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Memorandum

Date:	November 28, 2022	**Reference No.:**	VAN-22003875-A0
To:	Lamme Zarei, P.Eng., MBA	**Total No. of Pages:**	6+
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Project Name:	Portside/Blundell Road Improvement Project (PBRIP)		
	Richmond, BC		
Subject:	Single Pile design for axial capacity under static and seismic conditions		

Summary

As requested by McElhanney Engineering Services Ltd. ("MESL"), EXP Services Inc. ("EXP") has analyzed the design validity for the single piles which will be placed below the abutments and piers portion of the overpass. The objective is to access whether the dimensions and other considerations like construction method would be sufficient to tolerate the expected design forces supplied by Thurber Engineering.

1. Introduction

Vancouver Fraser Port Authority ("VFPA") is planning to improve the intersection of Portside and Blundell Road with a new overpass to eliminate the existing at-grade crossing. In addition, the scope of work also includes the widening of Blundell Road between No. 8 and York Road from two lanes to four lanes, construction of a new bridge and extension of Portside Road over the No. 7 Road Canal, and the construction of a new multi-use pathway (MUP) overpass along the north side of Blundell Road and south side of Portside Road. The objective is to determine whether the dimensions and other factors, such as construction method, are adequate to withstand the anticipated design forces supplied by Thurber Engineering. The alpha method for cohesionless materials and beta method for materials proposed in the Canadian Foundation Engineering Manual 5th Edition are used to calculate the ultimate load carrying capacities of the single driven piles. It is anticipated that the final design check will satisfy the criteria for the axial design load for both static and pseudo-static (here used synonymously as seismic) conditions.

2. Site and subsurface conditions

It should be noted that the generalized stratigraphy used for the current study is based on the gathered information based on a series of simple (CPT), seismic Cone penetration tests (SCPT), and auger hole (AH) tests on the north and south side of the overpass as shown in Table 1. The following in-situ tests were completed by EXP on June 1, 2022.

Table 1 Different in-situ tests conducted for the identification of stratigraphy

Type of test	**Side**	**Number**
CPT	N	CPT22-01 to CPT 22-05
SCPT	N	SCPT22-06
CPT	S	CPT22-07 to CPT 22-10
AH	N	AH22-01 to AH22-03
AH	S	AH22-04 to AH22-06

Table 2 depicts the different soil properties used for the analysis. The sandfill and the Fraser river sand are considered as purely cohesionless and are generally modelled using beta method, while other layers consisting of construction waste layer, peat and clay are modelled as partly or completely cohesive materials and thus used in the beta method of pile design.

Table 2. Soil parameters used for the current stability analysis of the embankments

Soil Type	**Unit weight (γ) in kN/m³**	**Model parameters**	
		c (kPa)	ϕ°
Sand fill	20	0	35
Construction waste/wood debris	15	5	20
Peat	12	25	0
Silt/Clay	17	75	0
Fraser river sand	18.5	0	32
Marine clay	17	75	0

3. Analysis

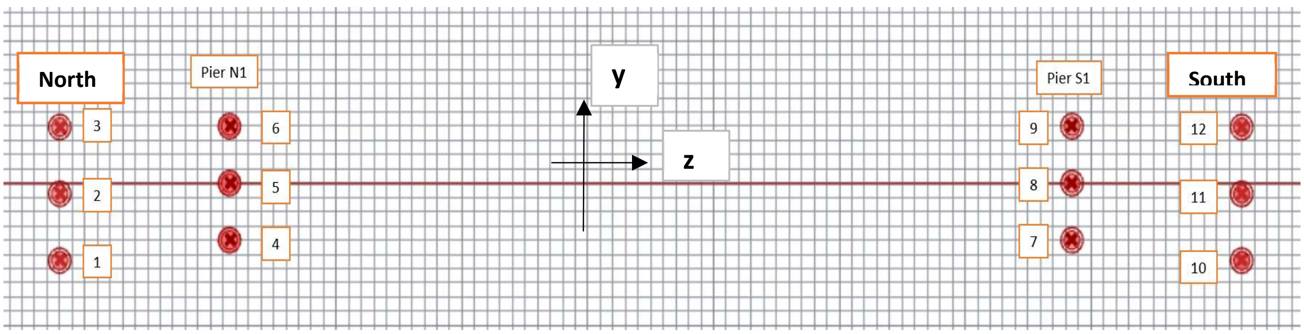
The CPT data and other ground characterization methods showed different thickness of sandfill, construction waste and peat in the north and south layers (as shown in Table 3) and hence and considered separately for the calculation of ultimate bearing capacity. Since there is a liquefiable deposit of thick Fraser River sand, it was important to check both the static and seismic cases to assess the ultimate bearing capacity of the piles.

Table 3 Interpreted stratigraphy at the proposed overpass area on the north and south side.

Soil Type	**Average thickness (m)**	
	North (N)	**South (S)**
Sand fill	1.9	3.4
Construction waste/wood debris	5.2	2.3
Peat	1.7	0.8
Silt	5.3	5.9
Fraser river sand (upper)	10	10
Fraser river sand (lower)	14	15.5
Marine clay	Over 14m	Over 13.0

In the project site there is an array of total 12 single piles, 6 on the north side of the Portside Blundell Road and the rest on the south side as shown in Figure 1. In both sides, the half of the piles are placed under the abutments i.e., namely P1, P2, P3 in the north, and P10, P11, P12 in the south. The other half are placed equally under the bridge piers which include P4, P5, P6 in the north, and P7, P8 and P9 in the south. The piles are designed as steel piles with reinforced concrete head up to 10m and an overall diameter of 1.372 m.

Figure 1 Placement of piles along the north abutments and piers along with their south counterparts.



The design loads noted in Table 4 show that the piles near the piers should bear more loads than the abutment piles. Hence, an initial consideration of longer length was chosen for these piles. In design, the piles 1, 2, 3 and 10, 11, 12 are considered to be 60 m length and 4, 5, 6 and 7, 8, and 9 are assumed to be of 75 m. Based on these, and the assumptions mentioned hereafter, the loads are unfactored load vs depth graphs are prepared.

Table 4 Factored axial compression axial demands on the piles as provided by COWI.

Piles		**Factored axial compression loads (kN)**	
	Static	**Seismic (Return 475 year)**	**Seismic (Return 2475 year)**
P1	3249	2321.1	3091.7
P2	2333.8	1450.1	1582.1
P3	2312.5	2078.2	2853.4
P4	6545.426	4734.8	5701.1
P5	5253	3353.1	3558.3
P6	5833.6	4385.5	5345.7
P7	6526.7	4743.2	5693
P8	5241.5	3330.2	3539.1
P9	5887.7	4430.1	5378.2
P10	2640	2002.4	2823.9
P11	2405.9	1500.8	1643.2
P12	2395.4	2133.0	2924.4

Compression is considered as positive

Assumptions made for calculation of the pile capacity

1. The top 10 m of the piles are considered as cast-in situ as per suggestions of Thurber which are made of reinforced concrete. The rest of the piles are considered as hollow, driven piles.
2. Each pile is 1.372 m in diameter and considered of mainly two lengths viz., 60m and 75 m.
3. A residual shear strength (s_u) of 12 kPa is assumed for the liquefied sand layer in both 475 return period (RP) and 2475 RP earthquakes; and for all the other layers, the s_u is considered to be 80% to that considered under static condition.
4. The allowable load capacity is divided by a resistance factor (RF) of 0.55 in the current static analysis to achieve the ultimate design load capacity since there are existing 10 CPTs, and 6 auger logs which give good description of the underneath layers. For the seismic case of both RP of 475 years and 2475 years, the value of RF is considered as 0.75 (0.55+0.2). One should refer to draft DBA references S6-19 and the BC Supplement to S6-19 for additional details. Also, it should be noted that the resistance factors used should require the piles to be tested with pile driving analyzer (PDA).
5. To calculate the ultimate capacity of a single pile, the mobilization of strength is attributed solely to the skin friction and the end bearing is disregarded because the piles are hollow at their ends i.e., $Q_{total} = Q_{shaft}$, where Q_{total} load bearing capacity of a single pile in kN, and Q_{shaft} is the total resistance mobilized from the surface area of the pile shaft.
6. Since all the piles are considered as friction piles, the ultimate uplift resistance is equal to the Q_{total} values presented in Appendix A.

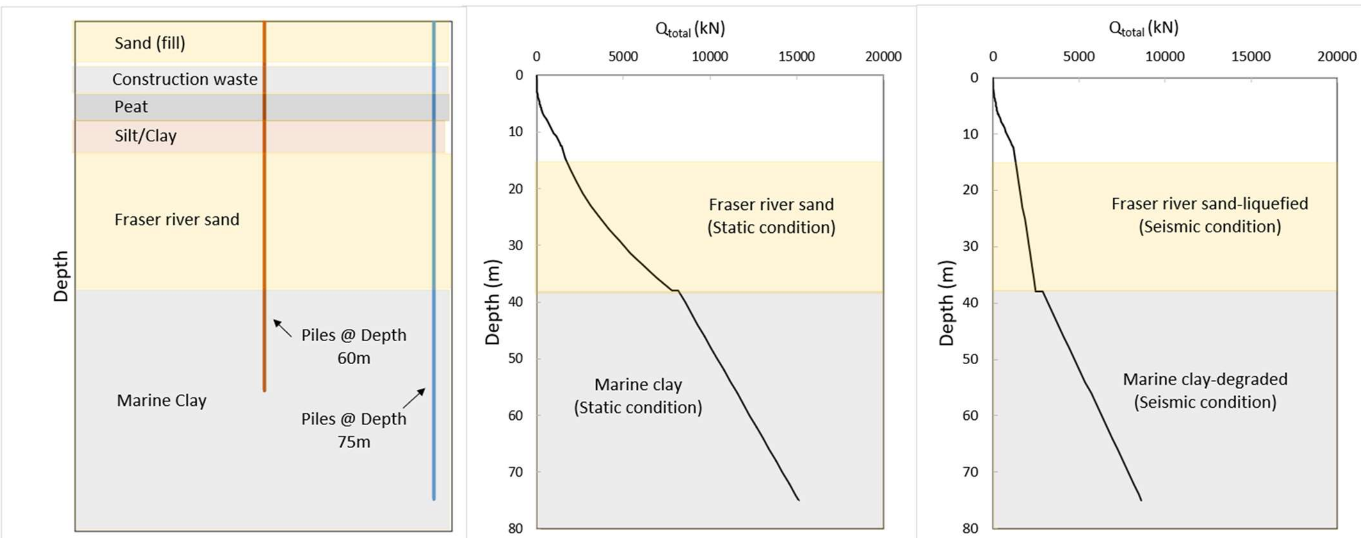
The calculation is based on the alpha-beta method stated in the Canadian Foundational manual which has its inherent assumptions and are not described here for brevity. The alpha-beta values for each layer are presented in Table 5 for both static and seismic analyses and are used to calculate the total pile load (Q_{total}) calculated for four cases, namely northside-static, northside-seismic, southside-static, and southside-seismic cases. These results are plotted in the Appendix A for the north side and Appendix B for the south side. The vertical lines in orange and blue are the "required unfactored ultimate pile resistance" or the "factored demands divided by the resistance factor" and are overlayed on this ultimate load capacity plots for reference.

Table 5 The empirical parameters used in the alpha-beta method for calculation of ultimate capacity of single driven piles in the current layered deposits.

Soil type	α_{static}	$\alpha_{seismic}$	β_{static}	$\beta_{seismic}$	$s_{u\ static}$ (kPa)	$s_{u\ seismic}$ (kPa)
Sand fill	-	-	0.25	0.25	-	-
Construction waste/wood debris	1.00	1.00	-	-	20	16
Peat	1.00	1.00	-	-	25	20
Silt	0.58	0.60	-	-	75	60
Fraser river sand (upper)	-	1.00	0.28	-	-	12
Fraser river sand (lower)	-	1.00	0.30	-	-	15
Marine clay	0.58	0.60	-	-	75	60

Figure 2a depicts the stratigraphy of the Portside Blundell site as well as the two pile lengths under consideration. Using the alpha-beta method and the static case, an overlay of the ultimate pile load capacity is calculated and presented in Figure 2b for the south side. As shown in Figure 2c, however, following seismic consideration, this capacity is significantly diminished due to degradation of the undrained residual shear strength in the sand and the clay layers.

Figure 2. Different soil profile (a) Soil layering and the single piles considered in the study, (b) Ultimate load vs. depth calculation for static condition, and (c) Modified curve due to liquefaction consideration for the 2475 year earthquake.



(a) (b) (c)

4. Conclusion

It can be said that the unfactored ultimate capacity of the single piles with 1.372m diameter with 60 and 75 m length (vertical orange line represents the 60 m pile and blue line for the 75 m pile) for the abutment and the piers location, respectively, fall below the unfactored Q_{total} values predicted from the alpha-beta method of single pile design for static, seismic 475 year RP and 2475 year RP cases as observed from Appendix A. The plots of the ultimate capacity using the alpha-beta method superimposed with the LCPC method in Appendix B based on the average CPTs on the north and south sides of the Portside-road demonstrated that the alpha-beta method underestimated the ultimate capacity of the piles.

Closure

The information presented in this memorandum is based on the referenced information and EXP's understanding of the project as described herein. If the project information differs from those described in this report, EXP should be notified promptly to review the geotechnical aspects of the project and modify them if necessary.

We trust that this meets your current requirements. Should you have any concerns or questions, please do not hesitate to contact the undersigned.

Submitted by:
EXP Services Inc.

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Reviewed by:

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Nov 28th, 2022

Yasser Abdelghany, Ph.D., P.Eng., PMP
Geotechnical Lead

APPENDIX:

A. Unfactored single pile axial resistance analysis on the northside and southside of the Blundell road
B. Comparisons between the alpha-beta method and LCPC method using existing site-specific CPT data

PERMIT TO PRACTICE
EXP SERVICES INC.
RR SIGNATURE:
RR EGBC: 36187 DATE: 28 Nov. 2022
PERMIT NUMBER: P1002313
Engineers & Geoscientists
British Columbia (EGBC)

INTERPRETATION & USE OF STUDY AND REPORT

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This study and Report have been prepared in accordance with generally accepted engineering consulting practices in this area. No other warranty, expressed or implied, is made. Engineering studies and reports do not include environmental consulting unless specifically stated in the engineering report.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

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a. Nature and Exactness of Descriptions: Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations, or building envelope descriptions, utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b. Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the report as a result of misstatements, omissions, misrepresentations or fraudulent acts of persons providing information.

c. To avoid misunderstandings, EXP Services Inc. (EXP) should be retained to work with the other design professionals to explain relevant engineering findings and to review their plans, drawings, and specifications relative to engineering issues pertaining to consulting services provided by EXP. Further, EXP should be retained to provide field reviews during the construction, consistent with building codes guidelines and generally accepted practices. Where applicable, the field services recommended for the project are the minimum necessary to ascertain that the Contractor’s work is being carried out in general conformity with EXP’s recommendations. Any reduction from the level of services normally recommended will result in EXP providing qualified opinions regarding adequacy of the work.

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When EXP submits both electronic file and hard copies of reports, drawings and other documents and deliverables (EXP’s instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by EXP shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancy, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by EXP shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of EXP’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EXP. The Client warrants that EXP’s instruments of professional service will be used only and exactly as submitted by EXP.

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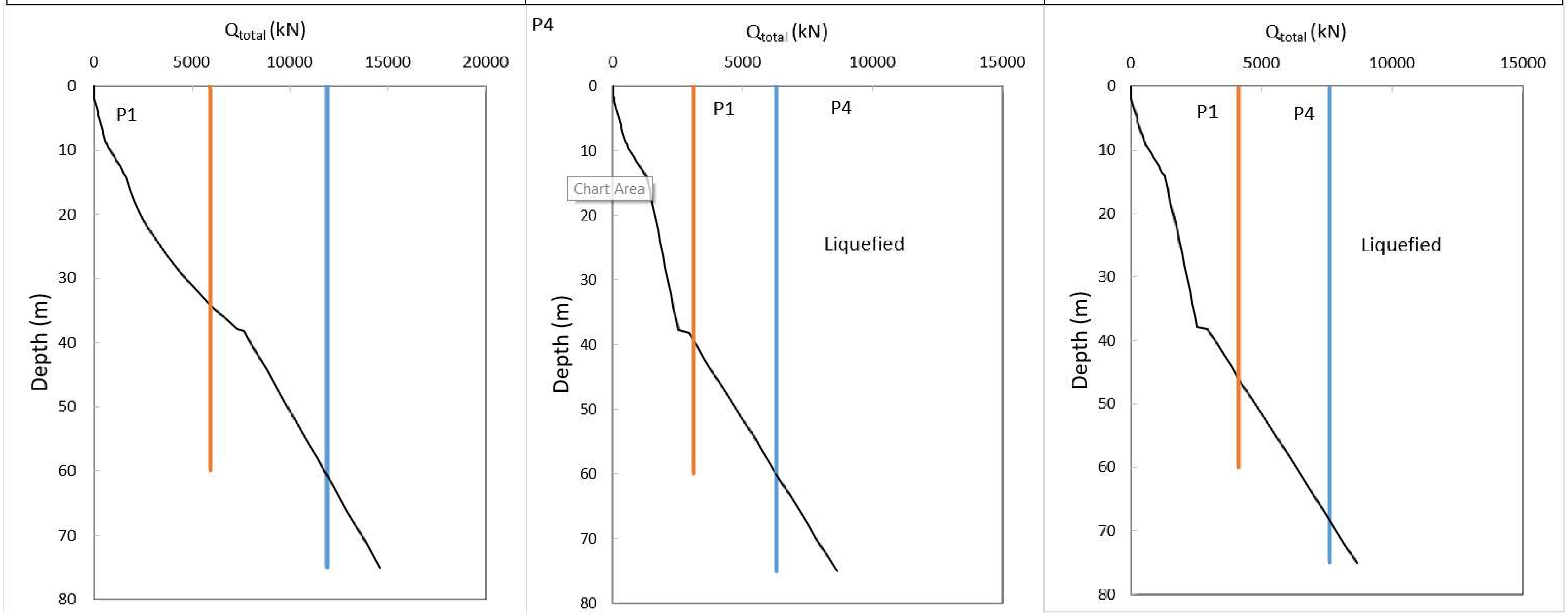
APPENDIX A

Unfactored single pile axial resistance analysis on the northside and southside of the Blundell road

NORTH		
STATIC	SEISMIC-475 YEAR RETURN PERIOD	SEISMIC-2475 YEAR RETURN PERIOD



General Notes:

- A geotechnical load resistance factor of 0.55 is applied for static case, 0.75 for 475-year earthquake case, and 0.75 for 2475-year earthquake case

-Both the unfactored Pile axial loads used in the design are found to be higher than the unfactored ultimate single pile loads indicating the design considerations are fine as per the alpha-beta method

exp. **EXP** Services Inc. 275-3001 Wayburne Drive Burnaby, BC V5G 4W3 Tel: 604-874-1245 Fax: 604-420-7723 www.exp.com	CLIENT: COWI				TITLE: UNFACTORED ULTIMATE AXIAL PILE RESISTANCE (NORTHSIDE) [DRIVEN, 1372mm DIA.]		
	PROJECT Portside/Blundell Road Improvement Project (PBRIP)						
	PROJECT NO. VAN-22003875-A0	DFTR. SB	DSGN. SB	CHK. YA	DATE: 11/28/2022	SCALE: NA	FIGURE: 1

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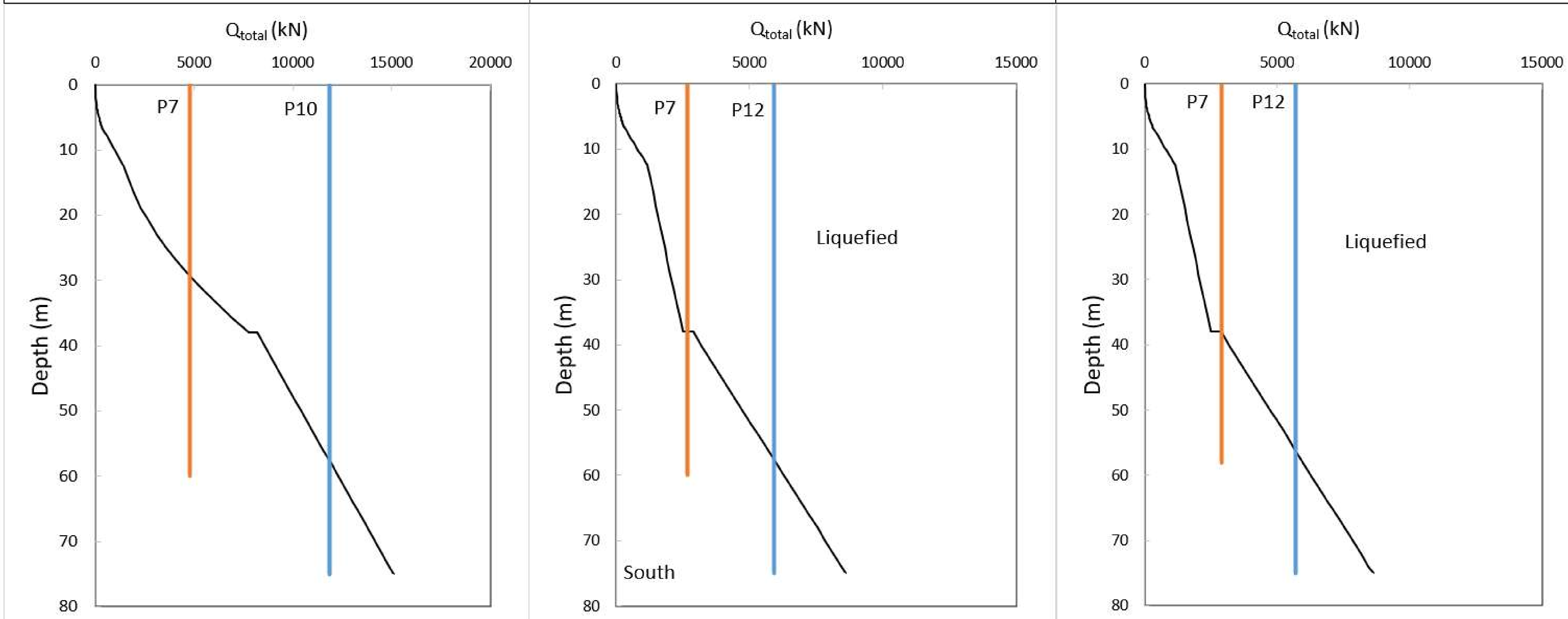
SOUTH

STATIC	SEISMIC-475 YEAR RETURN PERIOD	SEISMIC-2475 YEAR RETURN PERIOD



General Notes:

- A geotechnical load resistance factor of 0.55 is applied for static case, 0.75 for 475-year earthquake case, and 0.75 for 2475-year earthquake case

Both the unfactored Pile axial loads used in the design are found to be higher than the unfactored ultimate single pile loads indicating the design considerations are fine as per the alpha-beta method

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CLIENT: McElhanney				TITLE: UNFACTORED ULTIMATE AXIAL RESISTANCE (SOUTHSIDE) [DRIVEN, 1372mm DIA.]		
PROJECT: Portside/Blundell Road Improvement Project (PBRIP)						
PROJECT NO. VAN-22003875-A0	DFTR. SB	DSGN. SB	CHK. YA	DATE: 11/28/2022	SCALE: NA	FIGURE: 2

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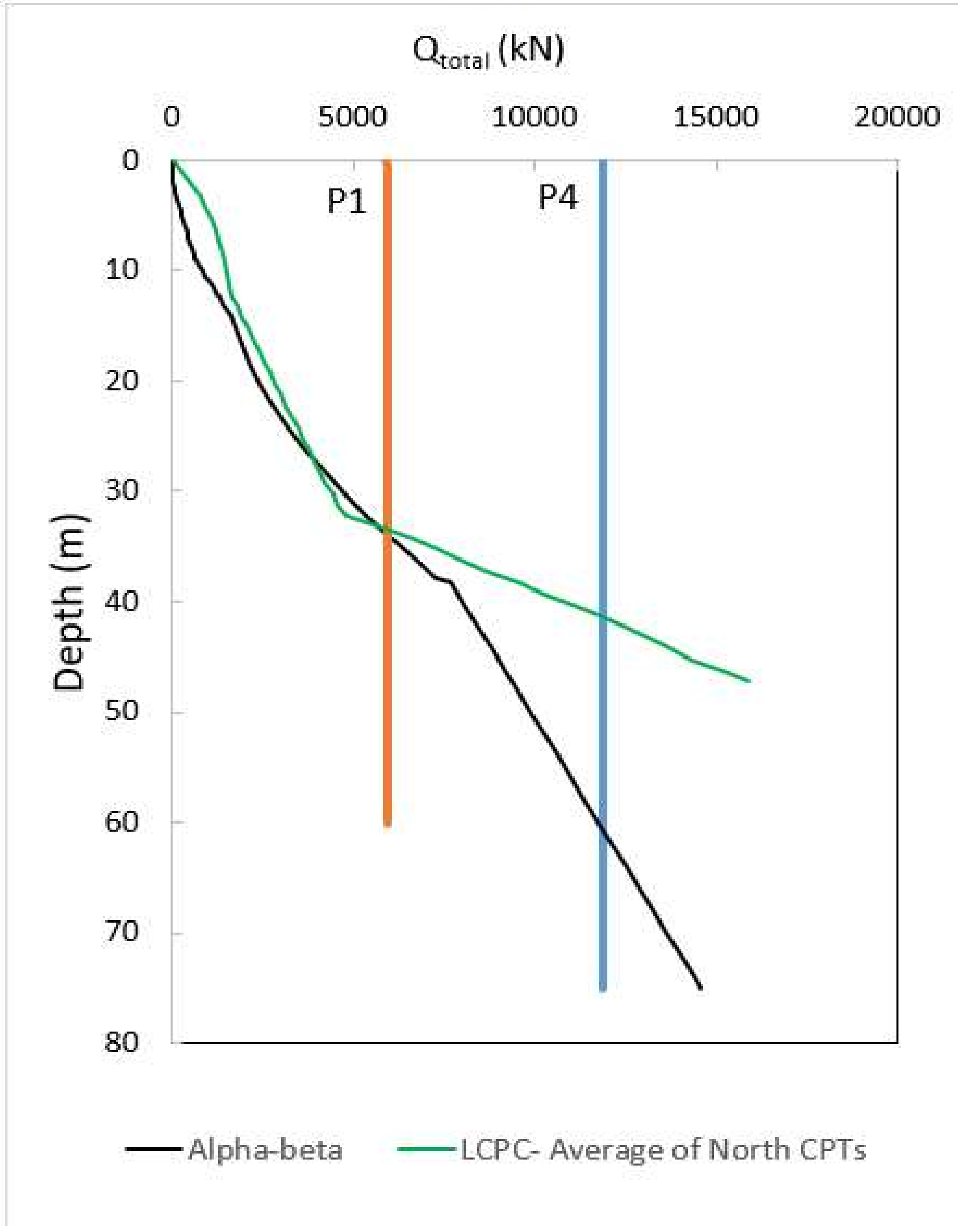
APPENDIX B

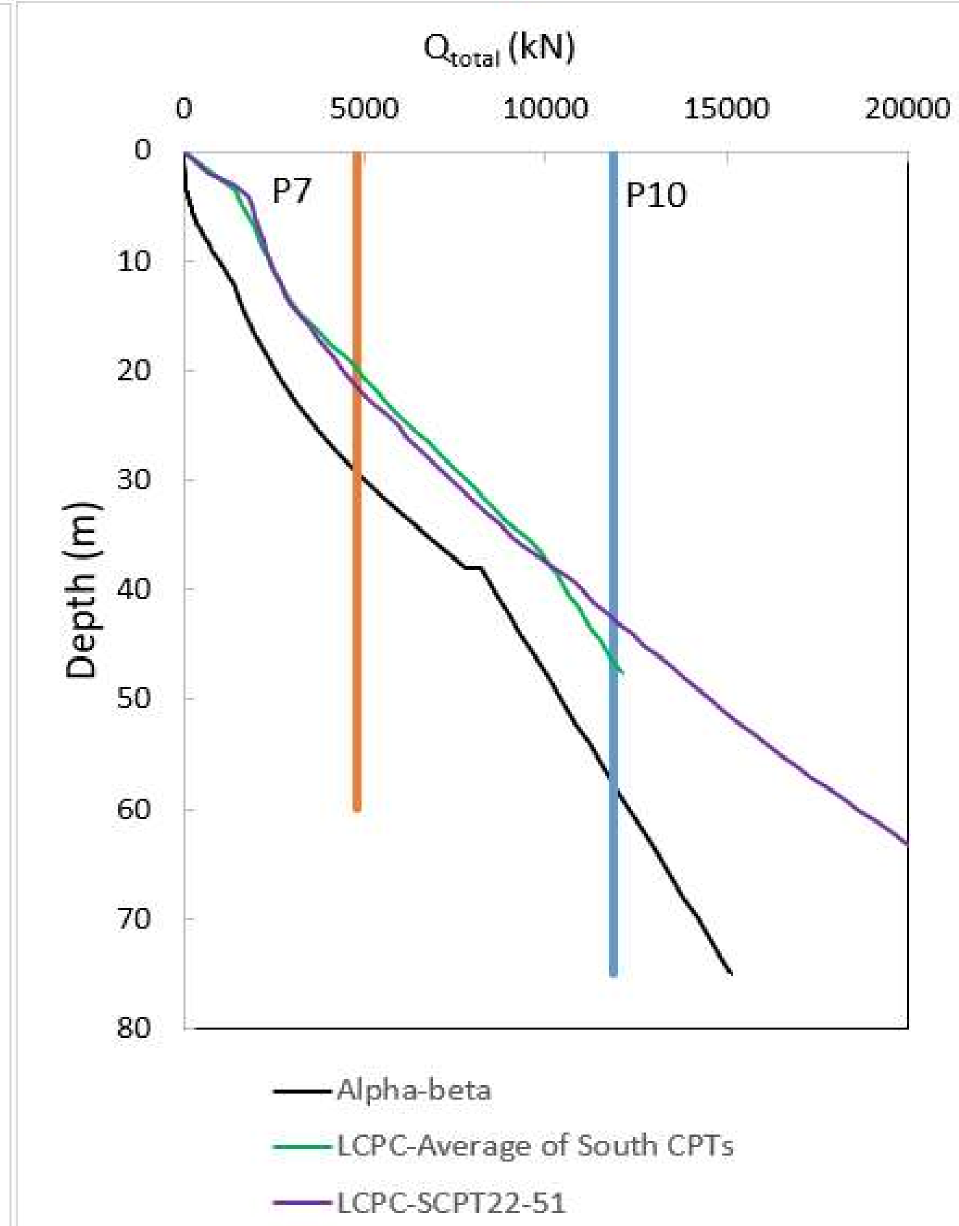
Comparisons between the alpha-beta method and LCPC method using existing site-specific CPT data

STATIC CASES COMPARISONS

North



South



General Notes:

A geotechnical load resistance factor of 0.55 is applied for static case

Cpet is used for LCPC analysis

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CLIENT: McElhanney				TITLE: ULTIMATE AXIAL PILE CAPACITY COMPARISONS [DRIVEN, 1372mm DIA.]	
PROJECT: Portside/Blundell Road Improvement Project (PBRIP)					
PROJECT NO.: VAN-22003875-A0	DFTR.: SB	DSGN.: SB	CHK.: YA	DATE: 11/28/2022	SCALE: NA	FIGURE: 3

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