



REPORT

Foundation Investigation and Design CPR Overhead Bridge Rehabilitation Site No. 3-302/1 (EBL) and Site 3-302/2 (WBL) Highway 417 Ottawa Ontario

G.W.P. 4074-11-00

W.P. 267-00-01 and 267-00-02

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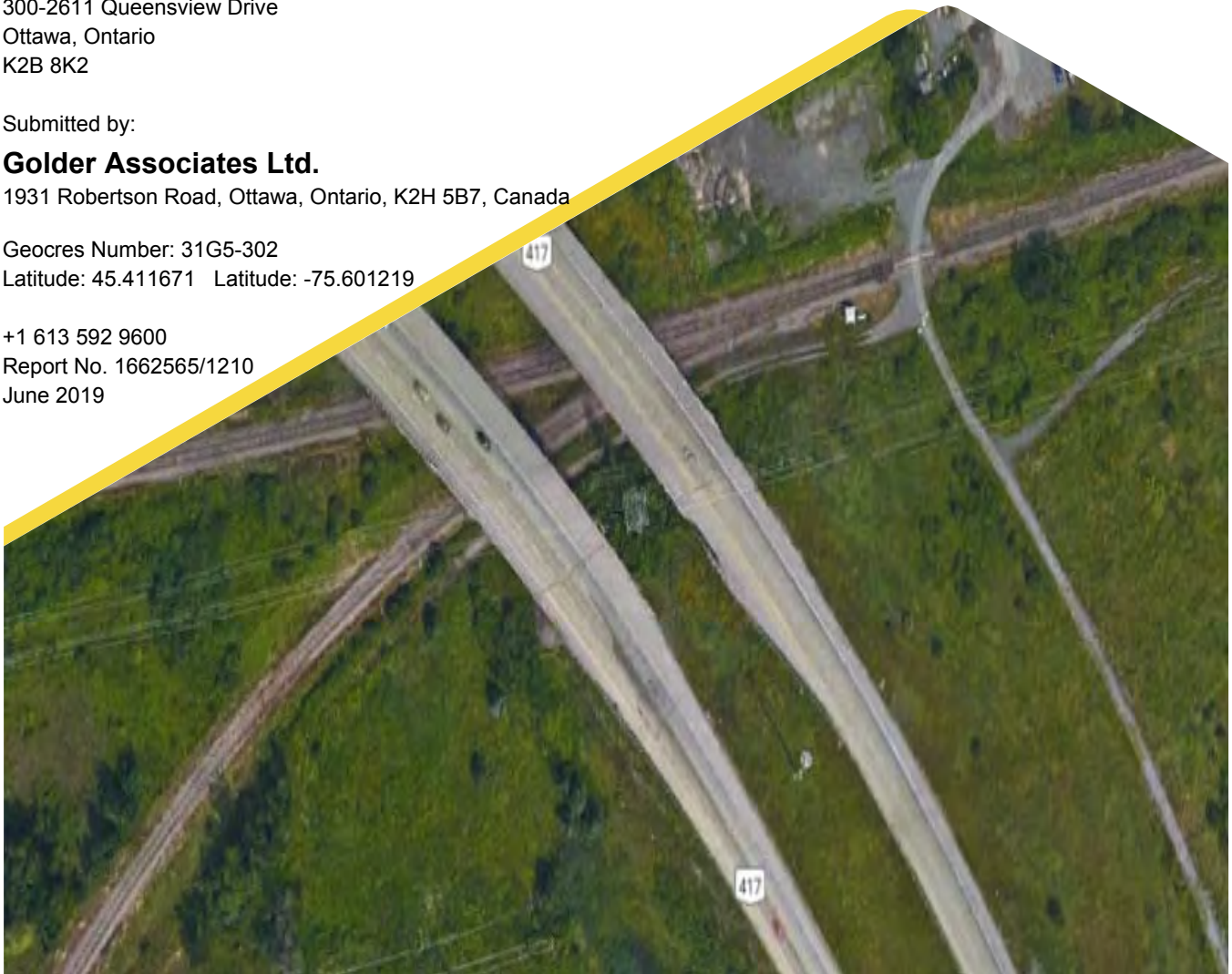
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PART A – FOUNDATION INVESTIGATION

Highway 417 CPR Overhead
Bridge Rehabilitation
Site No. 3-302/1 (EBL) and Site 3-302/2 (WBL)
Ottawa, Ontario
G.W.P. 4074-11-00
W.P. 267-00-01 and 267-00-02

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by WSP Canada Group Limited (WSP) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with numerous bridges and structural culverts rehabilitation and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road and also includes widening of Highway 417 from Ottawa Road 174 to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out to collect subsurface information required for the static and seismic assessment of the bridge foundations, and provision of temporary protection systems (TPS) as input to the rehabilitation of the Canadian Pacific Railway (CPR) Overhead bridge, Site No. 3-302/1 (Eastbound Lane) and Site No. 3-302/2 (Westbound Lane) located on Highway 417 in Ottawa, Ontario (G.W.P. 4074-11-00; W.P. 267-00-01 and 267-00-02, respectively). The rehabilitation of the existing structures is to be carried out in accordance with the current version of the Canadian Highway Bridge Design Code (CHBDC, S6-14).

The terms of reference and scope of work for the foundation investigation are outlined in the MTO's Request for Proposal, dated May 2016, and subsequent addenda. Golder's scope of work for foundation engineering services associated with the CPR Overhead bridge at Highway 417 is contained in Table 17.8.3 of WSP's Technical Proposal for this assignment dated June 28, 2016. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for this project dated March 13, 2017.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 Site Description

The CPR Overhead structures are located within a mixed-use area of the City of Ottawa, and are located approximately 740 m southeast of Innes Road exit on Highway 417. At this location, Highway 417 is a divided highway with two through lanes in each direction with a widened shoulder on each inside lane. The eastbound structure also accommodates an acceleration lane from the Innes Road interchange.

The railway tracks at this site are owned by CPR and operated by VIA Rail and Canadian National Railway (CNR). The tracks start to form a Y configuration just east of the CPR Overhead structures, forming two distinct rail lines west of the structures connecting to the mainline CNR line to Ottawa immediately west of Highway 417. The track of the main CPR line, splitting off to the southwest just west of the CPR Overhead structures, has been abandoned and removed approximately 400 m east of the structures where it has then been converted to a recreational trail.

The existing eastbound CPR Overhead bridge structure (Site No. 3-302/1) was constructed in 1975. The bridge is a four span, 79.0 m long (20.4 m, 19.1 m, 19.1 m and 20.4 m), reinforced concrete slab on prestressed girders (AASHTO III) structure. The overall structure width is 20.4 m including barrier walls, with a roadway width of 19.5 m. The bridge carries two through lanes of eastbound traffic and one on-ramp. The bridge abutments sit on "perched" foundations supported on vertical battered steel piles end bearing on bedrock. The piles are battered in line with the Highway 417 Lanes. The west and centre piers (Pier 1 and Pier 2, respectively) consist of five circular columns and the east pier (Pier 3) consists of 4 circular columns. The piers are supported on concrete caissons socketed in the bedrock.

The existing westbound CPR Overhead bridge structure (Site No. 3-302/2) was constructed in 1975. The bridge is a three span, 64.0 m long (19.5 m, 24.1 m and 20.4 m) reinforced concrete slab on prestressed girders (AASHTO III) structure. The overall structure width is 17.4 m including barrier walls, with a roadway width of 16.5 m. The bridge carries two through lanes of westbound traffic. The bridge abutments sit on “perched” foundations supported on vertical and battered steel piles end bearing on bedrock. The west and east piers (Pier 1 and Pier 2, respectively) consist of four circular columns supported on concrete caissons socketed in the bedrock.

Based on visual observation at the time of planning and carrying out the site investigation, the existing foundations and embankment side slopes appear to be performing satisfactorily.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984), this section of Highway 417 lies on the boundary of the minor physiographic regions known as the Ottawa Valley Clay Plain and the Russell and Prescott Sand plain, which lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Ottawa Valley Clay Plain region is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the Champlain Sea basin. These deposits, known as the Champlain Sea clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock. The Russell and Prescott Sand Plains are generally characterized by a sand mantle about 3 to 5 m thick overlying an extensive deposit of sensitive marine clay deposited within the Champlain Sea basin, underlain by glacial till and shale bedrock. This region is underlain by a series of sedimentary rocks, consisting of sandstones, dolostones, limestones and shales that are, in turn, underlain at depth by bedrock of the Carlsbad Formation.

The site falls within the Western Québec (WQ) seismic zone according to the Geological Survey of Canada. The WQ zone constitutes a large area which encompasses the urban areas of Montreal, Ottawa-Hull and Cornwall. Within the WQ zone recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. The two major earthquakes in the WQ zone includes the 1935 Témiscaming event which had a magnitude (i.e., a measure of the intensity of the earthquake) of 6.2, and the 1944 Cornwall-Massena event which had a magnitude of 5.6.

3.0 INVESTIGATION PROCEDURES

3.1 Current Investigation (2018)

The field work for the current subsurface investigation was carried out on June 8 and 9, 2018 and between June 20 to 27, 2018. During that time, four boreholes (numbered 18-2101 to 18-2104, inclusive) were advanced within the driving lanes of Highway 417 at the location of the existing abutments. The borehole location are shown on Drawings 1 and 2.

The boreholes were advanced using 108 inside diameter (200 mm outside diameter) continuous flight hollow stem augers on truck mounted drill rigs supplied and operated by George Downing Estate Drilling Ltd. of Grenville-sur-la-rouge, Québec. The boreholes were advanced to about 11.0 m to 25.4 m depth below the ground surface.

Samples of the overburden were obtained at 0.8 to 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586).

Upon reaching refusal to casing advancement in Borehole 18-2104, the borehole was advanced into the bedrock surface to a depth of about 3.4 m using rotary diamond drilling techniques while retrieving HQ3 sized core. A water truck was on site to supply the drill rig with water for advancing the casing in the overburden and for coring the bedrock. Traffic control required to close the driving lanes of Highway 417 at the site was supplied by Beacon Lite Ltd. of Ottawa, Ontario.

One monitoring well was installed in Borehole 18-2102 to monitor the groundwater level at the site. The monitoring well consisted of 30 mm outside diameter PVC tubing with a 3.0 m long screen. The groundwater level was measured in the monitoring well on July 25, 2018.

The remainder of the boreholes were backfilled with bentonite mixed with soil cuttings. The site conditions were restored following completion of the field work.

The field work was supervised on a full time basis by a member of Golder's staff who located the boreholes in the field, directed the drilling, sampling, and in-situ testing operations, logged the boreholes, and examined and cared for the soil and bedrock samples. The soil and bedrock samples were identified in the field, placed in appropriate containers, and transported to Golder's laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations, Atterberg Limit tests, and grain size distribution analyses were carried out on selected soil samples at the Golder Ottawa laboratory. One unconfined compressive strength test was carried out on a selected rock core specimen at Golder's laboratory. The laboratory tests were carried out to MTO and/or ASTM standards, as appropriate.

In addition to the borehole investigation, shear wave velocity profiling at the site was completed using the Multichannel Analysis of Surface Waves (MASW) technique. Two tests were conducted on July 18, 2018 by personnel from the Golder Associates' Mississauga office. A series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. A 9.9 kg sledge hammer and 45 kg weight drop were used as the seismic source. The source locations were offset at distances of 5, 10, and 15 m off the end and collinear with the geophone array.

The borehole locations and elevations were surveyed by Golder using a Trimble R8 GPS unit. The borehole locations, including MTM NAD83 northing and easting coordinates, ground surface elevations referenced to geodetic datum, and drilled depth are summarized in the following table and are shown on Drawing 1 and 2.

Table 1: Summary of Borehole Locations

Borehole Number	Borehole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Total Depth (m)
18-2101	Hwy 417 EBL west abutment	5030617.4	375081.8	75.0	17.4
18-2102	Hwy 417 WBL west abutment	5030619.8	375121.6	74.2	17.4
18-2103	Hwy 417 EBL east abutment	5030551.6	375173.1	75.6	11.0
18-2104	Hwy 417 WBL east abutment	5030560.7	375196.9	74.7	25.4

3.2 Previous Investigation (1972)

A previous investigation was carried out on November 1972 by the MTO (then the Department of Transportation and Communications) for the design of the existing overpass structures. The results of that investigation are contained in the report titled “*Foundation Investigation Report for Proposed New Structures at the Crossing of Hwy. #417 and C.P.R., Regional Municipality of Ottawa-Carleton, District #9 - Ottawa, W.O. 71-11126 - W.P. 13-68-06, 13-68-07*”, dated February 17, 1972 (GEOCRE No. 31G5-80).

As part of the current assignment, this previously collected subsurface information pertinent to the site was reviewed and compiled.

A total of twelve boreholes, ten with an adjacent Dynamic Cone Penetration Test (DCPT) were put down at the site as part of the original investigation along the then-proposed bridge alignments. The approximate borehole and ground surface elevations are shown on the Record of Borehole sheets included in Appendix C and are also shown on Drawings 1 and 2. The locations and ground surface elevations of the previous boreholes and DCPTs should be considered approximate since the locations were referenced to an imperial borehole location plan rather than metric MTM coordinates. The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the borehole records from the 1972 investigation.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The subsurface soil and groundwater conditions encountered in the boreholes and the results of in-situ and laboratory testing from the current investigation are given on the Record of Borehole sheets presented in Appendix A. The results of geotechnical laboratory testing from the current investigation are presented on Figures B1 to B5 in Appendix B. Photos of the bedrock core from the current investigation are provided in Figure A1 in Appendix A. The Record of Borehole sheets as well as laboratory testing from the previous investigation at the site (GEOCRE No. 31G5-80) are provided for reference in Appendix C. The results of basic chemical analysis completed on select soil samples are provided in Appendix D. The borehole locations and the interpreted stratigraphic profile projected along the CPR Overhead structures are shown on Drawings 1 and 2.

The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile are inferred from observations of drilling progress and noncontinuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

The MASW test results and report are presented in Appendix E and include the calculated shear wave velocity profile measured from the field testing and a graphical representation of the shear wave velocity profile with depth.

Photographs of the site are shown in Appendix G.

In general, the subsurface conditions at the borehole locations consist of pavement structure and embankment fill extending down to depths of about 7.6 m to 11.3 m (Elevations 63.5 m to 68.0 m) over a discontinuous deposit of silty clay extending down to a depth of about 12.2 m (Elevation 62.8 m). The fill and clayey silt are underlain by a deposit of sand to silty sand extending down to depths of about 17.4 m to 18.3 m (Elevations 56.4 m to 57.6 m). The embankment fill and sandy deposit are overlying a discontinuous deposit of glacial till extending down to depths of about 11.0 m to 22.0 m (Elevations 52.7 m to 64.6 m) and the shale bedrock. Shale bedrock was indicated to be present at depths of about 22.0 m (Elevation 52.7 m). The groundwater level was encountered at a depth of about 14.0 m (Elevation 60.2 m).

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2 Pavement Structure and Fill

Boreholes 18-2101 and 18-2103 were advanced through the pavement structure of the EBL left shoulder of Highway 417 and Boreholes 18-2102 and 18-2104 were advanced through the pavement structure of the WBL left shoulder of Highway 417. The pavement structure at these locations consists of about 200 mm of asphaltic concrete over 0.5 to 1.3 m of gravelly sand base layer.

SPT 'N' values ranging from 39 to 82 blows per 0.3 m of penetration were measured in the gravelly sand base layer, indicating a compact to very dense state of packing.

The pavement structure is underlain by embankment fill in Boreholes 18-2101 to 18-2104. The embankment fill extends to depths ranging from about 9.1 to 11.3 m below the existing ground surface (Elevations ranging from about 63.5 to 68.0 m) and consists of sand and gravel, sandy gravel to sand with varying amount of silt and clay to silty clay. The fill also contains cobbles, boulders, and shale fragments.

SPT 'N' values ranging from 6 to greater than 50 blows per 0.3 m of penetration were measured in the embankment fill, indicating a loose to very dense state of packing.

The results of grain size distribution testing were carried out on ten samples of the embankment fill are provided on Figure B1.

The results of Atterberg Limits testing on two samples of silty clay fill gave a plasticity index of about 9 and 12 percent and a liquid limit of about 25 and 28 percent, which indicates a silty clay of low plasticity.

The measured water content of 20 samples of the embankment fill range from about 3 to 22 percent. The results of the Atterberg limit testing are provided on Figure B2.

4.3 Silty Clay

A deposit of silty clay exists below the embankment fill in Borehole 18-2101. The silty clay extends to a depth of about 12.2 m below the existing ground surface (Elevation 62.8 m).

One SPT 'N' value of 11 blows per 0.3 m of penetration was measured in the silty clay, indicating a stiff consistency.

The results of Atterberg Limit testing carried out on one sample of the silty clay gave a plasticity index value of about 11 percent and a liquid limit value of about 26 percent indicating a silty clay of low plasticity. The measured water content of one sample of the silty clay is 21 percent. The results of the Atterberg limit testing are provided on Figure B3.

4.4 Silty Sand to Sand

A deposit of silty sand to sand with varying amounts of gravel and clay was encountered below the embankment fill and silty clay, where encountered, in Boreholes 18-2101, 18-2102, and 18-2104 and at the ground surface in Boreholes 1 to 12. Where penetrated, the silty sand to sand extends to a depth of about 18.3 m below the existing Highway 417 grade at Borehole 18-2104, and up to about 11.0 m below the existing natural ground surface at the time of the 1971 borehole investigation (Elevations ranging from about 54.0 to 56.4 m).

SPT 'N' values measured in the silty sand to sand deposit range from 18 to 48 blows per 0.3 m of penetration, indicating a compact to dense state of packing.

The measured water contents of the silty sand to sand range from about 7 to 20 percent.

The results of grain size distribution testing carried out on seven samples of the silty sand to sand deposit are provided on Figure B4.

4.5 Silty sand (Till)

A deposit of glacial till was encountered below the silty sand to sand in Borehole 18-2104. The till generally consists of a heterogeneous mixture of gravel, cobbles and boulders in a soil matrix of silty sand. Though not encountered at all borehole locations, the till is expected to contain cobbles and boulders. The till extends to a depth of about 22.0 m below the existing ground surface (Elevation 52.7 m) in Borehole 18-2104.

SPT 'N' values ranging from 30 to greater than 50 blows per 0.3 m of penetration were measured in the till deposit, indicating a dense to very dense state of packing.

The measured water contents of five samples of till range from about 9 to 15 percent.

The results of grain size distribution testing carried out on two samples of till are provided on Figure B5.

4.6 Auger Refusal and Bedrock

The bedrock was encountered below the overburden in Borehole 18-2104 from the current investigation and Boreholes 2, 7, 8, and 11 from the previous investigation.

The surface of the bedrock was encountered at a depth of about 22.0 m below the existing ground surface (Elevations 52.7 m) and was cored for a length of about 3.4 m while retrieving HQ3 sized bedrock core.

The following table summarizes the sound bedrock surface depths and elevations as encountered at the borehole location from the current and the previous investigations.

Table 2: Summary of Bedrock Depth and Elevation

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
18-2104	74.7	22	52.7
2	64.1	11.0	53.1
3	64.3	11.9 ⁽¹⁾	52.5 ⁽¹⁾
5	64.0	10.4	53.7
7	64.4	10.1	54.3
8	64.0	10.1	54.0
9	63.8	9.7 ⁽¹⁾	54.0 ⁽¹⁾
10	64.3	9.8 ⁽¹⁾	54.5 ⁽¹⁾
11	64.1	9.8	54.3

Note ⁽¹⁾: Depth and elevation to bedrock inferred from refusal to auger advancement.

The bedrock encountered at the site consists of fresh, thinly bedded, dark grey to black, fine grained shale. The Rock Quality Designation (RQD) values of the cored bedrock are about 39 to 100 percent, indicating a poor to excellent quality rock.

Photos of the bedrock core obtained from Borehole 18-2104 during the current investigation are provided in Appendix A on Figure A1.

Results of unconfined compressive strength testing carried out on one bedrock core sample are presented in Figure B6. The result is 71.5 MPa indicating a strong bedrock.

4.7 Groundwater Conditions

A monitoring well was installed in Borehole 18-2102 to monitor the groundwater level at the site. The water level measured in the monitoring well in Borehole 18-2102 on July 25, 2018 is summarized in the table below.

Table 3: Summary of Groundwater Conditions

Borehole Number	Existing Ground Surface Elevation (m)	Water Level Depth (m)	Screened Interval	Water Level Elevation (m)	Date
18-2102	74.2	14.0	Sand	60.2	July 25, 2018

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

5.0 CLOSURE

This report was prepared by Mr. Fady Ghobrial, Geotechnical Specialist. It was reviewed by Mr. Michael Snow, P.Eng., a Senior Geotechnical Engineer. Mr. Fintan Heffernan, P.Eng. a Senior Consultant with Golder and the Designated MTO Foundations Contact for this project, conducted an independent quality control review of this report.

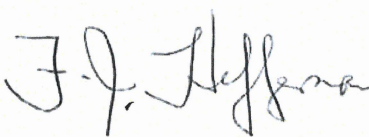
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MSS/FJH/mvrd

[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1210 cpr/final/1662565-1210-001-r-r-rev0-cpr overhead-06_2019 fidr.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6%20-%20reports/1210%20cpr/final/1662565-1210-001-r-r-rev0-cpr%20overhead-06_2019%20fidr.docx)

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PART B – FOUNDATION DESIGN

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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides geotechnical input to the rehabilitation and seismic evaluation, and temporary protection systems (TPSs) of the CPR Overhead bridge structure (MTO Structure Site No. 3-302/1 and 3-302/2) in Ottawa, Ontario. The input provided herein is based on an interpretation of the factual data obtained from the available GEOCRESS information and the boreholes advanced during the current subsurface investigation. The input includes static and seismic design considerations for assessment of the foundations as part of the seismic evaluation of the overpass bridge in accordance with the current Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC; CSA, 2014).

The foundation investigation report, discussion, and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including construction contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Existing Foundations

Based on the original structural design drawings for Site No. 3-302/1, (W.P. 13-68-06, Dwg Nos. 3-302A-1 to 3-302A-18), the grade of Highway 417 EBL ranges up to about Elevation 74.7 m at the west abutment and Elevation 75.2 at the east abutment. The bridge is a four-span, 79.0 m long (20.4 m, 19.1 m, 19.1 m, and 20.4 m), reinforced concrete slab on prestressed girders (AASHTO III) structure. The structure is supported by three piers and conventional spill-through abutments. The bridge abutments are supported on “perched” foundation on battered steel HP12×74 (HP310x110) piles end bearing on bedrock. The pile batters are 1H:6V and 1H:3V. The west and centre piers (Pier 1 and Pier 2, respectively) consist of five circular columns and the east pier (Pier 3) consists of 4 circular columns. The columns are supported on concrete caissons socketed in bedrock. The concrete caissons are surrounded by a 1,077 mm diameter steel casing through the overburden with a 914 mm diameter socket extending 300 mm into sound bedrock.

Based on the original structural design drawings for Site No. 3-302/2, (W.P. 13-68-07, Dwg Nos. 3-302B-1 to 3-302B-17), the grade of Highway 417 WBL ranges up to about Elevation 74.9 m at the west abutment and Elevation 75.2 m at the east abutment. The bridge is a three-span, 64.0 m long, (19.5 m, 24.1 m, and 20.4 m), reinforced concrete slab on prestressed girders (AASHTO III) structure. The structure is supported by two piers and conventional spill-through abutments. The bridge abutments are supported on “perched” foundation on battered steel HP12×74 (HP310x110) piles end bearing on bedrock. The pile batters are 1H:6V and 1H:3V. The west and east piers (Pier 1 and Pier 2, respectively) consist of four circular columns supported on concrete caissons socketed in bedrock. The concrete caissons are surrounded by a 1,077 mm diameter steel casing through the overburden with a 914 mm diameter socket extending 300 mm into sound bedrock.

6.3 Seismic Design

6.3.1 Seismic Hazard and Importance Category

The CHBDC states that the seismic hazard values associated with the design earthquakes should be those established for the National Building Code of Canada (NBCC) by the Geological Survey of Canada (GSC). The current seismic hazard maps (referred to as the 5th generation seismic hazard maps) were developed by the GSC and were made available for public use in December 2015 (NRCAN, 2019).

In accordance with Section 4.4.2 of the CHBDC, and as specified in the RFP by the MTO, the bridge structures have been given an importance category of “Major-Route” bridge.

6.3.2 Seismic Site Classification

Multichannel Analysis of Surface Waves (MASW) geophysical testing was carried out within the Highway 417 median between the EBL and WBL overhead bridges to evaluate the average shear wave velocity of the upper 30 m of soil/bedrock at the site. The shear wave velocities measured at the site are presented in a technical memorandum (see results in Appendix E) and indicate that the average shear wave velocity in the upper 30 m of the subsurface stratigraphy at the two MASW locations were 391 m/s and 494 m/s.

Based on drawing Nos 3-302A-3 and 3-302B-3 that show the foundation plan for EBL bridge and WBL bridge, respectively, the abutments and the north wall are supported on end-bearing steel piles driven to bedrock, while the columns of the piers are supported on caissons socketed into the bedrock. The elevation of the underside of pile caps at the abutments varies between 69.0 m and 70.7 m. Hence, based on the results of the MASW testing and the depth to bedrock encountered at Borehole 18-2104 location, the shear wave velocity in the upper 30 metres of the site is on the order of 460 to 547 m/s. For the piers of both bridges, the top of the casing is almost at ground surface at elevation of about 64.3 m to 64.9 m. Consequently, the shear wave velocity in the upper 30 metres of the site is on the order of 531 to 627 m/s. Based on these values it is considered that a Site Class C designation is appropriate for the seismic design of the bridge.

However, table 4.1 of the CHBDC also specifies circumstances for which a Site Class of F is applicable and a site-specific response evaluation must be carried out; the presence of liquefiable soils is one of those conditions. As presented below in Section 6.3.7, this site is underlain by very localized horizons of native soil identified in Geocres boreholes at the EBL pier locations which are considered to have a small probability to undergo liquefaction under the design 2,475 year earthquake event using a simplified approach. As such, a site-specific evaluation was undertaken to refine the liquefaction analysis at these piers during the 2,475 earthquake as described below. The refined analysis indicates that these localized areas at the EBL piers do not represent a risk for liquefaction under the 2,475 design earthquake and a Site Class C designation can be retained.

6.3.3 Site-Specific Ground Response Analysis

The site-specific seismic assessment was carried out to model the dynamic ground response at the site as input to the updated liquefaction assessment. 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.

6.3.4 Spectral Response Values, Target Spectrum and Seismic Performance Category

In accordance with Section 4.4.3.1 of the CHBDC and based on the location of the bridge (latitude 45.41 N and longitude 75.60 W), the following are the reference Site Class C (reference) peak seismic hazard values based on data obtained from Earthquakes Canada (NRCAN, 2019).

Table 4: Spectral Response Values - Site Class C

Parameter	Value at Given Probability of Exceedance in 50 Years		
	10% (475-year)	5% (975-year)	2% (2,475-year)
PGA	0.107 g	0.173 g	0.298 g
$T \leq 0.2$ second	0.169 g	0.269 g	0.465 g
$T = 0.5$ second	0.091 g	0.144 g	0.249 g
$T = 1$ second	0.046 g	0.072 g	0.122 g
$T = 2$ seconds	0.021 g	0.033 g	0.058 g
$T = 5$ seconds	0.005 g	0.008 g	0.015 g
$T \geq 10$ seconds	0.002 g	0.003 g	0.006 g

The fundamental periods of the rehabilitated structures have yet to be confirmed and may depend on the design modifications to the superstructure. Considering the structure's "Major-Route" importance category and the site specific seismic hazard values given above, the bridges would fall in Seismic Performance Category 2 if the fundamental period of the structure is greater than or equal to 0.5 seconds, or Seismic Performance Category 3 if the fundamental period of the structure is less than 0.5 seconds, in accordance with Table 4.10 of the CHBDC.

Since the WBL and EBL bridges have three and four spans, respectively, but the skew angle¹ exceeds 20 degrees at all supports, both bridges are considered as irregular. Hence, from Table 4.11 of the CHBDC, a "performance-based design" is required to design the structures as defined in the CHBDC, depending on the Seismic Performance Category (category 2 or 3) and on the Importance Category (Major-Route Bridge).

Based on the results of the MASW testing carried out at the site, the bedrock has an average shear wave velocity of 840 m/s, which corresponds to a Site Class B, as defined in Table 4.1 of the CHBDC. The reference peak seismic hazard values (Site Class C) for the 2,475-year earthquake were modified to the site-specific bedrock classification (Site Class B) using Table 4.2 to 4.8 in the Section 4.4.3.3 in the CHBDC. The site-specific, target firm-ground spectra are given in the table below.

¹ The angle between the longitudinal centreline of the bridge and a line perpendicular to the centreline of the bearings.

Table 5: Site Class B 2,475 Year Earthquake Spectral Values for Subject Site

Parameter	Value at Given Probability of Exceedance in 50 Years 2% (2,475-year)
PGA	0.259 g
T ≤ 0.2 s	0.358 g
T = 0.5 s	0.162 g
T = 1.0 s	0.077 g
T = 2.0 s	0.037 g
T = 5.0 s	0.010 g
T ≥ 10.0 s	0.004 g

6.3.5 Spectrum-Compatible Time Histories

To develop time histories compatible with the target firm-ground spectrum, a hazard deaggregation was first carried out to identify the primary contributors of earthquake magnitude and hypocentral distance for the 2,475-year design earthquake event. A suite of representative seed time histories that matched the primary contributors were selected for each design earthquake. The time histories were then scaled to match the Site Class B target spectra to represent the site-specific design firm-ground accelerations, for use in the site-specific ground response analyses. The period range of interest for selection and matching of time histories to the target spectra was taken as 0.05 s to 0.5 s, based on the range of the fundamental period of the site as measured from the MASW results.

A summary of the earthquake records used in the site-specific ground response analyses for the 2,475-year design earthquake are provided in the tables below.

Table 6: Summary of Input Time History Earthquake Events – 2,475-Year Design Earthquakes

Database	Event Name	Event Year	Station / Suite Name	Mag.	Dist. (km)
PEER	San Fernando	1971	Lake Hughes #4 (H1)	6.6	19.5
PEER	San Fernando	1971	Lake Hughes #4 (H2)	6.6	19.5
PEER	N. Palm Springs	1986	Winchester Bergman (H1)	6.1	48.9
PEER	N. Palm Springs	1986	Winchester Bergman (H2)	6.1	48.9
PEER	Coyote Lake	1979	Gilroy Array #1 (H1)	5.7	10.2
PEER	Coyote Lake	1979	Gilroy Array #1 (H2)	5.7	10.2
PEER	Northridge	1994	LA - Wonderland Ave (H1)	6.7	15.1
PEER	Northridge	1994	LA - Wonderland Ave (H2)	6.7	15.1
PEER	Nahanni	1985	Site 3 (H1)	6.8	4.9
PEER	Nahanni	1985	Site 3 (H2)	6.8	4.9
EST	Motion #40	-	East7a2 Suite	7.0	94

6.3.6 One-Dimensional Ground Response Analyses

One-dimensional ground response analyses were undertaken to assess the ground response at the site as input to the liquefaction assessment at the piers. A stratigraphic profile representative of the site conditions near the piers was selected for analysis. The ground response analyses were carried out for a typical profile for EBL piers during the design 2,475-year earthquake.

Based on the results of the field investigation and an average shear wave velocity of 840 m/s for the bedrock, representative index properties and shear wave velocity (V_s) variations of the overburden soil and rock were developed for the design soil profile in the vicinity of the EBL piers, and are summarized in the table below.

Table 7: Summary of Representative Stratigraphy and Material Properties EBL Piers

Soil Unit	Unit Weight (γ) (kN/m ³)	EBL Piers (Site No. 3-302/1)	
		Depth (m)	V_s (m/s)
Silty Sand	20	0 – 12.5	320 – 670
Bedrock	23	> 12.5	840

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 MASW testing. The values of G_{max} and V_s are related through the following expression:

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

6.3.6.1 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:

- Silty Sand: Seed and Idriss (1970) average curves for shear modulus and damping; and,
- Bedrock: EPRI, 1993.

6.3.6.2 Analysis Results

The ground response analyses were carried out to quantify the site-specific ground response as input to the updated liquefaction assessment for the 2,475-year design earthquake at the EBL piers.

The averaged 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.

6.3.7 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 methodology used to assess liquefaction potential at the site is consistent with the “simplified” approach presented outlined in the CHBDC and by Idriss and Boulanger (2008). 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.

Liquefaction analyses were carried out for the abutments and pier locations. The analyses carried out for the abutments used the in-situ testing data collected at the boreholes put down as part of the current investigation, as well as those advanced during the 1971 field investigation carried out prior to construction of the bridge and considered the influence of the increased confining stress beneath the subsequently constructed approach embankments. The analyses carried out for the piers used the in-situ testing data collected at the boreholes advanced during the previous field investigation carried out prior to construction of the bridge and are adjacent to the piers.

From the previous investigation, Boreholes 1, 2, 7, 8, 11 and 12 were drilled near the abutments or the future approaches. All boreholes from current investigation were drilled at the approaches. Boreholes 3, 4, 5, 6, 9 and 10 from the previous investigation were drilled near piers locations.

The design groundwater level was established based on the groundwater elevations measured in the standpipe piezometer installed in Borehole 18-2102 (see Section 4.7).

The CRR with depth was calculated at each current 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.

The results of the initial liquefaction assessment indicated that the overburden present at the abutments and WBL piers may be considered to be non-liquefiable for design purposes for return periods of 475-year, 975-year and 2,475-year design earthquake.

However, the results of the initial liquefaction analyses at the piers of the EBL indicated that portions of the granular deposits near the EBL piers are considered to be potentially liquefiable during the 2,475-year design earthquake, but non-liquefiable during the 475 or 975-year design earthquakes. The subsequent site-specific response analysis presented earlier provided a refined site-specific CSR profile which was used to re-assess the liquefaction potential at the EBL piers. The refined results indicate that there is no risk of liquefaction at the EBL piers at the 2,475-year design earthquake.

Based on the results of the analyses, the silty clay encountered at the site is not considered to be susceptible to cyclic softening.

Plots of the liquefaction results showing the CRR and CSR values, for the “simplified” approach at the abutments are provided in Figures F17 to F20 for the 2,475-year design earthquake. Plots of the liquefaction results showing the CRR and CSR values, comparing the results of the “simplified” approach to those of the site-specific ground response analyses at the boreholes put down near the EBL piers are provided in Figures F21 to F24 for the 2,475-year design earthquake.

6.4 Feasibility of Integral and Semi-Integral Abutments

As outlined in MTO's report SO-96-01 (Husain and Bagnariol, 1996), 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 or piers is influenced by a number of factors including geometry and subsurface conditions. The primary criterion is the need to support the abutments or piers on relatively flexible piles. 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 degrees; and abutment wall heights less than 6 m without a retained soil system.

As outlined in MTO's report BO-99-03 (Husain and Bagnariol, 1999), semi-integral abutment bridges are single or multiple span structures of less than 150 m in length with rigid foundations where the concrete deck is continuous with the approach slabs. Expansion joints are eliminated at the end of the deck and the superstructure is supported on movable bearings and is almost independent of the abutment. An expansion joint is provided at the end of the approach slab that is detailed to slide between or over the wingwalls. Unlike integral abutments the geometric constraints for semi-integral abutments are less restrictive.

From a foundation perspective, either integral or semi-integral abutments are considered feasible at this location.

6.5 Assessment of Existing Foundations

6.5.1 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the CHBDC and its Commentary, the existing bridges structures and foundation systems may be classified as having large traffic volumes and its performance as having potential impacts on other transportation corridors, hence having a "typical" consequence level associated with exceeding limits states design. Given the level of foundation investigation completed to date as presented in Sections 3.0 and 4.0, in comparison to the degree of site understanding in Section 6.5 of CHBDC, the level of confidence for design is considered to be a "typical degree of site and prediction model understanding." Accordingly, the appropriate corresponding ULS and SLS consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the CHBDC have been used for design, as indicated in the following Sections. For seismic design, the consequence factor, Ψ , should be taken as unity for major-route bridges and the geotechnical resistance factor, ϕ_{gu} , should be taken as 0.40 (for static analysis) and as unity (for seismic analysis), as per Section 4.6.3 of the CHBDC and this for a Performance-based Design.

6.5.2 Steel H-Piles (Abutments)

Based on the original structural design drawings for Site No. 3-302/1 (W.P. 13-68-06, Dwg Nos. 3-302A-1 to 3-302A-18) and Site No. 3-302/2 (W.P. 13-68-07, Dwg Nos. 3-302B-1 to 3-302B-17), the abutments are supported on "perched" foundations on steel HP12x74 (HP 310x110) piles end bearing on bedrock. The following table summarizes the data of driven H-Piles below the foundations of the abutments at EBL and WBL.

Table 8: Steel H-Pile Data as per structural drawings 3-302A-3 and 3-302B-3

Site No.	Location	Number of Piles	Length (m)
3-302/1	EBL West Abutment	26	18.2
	EBL East Abutment	20	17.1
	EBL North-East Wing Wall	4	18.9
	EBL North-West Wing Wall	6	19.5

Site No.	Location	Number of Piles	Length (m)
3-302/2	WBL West Abutment	22	17.7
	WBL East Abutment	18	17.1
	WBL North-East Wing Wall	6	18.3
	WBL North-West Wing Wall	6	18.9

The abutments piles are configured in two rows with the front-row piles towards the CPR rail line at 1H:3V and the back-row piles battered away from the CPR rail line at 1H:6V.

The wing walls piles are configured in two rows with the outer row of piles battered away from the centerline of Highway 417 at 1H:3V and the inner row of piles are vertical.

6.5.2.1 Factored Geotechnical Axial Resistance

Based on the GEOCRESS information, the MTO “Pile Load and Extraction Tests” manual, the pile installation methods likely used at the time of original construction, the measured uniaxial compressive strength of the rock at this site and the rock quality, for an HP 12x74 (HP 310x110) pile, the axial factored ultimate geotechnical resistance (ULS) will be 2,500 kN using a geotechnical resistance factor of 0.5 for a typical degree of understanding. The factored ULS geotechnical resistance may be greater than the structural capacity of the pile, which could govern the design and should be checked by the structural design engineer. The factored serviceability geotechnical resistance (SLS) does not apply to piles founded on the bedrock at this site, since the SLS resistance for 25 mm of settlement is greater than the factored axial geotechnical resistance at ULS.

Based on the site stratigraphy and the results of the analyses carried out as part of the current study, no downdrag loads on the existing piles are expected from either the original construction or the proposed rehabilitation works.

The granular fill and native silty sand to sand at the site will provide uplift resistance to the piles. The skin friction contributing to the uplift values on a single HP 310 x 110 pile was calculated using the Nordlund method (Hannigan et al., 2016) based on pile size/type, and friction angle in the granular deposits. The factored uplift resistance on a single HP 310 x 110 abutment pile (assuming it has been driven to the bedrock) may be taken as 742 kN using a geotechnical resistance factor of 0.3 for a typical degree of understanding.

6.5.2.2 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*, assuming that it acts over the the pile shaft to a depth equal to six pile diameters below the underside of the pile cap and an equivalent width equal to three pile diameters.

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.

For a HP 310 x 110 steel pile, the unfactored ULS lateral resistance is 105 kN at all four abutment locations. The ULS resistances obtained using the above parameter represent unfactored values; in accordance with the *CHBDC*, a resistance factor of 0.5 is to be applied in calculating the horizontal resistance. This value provides a limit on the lateral geotechnical resistance offered using the p-y curves given in Section 6.5.2.3 below the pile cap under static conditions.

6.5.2.3 Lateral Soil-Structure Interaction Springs

The foundation lateral soil-structure interaction springs required for the static and dynamic analyses of the bridge abutments were computed based on the available subsurface information on the soil layers surrounding the foundations and the pile dimensions.

The soil-structure interaction between the bridge foundations and the surrounding soils was modeled using the load transfer method. The lateral load-displacement behaviour of the piles can be modeled using p-y curves (CHBDC). P-y curves relate the lateral deflection of a single pile to the corresponding soil and bedrock reactions at any depth below ground surface.

The p-y curves were developed considering appropriate surcharge loads imposed by embankment fill loads (e.g., abutments) and artesian water conditions (e.g., in the deep glacial till deposits). The curves are considered appropriate for vertical piles as well as piles with batters of up to 1H:3V. Under cyclic loading, localized strength reduction of soil adjacent to the piles can occur resulting in increased deflection and bending moment above the respective values obtained in short-term, or static loading conditions.

The family of static and cyclic p-y curves calculated at 0.5 m increments of depth for a single, vertical HP 310X110 steel H-pile at the abutments are shown in tabular format and graphically in Figures F1, F2, F7, F8 to F10, F15 and F16 in Appendix F. The p-y curves were developed accounting for embankment surcharges. Should integral abutments be designed, these curves should be adjusted to reflect this modification.

For piles arranged in closely spaced groups, the pile-soil-pile interaction causes the individual piles in a group to be less effective than a single pile. These “group effects” can be incorporated into the design using a method that modifies the single pile p-y curves by some factor (i.e., a p-reduction factor). Generalized multipliers (i.e., p-reduction factors) for a range of pile spacings are provided in Section C6.11.3.4 of CHBDC.

It is understood that lateral loading will be resisted fully or partially by the battered steel H piles at the abutments. Additional resistance to lateral loading may be derived from the soil in front of the piles.

6.5.3 Socketed Caissons (Piers)

Based on the original structural design drawings for Site No. 3-302/1 (W.P. 13-68-06, Dwg Nos. 3-302A-1 to 3-302A-18) and Site No. 3-302/2 (W.P. 13-68-07, Dwg Nos. 3-302B-1 to 3-302B-17), the piers are supported on caissons socketed into the shale bedrock. The caissons are composed of concrete-filled tubular steel casing with a diameter of 1,077 mm and a wall thickness of 9.5 mm. The socket is 914 mm in diameter and extends about 300 mm into the sound bedrock. Table 9 summarizes the length of the steel casing under each pier of the EBL and WBL as well as the length of concrete socket into the bedrock. In the same table, elevations of the top of caissons are also shown.

Table 9: Summary of caisson lengths for the EBL and the WBL as per structural drawings 3-302A-3 and 3-302B-3

Site No.	Location	Length of steel casing (m)	Length of concrete socket (m)	Top of Caisson Elevation (m)
3-302/1	EBL Pier 1 (West Pier)	11.6	1.2	64.3
	EBL Pier 2 (Central Pier)	11.0	1.8	64.3
	EBL Pier 3 (East Pier)	11.6	2.1	64.9
3-302/2	WBL Pier 1 (West Pier)	11.0	1.8	64.3
	WBL Pier 2 (East Pier)	11.0	2.4	64.9

6.5.3.1 Factored Geotechnical Axial Resistance

Based on the GEOCREST information, the current investigation, the Canadian Foundation Engineering Manual (CGS, 2006), the MTO “Pile Load and Extraction Tests” manual, and the caisson installation methods likely used at the time of original construction, the caissons socketed into the bedrock supporting the pier may be considered to have a minimum static factored compressive geotechnical resistance of 2,800 kN at Ultimate Limit States (ULS) considering a geotechnical resistance factor of 0.4 for a typical degree of understanding. The static factored tensile geotechnical resistance may be taken as 2,100 kN at Ultimate Limit States (ULS) considering a geotechnical resistance factor of 0.3 for a typical degree of understanding.

Serviceability Limit States (SLS) resistances do not apply to piles founded on the bedrock, because the SLS resistance for 25 mm of settlement is greater than the factored axial geotechnical resistance at ULS.

Based on the site stratigraphy and the results of the analyses carried out as part of the current study, no downdrag loads on the existing caisson foundations are expected from either the original construction or the proposed rehabilitation works.

6.5.3.2 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*, assuming that it acts over the the caisson to a depth equal to six caisson diameters below the underside of the pile cap and an equivalent width equal to three caisson diameters.

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

For a 914 mm diameter caisson, the unfactored ULS lateral resistance is 285 kN at all pier locations. The ULS resistances obtained using the above parameter represent unfactored values; in accordance with the *CHBDC*, a resistance factor of 0.5 is to be applied in calculating the horizontal resistance. This value provides a limit on the lateral geotechnical resistance offered using the p-y curves given in Section 6.5.2.3 below the pile cap under static conditions.

6.5.3.3 Lateral Soil-Structure Interaction Springs

The foundation lateral soil-structure interaction springs required for the static and dynamic analyses of the bridge piers were computed based on the available subsurface information on the soil layers surrounding the foundations and the caisson dimensions.

The soil-structure interaction between the bridge foundations and the surrounding soils was modeled using the load transfer method. The lateral load-displacement behavior of the caissons can be modeled using p-y curves (CHBDC). P-y curves relate the lateral deflection of a single caisson to the corresponding soil and bedrock reactions at any depth below ground surface. Under cyclic loading, localized strength reduction of soil adjacent to the piles can occur resulting in increased deflection and bending moment above the respective values obtained in short-term, or static loading conditions.

The family of static and cyclic p-y curves calculated at 0.5 m increments of depth for a single, vertical 1,067/914 mm diameter caisson are shown in tabular format and graphically in Figures F3 to F6 and F11 to F14 to F16 in Appendix F.

For caissons arranged in closely spaced groups, the caisson-soil-caisson interaction causes the individual caissons in a group to be less effective than a single caisson. These “group effects” can be incorporated into the design using a method that modifies the single caisson p-y curves by some factor (i.e., a p-reduction factor).

6.6 Lateral Earth Pressures for Design

The lateral earth pressures acting on the abutment and wing walls 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.

The historical boreholes from the available GEOCRETS information were put down prior to embankment construction. Based on the findings of the current investigation, the abutment backfill consists principally of compact sand and gravel with some silt to silty sand and gravel.

The static lateral earth pressures may be calculated using the lateral earth pressure coefficients provided in the table below (assuming a compact sand and gravel backfill according to the site investigation findings with a unit weight of 20 kN/m³ and an angle of internal friction of 30 degrees).

Table 10: Static Lateral Earth Pressure Coefficients

State	Lateral earth pressure coefficient
At rest, K_o	0.50
Active, K_A	0.33
Passive, K_P	3.00

Where the abutment walls do not allow lateral yielding, at-rest earth pressures should be assumed for the design. Where the abutment walls allow lateral yielding of the stem, active earth pressures should be used in the design of the wall structure(s). The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the Commentary to the CHBDC.

The seismic active earth pressure acting on the abutment walls can be calculated using the seismic active earth pressure coefficients (K_{AE}) provided in the Table 11 below.

Table 11: Seismic Lateral Earth Pressure Coefficients

Type of Wall	Return Period	Site PGA (g)	K_h Value	Value of seismic active earth pressure coefficient, K_{AE}
Yielding Wall	475-year design earthquake	0.107	0.054	0.335
	975-year design earthquake	0.173	0.087	0.361
	2,475-year design earthquake	0.298	0.149	0.417
Non-yielding Wall	475-year design earthquake	0.107	0.107	0.378
	975-year design earthquake	0.173	0.173	0.441
	2,475-year design earthquake	0.298	0.298	0.605

In accordance with Sections 4.6.5 and C4.6.5 of the 2014 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 equal to the site adjusted PGA estimated at the ground surface (Site Class C). For structures which allow lateral yielding, k_h is taken as 0.5 times site adjusted PGA estimated at the ground surface. Values of k_h are presented in the above Table 11. The vertical seismic coefficient (k_v) is ignored as specified in section C4.6.5 of the Commentary to the 2014 CHBDC.

It should be noted that the seismic earth pressure coefficients provided in the table above were calculated considering that the back of the wall is vertical and the ground surface behind the wall is flat. According to drawings 3-302A-3 and 3-302B-3 of WP 13-68-06 and WP 13-68-07, the back of the abutment walls is vertical, however the back of the wing walls (retaining walls) are slightly inclined by 24H:1V which may increase the above values by up to about 5 to 6 percent based on the Mononobe-Okabe method outlined in Section C4.6.5 of the Commentary to the CHBDC. The ground surface of the backfill is generally sloping downward which is favorable for the earth pressure on the abutments and the walls. However, if the ground surface of the backfill is sloping upward i.e. 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.

As outlined in Section C4.6.5 of the Commentary to the CHBDC, the use of k_h equal to the half of site adjusted PGA estimated at the ground surface to determine K_{AE} value for a yielding wall is applicable provided that the wall can move up to $250 \times k_{ho}$ mm, where k_{ho} is the site-specific PGA at the base of the wall, which is also equal to the values given in Table 11 above. This corresponds to displacements of about 27, 43, and 104 mm for the 475-year, 975-year, and 2,475-year design earthquakes at this site, respectively.

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:

$$\sigma_h(z) = K_A \gamma z + (K_{AE} - K_A) \gamma (H-z) \text{ for yielding walls; and,}$$

$$\sigma_h(z) = K_o \gamma z + (K_{AE} - K_A) \gamma (H-z) \text{ for non-yielding walls}$$

Where: $\sigma_h(z)$ is the lateral earth pressure at depth 'z' (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 earth pressure coefficient;

γ is the unit weight of the backfill soil (kN/m³), use 20 kN/m³;

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

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

6.7 Construction Considerations

6.7.1 Open-Cut Excavations

Excavations should be carried out in accordance with the guidelines outlined in the latest edition of the Occupational Health and Safety Act (OHSA) for Construction Activities.

Excavations required for conversion to semi-integral abutments will extend into the native granular embankment fill. The existing embankment fill would be classified as Type 3 soils according to OHSA. Temporary excavations (i.e. those which are only open for a relatively short period) through these overburden soils should be made with side slopes no steeper 1H:1V.

6.7.2 Temporary Protection Systems

It is anticipated that temporary protection systems may be required to facilitate the excavations for semi-integral conversion. The design of the shoring will be entirely the responsibility of the contractor. Where required, temporary protection systems shall be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*) with amendments as per SSP 109S09, and the lateral movement should meet Performance Level 2. Traffic loading (either vehicle or train loading) should be included as a surcharge.

It is considered that soldier piles and lagging or an interlocking sheetpile system would be feasible at this site although the presence of cobbles or boulders within the fill may impact the depth that sheetpiling can be driven and the effectiveness of the system. The soldier pile and lagging or sheetpiling shall be supported against lateral movement using walers, tie backs and/or internal struts/braces.

Some settlement of the roadway surface at the edge of the temporary protection can be expected and may require some minor pavement padding at this boundary.

6.8 Corrosion and Cement Type

One soil sample from Borehole 18-2102 was submitted to Eurofins Environmental Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The results of the testing are provided in Appendix D and are summarized in the table below.

Table 12: Summary of Corrosivity Results

Borehole No.	Sample Depth (m)	Chloride (%)	pH	Electrical Conductivity (mS/cm)	Resistivity (ohm-cm)	Sulphate (%)
18-2102	12.2 - 12.8	0.015	8.42	0.55	1,820	0.03

The results of the testing indicate a low potential for concrete degradation due to the presence of sulphates, and that concrete made with Type GU Portland cement should be acceptable for substructures. However, the results also indicate a potential for corrosion of exposed ferrous metal which should be considered in the design.

7.0 CLOSURE

This report was prepared by Mr. Fady Ghobrial, Geotechnical Specialist and Mr. Matt Kennedy, P.Eng., Senior Geotechnical Engineer. It was reviewed by Mr. Michael Snow, P.Eng., a Senior Geotechnical Engineer and Principal of Golder. Mr. Fintan Heffernan, P.Eng. a Senior Consultant with Golder and the Designated MTO Foundations Contact for this project, conducted an independent quality control review of this report.

Golder Associates Ltd.

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MSS/FJH/mvrd

[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1210 cpr/final/1662565-1210-001-r-rev0-cpr overhead-06_2019 fidr.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6-reports/1210_cpr/final/1662565-1210-001-r-rev0-cpr_overhead-06_2019_fidr.docx)

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REFERENCES

Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

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

Canadian Standards Association (CSA), 2014. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-14. CSA Special Publication, S6.1-14.

Hannigan, P.J., Rausche, F., Likins, G.E., Robinson, B.R., Becker, M.L., 2016. *Geotechnical Engineering Circular No. 12 – Volume I Design and Construction of Driven Pile Foundations*. National Highway Institute, U.S. Department of Transportation, Federal Highway Administration , Report No. FHWA-NHI-16-009.

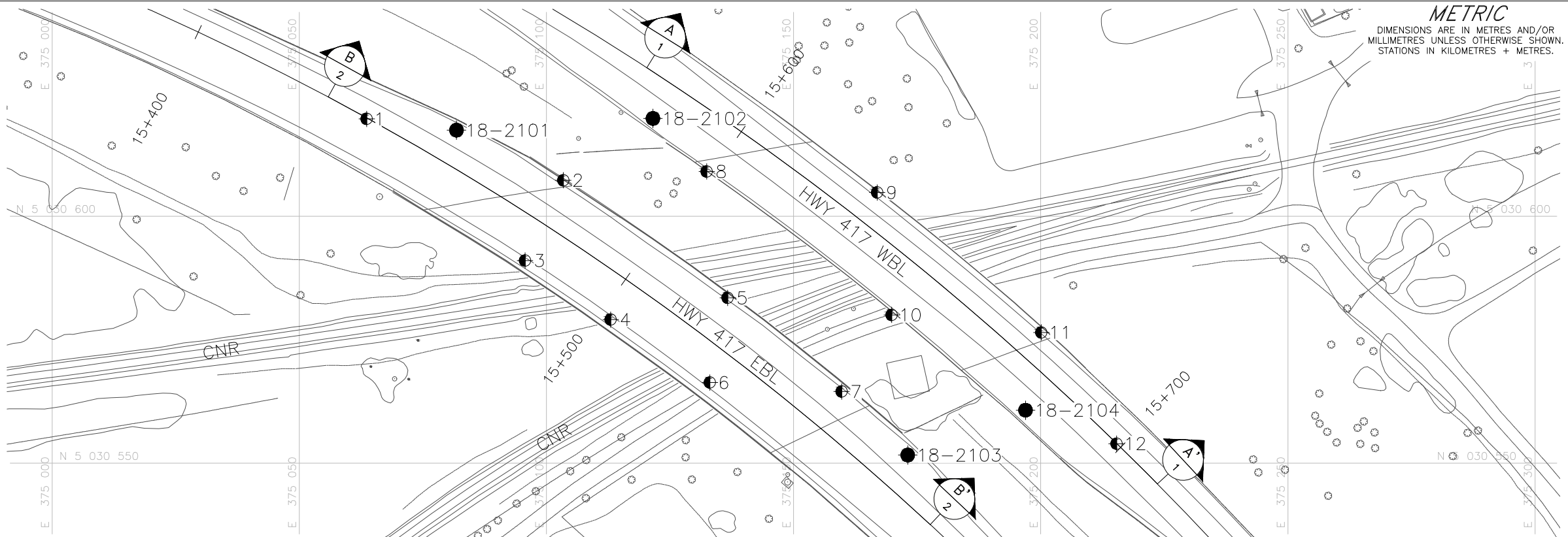
Idriss, I. M., and Boulanger, R. W., 2008. "Soil Liquefaction During Earthquakes", Earthquake Engineering Research Institute.

Isenhower, W. M., Wang, S.-T., and Vasquez, L.G., 2016. Technical Manual for LPile 2016, Ensoft, Inc.

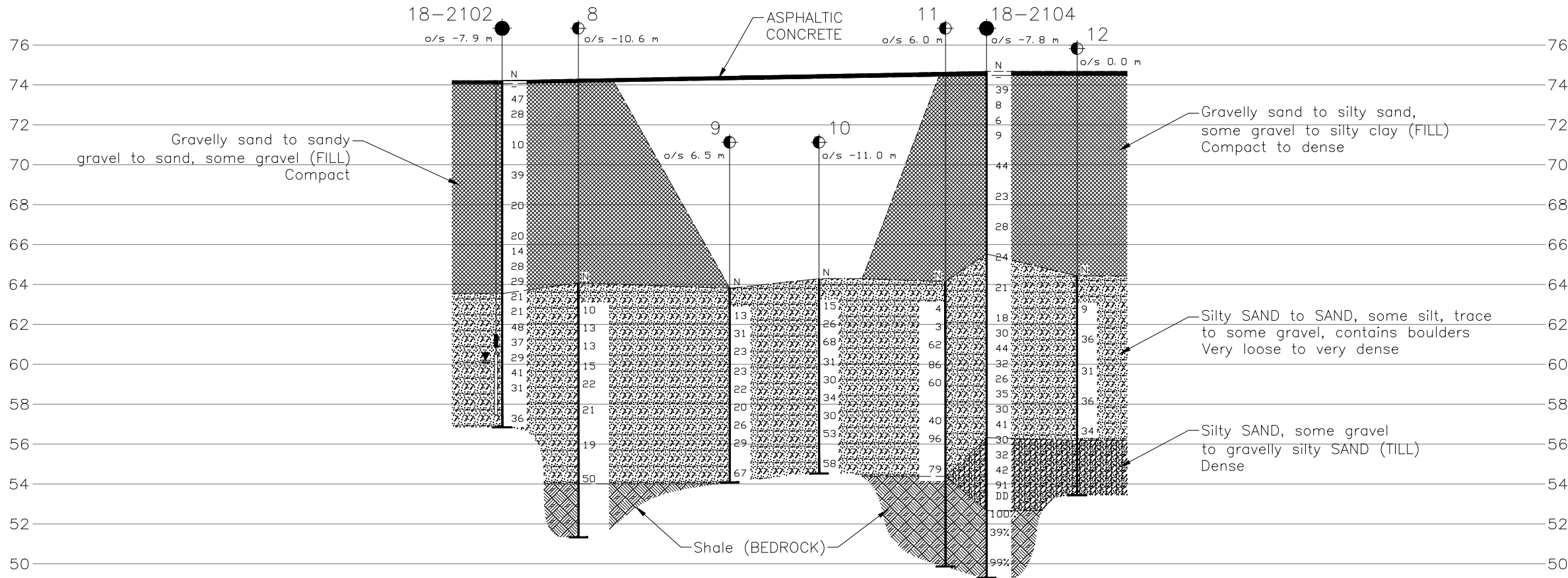
Husain, I. and Bagnariol, D., 1999. *Semi-Integral Abutment Bridges*. Ministry of Transportation of Ontario (MTO), Report BO-99-01.

Husain, I. and Bagnariol, D., 1996. *Integral Abutment Bridges*. Ministry of Transportation of Ontario (MTO), Report SO-96-01.

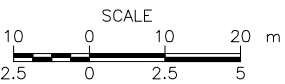
Natural Resources Canada (NRCAN), 2019. *Seismic Design Tools for Engineers*. Retrieved from <http://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index-en.php>



PLAN



PROFILE A-A'



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.

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

WP No. 4074-11-00

CPR OVERHEAD WIDENING

HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.411684 LONG. -75.601224



SHEET



KEY PLAN



SCALE
1 0 1 2 km

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation (Geocres No. 31G05-080)
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ≡ WL in piezometer, measured on July 2018

BOREHOLE CO-ORDINATES (MTM ZONE 9)

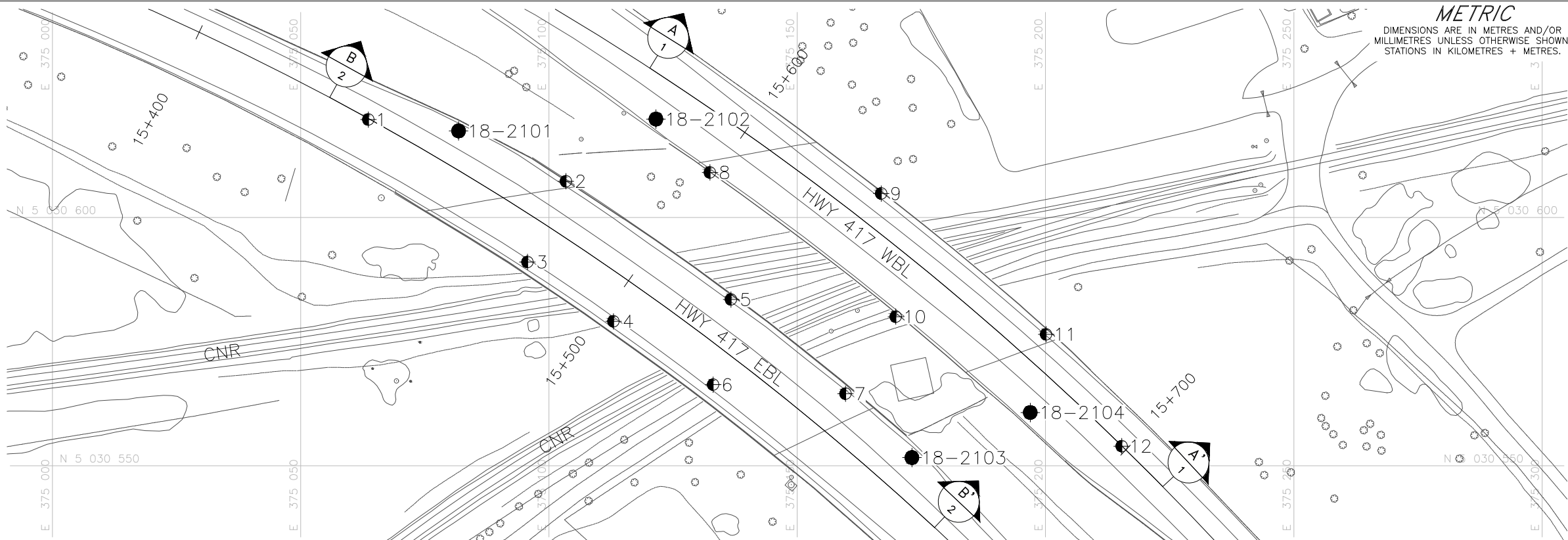
No.	ELEVATION	NORTHING	EASTING
1	64.0	5030619.7	375063.6
2	64.1	5030607.3	375103.4
3	64.4	5030591.0	375095.7
4	64.4	5030579.1	375113.0
5	64.1	5030583.5	375136.7
6	64.5	5030566.3	375133.1
7	64.4	5030564.5	375159.7
8	64.1	5030609.0	375132.4
9	63.8	5030604.8	375166.9
10	64.3	5030580.0	375169.8
11	64.1	5030576.5	375200.1
12	64.4	5030553.9	375215.3
18-2101	75.0	5030617.4	375081.8
18-2102	74.2	5030619.8	375121.6
18-2103	75.6	5030551.6	375173.1
18-2104	74.7	5030560.7	375196.9

REFERENCE

Base plans provided in digital format by WSP, drawing file nos. XA1-NAD 83.dwg and XB1-NAD 83 (CSRS).dwg, received APR. 19, 2017.

NO.	DATE	BY	REVISION
Geocres No. 31G5-302			
HWY. 417		PROJECT NO. 1662565	DIST. EASTERN
SUBM'D. FG	CHKD. FG	DATE: 11/12/2018	SITE: 3-302 A & B
DRAWN: JM	CHKD. SAT	APPD. FJH	DWG. 1





PLAN



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

WP No. 4074-11-00

CPR OVERHEAD WIDENING

HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.411684 LONG. -75.601224



SHEET



KEY PLAN



SCALE
1 0 1 2 km

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation (Geocres No. 31G05-080)
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ≡ WL in piezometer, measured on July 2018

BOREHOLE CO-ORDINATES (MTM ZONE 9)

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7	64.4	5030564.5	375159.7
8	64.1	5030609.0	375132.4
9	63.8	5030604.8	375166.9
10	64.3	5030580.0	375169.8
11	64.1	5030576.5	375200.1
12	64.4	5030553.9	375215.3
18-2101	75.0	5030617.4	375081.8
18-2102	74.2	5030619.8	375121.6
18-2103	75.6	5030551.6	375173.1
18-2104	74.7	5030560.7	375196.9

REFERENCE

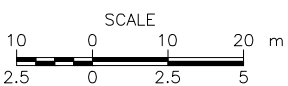
Base plans provided in digital format by WSP, drawing file nos. XA1-NAD 83.dwg and XB1-NAD 83 (CSRS).dwg, received APR. 19, 2017.

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.

PROFILE B-B'



Gravelly sand to sandy gravel to sand and gravel (FILL)
Dense to compact

SAND, some silt to silty sand, trace gravel to gravelly
Compact to dense

Silty CLAY
Stiff

Shale (BEDROCK)

Gravelly sand to silty sand to sand and gravel (FILL)
Loose to very dense



NO.	DATE	BY	REVISION
Geocres No. 31G5-302			
HWY. 417		PROJECT NO. 1662565	DIST. EASTERN
SUBM'D. FG	CHKD. FG	DATE: 11/12/2018	SITE: 3-302 A & B
DRAWN: JM	CHKD. SAT	APPD. FJH	DWG. 2

APPENDIX A

Borehole and Drillhole Records, Current Investigation
Lists of Abbreviations and Symbols
Lithological and Geotechnical Rock Description Terminology
Records of Boreholes 18-2101 to 18-2104
Figure A1 – Rock Core Photographs

LIST OF SYMBOLS

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

I. GENERAL		(a) Index Properties (continued)	
π	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 = $(w - w_p) / I_p$
		Ic	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)
II. STRESS AND STRAIN		(b) Hydraulic Properties	
γ	shear strain	h	hydraulic head or potential
Δ	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
ε	linear strain	v	velocity of flow
ε_v	volumetric strain	i	hydraulic gradient
η	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
ν	Poisson's ratio	j	seepage force per unit volume
	total stress		
σ'	effective stress ($\sigma' = \sigma - u$)	(c) Consolidation (one-dimensional)	
σ'_{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)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3) / 3$	C_s	swelling index
τ	shear stress	C_{α}	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
III. SOIL PROPERTIES		σ'_p	pre-consolidation stress
(a) Index Properties		OCR	over-consolidation ratio = σ'_p / σ'_{vo}
$\rho(\gamma)$	bulk density (bulk unit weight)*	(d) Shear Strength	
$\rho_d(\gamma_d)$	dry density (dry unit weight)	τ_p, τ_r	peak and residual shear strength
$\rho_w(\gamma_w)$	density (unit weight) of water	ϕ'	effective angle of internal friction
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	δ	angle of interface friction
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)	μ	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 ρ . Unit weight symbol is γ 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_d :

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 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), 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	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	100 to 200	1,000 to 2,000
Very stiff	over 200	over 4,000

IV. SOIL TESTS

w	water content
w _p	plastic limit
w _l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G_s)
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 ₄	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
0 to 10	Trace
10 to 20	Some
20 to 35	(ey) or (y)
over 35	And

Example
Trace sand
Some sand
Sandy
Sand and Gravel

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, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

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 1662565-1210		RECORD OF BOREHOLE No 18-2101		SHEET 1 OF 2		METRIC	
G.W.P. 4074-11-00		LOCATION N 5030617.4; E 375081.8 NAD 83 MTM ZONE 9 (LAT. 45.403120; LONG. -75.711130)		ORIGINATED BY DG			
DIST Eastern HWY 417		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)		COMPILED BY ZS			
DATUM Geodetic		DATE June 20-21, 2018		CHECKED BY MJK			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID 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
								20	40	60	80	100	W _p	W	W _L					
75.0	GROUND SURFACE																			
74.8	ASPHALTIC CONCRETE																			
0.2	(SP) Gravelly sand, angular (FILL) Moist		1	GRAB	-															
74.3																				
0.7	(SP/GP) Sand and gravel, some silt, trace to some clay, contains shale fragments (FILL) Very dense to compact Grey Moist		2	SS	80															
				3	SS	49														
			4	SS	19															
			5	SS	14															
			6	SS	20															
70.5																				
4.5	(GP-SP/GP) Sandy gravel to sand and gravel, some silt to silty, trace to some clay, contains shale fragments (FILL) Compact to dense Brown Moist		7	SS	12															
				8	SS	24														
				9	SS	24														
				10	SS	44														
				11	SS	26														
				12	SS	22														
			13	SS	18															

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMITO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 19-6-17 ZS

PROJECT		1662565-1210		RECORD OF BOREHOLE No 18-2101				SHEET 2 OF 2		METRIC							
G.W.P.		4074-11-00		LOCATION		N 5030617.4; E 375081.8 NAD 83 MTM ZONE 9 (LAT. 45.403120; LONG. -75.711130)				ORIGINATED BY		DG					
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)				COMPILED BY		ZS					
DATUM		Geodetic		DATE		June 20-21, 2018				CHECKED BY		MJK					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
--- CONTINUED FROM PREVIOUS PAGE ---																	
63.7	(GP-SP/GP) Sandy gravel to sand and gravel, some silt to silty, trace to some clay, contains shale fragments (FILL) Compact to dense Brown Moist		14	SS	27												37 35 21 7
			15	SS	50/0.13												
11.3	(CL) Silty CLAY, trace sand Stiff Grey Wet		16	SS	11												
62.8																	
12.2	(SM) Silty SAND, trace gravel Compact Grey-brown Wet		17	SS	28												
62.2																	
12.8	(SP/SM) SAND, trace to some silt, trace gravel, trace clay Compact to dense Wet		18	SS	37												
			19	SS	22												7 85 7 1
			20	SS	22												
			21	SS	29												0 85 14 1
			22	SS	26												
			23	SS	47												
57.6																	
17.4	END OF BOREHOLE																

PROJECT 1662565-1210		RECORD OF BOREHOLE No 18-2102		SHEET 1 OF 2		METRIC	
G.W.P. 4074-11-00		LOCATION N 5030619.8; E 375121.6 NAD 83 MTM ZONE 9 (LAT. 45.402700; LONG. -75.710870)		ORIGINATED BY DG			
DIST Eastern HWY 417		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)		COMPILED BY ZS			
DATUM Geodetic		DATE June 24-25, 2018		CHECKED BY MJK			

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					W _p	W	W _L		GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED				WATER CONTENT (%)							
74.2	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALTIC CONCRETE																			
0.2	(SP) Gravelly sand (FILL) Dense Grey Moist		1	GRAB	-															
			2	SS	47															
72.7																				
1.5	(GP) Sandy gravel (FILL) Compact Grey Moist		3	SS	28															
71.2																				
3.1	(SP/SM) Sand, some gravel to gravelly, some silt to silty, some clay (FILL) Compact to dense Brown Moist		4	SS	10								○							
			5	SS	39															
			6	SS	20								○					17 40 30 14		
			7	SS	20															
			8	SS	14								○					23 41 19 17		
			9	SS	28															

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL_IM\MTD\HWY417\REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 19-6-17 ZS

PROJECT		1662565-1210		RECORD OF BOREHOLE No 18-2102		SHEET 2 OF 2		METRIC				
G.W.P.		4074-11-00		LOCATION		N 5030619.8; E 375121.6 NAD 83 MTM ZONE 9 (LAT. 45.402700; LONG. -75.710870)		ORIGINATED BY				
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)		COMPILED BY				
DATUM		Geodetic		DATE		June 24-25, 2018		CHECKED BY				
								MJK				
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa		W _p W W _L		
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100					
63.5			10	SS	29							
10.7	(SP/SM) SAND, some silt, trace to some gravel, trace to some clay Compact to dense Brown Moist		11	SS	21							
			12	SS	21							
			13	SS	48							
61.4												
12.8	(SP) SAND, some gravel, trace silt and clay, contains cobbles and boulders Compact to dense Grey-brown Wet		14	SS	37							
			15	SS	29							
			16	SS	41							
			17	SS	31							
			18	SS	36							
56.8												
17.4	END OF BOREHOLE											
	NOTES: 1. Water level in well screen at a depth of 14.0 m below ground surface (Elev. 60.2 m), measured on July 25, 2018.											



GTA-MTO 001 N:\ACTIVE\SPATIAL IM\MTOWHWY417REHAB&WIDENING\02 DATA\GINT\1662565.GPJ GAL-GTA.GDT 19-6-17 ZS

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

PROJECT		RECORD OF BOREHOLE				No 18-2103		SHEET 2 OF 2		METRIC							
G.W.P. 4074-11-00		LOCATION				N 5030551.6; E 375173.1 NAD 83 MTM ZONE 9 (LAT. 45.403160; LONG. -75.710970)				ORIGINATED BY DG							
DIST Eastern HWY 417		BOREHOLE TYPE				Power Auger, 200 mm Diam. (Hollow Stem)				COMPILED BY ZS							
DATUM Geodetic		DATE				June 8-9, 2018				CHECKED BY MJK							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
	(SM) Gravelly silty SAND, trace to some clay (FILL) Compact to very dense Grey-brown Moist		13	SS	11												
64.6			14	SS	60/0.20		65										
11.0	END OF BOREHOLE AUGER REFUSAL																

PROJECT 1662565-1210		RECORD OF BOREHOLE No 18-2104		SHEET 1 OF 3		METRIC	
G.W.P. 4074-11-00		LOCATION N 5030560.7; E 375196.9 NAD 83 MTM ZONE 9 (LAT. 45.402720; LONG. -75.710700)		ORIGINATED BY DG			
DIST Eastern HWY 417		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring, HW Casing/ Rotary Drill, H		COMPILED BY ZS			
DATUM Geodetic		DATE June 25-27, 2018		CHECKED BY MJK			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID 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	20	40	60	80	100	W _p	W		W _L			
74.7	GROUND SURFACE																			
0.0 74.5	ASPHALTIC CONCRETE																			
0.2	(SP) Gravelly sand (FILL) Dense Brown Moist		1	GRAB	-															
			2	SS	39															
73.3	(SM) Silty sand, some gravel and clay (FILL) Loose Brown Moist		3	SS	8								○							
1.4			4	SS	6															
			5	SS	9								○							
70.1	(SM) Silty sand, contains shale fragments (FILL) Dense Grey Moist		6	SS	44							○								
4.6																				
68.6	(CL/SM) Silty clay and silty sand, layered (FILL) Compact Brown Moist		7	SS	23								○	—	—					
6.1																				
67.1	(SM) Silty sand, contains shale fragments (FILL) Compact Grey-brown Moist		8	SS	28								○							
7.6																				
65.6	(SM) Silty SAND, trace clay Compact Brown Moist		9	SS	24							○								
9.1																				

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMITOHWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 19-6-17 ZS



N:\ACTIVE\SPATIAL IM\TOIHWY417REHAB&WIDENING\02 DATA\GIN\1662565.GPJ GAL-GTA.GDT 19-6-17 ZS

Continued Next Page

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

PROJECT		1662565-1210		RECORD OF BOREHOLE No 18-2104		SHEET 3 OF 3		METRIC											
G.W.P.		4074-11-00		LOCATION		N 5030560.7; E 375196.9 NAD 83 MTM ZONE 9 (LAT. 45.402720; LONG. -75.710700)		ORIGINATED BY											
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring, HW Casing/ Rotary Drill, H		COMPILED BY											
DATUM		Geodetic		DATE		June 25-27, 2018		CHECKED BY											
								MJK											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)	
	--- CONTINUED FROM PREVIOUS PAGE ---																		
54.3	(SP/SM) Gravelly SAND, some silt, trace to some clay (TILL) Very dense Grey-brown Wet		21	SS	42												22 56 16 6		
20.4			22	SS	91														
			23	RC	DD														
52.7	Shale (BEDROCK) Bedrock cored from depths of 22.0 m to 25.4 m For bedrock coring details refer to Record of Drillhole 18-2104		1	RC	REC 100%												RQD = 100%		
22.0			2	RC	REC 97%													RQD = 39%	
			3	RC	REC 100%														RQD = 99%
49.3	END OF BOREHOLE																		
25.4																			

PROJECT: 1662565-1210

RECORD OF DRILLHOLE: 18-2104

SHEET 1 OF 1

LOCATION: N 5030560.7 ;E 375196.9

DRILLING DATE: June 25-27, 2018

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	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	Ja	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³	W1		W2	W3	W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
		BEDROCK SURFACE		52.67																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						</

DEPTH SCALE

1 : 50

**GOLDER**

LOGGED: DG

CHECKED: MJK

GTA-RCK 031 N:\ACTIVE\SPATIAL_IMMTO\HWY417\REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-MISS.GDT 19-6-17 ZS

BH 18-2204
Cored Length of 21.10 to 25.37 metres
Core Box 1 and 2 of 2

21.10 m Top of Core

22.01 m Top of Bedrock



25.37 m EOH

Note: Material in core box from 21.10 m to 22.01 m is a gravel in Glacial Till



Foundation Investigation
CPR Overhead
Ottawa, Ontario

Project No.	1662565 / 1210
Drawn:	WAM
Date:	12/14/2018
Checked:	
Review:	

Figure A1

APPENDIX B

Laboratory Test Results, Current Investigation

Figure B1 – Grain Size Distribution Test Results – Sand and Gravel (FILL)

Figure B2 – Plasticity Chart – Silty Clay (FILL)

Figure B3 – Plasticity Chart – Silty Clay

Figure B4 – Grain Size Distribution Test Results – Silty Sand to Sand

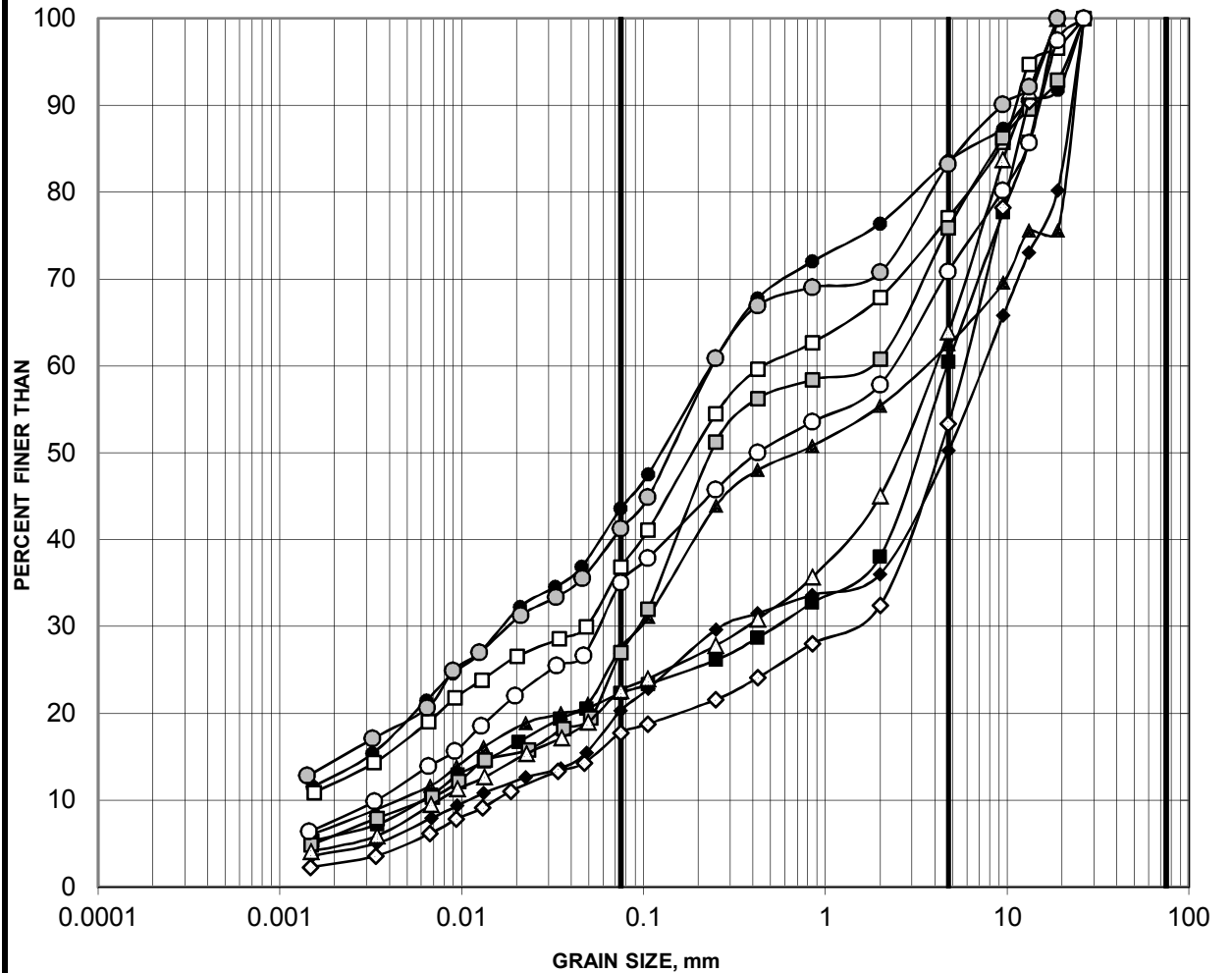
Figure B5 – Grain Size Distribution Test Results – Gravelly Silty Sand (TILL)

Figure B6 – Summary of Unconfined Compressive Strength Testing

GRAIN SIZE DISTRIBUTION

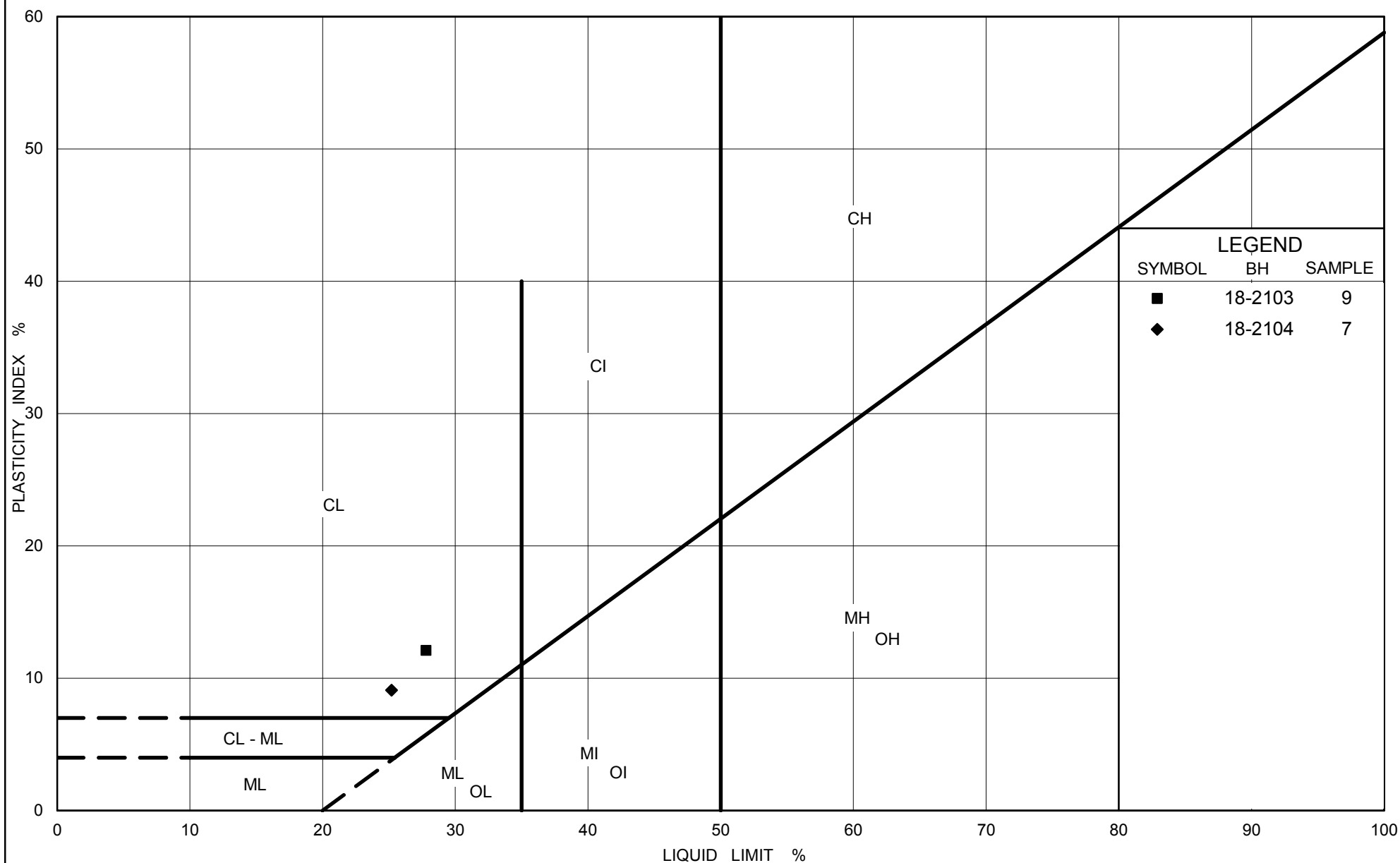
FIGURE B1

SAND AND GRAVEL (FILL)



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

Borehole	Sample	Depth (m)
18-2101	4	2.29-2.90
18-2101	10	6.86-7.47
18-2101	14	9.91-10.52
18-2102	6	6.10-6.71
18-2102	8	8.38-8.99
18-2103	3	2.29-2.90
18-2103	7	5.33-5.94
18-2103	10	7.62-8.23
18-2103	12	9.14-9.75
18-2104	5	3.05-3.66



Ministry of Transportation

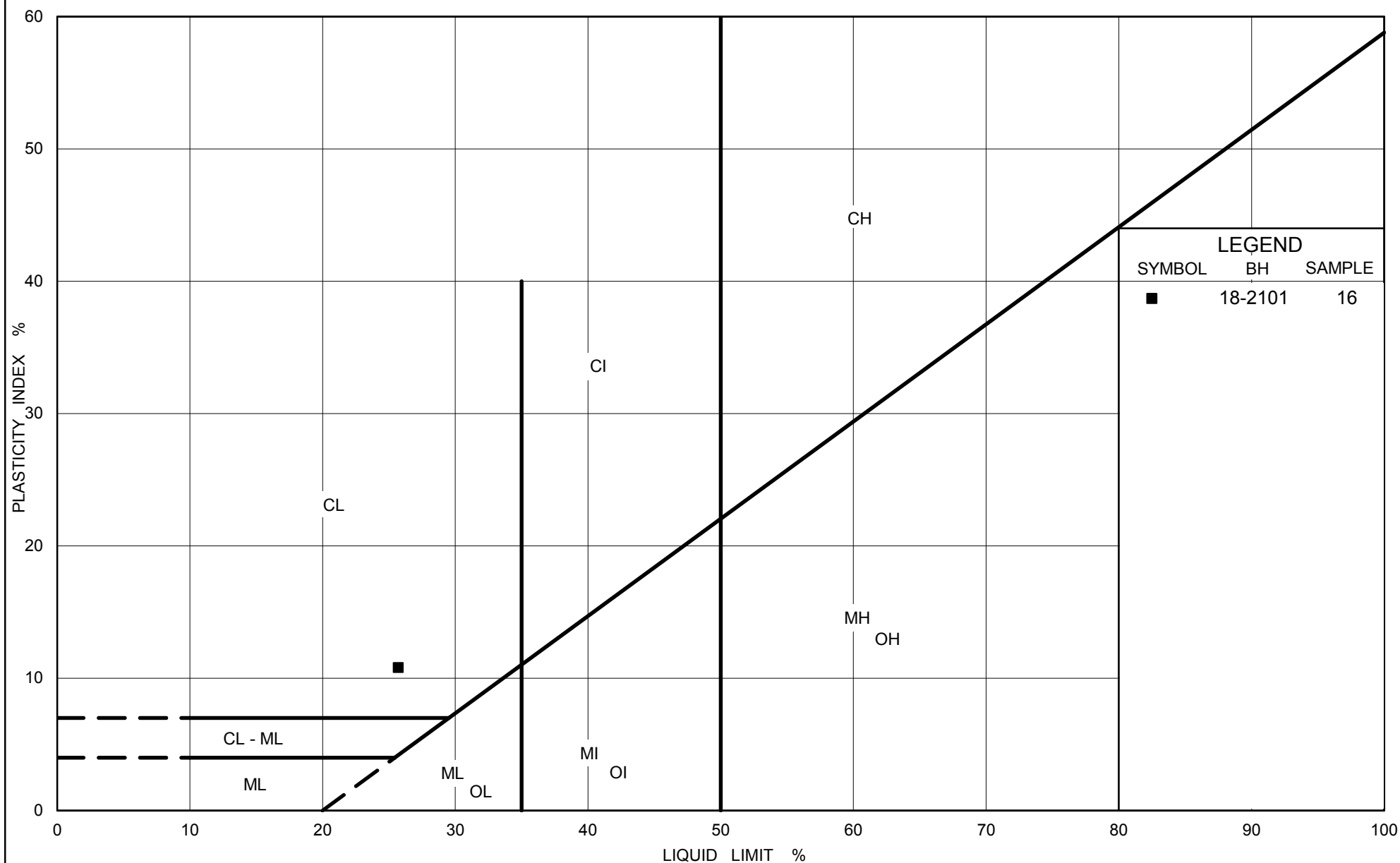
Ontario

PLASTICITY CHART SILTY CLAY (FILL)

FIG No. B2

Project No. 1662565/1210

Compiled By : MI Checked By : CW



Ontario

Ministry of Transportation

PLASTICITY CHART SILTY CLAY

FIG No. B3

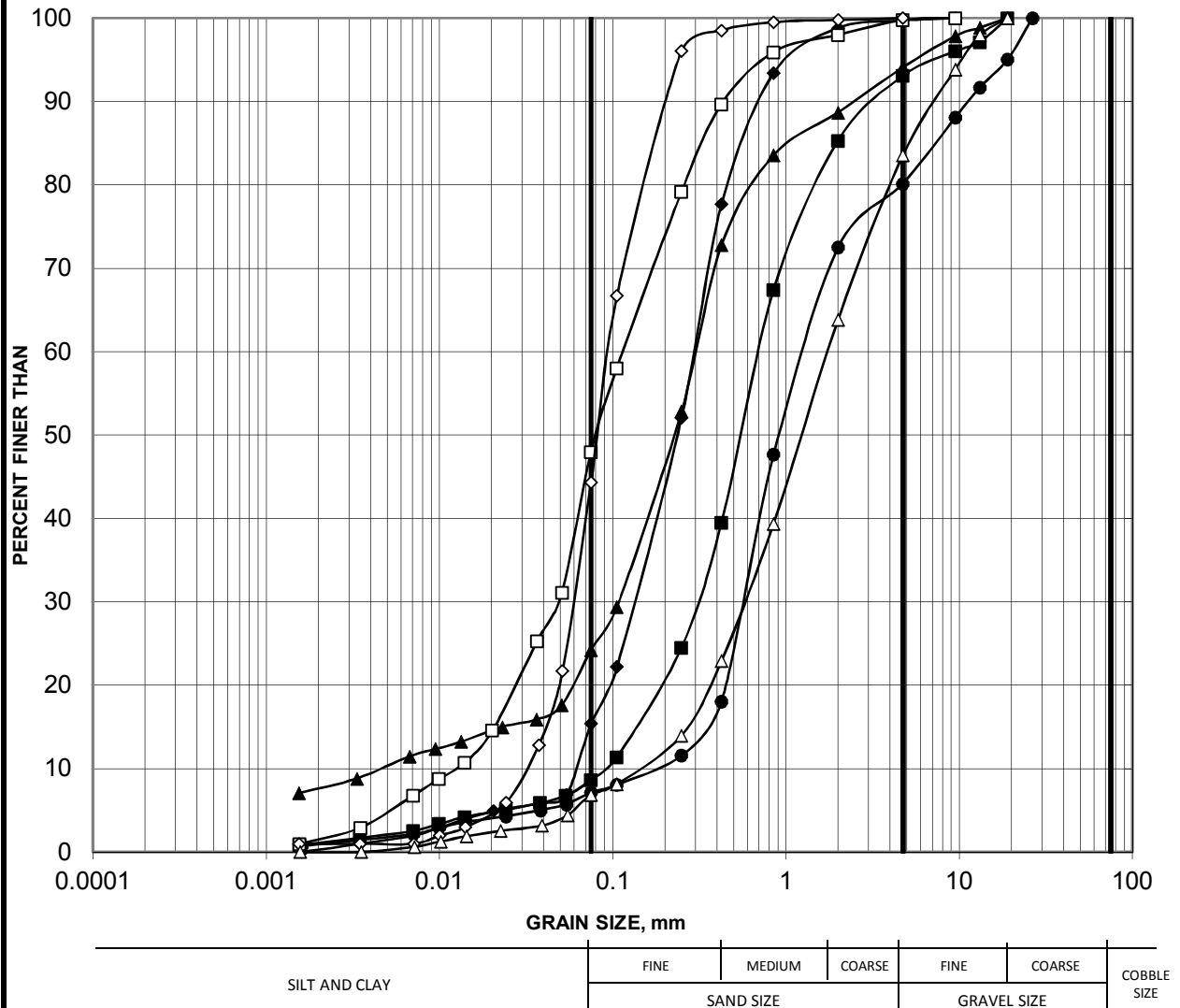
Project No. 1662565/1210

Compiled By : MI Checked By : CW

GRAIN SIZE DISTRIBUTION

FIGURE B4

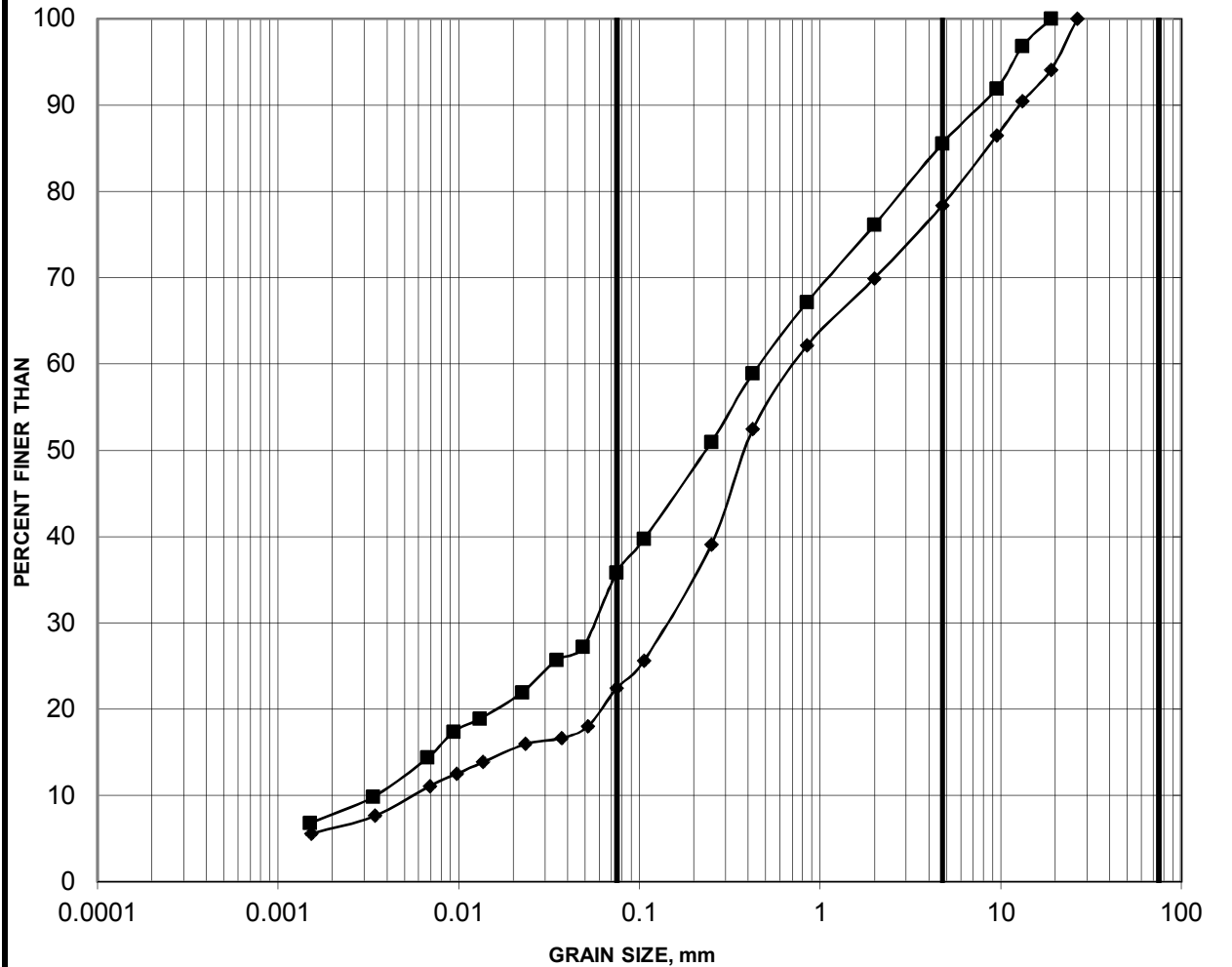
SILTY SAND TO SAND



GRAIN SIZE DISTRIBUTION

FIGURE B5

GRAVELLY SILTY SAND (TILL)

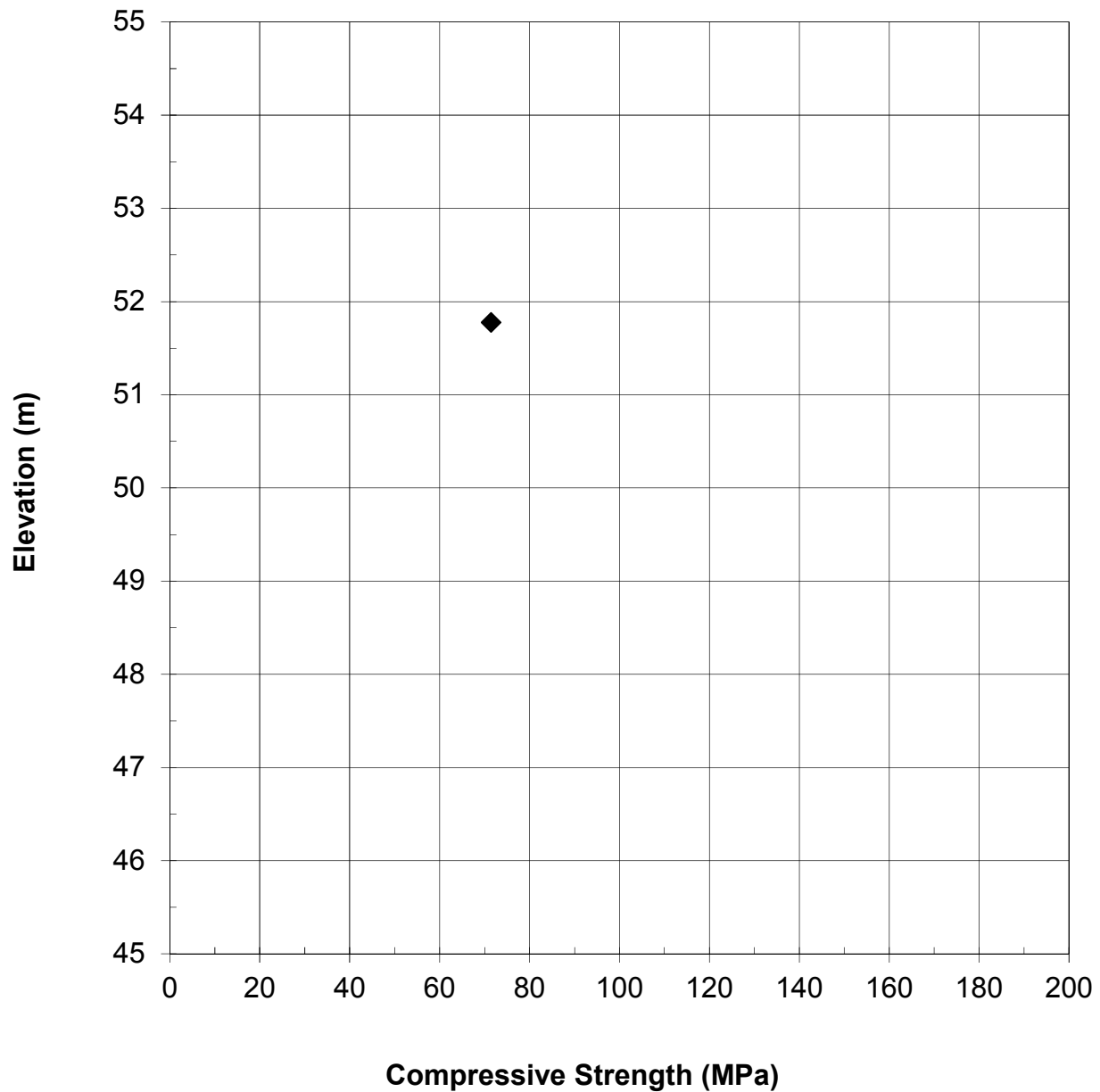


SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
18-2104	19	18.29-18.90
18-2104	22	20.57-21.18

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

FIGURE B6



◆ 18-2104

APPENDIX C

**Borehole Records and Laboratory Test Results
(Previous Investigation, GEOCREs No. 31G5-80)**

Records of Previous Boreholes 1 to 12

Laboratory Test Results

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

JOB 71-11126

LOCATION Co-ords. 16,503,918 N; 1,230,442 E.

ORIGINATED BY SAA

W.P. 13-68-06

BORING DATE Nov. 2, 1971

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Washbore NX Casing

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT PLASTIC LIMIT WATER CONTENT			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		BLOWS / FOOT		WATER CONTENT %				
							20	40	60	80	100		
							SHEAR STRENGTH P.S.F.		WATER CONTENT %				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE		w _p ——— w _L PLASTIC LIMIT ——— w _p WATER CONTENT ——— w _L				
202.2	Ground Level												
0.0	Silty sand with some gravel. Compact to Very Dense Brown Grey					200							208.2 25 69 (6) 7 91 (2) 0 96 (4)
			1	SS	37								
			2	SS	16								
			3	SS	15								
			4	SS	47								
			5	SS	25								
187.9			6	SS	74	190							
22.0	End of Borehole					180							

FOUNDATION SECTION

ORIGINATED BY WH

COMPILED BY SAA

CHECKED BY *SA*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — w_L			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT					PLASTIC LIMIT — w_p				
							SHEAR STRENGTH P.S.F.					WATER CONTENT %				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE					w_p — w — w_L				
211.1	Ground Level															
0.0	Silty sand with some gravel, occ. seams of clayey silt up to 1" thick. Compact to Very Dense Brown - Grey					210										
			1	SS	9											207.0
			2	SS	17											3 92 (5
			3	SS	26		200									20-75 (5
			4	SS	14											
			5	SS	12											
			6	SS	15											15 73 (12
			7	SS	65		190									
			8	SS	25											
			9	SS	20		180									43 47 (10
			10	SS	10											
172.2			11	SS	150/3"											
38.9	End of Borehole Probable Bedrock					170										

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 4

FOUNDATION SECTION

JOB 71-11126

LOCATION

Co-ords. 16,503,788 N; 1,230,600 E.

ORIGINATED BY WH

W.P. 13-68-06

BORING DATE

November 19, 1971.

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT						LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			BULK DENSITY γ P.C.F.	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		SHEAR STRENGTH P.S.F.						WATER CONTENT %					
							○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL		x LAB. VANE		w_p			w
211.2	Ground Level													10	20	30		
0.0	Grey silty sand with some gravel.					210												
			1	SS	16													208.2
			2	SS	12													195 (4)
	Compact to Dense																	
			3	SS	30		200											
	Brown - Grey																	3856 (6)
			4	SS	25													
			5	SS	41		190											
																	Piez. Tip El. 189.1	
184.2			6	SS	17													
27.0	End of Borehole					180												

FOUNDATION SECTION

CHECKED BY *[Signature]*

SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT ——— w_L			BULK DENSITY γ P.C.F.	REMARKS		
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	BLOWS / FOOT					PLASTIC LIMIT ——— w_p					
							20	40	60	80	100	WATER CONTENT ——— w					
							SHEAR STRENGTH P.S.F.					w_p ——— w ——— w_L			WATER CONTENT %		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE								10 20 30		
210.1	Ground Level																
0.0	Silty sand with some gravel - occ. seams of clayey silt.		1	SS	7												
			2	SS	17												
			3	SS	23												
	Compact to Dense		4	SS	24												
			5	SS	15												
	Brown - Grey		6	SS	13												
			7	SS	39												
			8	SS	15												
			9	SS	44												
			10	SS	91												
176.1			11	SS	106 1/6"												
34.0	End of Borehole Probable Bedrock																

FOUNDATION SECTION

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT		WATER CONTENT %				
							20	40	60	80	100		
							SHEAR STRENGTH P.S.F.						
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE						
211.6	Ground Level												
0.0	Silty sand with trace of gravel, occ. clayey silt seams.		1	SS	25	210							207.6
			2	SS	29								12 73 (15)
			3	SS	22								
	Compact to Very Dense		4	SS	30	200							
			5	SS	58								11 83 (6)
	Brown-Grey		6	SS	42								
			7	SS	53	190							2 93 (5)
			8	SS	19								7 59 25 9
			9	SS	11								
			10	SS	98	180							
178.7			11	SS	123								
32.9	End of Borehole					170							

FOUNDATION SECTION

ORIGINATED BY VK

COMPILED BY SAA

CHECKED BY *AK*

[illegible]

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 8

FOUNDATION SECTION

JOB 71-11126

LOCATION Co-ords. 16,503,885 N; 1,230,570 E.

ORIGINATED BY AO

W.P. 13-68-06

BORING DATE November 24, 1971

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Washboring, BX and NX Casing

CHECKED BY *[Signature]*

[illegible]

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 9

FOUNDATION SECTION

JOB 71-11126

LOCATION Coords. 16,503,872 N; 1,230,780 E.

ORIGINATED BY SAA

WP 13-68-06

BORING DATE November 23, 1971

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Washboring-BX & NX Casing

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION	RESISTANCE	LIQUID LIMIT ———— w_L	PLASTIC LIMIT ———— w_p	BULK DENSITY γ P.C.F.	REMARKS			
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT	20	40	60			80	100	WATER CONTENT ———— w
							SHEAR STRENGTH P.S.F.						w_p ———— w ———— w_L		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE						WATER CONTENT % 10 20 30		
209.2	Ground Level														
0.0	Silty sand with some gravel, occ. seams of clayey silt. Compact to Dense Brown - Grey		1	SS	13									15 82 (3) 32 61 (7)	
			2	SS	31										
			3	SS	23	200									
			4	SS	23										
			5	SS	22										
			6	SS	20	190									
			7	SS	26										
			8	SS	29										
177.3			9	SS	67	180									
31.9	End of Borehole Probable Bedrock					170									

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 10

FOUNDATION SECTION

JOB 71-11126

LOCATION Co-ords. 16,503,790 N; 1,230,788 E.

ORIGINATED BY WH

W.P. 13-68-06

BORING DATE November 19, 1971

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE

CHECKED BY

[illegible]

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 11

FOUNDATION SECTION

JOB 71-11126

LOCATION Co-ords. 16,503,778 N; 1,230,886 E.

ORIGINATED BY SAA

W.P. 13-68-06

BORING DATE November 23, 1971

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w			BULK DENSITY γ	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT					SHEAR STRENGTH P.S.F.					WATER CONTENT %
							20	40	60	80	100	○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE x LAB. VANE				
210.3	Ground Level																
0.0	Silty sand with some gravel, occ. seams of clayey silt.		1	SS	4	210											
			2	SS	3												
			3	SS	62												
	Very Loose-Very Dense		4	SS	86	200											
	Brown Grey		5	SS	60												
			6	SS	40	190											
			7	SS	96												
178.3			8	SS	79	180											
32.0	Fractured weathered shale.		9	RC	59%												
			10	SS	60/2"												
169.3	Grey		11	RC	37%	170											
41.0	Shale Bedrock		12	RC	100%												
163.5	Sound Grey																

205.

53 (42)

97 (3)

Piez. Tip
El. 181.0

FOUNDATION SECTION
AQ

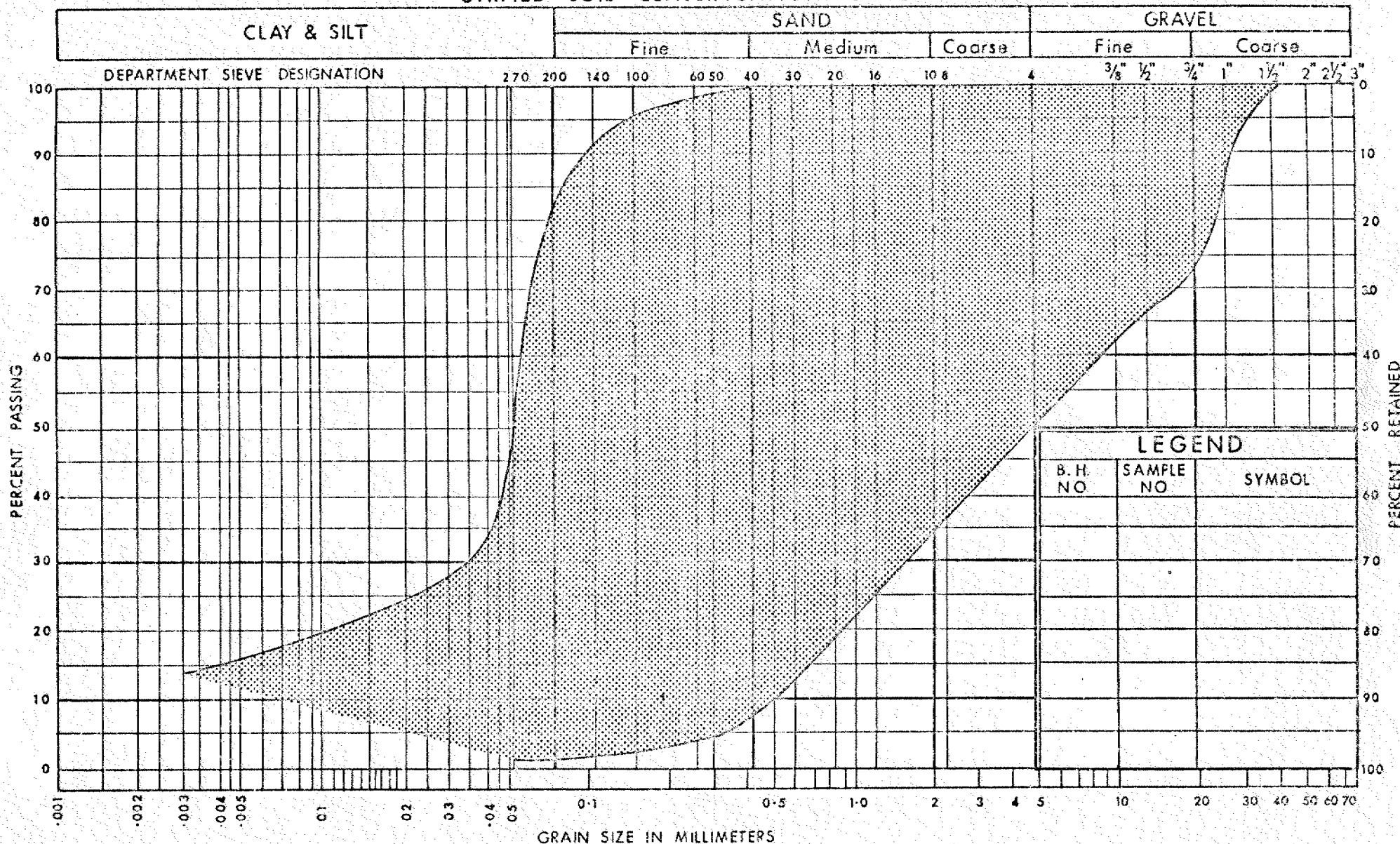
40

SAA

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT		LIQUID LIMIT — w_L PLASTIC LIMIT — w_p WATER CONTENT — w		BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB. VANE		WATER CONTENT % 10 20 30			
211.2	Ground Level											
0.0	Silty sand with some gravel, occ. seams of clayey silt. Loose to Dense Brown to Grey		1	SS	9	210						Nov. 25/72 206.2 4.83 (13)
			2	SS	36	200						30 60 (10)
			3	SS	31							
			4	SS	36	190						
184.2			5	SS	34							1 94 (5)
27.0	End of Borehole					180						
175.2												
36.0	End of Cone Test					170						

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND

B.H. NO.	SAMPLE NO.	SYMBOL

DEPARTMENT
OF
TRANSPORTATION AND COMMUNICATIONS



DESIGN SERVICES
BRANCH

GRAIN SIZE DISTRIBUTION
SILTY SAND WITH SOME GRAVEL

W.P. No. 13-68-06

JOB No. 71-11126

FIG No. 1

APPENDIX D

Basic Chemical Analysis – Eurofins Report No. 1814200



Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Mr. Alex Meacoe
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1814200
Date Submitted: 2018-08-09
Date Reported: 2018-08-16
Project: 1662565/1210
COC #: 834571

Lab I.D.
Sample Matrix
Sample Type
Sampling Date
Sample I.D.

1379728
Soil
2018-08-09
18-2102Sa13/40-42'

Group	Analyte	MRL	Units	Guideline	
Anions	Cl	0.002	%		0.015
	SO4	0.01	%		0.03
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.55
	pH	2.00			8.42
	Resistivity	1	ohm-cm		1820

Guideline =

* = Guideline Exceedence

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 E

Results of MASW Testing

TECHNICAL MEMORANDUM

DATE June 27, 2019

Project No. 1662565/1210

TO Susan Trickey, Golder Associates Ltd.

FROM Peter Giamou, Christopher Phillips

EMAIL pgiamou@golder.com, cphillips@golder.com

CHBDC SEISMIC SITE CLASS TESTING RESULTS CPR AND HIGHWAY 417, OTTAWA, ONTARIO

This technical memorandum presents the results of two Multichannel Analysis of Surface Waves (MASW) tests performed for the purpose of the Canadian Highway Bridge Design Code (CHBDC 2014) Seismic Site Classification (Figure 1). The tests are located on each side of the interchange between Canadian Pacific Railway (CPR) and Highway 417 in Ottawa. The geophysical testing was performed by Golder Associates Ltd. (Golder) personnel on July 18, 2018.



Figure 1: MASW Location Site Map. MASW Lines in red – Line 1 and Line 2.

Methodology

The MASW method measures variations in surface-wave velocity with increasing distance and wavelength and can be used to infer the rock/soil types, stratigraphy and soil conditions.

A typical MASW survey requires a seismic source, to generate surface waves, and a minimum of two geophone receivers, to measure the ground response at some distance from the source. Surface waves are a special type of seismic wave whose propagation is confined to the near surface medium.

The depth of penetration of a surface wave into a medium is directly proportional to its wavelength. In a non-homogeneous medium, surface waves are dispersive, i.e., each wavelength has a characteristic velocity owing to the subsurface heterogeneities within the depth interval that particular wavelength of surface wave propagates through. The relationship between surface-wave velocity and wavelength is used to obtain the shear-wave velocity and attenuation profile of the medium with increasing depth.

The seismic source used can be either active or passive, depending on the application and location of the survey. Examples of active sources include explosives, weight-drops, sledge hammer and vibrating pads. Examples of passive sources are road traffic, micro-tremors, and water-wave action (in near-shore environments).

The geophone receivers measure the wave-train associated with the surface wave travelling from a seismic source at different distances from the source.

The participation of surface waves with different wavelengths can be determined from the wave-train by transforming the wave-train results into the frequency domain. The surface-wave velocity profile with respect to wavelength (called the 'dispersion curve') is determined by the delay in wave propagation measured between the geophone receivers. The dispersion curve is then matched to a theoretical dispersion curve using an iterative forward-modelling procedure. The result is a shear-wave velocity profile of the tested medium with depth, which can be used to estimate the dynamic shear-modulus of the medium as a function of depth.

Field Work

The MASW field work was conducted on July 18, 2018, by personnel from the Golder Mississauga office. For each MASW line, a series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. Both active and passive readings were recorded along the MASW lines. For the active investigation, a seismic drop of 45 kg and a 9.9 kg sledge hammer were used as seismic sources. Active seismic records were collected with seismic sources located 5, 10, and 15 m from and collinear to the geophone array. A seismic refraction survey was also conducted along both lines to be able to determine the depth to bedrock as well as to estimate the shear wave velocity of the overburden. An example of active seismic records collected at each line are shown in Figures 2 and 3, below.

Table 1: Location of MASW Lines

Location	MTM NAD83 Zone 9 Northing (m)	MTM NAD83 Zone 9 Easting (m)
Line 1 – Start	5,030,492.3	375,256.1
Line 1 – End	5,030,539.4	375,206.2
Line 2 – Start	5,030,620.4	375,097.7
Line 2 – End	5,030,649.3	375,036.1

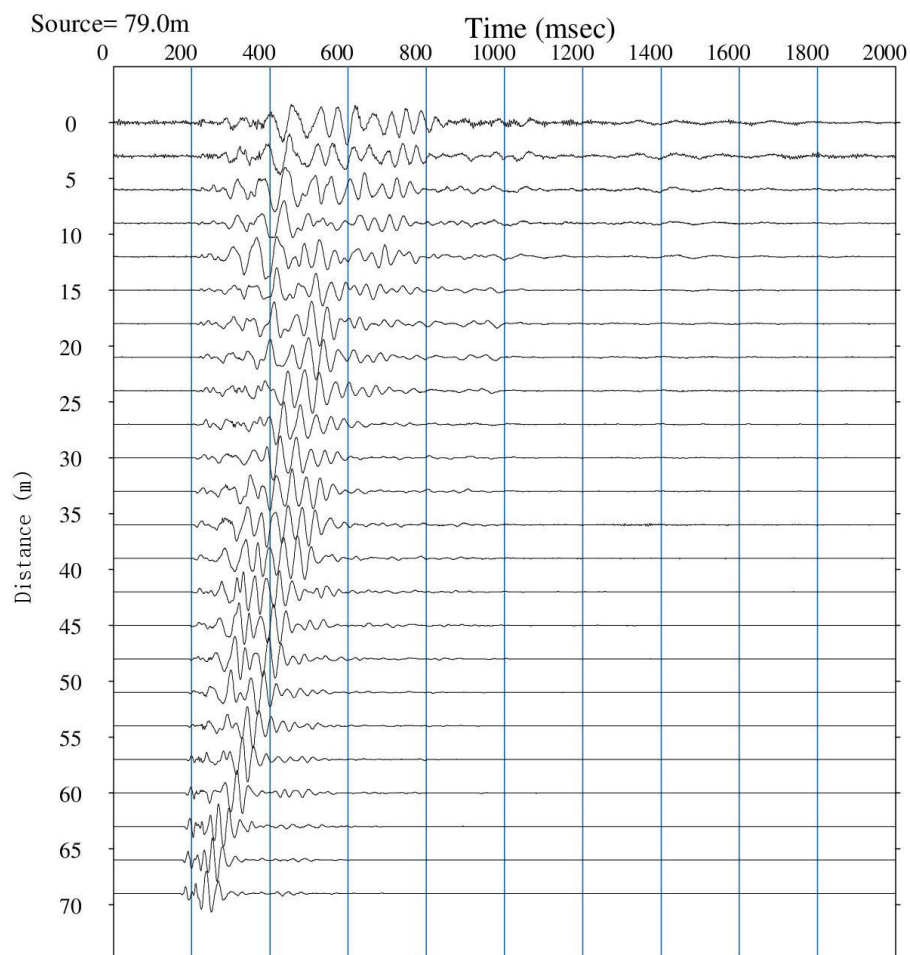


Figure 2: Typical seismic record collected at the site of MASW Line 1.

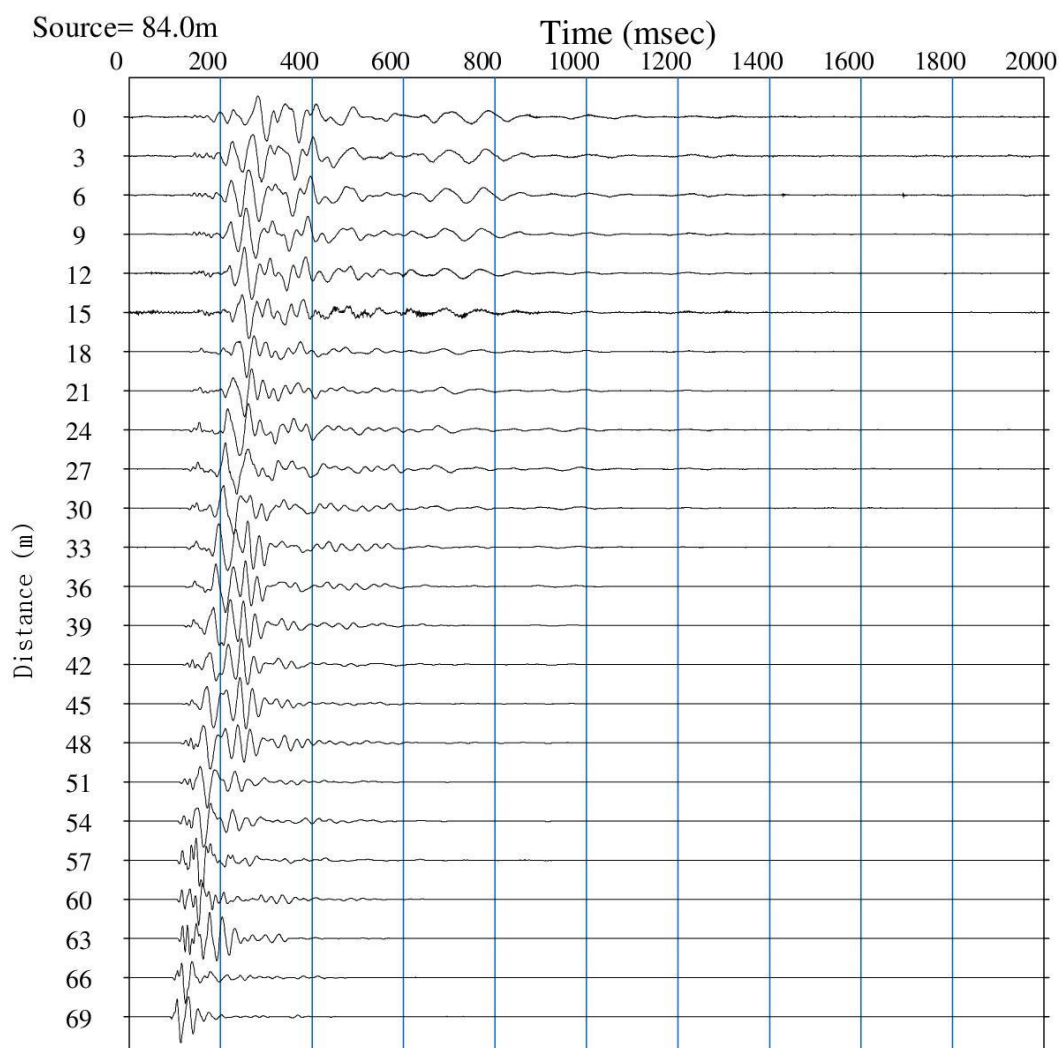


Figure 3: Typical seismic record collected at the site of MASW Line 2.

Data Processing

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

- 1) Transformation of the time domain data into the frequency domain using a Fast-Fourier Transform (FFT) for each source location;
- 2) Calculation of the phase for each frequency component;
- 3) Linear regression to calculate phase velocity for each frequency component;
- 4) Filtering of the calculated phase velocities based on the Pearson correlation coefficient (r^2) between the data and the linear regression best fit line used to calculate phase velocity;
- 5) Generation of the dispersion curve by combining calculated phase velocities for each shot location of a single MASW test; and,
- 6) Generation of the stiffness profile, through forward iterative modelling and matching of model data to the field collected dispersion curve.

Processing of the MASW data was completed using the SeisImager/SW software package (Geometrics Inc.). The calculated phase velocities for a seismic shot point were combined and the dispersion curve generated by choosing the minimum phase velocity calculated for each frequency component as shown on Figure 4 for Line 1 and Figure 5 for Line 2. Shear wave velocity profiles were generated through inverse modelling to best fit the calculated dispersion curves. The active survey of Line 1 provided a dispersion curve with a suitable frequency range (6-25 Hz). The active survey of Line 2 provided a dispersion curve with a suitable frequency range (9-38 Hz).

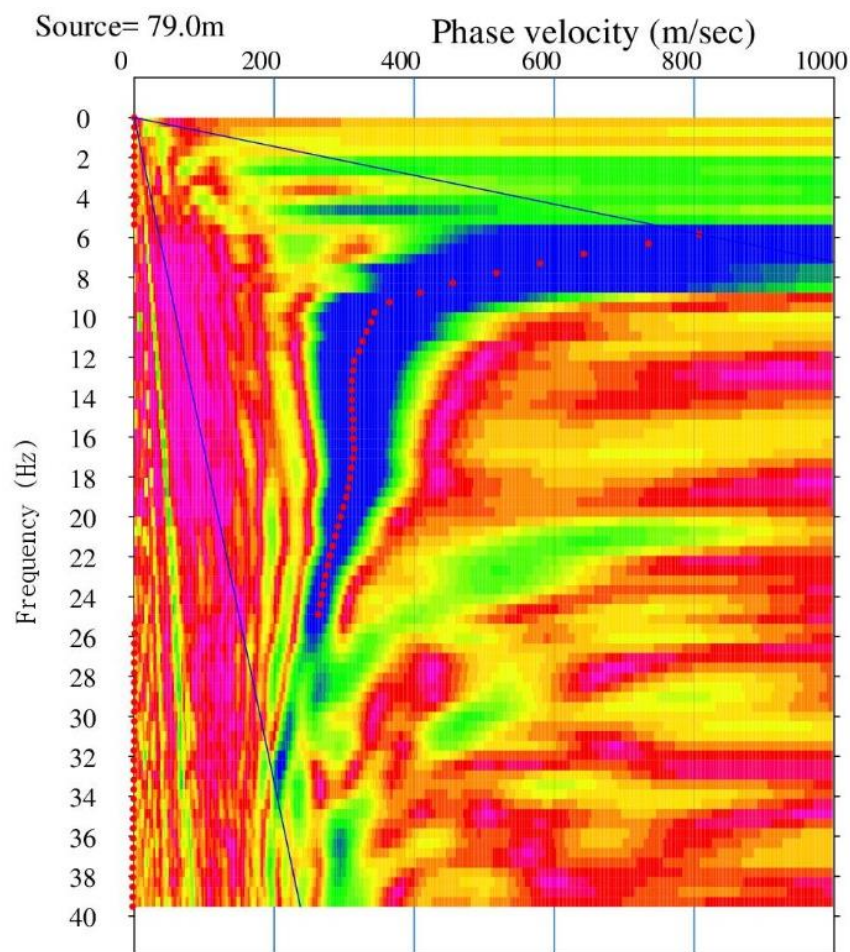


Figure 4: Active MASW Dispersion Curve Picks (red dots) along MASW Line 1

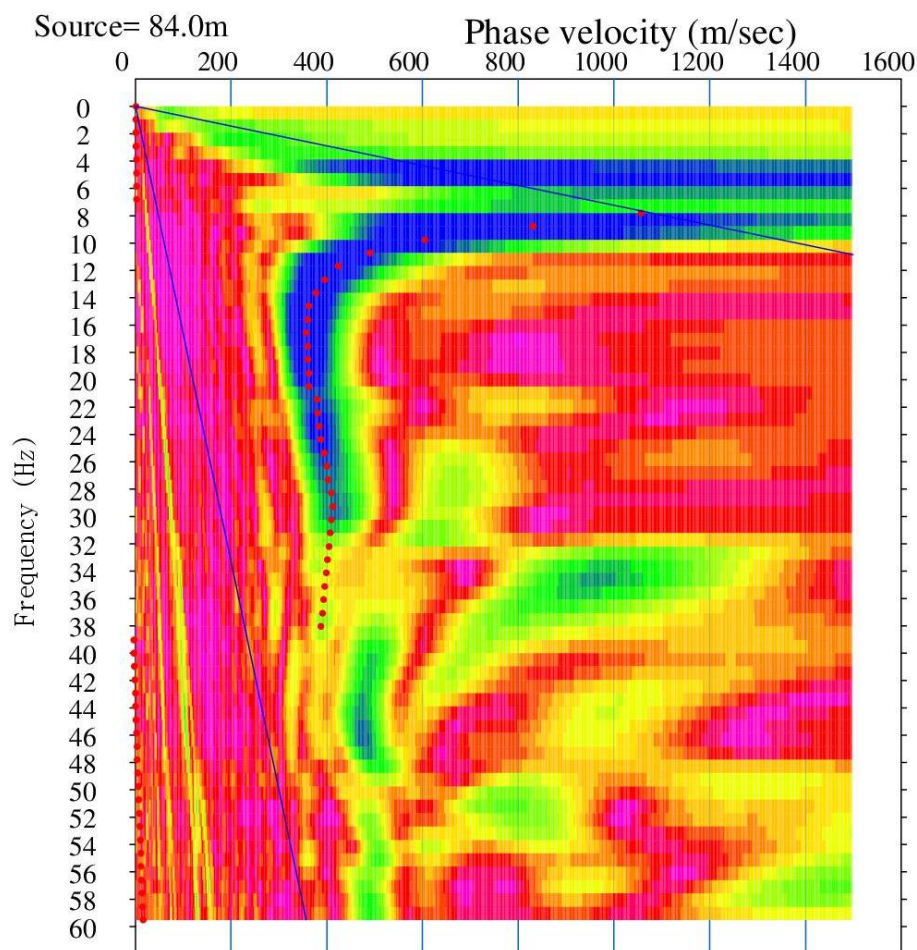


Figure 5: Active MASW Dispersion Curve Picks (red dots) along MASW Line 2

Results

The MASW test results are presented in Figures 6 and 7, which present the calculated shear wave velocity profile derived from the field testing along MASW Lines 1 and 2, respectively. The results along MASW Line 1 have been calculated using a weight-drop located 10 m from the last geophone. The results along MASW Line 2 have also been calculated using a weight-drop located 5 m from the last geophone. The field collected dispersion curves are compared with the model generated dispersion curves on Figures 8 and 9 for MASW Lines 1 and 2, respectively. There is a satisfactory correlation between the field collected and model calculated dispersion curves, with a root mean squared error of less than 3% along both lines.

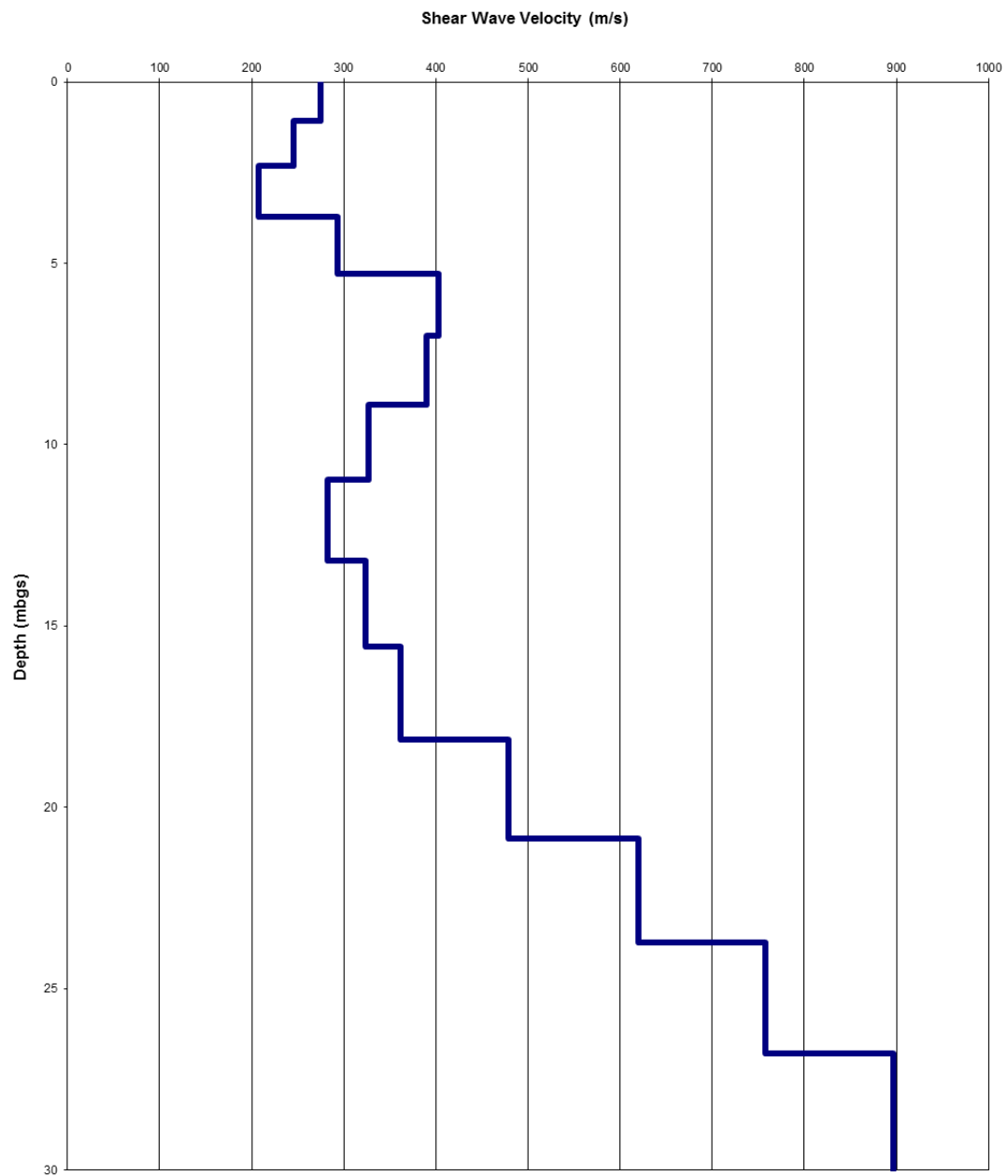


Figure 6: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 1

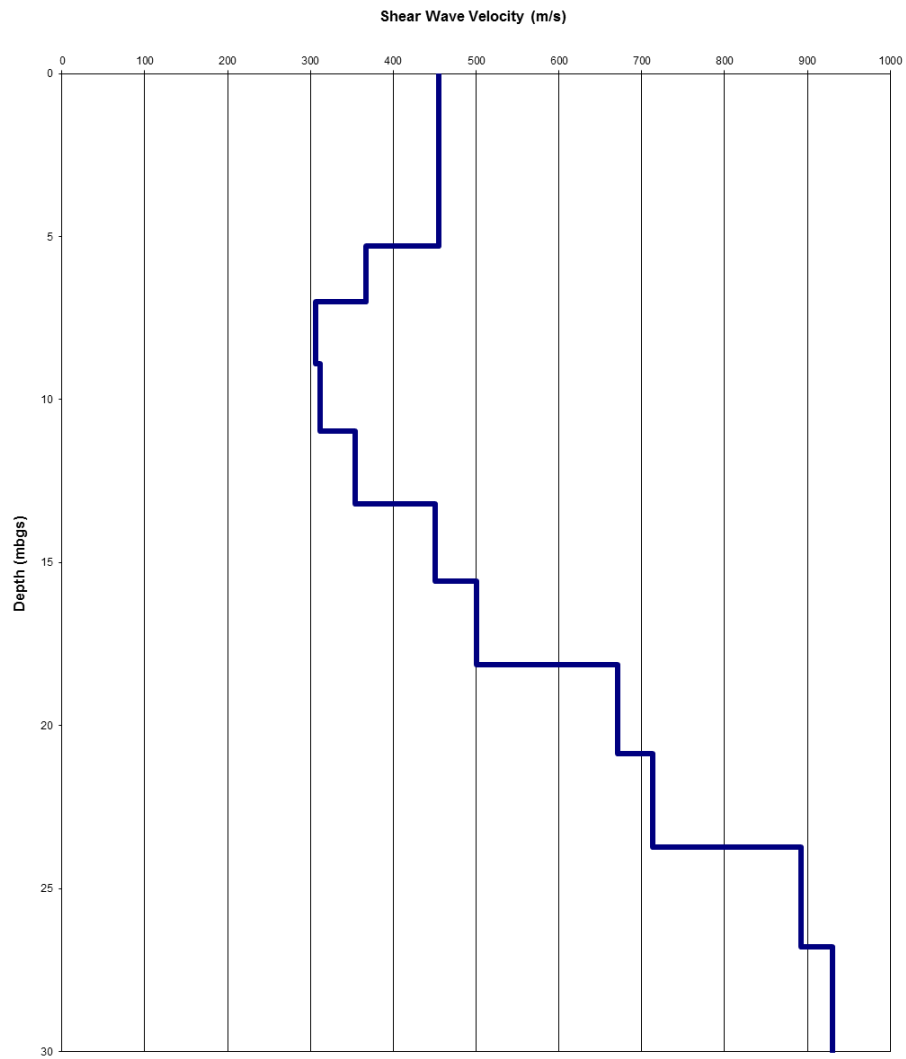


Figure 7: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 2

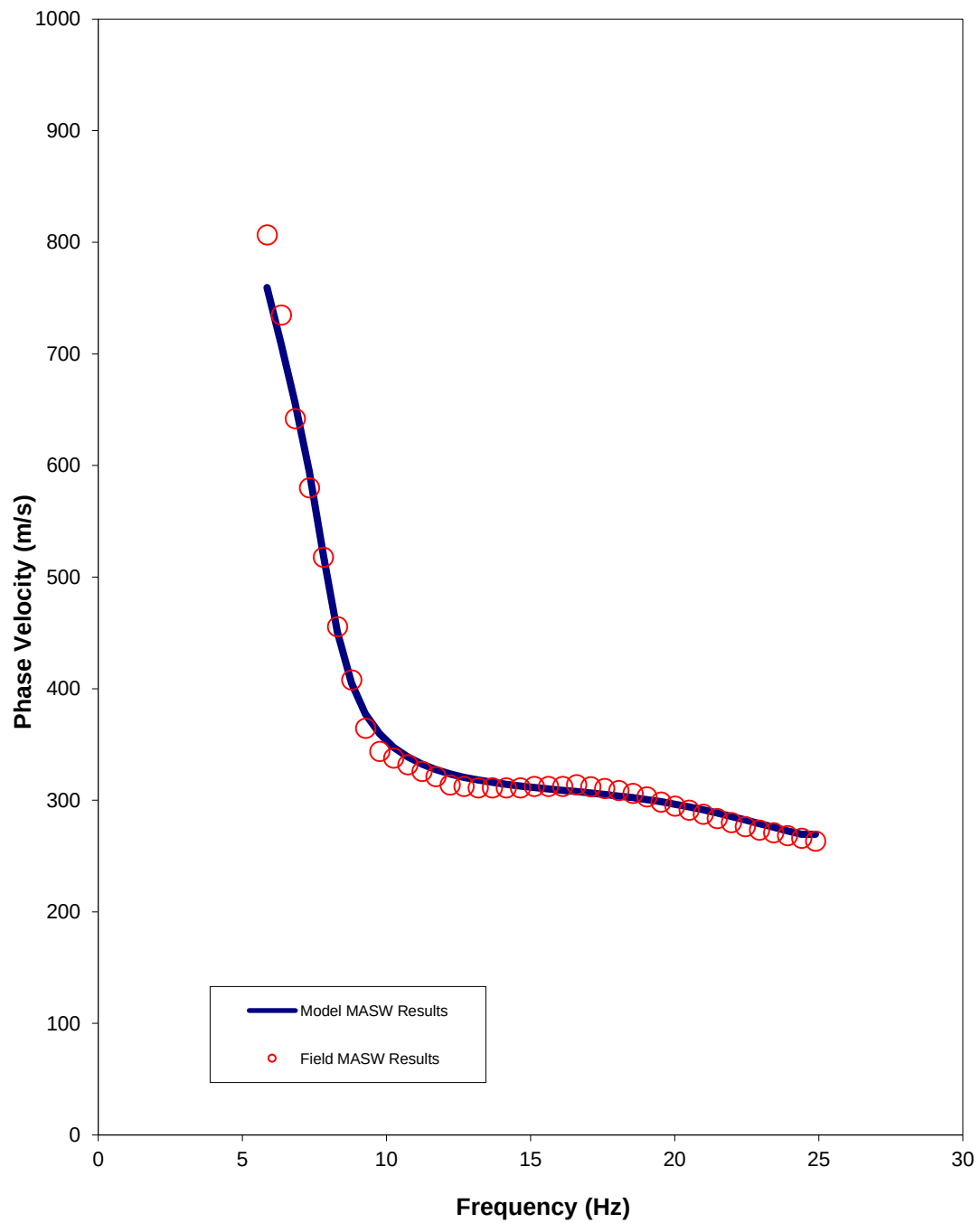


Figure 8: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 1

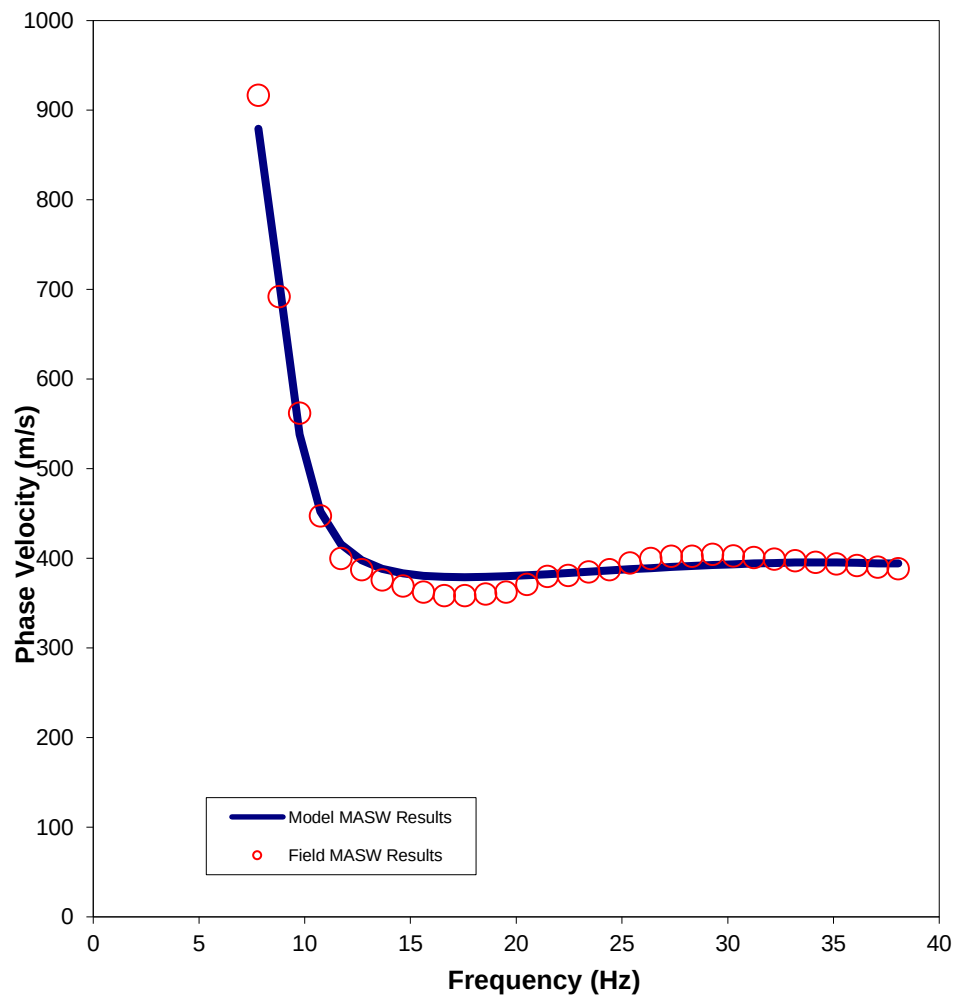


Figure 9: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 2

To calculate the average shear-wave velocity as required by the CHBDC 2014, the results were modelled to 30 metres below ground surface. The average shear-wave velocity along MASW Line 1 in the south was found to be 391 m/s (Table 1). The average shear-wave velocity along MASW Line 2 in the north was found to be 494 m/s (Table 2).

Table 2: Shear-Wave Velocity Profile along MASW Line 1

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
0.00	1.07	1.07	275	0.003893
1.07	2.31	1.24	245	0.005043
2.31	3.71	1.40	208	0.006747
3.71	5.27	1.57	293	0.005343
5.27	7.01	1.73	403	0.004297
7.01	8.90	1.90	390	0.004866
8.90	10.96	2.06	326	0.006311
10.96	13.19	2.23	282	0.007882
13.19	15.58	2.39	324	0.007378
15.58	18.13	2.55	361	0.007071
18.13	20.85	2.72	479	0.005682
20.85	23.74	2.88	619	0.004657
23.74	26.79	3.05	758	0.004023
26.79	30.00	3.21	897	0.003585
Vs Average to 30 mbgs (m/s)				391

Table 3: Shear-Wave Velocity Profile along MASW Line 2

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
0.00	1.07	1.07	455	0.002353
1.07	2.31	1.24	455	0.002714
2.31	3.71	1.40	455	0.003076

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
3.71	5.27	1.57	455	0.003438
5.27	7.01	1.73	368	0.004709
7.01	8.90	1.90	306	0.006193
8.90	10.96	2.06	311	0.006618
10.96	13.19	2.23	354	0.006281
13.19	15.58	2.39	450	0.005308
15.58	18.13	2.55	500	0.005106
18.13	20.85	2.72	671	0.004054
20.85	23.74	2.88	713	0.004044
23.74	26.79	3.05	892	0.003418
26.79	30.00	3.21	931	0.003453
Vs Average to 30 mbgs (m/s)				494

The CHBDC 2014 requires special site specific evaluation if certain soil types are encountered on the site, so the site classification stated here should be reviewed, and modified if necessary, according to borehole stratigraphy, standard penetration resistance results, and undrained shear strength measurements, if available for this site.

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 this technical memorandum meets your needs at the present time. If you have any questions or require clarification, please contact the undersigned at your convenience.

GOLDER ASSOCIATES LTD.



Peter Giamou, B.Sc, P. Geo.
Geophysicist

SS/CRP/PG/jl



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

APPENDIX F

Results of Analysis

Figures F1 to F16 – P-Y Curves

Figures F17 to F24 – Results of Liquefaction Analysis

P-Y CURVES

CPR Overhead

H-Pile 310x110 - EBL West Abutment

Figure F1

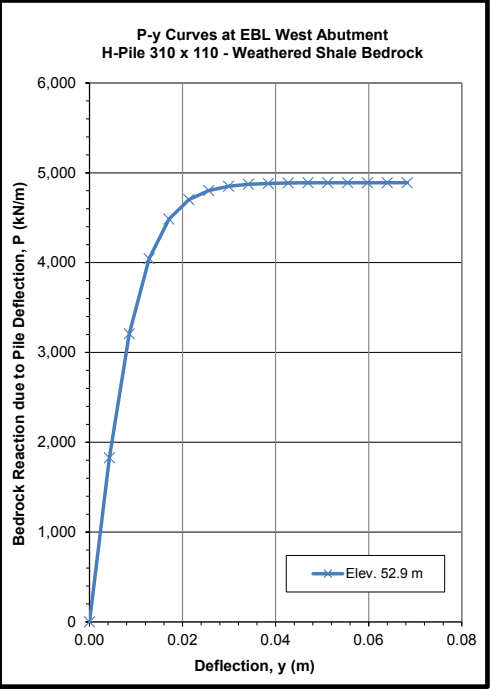
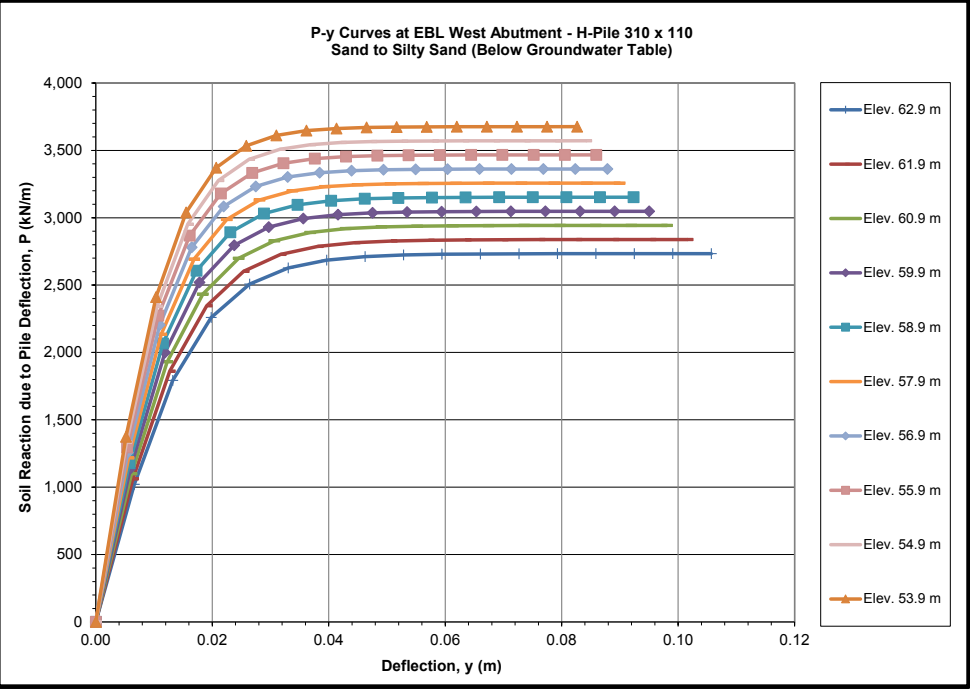
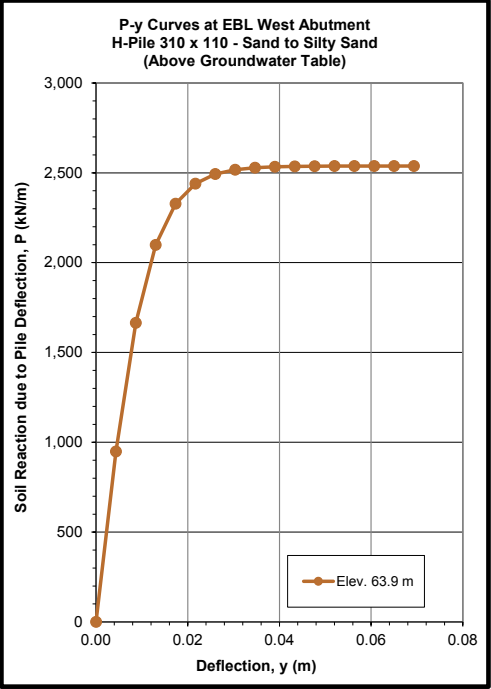
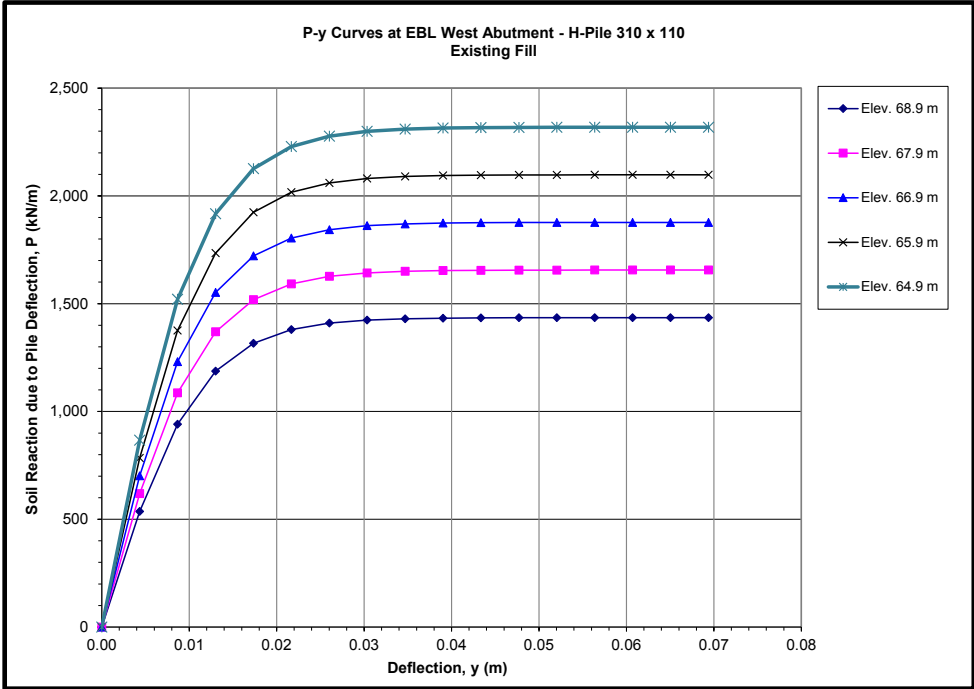
SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - EBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	Existing Fill										Sand to Silty Sand																Wthrd. Bedrock							
	z= 6.5 m		z= 7.5 m		z= 8.5 m		z= 9.5 m		z= 10.5 m		z= 11.5 m		z= 12.5 m		z= 13.5 m		z= 14.5 m		z= 15.5 m		z= 16.5 m		z= 17.5 m		z= 18.5 m		z= 19.5 m		z= 20.5 m		z= 21.5 m		z= 22.5 m	
	Elev. 68.9 m		Elev. 67.9 m		Elev. 66.9 m		Elev. 65.9 m		Elev. 64.9 m		Elev. 63.9 m		Elev. 62.9 m		Elev. 61.9 m		Elev. 60.9 m		Elev. 59.9 m		Elev. 58.9 m		Elev. 57.9 m		Elev. 56.9 m		Elev. 55.9 m		Elev. 54.9 m		Elev. 53.9 m		Elev. 52.9 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.004	536.382	0.004	618.903	0.004	701.423	0.004	783.943	0.004	866.464	0.004	948.408	0.007	1021.410	0.006	1060.559	0.006	1099.708	0.006	1138.857	0.006	1178.007	0.006	1217.156	0.005	1256.305	0.005	1295.454	0.005	1334.603	0.005	1373.753	0.004	1827.519	
0.009	941.318	0.009	1086.137	0.009	1230.955	0.009	1375.773	0.009	1520.591	0.009	1664.399	0.013	1792.513	0.013	1861.217	0.012	1929.922	0.012	1998.626	0.012	2067.331	0.011	2136.035	0.011	2204.740	0.011	2273.444	0.011	2342.148	0.010	2410.853	0.009	3207.186	
0.013	1186.851	0.013	1369.443	0.013	1552.035	0.013	1734.628	0.013	1917.220	0.013	2098.539	0.020	2260.069	0.019	2346.695	0.018	2433.320	0.018	2519.945	0.017	2606.570	0.017	2693.196	0.016	2779.821	0.016	2866.446	0.016	2953.071	0.016	3039.697	0.013	4043.745	
0.017	1316.468	0.017	1519.002	0.017	1721.536	0.017	1924.069	0.017	2126.603	0.017	2327.724	0.026	2506.895	0.025	2602.981	0.025	2699.067	0.024	2795.152	0.023	2891.238	0.022	2987.324	0.022	3083.409	0.021	3179.495	0.021	3275.581	0.021	3371.667	0.017	4485.368	
0.022	1379.917	0.022	1592.212	0.022	1804.507	0.022	2016.802	0.022	2229.097	0.022	2439.911	0.033	2627.718	0.032	2728.435	0.031	2829.151	0.030	2929.868	0.029	3030.585	0.028	3131.302	0.027	3232.018	0.027	3332.735	0.026	3433.452	0.026	3534.168	0.021	4701.546	
0.026	1409.828	0.026	1626.724	0.026	1843.621	0.026	2060.517	0.026	2277.414	0.026	2492.797	0.040	2684.675	0.038	2787.575	0.037	2890.474	0.036	2993.374	0.035	3096.274	0.034	3199.174	0.033	3302.073	0.032	3404.973	0.032	3507.873	0.031	3610.773	0.026	4803.454	
0.030	1423.677	0.030	1642.704	0.030	1861.731	0.030	2080.758	0.030	2299.785	0.030	2517.285	0.046	2711.047	0.044	2814.958	0.043	2918.868	0.042	3022.779	0.040	3126.689	0.039	3230.600	0.038	3334.511	0.038	3438.421	0.037	3542.332	0.036	3646.242	0.030	4850.640	
0.035	1430.036	0.035	1650.041	0.035	1870.047	0.035	2090.052	0.035	2310.058	0.035	2528.529	0.053	2723.157	0.051	2827.531	0.049	2931.906	0.048	3036.281	0.046	3140.656	0.045	3245.030	0.044	3349.405	0.043	3453.780	0.042	3558.154	0.041	3662.529	0.034	4872.306	
0.039	1432.945	0.039	1653.398	0.039	1873.851	0.039	2094.304	0.039	2314.757	0.039	2533.672	0.059	2728.696	0.057	2833.283	0.055	2937.870	0.053	3042.457	0.052	3147.044	0.051	3251.631	0.049	3356.218	0.048	3460.805	0.047	3565.392	0.046	3669.979	0.038	4882.217	
0.043	1434.273	0.043	1654.930	0.043	1875.588	0.043	2096.245	0.043	2316.902	0.043	2536.020	0.066	2731.225	0.064	2835.909	0.061	2940.593	0.059	3045.277	0.058	3149.961	0.056	3254.645	0.055	3359.329	0.054	3464.013	0.053	3568.697	0.052	3673.381	0.043	4886.742	
0.048	1434.879	0.048	1655.630	0.048	1876.380	0.048	2097.131	0.048	2317.881	0.048	2537.092	0.073	2732.379	0.070	2837.107	0.067	2941.835	0.065	3046.564	0.063	3151.292	0.062	3256.020	0.060	3360.748	0.059	3465.476	0.058	3570.205	0.057	3674.933	0.047	4888.807	
0.052	1435.155	0.052	1655.948	0.052	1876.742	0.052	2097.535	0.052	2318.328	0.052	2537.580	0.079	2732.905	0.076	2837.654	0.074	2942.402	0.071	3047.150	0.069	3151.899	0.067	3256.647	0.066	3361.396	0.064	3466.144	0.063	3570.892	0.062	3675.641	0.051	4889.749	
0.056	1435.281	0.056	1656.094	0.056	1876.906	0.056	2097.719	0.056	2318.531	0.056	2537.803	0.086	2733.145	0.083	2837.903	0.080	2942.660	0.077	3047.418	0.075	3152.176	0.073	3256.933	0.071	3361.691	0.070	3466.448	0.068	3571.206	0.067	3675.963	0.055	4890.178	
0.061	1435.339	0.061	1656.160	0.061	1876.981	0.061	2097.803	0.061	2318.624	0.061	2537.905	0.092	2733.255	0.089	2838.017	0.086	2942.778	0.083	3047.540	0.081	3152.302	0.079	3257.064	0.077	3361.825	0.075	3466.587	0.074	3571.349	0.072	3676.111	0.060	4890.374	
0.065	1435.365	0.065	1656.190	0.065	1877.016	0.065	2097.841	0.065	2318.666	0.065	2537.951	0.099	2733.305	0.095	2838.068	0.092	2942.832	0.089	3047.596	0.087	3152.359	0.084	3257.123	0.082	3361.887	0.081	3466.650	0.079	3571.414	0.077	3676.178	0.064	4890.463	
0.069	1435.377	0.069	1656.204	0.069	1877.031	0.069	2097.859	0.069	2318.686	0.069	2537.972	0.106	2733.327	0.102	2838.092	0.098	2942.856	0.095	3047.621	0.092	3152.386	0.090	3257.150	0.088	3361.915	0.086	3466.679	0.084	3571.444	0.083	3676.208	0.068	4890.504	

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 group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment locations and details as per DeLeuw, Cather Drawing No. 3-302A-1 and 3-302A-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of pile at Elevation 69.3 m.
8. Piles driven 1 m depth into weathered shale bedrock.
9. Program: Lpile 2018.10.07



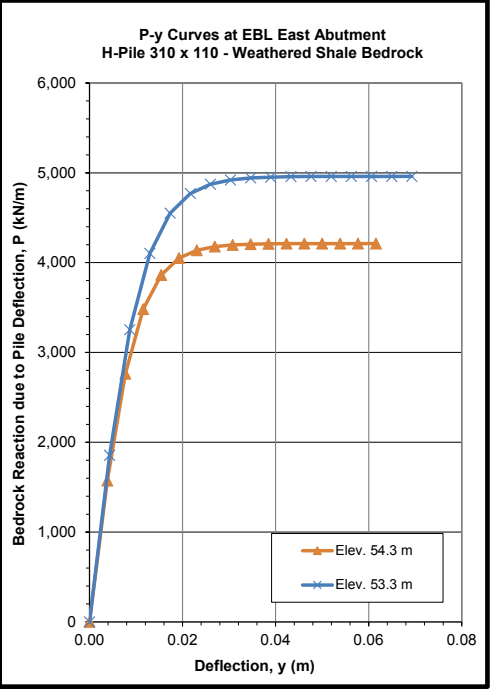
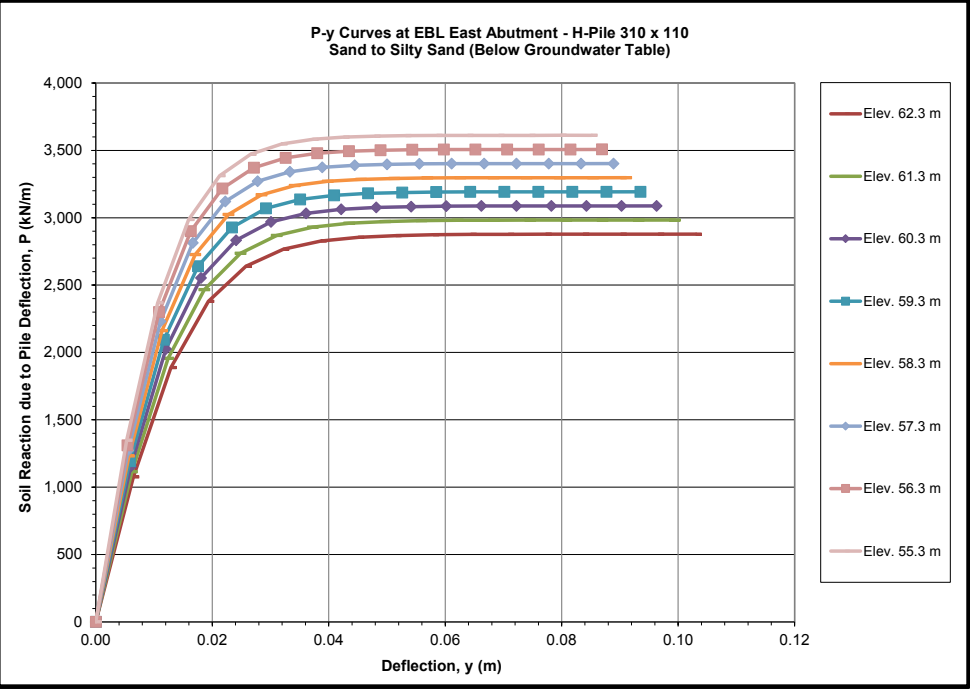
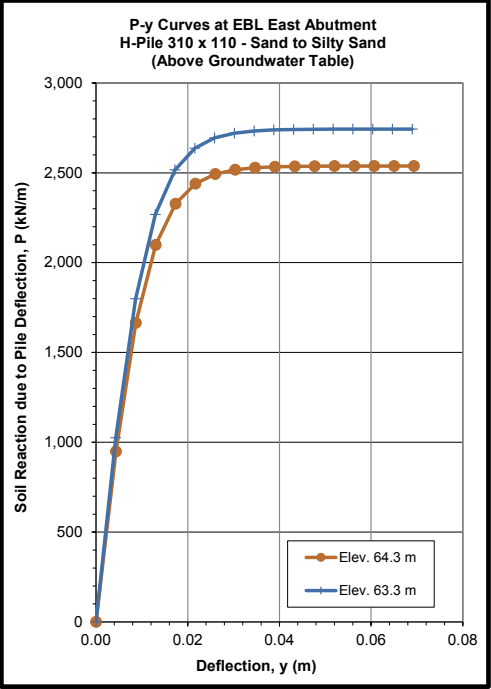
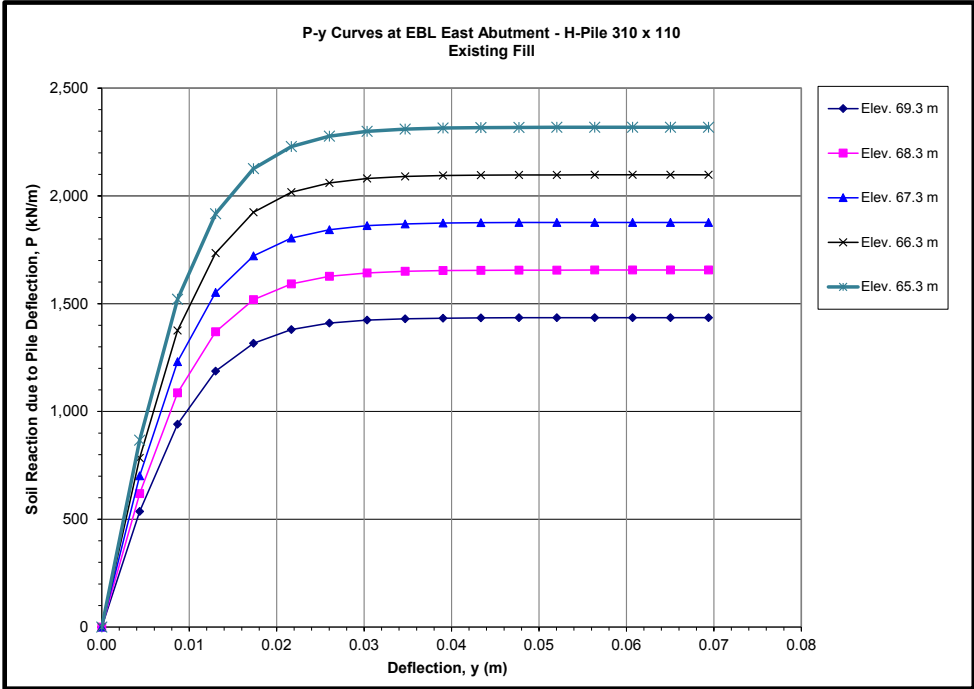
SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - EBL EAST ABUTMENT

Description Depth (z) * Elevation P-y Curves	Existing Fill										Sand to Silty Sand																Weathered Shale Bedrock							
	z= 6.5 m		z= 7.5 m		z= 8.5 m		z= 9.5 m		z= 10.5 m		z= 11.5 m		z= 12.5 m		z= 13.5 m		z= 14.5 m		z= 15.5 m		z= 16.5 m		z= 17.5 m		z= 18.5 m		z= 19.5 m		z= 20.5 m		z= 21.5 m		z= 22.5 m	
	Elev. 69.3 m		Elev. 68.3 m		Elev. 67.3 m		Elev. 66.3 m		Elev. 65.3 m		Elev. 64.3 m		Elev. 63.3 m		Elev. 62.3 m		Elev. 61.3 m		Elev. 60.3 m		Elev. 59.3 m		Elev. 58.3 m		Elev. 57.3 m		Elev. 56.3 m		Elev. 55.3 m		Elev. 54.3 m		Elev. 53.3 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.004	536.382	0.004	618.903	0.004	701.423	0.004	783.943	0.004	866.464	0.004	948.408	0.004	1025.171	0.006	1075.605	0.006	1114.754	0.006	1153.903	0.006	1193.052	0.006	1232.201	0.006	1271.351	0.005	1310.500	0.005	1349.649	0.004	1574.084	0.004	1853.781	
0.009	941.318	0.009	1086.137	0.009	1230.955	0.009	1375.773	0.009	1520.591	0.009	1664.399	0.009	1799.114	0.012	1887.621	0.012	1956.326	0.012	2025.030	0.012	2093.735	0.011	2162.439	0.011	2231.144	0.011	2299.848	0.011	2368.552	0.008	2762.422	0.009	3253.273	
0.013	1186.851	0.013	1369.443	0.013	1552.035	0.013	1734.628	0.013	1917.220	0.013	2098.539	0.013	2268.392	0.019	2379.968	0.019	2466.611	0.018	2553.236	0.018	2639.862	0.017	2726.487	0.017	2813.112	0.016	2899.737	0.016	2986.363	0.012	3482.968	0.013	4101.852	
0.017	1316.468	0.017	1519.002	0.017	1721.536	0.017	1924.069	0.017	2126.603	0.017	2327.724	0.017	2516.127	0.026	2639.908	0.025	2735.994	0.024	2832.079	0.023	2928.165	0.023	3024.251	0.022	3120.336	0.022	3216.422	0.021	3312.508	0.015	3863.349	0.017	4549.822	
0.022	1379.917	0.022	1592.212	0.022	1804.507	0.022	2016.802	0.022	2229.097	0.022	2439.911	0.022	2637.395	0.032	2767.142	0.031	2867.858	0.030	2968.575	0.029	3069.292	0.028	3170.008	0.028	3270.725	0.027	3371.442	0.027	3472.158	0.019	4049.548	0.022	4769.107	
0.026	1409.828	0.026	1626.724	0.026	1843.621	0.026	2060.517	0.026	2277.414	0.026	2492.797	0.026	2694.561	0.039	2827.120	0.037	2930.020	0.036	3032.920	0.035	3135.820	0.034	3238.719	0.033	3341.619	0.033	3444.519	0.032	3547.419	0.023	4137.323	0.026	4872.479	
0.030	1423.677	0.030	1642.704	0.030	1861.731	0.030	2080.758	0.030	2299.785	0.030	2517.285	0.030	2721.031	0.045	2854.892	0.044	2958.803	0.042	3062.713	0.041	3166.624	0.040	3270.534	0.039	3374.445	0.038	3478.355	0.037	3582.266	0.027	4177.965	0.030	4920.343	
0.035	1430.036	0.035	1650.041	0.035	1870.047	0.035	2090.052	0.035	2310.058	0.035	2528.529	0.034	2733.185	0.052	2867.644	0.050	2972.019	0.048	3076.394	0.047	3180.768	0.046	3285.143	0.044	3389.518	0.043	3493.892	0.043	3598.267	0.031	4196.627	0.035	4942.320	
0.039	1432.945	0.039	1653.398	0.039	1873.851	0.039	2094.304	0.039	2314.757	0.039	2533.672	0.039	2738.744	0.058	2873.477	0.056	2978.064	0.054	3082.651	0.053	3187.238	0.051	3291.825	0.050	3396.412	0.049	3500.999	0.048	3605.586	0.035	4205.164	0.039	4952.374	
0.043	1434.273	0.043	1654.930	0.043	1875.588	0.043	2096.245	0.043	2316.902	0.043	2536.020	0.043	2741.283	0.064	2876.141	0.062	2980.825	0.060	3085.508	0.058	3190.192	0.057	3294.876	0.056	3399.560	0.054	3504.244	0.053	3608.928	0.038	4209.061	0.043	4956.964	
0.048	1434.879	0.048	1655.630	0.048	1876.380	0.048	2097.131	0.048	2317.881	0.048	2537.092	0.047	2742.441	0.071	2877.356	0.068	2982.084	0.066	3086.812	0.064	3191.540	0.063	3296.268	0.061	3400.997	0.060	3505.725	0.059	3610.453	0.042	4210.840	0.048	4959.058	
0.052	1435.155	0.052	1655.948	0.052	1876.742	0.052	2097.535	0.052	2318.328	0.052	2537.580	0.052	2742.969	0.077	2877.910	0.075	2982.658	0.072	3087.407	0.070	3192.155	0.068	3296.903	0.067	3401.652	0.065	3506.400	0.064	3611.148	0.046	4211.651	0.052	4960.413	
0.056	1435.281	0.056	1656.094	0.056	1876.906	0.056	2097.719	0.056	2318.531	0.056	2537.803	0.056	2743.210	0.084	2878.163	0.081	2982.920	0.078	3087.678	0.076	3192.435	0.074	3297.193	0.072	3401.950	0.071	3506.708	0.069	3611.466	0.040	4212.012	0.056	4960.449	
0.061	1435.339	0.061	1656.160	0.061	1876.981	0.061	2097.803	0.061	2318.624	0.061	2537.905	0.060	2743.320	0.090	2878.278	0.087	2983.040	0.084	3087.801	0.082	3192.563	0.080	3297.325	0.078	3402.087	0.076	3506.848	0.075	3611.610	0.054	4212.189	0.061	4960.648	
0.065	1435.365	0.065	1656.190	0.065	1877.016	0.065	2097.841	0.065	2318.666	0.065	2537.951	0.065	2743.370	0.097	2878.330	0.093	2983.094	0.090	3087.858	0.088	3192.621	0.085	3297.385	0.083	3402.149	0.081	3506.912	0.080	3611.676	0.058	4212.266	0.065	4960.738	
0.069	1435.377	0.069	1656.204	0.069	1877.031	0.069	2097.859	0.069	2318.686	0.069	2537.972	0.069	2743.393	0.103	2878.354	0.099	2983.119	0.096	3087.883	0.094	3192.648	0.091	3297.413	0.089	3402.177	0.087	3506.942	0.085	3611.706	0.062	4212.301	0.069	4960.779	

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 group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment locations and details as per DeLeuw, Cather Drawing No. 3-302A-1 and 3-302A-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of pile at Elevation 69.5 m.
8. Piles driven 1 m depth into weathered shale bedrock.
9. Program: Lpile 2018.10.07



SUMMARY OF P-Y CURVES FOR EBL PIER 1

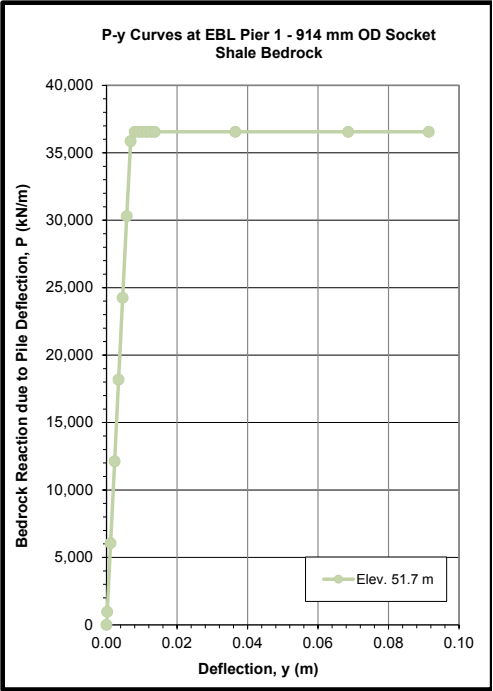
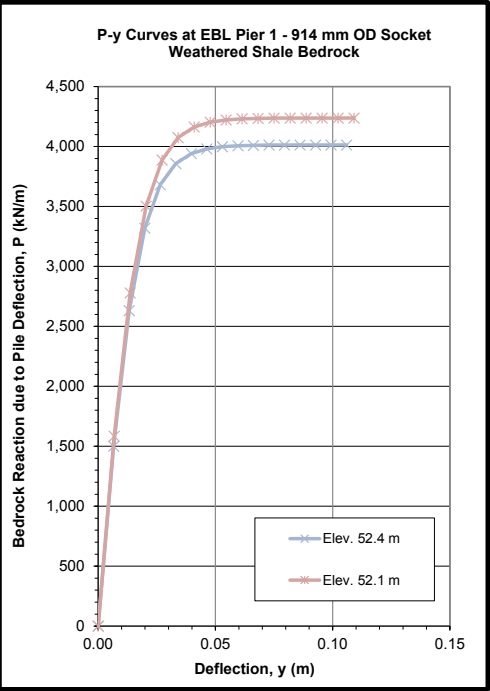
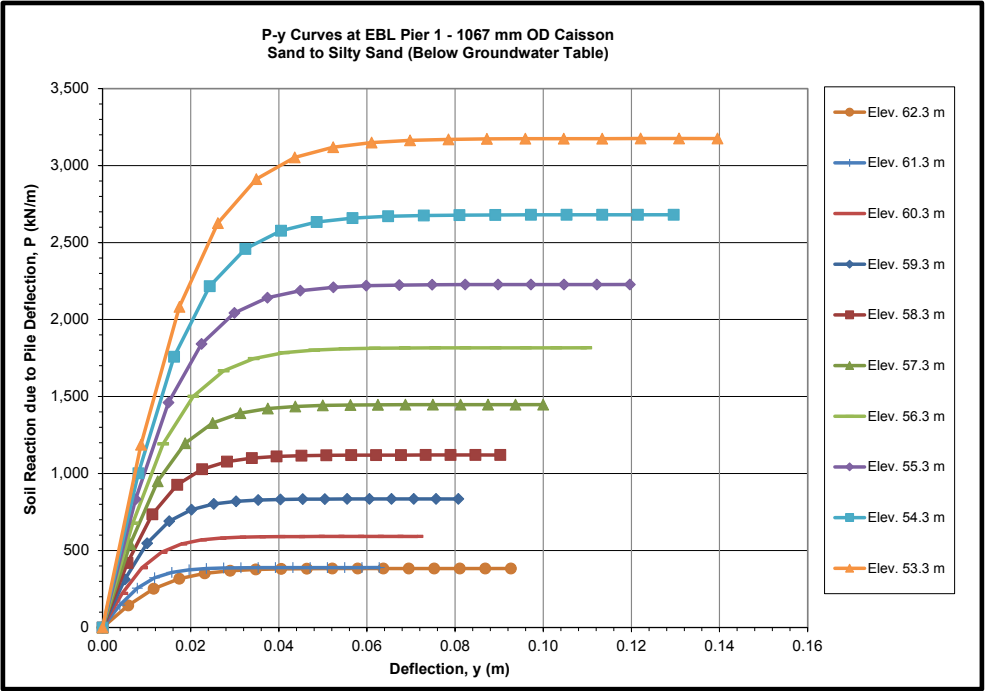
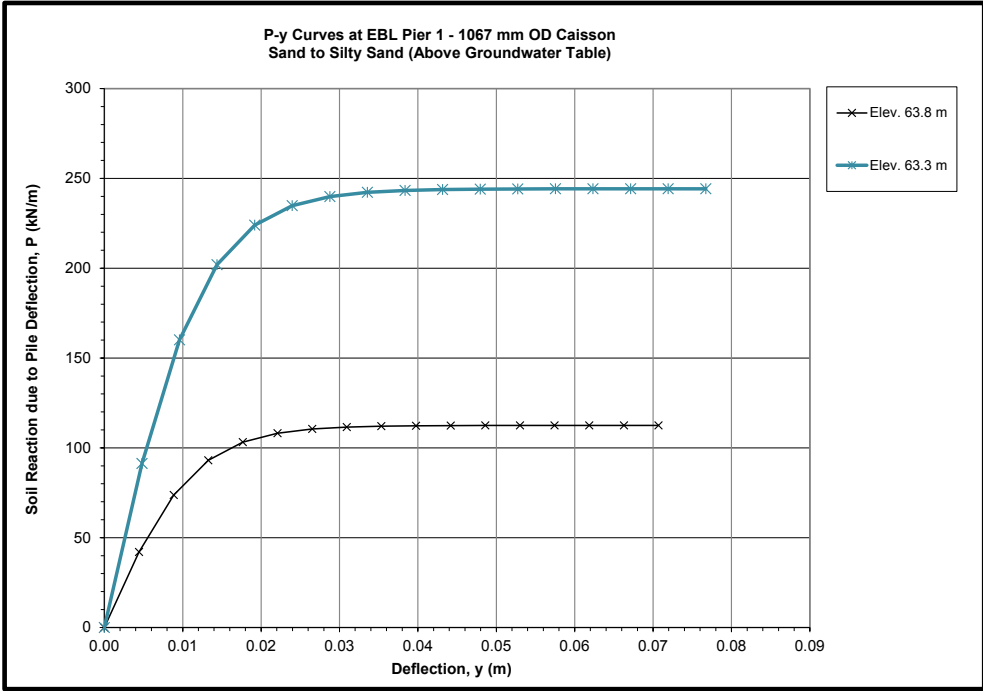
Description Depth (z) * Elevation P-y Curves	Sand to Silty Sand																						Weathered Shale Bedrock				Shale Bedrock				
	z= 5 m		z= 1.0 m		z= 2.0 m		z= 3.0 m		z= 4.0 m		z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 11.9 m		z= 12.2 m		z= 12.7 m		
	Elev. 63.8 m		Elev. 63.3 m		Elev. 62.3 m		Elev. 61.3 m		Elev. 60.3 m		Elev. 59.3 m		Elev. 58.3 m		Elev. 57.3 m		Elev. 56.3 m		Elev. 55.3 m		Elev. 54.3 m		Elev. 53.3 m		Elev. 52.4 m		Elev. 52.1 m		Elev. 51.7 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	
0.004	42.039	0.005	91.255	0.006	143.218	0.004	145.596	0.004	220.941	0.005	311.938	0.006	418.586	0.006	540.887	0.007	678.839	0.007	832.443	0.008	1001.700	0.009	1186.608	0.007	1499.710	0.007	1583.613	0.000	969.920	0.000	0.000
0.009	73.776	0.010	160.146	0.012	251.339	0.008	255.513	0.009	387.738	0.010	547.432	0.011	734.593	0.012	949.223	0.014	1191.321	0.015	1460.888	0.016	1757.922	0.017	2082.425	0.013	2631.900	0.014	2779.146	0.001	6062.000	0.001	0.000
0.013	93.020	0.014	201.918	0.017	316.898	0.012	322.161	0.013	488.875	0.015	690.223	0.017	926.204	0.019	1196.817	0.021	1502.064	0.022	1841.944	0.024	2216.456	0.026	2625.602	0.020	3318.402	0.020	3504.054	0.002	12124.000	0.002	0.000
0.018	103.178	0.019	223.970	0.023	351.506	0.016	357.344	0.018	542.266	0.020	765.603	0.023	1027.356	0.025	1327.524	0.027	1666.107	0.030	2043.105	0.032	2458.519	0.035	2912.348	0.026	3680.810	0.027	3886.738	0.003	18186.000	0.003	0.000
0.022	108.151	0.024	234.765	0.029	368.448	0.020	374.567	0.022	568.401	0.025	802.503	0.028	1076.871	0.031	1391.505	0.034	1746.407	0.037	2141.575	0.040	2577.010	0.044	3052.712	0.033	3858.211	0.034	4074.064	0.005	24248.000	0.005	0.000
0.027	110.495	0.029	239.853	0.035	376.434	0.024	382.686	0.027	580.722	0.030	819.897	0.034	1100.212	0.037	1421.667	0.041	1784.261	0.045	2187.995	0.049	2632.868	0.052	3118.881	0.040	3941.839	0.041	4162.371	0.006	30310.000	0.006	0.000
0.031	111.581	0.034	242.210	0.041	380.132	0.027	386.445	0.031	586.426	0.035	827.951	0.039	1111.020	0.044	1435.632	0.048	1801.788	0.052	2209.488	0.057	2658.731	0.061	3149.519	0.046	3980.561	0.048	4203.259	0.007	35874.940	0.007	0.000
0.035	112.079	0.038	243.291	0.046	381.830	0.031	388.171	0.036	589.046	0.040	831.649	0.045	1115.982	0.050	1442.045	0.055	1809.836	0.060	2219.357	0.065	2670.607	0.070	3163.587	0.053	3998.341	0.055	4222.034	0.008	36560.000	0.008	0.000
0.040	112.307	0.043	243.786	0.052	382.606	0.035	388.961	0.040	590.244	0.045	833.341	0.051	1118.252	0.056	1444.978	0.062	1813.518	0.067	2223.872	0.073	2676.040	0.078	3170.022	0.060	4006.474	0.061	4230.622	0.009	36560.000	0.009	0.000
0.044	112.411	0.048	244.012	0.058	382.961	0.039	389.321	0.045	590.791	0.050	834.114	0.056	1119.289	0.062	1446.317	0.069	1815.199	0.075	2225.933	0.081	2678.520	0.087	3172.960	0.066	4010.188	0.068	4234.543	0.010	36560.000	0.010	0.000
0.049	112.459	0.053	244.115	0.064	383.123	0.043	389.486	0.049	591.041	0.055	834.466	0.062	1119.762	0.069	1446.928	0.075	1815.966	0.082	2226.873	0.089	2679.652	0.096	3174.301	0.073	4011.882	0.075	4236.332	0.011	36560.000	0.011	0.000
0.053	112.481	0.058	244.162	0.069	383.197	0.047	389.561	0.054	591.154	0.061	834.627	0.068	1119.978	0.075	1447.207	0.082	1816.315	0.090	2227.302	0.097	2680.168	0.105	3174.912	0.079	4012.655	0.082	4237.148	0.013	36560.000	0.013	0.000
0.057	112.490	0.062	244.184	0.075	383.230	0.051	389.595	0.058	591.206	0.066	834.700	0.073	1120.076	0.081	1447.334	0.089	1816.475	0.097	2227.498	0.105	2680.403	0.113	3175.191	0.086	4013.007	0.089	4237.520	0.014	36560.000	0.014	0.000
0.062	112.495	0.067	244.194	0.081	383.246	0.055	389.611	0.063	591.230	0.071	834.733	0.079	1120.121	0.087	1447.392	0.096	1816.548	0.105	2227.587	0.113	2680.510	0.122	3175.318	0.093	4013.168	0.095	4237.690	0.037	36560.000	0.037	0.000
0.066	112.497	0.072	244.198	0.087	383.253	0.059	389.618	0.067	591.241	0.076	834.749	0.085	1120.141	0.094	1447.419	0.103	1816.581	0.112	2227.628	0.121	2680.559	0.131	3175.376	0.099	4013.241	0.102	4237.767	0.069	36560.000	0.069	0.000
0.071	112.498	0.077	244.200	0.093	383.256	0.063	389.621	0.071	591.246	0.081	834.756	0.090	1120.151	0.100	1447.431	0.110	1816.596	0.120	2227.646	0.130	2680.582	0.140	3175.402	0.106	4013.274	0.109	4237.803	0.091	36560.000	0.091	0.000

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 caisson (i.e., no inclination) socketed into bedrock, with a ground slope angle of zero.
2. Static loading condition is considered.
3. There are no group effects (i.e., analysis is based on a single caisson).
4. The effects of construction disturbance are not considered.

5. Pier location and details (including socket geometry) as per DeLeuw, Cather Drawing No. 3-302A-1 and 3-302A-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of caisson at Elevation 64.3 m.
8. Program: Lpile 2018.10.07



P-Y CURVES

CPR Overhead
1067 mm OD Caisson with 914 mm OD Socket - EBL Pier 2, WBL Pier 1

Figure F4

SUMMARY OF P-Y CURVES FOR EBL PIER 2, WBL PIER 1

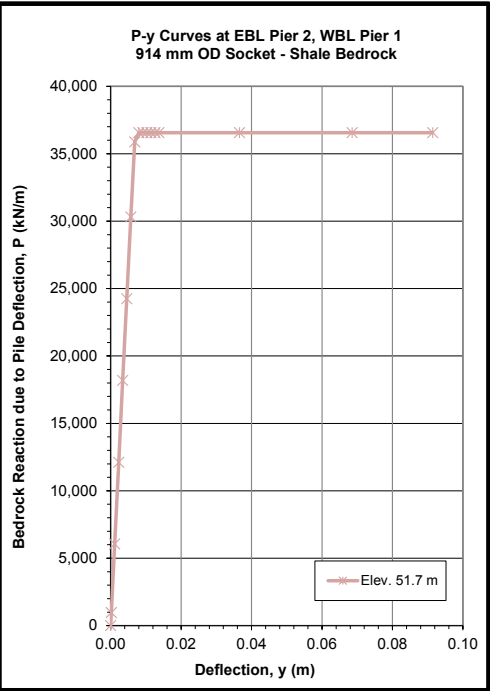
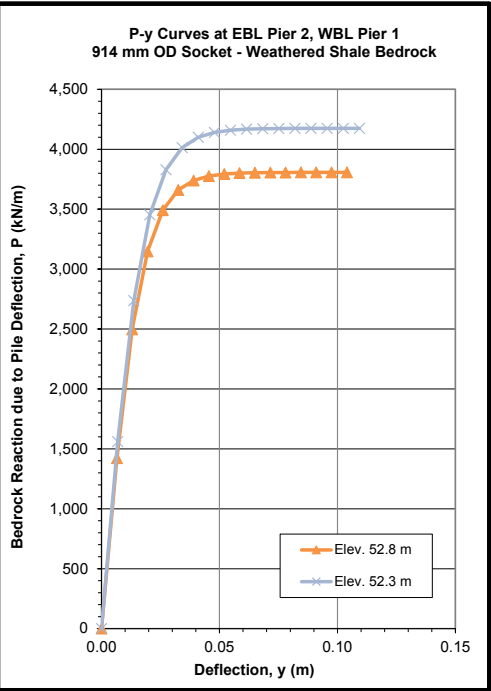
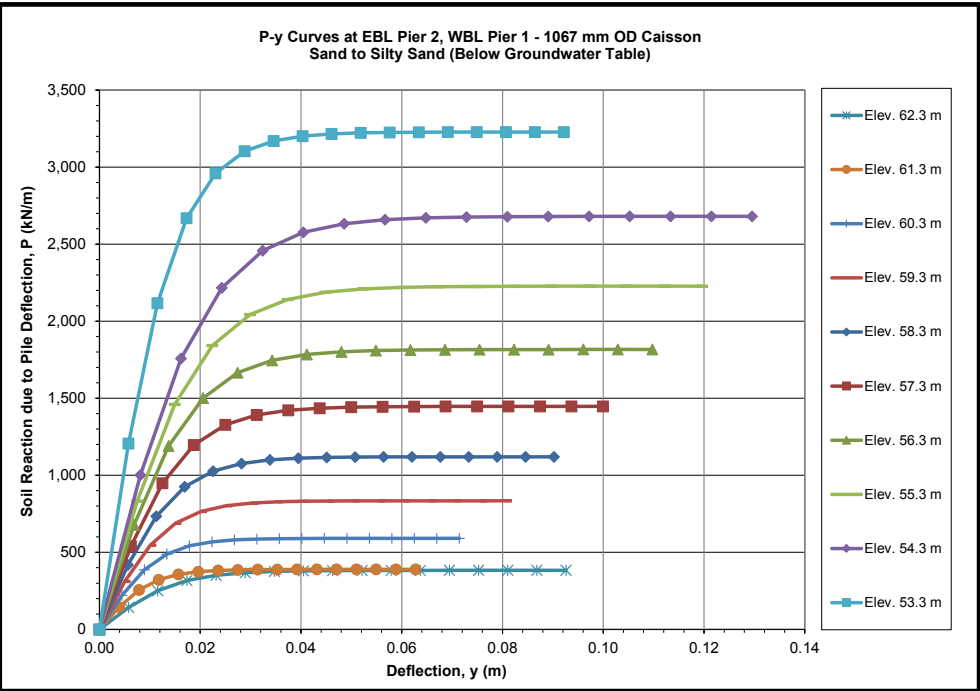
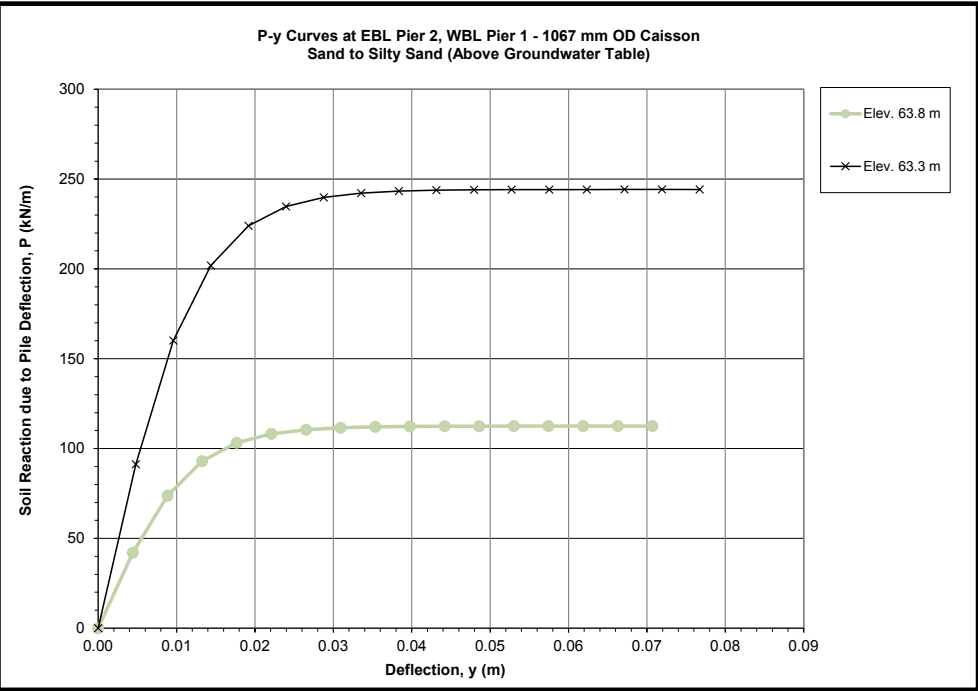
Description Depth (z) * Elevation P-y Curves	Sand to Silty Sand																								Weathered Shale Bedrock				Shale Bedrock	
	z= .5 m		z= 1.0 m		z= 2.0 m		z= 3.0 m		z= 4.0 m		z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 11.5 m		z= 12.0 m			
	Elev. 63.8 m		Elev. 63.3 m		Elev. 62.3 m		Elev. 61.3 m		Elev. 60.3 m		Elev. 59.3 m		Elev. 58.3 m		Elev. 57.3 m		Elev. 56.3 m		Elev. 55.3 m		Elev. 54.3 m		Elev. 53.3 m		Elev. 52.8 m		Elev. 52.3 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)	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	0.000	0.000	0.000	0.000		
0.004	42.039	0.005	91.255	0.006	143.218	0.004	145.596	0.004	220.941	0.005	311.938	0.006	418.586	0.006	540.887	0.007	678.839	0.007	832.443	0.008	1001.700	0.006	1206.170	0.007	1422.568	0.007	1560.054	0.000	969.920	
0.009	73.776	0.010	160.146	0.012	251.339	0.008	255.513	0.009	387.738	0.010	547.432	0.011	734.593	0.012	949.223	0.014	1191.321	0.015	1460.888	0.016	1757.922	0.012	2116.755	0.013	2496.520	0.014	2737.801	0.001	6062.000	
0.013	93.020	0.014	201.918	0.017	316.898	0.012	322.161	0.013	488.875	0.015	690.223	0.017	926.204	0.019	1196.817	0.021	1502.064	0.022	1841.944	0.024	2216.456	0.017	2668.886	0.020	3147.709	0.020	3451.926	0.002	12124.000	
0.018	103.178	0.019	223.970	0.023	351.506	0.016	357.344	0.018	542.266	0.020	765.603	0.023	1027.356	0.025	1327.524	0.027	1666.107	0.030	2043.105	0.032	2458.519	0.023	2960.360	0.026	3491.475	0.027	3828.916	0.003	18166.000	
0.022	108.151	0.024	234.765	0.029	368.448	0.020	374.567	0.022	568.401	0.025	802.503	0.028	1076.871	0.031	1391.505	0.034	1746.407	0.037	2141.575	0.040	2577.010	0.029	3103.038	0.033	3659.752	0.034	4013.456	0.005	24248.000	
0.027	110.495	0.029	239.853	0.035	376.434	0.024	382.686	0.027	580.722	0.030	819.897	0.034	1100.212	0.037	1421.667	0.041	1784.261	0.045	2187.995	0.049	2632.868	0.035	3170.297	0.039	3739.078	0.041	4100.449	0.006	30310.000	
0.031	111.581	0.034	242.210	0.041	380.132	0.027	386.445	0.031	586.426	0.035	827.951	0.039	1111.020	0.044	1435.632	0.048	1801.788	0.052	2209.488	0.057	2658.731	0.040	3201.440	0.046	3775.808	0.048	4140.729	0.007	35874.940	
0.035	112.079	0.038	243.291	0.046	381.830	0.031	388.171	0.036	589.046	0.040	831.649	0.045	1115.982	0.050	1442.045	0.055	1809.836	0.060	2219.357	0.065	2670.607	0.046	3215.740	0.052	3792.674	0.055	4159.224	0.008	36560.000	
0.040	112.307	0.043	243.786	0.052	382.606	0.035	388.961	0.040	590.244	0.045	833.341	0.051	1118.252	0.056	1444.978	0.062	1813.518	0.067	2223.872	0.073	2676.040	0.052	3222.281	0.059	3800.388	0.061	4167.684	0.009	36560.000	
0.044	112.411	0.048	244.012	0.058	382.961	0.039	389.321	0.045	590.791	0.050	834.114	0.056	1119.289	0.062	1446.317	0.069	1815.199	0.075	2225.933	0.081	2678.520	0.058	3225.268	0.065	3803.911	0.068	4171.548	0.010	36560.000	
0.049	112.459	0.053	244.115	0.064	383.123	0.043	389.486	0.049	591.041	0.055	834.466	0.062	1119.762	0.069	1446.928	0.075	1815.966	0.082	2226.873	0.089	2679.652	0.063	3226.631	0.072	3805.518	0.075	4173.310	0.011	36560.000	
0.053	112.481	0.058	244.162	0.069	383.197	0.047	389.561	0.054	591.154	0.061	834.627	0.068	1119.978	0.075	1447.207	0.082	1816.315	0.090	2227.302	0.097	2680.168	0.069	3227.252	0.078	3806.251	0.082	4174.114	0.013	36560.000	
0.057	112.490	0.062	244.184	0.075	383.230	0.051	389.595	0.058	591.206	0.066	834.700	0.073	1120.076	0.081	1447.334	0.089	1816.475	0.097	2227.498	0.105	2680.403	0.075	3227.536	0.085	3806.585	0.089	4174.480	0.014	36560.000	
0.062	112.495	0.067	244.194	0.081	383.246	0.055	389.611	0.063	591.230	0.071	834.733	0.079	1120.121	0.087	1447.392	0.096	1816.548	0.105	2227.587	0.113	2680.510	0.081	3227.665	0.091	3806.738	0.096	4174.648	0.037	36560.000	
0.066	112.497	0.072	244.198	0.087	383.253	0.059	389.618	0.067	591.241	0.076	834.749	0.085	1120.141	0.094	1447.419	0.103	1816.581	0.112	2227.628	0.121	2680.559	0.086	3227.724	0.098	3806.807	0.102	4174.724	0.069	36560.000	
0.071	112.498	0.077	244.200	0.093	383.256	0.063	389.621	0.071	591.246	0.081	834.756	0.090	1120.151	0.100	1447.431	0.110	1816.596	0.120	2227.646	0.130	2680.582	0.092	3227.751	0.104	3806.839	0.109	4174.758	0.091	36560.000	

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 caisson (i.e., no inclination) socketed into bedrock, with a ground slope angle of zero.
2. Static loading condition is considered.
3. There are no group effects (i.e., analysis is based on a single caisson).
4. The effects of construction disturbance are not considered.

5. Pier locations and details (including socket geometry) as per DeLeuw, Cather Drawing No. 3-302A-1, 3-302A-3, 3-302B-1, and 3-302B-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of caisson at Elevation 64.3 m.
8. Program: Lpile 2018.10.07

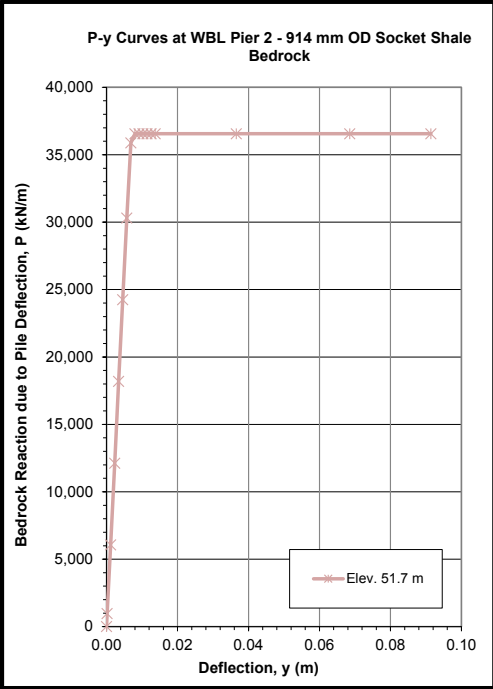
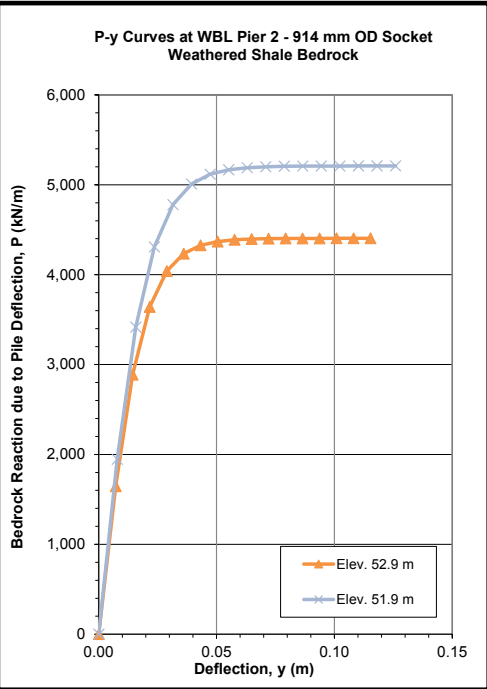
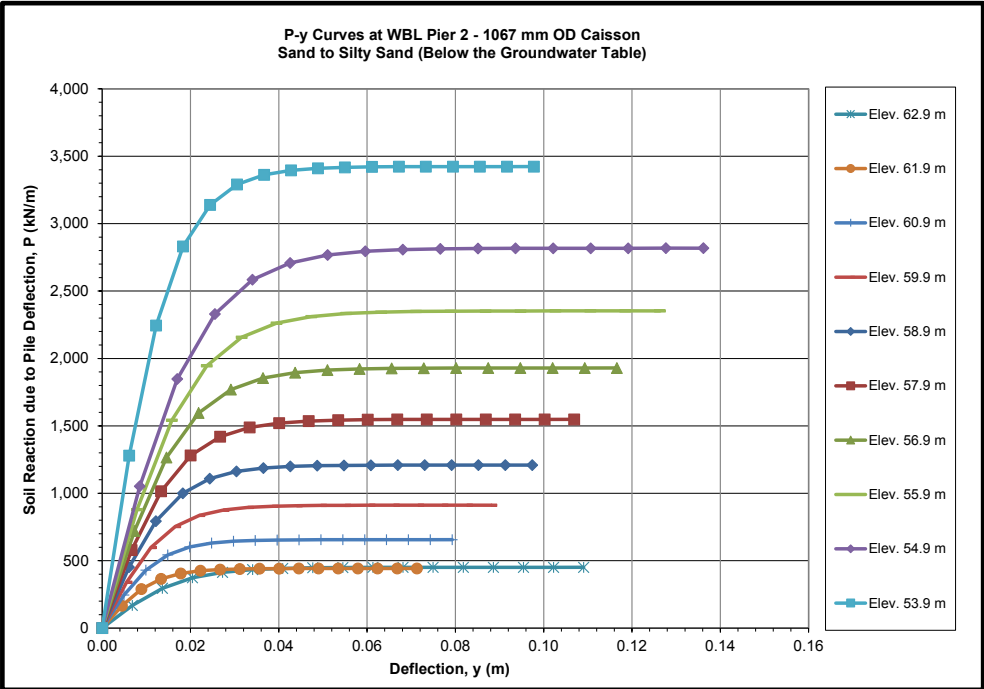
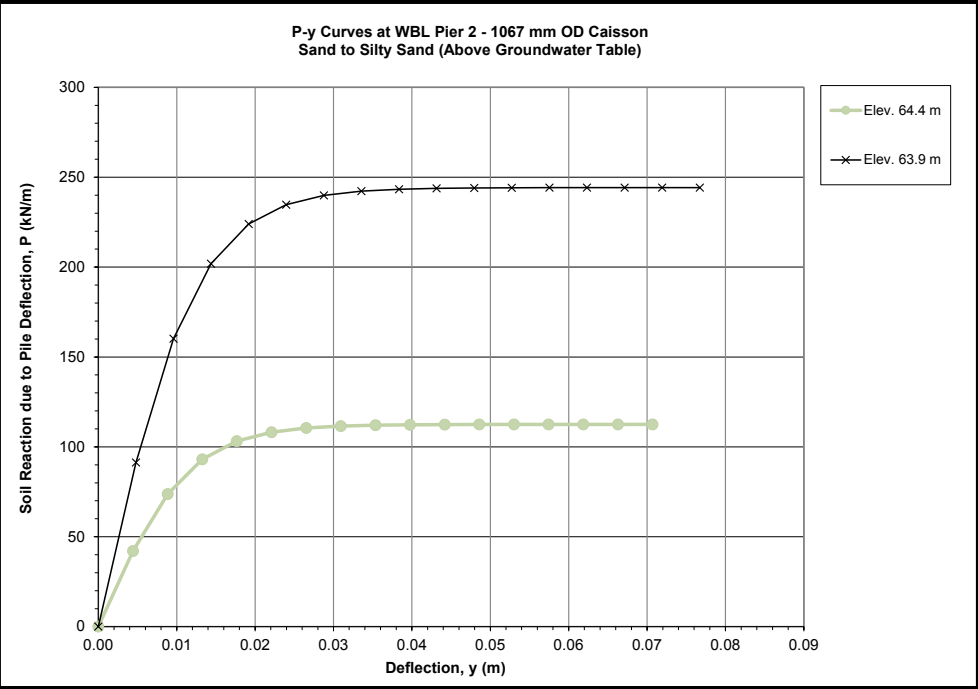


SUMMARY OF P-Y CURVES FOR WBL PIER 2

Description Depth (z) * Elevation P-y Curves	Sand to Silty Sand																								Weathered Shale Bedrock				Shale Bedrock		
	z= .5 m		z= 1.0 m		z= 2.0 m		z= 3.0 m		z= 4.0 m		z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m		z= 13.0 m		z= 13.3 m		
	Elev. 64.4 m		Elev. 63.9 m		Elev. 62.9 m		Elev. 61.9 m		Elev. 60.9 m		Elev. 59.9 m		Elev. 58.9 m		Elev. 57.9 m		Elev. 56.9 m		Elev. 55.9 m		Elev. 54.9 m		Elev. 53.9 m		Elev. 52.9 m		Elev. 51.9 m		Elev. 51.7 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	
0.004	42.039	0.005	91.255	0.007	168.629	0.004	165.350	0.005	245.206	0.006	340.714	0.006	451.874	0.007	578.686	0.007	721.150	0.008	879.266	0.009	1053.033	0.006	1279.353	0.007	1645.792	0.008	1946.790	0.000	969.920	0.000	969.920
0.009	73.776	0.010	160.146	0.014	295.934	0.009	290.179	0.010	430.322	0.011	597.933	0.012	793.012	0.013	1015.559	0.015	1265.574	0.016	1543.058	0.017	1848.010	0.012	2245.188	0.014	2888.266	0.016	3416.500	0.001	6062.000	0.001	6062.000
0.013	93.020	0.014	201.918	0.020	373.125	0.013	365.869	0.015	542.566	0.017	753.897	0.018	999.860	0.020	1280.456	0.022	1595.685	0.024	1945.547	0.026	2330.042	0.018	2830.820	0.022	3641.637	0.024	4307.655	0.002	12124.000	0.002	12124.000
0.018	103.178	0.019	223.970	0.027	413.874	0.018	405.826	0.020	601.821	0.022	836.231	0.024	1109.056	0.027	1420.296	0.029	1769.952	0.032	2158.023	0.034	2584.510	0.024	3139.978	0.029	4039.346	0.031	4778.101	0.003	18186.000	0.003	18186.000
0.022	108.151	0.024	234.765	0.034	433.821	0.022	425.386	0.025	630.826	0.028	876.534	0.030	1162.508	0.033	1488.749	0.036	1855.257	0.039	2262.032	0.043	2709.074	0.031	3291.314	0.036	4234.027	0.039	5008.387	0.005	24248.000	0.005	24248.000
0.027	110.495	0.029	239.853	0.041	443.225	0.027	434.606	0.030	644.500	0.033	895.533	0.037	1187.706	0.040	1521.019	0.044	1895.471	0.047	2311.062	0.051	2767.794	0.037	3362.654	0.043	4325.801	0.047	5116.946	0.006	30310.000	0.006	30310.000
0.031	111.581	0.034	242.210	0.048	447.579	0.031	438.875	0.035	650.831	0.039	904.330	0.043	1199.373	0.047	1535.960	0.051	1914.091	0.055	2333.765	0.060	2794.983	0.043	3395.686	0.050	4368.295	0.055	5167.211	0.007	35874.940	0.007	35874.940
0.035	112.079	0.038	243.291	0.055	449.578	0.036	440.836	0.040	653.738	0.044	908.370	0.049	1204.731	0.053	1542.821	0.058	1922.640	0.063	2344.189	0.068	2807.467	0.049	3410.854	0.058	4387.807	0.063	5190.292	0.008	36560.000	0.008	36560.000
0.040	112.307	0.043	243.786	0.061	450.492	0.040	441.732	0.045	655.068	0.050	910.217	0.055	1207.181	0.060	1545.959	0.066	1926.551	0.071	2348.957	0.077	2813.178	0.055	3417.792	0.065	4396.732	0.071	5200.849	0.009	36560.000	0.009	36560.000
0.044	112.411	0.048	244.012	0.068	450.910	0.045	442.142	0.050	655.675	0.055	911.061	0.061	1208.300	0.067	1547.392	0.073	1928.337	0.079	2351.135	0.085	2815.785	0.061	3420.960	0.072	4400.808	0.079	5205.670	0.010	36560.000	0.010	36560.000
0.049	112.459	0.053	244.115	0.075	451.100	0.049	442.329	0.055	655.952	0.061	911.446	0.067	1208.811	0.074	1548.046	0.080	1929.152	0.087	2352.128	0.094	2816.975	0.067	3422.405	0.079	4402.667	0.087	5207.869	0.011	36560.000	0.011	36560.000
0.053	112.481	0.058	244.162	0.082	451.187	0.053	442.414	0.059	656.078	0.066	911.621	0.073	1209.043	0.080	1548.344	0.087	1929.523	0.095	2352.581	0.102	2817.518	0.073	3423.064	0.086	4403.515	0.094	5208.872	0.013	36560.000	0.013	36560.000
0.057	112.490	0.062	244.184	0.089	451.227	0.058	442.453	0.064	656.136	0.072	911.702	0.079	1209.150	0.087	1548.480	0.095	1929.693	0.103	2352.788	0.111	2817.765	0.079	3423.365	0.094	4403.902	0.102	5209.330	0.014	36560.000	0.014	36560.000
0.062	112.495	0.067	244.194	0.095	451.245	0.062	442.470	0.069	656.162	0.077	911.738	0.085	1209.198	0.094	1548.542	0.102	1929.770	0.111	2352.882	0.119	2817.878	0.086	3423.502	0.101	4404.078	0.110	5209.538	0.037	36560.000	0.037	36560.000
0.066	112.497	0.072	244.198	0.102	451.253	0.067	442.478	0.074	656.174	0.083	911.755	0.091	1209.220	0.100	1548.570	0.109	1929.805	0.118	2352.925	0.128	2817.929	0.092	3423.565	0.108	4404.158	0.118	5209.633	0.069	36560.000	0.069	36560.000
0.071	112.498	0.077	244.200	0.109	451.257	0.071	442.482	0.079	656.180	0.088	911.762	0.097	1209.230	0.107	1548.583	0.117	1929.821	0.126	2352.944	0.136	2817.953	0.098	3423.593	0.115	4404.195	0.126	5209.677	0.091	36560.000	0.091	36560.000

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 caisson (i.e., no inclination) socketed into bedrock, with a ground slope angle of zero.
2. Static loading condition is considered.
3. There are no group effects (i.e., analysis is based on a single caisson).
4. The effects of construction disturbance are not considered.

5. Pier location and details (including socket geometry) as per DeLeuw, Cather Drawing No. 3-302B-1 and 3-302B-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of caisson at Elevation 64.9 m.
8. Program: Lpile 2018.10.07



SUMMARY OF P-Y CURVES FOR EBL PIER 3

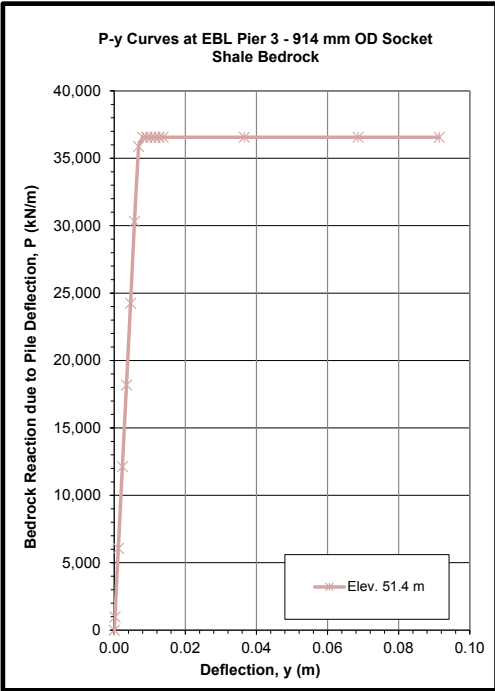
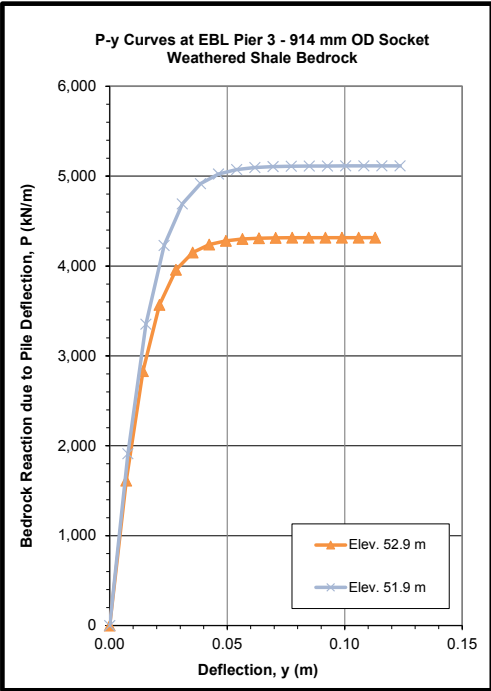
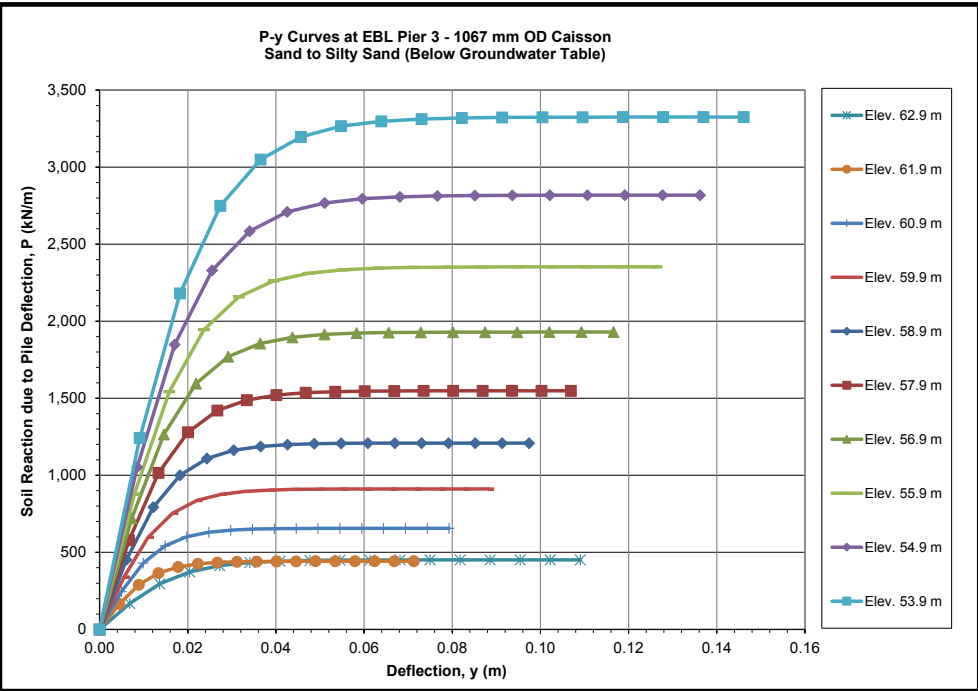
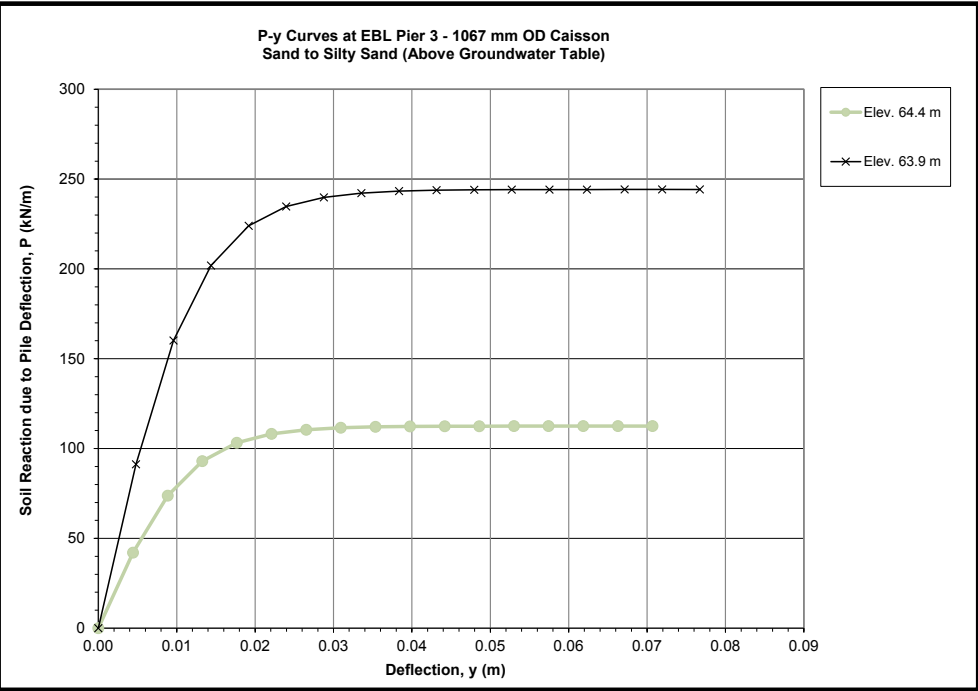
Description Depth (z) * Elevation P-y Curves	Sand to Silty Sand																								Weathered Shale Bedrock				Shale Bedrock	
	z= .5 m		z= 1.0 m		z= 2.0 m		z= 3.0 m		z= 4.0 m		z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m		z= 13.0 m		z= 13.6 m	
	Elev. 64.4 m		Elev. 63.9 m		Elev. 62.9 m		Elev. 61.9 m		Elev. 60.9 m		Elev. 59.9 m		Elev. 58.9 m		Elev. 57.9 m		Elev. 56.9 m		Elev. 55.9 m		Elev. 54.9 m		Elev. 53.9 m		Elev. 52.9 m		Elev. 51.9 m		Elev. 51.4 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)	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	0.000	0.000	0.000	0.000	0.000	0.000
0.004	42.039	0.005	91.255	0.007	168.629	0.004	165.350	0.005	245.206	0.006	340.714	0.006	451.874	0.007	578.686	0.007	721.150	0.008	879.266	0.009	1053.033	0.009	1242.453	0.007	1612.807	0.008	1911.022	0.000	0.000	969.920
0.009	73.776	0.010	160.146	0.014	295.934	0.009	290.179	0.010	430.322	0.011	597.933	0.012	793.012	0.013	1015.559	0.015	1265.574	0.016	1543.058	0.017	1848.010	0.018	2180.430	0.014	2830.379	0.015	3353.728	0.001	6062.000	
0.013	93.020	0.014	201.918	0.020	373.125	0.013	365.869	0.015	542.566	0.017	753.897	0.018	999.860	0.020	1280.456	0.022	1595.685	0.024	1945.547	0.026	2330.042	0.027	2749.171	0.021	3568.651	0.023	4228.510	0.002	12124.000	
0.018	103.178	0.019	223.970	0.027	413.874	0.018	405.826	0.020	601.821	0.022	836.231	0.024	1109.056	0.027	1420.296	0.029	1769.952	0.032	2158.023	0.034	2584.510	0.037	3049.412	0.028	3958.389	0.031	4690.313	0.003	18186.000	
0.022	108.151	0.024	234.765	0.034	433.821	0.022	425.386	0.025	630.826	0.028	876.534	0.030	1162.508	0.033	1488.749	0.036	1855.257	0.039	2262.032	0.043	2709.074	0.046	3196.382	0.035	4149.169	0.039	4916.368	0.005	24248.000	
0.027	110.495	0.029	239.853	0.041	443.225	0.027	434.606	0.030	644.500	0.033	895.533	0.037	1187.706	0.040	1521.019	0.044	1895.471	0.047	2311.062	0.051	2767.794	0.055	3265.665	0.042	4239.103	0.046	5022.932	0.006	30310.000	
0.031	111.581	0.034	242.210	0.048	447.579	0.031	438.875	0.035	650.831	0.039	904.330	0.043	1199.373	0.047	1535.960	0.051	1914.091	0.055	2333.765	0.060	2794.983	0.064	3297.744	0.049	4280.745	0.054	5072.274	0.007	35874.940	
0.035	112.079	0.038	243.291	0.055	449.578	0.036	440.836	0.040	653.738	0.044	908.370	0.049	1204.731	0.053	1542.821	0.058	1922.640	0.063	2344.189	0.068	2807.467	0.073	3312.475	0.057	4299.866	0.062	5094.931	0.008	36560.000	
0.040	112.307	0.043	243.786	0.061	450.492	0.040	441.732	0.045	655.068	0.050	910.217	0.055	1207.181	0.060	1545.959	0.066	1926.551	0.071	2348.957	0.077	2813.178	0.082	3319.212	0.064	4308.613	0.070	5105.294	0.009	36560.000	
0.044	112.411	0.048	244.012	0.068	450.910	0.045	442.142	0.050	655.675	0.055	911.061	0.061	1208.300	0.067	1547.392	0.073	1928.337	0.079	2351.135	0.085	2815.785	0.091	3322.289	0.071	4312.606	0.077	5110.026	0.010	36560.000	
0.049	112.459	0.053	244.115	0.075	451.100	0.049	442.329	0.055	655.952	0.061	911.446	0.067	1208.811	0.074	1548.046	0.080	1929.152	0.087	2352.128	0.094	2816.975	0.100	3323.693	0.078	4314.428	0.085	5112.185	0.011	36560.000	
0.053	112.481	0.058	244.162	0.082	451.187	0.053	442.414	0.059	656.078	0.066	911.621	0.073	1209.043	0.080	1548.344	0.087	1929.523	0.095	2352.581	0.102	2817.518	0.110	3324.333	0.085	4315.259	0.093	5113.170	0.013	36560.000	
0.057	112.490	0.062	244.184	0.089	451.227	0.058	442.453	0.064	656.136	0.072	911.702	0.079	1209.150	0.087	1548.480	0.095	1929.693	0.103	2352.788	0.111	2817.765	0.119	3324.625	0.092	4315.638	0.100	5113.619	0.014	36560.000	
0.062	112.495	0.067	244.194	0.095	451.245	0.062	442.470	0.069	656.162	0.077	911.738	0.085	1209.198	0.094	1548.542	0.102	1929.770	0.111	2352.882	0.119	2817.878	0.128	3324.758	0.099	4315.811	0.108	5113.824	0.037	36560.000	
0.066	112.497	0.072	244.198	0.102	451.253	0.067	442.478	0.074	656.174	0.083	911.755	0.091	1209.220	0.100	1548.570	0.109	1929.805	0.118	2352.925	0.128	2817.929	0.137	3324.819	0.106	4315.890	0.116	5113.917	0.069	36560.000	
0.071	112.498	0.077	244.200	0.109	451.257	0.071	442.482	0.079	656.180	0.088	911.762	0.097	1209.230	0.107	1548.583	0.117	1929.821	0.126	2352.944	0.136	2817.953	0.146	3324.846	0.113	4315.926	0.124	5113.959	0.091	36560.000	

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 caisson (i.e., no inclination) socketed into bedrock, with a ground slope angle of zero.
2. Static loading condition is considered.
3. There are no group effects (i.e., analysis is based on a single caisson).
4. The effects of construction disturbance are not considered.

5. Pier location and details (including socket geometry) as per DeLeuw, Cather Drawing No. 3-302A-1 and 3-302A-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of caisson at Elevation 64.9 m.
8. Program: Lpile 2018.10.07



P-Y CURVES

CPR Overhead

H-Pile 310x110 - WBL West Abutment

Figure F7

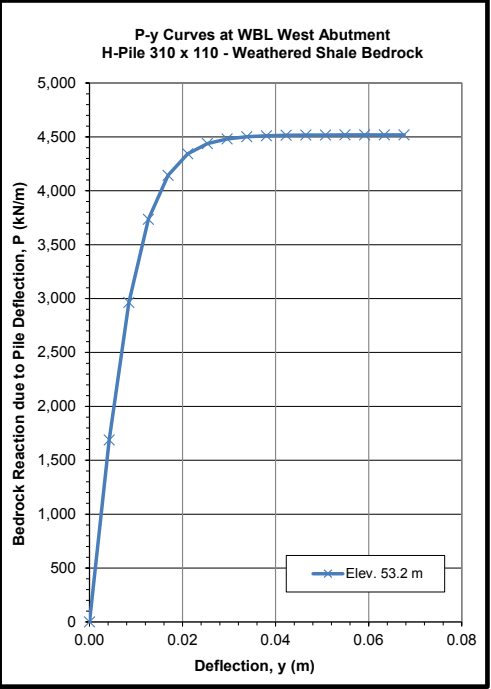
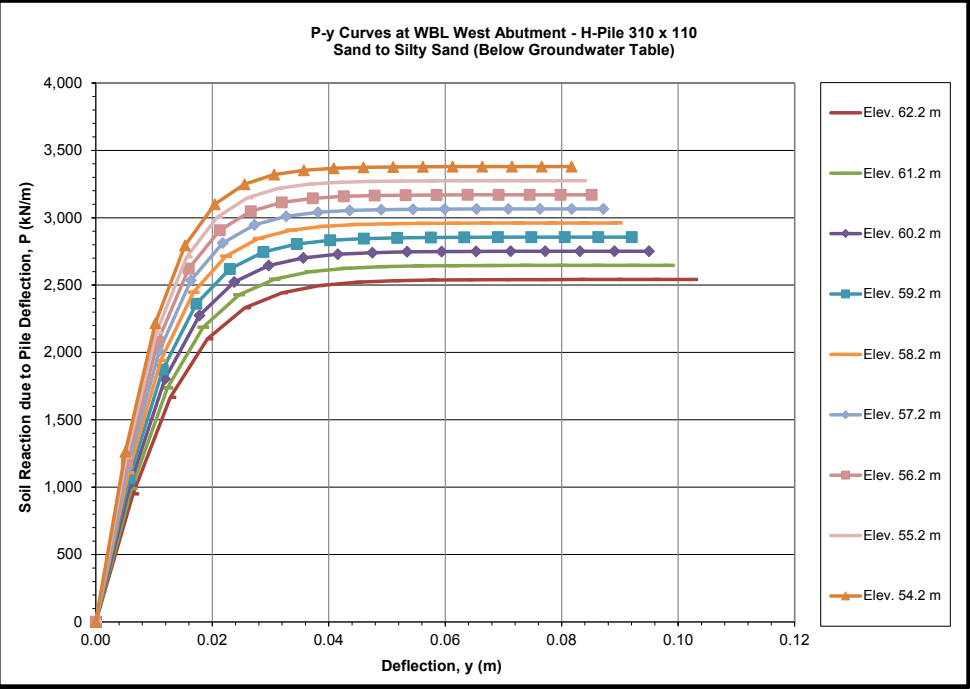
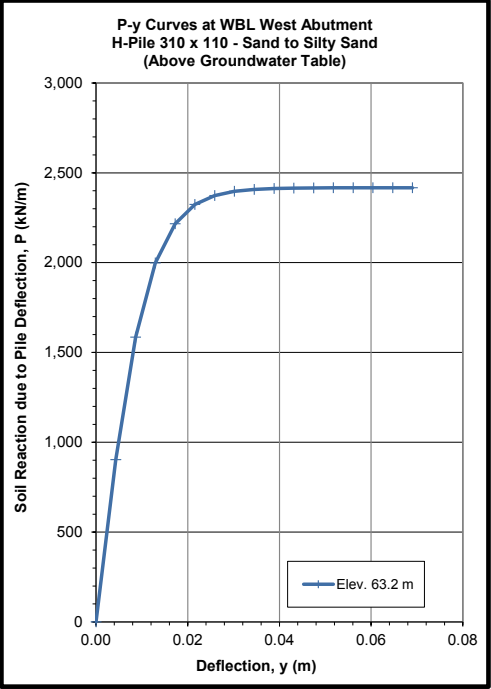
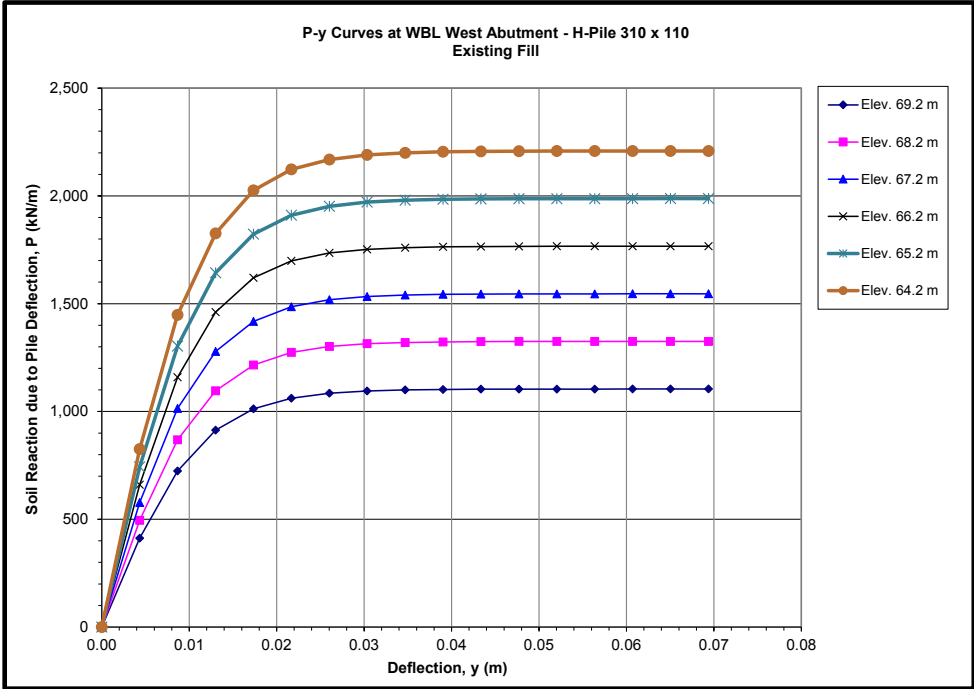
SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - WBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	Existing Fill												Sand to Silty Sand																Withrd. Bedrock					
	z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m		z= 13.0 m		z= 14.0 m		z= 15.0 m		z= 16.0 m		z= 17.0 m		z= 18.0 m		z= 19.0 m		z= 20.0 m		z= 21.0 m	
	Elev. 69.2 m		Elev. 68.2 m		Elev. 67.2 m		Elev. 66.2 m		Elev. 65.2 m		Elev. 64.2 m		Elev. 63.2 m		Elev. 62.2 m		Elev. 61.2 m		Elev. 60.2 m		Elev. 59.2 m		Elev. 58.2 m		Elev. 57.2 m		Elev. 56.2 m		Elev. 55.2 m		Elev. 54.2 m		Elev. 53.2 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.004	412.602	0.004	495.122	0.004	577.642	0.004	660.163	0.004	742.683	0.004	825.203	0.004	903.118	0.006	949.790	0.006	988.939	0.006	1028.088	0.006	1067.237	0.006	1106.387	0.005	1145.536	0.005	1184.685	0.005	1223.834	0.005	1262.983	0.004	1688.513	
0.009	724.091	0.009	868.909	0.009	1013.728	0.009	1158.546	0.009	1303.364	0.009	1448.182	0.009	1584.918	0.013	1666.824	0.012	1735.528	0.012	1804.233	0.012	1872.937	0.011	1941.642	0.011	2010.346	0.011	2079.051	0.010	2147.755	0.010	2216.460	0.008	2963.239	
0.013	912.962	0.013	1095.554	0.013	1278.147	0.013	1460.739	0.013	1643.332	0.013	1825.924	0.013	1998.325	0.019	2101.596	0.018	2188.221	0.018	2274.847	0.017	2361.472	0.017	2448.097	0.016	2534.722	0.016	2621.348	0.016	2707.973	0.015	2794.598	0.013	3736.166	
0.017	1012.668	0.017	1215.202	0.017	1417.735	0.017	1620.269	0.017	1822.803	0.017	2025.336	0.017	2216.566	0.026	2331.115	0.025	2427.200	0.024	2523.286	0.023	2619.372	0.022	2715.458	0.022	2811.543	0.021	2907.629	0.021	3003.715	0.020	3099.800	0.017	4144.198	
0.022	1061.475	0.022	1273.770	0.022	1486.065	0.022	1698.360	0.022	1910.655	0.022	2122.950	0.022	2323.396	0.032	2443.466	0.031	2544.182	0.030	2644.899	0.029	2745.616	0.028	2846.333	0.027	2947.049	0.027	3047.766	0.026	3148.483	0.026	3249.199	0.021	4343.933	
0.026	1084.483	0.026	1301.379	0.026	1518.276	0.026	1735.172	0.026	1952.069	0.026	2168.965	0.026	2373.756	0.038	2496.429	0.037	2599.329	0.036	2702.228	0.035	2805.128	0.034	2908.028	0.033	3010.928	0.032	3113.827	0.031	3216.727	0.031	3319.627	0.025	4438.089	
0.030	1095.136	0.030	1314.163	0.030	1533.190	0.030	1752.217	0.030	1971.245	0.030	2190.272	0.030	2397.074	0.045	2520.952	0.043	2624.863	0.042	2728.773	0.040	2832.684	0.039	2936.594	0.038	3040.505	0.037	3144.415	0.036	3248.326	0.036	3352.237	0.030	4481.686	
0.035	1100.028	0.035	1320.033	0.035	1540.039	0.035	1760.044	0.035	1980.050	0.035	2200.055	0.035	2407.781	0.051	2532.212	0.049	2636.587	0.047	2740.962	0.046	2845.337	0.045	2949.711	0.044	3054.086	0.043	3158.461	0.042	3262.835	0.041	3367.210	0.034	4501.705	
0.039	1102.265	0.039	1322.718	0.039	1543.171	0.039	1763.624	0.039	1984.077	0.039	2204.530	0.039	2412.679	0.058	2537.363	0.055	2641.950	0.053	2746.537	0.052	2851.124	0.050	2955.711	0.049	3060.298	0.048	3164.885	0.047	3269.472	0.046	3374.059	0.038	4510.861	
0.043	1103.287	0.043	1323.944	0.043	1544.602	0.043	1765.259	0.043	1985.916	0.043	2206.574	0.043	2414.915	0.064	2539.715	0.061	2644.399	0.059	2749.083	0.058	2853.767	0.056	2958.451	0.054	3063.135	0.053	3167.819	0.052	3272.503	0.051	3377.187	0.042	4515.043	
0.048	1103.753	0.048	1324.504	0.048	1545.254	0.048	1766.005	0.048	1986.755	0.048	2207.506	0.047	2415.936	0.070	2540.788	0.068	2645.516	0.065	2750.244	0.063	2854.973	0.061	2959.701	0.060	3064.429	0.059	3169.157	0.057	3273.885	0.056	3378.614	0.046	4516.950	
0.052	1103.966	0.052	1324.759	0.052	1545.552	0.052	1766.345	0.052	1987.138	0.052	2207.931	0.052	2416.401	0.077	2541.277	0.074	2646.026	0.071	2750.774	0.069	2855.523	0.067	2960.271	0.065	3065.019	0.064	3169.768	0.062	3274.516	0.061	3379.264	0.051	4517.820	
0.056	1104.063	0.056	1324.875	0.056	1545.688	0.056	1766.500	0.056	1987.313	0.056	2208.125	0.056	2416.613	0.083	2541.501	0.080	2646.258	0.077	2751.016	0.075	2855.773	0.073	2960.531	0.071	3065.288	0.069	3170.046	0.068	3274.804	0.066	3379.561	0.055	4518.217	
0.061	1104.107	0.061	1324.928	0.061	1545.749	0.061	1766.571	0.061	1987.392	0.061	2208.213	0.060	2416.710	0.090	2541.602	0.086	2646.364	0.083	2751.126	0.081	2855.888	0.078	2960.649	0.076	3065.411	0.074	3170.173	0.073	3274.935	0.071	3379.696	0.059	4518.398	
0.065	1104.127	0.065	1324.952	0.065	1545.778	0.065	1766.603	0.065	1987.428	0.065	2208.254	0.065	2416.754	0.096	2541.649	0.092	2646.412	0.089	2751.176	0.086	2855.940	0.084	2960.703	0.082	3065.467	0.080	3170.231	0.078	3274.994	0.077	3379.758	0.063	4518.480	
0.069	1104.136	0.069	1324.963	0.069	1545.791	0.069	1766.618	0.069	1987.445	0.069	2208.272	0.069	2416.774	0.102	2541.670	0.098	2646.434	0.095	2751.199	0.092	2855.964	0.089	2960.728	0.087	3065.493	0.085	3170.257	0.083	3275.022	0.082	3379.786	0.068	4518.518	

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 group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment locations and details as per DeLeuw, Cather Drawing No. 3-302B-1 and 3-302B-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of pile at Elevation 69.5 m.
8. Piles driven 1 m depth into weathered shale bedrock.
9. Program: Lpile 2018.10.07



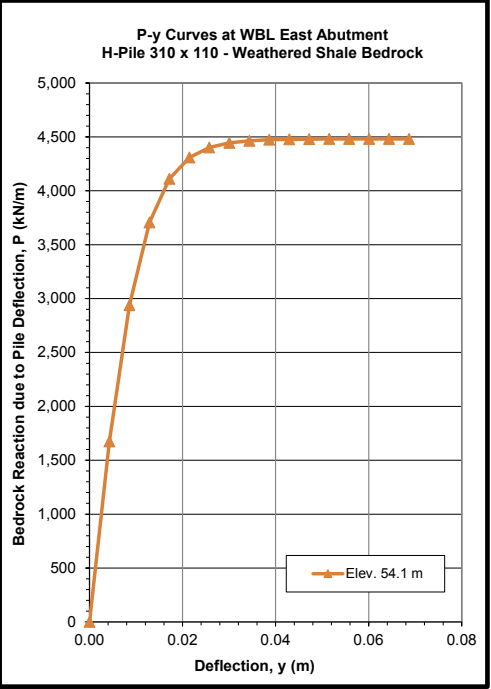
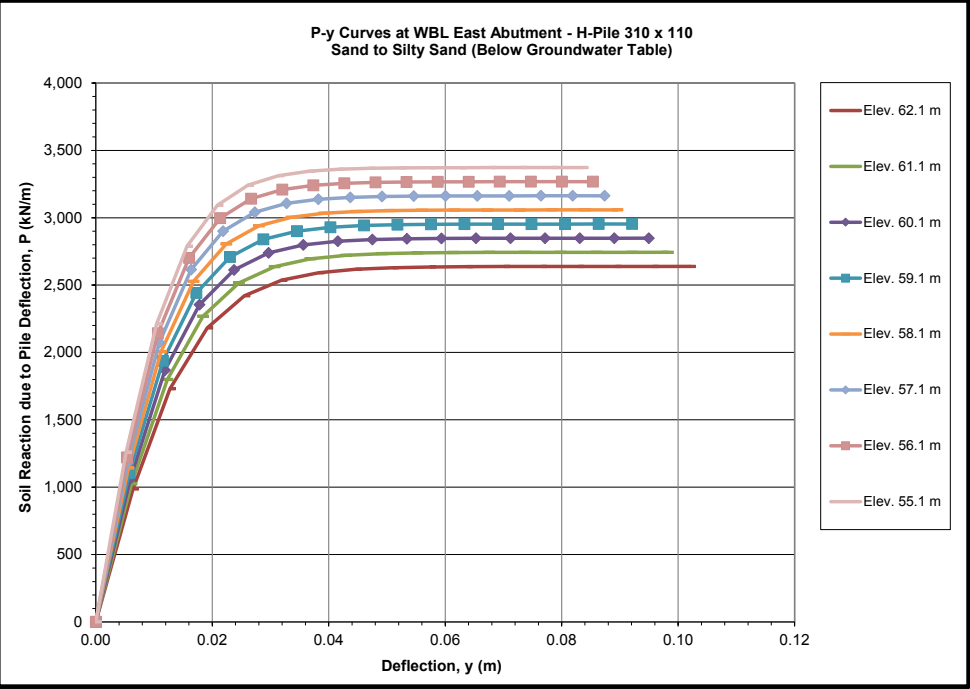
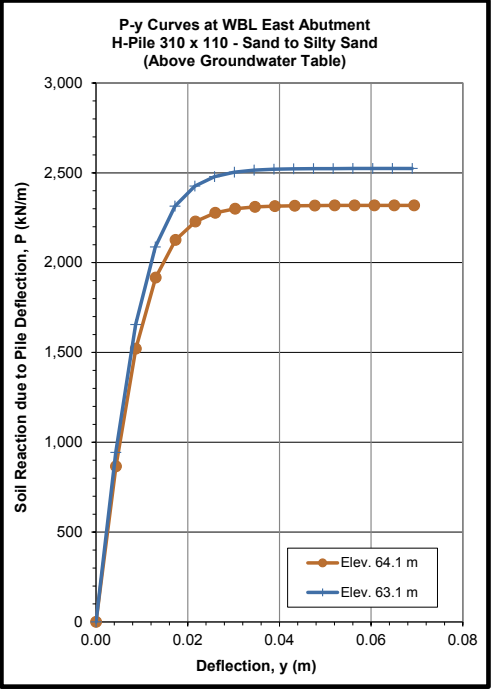
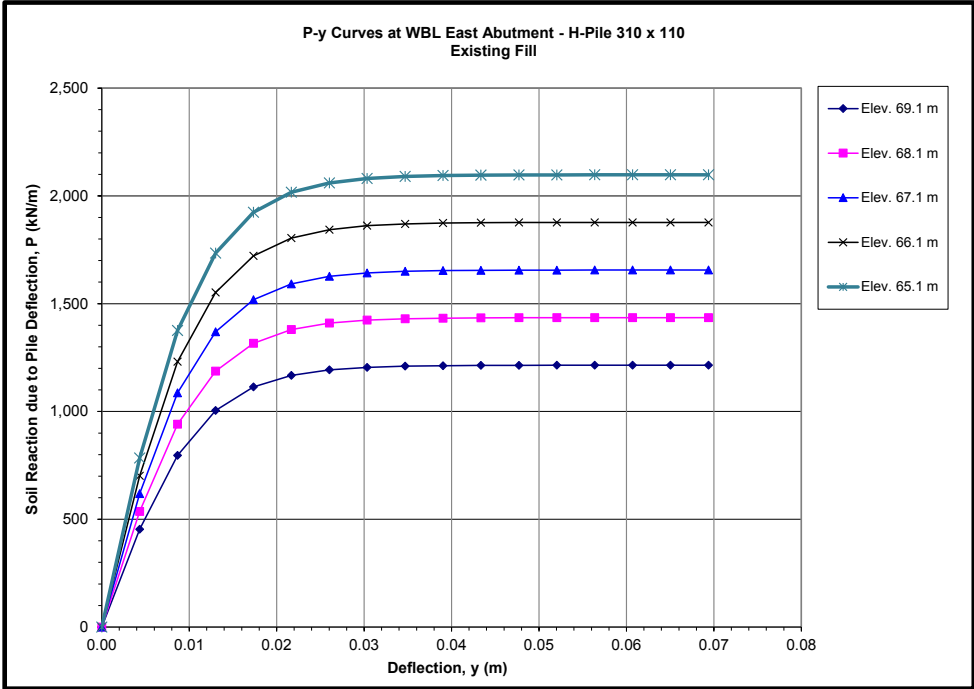
SUMMARY OF P-Y CURVES FOR H-PILE 310x110 - WBL EAST ABUTMENT

Description Depth (z) * Elevation P-y Curves	Existing Fill										Sand to Silty Sand																Wthrd. Bedrock					
	z= 5.5 m		z= 6.5 m		z= 7.5 m		z= 8.5 m		z= 9.5 m		z= 10.5 m		z= 11.5 m		z= 12.5 m		z= 13.5 m		z= 14.5 m		z= 15.5 m		z= 16.5 m		z= 17.5 m		z= 18.5 m		z= 19.5 m		z= 20.5 m	
	Elev. 69.1 m		Elev. 68.1 m		Elev. 67.1 m		Elev. 66.1 m		Elev. 65.1 m		Elev. 64.1 m		Elev. 63.1 m		Elev. 62.1 m		Elev. 61.1 m		Elev. 60.1 m		Elev. 59.1 m		Elev. 58.1 m		Elev. 57.1 m		Elev. 56.1 m		Elev. 55.1 m		Elev. 54.1 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.004	453.862	0.004	536.382	0.004	618.903	0.004	701.423	0.004	783.943	0.004	866.464	0.004	943.227	0.006	986.137	0.006	1025.286	0.006	1064.436	0.006	1103.585	0.006	1142.734	0.005	1181.883	0.005	1221.032	0.005	1260.182	0.004	1674.543	0.004
0.009	796.500	0.009	941.318	0.009	1086.137	0.009	1230.955	0.009	1375.773	0.009	1520.591	0.009	1655.306	0.013	1730.611	0.012	1799.316	0.012	1868.020	0.012	1936.725	0.011	2005.429	0.011	2074.134	0.011	2142.838	0.010	2211.543	0.009	2938.722	0.009
0.013	1004.258	0.013	1186.851	0.013	1369.443	0.013	1552.035	0.013	1734.628	0.013	1917.220	0.013	2087.074	0.019	2182.022	0.018	2268.647	0.018	2355.272	0.017	2441.897	0.017	2528.523	0.016	2615.148	0.016	2701.773	0.016	2788.398	0.013	3705.255	0.013
0.017	1113.935	0.017	1316.468	0.017	1519.002	0.017	1721.536	0.017	1924.069	0.017	2126.603	0.017	2315.006	0.026	2420.324	0.025	2516.409	0.024	2612.495	0.023	2708.581	0.022	2804.667	0.022	2900.752	0.021	2996.838	0.021	3092.924	0.017	4109.912	0.017
0.022	1167.622	0.022	1379.917	0.022	1592.212	0.022	1804.507	0.022	2016.802	0.022	2229.097	0.022	2426.581	0.032	2536.974	0.031	2637.691	0.030	2738.408	0.029	2839.124	0.028	2939.841	0.027	3040.558	0.027	3141.274	0.026	3241.991	0.021	4307.994	0.021
0.026	1192.931	0.026	1409.828	0.026	1626.724	0.026	1843.621	0.026	2060.517	0.026	2277.414	0.026	2479.178	0.038	2591.964	0.037	2694.864	0.036	2797.764	0.035	2900.663	0.034	3003.563	0.033	3106.463	0.032	3209.363	0.031	3312.262	0.026	4401.371	0.026
0.030	1204.650	0.030	1423.677	0.030	1642.704	0.030	1861.731	0.030	2080.758	0.030	2299.785	0.030	2503.532	0.045	2617.426	0.043	2721.336	0.042	2825.247	0.040	2929.158	0.039	3033.068	0.038	3136.979	0.037	3240.889	0.037	3344.800	0.030	4444.607	0.030
0.035	1210.030	0.035	1430.036	0.035	1650.041	0.035	1870.047	0.035	2090.052	0.035	2310.058	0.034	2514.714	0.051	2629.117	0.049	2733.492	0.047	2837.867	0.046	2942.241	0.045	3046.616	0.044	3150.991	0.043	3255.365	0.042	3359.740	0.034	4464.460	0.034
0.039	1212.492	0.039	1432.945	0.039	1653.398	0.039	1873.851	0.039	2094.304	0.039	2314.757	0.039	2519.829	0.057	2634.465	0.055	2739.052	0.053	2843.639	0.052	2948.226	0.050	3052.813	0.049	3157.400	0.048	3261.987	0.047	3366.574	0.039	4473.541	0.039
0.043	1213.616	0.043	1434.273	0.043	1654.930	0.043	1875.588	0.043	2096.245	0.043	2316.902	0.043	2522.165	0.064	2636.907	0.061	2741.591	0.059	2846.275	0.058	2950.959	0.056	3055.643	0.055	3160.327	0.053	3265.011	0.052	3369.695	0.043	4477.688	0.043
0.048	1214.128	0.048	1434.879	0.048	1655.630	0.048	1876.380	0.048	2097.131	0.048	2317.881	0.047	2523.231	0.070	2638.021	0.068	2742.749	0.065	2847.477	0.063	2952.206	0.062	3056.934	0.060	3161.662	0.059	3266.390	0.057	3371.118	0.047	4479.580	0.047
0.052	1214.362	0.052	1435.155	0.052	1655.948	0.052	1876.742	0.052	2097.535	0.052	2318.328	0.052	2523.717	0.077	2638.529	0.074	2743.277	0.071	2848.026	0.069	2952.774	0.067	3057.523	0.066	3162.271	0.064	3267.019	0.063	3371.768	0.052	4480.442	0.052
0.056	1214.469	0.056	1435.281	0.056	1656.094	0.056	1876.906	0.056	2097.719	0.056	2318.531	0.056	2523.938	0.083	2638.761	0.080	2743.518	0.077	2848.276	0.075	2953.034	0.073	3057.791	0.071	3162.549	0.069	3267.306	0.068	3372.064	0.056	4480.836	0.056
0.061	1214.517	0.061	1435.339	0.061	1656.160	0.061	1876.981	0.061	2097.803	0.061	2318.624	0.060	2524.039	0.089	2638.866	0.086	2743.628	0.083	2848.390	0.081	2953.152	0.078	3057.913	0.076	3162.675	0.075	3267.437	0.073	3372.199	0.060	4481.015	0.060
0.065	1214.540	0.065	1435.365	0.065	1656.190	0.065	1877.016	0.065	2097.841	0.065	2318.666	0.065	2524.085	0.096	2638.915	0.092	2743.678	0.089	2848.442	0.086	2953.206	0.084	3057.969	0.082	3162.733	0.080	3267.497	0.078	3372.260	0.064	4481.097	0.064
0.069	1214.550	0.069	1435.377	0.069	1656.204	0.069	1877.031	0.069	2097.859	0.069	2318.686	0.069	2524.106	0.102	2638.937	0.098	2743.701	0.095	2848.466	0.092	2953.230	0.090	3057.995	0.087	3162.759	0.085	3267.524	0.084	3372.288	0.069	4481.134	0.069

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 group effects (i.e., analysis is based on a single pile).
4. The effects of construction disturbance are not considered.

5. Abutment locations and details as per DeLeuw, Cather Drawing No. 3-302B-1 and 3-302B-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of pile at Elevation 69.5 m.
8. Piles driven 1 m depth into weathered shale bedrock.
9. Program: Lpile 2018.10.07



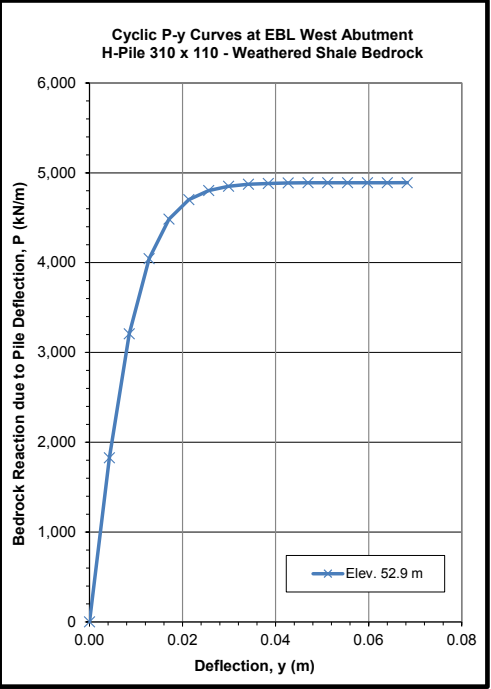
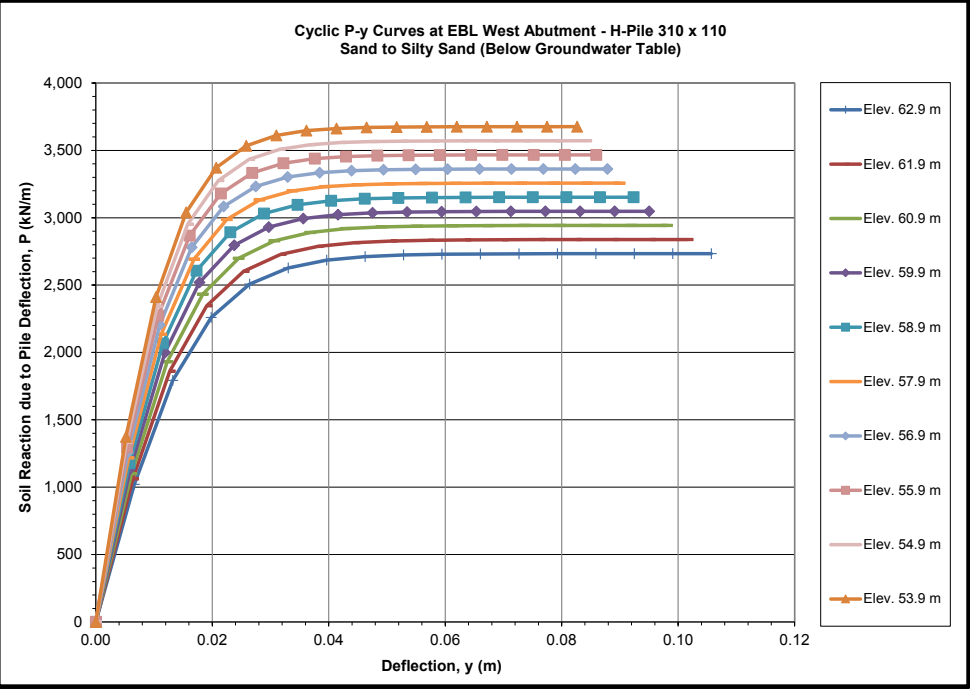
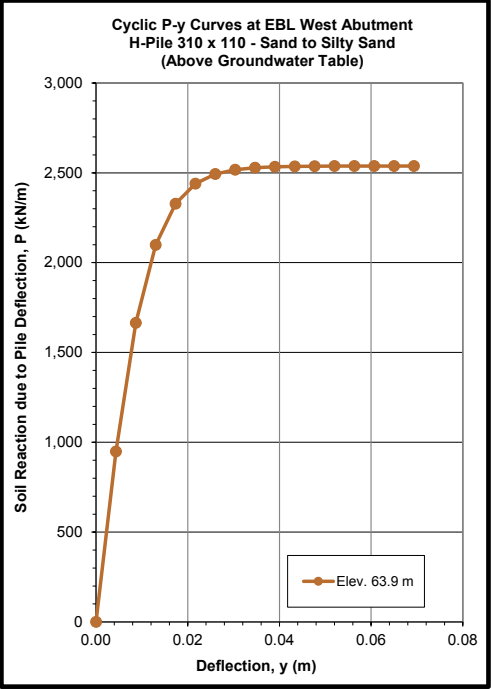
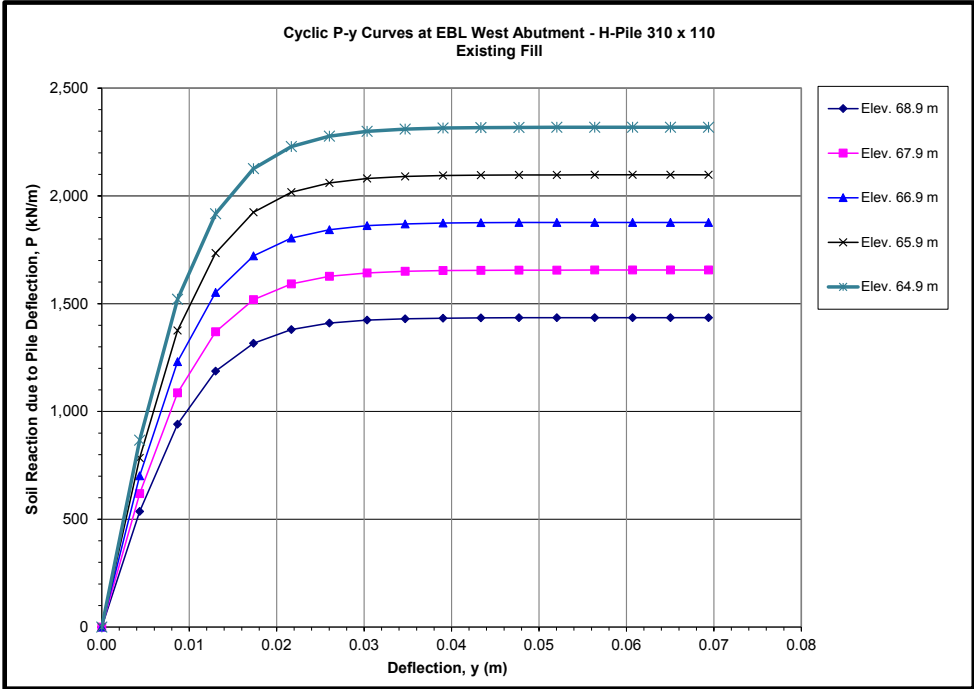
SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - EBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	Existing Fill										Sand to Silty Sand																Withrd. Bedrock							
	z= 6.5 m		z= 7.5 m		z= 8.5 m		z= 9.5 m		z= 10.5 m		z= 11.5 m		z= 12.5 m		z= 13.5 m		z= 14.5 m		z= 15.5 m		z= 16.5 m		z= 17.5 m		z= 18.5 m		z= 19.5 m		z= 20.5 m		z= 21.5 m		z= 22.5 m	
	Elev. 68.9 m		Elev. 67.9 m		Elev. 66.9 m		Elev. 65.9 m		Elev. 64.9 m		Elev. 63.9 m		Elev. 62.9 m		Elev. 61.9 m		Elev. 60.9 m		Elev. 59.9 m		Elev. 58.9 m		Elev. 57.9 m		Elev. 56.9 m		Elev. 55.9 m		Elev. 54.9 m		Elev. 53.9 m		Elev. 52.9 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.004	536.382	0.004	618.903	0.004	701.423	0.004	783.943	0.004	866.464	0.004	948.408	0.007	1021.410	0.006	1060.559	0.006	1099.708	0.006	1138.857	0.006	1178.007	0.006	1217.156	0.005	1256.305	0.005	1295.454	0.005	1334.603	0.005	1373.753	0.004	1827.519	
0.009	941.318	0.009	1086.137	0.009	1230.955	0.009	1375.773	0.009	1520.591	0.009	1664.399	0.013	1792.513	0.013	1861.217	0.012	1929.922	0.012	1998.626	0.012	2067.331	0.011	2136.035	0.011	2204.740	0.011	2273.444	0.011	2342.148	0.010	2410.853	0.009	3207.186	
0.013	1186.851	0.013	1369.443	0.013	1552.035	0.013	1734.628	0.013	1917.220	0.013	2098.539	0.020	2260.069	0.019	2346.695	0.018	2433.320	0.018	2519.945	0.017	2606.570	0.017	2693.196	0.016	2779.821	0.016	2866.446	0.016	2953.071	0.016	3039.697	0.013	4043.745	
0.017	1316.468	0.017	1519.002	0.017	1721.536	0.017	1924.069	0.017	2126.603	0.017	2327.724	0.026	2506.895	0.025	2602.981	0.025	2699.067	0.024	2795.152	0.023	2891.238	0.022	2987.324	0.022	3083.409	0.021	3179.495	0.021	3275.581	0.021	3371.667	0.017	4485.368	
0.022	1379.917	0.022	1592.212	0.022	1804.507	0.022	2016.802	0.022	2229.097	0.022	2439.911	0.033	2627.718	0.032	2728.435	0.031	2829.151	0.030	2929.868	0.029	3030.585	0.028	3131.302	0.027	3232.018	0.027	3332.735	0.026	3433.452	0.026	3534.168	0.021	4701.546	
0.026	1409.828	0.026	1626.724	0.026	1843.621	0.026	2060.517	0.026	2277.414	0.026	2492.797	0.040	2684.675	0.038	2787.575	0.037	2890.474	0.036	2993.374	0.035	3096.274	0.034	3199.174	0.033	3302.073	0.032	3404.973	0.032	3507.873	0.031	3610.773	0.026	4803.454	
0.030	1423.677	0.030	1642.704	0.030	1861.731	0.030	2080.758	0.030	2299.785	0.030	2517.285	0.046	2711.047	0.044	2814.958	0.043	2918.868	0.042	3022.779	0.040	3126.689	0.039	3230.600	0.038	3334.511	0.038	3438.421	0.037	3542.332	0.036	3646.242	0.030	4850.640	
0.035	1430.036	0.035	1650.041	0.035	1870.047	0.035	2090.052	0.035	2310.058	0.035	2528.529	0.053	2723.157	0.051	2827.531	0.049	2931.906	0.048	3036.281	0.046	3140.656	0.045	3245.030	0.044	3349.405	0.043	3453.780	0.042	3558.154	0.041	3662.529	0.034	4872.306	
0.039	1432.945	0.039	1653.398	0.039	1873.851	0.039	2094.304	0.039	2314.757	0.039	2533.672	0.059	2728.696	0.057	2833.283	0.055	2937.870	0.053	3042.457	0.052	3147.044	0.051	3251.631	0.049	3356.218	0.048	3460.805	0.047	3565.392	0.046	3669.979	0.038	4882.217	
0.043	1434.273	0.043	1654.930	0.043	1875.588	0.043	2096.245	0.043	2316.902	0.043	2536.020	0.066	2731.225	0.064	2835.909	0.061	2940.593	0.059	3045.277	0.058	3149.961	0.056	3254.645	0.055	3359.329	0.054	3464.013	0.053	3568.697	0.052	3673.381	0.043	4886.742	
0.048	1434.879	0.048	1655.630	0.048	1876.380	0.048	2097.131	0.048	2317.881	0.048	2537.092	0.073	2732.379	0.070	2837.107	0.067	2941.835	0.065	3046.564	0.063	3151.292	0.062	3256.020	0.060	3360.748	0.059	3465.476	0.058	3570.205	0.057	3674.933	0.047	4888.807	
0.052	1435.155	0.052	1655.948	0.052	1876.742	0.052	2097.535	0.052	2318.328	0.052	2537.580	0.079	2732.905	0.076	2837.654	0.074	2942.402	0.071	3047.150	0.069	3151.899	0.067	3256.647	0.066	3361.396	0.064	3466.144	0.063	3570.892	0.062	3675.641	0.051	4889.749	
0.056	1435.281	0.056	1656.094	0.056	1876.906	0.056	2097.719	0.056	2318.531	0.056	2537.803	0.086	2733.145	0.083	2837.903	0.080	2942.660	0.077	3047.418	0.075	3152.176	0.073	3256.933	0.071	3361.691	0.070	3466.448	0.068	3571.206	0.067	3675.963	0.055	4890.178	
0.061	1435.339	0.061	1656.160	0.061	1876.981	0.061	2097.803	0.061	2318.624	0.061	2537.905	0.092	2733.255	0.089	2838.017	0.086	2942.778	0.083	3047.540	0.081	3152.302	0.079	3257.064	0.077	3361.825	0.075	3466.587	0.074	3571.349	0.072	3676.111	0.060	4890.374	
0.065	1435.365	0.065	1656.190	0.065	1877.016	0.065	2097.841	0.065	2318.666	0.065	2537.951	0.099	2733.305	0.095	2838.068	0.092	2942.832	0.089	3047.596	0.087	3152.359	0.084	3257.123	0.082	3361.887	0.081	3466.650	0.079	3571.414	0.077	3676.178	0.064	4890.463	
0.069	1435.377	0.069	1656.204	0.069	1877.031	0.069	2097.859	0.069	2318.686	0.069	2537.972	0.106	2733.327	0.102	2838.092	0.098	2942.856	0.095	3047.621	0.092	3152.386	0.090	3257.150	0.088	3361.915	0.086	3466.679	0.084	3571.444	0.083	3676.208	0.068	4890.504	

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

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

- Abutment locations and details as per DeLeuw, Cather Drawing No. 3-302A-1 and 3-302A-3, dated February 1973.
- Groundwater table at Elevation 63.0 m.
- Top of pile at Elevation 69.3 m.
- Piles driven 1 m depth into weathered shale bedrock.
- Program: Lpile 2018.10.07



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

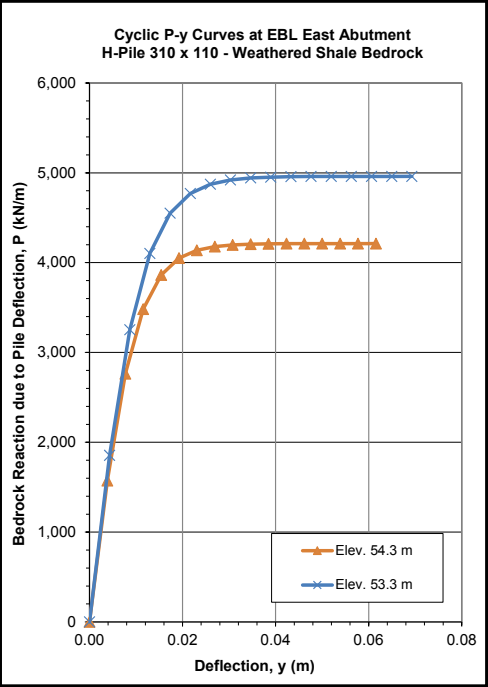
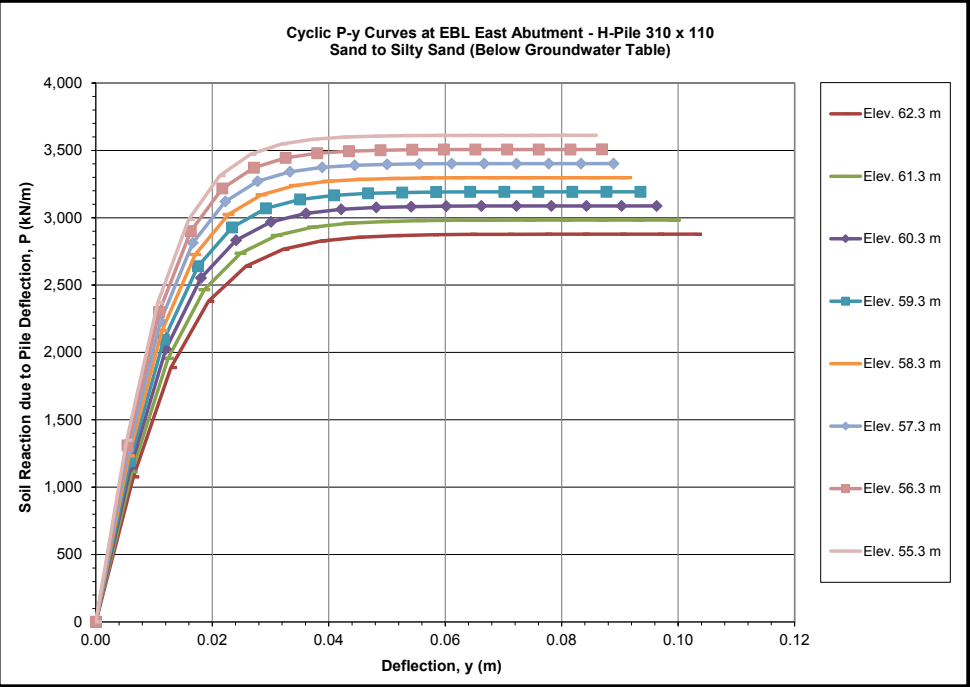
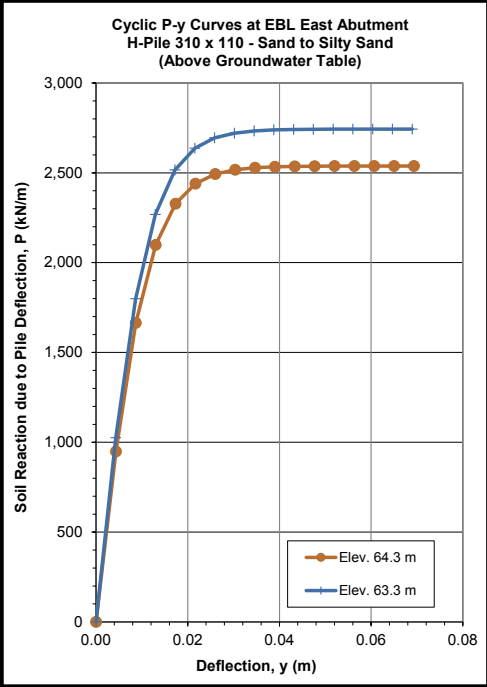
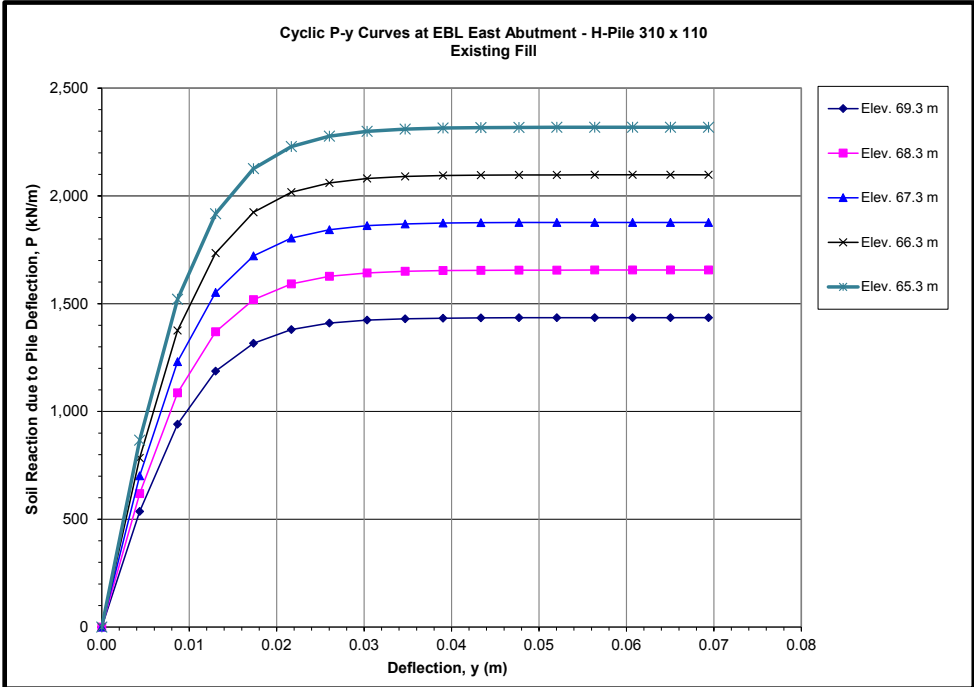
Description Depth (z) * Elevation P-y Curves	Existing Fill										Sand to Silty Sand																Weathered Shale Bedrock							
	z= 6.5 m		z= 7.5 m		z= 8.5 m		z= 9.5 m		z= 10.5 m		z= 11.5 m		z= 12.5 m		z= 13.5 m		z= 14.5 m		z= 15.5 m		z= 16.5 m		z= 17.5 m		z= 18.5 m		z= 19.5 m		z= 20.5 m		z= 21.5 m		z= 22.5 m	
	Elev. 69.3 m		Elev. 68.3 m		Elev. 67.3 m		Elev. 66.3 m		Elev. 65.3 m		Elev. 64.3 m		Elev. 63.3 m		Elev. 62.3 m		Elev. 61.3 m		Elev. 60.3 m		Elev. 59.3 m		Elev. 58.3 m		Elev. 57.3 m		Elev. 56.3 m		Elev. 55.3 m		Elev. 54.3 m		Elev. 53.3 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.004	536.382	0.004	618.903	0.004	701.423	0.004	783.943	0.004	866.464	0.004	948.408	0.004	1025.171	0.006	1075.605	0.006	1114.754	0.006	1153.903	0.006	1193.052	0.006	1232.201	0.006	1271.351	0.005	1310.500	0.005	1349.649	0.004	1574.084	0.004	1853.781	
0.009	941.318	0.009	1086.137	0.009	1230.955	0.009	1375.773	0.009	1520.591	0.009	1664.399	0.009	1799.114	0.013	1887.621	0.012	1956.326	0.012	2025.030	0.012	2093.735	0.011	2162.439	0.011	2231.144	0.011	2299.848	0.011	2368.552	0.008	2762.422	0.009	3253.273	
0.013	1186.851	0.013	1369.443	0.013	1552.035	0.013	1734.628	0.013	1917.220	0.013	2098.539	0.013	2268.392	0.019	2379.986	0.019	2466.611	0.018	2553.236	0.018	2639.862	0.017	2726.487	0.017	2813.112	0.016	2899.737	0.016	2986.363	0.012	3482.968	0.013	4101.852	
0.017	1316.468	0.017	1519.002	0.017	1721.536	0.017	1924.069	0.017	2126.603	0.017	2327.724	0.017	2516.127	0.026	2639.908	0.025	2735.994	0.024	2832.079	0.023	2928.165	0.023	3024.251	0.022	3120.336	0.022	3216.422	0.021	3312.508	0.015	3863.349	0.017	4549.822	
0.022	1379.917	0.022	1592.212	0.022	1804.507	0.022	2016.802	0.022	2229.097	0.022	2439.911	0.022	2637.395	0.032	2767.142	0.031	2867.858	0.030	2968.575	0.029	3069.292	0.028	3170.008	0.028	3270.725	0.027	3371.442	0.027	3472.158	0.019	4049.548	0.022	4769.107	
0.026	1409.828	0.026	1626.724	0.026	1843.621	0.026	2060.517	0.026	2277.414	0.026	2492.797	0.026	2694.561	0.039	2827.120	0.037	2930.020	0.036	3032.920	0.035	3135.820	0.034	3238.719	0.033	3341.619	0.033	3444.519	0.032	3547.419	0.023	4137.323	0.026	4872.479	
0.030	1423.677	0.030	1642.704	0.030	1861.731	0.030	2080.758	0.030	2299.785	0.030	2517.285	0.030	2721.031	0.045	2854.892	0.044	2958.803	0.042	3062.713	0.041	3166.624	0.040	3270.534	0.039	3374.445	0.038	3478.355	0.037	3582.266	0.027	4177.965	0.030	4920.343	
0.035	1430.036	0.035	1650.041	0.035	1870.047	0.035	2090.052	0.035	2310.058	0.035	2528.529	0.034	2733.185	0.052	2867.644	0.050	2972.019	0.048	3076.394	0.047	3180.768	0.046	3285.143	0.044	3389.518	0.043	3493.892	0.043	3598.267	0.031	4196.627	0.035	4942.320	
0.039	1432.945	0.039	1653.398	0.039	1873.851	0.039	2094.304	0.039	2314.757	0.039	2533.672	0.039	2738.744	0.058	2873.477	0.056	2978.064	0.054	3082.651	0.053	3187.238	0.051	3291.825	0.050	3396.412	0.049	3500.999	0.048	3605.586	0.035	4205.164	0.039	4952.374	
0.043	1434.273	0.043	1654.930	0.043	1875.588	0.043	2096.245	0.043	2316.902	0.043	2536.020	0.043	2741.283	0.064	2876.141	0.062	2980.825	0.060	3085.508	0.058	3190.192	0.057	3294.876	0.056	3399.560	0.054	3504.244	0.053	3608.928	0.038	4209.061	0.043	4956.964	
0.048	1434.879	0.048	1655.630	0.048	1876.380	0.048	2097.131	0.048	2317.881	0.048	2537.092	0.047	2742.441	0.071	2877.356	0.068	2982.084	0.066	3086.812	0.064	3191.540	0.063	3296.268	0.061	3400.997	0.060	3505.725	0.059	3610.453	0.042	4210.840	0.048	4959.058	
0.052	1435.155	0.052	1655.948	0.052	1876.742	0.052	2097.535	0.052	2318.328	0.052	2537.580	0.052	2742.969	0.077	2877.910	0.075	2982.658	0.072	3087.407	0.070	3192.155	0.068	3296.903	0.067	3401.652	0.065	3506.400	0.064	3611.148	0.046	4211.651	0.052	4960.013	
0.056	1435.281	0.056	1656.094	0.056	1876.906	0.056	2097.719	0.056	2318.531	0.056	2537.803	0.056	2743.210	0.084	2878.163	0.081	2982.920	0.078	3087.678	0.076	3192.435	0.074	3297.193	0.072	3401.950	0.071	3506.708	0.069	3611.466	0.050	4212.021	0.056	4960.449	
0.061	1435.339	0.061	1656.160	0.061	1876.981	0.061	2097.803	0.061	2318.624	0.061	2537.905	0.060	2743.320	0.090	2878.278	0.087	2983.040	0.084	3087.801	0.082	3192.563	0.080	3297.325	0.078	3402.087	0.076	3506.848	0.075	3611.610	0.054	4212.189	0.061	4960.648	
0.065	1435.365	0.065	1656.190	0.065	1877.016	0.065	2097.841	0.065	2318.666	0.065	2537.951	0.065	2743.370	0.097	2878.330	0.093	2983.094	0.090	3087.858	0.088	3192.621	0.085	3297.385	0.083	3402.149	0.081	3506.912	0.080	3611.676	0.058	4212.266	0.065	4960.738	
0.069	1435.377	0.069	1656.204	0.069	1877.031	0.069	2097.859	0.069	2318.686	0.069	2537.972	0.069	2743.393	0.103	2878.354	0.099	2983.119	0.096	3087.883	0.094	3192.648	0.091	3297.413	0.089	3402.177	0.087	3506.942	0.085	3611.706	0.062	4212.301	0.069	4960.779	

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

Please note the following assumptions:

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

- Abutment locations and details as per DeLeuw, Cather Drawing No. 3-302A-1 and 3-302A-3, dated February 1973.
- Groundwater table at Elevation 63.0 m.
- Top of pile at Elevation 69.5 m.
- Piles driven 1 m depth into weathered shale bedrock.
- Program: Lpile 2018.10.07



CYCLIC P-Y CURVES

CPR Overhead
1067 mm OD Caisson with 914 mm OD Socket - EBL Pier 1

Figure F11

SUMMARY OF CYCLIC P-Y CURVES FOR EBL PIER 1

Description Depth (z) * Elevation P-y Curves	Sand to Silty Sand																								Weathered Shale Bedrock				Shale Bedrock	
	z= .5 m		z= 1.0 m		z= 2.0 m		z= 3.0 m		z= 4.0 m		z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 11.9 m		z= 12.2 m		z= 12.7 m	
	Elev. 63.8 m		Elev. 63.3 m		Elev. 62.3 m		Elev. 61.3 m		Elev. 60.3 m		Elev. 59.3 m		Elev. 58.3 m		Elev. 57.3 m		Elev. 56.3 m		Elev. 55.3 m		Elev. 54.3 m		Elev. 53.3 m		Elev. 52.4 m		Elev. 52.1 m		Elev. 51.7 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)	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	0.000	0.000	0.000	0.000	0.000
0.002	14.413	0.002	36.498	0.002	56.537	0.003	109.559	0.004	177.885	0.004	261.723	0.005	361.144	0.005	476.177	0.006	606.837	0.007	753.133	0.007	915.069	0.008	1092.648	0.006	1367.044	0.006	1446.872	0.000	969.920	0.000
0.003	25.293	0.004	64.052	0.005	99.219	0.006	192.269	0.007	312.177	0.008	459.309	0.010	633.786	0.011	835.662	0.012	1064.963	0.014	1321.703	0.015	1605.891	0.016	1917.532	0.012	2399.081	0.012	2539.173	0.001	6062.000	0.001
0.005	31.891	0.006	80.759	0.007	125.099	0.009	242.420	0.011	393.605	0.013	579.114	0.015	799.102	0.016	1053.635	0.018	1342.747	0.020	1666.454	0.022	2024.769	0.024	2417.698	0.018	3024.853	0.019	3201.488	0.002	12124.000	0.002
0.006	35.374	0.008	89.579	0.009	138.761	0.012	268.895	0.014	436.591	0.017	642.360	0.019	886.373	0.022	1168.705	0.025	1489.390	0.027	1848.450	0.030	2245.897	0.032	2681.739	0.024	3355.202	0.025	3551.127	0.003	18186.000	0.003
0.008	37.079	0.010	93.896	0.011	145.449	0.015	281.855	0.018	457.633	0.021	673.319	0.024	929.093	0.027	1225.032	0.031	1561.173	0.034	1937.539	0.037	2354.141	0.040	2810.989	0.030	3516.911	0.031	3722.279	0.005	24248.000	0.005
0.009	37.882	0.012	95.931	0.014	148.602	0.018	287.964	0.022	467.552	0.025	687.914	0.029	949.232	0.033	1251.585	0.037	1595.012	0.041	1979.535	0.044	2405.168	0.048	2871.918	0.036	3593.141	0.037	3802.960	0.006	30310.000	0.006
0.011	38.255	0.013	96.874	0.016	150.061	0.021	290.793	0.025	472.145	0.030	694.671	0.034	958.556	0.038	1263.879	0.043	1610.680	0.047	1998.981	0.052	2428.795	0.056	2900.129	0.042	3628.437	0.044	3840.318	0.007	35874.940	0.007
0.012	38.425	0.015	97.306	0.018	150.732	0.024	292.092	0.029	474.254	0.034	697.774	0.039	962.838	0.044	1269.525	0.049	1617.875	0.054	2007.910	0.059	2439.643	0.064	2913.084	0.048	3644.645	0.050	3857.472	0.008	36560.000	0.008
0.014	38.504	0.017	97.504	0.021	151.038	0.027	292.686	0.032	475.219	0.038	699.193	0.044	964.796	0.049	1272.107	0.055	1621.166	0.061	2011.994	0.067	2444.606	0.072	2919.009	0.054	3652.058	0.056	3865.318	0.009	36560.000	0.009
0.015	38.539	0.019	97.595	0.023	151.178	0.030	292.958	0.036	475.659	0.042	699.842	0.049	965.691	0.055	1273.286	0.061	1622.668	0.068	2013.859	0.074	2446.872	0.080	2921.715	0.060	3655.443	0.062	3868.901	0.010	36560.000	0.010
0.017	38.556	0.021	97.636	0.025	151.242	0.032	293.081	0.040	475.860	0.047	700.137	0.054	966.099	0.060	1273.824	0.067	1623.354	0.074	2014.710	0.081	2447.906	0.088	2922.949	0.066	3656.988	0.069	3870.535	0.011	36560.000	0.011
0.018	38.563	0.023	97.655	0.027	151.271	0.035	293.138	0.043	475.952	0.051	700.272	0.058	966.285	0.066	1274.070	0.074	1623.667	0.081	2015.098	0.089	2448.377	0.096	2923.512	0.072	3657.692	0.075	3871.281	0.013	36560.000	0.013
0.020	38.566	0.025	97.663	0.030	151.284	0.038	293.164	0.047	475.994	0.055	700.334	0.063	966.370	0.071	1274.181	0.080	1623.809	0.088	2015.275	0.096	2448.592	0.104	2923.769	0.078	3658.013	0.081	3871.621	0.014	36560.000	0.014
0.021	38.568	0.027	97.667	0.032	151.291	0.041	293.175	0.050	476.013	0.059	700.362	0.068	966.408	0.077	1274.232	0.086	1623.874	0.095	2015.356	0.104	2448.690	0.112	2923.886	0.085	3658.160	0.087	3871.776	0.037	36560.000	0.037
0.023	38.569	0.029	97.669	0.034	151.293	0.044	293.181	0.054	476.021	0.063	700.374	0.073	966.426	0.082	1274.256	0.092	1623.904	0.101	2015.392	0.111	2448.735	0.120	2923.939	0.091	3658.227	0.093	3871.847	0.069	36560.000	0.069
0.024	38.569	0.031	97.670	0.037	151.295	0.047	293.183	0.058	476.025	0.068	700.380	0.078	966.434	0.088	1274.266	0.098	1623.917	0.108	2015.409	0.118	2448.755	0.128	2923.964	0.097	3658.257	0.100	3871.879	0.091	36560.000	0.091

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

Please note the following assumptions:

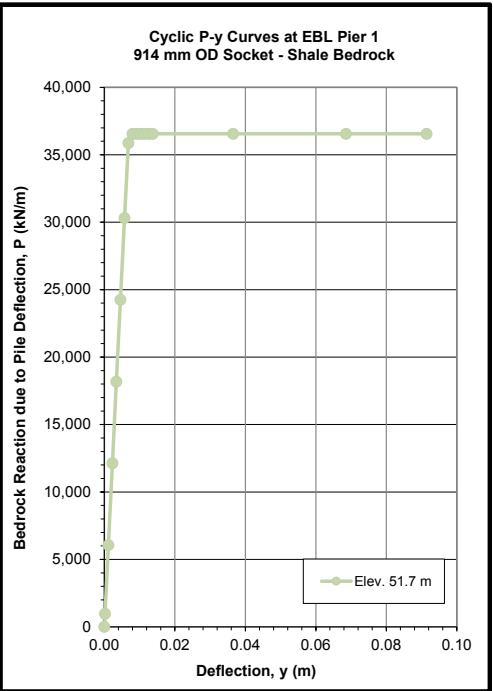
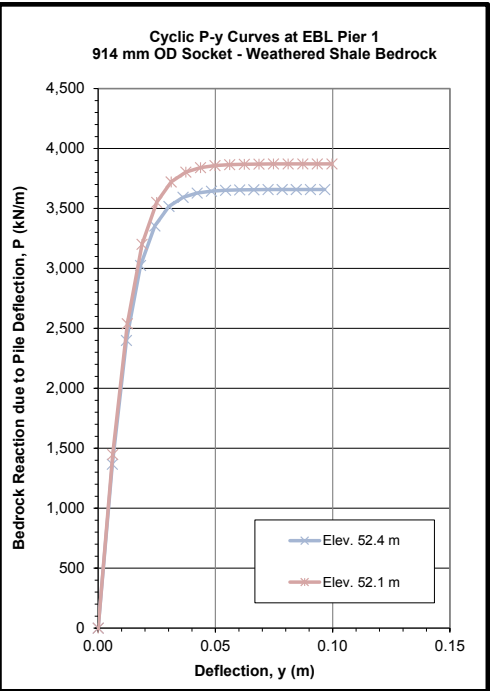
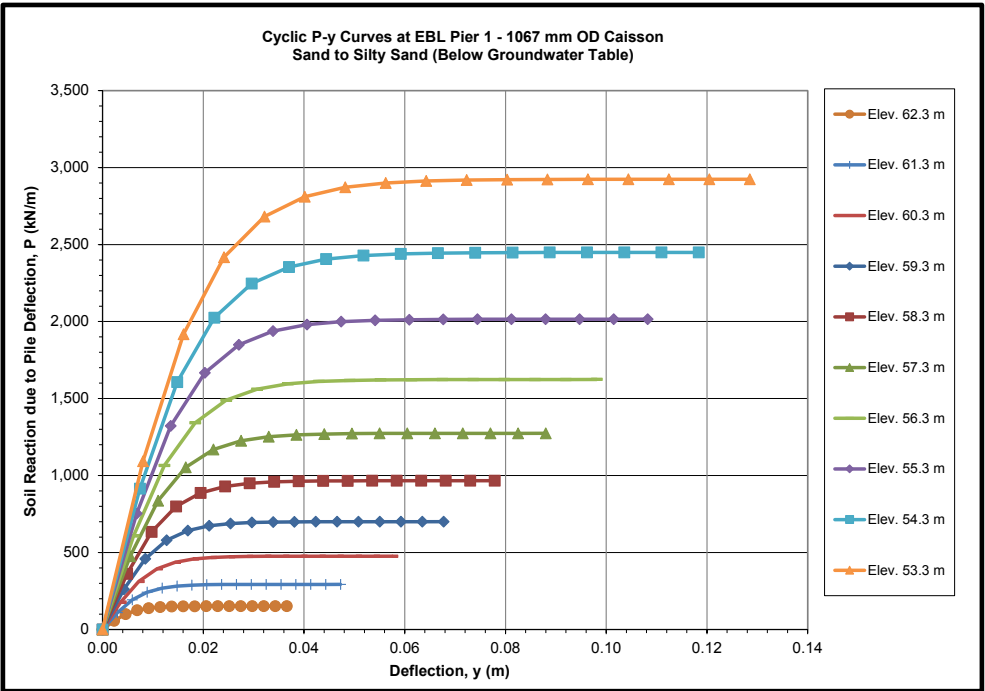
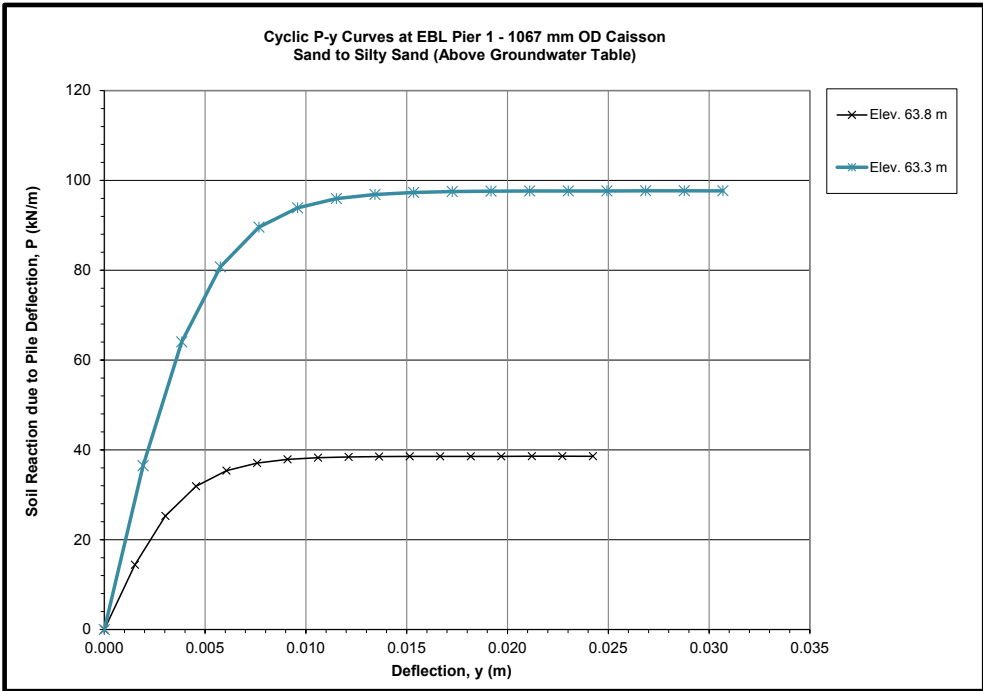
1. Cyclic p-y curves have been generated for a vertical caisson (i.e., no inclination) socketed into bedrock, with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 loading cycles are assumed.
3. There are no group effects (i.e., analysis is based on a single caisson).
4.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

5. Pier location and details (including socket geometry) as per DeLeuw, Cather Drawing No. 3-302A-1 and 3-302A-3, dated February 1973.

6. Groundwater table at Elevation 63.0 m.

7. Top of caisson at Elevation 64.3 m.

8. Program: Lpile 2018.10.07



SUMMARY OF CYCLIC P-Y CURVES FOR EBL PIER 2, WBL PIER 1

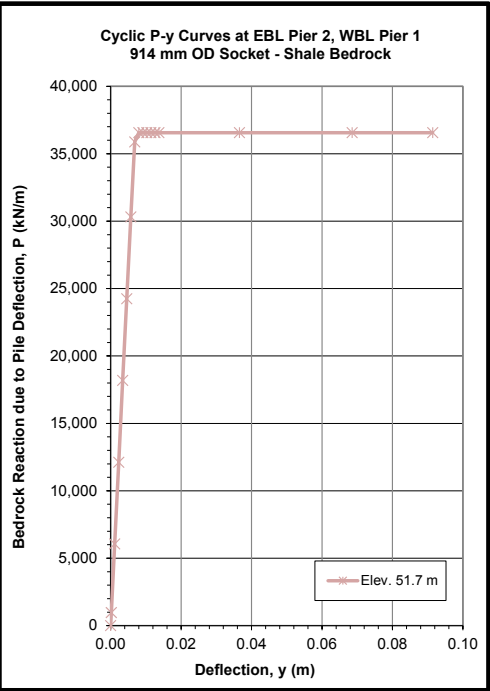
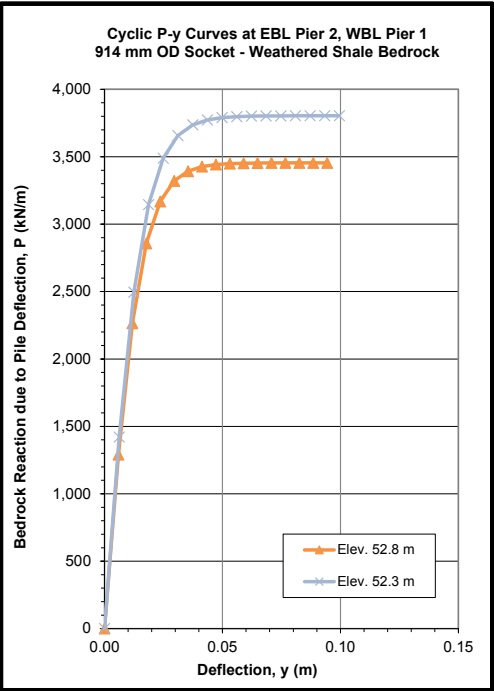
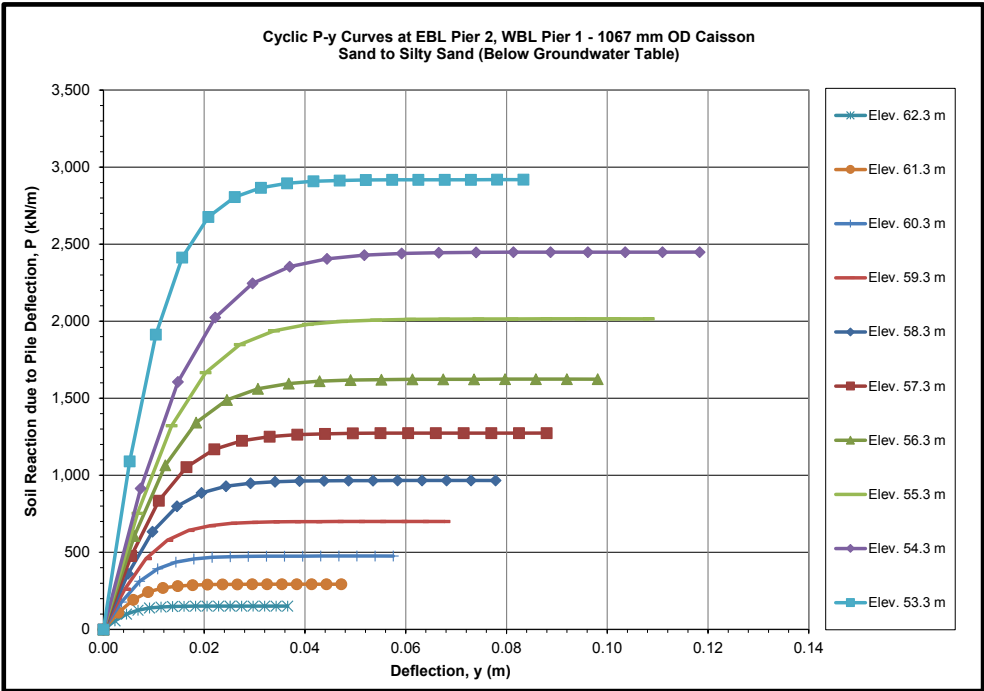
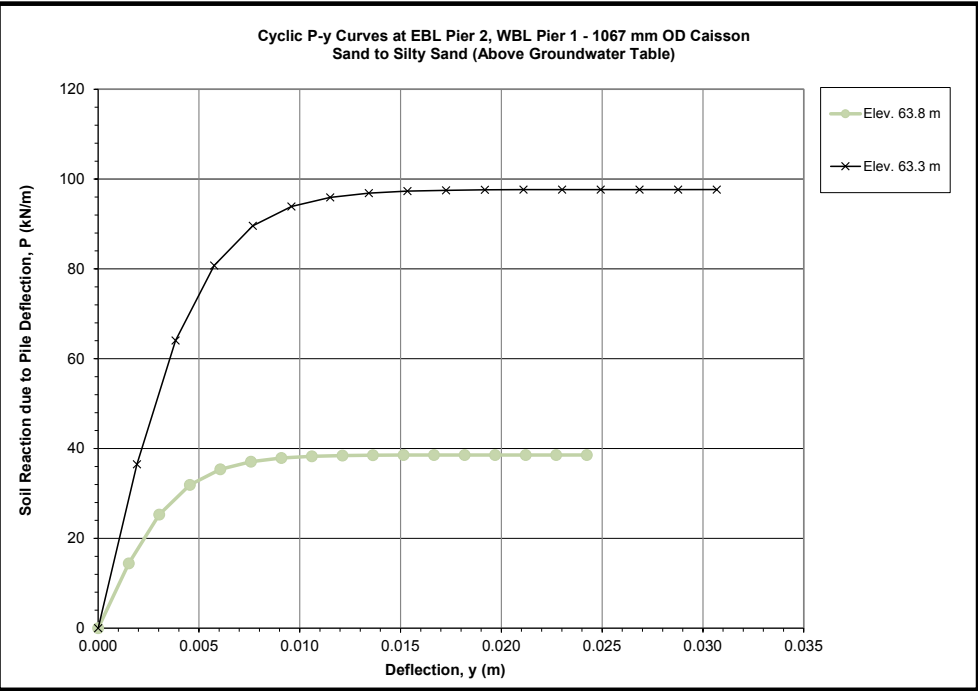
Description		Sand to Silty Sand																								Weathered Shale Bedrock				Shale Bedrock	
Depth (z) * Elevation	z= 5 m		z= 1.0 m		z= 2.0 m		z= 3.0 m		z= 4.0 m		z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m		z= 12.7 m				
	Elev. 63.8 m		Elev. 63.3 m		Elev. 62.3 m		Elev. 61.3 m		Elev. 60.3 m		Elev. 59.3 m		Elev. 58.3 m		Elev. 57.3 m		Elev. 56.3 m		Elev. 55.3 m		Elev. 54.3 m		Elev. 53.3 m		Elev. 52.8 m		Elev. 52.3 m		Elev. 51.7 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)	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	0.000	0.000	0.000	0.000	0.000	
	0.002	14.413	0.002	36.498	0.002	56.537	0.003	109.559	0.004	177.885	0.004	261.723	0.005	361.144	0.005	476.177	0.006	606.837	0.007	753.133	0.007	915.069	0.005	1090.677	0.006	1290.891	0.006	1421.476	0.000	969.920	
	0.003	25.293	0.004	64.052	0.005	99.219	0.006	192.269	0.007	312.177	0.008	459.309	0.010	633.786	0.011	835.662	0.012	1064.963	0.014	1321.703	0.015	1605.891	0.010	1914.072	0.012	2265.437	0.012	2494.605	0.001	6062.000	
	0.005	31.891	0.006	80.759	0.007	125.099	0.009	242.420	0.011	393.605	0.013	579.114	0.015	799.102	0.016	1053.635	0.018	1342.747	0.020	1666.454	0.022	2024.769	0.016	2413.336	0.018	2856.350	0.019	3145.294	0.002	12124.000	
	0.006	35.374	0.008	89.579	0.009	138.761	0.012	268.895	0.014	436.591	0.017	642.360	0.019	886.373	0.022	1168.705	0.025	1489.390	0.027	1848.450	0.030	2245.897	0.021	2676.900	0.024	3168.297	0.025	3488.797	0.003	18186.000	
	0.008	37.079	0.010	93.896	0.011	145.449	0.015	281.855	0.018	457.633	0.021	673.319	0.024	929.093	0.027	1225.032	0.031	1561.173	0.034	1937.539	0.037	2354.141	0.026	2805.917	0.029	3320.997	0.031	3656.944	0.005	24248.000	
	0.009	37.882	0.012	95.931	0.014	148.602	0.018	287.964	0.022	467.552	0.025	687.914	0.029	949.232	0.033	1251.585	0.037	1595.012	0.041	1979.535	0.044	2405.168	0.031	2866.736	0.035	3392.980	0.037	3736.209	0.006	30310.000	
	0.011	38.255	0.013	96.874	0.016	150.061	0.021	290.793	0.025	472.145	0.030	694.671	0.034	958.556	0.038	1263.879	0.043	1610.680	0.047	1998.981	0.052	2428.795	0.036	2894.897	0.041	3426.311	0.044	3772.911	0.007	35874.940	
	0.012	38.425	0.015	97.306	0.018	150.732	0.024	292.092	0.029	474.254	0.034	697.774	0.039	962.838	0.044	1269.525	0.049	1617.875	0.054	2007.910	0.059	2439.643	0.042	2907.828	0.047	3441.615	0.050	3789.764	0.008	36560.000	
	0.014	38.504	0.017	97.504	0.021	151.038	0.027	292.686	0.032	475.219	0.038	699.193	0.044	964.796	0.049	1272.107	0.055	1621.166	0.061	2011.994	0.067	2444.606	0.047	2913.743	0.053	3448.616	0.056	3797.473	0.009	36560.000	
	0.015	38.539	0.019	97.595	0.023	151.178	0.030	292.958	0.036	475.659	0.042	699.842	0.049	965.691	0.055	1273.286	0.061	1622.668	0.068	2013.859	0.074	2446.872	0.052	2916.443	0.059	3451.812	0.062	3800.992	0.010	36560.000	
	0.017	38.556	0.021	97.636	0.025	151.242	0.032	293.081	0.040	475.860	0.047	700.137	0.054	966.099	0.060	1273.824	0.067	1623.354	0.074	2014.710	0.081	2447.906	0.057	2917.676	0.065	3453.271	0.068	3802.598	0.011	36560.000	
	0.018	38.563	0.023	97.655	0.027	151.271	0.035	293.138	0.043	475.952	0.051	700.272	0.058	966.285	0.066	1274.070	0.074	1623.667	0.081	2015.098	0.089	2448.377	0.063	2918.238	0.071	3453.936	0.075	3803.331	0.013	36560.000	
0.020	38.566	0.025	97.663	0.030	151.284	0.038	293.164	0.047	475.994	0.055	700.334	0.063	966.370	0.071	1274.181	0.080	1623.809	0.088	2015.275	0.096	2448.592	0.068	2918.494	0.077	3454.239	0.081	3803.665	0.014	36560.000		
0.021	38.568	0.027	97.667	0.032	151.291	0.041	293.175	0.050	476.013	0.059	700.362	0.068	966.408	0.077	1274.232	0.086	1623.874	0.095	2015.356	0.104	2448.690	0.073	2918.611	0.083	3454.377	0.087	3803.817	0.037	36560.000		
0.023	38.569	0.029	97.669	0.034	151.293	0.044	293.181	0.054	476.021	0.063	700.374	0.073	966.426	0.082	1274.256	0.092	1623.904	0.101	2015.392	0.111	2448.735	0.078	2918.664	0.088	3454.440	0.093	3803.887	0.069	36560.000		
0.024	38.569	0.031	97.670	0.037	151.295	0.047	293.183	0.058	476.025	0.068	700.380	0.078	966.434	0.088	1274.266	0.098	1623.917	0.108	2015.409	0.118	2448.755	0.083	2918.688	0.094	3454.469	0.100	3803.918	0.091	36560.000		

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 caisson (i.e., no inclination) socketed into bedrock, with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 loading cycles are assumed.
3. There are no group effects (i.e., analysis is based on a single caisson).
4. The effects of construction disturbance are not considered.

5. Pier locations and details (including socket geometry) as per DeLeuw, Cather Drawing No. 3-302A-1, 3-302A-3, 3-302B-1, and 3-302B-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of caisson at Elevation 64.3 m.
8. Program: Lpile 2018.10.07



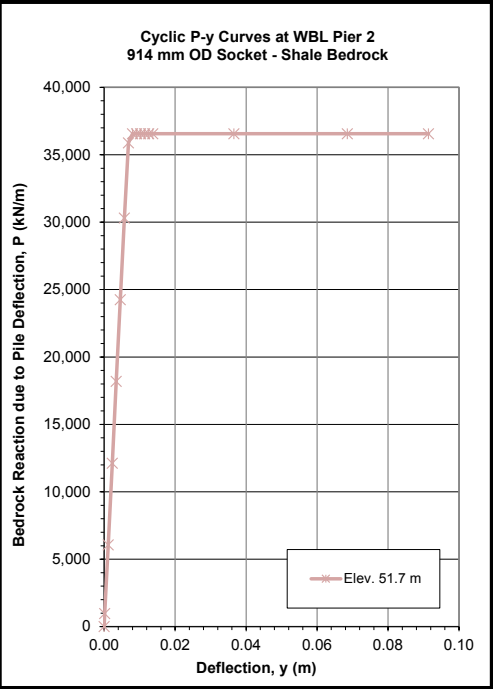
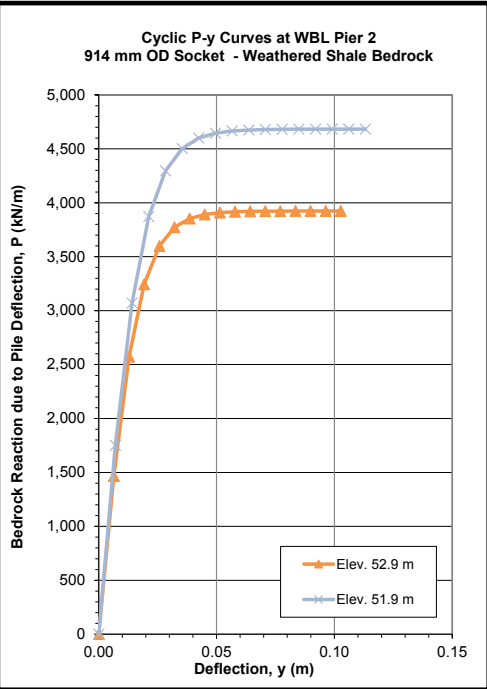
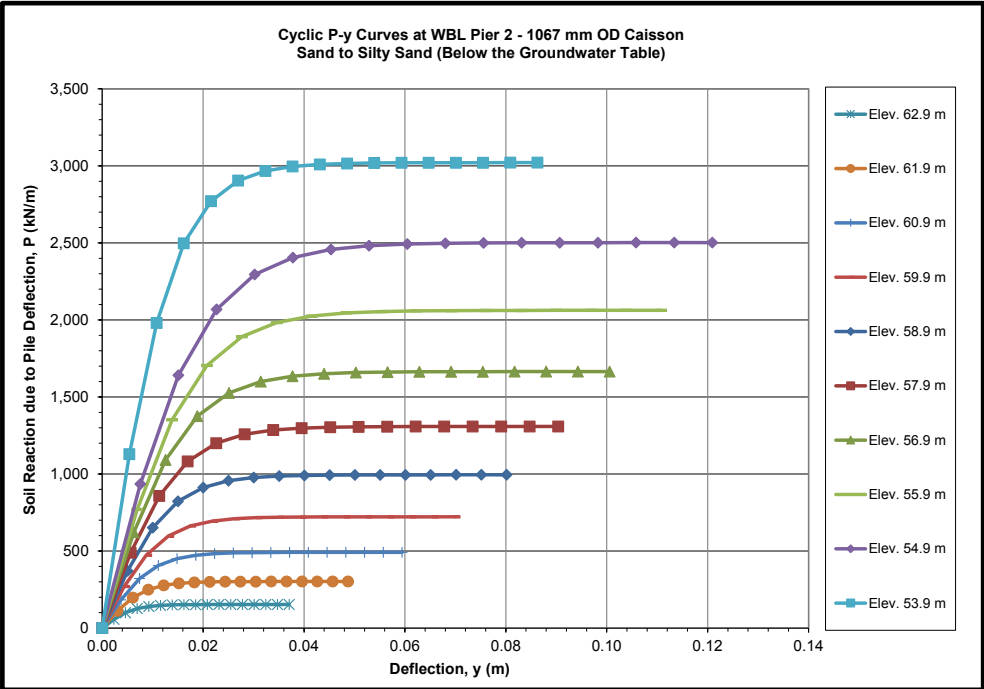
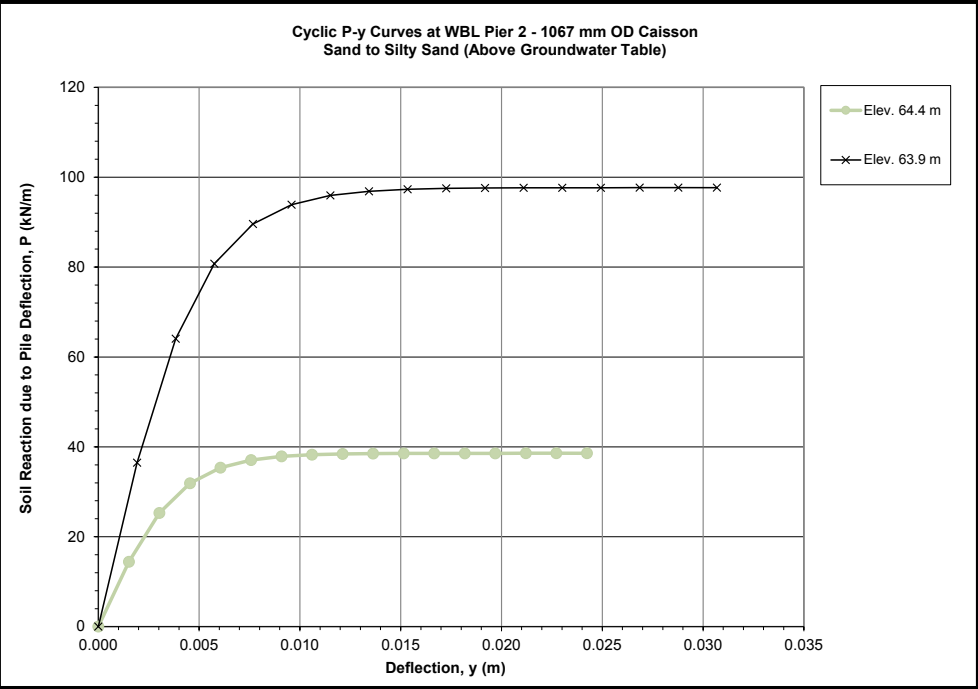
SUMMARY OF CYCLIC P-Y CURVES FOR WBL PIER 2

Description Depth (z) * Elevation P-y Curves	Sand to Silty Sand																								Weathered Shale Bedrock				Shale Bedrock		
	z= .5 m		z= 1.0 m		z= 2.0 m		z= 3.0 m		z= 4.0 m		z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m		z= 13.0 m		z= 13.3 m		
	Elev. 64.4 m		Elev. 63.9 m		Elev. 62.9 m		Elev. 61.9 m		Elev. 60.9 m		Elev. 59.9 m		Elev. 58.9 m		Elev. 57.9 m		Elev. 56.9 m		Elev. 55.9 m		Elev. 54.9 m		Elev. 53.9 m		Elev. 52.9 m		Elev. 51.9 m		Elev. 51.7 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	
0.002	14.413	0.002	36.498	0.002	57.319	0.003	113.022	0.004	183.817	0.004	270.041	0.005	371.806	0.006	489.158	0.006	622.122	0.007	770.712	0.008	934.935	0.005	1128.914	0.006	1466.090	0.007	1749.914	0.000	969.920	0.000	969.920
0.003	25.293	0.004	64.052	0.005	100.592	0.006	198.347	0.007	322.589	0.009	473.906	0.010	652.496	0.011	858.442	0.013	1091.787	0.014	1352.552	0.015	1640.754	0.011	1981.176	0.013	2572.900	0.014	3070.994	0.001	6062.000	0.001	6062.000
0.005	31.891	0.006	80.759	0.007	126.830	0.009	250.083	0.011	406.732	0.013	597.520	0.015	822.693	0.017	1082.357	0.019	1376.567	0.021	1705.350	0.023	2068.726	0.016	2497.943	0.019	3244.011	0.021	3872.028	0.002	12124.000	0.002	12124.000
0.006	35.374	0.008	89.579	0.009	140.681	0.012	277.395	0.015	451.152	0.017	662.776	0.020	912.540	0.023	1200.563	0.025	1526.904	0.028	1891.594	0.030	2294.654	0.022	2770.748	0.026	3598.295	0.028	4294.899	0.003	18186.000	0.003	18186.000
0.008	37.079	0.010	93.896	0.012	147.462	0.015	290.764	0.019	472.896	0.022	694.719	0.025	956.521	0.028	1258.426	0.031	1600.495	0.035	1982.762	0.038	2405.248	0.027	2904.287	0.032	3771.719	0.035	4501.897	0.005	24248.000	0.005	24248.000
0.009	37.882	0.012	95.931	0.014	150.658	0.018	297.067	0.022	483.146	0.026	709.777	0.030	977.254	0.034	1285.703	0.038	1635.186	0.042	2025.739	0.045	2457.383	0.032	2967.239	0.039	3853.473	0.042	4599.477	0.006	30310.000	0.006	30310.000
0.011	38.255	0.013	96.874	0.016	152.138	0.021	299.985	0.026	487.892	0.031	716.750	0.035	986.854	0.040	1298.333	0.044	1651.249	0.048	2045.639	0.053	2481.522	0.038	2996.387	0.045	3891.327	0.050	4644.659	0.007	35874.940	0.007	35874.940
0.012	38.425	0.015	97.306	0.019	152.817	0.024	301.325	0.030	490.071	0.035	719.951	0.040	991.262	0.045	1304.132	0.050	1658.625	0.055	2054.776	0.060	2492.607	0.043	3009.771	0.051	3908.708	0.057	4665.406	0.008	36560.000	0.008	36560.000
0.014	38.504	0.017	97.504	0.021	153.128	0.027	301.938	0.033	491.068	0.039	721.416	0.045	993.278	0.051	1306.785	0.057	1661.999	0.062	2058.956	0.068	2497.677	0.049	3015.893	0.058	3916.659	0.064	4674.895	0.009	36560.000	0.009	36560.000
0.015	38.539	0.019	97.595	0.023	153.270	0.030	302.218	0.037	491.523	0.044	722.084	0.050	994.199	0.056	1307.996	0.063	1663.539	0.069	2060.864	0.076	2499.992	0.054	3018.688	0.064	3920.289	0.071	4679.228	0.010	36560.000	0.010	36560.000
0.017	38.556	0.021	97.636	0.025	153.335	0.034	302.345	0.041	491.731	0.048	722.389	0.055	994.619	0.062	1308.549	0.069	1664.242	0.076	2061.735	0.083	2501.048	0.059	3019.964	0.071	3921.945	0.078	4681.205	0.011	36560.000	0.011	36560.000
0.018	38.563	0.023	97.655	0.028	153.365	0.037	302.404	0.045	491.826	0.052	722.528	0.060	994.811	0.068	1308.801	0.075	1664.563	0.083	2062.132	0.091	2501.530	0.065	3020.546	0.077	3922.701	0.085	4682.107	0.013	36560.000	0.013	36560.000
0.020	38.566	0.025	97.663	0.030	153.378	0.040	302.430	0.048	491.869	0.057	722.592	0.065	994.898	0.073	1308.916	0.082	1664.709	0.090	2062.313	0.098	2501.750	0.070	3020.811	0.083	3923.045	0.092	4682.518	0.014	36560.000	0.014	36560.000
0.021	38.568	0.027	97.667	0.032	153.384	0.043	302.442	0.052	491.889	0.061	722.621	0.070	994.938	0.079	1308.968	0.088	1664.775	0.097	2062.395	0.106	2501.850	0.075	3020.932	0.090	3923.202	0.099	4682.706	0.037	36560.000	0.037	36560.000
0.023	38.569	0.029	97.669	0.035	153.387	0.046	302.448	0.056	491.898	0.065	722.634	0.075	994.956	0.085	1308.992	0.094	1664.806	0.104	2062.433	0.113	2501.895	0.081	3020.987	0.096	3923.274	0.106	4682.791	0.069	36560.000	0.069	36560.000
0.024	38.569	0.031	97.670	0.037	153.388	0.049	302.450	0.059	491.902	0.070	722.640	0.080	994.964	0.090	1309.003	0.101	1664.820	0.111	2062.450	0.121	2501.916	0.086	3021.012	0.103	3923.307	0.113	4682.830	0.091	36560.000	0.091	36560.000

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

- Cyclic p-y curves have been generated for a vertical caisson (i.e., no inclination) socketed into bedrock, with a ground slope angle of zero.
- Cyclic loading condition is considered and 500 loading cycles are assumed.
- There are no group effects (i.e., analysis is based on a single caisson).
- The effects of construction disturbance are not considered.

- Pier location and details (including socket geometry) as per DeLeuw, Cather Drawing No. 3-302B-1 and 3-302B-3, dated February 1973.
- Groundwater table at Elevation 63.0 m.
- Top of caisson at Elevation 64.9 m.
- Program: Lpile 2018.10.07



SUMMARY OF CYCLIC P-Y CURVES FOR EBL PIER 3

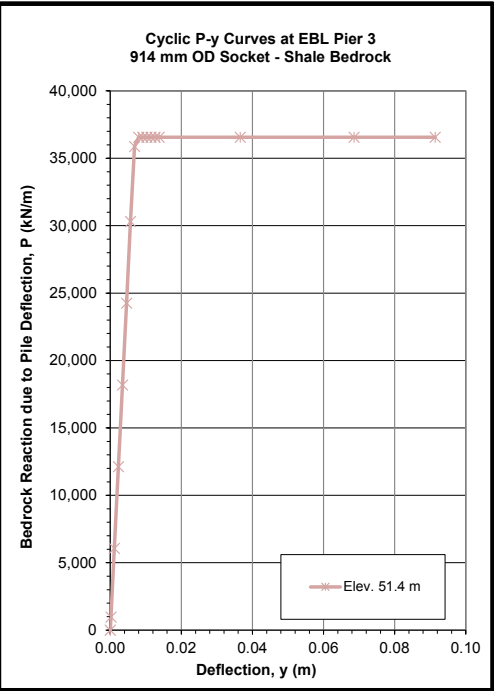
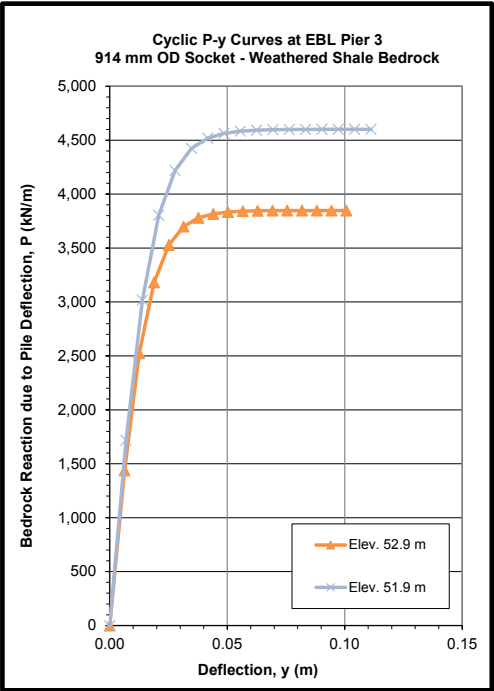
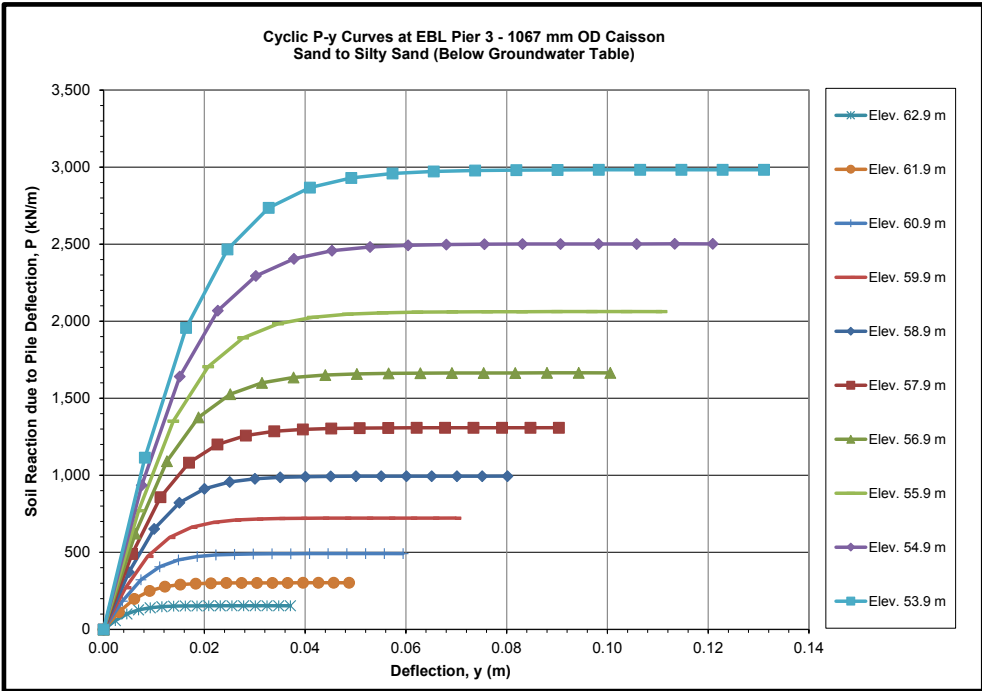
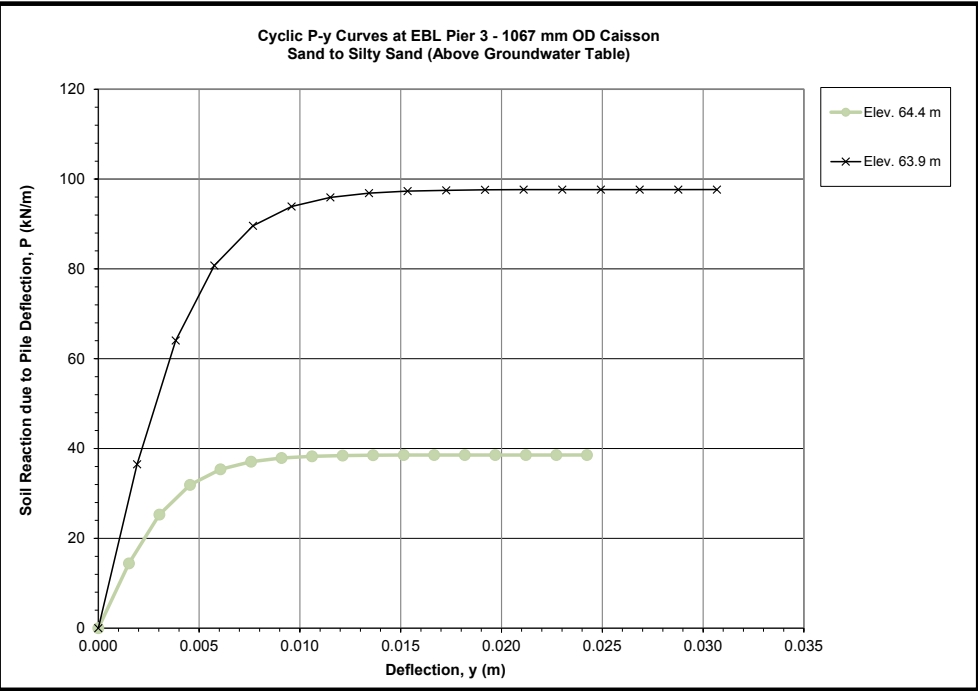
Description Depth (z) * Elevation P-y Curves	Sand to Silty Sand																								Weathered Shale Bedrock				Shale Bedrock		
	z= .5 m		z= 1.0 m		z= 2.0 m		z= 3.0 m		z= 4.0 m		z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m		z= 13.0 m		z= 13.6 m		
	Elev. 64.4 m		Elev. 63.9 m		Elev. 62.9 m		Elev. 61.9 m		Elev. 60.9 m		Elev. 59.9 m		Elev. 58.9 m		Elev. 57.9 m		Elev. 56.9 m		Elev. 55.9 m		Elev. 54.9 m		Elev. 53.9 m		Elev. 52.9 m		Elev. 51.9 m		Elev. 51.4 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	
0.002	14.413	0.002	36.498	0.002	57.319	0.003	113.022	0.004	183.817	0.004	270.041	0.005	371.806	0.006	489.158	0.006	622.122	0.007	770.712	0.008	934.935	0.008	1114.796	0.006	1437.983	0.007	1719.208	0.000	969.920		
0.003	25.293	0.004	64.052	0.005	100.592	0.006	198.347	0.007	322.589	0.009	473.906	0.010	652.496	0.011	858.442	0.013	1091.787	0.014	1352.552	0.015	1640.754	0.016	1956.399	0.013	2523.574	0.014	3017.106	0.001	6062.000		
0.005	31.891	0.006	80.759	0.007	126.830	0.009	250.083	0.011	406.732	0.013	597.520	0.015	822.693	0.017	1082.357	0.019	1376.567	0.021	1705.350	0.023	2068.726	0.025	2466.704	0.019	3181.820	0.021	3804.084	0.002	12184.000		
0.006	35.374	0.008	89.579	0.009	140.681	0.012	277.395	0.015	451.152	0.017	662.776	0.020	912.540	0.023	1200.563	0.025	1526.904	0.028	1891.594	0.030	2294.654	0.033	2736.097	0.025	3529.311	0.028	4219.534	0.003	18126.000		
0.008	37.079	0.010	93.896	0.012	147.462	0.015	290.764	0.019	472.896	0.022	694.719	0.025	956.521	0.028	1258.426	0.031	1600.495	0.035	1982.762	0.038	2405.248	0.041	2867.966	0.031	3699.411	0.035	4422.899	0.005	24248.000		
0.009	37.882	0.012	95.931	0.014	150.658	0.018	297.067	0.022	483.146	0.026	709.777	0.030	977.254	0.034	1285.703	0.038	1635.186	0.042	2025.739	0.045	2457.383	0.049	2930.130	0.038	3779.597	0.042	4518.767	0.006	30310.000		
0.011	38.255	0.013	96.874	0.016	152.138	0.021	299.985	0.026	487.892	0.031	716.750	0.035	986.854	0.040	1298.333	0.044	1651.249	0.048	2045.639	0.053	2481.522	0.057	2958.914	0.044	3816.725	0.049	4563.156	0.007	35874.940		
0.012	38.425	0.015	97.306	0.019	152.817	0.024	301.325	0.030	490.071	0.035	719.951	0.040	991.262	0.045	1304.132	0.050	1658.625	0.055	2054.776	0.060	2492.607	0.066	2972.131	0.050	3833.774	0.056	4583.539	0.008	36560.000		
0.014	38.504	0.017	97.504	0.021	153.128	0.027	301.938	0.033	491.068	0.039	721.416	0.045	993.278	0.051	1306.785	0.057	1661.999	0.062	2058.956	0.068	2497.677	0.074	2978.176	0.057	3841.572	0.063	4592.862	0.009	36560.000		
0.015	38.539	0.019	97.595	0.023	153.270	0.030	302.218	0.037	491.523	0.044	722.084	0.050	994.199	0.056	1307.996	0.063	1663.539	0.069	2060.864	0.076	2499.992	0.082	2980.937	0.063	3845.132	0.069	4597.119	0.010	36560.000		
0.017	38.556	0.021	97.636	0.025	153.335	0.034	302.345	0.041	491.731	0.048	722.389	0.055	994.619	0.062	1308.549	0.069	1664.242	0.076	2061.735	0.083	2501.048	0.090	2982.196	0.069	3846.757	0.076	4599.062	0.011	36560.000		
0.018	38.563	0.023	97.655	0.028	153.365	0.037	302.404	0.045	491.826	0.052	722.528	0.060	994.811	0.068	1308.801	0.075	1664.563	0.083	2062.132	0.091	2501.530	0.098	2982.771	0.076	3847.498	0.083	4599.947	0.013	36560.000		
0.020	38.566	0.025	97.663	0.030	153.378	0.040	302.430	0.048	491.869	0.057	722.592	0.065	994.898	0.073	1308.916	0.082	1664.709	0.090	2062.313	0.098	2501.750	0.107	2983.032	0.082	3847.836	0.090	4600.351	0.014	36560.000		
0.021	38.568	0.027	97.667	0.032	153.384	0.043	302.442	0.052	491.889	0.061	722.621	0.070	994.938	0.079	1308.968	0.088	1664.775	0.097	2062.395	0.106	2501.850	0.115	2983.152	0.088	3847.990	0.097	4600.536	0.037	36560.000		
0.023	38.569	0.029	97.669	0.035	153.387	0.046	302.448	0.056	491.898	0.065	722.634	0.075	994.956	0.085	1308.992	0.094	1664.806	0.104	2062.433	0.113	2501.895	0.123	2983.206	0.094	3848.060	0.104	4600.620	0.069	36560.000		
0.024	38.569	0.031	97.670	0.037	153.388	0.049	302.450	0.059	491.902	0.070	722.640	0.080	994.964	0.090	1309.003	0.101	1664.820	0.111	2062.450	0.121	2501.916	0.131	2983.231	0.101	3848.092	0.111	4600.658	0.091	36560.000		

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 caisson (i.e., no inclination) socketed into bedrock, with a ground slope angle of zero.
2. Cyclic loading condition is considered and 500 loading cycles are assumed.
3. There are no group effects (i.e., analysis is based on a single caisson).
4. The effects of construction disturbance are not considered.

5. Pier location and details (including socket geometry) as per DeLeuw, Cather Drawing No. 3-302A-1 and 3-302A-3, dated February 1973.
6. Groundwater table at Elevation 63.0 m.
7. Top of caisson at Elevation 64.9 m.
8. Program: Lpile 2018.10.07



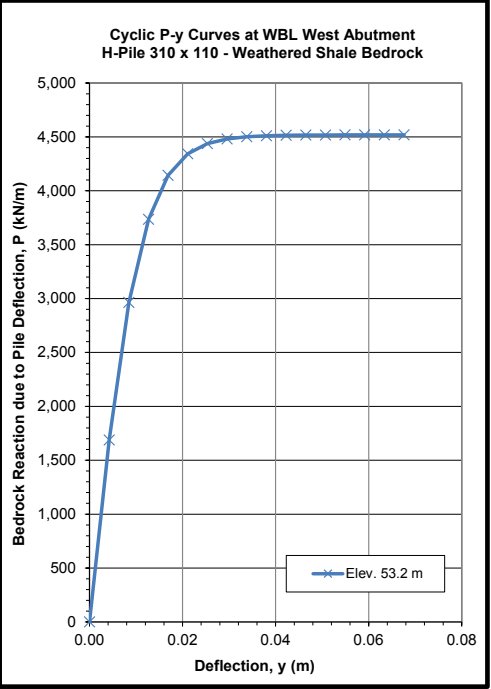
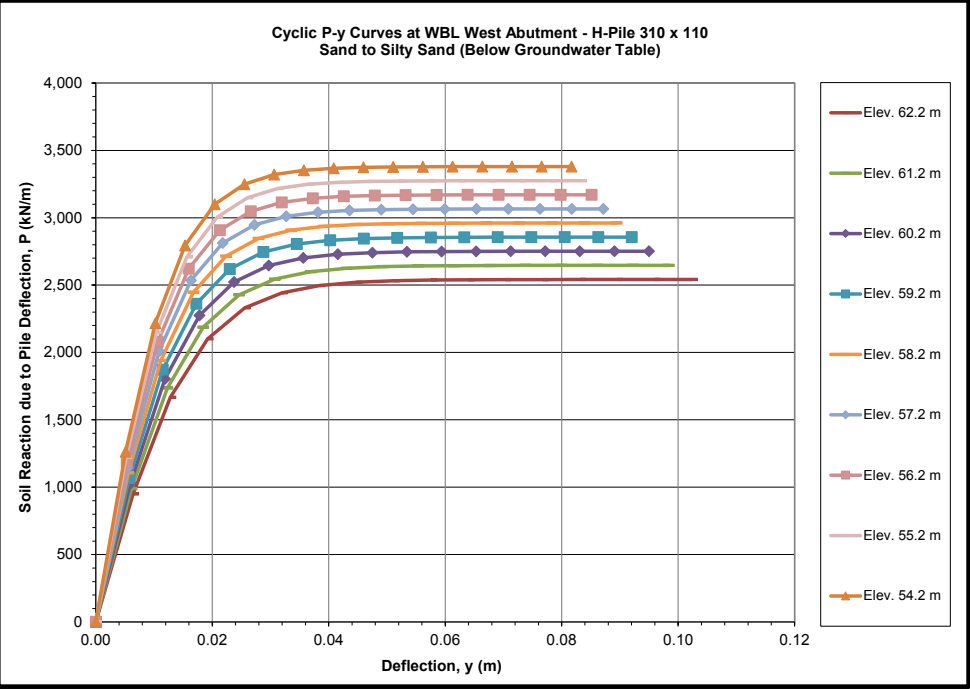
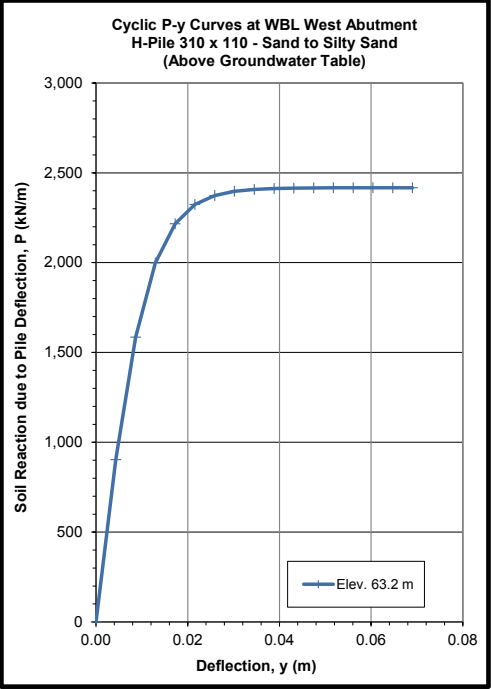
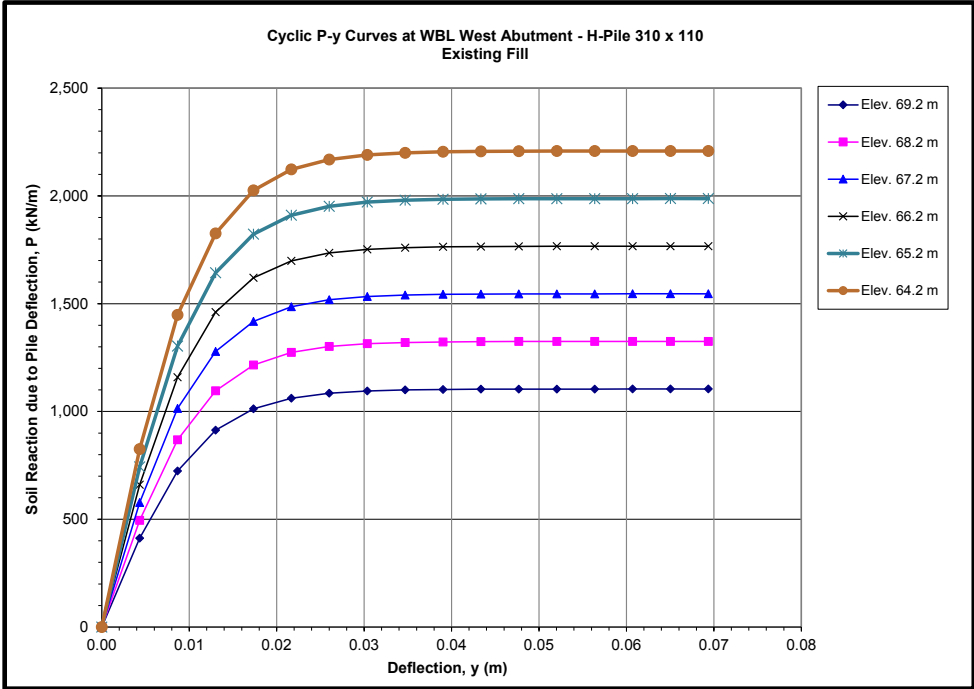
SUMMARY OF CYCLIC P-Y CURVES FOR H-PILE 310x110 - WBL WEST ABUTMENT

Description Depth (z) * Elevation P-y Curves	Existing Fill												Sand to Silty Sand																Withrd. Bedrock					
	z= 5.0 m		z= 6.0 m		z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m		z= 13.0 m		z= 14.0 m		z= 15.0 m		z= 16.0 m		z= 17.0 m		z= 18.0 m		z= 19.0 m		z= 20.0 m		z= 21.0 m	
	Elev. 69.2 m		Elev. 68.2 m		Elev. 67.2 m		Elev. 66.2 m		Elev. 65.2 m		Elev. 64.2 m		Elev. 63.2 m		Elev. 62.2 m		Elev. 61.2 m		Elev. 60.2 m		Elev. 59.2 m		Elev. 58.2 m		Elev. 57.2 m		Elev. 56.2 m		Elev. 55.2 m		Elev. 54.2 m		Elev. 53.2 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.004	412.602	0.004	495.122	0.004	577.642	0.004	660.163	0.004	742.683	0.004	825.203	0.004	903.118	0.006	949.790	0.006	988.939	0.006	1028.088	0.006	1067.238	0.006	1106.387	0.005	1145.536	0.005	1184.685	0.005	1223.834	0.005	1262.983	0.004	1688.513	
0.009	724.091	0.009	868.909	0.009	1013.728	0.009	1158.546	0.009	1303.364	0.009	1448.182	0.009	1584.918	0.013	1666.824	0.012	1735.529	0.012	1804.233	0.012	1872.937	0.011	1941.642	0.011	2010.346	0.011	2079.051	0.010	2147.755	0.010	2216.460	0.008	2963.239	
0.013	912.962	0.013	1095.555	0.013	1278.147	0.013	1460.739	0.013	1643.332	0.013	1825.924	0.013	1998.325	0.019	2101.596	0.018	2188.221	0.018	2274.847	0.017	2361.472	0.017	2448.097	0.016	2534.722	0.016	2621.348	0.016	2707.973	0.015	2794.598	0.013	3736.166	
0.017	1012.668	0.017	1215.202	0.017	1417.735	0.017	1620.269	0.017	1822.803	0.017	2025.336	0.017	2216.566	0.026	2331.115	0.025	2427.201	0.024	2523.286	0.023	2619.372	0.022	2715.458	0.022	2811.543	0.021	2907.629	0.021	3003.715	0.020	3099.801	0.017	4144.198	
0.022	1061.475	0.022	1273.770	0.022	1486.065	0.022	1698.360	0.022	1910.655	0.022	2122.950	0.022	2323.396	0.032	2443.466	0.031	2544.183	0.030	2644.899	0.029	2745.616	0.028	2846.333	0.027	2947.049	0.027	3047.766	0.026	3148.483	0.026	3249.199	0.021	4343.933	
0.026	1084.483	0.026	1301.379	0.026	1518.276	0.026	1735.172	0.026	1952.069	0.026	2168.965	0.026	2373.756	0.038	2496.429	0.037	2599.329	0.036	2702.228	0.035	2805.128	0.034	2908.028	0.033	3010.928	0.032	3113.827	0.031	3216.727	0.031	3319.627	0.025	4438.089	
0.030	1095.136	0.030	1314.163	0.030	1533.190	0.030	1752.218	0.030	1971.245	0.030	2190.272	0.030	2397.074	0.045	2520.952	0.043	2624.863	0.042	2728.773	0.040	2832.684	0.039	2936.594	0.038	3040.505	0.037	3144.415	0.036	3248.326	0.036	3352.237	0.030	4481.686	
0.035	1100.028	0.035	1320.033	0.035	1540.039	0.035	1760.044	0.035	1980.050	0.035	2200.055	0.035	2407.781	0.051	2532.212	0.049	2636.587	0.047	2740.962	0.046	2845.337	0.045	2949.711	0.044	3054.086	0.043	3158.461	0.042	3262.835	0.041	3367.210	0.034	4501.705	
0.039	1102.265	0.039	1322.718	0.039	1543.171	0.039	1763.624	0.039	1984.077	0.039	2204.530	0.039	2412.679	0.058	2537.363	0.055	2641.950	0.053	2746.537	0.052	2851.124	0.050	2955.711	0.049	3060.298	0.048	3164.885	0.047	3269.472	0.046	3374.059	0.038	4510.861	
0.043	1103.287	0.043	1323.944	0.043	1544.602	0.043	1765.259	0.043	1985.916	0.043	2206.574	0.043	2414.915	0.064	2539.715	0.061	2644.399	0.059	2749.083	0.058	2853.767	0.056	2958.451	0.054	3063.135	0.053	3167.819	0.052	3272.503	0.051	3377.187	0.042	4515.043	
0.048	1103.753	0.048	1324.504	0.048	1545.254	0.048	1766.005	0.048	1986.755	0.048	2207.506	0.047	2415.936	0.070	2540.788	0.068	2645.516	0.065	2750.244	0.063	2854.973	0.061	2959.701	0.060	3064.429	0.059	3169.157	0.057	3273.885	0.056	3378.614	0.046	4516.950	
0.052	1103.966	0.052	1324.759	0.052	1545.552	0.052	1766.345	0.052	1987.138	0.052	2207.931	0.052	2416.401	0.077	2541.277	0.074	2646.026	0.071	2750.774	0.069	2855.523	0.067	2960.271	0.065	3065.019	0.064	3169.768	0.062	3274.516	0.061	3379.264	0.051	4517.820	
0.056	1104.063	0.056	1324.875	0.056	1545.688	0.056	1766.500	0.056	1987.313	0.056	2208.125	0.056	2416.613	0.083	2541.501	0.080	2646.258	0.077	2751.016	0.075	2855.773	0.073	2960.531	0.071	3065.288	0.069	3170.046	0.068	3274.804	0.066	3379.561	0.055	4518.217	
0.061	1104.107	0.061	1324.928	0.061	1545.749	0.061	1766.571	0.061	1987.392	0.061	2208.214	0.060	2416.710	0.090	2541.602	0.086	2646.364	0.083	2751.126	0.081	2855.888	0.078	2960.649	0.076	3065.411	0.074	3170.173	0.073	3274.935	0.071	3379.696	0.059	4518.398	
0.065	1104.127	0.065	1324.952	0.065	1545.778	0.065	1766.603	0.065	1987.428	0.065	2208.254	0.065	2416.754	0.096	2541.649	0.092	2646.412	0.089	2751.176	0.086	2855.940	0.084	2960.703	0.082	3065.467	0.080	3170.231	0.078	3274.994	0.077	3379.758	0.063	4518.480	
0.069	1104.136	0.069	1324.963	0.069	1545.791	0.069	1766.618	0.069	1987.445	0.069	2208.272	0.069	2416.774	0.102	2541.670	0.098	2646.435	0.095	2751.199	0.092	2855.964	0.089	2960.728	0.087	3065.493	0.085	3170.257	0.083	3275.022	0.082	3379.786	0.068	4518.518	

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

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

- Abutment locations and details as per DeLeuw, Cather Drawing No. 3-302B-1 and 3-302B-3, dated February 1973.
- Groundwater table at Elevation 63.0 m.
- Top of pile at Elevation 69.5 m.
- Piles driven 1 m depth into weathered shale bedrock.
- Program: Lpile 2018.10.07



CYCLIC P-Y CURVES

CPR Overhead
H-Pile 310x110 - WBL East Abutment

Figure F16

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

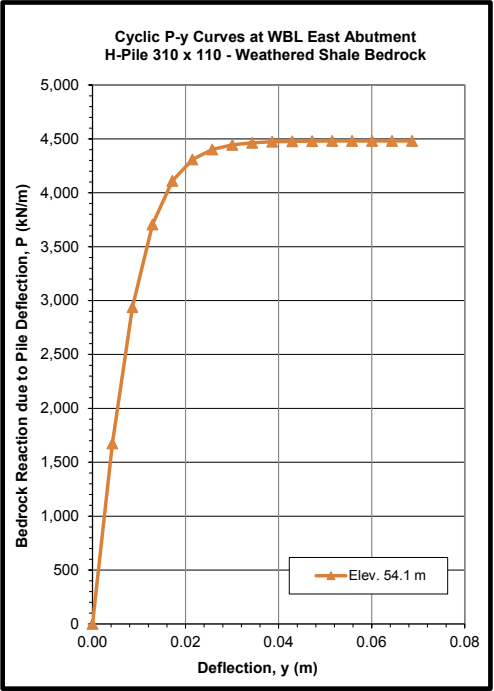
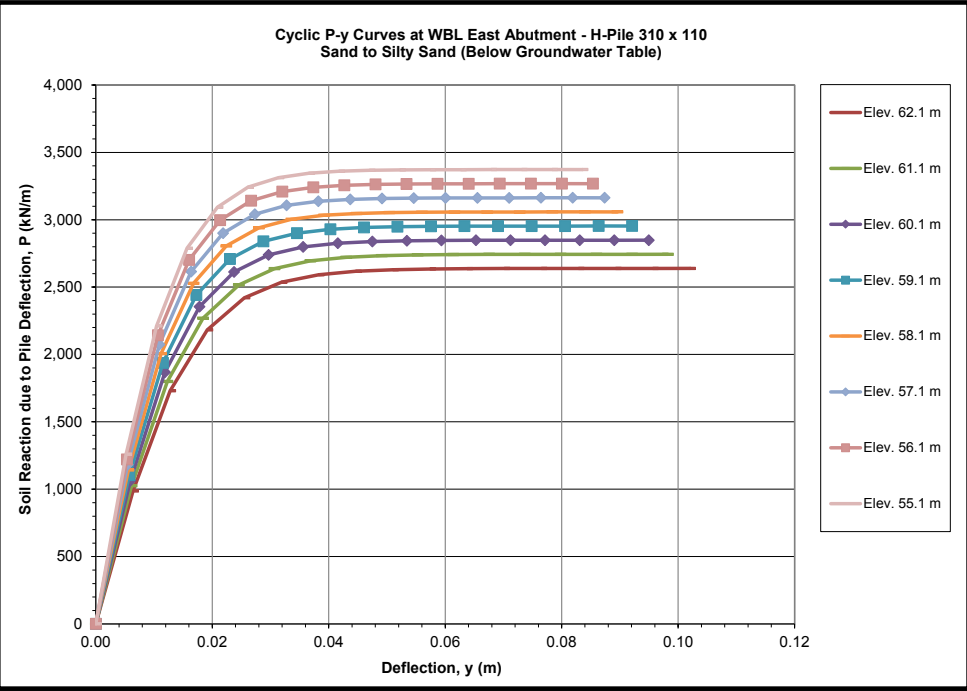
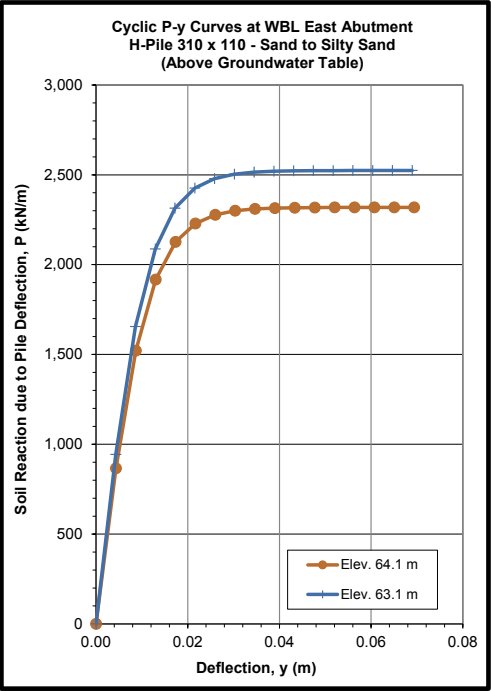
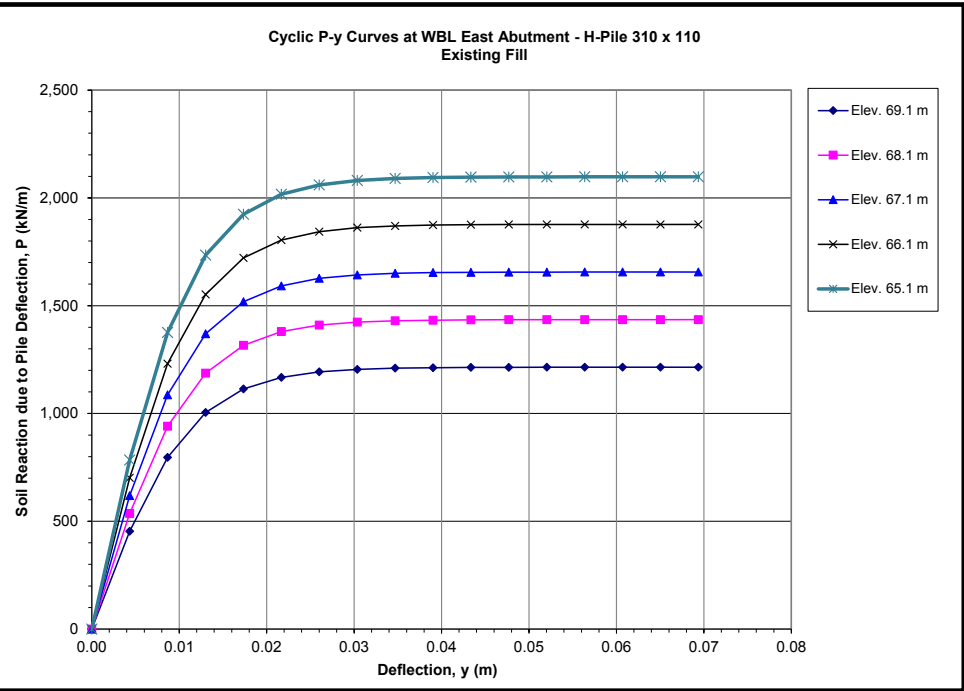
Description Depth (z) * Elevation P-y Curves	Existing Fill										Sand to Silty Sand																Wthrd. Bedrock						
	z= 5.5 m		z= 6.5 m		z= 7.5 m		z= 8.5 m		z= 9.5 m		z= 10.5 m		z= 11.5 m		z= 12.5 m		z= 13.5 m		z= 14.5 m		z= 15.5 m		z= 16.5 m		z= 17.5 m		z= 18.5 m		z= 19.5 m		z= 20.5 m		
	Elev. 69.1 m		Elev. 68.1 m		Elev. 67.1 m		Elev. 66.1 m		Elev. 65.1 m		Elev. 64.1 m		Elev. 63.1 m		Elev. 62.1 m		Elev. 61.1 m		Elev. 60.1 m		Elev. 59.1 m		Elev. 58.1 m		Elev. 57.1 m		Elev. 56.1 m		Elev. 55.1 m		Elev. 54.1 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)	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.004	453.862	0.004	536.382	0.004	618.903	0.004	701.423	0.004	783.943	0.004	866.464	0.004	943.227	0.006	986.137	0.006	1025.286	0.006	1064.436	0.006	1103.585	0.006	1142.734	0.005	1181.883	0.005	1221.032	0.005	1260.182	0.004	1674.543	0.004	1674.543
0.009	796.500	0.009	941.318	0.009	1086.137	0.009	1230.955	0.009	1375.773	0.009	1520.591	0.009	1655.306	0.013	1730.611	0.012	1799.316	0.012	1868.020	0.012	1936.725	0.011	2005.429	0.011	2074.134	0.011	2142.838	0.010	2211.543	0.009	2938.722	0.009	2938.722
0.013	1004.258	0.013	1186.851	0.013	1369.443	0.013	1552.036	0.013	1734.628	0.013	1917.220	0.013	2087.074	0.019	2182.022	0.018	2268.647	0.018	2355.272	0.017	2441.898	0.017	2528.523	0.016	2615.148	0.016	2701.773	0.016	2788.398	0.013	3705.255	0.013	3705.255
0.017	1113.935	0.017	1316.469	0.017	1519.002	0.017	1721.536	0.017	1924.069	0.017	2126.603	0.017	2315.006	0.026	2420.324	0.025	2516.410	0.024	2612.495	0.023	2708.581	0.022	2804.667	0.022	2900.752	0.021	2996.838	0.021	3092.924	0.017	4109.912	0.017	4109.912
0.022	1167.622	0.022	1379.917	0.022	1592.212	0.022	1804.507	0.022	2016.802	0.022	2229.097	0.022	2426.581	0.032	2536.974	0.031	2637.691	0.030	2738.408	0.029	2839.124	0.028	2939.841	0.027	3040.558	0.027	3141.274	0.026	3241.991	0.021	4307.994	0.021	4307.994
0.026	1192.931	0.026	1409.828	0.026	1626.724	0.026	1843.621	0.026	2060.517	0.026	2277.414	0.026	2479.178	0.038	2591.964	0.037	2694.864	0.036	2797.764	0.035	2900.663	0.034	3003.563	0.033	3106.463	0.032	3209.363	0.031	3312.262	0.026	4401.371	0.026	4401.371
0.030	1204.650	0.030	1423.677	0.030	1642.704	0.030	1861.731	0.030	2080.758	0.030	2299.785	0.030	2503.532	0.045	2617.426	0.043	2721.336	0.042	2825.247	0.040	2929.158	0.039	3033.068	0.038	3136.979	0.037	3240.889	0.037	3344.800	0.030	4444.607	0.030	4444.607
0.035	1210.030	0.035	1430.036	0.035	1650.041	0.035	1870.047	0.035	2090.053	0.035	2310.058	0.034	2514.714	0.051	2629.117	0.049	2733.492	0.047	2837.867	0.046	2942.241	0.045	3046.616	0.044	3150.991	0.043	3255.366	0.042	3359.740	0.034	4464.460	0.034	4464.460
0.039	1212.492	0.039	1432.945	0.039	1653.398	0.039	1873.851	0.039	2094.304	0.039	2314.757	0.039	2519.829	0.057	2634.465	0.055	2739.052	0.053	2843.639	0.052	2948.226	0.050	3052.813	0.049	3157.400	0.048	3261.987	0.047	3366.574	0.039	4473.541	0.039	4473.541
0.043	1213.616	0.043	1434.273	0.043	1654.930	0.043	1875.588	0.043	2096.245	0.043	2316.902	0.043	2522.165	0.064	2636.907	0.061	2741.591	0.059	2846.275	0.058	2950.959	0.056	3055.643	0.055	3160.327	0.053	3265.011	0.052	3369.695	0.043	4477.688	0.043	4477.688
0.048	1214.128	0.048	1434.879	0.048	1655.630	0.048	1876.380	0.048	2097.131	0.048	2317.881	0.047	2523.231	0.070	2638.021	0.068	2742.749	0.065	2847.477	0.063	2952.206	0.062	3056.934	0.060	3161.662	0.059	3266.390	0.057	3371.118	0.047	4479.580	0.047	4479.580
0.052	1214.362	0.052	1435.155	0.052	1655.948	0.052	1876.742	0.052	2097.535	0.052	2318.328	0.052	2523.717	0.077	2638.529	0.074	2743.278	0.071	2848.026	0.069	2952.774	0.067	3057.523	0.066	3162.271	0.064	3267.019	0.063	3371.768	0.052	4480.442	0.052	4480.442
0.056	1214.469	0.056	1435.281	0.056	1656.094	0.056	1876.906	0.056	2097.719	0.056	2318.531	0.056	2523.938	0.083	2638.761	0.080	2743.518	0.077	2848.276	0.075	2953.034	0.073	3057.791	0.071	3162.549	0.069	3267.306	0.068	3372.064	0.056	4480.836	0.056	4480.836
0.061	1214.517	0.061	1435.339	0.061	1656.160	0.061	1876.982	0.061	2097.803	0.061	2318.624	0.060	2524.039	0.089	2638.867	0.086	2743.628	0.083	2848.390	0.081	2953.152	0.078	3057.914	0.076	3162.675	0.075	3267.437	0.073	3372.199	0.060	4481.015	0.060	4481.015
0.065	1214.540	0.065	1435.365	0.065	1656.190	0.065	1877.016	0.065	2097.841	0.065	2318.667	0.065	2524.085	0.096	2638.915	0.092	2743.678	0.089	2848.442	0.086	2953.206	0.084	3057.969	0.082	3162.733	0.080	3267.497	0.078	3372.260	0.064	4481.097	0.064	4481.097
0.069	1214.550	0.069	1435.377	0.069	1656.204	0.069	1877.031	0.069	2097.859	0.069	2318.686	0.069	2524.106	0.102	2638.937	0.098	2743.701	0.095	2848.466	0.092	2953.230	0.090	3057.995	0.087	3162.759	0.085	3267.524	0.084	3372.288	0.069	4481.134	0.069	4481.134

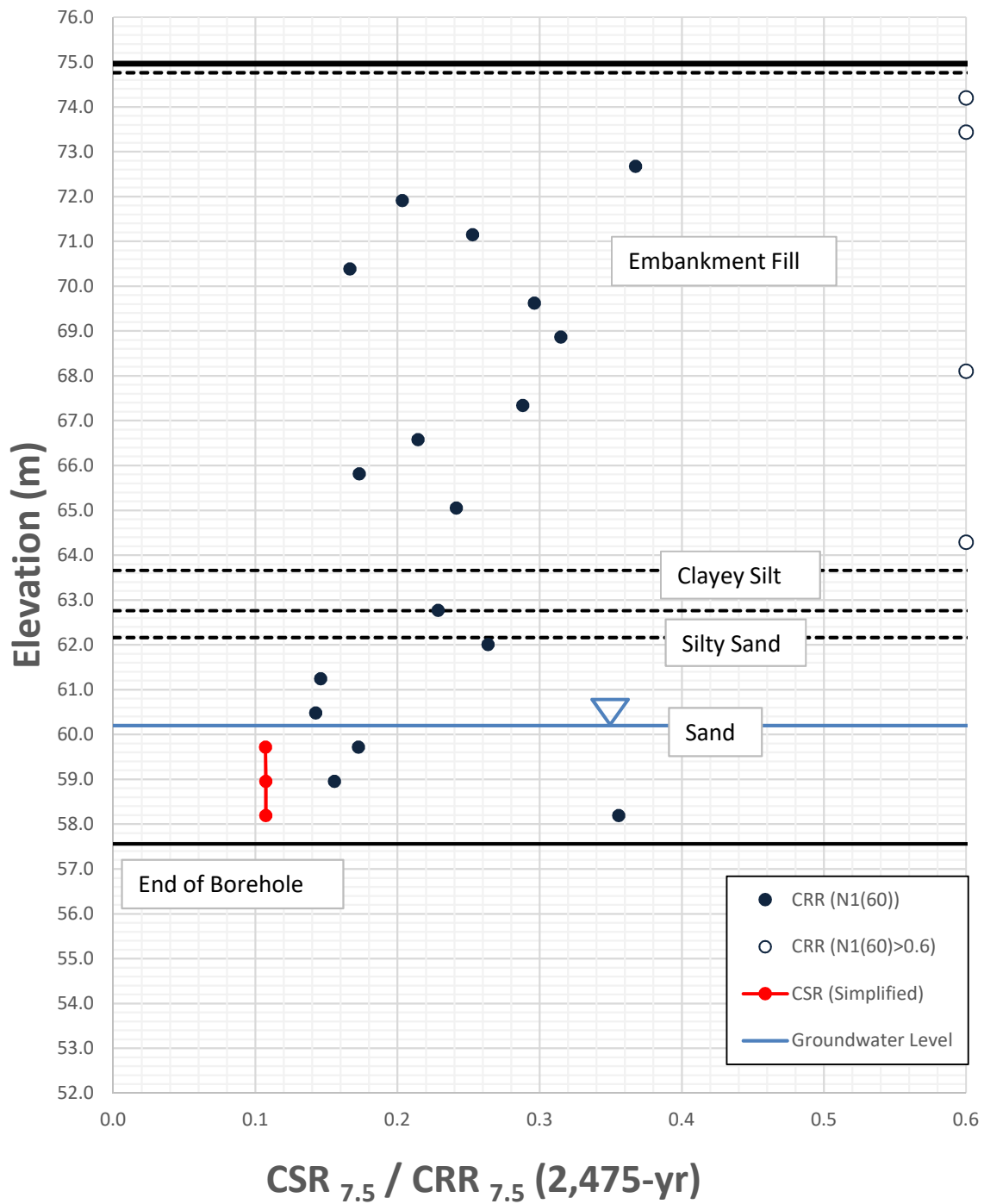
NOTES: * Depth (z) is measured to be positive below the existing ground surface.

Please note the following assumptions:

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

- Abutment locations and details as per DeLeuw, Cather Drawing No. 3-302B-1 and 3-302B-3, dated February 1973.
- Groundwater table at Elevation 63.0 m.
- Top of pile at Elevation 69.5 m.
- Piles driven 1 m depth into weathered shale bedrock.
- Program: Lpile 2018.10.07

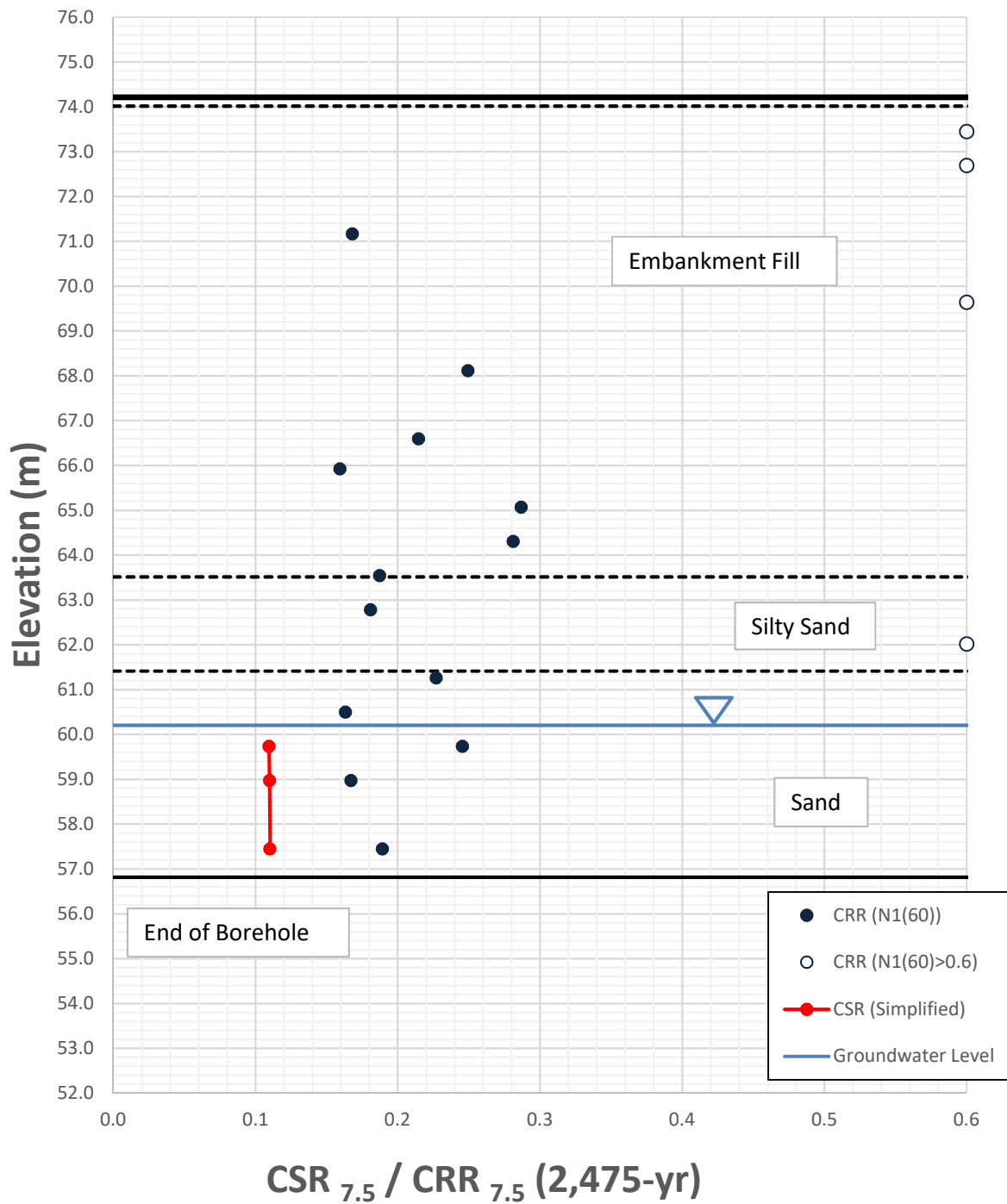




Results of Liquefaction Analysis
BH 18-2101
CPR Overhead
Ottawa, Ontario

Project No. 1662565 / 1210
 Drawn: WAM
 Date: 2019/03/08
 Checked: MJK
 Review: MSS

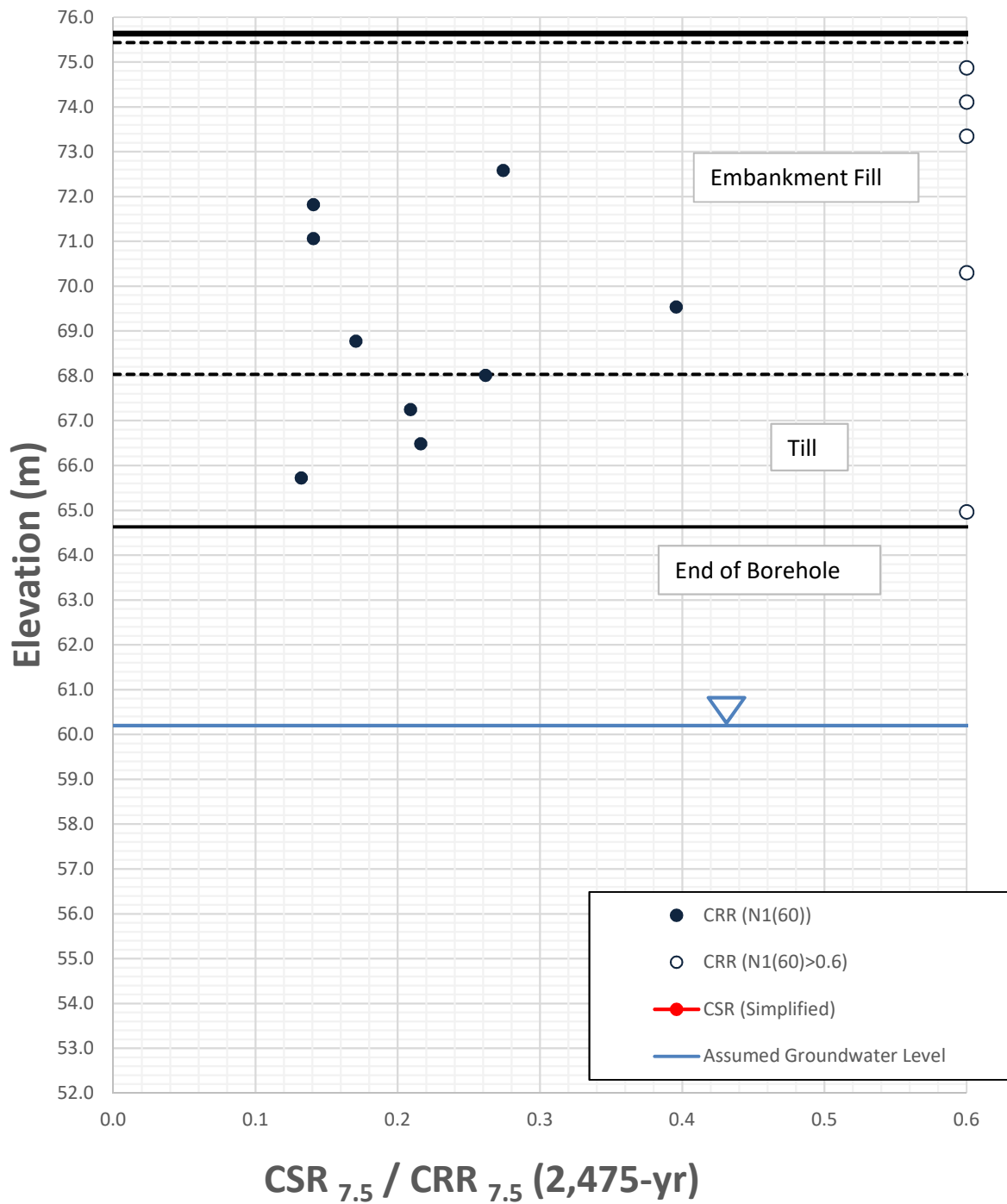
Figure F17



Results of Liquefaction Analysis
BH 18-2102
CPR Overhead
Ottawa, Ontario

Project No. 1662565 / 1210
 Drawn: WAM
 Date: 2019/03/08
 Checked: MJK
 Review: MSS

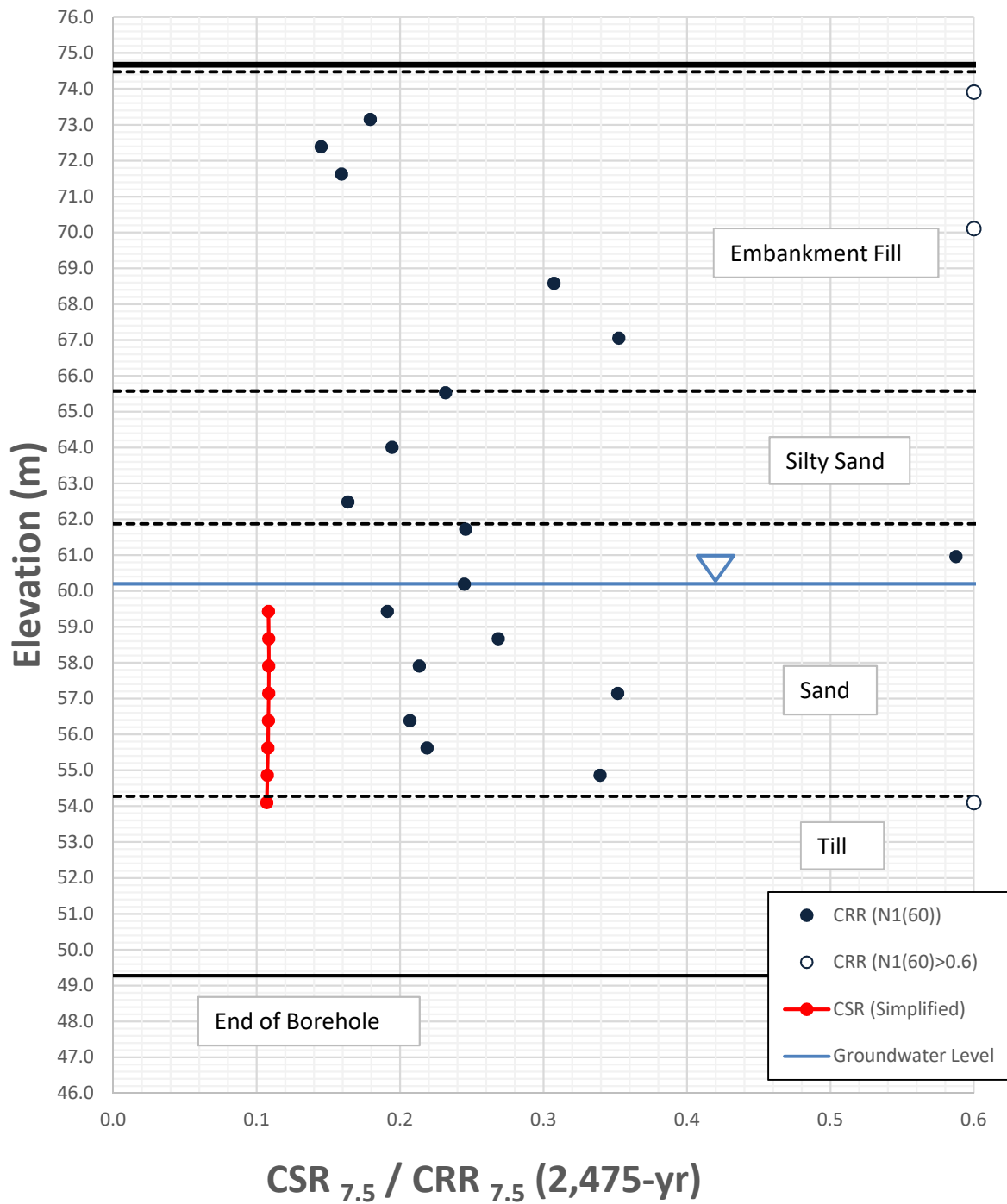
Figure F18



Results of Liquefaction Analysis
BH 18-2103
CPR Overhead
Ottawa, Ontario

Project No. 1662565 / 1210
 Drawn: WAM
 Date: 2019/03/08
 Checked: MJK
 Review: MSS

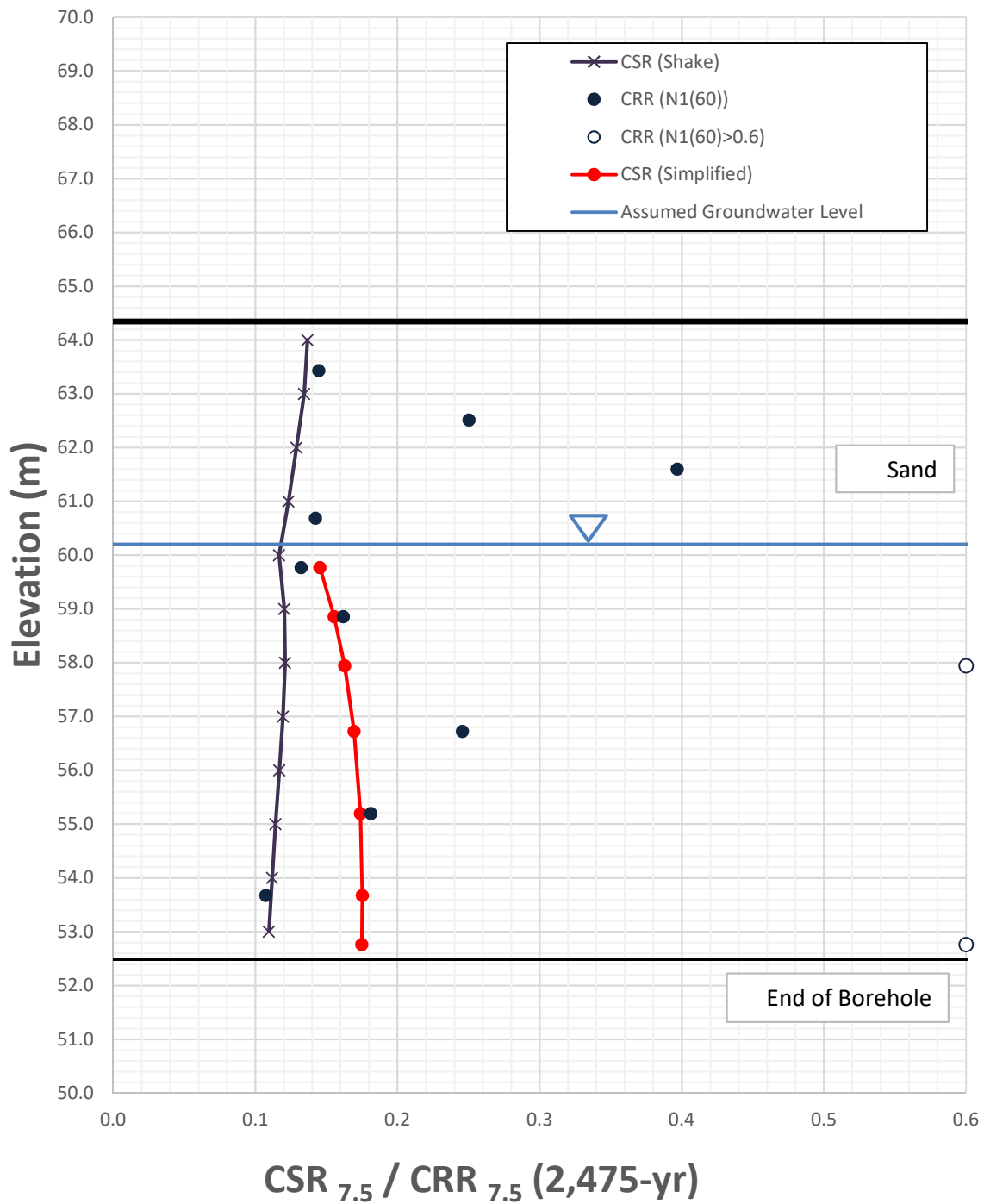
Figure F19



Results of Liquefaction Analysis
BH 18-2104
CPR Overhead
Ottawa, Ontario

Project No. 1662565 / 1210
 Drawn: WAM
 Date: 2019/03/08
 Checked: MJK
 Review: MSS

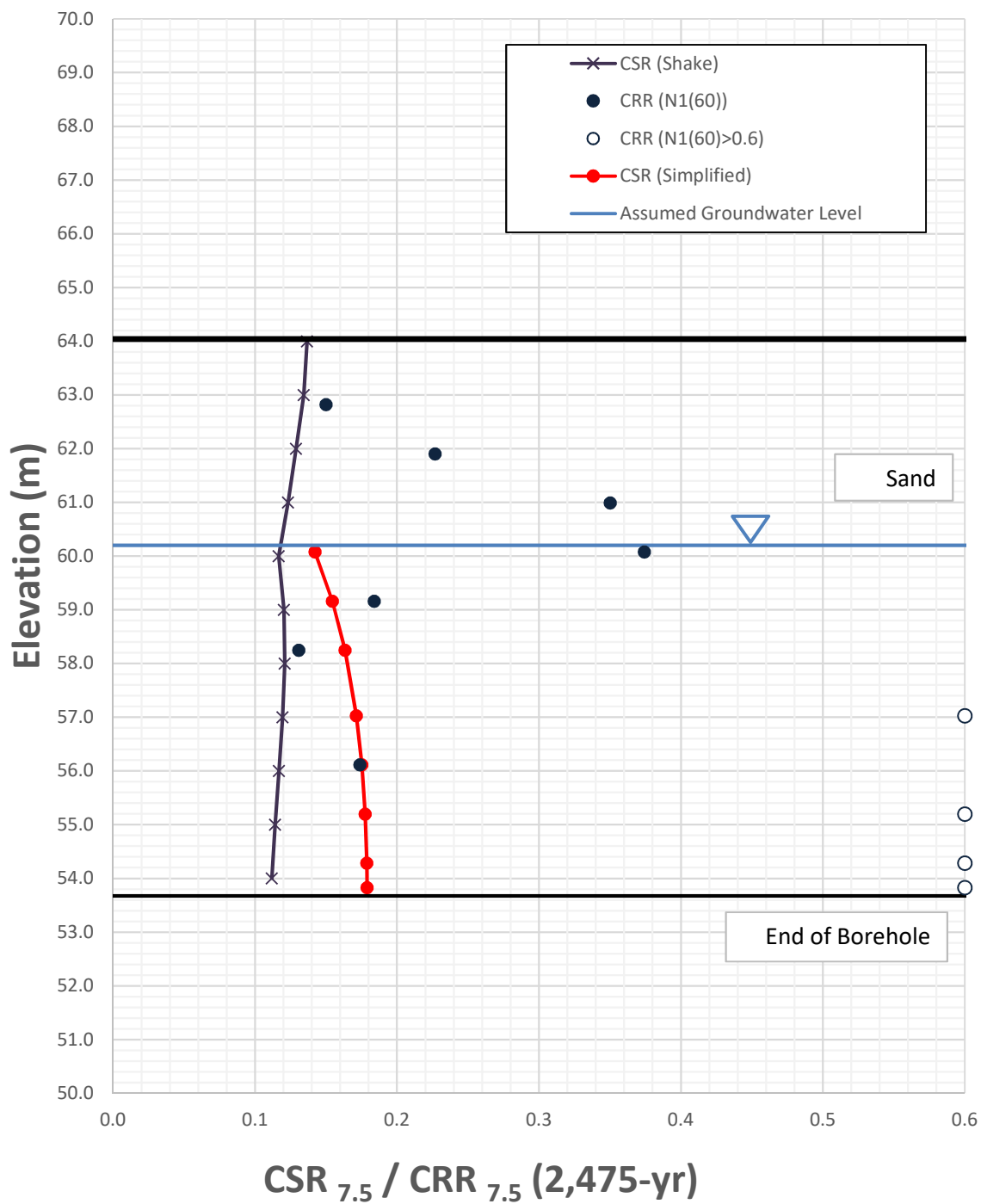
Figure F20



Results of Liquefaction Analysis
BH 3
CPR Overhead
Ottawa, Ontario

Project No. 1662565 / 1210
 Drawn: WAM
 Date: 2019/06/11
 Checked: MJK
 Review: MSS

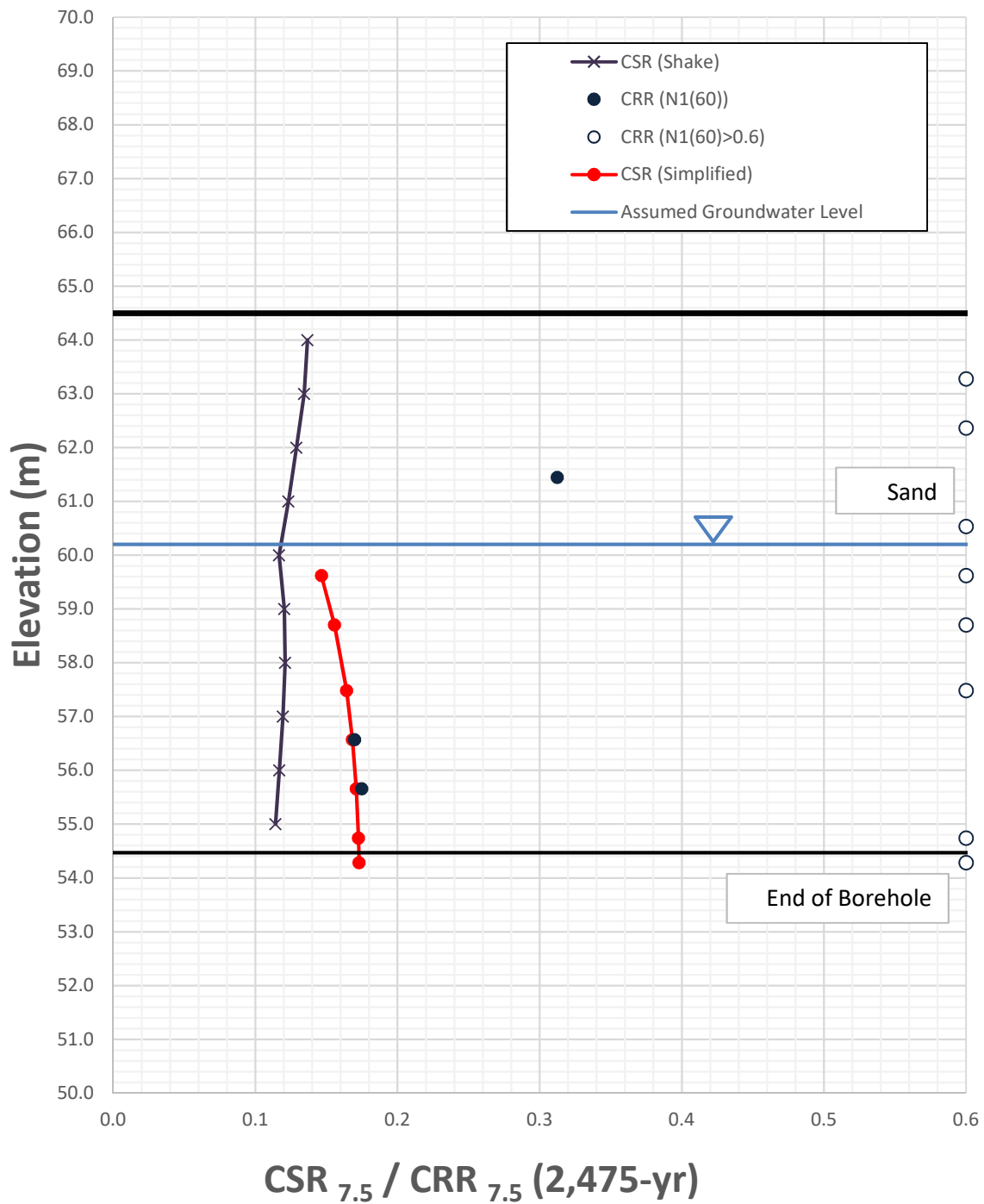
Figure F21



Results of Liquefaction Analysis
BH 5
CPR Overhead
Ottawa, Ontario

Project No. 1662565 / 1210
 Drawn: WAM
 Date: 2019/06/11
 Checked: MJK
 Review: MSS

Figure F23



Results of Liquefaction Analysis
BH 6
CPR Overhead
Ottawa, Ontario

Project No. 1662565 / 1210
 Drawn: WAM
 Date: 2019/06/11
 Checked: MJK
 Review: MSS

Figure F24

APPENDIX G

Site Photographs



Photograph 1: East of Site 3-302/1 (EBL), looking southeast (November 2018).



Photograph 2: South of west abutment of Site 3-302/1 (EBL), looking north (November 2018).

CLIENT
WSP CANADA GROUP LIMITED

CONSULTANT



YYYY-MM-DD 2019/03/07

PREPARED WAM

DESIGN --

REVIEW MJK

APPROVED --

PROJECT
CPR OVERHEAD BRIDGE REHABILITATION
SITE NO. 3-302/1 (EBL) AND 3-302/2 (WBL)
HIGHWAY 417, OTTAWA, ONTARIO

TITLE
SELECTED SITE PHOTOGRAPHS

PROJECT No.
1662565

Phase
1210

Rev.
1

Figure
G1



Photograph 3: East of east abutment and piers of Site 3-302/2 (WBL), looking west (November 2018).



Photograph 4: West abutment and piers of Site 3-302/2 (WBL), looking northwest (November 2018).

CLIENT
WSP CANADA GROUP LIMITED

CONSULTANT



YYYY-MM-DD 2019/03/07

PREPARED WAM

DESIGN --

REVIEW MJK

APPROVED --

PROJECT
CPR OVERHEAD BRIDGE REHABILITATION
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TITLE
SELECTED SITE PHOTOGRAPHS

PROJECT No.
1662565

Phase
1210

Rev.
1

Figure
G2

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

1 in



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