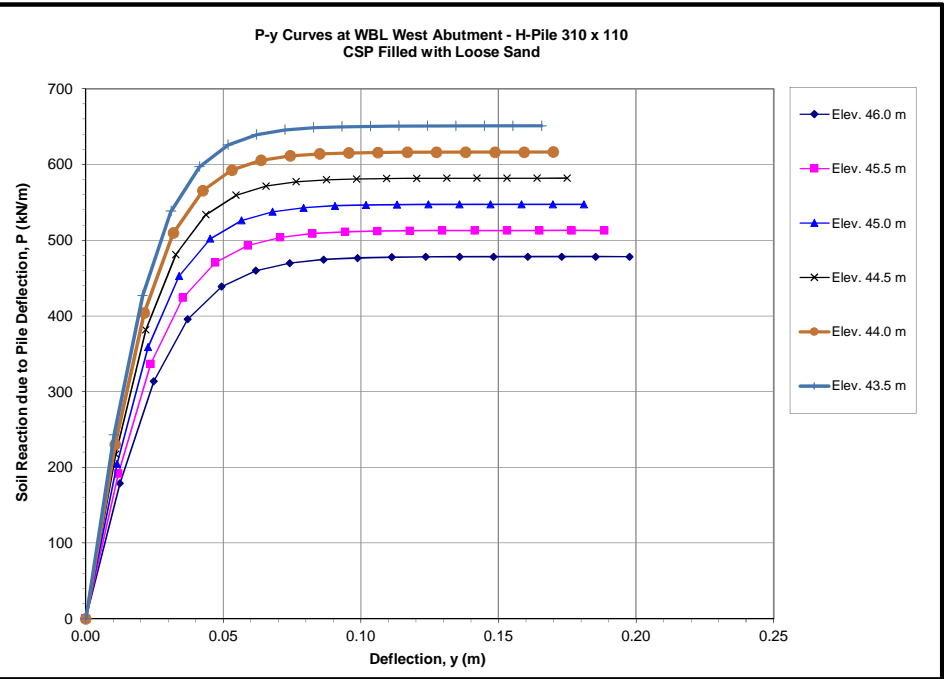
NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. P-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Static loading condition is considered. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Organic deposits layer removed and replaced with new embankment fill.

9. Program: Lpile 2016.9.11



CYCLIC P-Y CURVES

Raisin River Overpass  
H-Pile 310x110 - EBL West Abutment (Borehole 17-107, 17-108)

FIGURE F10

SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - EBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Grey Silty Clay to Clay									
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m	
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.012	171.823	0.011	180.628	0.010	189.433	0.010	198.238	0.010	207.043	0.009	215.847	0.000	5.748	0.000	5.748	0.000	5.748	0.000	5.748	0.000	5.748	
0.024	301.539	0.022	316.991	0.021	332.443	0.020	347.895	0.019	363.347	0.018	378.799	0.000	11.497	0.000	11.497	0.000	11.497	0.000	11.497	0.000	11.497	
0.036	380.193	0.033	399.675	0.031	419.157	0.030	438.640	0.029	458.122	0.028	477.605	0.000	17.245	0.000	17.245	0.000	17.245	0.000	17.245	0.000	17.245	
0.048	421.714	0.044	443.324	0.042	464.934	0.040	486.544	0.038	508.154	0.037	529.764	0.001	22.994	0.001	22.994	0.001	22.994	0.001	22.994	0.001	22.994	
0.059	442.039	0.056	464.691	0.052	487.342	0.050	509.994	0.048	532.645	0.046	555.297	0.001	28.742	0.001	28.742	0.001	28.742	0.001	28.742	0.001	28.742	
0.071	451.620	0.067	474.763	0.063	497.906	0.060	521.048	0.057	544.191	0.055	567.333	0.002	34.490	0.002	34.490	0.002	34.490	0.002	34.490	0.002	34.490	
0.083	456.057	0.078	479.427	0.073	502.797	0.070	526.167	0.067	549.537	0.064	572.906	0.003	40.239	0.003	40.239	0.003	40.239	0.003	40.239	0.003	40.239	
0.095	458.094	0.089	481.568	0.084	505.043	0.080	528.517	0.076	551.991	0.073	575.466	0.004	45.987	0.004	45.987	0.004	45.987	0.004	45.987	0.004	45.987	
0.107	459.026	0.100	482.548	0.094	506.070	0.090	529.592	0.086	553.114	0.083	576.636	0.006	51.736	0.006	51.736	0.006	51.736	0.006	51.736	0.006	51.736	
0.119	459.451	0.111	482.995	0.105	506.539	0.100	530.083	0.095	553.627	0.092	577.171	0.008	57.484	0.008	57.484	0.008	57.484	0.008	57.484	0.008	57.484	
0.131	459.645	0.122	483.199	0.115	506.753	0.110	530.307	0.105	553.861	0.101	577.414	0.011	63.232	0.011	63.232	0.011	63.232	0.011	63.232	0.011	63.232	
0.143	459.734	0.133	483.292	0.126	506.850	0.120	530.409	0.115	553.967	0.110	577.526	0.015	68.981	0.015	68.981	0.015	68.981	0.015	68.981	0.015	68.981	
0.154	459.774	0.144	483.335	0.136	506.895	0.130	530.455	0.124	554.016	0.119	577.576	0.019	74.729	0.019	74.729	0.019	74.729	0.019	74.729	0.019	74.729	
0.166	459.793	0.155	483.354	0.147	506.915	0.140	530.477	0.134	554.038	0.129	577.599	0.023	80.478	0.023	80.478	0.023	80.478	0.023	80.478	0.023	80.478	
0.178	459.801	0.167	483.363	0.157	506.925	0.150	530.486	0.143	554.048	0.138	577.610	0.116	80.478	0.116	80.478	0.116	80.478	0.116	80.478	0.116	80.478	
0.190	459.805	0.178	483.367	0.168	506.929	0.159	530.491	0.153	554.053	0.147	577.615	0.124	80.478	0.124	80.478	0.124	80.478	0.124	80.478	0.124	80.478	

Description Depth (z) * Elevation P-y Curves	Glacial Till					
	z= 9.5 m		z= 10.0 m		z= 10.5 m	
	Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.003	426.227	0.003	448.680	0.003	471.134	0.003
0.006	748.003	0.006	787.407	0.006	826.811	0.006
0.009	943.111	0.009	992.793	0.009	1042.475	0.009
0.013	1046.110	0.013	1101.218	0.013	1156.326	0.013
0.016	1096.528	0.016	1154.292	0.016	1212.056	0.016
0.019	1120.296	0.019	1179.312	0.019	1238.328	0.019
0.022	1131.301	0.022	1190.897	0.022	1250.492	0.022
0.025	1136.354	0.025	1196.216	0.025	1256.078	0.025
0.028	1138.666	0.028	1198.649	0.028	1258.633	0.028
0.031	1139.721	0.031	1199.760	0.031	1259.800	0.031
0.035	1140.203	0.035	1200.267	0.035	1260.332	0.035
0.038	1140.422	0.038	1200.498	0.038	1260.575	0.038
0.041	1140.522	0.041	1200.604	0.041	1260.685	0.041
0.044	1140.568	0.044	1200.652	0.044	1260.736	0.044
0.047	1140.589	0.047	1200.674	0.047	1260.759	0.047
0.050	1140.598	0.050	1200.684	0.050	1260.769	0.050

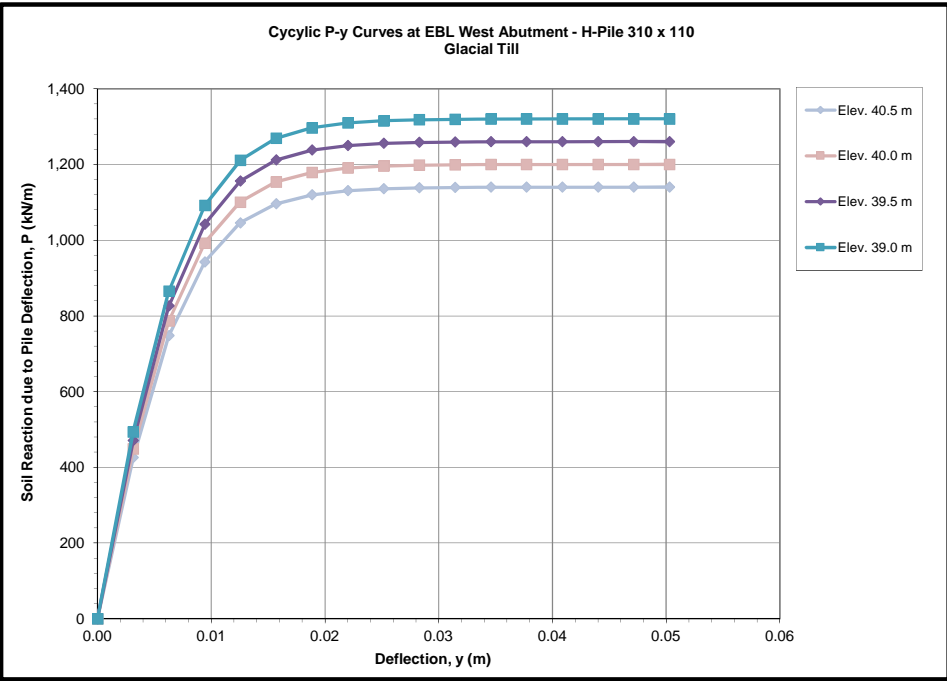
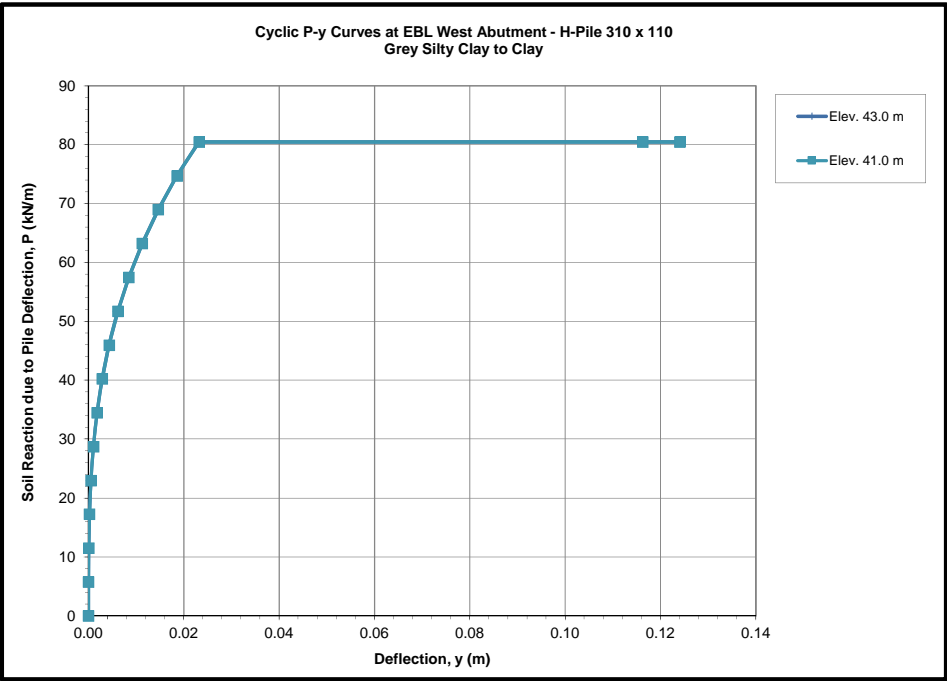
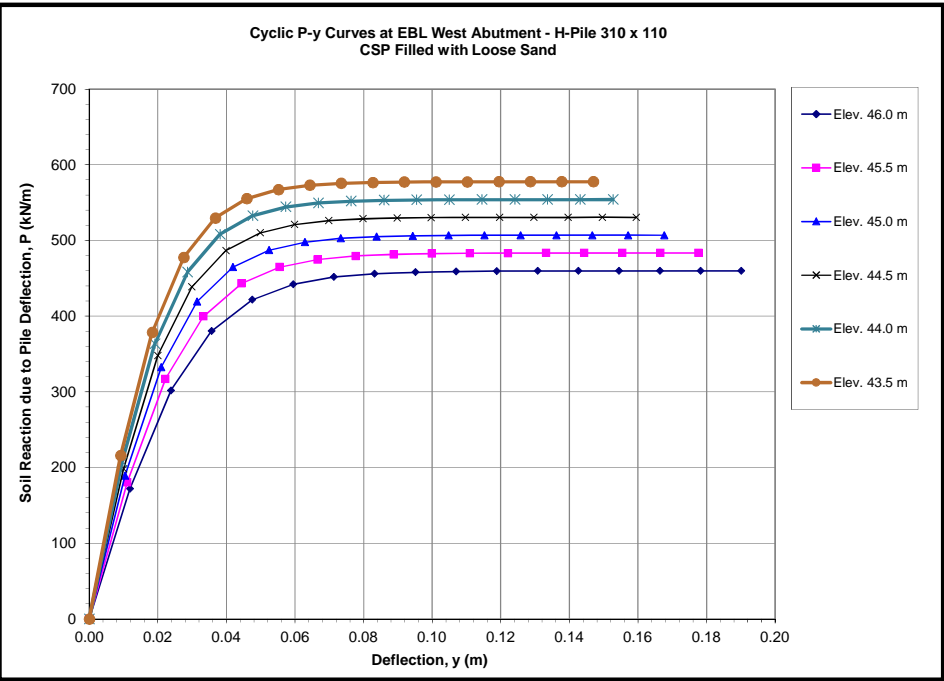
NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Program: Lpile 2016.9.11

9. Organic deposits layer assumed to remain *in situ*.

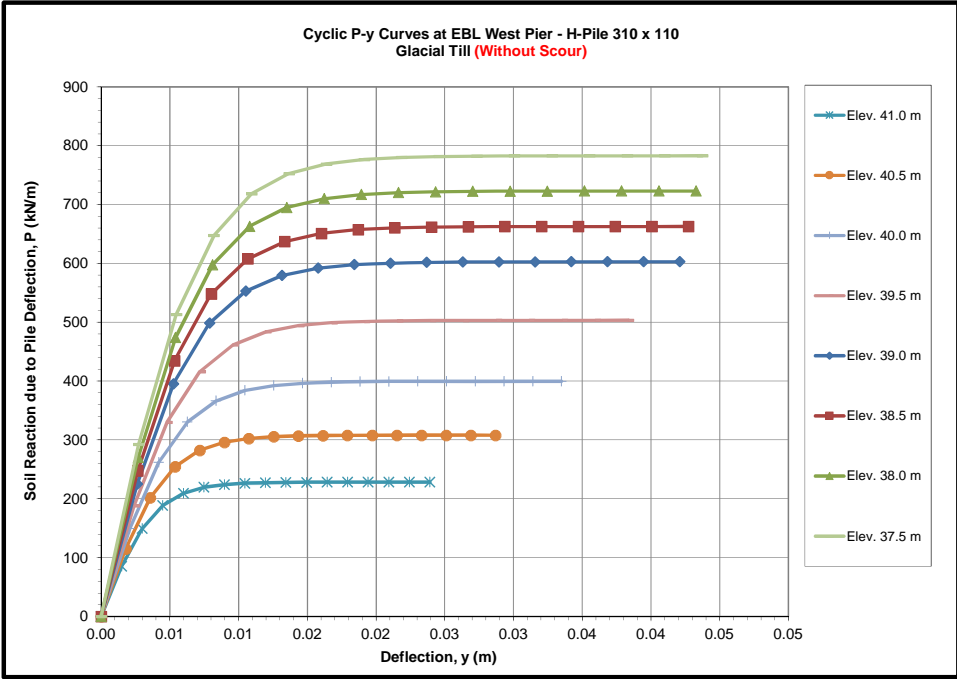
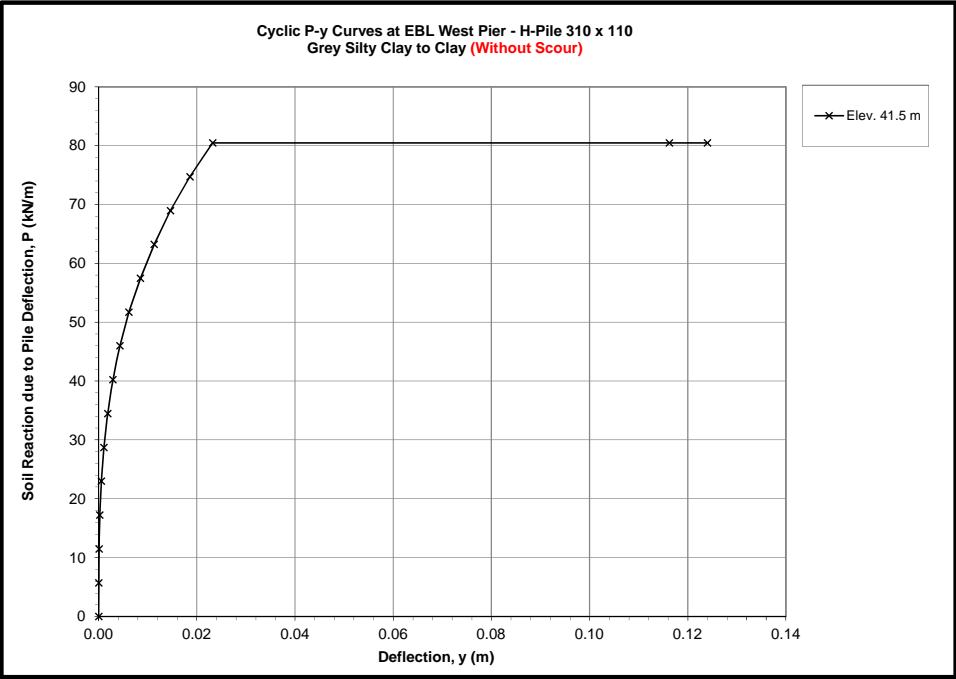


SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - EBL WEST PIER

Description Depth (z) * Elevation P-y Curves	Silty Clay / Clay		Glacial Till													
	z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m	
	Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	5.748	0.001	85.338	0.002	115.129	0.002	149.400	0.002	188.155	0.003	225.300	0.003	247.753	0.003	270.206	0.003
0.000	11.497	0.003	149.763	0.004	202.044	0.004	262.189	0.005	330.200	0.005	395.387	0.005	434.791	0.005	474.195	0.005
0.000	17.245	0.004	188.827	0.005	254.745	0.006	330.578	0.007	416.329	0.008	498.520	0.008	548.202	0.008	597.884	0.008
0.001	22.994	0.006	209.449	0.007	282.566	0.008	366.681	0.010	461.797	0.011	552.964	0.011	608.072	0.011	663.180	0.011
0.001	28.742	0.007	219.544	0.009	296.185	0.010	384.353	0.012	484.054	0.013	579.615	0.013	637.379	0.014	695.143	0.014
0.002	34.490	0.009	224.303	0.011	302.605	0.013	392.684	0.014	494.546	0.016	592.178	0.016	651.194	0.016	710.210	0.016
0.003	40.239	0.010	226.506	0.013	305.578	0.015	396.542	0.017	499.404	0.018	597.995	0.019	657.591	0.019	717.187	0.019
0.004	45.987	0.012	227.518	0.014	306.942	0.017	398.313	0.019	501.635	0.021	600.666	0.021	660.528	0.022	720.390	0.022
0.006	51.736	0.013	227.981	0.016	307.567	0.019	399.123	0.022	502.655	0.024	601.888	0.024	661.872	0.024	721.856	0.025
0.008	57.484	0.015	228.192	0.018	307.852	0.021	399.493	0.024	503.121	0.026	602.446	0.027	662.485	0.027	722.525	0.027
0.011	63.232	0.016	228.289	0.020	307.982	0.023	399.662	0.026	503.334	0.029	602.700	0.029	662.765	0.030	722.830	0.030
0.015	68.981	0.018	228.333	0.022	308.041	0.025	399.739	0.029	503.431	0.032	602.817	0.032	662.893	0.032	722.969	0.033
0.019	74.729	0.019	228.353	0.023	308.068	0.027	399.774	0.031	503.475	0.034	602.870	0.035	662.951	0.035	723.033	0.036
0.023	80.478	0.021	228.362	0.025	308.081	0.029	399.790	0.034	503.495	0.037	602.894	0.037	662.978	0.038	723.062	0.038
0.116	80.478	0.022	228.366	0.027	308.086	0.031	399.797	0.036	503.504	0.039	602.905	0.040	662.990	0.041	723.075	0.041
0.124	80.478	0.024	228.368	0.029	308.089	0.033	399.801	0.038	503.508	0.042	602.910	0.043	662.995	0.043	723.081	0.044

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.  
Please note the following assumptions:  
1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.  
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.  
3. There are no pile group effects (i.e., analysis is based on a single pile).  
4. The effects of construction disturbance are not considered.

5. Pier location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.  
6. Groundwater table assumed above top of pile.  
7. Top of pile assumed at Elevation 41.9 m.  
8. No scour is considered, as per Dillon.  
9. Program: Lpile 2016.9.11



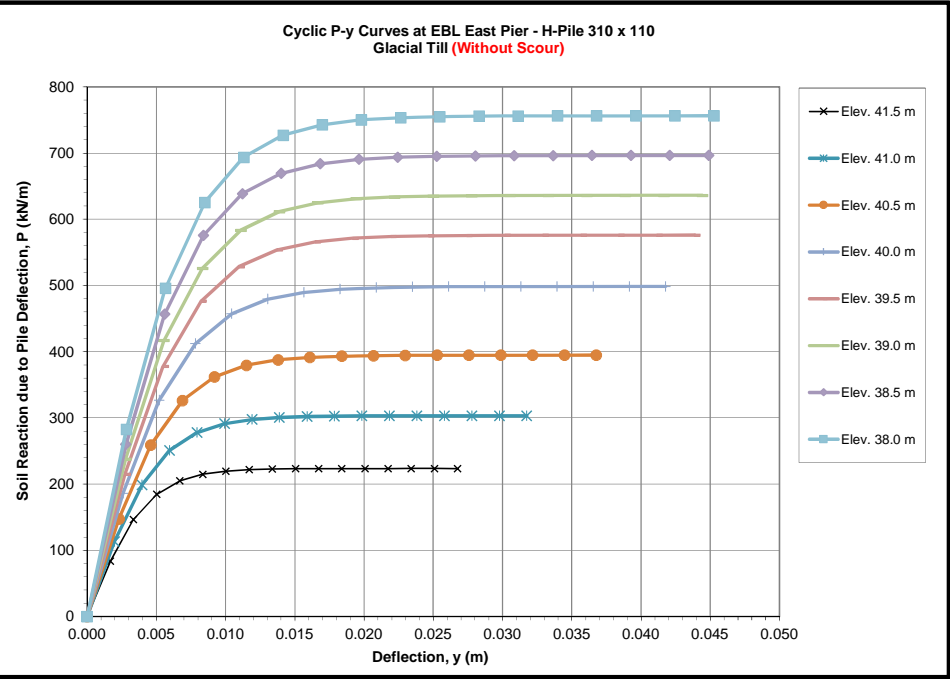


SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - EBL EAST PIER

Description Depth (z) * Elevation P-y Curves	Glacial Till															
	z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m	
	Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.002	83.541	0.002	113.311	0.002	147.571	0.003	186.321	0.003	215.321	0.003	237.774	0.003	260.227	0.003	282.680
	0.003	146.610	0.004	198.854	0.005	258.978	0.005	326.981	0.005	377.875	0.006	417.279	0.006	456.683	0.006	496.087
	0.005	184.851	0.006	250.723	0.007	326.530	0.008	412.271	0.008	476.439	0.008	526.121	0.008	575.803	0.008	625.485
	0.007	205.039	0.008	278.105	0.009	362.191	0.010	457.295	0.011	528.471	0.011	583.579	0.011	638.687	0.011	693.795
	0.008	214.922	0.010	291.508	0.011	379.647	0.013	479.335	0.014	553.942	0.014	611.706	0.014	669.470	0.014	727.234
	0.010	219.580	0.012	297.827	0.014	387.876	0.016	489.725	0.016	565.949	0.017	624.965	0.017	683.981	0.017	742.997
	0.012	221.737	0.014	300.753	0.016	391.686	0.018	494.536	0.019	571.508	0.019	631.104	0.020	690.700	0.020	750.295
	0.013	222.727	0.016	302.096	0.018	393.436	0.021	496.745	0.022	574.061	0.022	633.923	0.022	693.785	0.023	753.647
	0.015	223.181	0.018	302.711	0.021	394.236	0.024	497.755	0.025	575.229	0.025	635.212	0.025	695.196	0.025	755.180
	0.017	223.387	0.020	302.991	0.023	394.601	0.026	498.217	0.027	575.762	0.028	635.801	0.028	695.840	0.028	755.880
	0.018	223.482	0.022	303.119	0.025	394.768	0.029	498.427	0.030	576.005	0.031	636.070	0.031	696.134	0.031	756.199
	0.020	223.525	0.024	303.178	0.028	394.844	0.031	498.523	0.033	576.116	0.033	636.192	0.034	696.269	0.034	756.345
	0.022	223.544	0.026	303.204	0.030	394.879	0.034	498.567	0.036	576.167	0.036	636.248	0.036	696.330	0.037	756.411
	0.023	223.553	0.028	303.216	0.032	394.895	0.037	498.587	0.038	576.190	0.039	636.274	0.039	696.358	0.040	756.442
	0.025	223.557	0.030	303.222	0.034	394.902	0.039	498.596	0.041	576.200	0.042	636.285	0.042	696.370	0.042	756.455
	0.027	223.559	0.032	303.224	0.037	394.905	0.042	498.600	0.044	576.205	0.044	636.291	0.045	696.376	0.045	756.462

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.  
Please note the following assumptions:  
1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.  
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.  
3. There are no pile group effects (i.e., analysis is based on a single pile).  
4. The effects of construction disturbance are not considered.

5. Pier location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.  
6. Groundwater table assumed above top of pile.  
7. Top of pile assumed at Elevation 41.9 m.  
8. No scour is considered, as per Dillon.  
9. Program: Lpile 2016.9.11



SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - EBL EAST ABUTMENT

Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Glacial Till												
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m		z= 9.5 m		
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.012	178.280	0.012	188.846	0.011	199.412	0.011	209.977	0.010	220.543	0.010	231.109	0.004	396.098	0.004	418.551	0.004	441.004	0.004	463.457	0.004	485.910	0.004	508.364		
0.025	312.871	0.023	331.413	0.022	349.955	0.021	368.498	0.020	387.040	0.020	405.582	0.008	695.127	0.008	734.531	0.008	773.936	0.008	813.340	0.008	852.744	0.008	892.148		
0.037	394.480	0.035	417.858	0.033	441.237	0.032	464.616	0.031	487.995	0.030	511.374	0.012	876.444	0.012	926.126	0.012	975.808	0.011	1025.490	0.011	1075.172	0.011	1124.854		
0.049	437.561	0.046	463.493	0.044	489.426	0.042	515.358	0.041	541.290	0.039	567.222	0.016	972.161	0.016	1027.269	0.015	1082.377	0.015	1137.485	0.015	1192.593	0.015	1247.701		
0.062	458.650	0.058	485.832	0.055	513.014	0.053	540.196	0.051	567.378	0.049	594.560	0.020	1019.016	0.020	1076.780	0.019	1134.544	0.019	1192.308	0.019	1250.072	0.019	1307.836		
0.074	468.592	0.070	496.363	0.066	524.134	0.063	551.905	0.061	579.676	0.059	607.447	0.024	1041.103	0.023	1100.119	0.023	1159.135	0.023	1218.152	0.023	1277.168	0.022	1336.184		
0.086	473.195	0.081	501.239	0.077	529.283	0.074	557.327	0.071	585.370	0.069	613.414	0.028	1051.330	0.027	1110.926	0.027	1170.522	0.027	1230.118	0.026	1289.714	0.026	1349.309		
0.099	475.308	0.093	503.478	0.088	531.647	0.084	559.816	0.081	587.985	0.079	616.154	0.032	1056.027	0.031	1115.888	0.031	1175.750	0.031	1235.612	0.030	1295.474	0.030	1355.336		
0.111	476.275	0.104	504.502	0.099	532.728	0.095	560.955	0.091	589.181	0.088	617.408	0.036	1058.175	0.035	1118.158	0.035	1178.142	0.034	1238.126	0.034	1298.109	0.034	1358.093		
0.123	476.717	0.116	504.969	0.110	533.222	0.106	561.475	0.102	589.727	0.098	617.980	0.040	1059.155	0.039	1119.195	0.039	1179.234	0.038	1239.273	0.038	1299.313	0.037	1359.352		
0.136	476.918	0.128	505.183	0.121	533.447	0.116	561.712	0.112	589.976	0.108	618.241	0.044	1059.603	0.043	1119.668	0.042	1179.732	0.042	1239.797	0.042	1299.862	0.041	1359.926		
0.148	477.010	0.139	505.280	0.132	533.550	0.127	561.820	0.122	590.090	0.118	618.360	0.048	1059.807	0.047	1119.883	0.046	1179.960	0.046	1240.036	0.045	1300.112	0.045	1360.188		
0.160	477.052	0.151	505.324	0.143	533.597	0.137	561.869	0.132	590.142	0.128	618.414	0.052	1059.900	0.051	1119.982	0.050	1180.063	0.050	1240.145	0.049	1300.226	0.049	1360.308		
0.173	477.071	0.162	505.345	0.154	533.618	0.148	561.892	0.142	590.166	0.138	618.439	0.056	1059.942	0.055	1120.026	0.054	1180.110	0.053	1240.194	0.053	1300.278	0.052	1360.362		
0.185	477.080	0.174	505.354	0.165	533.628	0.158	561.902	0.152	590.176	0.147	618.450	0.059	1059.962	0.059	1120.047	0.058	1180.132	0.057	1240.217	0.057	1300.302	0.056	1360.387		
0.197	477.084	0.186	505.358	0.176	533.632	0.169	561.907	0.163	590.181	0.157	618.456	0.063	1059.971	0.063	1120.056	0.062	1180.142	0.061	1240.227	0.061	1300.313	0.060	1360.398		

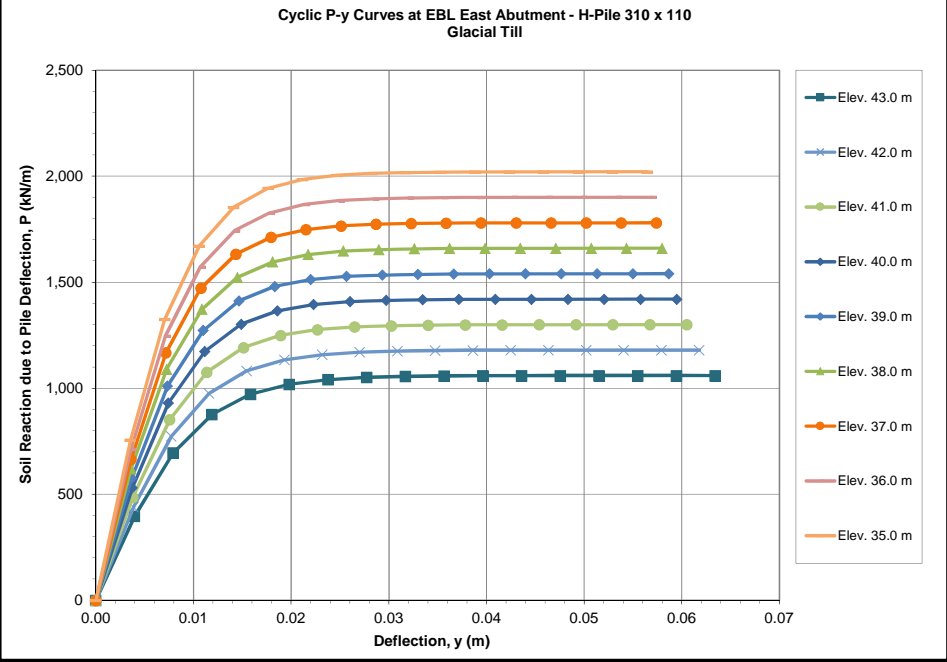
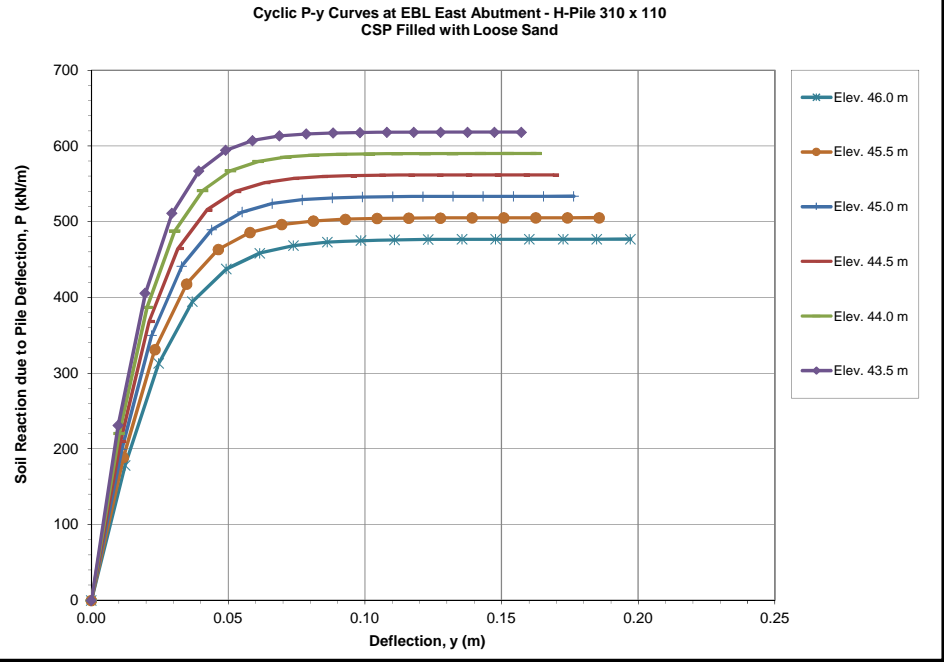
Description Depth (z) * Elevation P-y Curves	Glacial Till (continued)																					
	z= 10.0 m		z= 10.5 m		z= 11.0 m		z= 11.5 m		z= 12.0 m		z= 12.5 m		z= 13.0 m		z= 13.5 m		z= 14.0 m		z= 14.5 m		z= 15.0 m	
	Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m		Elev. 36.5 m		Elev. 36.0 m		Elev. 35.5 m		Elev. 35.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.004	530.817	0.004	553.270	0.004	575.723	0.004	598.177	0.004	620.630	0.004	643.083	0.004	665.536	0.004	687.989	0.004	710.443	0.004	732.896	0.004	755.349	
0.007	931.552	0.007	970.956	0.007	1010.360	0.007	1049.764	0.007	1089.168	0.007	1128.572	0.007	1167.976	0.007	1207.380	0.007	1246.784	0.007	1286.188	0.007	1325.592	
0.011	1174.536	0.011	1224.218	0.011	1273.901	0.011	1323.583	0.011	1373.265	0.011	1422.947	0.011	1472.629	0.011	1522.311	0.011	1571.993	0.011	1621.675	0.011	1671.357	
0.015	1302.809	0.015	1357.917	0.015	1413.025	0.015	1468.133	0.014	1523.241	0.014	1578.349	0.014	1633.457	0.014	1688.565	0.014	1743.673	0.014	1798.781	0.014	1853.889	
0.019	1365.600	0.018	1423.364	0.018	1481.128	0.018	1538.892	0.018	1596.656	0.018	1654.420	0.018	1712.184	0.018	1769.948	0.018	1827.712	0.018	1885.476	0.018	1943.240	
0.022	1395.200	0.022	1454.216	0.022	1513.232	0.022	1572.248	0.022	1631.264	0.022	1690.280	0.022	1749.296	0.021	1808.312	0.021	1867.328	0.021	1926.344	0.021	1985.360	
0.026	1408.905	0.026	1468.501	0.026	1528.097	0.026	1587.692	0.025	1647.288	0.025	1706.884	0.025	1766.480	0.025	1826.075	0.025	1885.671	0.025	1945.267	0.025	2004.863	
0.030	1415.198	0.030	1475.060	0.029	1534.922	0.029	1594.784	0.029	1654.646	0.029	1714.508	0.029	1774.370	0.029	1834.232	0.028	1894.094	0.028	1953.956	0.028	2013.818	
0.033	1418.077	0.033	1478.061	0.033	1538.044	0.033	1598.028	0.033	1658.012	0.032	1717.996	0.032	1777.979	0.032	1837.963	0.032	1897.947	0.032	1957.931	0.032	2017.914	
0.037	1419.391	0.037	1479.431	0.037	1539.470	0.036	1599.509	0.036	1659.549	0.036	1719.588	0.036	1779.627	0.036	1839.667	0.036	1899.706	0.035	1959.745	0.035	2019.785	
0.041	1419.991	0.041	1480.056	0.040	1540.120	0.040	1600.185	0.040	1660.250	0.040	1720.315	0.039	1780.379	0.039	1840.444	0.039	1900.509	0.039	1960.573	0.039	2020.638	
0.045	1420.265	0.044	1480.341	0.044	1540.417	0.044	1600.493	0.043	1660.570	0.043	1720.646	0.043	1780.722	0.043	1840.798	0.043	1900.875	0.042	1960.951	0.042	2021.027	
0.048	1420.389	0.048	1480.471	0.048	1540.552	0.047	1600.634	0.047	1660.715	0.047	1720.797	0.047	1780.879	0.046	1840.960	0.046	1901.042	0.046	1961.123	0.046	2021.205	
0.052	1420.446	0.052	1480.530	0.051	1540.614	0.051	1600.698	0.051	1660.782	0.050	1720.866	0.050	1780.950	0.050	1841.034	0.050	1901.118	0.050	1961.202	0.049	2021.286	
0.056	1420.472	0.055	1480.557	0.055	1540.642	0.055	1600.727	0.054	1660.812	0.054	1720.897	0.054	1780.982	0.054	1841.067	0.053	1901.152	0.053	1961.238	0.053	2021.323	
0.060	1420.484	0.059	1480.569	0.059	1540.655	0.058	1600.741	0.058	1660.826	0.058	1720.912	0.057	1780.997	0.057	1841.083	0.057	1901.168	0.057	1961.254	0.056	2021.339	

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Program: Lpile 2016.9.11





SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - WBL EAST ABUTMENT

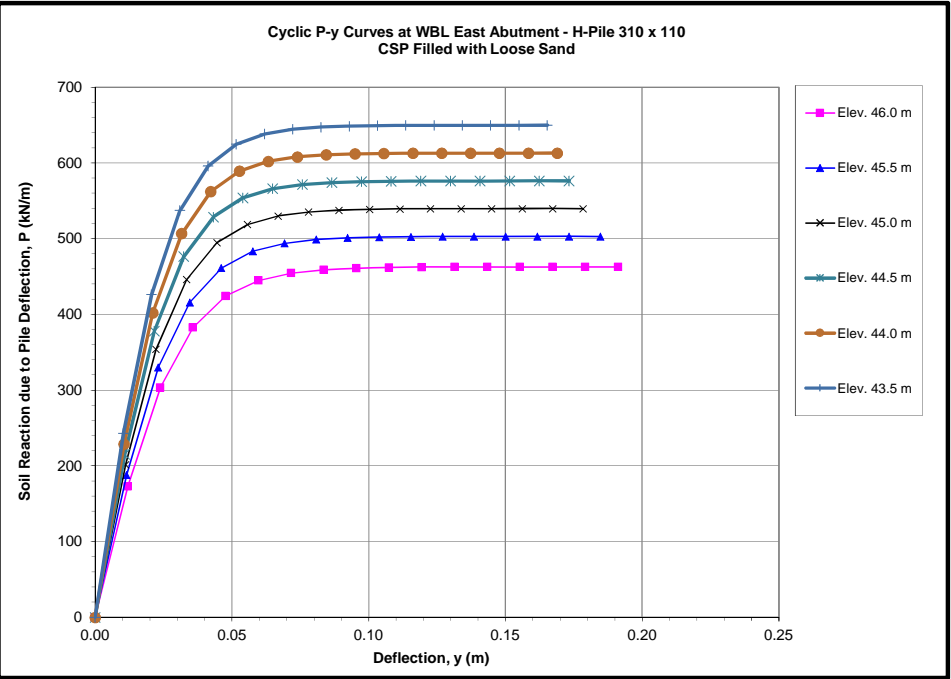
Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Glacial Till												
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m		z= 9.5 m		
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.012	172.922	0.012	187.954	0.011	201.689	0.011	215.425	0.011	229.160	0.010	242.896	0.004	419.510	0.004	441.964	0.004	464.417	0.004	486.870	0.004	509.323	0.004	531.776		
0.024	303.468	0.023	329.847	0.022	353.952	0.022	378.057	0.022	402.162	0.021	426.267	0.008	736.215	0.008	775.619	0.008	815.023	0.008	854.427	0.008	893.832	0.008	933.236		
0.036	382.625	0.035	415.884	0.033	446.277	0.033	476.669	0.032	507.062	0.031	537.454	0.013	928.249	0.012	977.931	0.012	1027.613	0.012	1077.295	0.012	1126.977	0.012	1176.659		
0.048	424.412	0.046	461.304	0.045	495.015	0.043	528.727	0.042	562.439	0.041	596.151	0.017	1029.624	0.017	1084.732	0.016	1139.840	0.016	1194.948	0.016	1250.056	0.016	1305.164		
0.060	444.867	0.058	483.537	0.056	518.873	0.054	554.210	0.053	589.546	0.052	624.883	0.021	1079.248	0.021	1137.012	0.020	1194.776	0.020	1252.540	0.020	1310.304	0.020	1368.068		
0.072	454.509	0.069	494.018	0.067	530.120	0.065	566.223	0.063	602.325	0.062	638.427	0.025	1102.642	0.025	1161.658	0.024	1220.674	0.024	1279.690	0.024	1338.706	0.024	1397.722		
0.084	458.974	0.081	498.870	0.078	535.328	0.076	571.785	0.074	608.242	0.072	644.699	0.029	1113.473	0.029	1173.069	0.028	1232.665	0.028	1292.260	0.028	1351.856	0.027	1411.452		
0.096	461.024	0.092	501.099	0.089	537.719	0.087	574.339	0.085	610.959	0.083	647.579	0.034	1118.447	0.033	1178.309	0.033	1238.171	0.032	1298.033	0.032	1357.895	0.031	1417.757		
0.108	461.962	0.104	502.118	0.100	538.813	0.097	575.507	0.095	612.201	0.093	648.896	0.038	1120.722	0.037	1180.705	0.037	1240.689	0.036	1300.673	0.036	1360.657	0.035	1420.640		
0.120	462.390	0.116	502.583	0.112	539.312	0.108	576.040	0.106	612.769	0.103	649.497	0.042	1121.761	0.041	1181.800	0.041	1241.839	0.040	1301.878	0.040	1361.918	0.039	1421.957		
0.132	462.586	0.127	502.796	0.123	539.540	0.119	576.284	0.116	613.028	0.114	649.772	0.046	1122.234	0.045	1182.299	0.045	1242.364	0.044	1302.429	0.044	1362.493	0.043	1422.558		
0.143	462.675	0.139	502.893	0.134	539.644	0.130	576.395	0.127	613.146	0.124	649.897	0.050	1122.451	0.050	1182.527	0.049	1242.603	0.048	1302.679	0.048	1362.756	0.047	1422.832		
0.155	462.715	0.150	502.937	0.145	539.691	0.141	576.445	0.137	613.200	0.134	649.954	0.055	1122.549	0.054	1182.631	0.053	1242.712	0.052	1302.794	0.052	1362.875	0.051	1422.957		
0.167	462.734	0.162	502.957	0.156	539.713	0.152	576.468	0.148	613.224	0.145	649.980	0.059	1122.594	0.058	1182.678	0.057	1242.762	0.056	1302.846	0.056	1362.930	0.055	1423.014		
0.179	462.742	0.173	502.966	0.167	539.723	0.162	576.479	0.158	613.235	0.155	649.992	0.063	1122.615	0.062	1182.700	0.061	1242.785	0.060	1302.870	0.059	1362.955	0.059	1423.040		
0.191	462.746	0.185	502.970	0.178	539.727	0.173	576.484	0.169	613.241	0.165	649.997	0.067	1122.624	0.066	1182.709	0.065	1242.795	0.064	1302.881	0.063	1362.966	0.063	1423.052		
Description Depth (z) * Elevation P-y Curves	Glacial Till (continued)																								
	z= 10.0 m		z= 10.5 m		z= 11.0 m		z= 11.5 m		z= 12.0 m		z= 12.5 m		z= 13.0 m		z= 13.5 m		z= 14.0 m		z= 14.5 m		z= 15.0 m		z= 15.5 m		
	Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m		Elev. 36.5 m		Elev. 36.0 m		Elev. 35.5 m		Elev. 35.0 m		Elev. 34.5 m		
y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.004	554.230	0.004	576.683	0.004	599.136	0.004	621.589	0.004	644.042	0.004	666.496	0.004	688.949	0.004	711.402	0.004	733.855	0.004	756.309	0.004	778.762	0.004	801.215		
0.008	972.640	0.008	1012.044	0.008	1051.448	0.008	1090.852	0.008	1130.256	0.007	1169.660	0.007	1209.064	0.007	1248.468	0.007	1287.872	0.007	1327.276	0.007	1366.680	0.007	1406.084		
0.012	1226.342	0.012	1276.024	0.011	1325.706	0.011	1375.388	0.011	1425.070	0.011	1474.752	0.011	1524.434	0.011	1574.116	0.011	1623.799	0.011	1673.481	0.011	1723.163	0.011	1772.845		
0.016	1360.272	0.015	1415.380	0.015	1470.488	0.015	1525.596	0.015	1580.704	0.015	1635.812	0.015	1690.920	0.015	1746.028	0.015	1801.136	0.015	1856.244	0.015	1911.352	0.015	1966.460		
0.019	1425.832	0.019	1483.596	0.019	1541.360	0.019	1599.124	0.019	1656.888	0.019	1714.652	0.019	1772.416	0.018	1830.180	0.018	1887.944	0.018	1945.708	0.018	2003.472	0.018	2061.236		
0.023	1456.738	0.023	1515.754	0.023	1574.770	0.023	1633.786	0.023	1692.802	0.022	1751.818	0.022	1810.834	0.022	1869.850	0.022	1928.866	0.022	1987.882	0.022	2046.898	0.022	2105.914		
0.027	1471.048	0.027	1530.643	0.027	1590.239	0.027	1649.835	0.026	1709.431	0.026	1769.027	0.026	1828.622	0.026	1888.218	0.026	1947.814	0.026	2007.410	0.025	2067.005	0.025	2126.601		
0.031	1477.619	0.031	1537.480	0.031	1597.342	0.030	1657.204	0.030	1717.066	0.030	1776.928	0.030	1836.790	0.030	1896.652	0.029	1956.514	0.029	2016.376	0.029	2076.238	0.029	2136.100		
0.035	1480.624	0.035	1540.608	0.034	1600.592	0.034	1660.575	0.034	1720.559	0.034	1780.543	0.033	1840.526	0.033	1900.510	0.033	1960.494	0.033	2020.478	0.033	2080.461	0.033	2140.445		
0.039	1481.996	0.038	1542.036	0.038	1602.075	0.038	1662.114	0.038	1722.154	0.037	1782.193	0.037	1842.232	0.037	1902.272	0.037	1962.311	0.037	2022.350	0.036	2082.390	0.036	2142.429		
0.043	1482.623	0.042	1542.687	0.042	1602.752	0.042	1662.817	0.041	1722.881	0.041	1782.946	0.041	1843.011	0.041	1903.076	0.040	1963.140	0.040	2023.205	0.040	2083.270	0.040	2143.334		
0.047	1482.908	0.046	1542.984	0.046	1603.061	0.045	1663.137	0.045	1723.213	0.045	1783.290	0.045	1843.366	0.044	1903.442	0.044	1963.518	0.044	2023.595	0.044	2083.671	0.043	2143.747		
0.050	1483.038	0.050	1543.120	0.050	1603.202	0.049	1663.283	0.049	1723.365	0.049	1783.446	0.048	1843.528	0.048	1903.609	0.048	1963.691	0.048	2023.772	0.047	2083.854	0.047	2143.935		
0.054	1483.098	0.054	1543.182	0.053	1603.266	0.053	1663.350	0.053	1723.434	0.052	1783.518	0.052	1843.601	0.052	1903.685	0.051	1963.769	0.051	2023.853	0.051	2083.937	0.051	2144.021		
0.058	1483.125	0.058	1543.210	0.057	1603.295	0.057	1663.380	0.056	1723.465	0.056	1783.550	0.056	1843.635	0.055	1903.720	0.055	1963.805	0.055	2023.890	0.055	2083.975	0.054	2144.060		
0.062	1483.137	0.062	1543.223	0.061	1603.308	0.061	1663.394	0.060	1723.479	0.060	1783.565	0.059	1843.650	0.059	1903.736	0.059	1963.822	0.058	2023.907	0.058	2083.993	0.058	2144.078		

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Program: Lpile 2016.9.11



SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - WBL EAST PIER

Description Depth (z) * Elevation P-y Curves	Glacial Till															
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m	
	Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.002	141.129	0.003	179.160	0.003	205.341	0.003	227.795	0.003	250.248	0.003	272.701	0.003	295.154	0.003	317.607	0.003
0.005	247.673	0.006	314.415	0.006	360.362	0.006	399.766	0.006	439.170	0.006	478.574	0.006	517.978	0.006	557.382	0.006
0.007	312.276	0.008	396.427	0.009	454.358	0.009	504.040	0.009	553.722	0.009	603.404	0.009	653.086	0.009	702.768	0.009
0.010	346.380	0.011	439.721	0.012	503.979	0.012	559.087	0.012	614.195	0.012	669.303	0.012	724.411	0.012	779.519	0.012
0.012	363.074	0.014	460.914	0.014	528.269	0.015	586.033	0.015	643.797	0.015	701.561	0.015	759.325	0.015	817.089	0.015
0.015	370.944	0.017	470.905	0.017	539.719	0.017	598.735	0.018	657.751	0.018	716.767	0.018	775.783	0.018	834.799	0.018
0.017	374.588	0.020	475.530	0.020	545.021	0.020	604.617	0.020	664.213	0.021	723.808	0.021	783.404	0.021	843.000	0.021
0.020	376.261	0.022	477.655	0.023	547.456	0.023	607.318	0.023	667.180	0.024	727.042	0.024	786.903	0.024	846.765	0.024
0.022	377.026	0.025	478.626	0.026	548.569	0.026	608.553	0.026	668.537	0.026	728.520	0.027	788.504	0.027	848.488	0.027
0.025	377.376	0.028	479.070	0.029	549.078	0.029	609.117	0.029	669.156	0.029	729.196	0.030	789.235	0.030	849.274	0.030
0.027	377.535	0.031	479.272	0.032	549.310	0.032	609.374	0.032	669.439	0.032	729.504	0.032	789.568	0.033	849.633	0.033
0.030	377.608	0.033	479.364	0.035	549.415	0.035	609.492	0.035	669.568	0.035	729.644	0.035	789.721	0.036	849.797	0.036
0.032	377.641	0.036	479.407	0.037	549.464	0.038	609.545	0.038	669.627	0.038	729.708	0.038	789.790	0.039	849.871	0.039
0.035	377.656	0.039	479.426	0.040	549.486	0.041	609.570	0.041	669.654	0.041	729.738	0.041	789.821	0.042	849.905	0.042
0.037	377.663	0.042	479.435	0.043	549.496	0.044	609.581	0.044	669.666	0.044	729.751	0.044	789.836	0.045	849.921	0.045
0.040	377.666	0.045	479.438	0.046	549.500	0.046	609.586	0.047	669.671	0.047	729.757	0.047	789.842	0.047	849.928	0.047

Description Depth (z) * Elevation P-y Curves	Glacial Till (continued)															
	z= 8.0 m		z= 8.5 m		z= 9.0 m		z= 9.5 m		z= 10.0 m		z= 10.5 m					
	Elev. 37.5 m		Elev. 37.0 m		Elev. 36.5 m		Elev. 36.0 m		Elev. 35.5 m		Elev. 35.0 m					
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)				
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
0.003	340.061	0.003	362.514	0.003	384.967	0.003	407.420	0.003	429.873	0.003	452.327	0.003				
0.006	596.786	0.006	636.190	0.006	675.594	0.006	714.998	0.006	754.402	0.006	793.806	0.006				
0.009	752.451	0.009	802.133	0.009	851.815	0.009	901.497	0.009	951.179	0.009	1000.861	0.009				
0.012	834.627	0.012	889.735	0.012	944.843	0.012	999.951	0.012	1055.059	0.012	1110.167	0.012				
0.015	874.853	0.015	932.617	0.015	990.381	0.015	1048.145	0.015	1105.909	0.015	1163.673	0.015				
0.018	893.816	0.018	952.832	0.018	1011.848	0.018	1070.864	0.018	1129.880	0.018	1188.896	0.018				
0.021	902.596	0.021	962.192	0.021	1021.787	0.021	1081.383	0.021	1140.979	0.021	1200.575	0.021				
0.024	906.627	0.024	966.489	0.024	1026.351	0.024	1086.213	0.024	1146.075	0.024	1205.937	0.024				
0.027	908.472	0.027	968.455	0.027	1028.439	0.027	1088.423	0.027	1148.407	0.027	1208.390	0.027				
0.030	909.314	0.030	969.353	0.030	1029.392	0.030	1089.432	0.030	1149.471	0.030	1209.510	0.030				
0.033	909.698	0.033	969.763	0.033	1029.827	0.033	1089.892	0.033	1149.957	0.033	1210.021	0.033				
0.036	909.873	0.036	969.949	0.036	1030.026	0.036	1090.102	0.036	1150.178	0.036	1210.254	0.036				
0.039	909.953	0.039	970.034	0.039	1030.116	0.039	1090.198	0.039	1150.279	0.039	1210.361	0.039				
0.042	909.989	0.042	970.073	0.042	1030.157	0.042	1090.241	0.042	1150.325	0.042	1210.409	0.042				
0.045	910.006	0.045	970.091	0.045	1030.176	0.045	1090.261	0.045	1150.346	0.045	1210.431	0.045				
0.048	910.014	0.048	970.099	0.048	1030.185	0.048	1090.270	0.048	1150.356	0.048	1210.441	0.048				

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

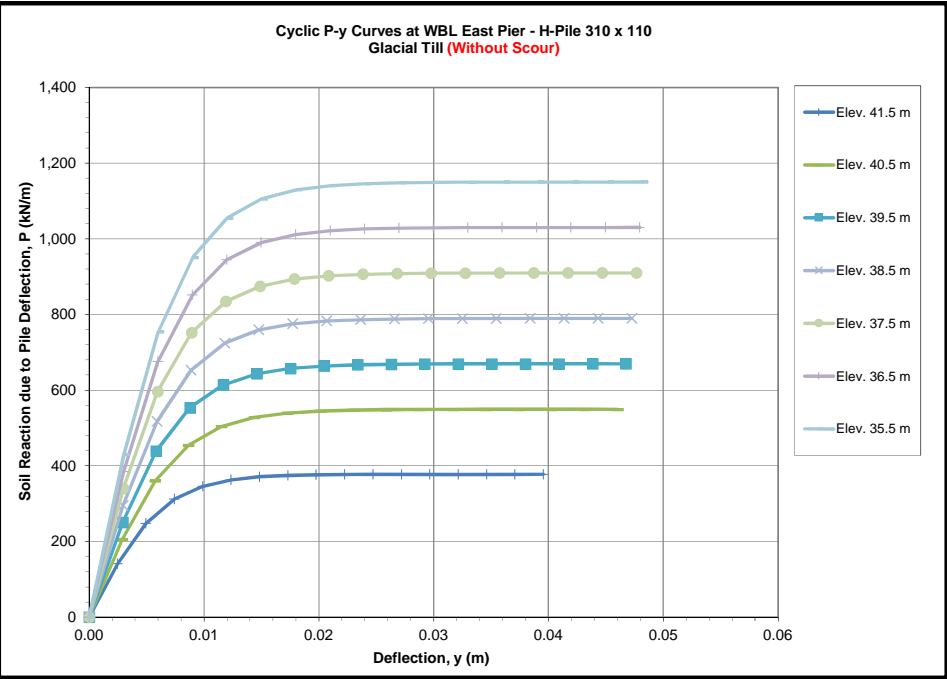
5. Pier location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.

9. Program: Lpile 2016.9.11

6. Groundwater table assumed above top of pile.

7. Top of pile assumed at Elevation 41.9 m.

8. No scour is considered, as per Dillon.



CYCLIC P-Y CURVES

Raisin River Overpass  
H-Pile 310x110 - WBL West Pier (Borehole 17-05, 17-06) - Without Scour

FIGURE F16

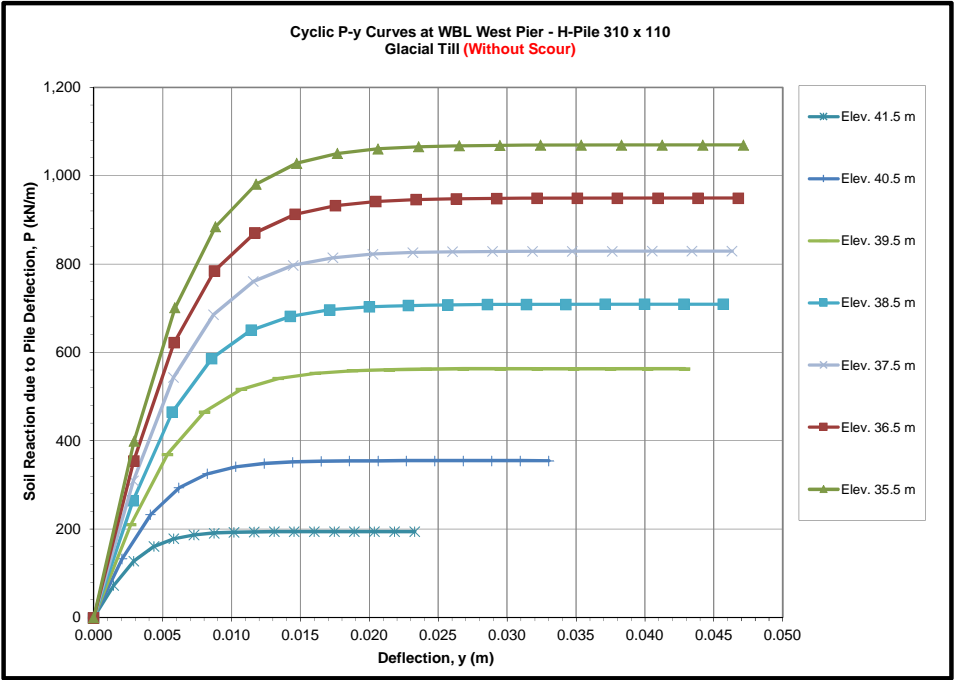
SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - WBL WEST PIER

Description Depth (z) * Elevation P-y Curves	Glacial Till																			
	z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m	
	Elev. 41.5 m		Elev. 41.0 m		Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.001	72.749	0.002	100.450	0.002	132.635	0.002	169.306	0.003	210.463	0.003	242.571	0.003	265.025	0.003	287.478	0.003	309.931	0.003	332.384	0.003
0.003	127.671	0.004	176.284	0.004	232.766	0.005	297.121	0.005	369.349	0.006	425.698	0.006	465.102	0.006	504.506	0.006	543.910	0.006	583.314	0.006
0.004	180.972	0.005	222.265	0.006	293.481	0.007	374.622	0.008	465.690	0.009	536.737	0.009	586.419	0.009	636.101	0.009	685.783	0.009	735.465	0.009
0.006	178.552	0.007	246.539	0.008	325.532	0.009	415.535	0.011	516.549	0.011	595.355	0.011	650.463	0.012	705.571	0.012	760.679	0.012	815.787	0.012
0.007	187.157	0.009	258.421	0.010	341.222	0.012	435.562	0.013	541.444	0.014	624.048	0.014	681.812	0.014	739.576	0.014	797.340	0.014	855.104	0.015
0.009	191.214	0.011	264.023	0.012	348.618	0.014	445.003	0.016	553.180	0.017	637.575	0.017	696.591	0.017	755.607	0.017	814.623	0.017	873.639	0.017
0.010	193.092	0.012	266.616	0.014	352.042	0.017	449.374	0.019	558.614	0.020	643.838	0.020	703.434	0.020	763.030	0.020	822.625	0.020	882.221	0.020
0.012	193.955	0.014	267.807	0.017	353.615	0.019	451.382	0.021	561.110	0.023	646.714	0.023	706.576	0.023	766.438	0.023	826.300	0.023	886.162	0.023
0.013	194.350	0.016	268.352	0.019	354.334	0.021	452.300	0.024	562.251	0.025	648.029	0.026	708.013	0.026	767.997	0.026	827.981	0.026	887.964	0.026
0.015	194.530	0.018	268.601	0.021	354.663	0.024	452.719	0.027	562.772	0.028	648.630	0.029	708.669	0.029	768.709	0.029	828.748	0.029	888.787	0.029
0.016	194.612	0.019	268.714	0.023	354.812	0.026	452.910	0.029	563.010	0.031	648.904	0.031	708.969	0.032	769.033	0.032	829.098	0.032	889.163	0.032
0.017	194.649	0.021	268.766	0.025	354.881	0.028	452.998	0.032	563.118	0.034	649.029	0.034	709.105	0.035	769.182	0.035	829.258	0.035	889.334	0.035
0.019	194.666	0.023	268.789	0.027	354.912	0.031	453.037	0.035	563.168	0.037	649.086	0.037	709.168	0.038	769.249	0.038	829.331	0.038	889.412	0.038
0.020	194.674	0.025	268.800	0.029	354.926	0.033	453.056	0.038	563.190	0.040	649.112	0.040	709.196	0.040	769.280	0.041	829.364	0.041	889.448	0.041
0.022	194.678	0.026	268.805	0.031	354.933	0.036	453.064	0.040	563.201	0.042	649.124	0.043	709.209	0.043	769.294	0.043	829.379	0.044	889.464	0.044
0.023	194.679	0.028	268.807	0.033	354.936	0.038	453.068	0.043	563.205	0.045	649.129	0.046	709.215	0.046	769.300	0.046	829.386	0.047	889.471	0.047

Description Depth (z) * Elevation P-y Curves	Glacial Till (continued)					
	z= 8.5 m		z= 9.0 m		z= 9.5 m	
	Elev. 36.5 m		Elev. 36.0 m		Elev. 35.5 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.003	354.837	0.003	377.291	0.003	399.744	0.003
0.006	622.718	0.006	662.122	0.006	701.526	0.006
0.009	785.147	0.009	834.829	0.009	884.512	0.009
0.012	870.895	0.012	926.003	0.012	981.110	0.012
0.015	912.868	0.015	970.632	0.015	1028.396	0.015
0.018	932.655	0.018	991.671	0.018	1050.687	0.018
0.020	941.817	0.021	1001.413	0.021	1061.008	0.021
0.023	946.024	0.024	1005.886	0.024	1065.748	0.024
0.026	947.948	0.026	1007.932	0.027	1067.916	0.027
0.029	948.827	0.029	1008.866	0.029	1068.905	0.030
0.032	949.228	0.032	1009.292	0.032	1069.357	0.033
0.035	949.410	0.035	1009.487	0.035	1069.563	0.035
0.038	949.494	0.038	1009.575	0.038	1069.657	0.038
0.041	949.532	0.041	1009.616	0.041	1069.700	0.041
0.044	949.549	0.044	1009.634	0.044	1069.719	0.044
0.047	949.557	0.047	1009.643	0.047	1069.728	0.047

NOTES: \* Depth (z) is measured to be positive below the existing ground surface.  
Please note the following assumptions:  
1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.  
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.  
3. There are no pile group effects (i.e., analysis is based on a single pile).  
4. The effects of construction disturbance are not considered.

5. Pier location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.  
6. Groundwater table assumed above top of pile.  
7. Top of pile assumed at Elevation 41.9 m.  
8. No scour is considered, as per Dillon.  
9. Program: Lpile 2016.9.11



CYCLIC P-Y CURVES

Raisin River Overpass  
H-Pile 310x110 - WBL West Abutment (Borehole 17-105, 17-106) - With Organic Deposits

FIGURE F17

SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - WBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Grey Silty Clay to Clay										
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m		
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m		
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.012	171.307	0.011	177.529	0.010	183.751	0.010	189.973	0.009	196.195	0.009	202.417	0.000	5.748	0.000	5.748	0.000	5.748	0.000	5.748	0.000	5.748	0.000	5.748
0.024	300.633	0.022	311.552	0.020	322.472	0.019	333.391	0.018	344.310	0.017	355.230	0.000	11.497	0.000	11.497	0.000	11.497	0.000	11.497	0.000	11.497	0.000	11.497
0.036	379.050	0.033	392.817	0.030	406.585	0.029	420.352	0.027	434.120	0.026	447.887	0.000	17.245	0.000	17.245	0.000	17.245	0.000	17.245	0.000	17.245	0.000	17.245
0.047	420.446	0.044	435.717	0.041	450.988	0.038	466.260	0.036	481.531	0.034	496.802	0.001	22.994	0.001	22.994	0.001	22.994	0.001	22.994	0.001	22.994	0.001	22.994
0.059	440.710	0.055	456.717	0.051	472.724	0.048	488.732	0.045	504.739	0.043	520.746	0.001	28.742	0.001	28.742	0.001	28.742	0.001	28.742	0.001	28.742	0.001	28.742
0.071	450.263	0.065	466.617	0.061	482.971	0.057	499.325	0.054	515.679	0.052	532.033	0.002	34.490	0.002	34.490	0.002	34.490	0.002	34.490	0.002	34.490	0.002	34.490
0.083	454.686	0.076	471.200	0.071	487.715	0.067	504.230	0.063	520.745	0.060	537.260	0.003	40.239	0.003	40.239	0.003	40.239	0.003	40.239	0.003	40.239	0.003	40.239
0.095	456.717	0.087	473.305	0.081	489.894	0.076	506.482	0.072	523.071	0.069	539.659	0.004	45.987	0.004	45.987	0.004	45.987	0.004	45.987	0.004	45.987	0.004	45.987
0.107	457.646	0.098	474.268	0.091	490.890	0.086	507.512	0.081	524.135	0.078	540.757	0.006	51.736	0.006	51.736	0.006	51.736	0.006	51.736	0.006	51.736	0.006	51.736
0.118	458.070	0.109	474.708	0.102	491.345	0.096	507.983	0.090	524.621	0.086	541.258	0.008	57.484	0.008	57.484	0.008	57.484	0.008	57.484	0.008	57.484	0.008	57.484
0.130	458.263	0.120	474.908	0.112	491.553	0.105	508.198	0.099	524.842	0.095	541.487	0.011	63.232	0.011	63.232	0.011	63.232	0.011	63.232	0.011	63.232	0.011	63.232
0.142	458.352	0.131	475.000	0.122	491.647	0.115	508.295	0.109	524.943	0.103	541.591	0.015	68.981	0.015	68.981	0.015	68.981	0.015	68.981	0.015	68.981	0.015	68.981
0.154	458.392	0.142	475.041	0.132	491.691	0.124	508.340	0.118	524.989	0.112	541.639	0.019	74.729	0.019	74.729	0.019	74.729	0.019	74.729	0.019	74.729	0.019	74.729
0.166	458.410	0.153	475.060	0.142	491.710	0.134	508.360	0.127	525.010	0.121	541.660	0.023	80.478	0.023	80.478	0.023	80.478	0.023	80.478	0.023	80.478	0.023	80.478
0.178	458.419	0.164	475.069	0.152	491.719	0.143	508.370	0.136	525.020	0.129	541.670	0.116	80.478	0.116	80.478	0.116	80.478	0.116	80.478	0.116	80.478	0.116	80.478
0.190	458.422	0.175	475.073	0.163	491.723	0.153	508.374	0.145	525.024	0.138	541.675	0.124	80.478	0.124	80.478	0.124	80.478	0.124	80.478	0.124	80.478	0.124	80.478
Description Depth (z) * Elevation P-y Curves	Glacial Till																						
	z= 9.5 m		z= 10.0 m		z= 10.5 m		z= 11.0 m		z= 11.5 m		z= 12.0 m		z= 12.5 m		z= 13.0 m								
	Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m								
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)							
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000						
0.003	400.895	0.003	423.349	0.003	445.802	0.003	468.255	0.003	490.708	0.003	513.161	0.003	535.615	0.003	558.068								
0.006	703.547	0.006	742.951	0.006	782.355	0.006	821.759	0.006	861.163	0.006	900.567	0.006	939.971	0.006	979.375								
0.009	887.059	0.009	936.742	0.009	986.424	0.009	1036.106	0.009	1085.788	0.009	1135.470	0.009	1185.152	0.009	1234.834								
0.012	983.937	0.012	1039.045	0.012	1094.153	0.012	1149.260	0.012	1204.368	0.012	1259.476	0.012	1314.584	0.012	1369.692								
0.015	1031.359	0.015	1089.123	0.015	1146.887	0.015	1204.651	0.015	1262.415	0.015	1320.179	0.015	1377.943	0.015	1435.706								
0.018	1053.714	0.018	1112.730	0.018	1171.746	0.018	1230.762	0.018	1289.778	0.018	1348.794	0.018	1407.810	0.018	1466.826								
0.021	1064.065	0.021	1123.660	0.021	1183.256	0.021	1242.852	0.021	1302.448	0.021	1362.043	0.021	1421.639	0.021	1481.235								
0.024	1068.818	0.024	1128.680	0.024	1188.541	0.024	1248.403	0.024	1308.265	0.024	1368.127	0.024	1427.989	0.024	1487.851								
0.027	1070.992	0.027	1130.975	0.027	1190.959	0.027	1250.943	0.027	1310.927	0.027	1370.910	0.027	1430.894	0.027	1490.878								
0.030	1071.984	0.030	1132.024	0.030	1192.063	0.030	1252.102	0.030	1312.142	0.030	1372.181	0.030	1432.220	0.030	1492.260								
0.033	1072.437	0.033	1132.502	0.033	1192.567	0.033	1252.631	0.033	1312.696	0.033	1372.761	0.033	1432.825	0.033	1492.890								
0.035	1072.644	0.036	1132.720	0.036	1192.796	0.036	1252.873	0.036	1312.949	0.036	1373.025	0.036	1433.101	0.036	1493.178								
0.038	1072.738	0.039	1132.820	0.039	1192.901	0.039	1252.983	0.039	1313.064	0.039	1373.146	0.039	1433.227	0.039	1493.309								
0.041	1072.781	0.042	1132.865	0.042	1192.949	0.042	1253.033	0.042	1313.117	0.042	1373.201	0.042	1433.285	0.042	1493.369								
0.044	1072.801	0.044	1132.886	0.045	1192.971	0.045	1253.056	0.045	1313.141	0.045	1373.226	0.045	1433.311	0.045	1493.396								
0.047	1072.809	0.047	1132.895	0.048	1192.981	0.048	1253.066	0.048	1313.152	0.048	1373.237	0.048	1433.323	0.048	1493.408								

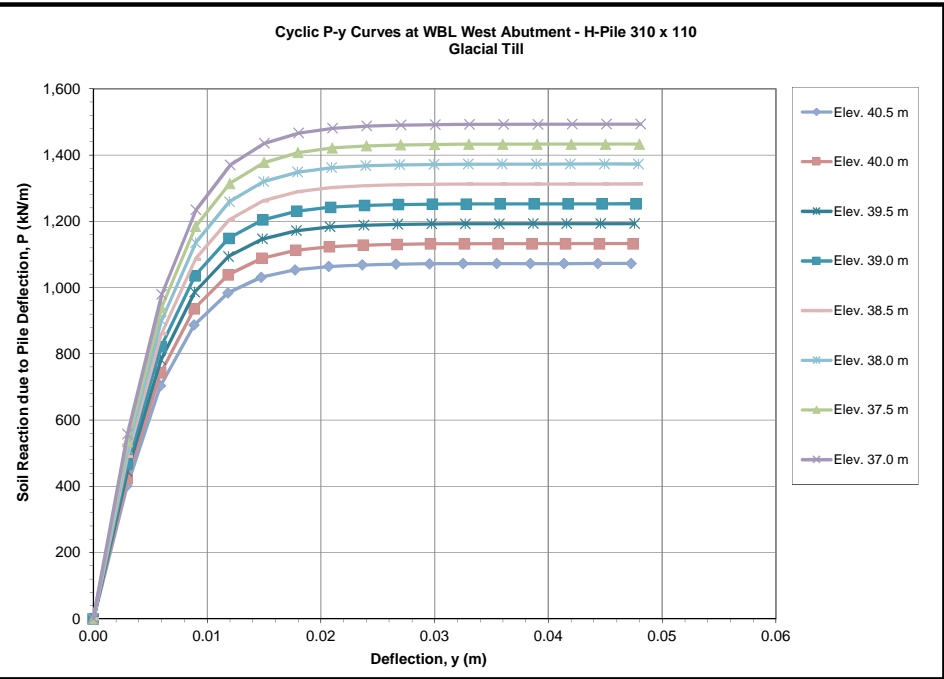
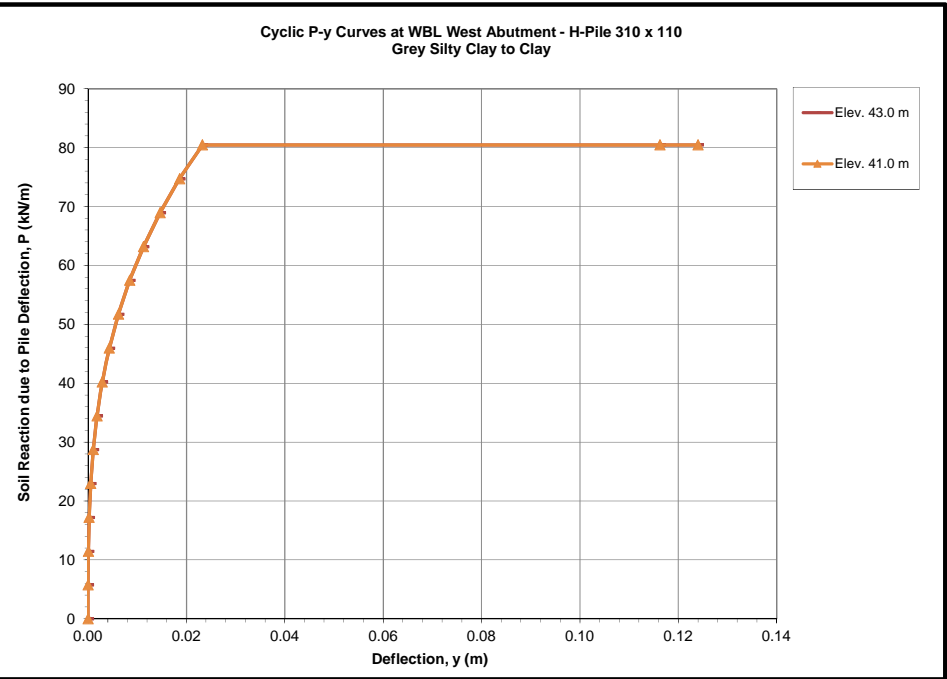
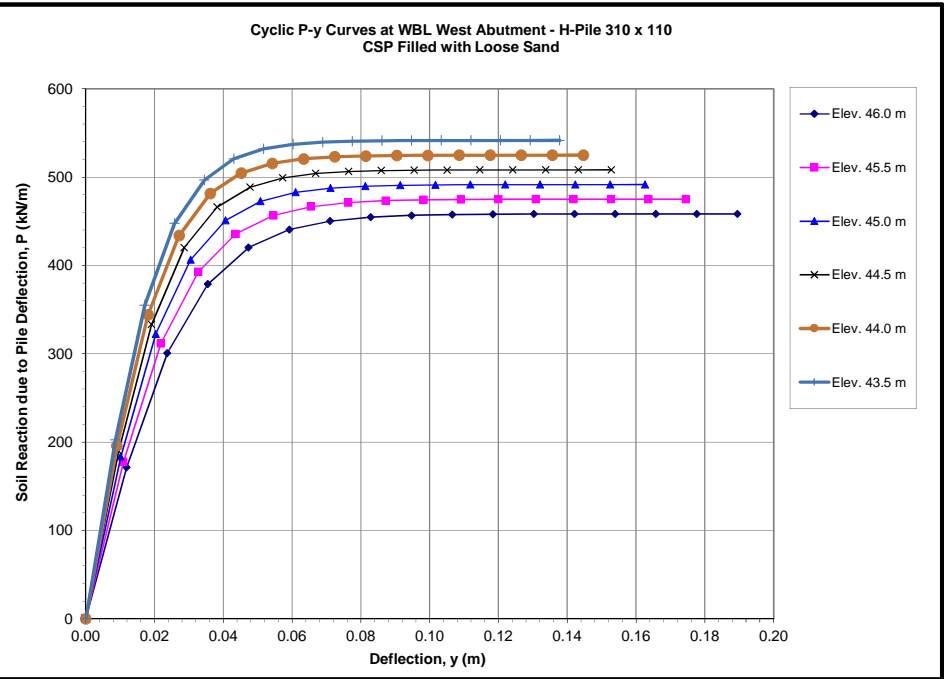
NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Organic deposits layer assumed to remain *in situ*.

9. Program: Lpile 2016.9.11



CYCLIC P-Y CURVES

Raisin River Overpass  
H-Pile 310x110 - WBL West Abutment (Borehole 17-105, 17-106) - Without Organic Deposits

FIGURE F18

SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - WBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	CSP Filled with Loose Sand												Grey Silty Clay to Clay											
	z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 5.5 m		z= 6.0 m		z= 6.5 m		z= 7.0 m		z= 7.5 m		z= 8.0 m		z= 8.5 m		z= 9.0 m			
	Elev. 46.0 m		Elev. 45.5 m		Elev. 45.0 m		Elev. 44.5 m		Elev. 44.0 m		Elev. 43.5 m		Elev. 43.0 m		Elev. 42.5 m		Elev. 42.0 m		Elev. 41.5 m		Elev. 41.0 m			
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)		
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
0.012	178.750	0.012	191.663	0.011	204.577	0.011	217.491	0.011	230.405	0.010	243.318	0.000	5.748	0.000	5.748	0.000	5.748	0.000	5.748	0.000	5.748	0.000	5.748	
0.025	313.695	0.024	336.358	0.023	359.021	0.022	381.683	0.021	404.346	0.021	427.009	0.000	11.497	0.000	11.497	0.000	11.497	0.000	11.497	0.000	11.497	0.000	11.497	
0.037	395.519	0.035	424.093	0.034	452.667	0.033	481.241	0.032	509.815	0.031	538.390	0.000	17.245	0.000	17.245	0.000	17.245	0.000	17.245	0.000	17.245	0.000	17.245	
0.049	438.714	0.047	470.409	0.045	502.104	0.044	533.798	0.042	565.493	0.041	597.188	0.001	22.994	0.001	22.994	0.001	22.994	0.001	22.994	0.001	22.994	0.001	22.994	
0.062	459.858	0.059	493.081	0.057	526.303	0.055	559.525	0.053	592.748	0.052	625.970	0.001	28.742	0.001	28.742	0.001	28.742	0.001	28.742	0.001	28.742	0.001	28.742	
0.074	469.826	0.071	503.768	0.068	537.711	0.066	571.653	0.064	605.596	0.062	639.538	0.002	34.490	0.002	34.490	0.002	34.490	0.002	34.490	0.002	34.490	0.002	34.490	
0.087	474.441	0.082	508.717	0.079	542.993	0.077	577.269	0.074	611.545	0.072	645.821	0.003	40.239	0.003	40.239	0.003	40.239	0.003	40.239	0.003	40.239	0.003	40.239	
0.099	476.560	0.094	510.989	0.091	545.418	0.087	579.847	0.085	614.276	0.083	648.705	0.004	45.987	0.004	45.987	0.004	45.987	0.004	45.987	0.004	45.987	0.004	45.987	
0.111	477.530	0.106	512.029	0.102	546.528	0.098	581.027	0.096	615.526	0.093	650.025	0.006	51.736	0.006	51.736	0.006	51.736	0.006	51.736	0.006	51.736	0.006	51.736	
0.124	477.972	0.118	512.503	0.113	547.034	0.109	581.565	0.106	616.096	0.104	650.627	0.008	57.484	0.008	57.484	0.008	57.484	0.008	57.484	0.008	57.484	0.008	57.484	
0.136	478.174	0.130	512.720	0.124	547.265	0.120	581.811	0.117	616.357	0.114	650.902	0.011	63.232	0.011	63.232	0.011	63.232	0.011	63.232	0.011	63.232	0.011	63.232	
0.148	478.266	0.141	512.819	0.136	547.371	0.131	581.923	0.127	616.475	0.124	651.028	0.015	68.981	0.015	68.981	0.015	68.981	0.015	68.981	0.015	68.981	0.015	68.981	
0.161	478.308	0.153	512.864	0.147	547.419	0.142	581.974	0.138	616.530	0.135	651.085	0.019	74.729	0.019	74.729	0.019	74.729	0.019	74.729	0.019	74.729	0.019	74.729	
0.173	478.327	0.165	512.884	0.158	547.441	0.153	581.998	0.149	616.554	0.145	651.111	0.023	80.478	0.023	80.478	0.023	80.478	0.023	80.478	0.023	80.478	0.023	80.478	
0.185	478.336	0.177	512.894	0.170	547.451	0.164	582.008	0.159	616.566	0.155	651.123	0.116	80.478	0.116	80.478	0.116	80.478	0.116	80.478	0.116	80.478	0.116	80.478	
0.198	478.340	0.188	512.898	0.181	547.455	0.175	582.013	0.170	616.571	0.166	651.128	0.124	80.478	0.124	80.478	0.124	80.478	0.124	80.478	0.124	80.478	0.124	80.478	

Description Depth (z) * Elevation P-y Curves	Glacial Till															
	z= 9.5 m		z= 10.0 m		z= 10.5 m		z= 11.0 m		z= 11.5 m		z= 12.0 m		z= 12.5 m		z= 13.0 m	
	Elev. 40.5 m		Elev. 40.0 m		Elev. 39.5 m		Elev. 39.0 m		Elev. 38.5 m		Elev. 38.0 m		Elev. 37.5 m		Elev. 37.0 m	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.004	476.507	0.004	498.960	0.003	521.413	0.003	543.867	0.003	566.320	0.003	588.773	0.003	611.226	0.003	633.679	
0.007	836.241	0.007	875.645	0.007	915.049	0.007	954.453	0.007	993.857	0.007	1033.261	0.007	1072.665	0.007	1112.069	
0.011	1054.365	0.010	1104.047	0.010	1153.729	0.010	1203.411	0.010	1253.093	0.010	1302.776	0.010	1352.458	0.010	1402.140	
0.014	1169.514	0.014	1224.622	0.014	1279.730	0.014	1334.838	0.014	1389.946	0.014	1445.054	0.014	1500.162	0.014	1555.270	
0.018	1225.880	0.017	1283.644	0.017	1341.408	0.017	1399.172	0.017	1456.936	0.017	1514.700	0.017	1572.464	0.017	1630.228	
0.021	1252.451	0.021	1311.467	0.021	1370.484	0.021	1429.500	0.021	1488.516	0.021	1547.532	0.021	1606.548	0.020	1665.564	
0.025	1264.755	0.024	1324.350	0.024	1383.946	0.024	1443.542	0.024	1503.138	0.024	1562.733	0.024	1622.329	0.024	1681.925	
0.028	1270.404	0.028	1330.266	0.028	1390.128	0.028	1449.990	0.028	1509.852	0.028	1569.714	0.027	1629.576	0.027	1689.438	
0.032	1272.988	0.031	1332.972	0.031	1392.956	0.031	1452.939	0.031	1512.923	0.031	1572.907	0.031	1632.890	0.031	1692.874	
0.035	1274.168	0.035	1334.207	0.035	1394.247	0.035	1454.286	0.035	1514.325	0.034	1574.365	0.034	1634.404	0.034	1694.443	
0.039	1274.706	0.038	1334.771	0.038	1394.836	0.038	1454.900	0.038	1514.965	0.038	1575.030	0.038	1635.095	0.038	1695.159	
0.042	1274.952	0.042	1335.028	0.042	1395.104	0.042	1455.181	0.041	1515.257	0.041	1575.333	0.041	1635.410	0.041	1695.486	
0.046	1275.064	0.045	1335.145	0.045	1395.227	0.045	1455.308	0.045	1515.390	0.045	1575.472	0.045	1635.553	0.044	1695.635	
0.049	1275.115	0.049	1335.199	0.049	1395.283	0.048	1455.367	0.048	1515.451	0.048	1575.535	0.048	1635.619	0.048	1695.703	
0.053	1275.138	0.052	1335.223	0.052	1395.308	0.052	1455.393	0.052	1515.478	0.052	1575.563	0.051	1635.648	0.051	1695.733	
0.056	1275.149	0.056	1335.234	0.056	1395.320	0.055	1455.405	0.055	1515.491	0.055	1575.577	0.055	1635.662	0.055	1695.748	

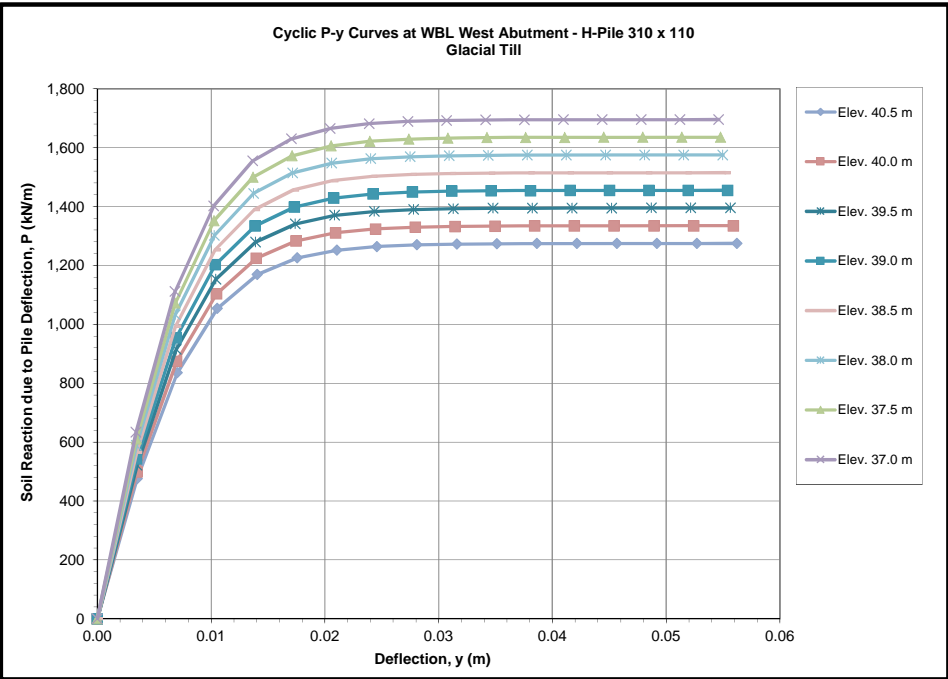
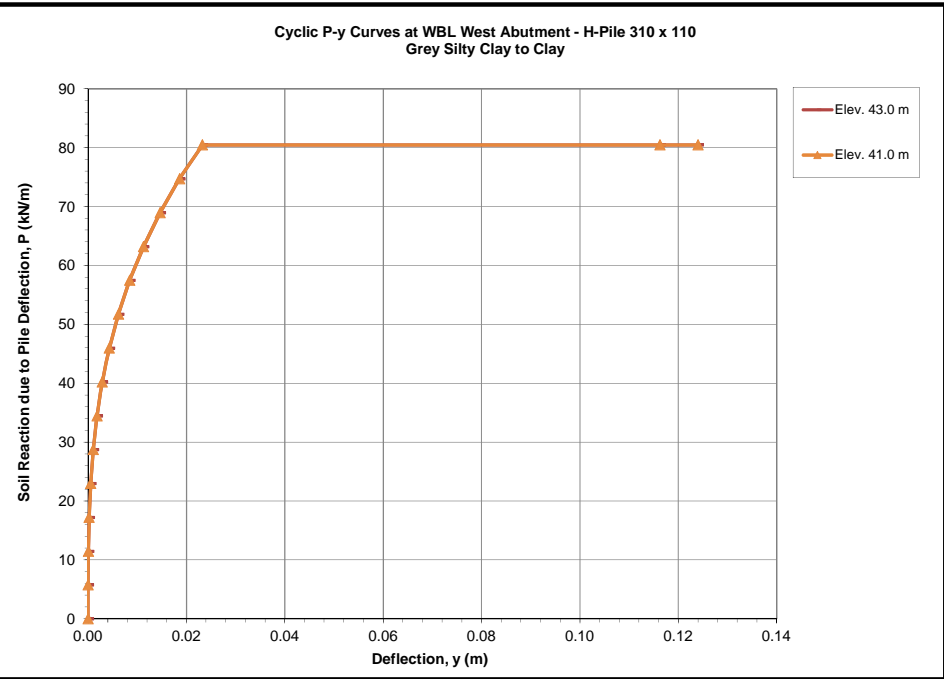
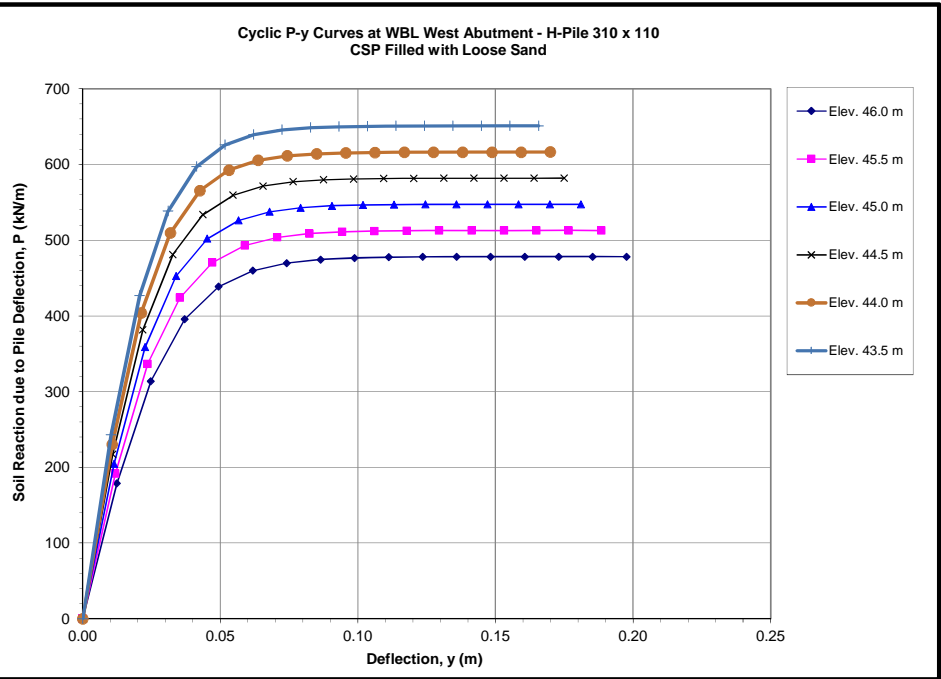
NOTES: \* Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

1. Cyclic p-y curves have been generated for a vertical pile (i.e., no inclination) with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 cycles of loading are assumed. Lateral loading is considered normal to the strong axis.
3. There are no pile group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment location as per Dillon's 31-231-09-GA.dwg, received September 20, 2018.
6. Groundwater table assumed at Elevation 47.0 m.
7. Top of pile assumed at Elevation 46.1 m.
8. Organic deposits layer removed and replaced with new embankment fill.

9. Program: Lpile 2016.9.11



**APPENDIX G**

**Non-Standard Special Provisions**

## **DEWATERING – Item No.**

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### **Special Provision**

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#### **Amendment to OPSS.PROV 517, November 2016**

##### **517.01 SCOPE**

Section 517.01 of OPSS.PROV 517 shall be amended by the addition of the following:

Construction of the foundations for the bridge replacements will require excavation into the existing granular embankment fill and the underlying native granular deposits, organic material, silty clay to clay and/or till below the groundwater level at the site and below the water level in the Raisin River. The cohesionless soils below the groundwater table will be subjected to conditions of unbalanced hydrostatic head and can slough, boil and cave in during temporary excavation work.

##### **517.02 REFERENCES**

Section 517.02 of OPSS.PROV 517 shall be amended by the addition of the following:

OPSS 902                      Construction Specification for Excavation and Backfilling - Structures

##### **517.04 DESIGN AND SUBMISSION REQUIREMENTS**

Section 517.04.01 of OPSS.PROV 517 shall be amended by the addition of the following:

Written details for the proposed dewatering system shall be submitted to the Contract Administrator for information purposes a minimum of ten business days prior to commencing dewatering operations. The Contractor shall reference borehole logs included in the contract documents as a guide in determining dewatering requirements.

##### **517.07 CONSTRUCTION**

Section 517.07.02 of OPSS.PROV 517 shall be amended by the addition of the following:

The Contractor shall select and design temporary dewatering system(s) to lower surface water and groundwater levels in the excavation areas to at least 0.3 m below the required excavation level for the bridge replacements, to allow excavation, foundation subgrade preparation and foundation construction in dry conditions.

Water pumped from excavations shall be redirected into the watercourse downstream of the work area in a manner that is not injurious to public health or safety, to property, to the environment or to any part of the work already completed or under construction.

Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade soils.

A continuous dewatering operation shall be provided to facilitate the construction at all times during the work. All components of the dewatering system shall be maintained in an effective, functioning and stable condition at all times during the work. Notwithstanding the above, the work shall be completed in

accordance with the environmental and operational constraints specified elsewhere in the contract.

All equipment and materials placed shall be removed from the right-of-way upon the completion of the work and all areas disturbed as part of this work shall be restored to their preconstruction conditions, unless specified otherwise.



## **Deep Foundations - Item No.**

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Special Provision

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### **Amendment to OPSS 903, April 2016**

#### **Vibration Monitoring During Piling**

This special provision describes requirements for vibration monitoring during pile installation works.

#### **Definitions**

Contractor's Engineer: An Engineer with a minimum of five (5) years experience in the field of installation of piling and vibration monitoring or alternatively has demonstrated expertise by providing satisfactory quality verification services for the piling work at a minimum of two (2) projects of similar scope to the contract. The Contractor's Engineer shall be retained by the Contractor to ensure general conformance with the contract documents and shall issue certificate(s) of conformance.

#### **Submission Requirements**

The Contractor shall submit details of the vibration monitoring plan to the Contractor's Engineer for review. The submittals shall satisfy the specifications and at a minimum contain the following specific information:

- Qualifications of vibrations monitoring specialist;
- Proposed instrumentation;
- Proposed location of instruments;
- Proposed frequency of readings; and,
- Proposed methods for adjusting piling methods if readings show vibrations exceeding tolerable levels.

The submittals shall satisfy the specifications and at a minimum contain the above information as provided to the Contractor's Engineer.

#### **Monitoring**

The Contractor's Engineer shall take readings during driving of each pile. The readings should be taken and recorded during the entire length of driving and during seating of the pile on the bedrock (if applicable). As a minimum, one vibration monitoring point shall be installed on the nearest existing abutment wall to the pile driving activities.

The pile(s) furthest from the monitored structure or utility should be driven first to assess the vibration level at the existing structures. If necessary, the contractor must alter the pile driving procedures for the remaining piles. The revised procedure shall be submitted to the Contract Administrator for approval prior to driving the remaining piles.

The measured vibrations shall not exceed 100 mm/s (peak particle velocity).

If it is not practical to drive the piles furthest from the existing structure first due to space constraints, the piles nearest the existing structure may be driven first but the measured vibrations in that case shall not exceed 50 mm/s.

The results shall be submitted to the Contract Administrator after each pile has been driven and prior to continuing with the subsequent piles. As a minimum, the pile number, location, set criteria and driving log must be submitted with vibration monitoring results.

If the vibration monitoring results are acceptable, the Contractor may continue with the next piles with readings taken during driving of each pile. The results of subsequent piles should be submitted to the Contract Administrator after each pile has been driven.

If the readings are not within the limits stated above, the Contractor must alter the driving procedures until the vibrations are within acceptable levels. The above process must be repeated for each pile.

### **Basis of Payment**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

**Deep Foundations - Item No.**

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Special Provision

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**Amendment to OPSS 903, April 2016**

**Obstructions During Piling**

This special provision describes requirements for pile installation through obstructions and natural cobbles and boulders.

**Definitions**

Foundation Engineering Specialist (FES): An Engineer with a minimum of five (5) years experience in the field of installation of piling and vibration monitoring or alternatively has demonstrated expertise by providing satisfactory quality verification services for the piling work at a minimum of two (2) projects of similar scope to the contract. The FES shall be retained by the Contract Administrator to ensure general conformance with the contract documents and shall issue certificate(s) of conformance.

**Submission Requirements**

The Contractor shall submit details for advancing the piles through obstructions, cobbles and boulders. The submittals shall satisfy the specifications and at a minimum contain specific information on their approach to advancing the piles in the event such conditions are encountered.

**Pile Driving Through Obstacles, Cobbles, Boulders**

The soils at the site are glacially-derived and are known to contain cobbles and boulders within the till deposits. The embankment fills at the site may also contain some obstructions. The Contractor is advised that appropriate equipment and construction procedures will be required to penetrate or remove obstructions, such as cobbles and boulders, to permit installation of deep foundations.

**Basis of Payment**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION



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