April 03, 2017 Reference No. VAN-00222989-A0

Parrish & Hiembercker Ltd.
c/o CMC Engineering and Management Ltd.
300 - 1160 Douglas Road
Burnaby, BC V5C 4Z6 Email: mvandernoot@cmcengineering.com

Attention: Mr. Michel Vander Noot, P.Eng.

Re: Proposed P&H Fraser Terminal
Fraser Surrey Docks, Surrey, BC
Geotechnical Assessment Report

Dear Sir:

1.0 INTRODUCTION

As authorized, **exp** Services Inc. (**exp**) has completed a geotechnical exploration and assessment for the proposed P&H Fraser Terminal at Fraser Surrey Docks in accordance with **exp**'s proposal dated October 16, 2014 (our Ref No. 999-00033791-PP).

The scope of services was limited to characterizing soil and groundwater conditions underlying the site and to provide geotechnical design recommendations. Environmental or chemical assessment of soil and groundwater at the site was not part of our work scope.

2.0 SITE AND PROJECT DESCRIPTION

The subject of this geotechnical report is a proposed P&H Fraser Terminal to be located behind Berth 4 at Fraser Surrey Docks (FSD) container and break bulk terminal in Surrey, BC. Based on drawings provided to us by CMC Engineering and Management Ltd. (CMC), it is understood that the main components of the project requiring geotechnical input would consist of the silos, associated conveyor and ship loader system, unloading building and transfer towers. The majority of the site of the proposed silos is currently developed with an existing building, previously leased by Bekaert Canada Ltd. The remaining areas are currently asphalt paved exterior yard area. It is understood that the existing building will be demolished prior to the proposed development.

According to the current layout scheme provided by CMC Engineering and Management Ltd., two groups of 14.6m diameter silo are proposed side by side. Each group consists of sixteen (16) silos with two rows of eight silos. Approximate length and width of each group would be 140m by 35m. Proposed silos will cover most part of the existing Bekaert Building. The silos will have an overhead conveyor connecting to a transfer tower. Other key project features include a rail car unloading tunnel of about 5.3m deep with an approximately 12.8m deep pit (unloading building) at the northwest (based on project North) corner of the existing Bekaert Building. The overall length of the tunnel and pit would be

approximately 47.4m. There will be a reclaimed pit/trench located 4 to 5m south of the proposed silo area.
It has been assumed that the below grade structures would be designed as a sealed and "tanked" structure and designed to resist hydrostatic uplift.

Preliminary soil pressure estimates based on service load conditions provided by Madjid Rezqi of CMC Engineers and Management Ltd., are as follows:

Smalls Silo Foundation Pressure:
Static (Dead + Live): 150 kPa

Unloading Deep Pit:
Static (Dead + Live): Varies from 100kPa to 180kPa

Reclaimed Pit/Tranch:
Static (Dead + Live): Varies from 20kPa to 80kPa

Transfer Tower:
Static (Dead + Live): 80 kPa

Truck and Container Loading Beans:
Static (Dead + Live): 120 kPa

A geotechnical site exploration was carried out between December 11, 2014 and December 17, 2014. Some of the previous test hole information and analysis from other nearby projects at Fraser Surrey Docks has been used for the proposed project, where relevant.

The subject site and study area are shown on the attached Testhole Location Plan, Figure 1.

A Supplemental coring and hand auger exploration was conducted between October 07, 2015 and October 08, 2015. The scope of services was limited to measuring existing concrete slab and asphalt pavement thickness at core locations, characterizing underlying shallow soil conditions, and to provide geotechnical comments with respect to the findings. Summary of the findings and recommendations were provided in a memo dated October 15, 2015. The memo is presented in Appendix H.

3.0 SCOPE OF WORK

Key geotechnical evaluation and design issues for the project are:

a. Identify the subsurface soil and groundwater conditions;
b. Provide recommendations for excavation, dewatering and backfilling for the proposed below grade structures;
c. Assess foundation options, including settlement considerations, design parameters and subgrade preparation for the proposed below grade and above grade structures;
d. Assess liquefaction potential and associated lateral and vertical displacement and differential movements and discuss consideration of consequences with respect to the proposed development;

e. Provide lateral pressures for design of below grade walls.

4.0 SUB-SOIL CONDITION

4.1 Surficial Geology

Surficial Geology Map from the Geological Survey of Canada Map (1486A) and local experience indicate that the area is underlain by Fraser River sediments which consist of sandy to silt clay loam normally less than 2m thick overlying 15m or more of deltaic and distributary channel fill typically comprised of silty sand to sand and minor silt.

4.2 Geotechnical Drilling and Subsurface Exploration

The field work was carried out between December 11, 2014 and December 17, 2014 and included the following:

- Eight (8) Cone Penetration Tests (CPT) between 20 and 38m depth, by sub-contractor Schwartz Soil Tech Inc., of Vancouver, BC;
- Five (5) boreholes with SPT drilled to depths between 21.3 and 30.5m, by Sea To Sky Drilling Services Ltd., of Coquitlam, BC;
- Prior to the drilling work, BC One Call was made. An electro-magnetic survey of the site was completed prior to drilling to locate buried utility lines. This survey was carried out by sub-contractor Western Locate Services Ltd., of Coquitlam, BC.

A representative from **exp** supervised and directed the drilling work, completed the field logs and obtained soil samples for laboratory testing and classification.

Locations of the test holes/CPT are shown in the attached Testhole Location Plan, Figure 1.

4.2.1 Cone Penetration Test (CPT)

Schwartz Soil Tech operated the CPT from a truck mounted drill rig supplied by Sea to Sky Drilling. The cone has a tip area of 15cm^2, friction sleeve area of 225cm^2 and “Net Area Ratio” of 0.8. In CPTu test, the cone tip resistance (qc), sleeve friction (fs) and porewater pressure are monitored continuously using electronic transducers and saved in an on-board computer at 50mm depth intervals as the cone is pushed into the ground. The CPT work was carried out in accordance with ASTMD-5778-07. Graphical plots of all CPT data including the cone tip resistance (qt, corrected for the effects pore water pressure on cone tip), sleeve friction (fs), friction ratio (Rf = fs / qt x 100%) and porewater pressure are presented in Appendix B. The friction ratio, Rf is a calculated parameter used for the purpose of identifying soil types.

The CPT data was utilized for interpretation of soil type and density/consistency at the cone test locations and for geotechnical analyses, including seismic design and liquefaction assessment.

4.2.2 Standard Cone Penetration Test (SPT)

The Standard Penetration Test (SPT) involves driving a standard thick-walled (2 inch/51mm) split-barrel sample tube into the ground at the bottom of a borehole with blows from an automatic drop hammer containing a standardized weight (140 lbs/63.5 kg) and drop height (30 inch/76 cm). The sample tube is driven into the ground with the blow counts recorded for each 6 inch/152mm interval until the sampler has been driven a total of 2 ft/610mm. The sum of the number of blows recorded for the second and third 6inch/152mm intervals of penetration is reported as the SPT blow count value, commonly termed "standard penetration resistance" or "N-value". The results of the SPT are presented on the borehole logs in Appendix A.

The SPT data was utilized for interpretation of soil density at the borehole locations and for geotechnical analyses, including seismic design and liquefaction assessment.

4.2.3 Boreholes

A truck mounted Mud Rotary drill rig, supplied and operated by Sea To Sky Drilling Services Ltd., of Coquitlam, was used to complete the boreholes. Five (5) boreholes with SPT were drilled to depths between 21.3 and 30.5m below ground surface.

All field work was carried out under the full-time supervision of a member of our geotechnical staff, who located the boreholes in the field, examined and logged the subsurface conditions encountered, and collected representative soil samples for detailed visual examination and testing in our laboratory. Following completion of drilling, the CPT and boreholes were backfilled and sealed according to the regulations of the B.C. Groundwater Protection Act.

The borehole logs are provided in Appendix A.

4.3 Laboratory Tests

A number of laboratory tests were conducted on representative soil samples taken from the bore holes. The tests included natural moisture content tests, sieve analysis on granular soil, Atterberg limits tests on cohesive soils and consolidation tests on undisturbed cohesive soil samples. The following is a summary of the laboratory tests carried out.

4.3.1 Natural Moisture Content Test

Moisture content determinations were performed on each soil sample obtained from the exploration to aid in identification of soil types and to correlate with engineering design parameters. The tests were done in general accordance with the test procedures in ASTM D-2216. The results of the tests are shown on the borehole logs, provided in Appendix A.

4.3.2 Atterberg Limit Tests

Atterberg limits, the liquid and plastic limit, are used for classification and indexing of cohesive soils and for correlating with engineering design parameters. The liquid and plastic limits are defined as the moisture content of a cohesive soil at arbitrarily established limits for liquid and plastic behavior,

respectively. Liquid and plastic limits were conducted on three (3) selected samples in accordance with ASTM D-423 and ASTM D-424, respectively. The results of the tests are provided in Appendix C.

4.3.3 Sieve Analysis

Sieve analysis was conducted to determine the grain size distribution of granular soils. Sieve analysis was conducted on six selected samples in accordance with ASTM C-136 and ASTM C-117, respectively. The results of the tests reports are presented in Appendix C.

4.3.4 Consolidation Tests

One dimensional consolidation tests were carried out to obtain consolidation settlement characteristics of the cohesive soils. The tests were conducted on three (3) undisturbed Shelby tube samples obtained from boreholes and in accordance with ASTM D-2435. Results of the tests are provided in Appendix C of this report.

4.4 Subsoil Conditions

In general, the test hole information indicates the following subsurface soil conditions, in the order of increasing depth:

UNIT A1 FILL – 25mm to 38mm thick asphalt (BH14-01 and BH14-03) followed by compact to dense SAND and some gravel/gravelly sand with trace silt. Thickness varied from 0.2m to 0.3m; 140mm to 190mm thick concrete slab (BH14-06, BH14-10 and BH14-12) followed by compact to dense gravelly sand with trace silt. Thickness varied from 0.2 to 0.3mm.

UNIT A2 FILL – Loose to compact sand with trace gravel and silt. Thickness varied from 4 to 7m. Fines content in the sand varied from 5% to 10%.

UNIT C Grey, wet, SILT, trace to some clay with occasional thin sandy silt and silty sand interbeds and organic pockets, loose to compact/soft to firm. Thickness varied from 1.5m to 5m. Moisture content in the soils varied from 35% to 50%.

UNIT D Grey, wet, silty SAND or sandy SILT, loose to compact. Thickness varied from 4 to 6m.

UNIT E Grey, wet, SAND, trace to some silt, loose to compact. Thickness > 20m, continued to end of CPT14-07 at 38m depth. Fines content in the sand varied from 8% to 10%.

4.5 Groundwater Conditions

Inferred groundwater depths at time of drilling and subsequently measured in piezometers (including several existing monitoring wells installed by others) on January 6 was between about 2.6 and 3.3m depth below the existing ground surface. It should be noted that groundwater conditions may vary and fluctuate seasonally in response to climate conditions and possibly also due to tidal effects, river levels, changes in land use, and other factors.

5.0 SEISMIC CONSIDERATIONS

5.1 Seismic Design Parameters

Earthquake ground motions corresponding to the 475 and 2475 year return period (10% and 2% probability of exceedence in 50 years) have been considered for the present analyses. Site-specific seismic parameters obtained from the Geological Survey of Canada shows that the Peak Ground Acceleration (PGA) for this site at the top of a hypothetical "firm ground" would be 0.270g and 0.506g for corresponding earthquake magnitudes of 6.7 and 7.0 for the 475 and 2475 year return period respectively.

Table 1 below presents the parameters in the form of response spectrum for motions at a hypothetical, "outcropping firm ground", for the design 475 and 2475 year earthquake event respectively.

Table 1: Response Spectrum for 5% Damping at "Outcropping Firm Ground" (BCBC 2012)

Periods, (s)	Acceleration Response Spectra (g) 475 Earthquake	Acceleration Response Spectra (g) 2475 Earthquake
0.2	0.534	1.020
0.5	0.350	0.680
1.0	0.172	0.332
2.0	0.087	0.172
PGA	**0.270**	**0.506**

The "outcropping firm ground" is specified as soils with average shear wave velocity in the range of 360 m/s to 750 m/s. Very dense soils or soft bedrock could be classified as "firm ground". The ground motions would be altered (amplified or attenuated) as earthquake induced shear waves propagate through the soils which overlie the "firm ground". Note that no "outcropping firm-ground" was encountered in current or previous test holes completed at the site, but is expected to be in the order of 100m below the ground surface (estimated based on published data by Geological Survey of Canada, e.g., Hunter et al, 1999).

No seismic ground response analysis was carried out for the proposed site. There was a site-specific shake analysis conducted by **exp** about 50m north from the current site. 475 and 2475 year earthquake event was considered in the design. For the current project, we have used same soil model and shake out results for the seismic design. Response spectra for 475 and 2475 earthquake event can be found in the Figures 2 to 5 in Appendix D.

PGA (Peak Ground Acceleration) at existing ground surface for 475 and 2475 earthquake events of 0.21g and 0.29g, respectively should be used in design.

5.2 Liquefaction Assessment

When subjected to strong shaking, water saturated loose sands and non-plastic silts may experience large increase in pore water pressure, lose a significant portion of their shear strength and behave like a heavy liquid, which is defined as liquefaction.

Liquefaction potential of the soils at this site was assessed using "Seed's simplified procedure" (Youd et al. 2001) with data from the CPT and previously completed SCPT (CPT with shear wave velocity measurements). The Seed's simplified procedure compares the Cyclic shear Resistance Ratio (CRR) with the earthquake induced Cyclic shear Stress Ratio (CSR) from a specified design earthquake at a given depth. Factor of Safety (FOS) against liquefaction is calculated as the ratio of CRR/CSR. FOS less than 1.0 represents potential liquefaction. It can be seen from Figures 6, 7, 8 and 9 in Appendix D that the sandy soils below the water table are generally liquefiable to a depth of about 14m, and then liquefiable layers occur intermittently below a depth of about 16.5m for 475 earthquakes. Analysis shows for 2475 earthquake event, liquefiable layers continue to 25 m below the existing grade.

Following liquefaction, the soils lose a significant portion of their shear strength and behave like a heavy liquid. Some of the consequences are: liquefaction induced settlement of the ground, potential buoyancy induced uplift of buried structures, lateral spreading of the ground and overlying structures, lateral flow or potential flow slide where a nearby free face situation exists, such as, river bank, tilting and/or shear failure of foundations.

5.3.1 Post-Liquefaction Settlement

Dissipation of the excess pore water pressure developed during shaking and liquefaction would cause settlement of the ground. Post-liquefaction settlement was estimated to be in the order of 400mm and 600mm for 475 and 2475 earthquake events respectively, based on the CPT data using the procedure of Zhang et al. (2002).

5.3.2 Lateral Spreading

Magnitude of lateral spreading of the ground was calculated using Youd et al (2002) procedure. The existing topography around the site is generally flat. However, the presence of the Fraser River at about 100m distance from the water's edge to the proposed structures (a "ground slope" condition) would likely influence lateral movement of the ground towards the water following soil liquefaction. The analysis indicates that ground movements in the order of 200mm to 300mm and 700mm to 900mm due to 475 and 2475 year design earthquake event, respectively. This does not take into account the integrity of the existing sheetpile bulkhead along the berth face, which was likely not designed to current seismic standards. Greater lateral movements could occur if this were to fail during the design earthquake event. Note that Youd et al. (2002) procedure is highly empirical and significant uncertainty exists in the calculated numbers. A range of half to twice the values given above is recommended for design considerations.

5.3.3 Flotation

Note that measured groundwater water level is about 3m below existing ground surface. This groundwater level is likely representative of a near seasonal high. However, groundwater in the area is known to fluctuate seasonally and can possibly be influenced by tide and river levels with the close proximity to the Fraser River. Therefore, we recommend using a condition representative of the maximum high groundwater level for long-term static buoyancy design. This may be difficult to identify with any degree of certainty, and assuming groundwater table at existing ground surface would be the recommended approach. An alternate approach could be to design for what would be considered an infrequent high groundwater table and incorporate a back-up pressure relief system which would be triggered if the groundwater table ever exceeded the design level. In such case, the below grade structures such as the unload building would be allowed to flood.

Following liquefaction, the liquefied soil would behave like a heavy liquid, inducing added buoyancy forces on buried structures and possibly leading to floatation. The buoyancy force can be calculated using an equivalent fluid pressure of 18.5 kN/m^3 for liquefied soils. The magnitude of the buoyancy force depends on the depth and thickness of the liquefiable soil layer. As indicated above, the soils below the measured groundwater table showed potential to liquefy to depths of 14m or more. Therefore, the uplift force due to buoyancy during liquefaction may be calculated using the equivalent fluid pressure for liquefied soils for the portion of the structure submerged below the groundwater table. A groundwater table at 2.5m below existing ground surface level (slightly above the current measured level) would be reasonable for floatation assessment during a major seismic event.

The dead load of the structure and the mass of soil column engaged by the perimeter area of the foundation slab and the shear resistance of the non-liquefied soil near the surface (a friction coefficient of 0.3 is appropriate) should be used to check the resistance to buoyancy from liquefied soils. The upper 2.5m of soil can be taken as non-liquefiable for purposes of the analysis. Further consultation between the Structural and Geotechnical engineers may be required for this assessment.

It is pointed out that a pressure relief system which would allow the below grade structures such as the unloading pit to flood, as mentioned above, could be considered to significantly reduce the risk of floatation if the sub-soils were to liquefy during a major earthquake. Further discussion regarding a pressure relief system can be found in Section 7.4 below.

5.3.4 Potential Liquefaction Remedial Measures

Prevention of liquefaction by means of ground densification is a commonly used remedial measure in the Fraser delta. For purposes of significantly mitigating liquefaction impacts on the proposed big and small silos, transfer towers, bent locations and unload building, this would likely involve densification some distance beyond the actual footprint of the structures. The presence of the existing Fraser Surrey Docks facility and contaminated soil under the existing Bekaert building would pose challenges to effectively densifying the site. Further details regarding ground densification can be provided at a later date if this approach is to be pursued.

6.0 Foundations

Based on the preliminary drawings and structural loading provided to us, different foundation options can be considered for the different types of structures. As discussed in Section 4, the site was found to be underlain by a variable thickness of compressible silt to clayey silt soils which were more prevalent under the area of proposed silos. Therefore, shallow foundations with raft slab or pile foundation were determined to be suitable for supporting the heavily loaded foundations due to total and differential settlement concerns. Based on the preliminary discussions with CMC Engineering, the silos and unloading building could be founded on a raft foundation. The transfer towers would be founded on 305mm (nominal 300mm), 610mm (nominal 600mm) or 914mm (nominal 900mm) diameter steel pipe piles. Light at-grade structures could be founded on shallow spread footings. The following sections provide a detailed discussion on the foundation options and calculated settlements.

6.1 Capacity of Pile Foundations

As mentioned above the transfer towers and bents are considered best to be founded on a piled foundation system to moderate post-construction settlements.

Axial capacities of the steel pipe piles have been calculated using:

- The CPT data and the LCPC method (Bustamante and Gianeselli 1982, Canadian Foundation Engineering Manual, 2006);
- Effective stress (beta) method (Canadian Foundation Engineering Manual, 2006).

Calculated unfactored ultimate axial capacities of the 300, 600 and 900mm diameter driven closed and open-ended steel pipe piles are provided in Appendix E.

The following are the resistance factors for the derivation of factored pile resistances in accordance with the provisions of BC Supplement to CAN/CSA-S6-06:

- Resistance factor for compression loading, non-seismic = 0.45
- Resistance factor for tension loading, non-seismic = 0.35
- Resistance factor for seismic loading combination = 0.8

Factored Pile Resistance = (Unfactored Ultimate Axial Capacity) x (Resistance Factor)

A minimum pile spacing of 3 pile diameters, centre-to-centre, was considered for the design. A minimum wall thickness of 12.7mm has been considered for steel pipe piles. Group effects of the piles and block failure mechanism have been considered in the design and the capacities used are found to be satisfactory.

6.2 Settlement

Settlement analysis was completed using loading conditions provided by CMC's structural engineer. The preferred configuration of raft foundation for the silos was used to conduct the settlement analysis. The computer program Settle3D was used to calculate the settlement. Two types of soil parameters were used to prepare the soil model. Soil parameters in Table 2 were used for settlement calculation in the eastern group of silos and soil parameters in Table 3 were used for settlement calculation in the western group of silos. Based on the consolidation test results and CPT interpretation, the silt to clayey silt layer is over-consolidated. An over-consolidation difference (OCD) of 100 kPa was used in the settlement analysis.

The calculated total settlement at the different locations of the silos can be found in Appendix F.

A settlement profile was prepared along the center line of the rail damper pit area to estimate the total and differential settlement along the pit. Settlement profile can be found in Appendix F.

The effect of settlement on the reclaimed pit/trench due to the adjacent heavily loaded raft slab soil was examined considering the foundation of the pit and silo constructed at the same time, but the full loads from silo applied one year later. Predicted settlements along the center line of the pit can found in Appendix F.

Table 2: Soil Parameters - Settlement Analysis - East Silos

Depth (m)	Soil Unit	Unit Weight (kN/m^3)	Initial Void Ratio, e_0	Coefficient of Compression C_c	Coefficient of Re-compression C_r
0 to 5.5	Sand Fill	18.5	0.8	-	-
5.5 to 7	Clay/Silt	17.5	1.2	0.32	.038
7 to 7.2	Sand	18.5	0.8	-	-
7.2 to 11.5	Silt	17.5	1.31	0.3	0.03
11.5 to 14.7	Silty sand	17.5	.9	-	-
17.7 to 25.3	Sand	18.5	0.8	-	-
25.3 to 25.8	Silt	17.5	1.31	0.3	0.03
25.8 to 40	Sand	18.5	0.8	-	-
>40	Interlayered Silt and Sand	17.5/18.5	1.31/0.8	0.3/-?	0.03/-?

Table 3: Soil Parameters - Settlement Analysis - West Silos

Depth (m)	Soil Unit	Unit Weight (kN/m^3)	Initial Void Ratio, e_0	Coefficient of Compression C_c	Coefficient of Re-compression C_r
0 to 4.5	Sand Fill	18	0.8	-	-
4.5 to 5.5	Clay/Silt	17.5	1.2	0.32	.038
5.5 to 8	Silty sand	18	0.8	-	-
8 to 9	Silt	17.5	1.31	0.3	0.03
9 to 40	Sand	18	0.8	-	-
>40	Interlayered Silt and Sand	17.5/18	1.31/0.8	0.3/-?	0.03/-?

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 General

The boreholes generally encountered asphalt or concrete surfacing overlying sand fill to about 4 to 7m depth followed by native soils comprised of silt to clayey silt/silty clay with interlayered sand to sandy silt to a maximum of about 11m depth followed by silty sand/sandy silt up to a maximum of about 15m depth, and then sand with trace silt to the maximum 38m depth of the CPT. Thickness of compressive silt to clayey silt/silty clay varied from east to west. The thickness of the compressible silt/clay is thicker in the eastern portion of the existing Bekaert Building and thinner in the western portion. The native sands were typically loose to compact to about 10m to 15m depth and then compact below. The measured groundwater table was about 3m below existing ground surface. The groundwater table is expected to fluctuate with season and possibly tide.

The unloading building pit invert depth is shown to be about 5.3m in the tunnel portion with a deepened pit area of about 12.8m depth. Actual excavation depths would be somewhat greater to facilitate installation of a gravel working pad/levelling course and depending on the actual thickness of base slab. Based on the soil and groundwater conditions encountered, the excavations for the pit are expected to extend well below the groundwater table and into loose to compact silty sand to cleaner sand, becoming compact at depth. Therefore, particular attention to construction dewatering, temporary excavation stability, foundation support, and backfilling will be important in the short-term and long-term performance of the structure. Geotechnical considerations regarding these issues are summarized in the following subsections of this report.

Based on the structural loads and existing site conditions, it is understood that a piled foundation system would be more appropriate for the tower structures and a raft foundation for the silos. For the transfer tower structures, 300, 600 and 900 diameter steel pipe piles could be considered.

As discussed above, the site area was determined to have subsurface soil layers that are susceptible to liquefaction under a major earthquake event. This phenomenon is common to areas of Surrey and Richmond (and others) underlain by similar Fraser Delta deposits. Significant lateral and vertical ground displacements (as estimated above) are expected to occur if soil layers beneath the site were to liquefy.

Ground improvement techniques would need to be employed to mitigate liquefaction potential of the proposed silos, transfer tower, bent locations, uploading building, and other project elements. The common practice for densification is the use of vibro-replacement with stone columns. However, even with mitigation of liquefaction for the structures mentioned above, the supporting infrastructure may be rendered unserviceable during a major earthquake. If the Owner is to go forward without densification, then they must accept the risk that all of the proposed structures may experience major damage and be rendered unserviceable following a major earthquake. Some means to potentially reduce liquefaction related impacts can be considered for lighter structure supported structures such as outfitted conveyor bents supported on spread footings and are discussed subsequently in the report.

7.2 Excavation and Dewatering

Based on the groundwater depths encountered at the time of drilling, it appears that the excavation for the rail car uploading building and transfer tower pits will extend well below the groundwater table which was measured at about 3m depth. It appears that the tunnel under the larger silos would also extend below the groundwater table. Based on review of the test hole logs, it appears that below the upper 4 to 5.5 m of existing building floor slab and compact sand fill, the excavation would encounter variable interlayers of silty sand, sandy silt, and silt/clay potentially up to about 6 to 10m below grade, followed by primarily loose to compact sand and silty sand becoming compact at depth. The cleaner sand layers are expected to have a high permeability.

Dewatering will be required to provide a stable excavation base for construction and backfill of the various below grade structures in the dry.

Sheet pile shoring combined with vacuum well point dewatering or deep vertical pumped wells would typically be common for excavation and dewatering in such a situation where the excavation is expected to extend into highly permeable granular deposits and extend up to about 10m below the groundwater table. With such a system, sheet-pile shoring would need to be embedded to sufficient

depth to prevent kick-out of the toe and "blow-out" of the base, combined with internal bracing (struts and walers) for stability.

However, as groundwater contamination is understood to occur at the site, continuous dewatering at high pumping rates with the type of system described above is not desirable for the unloading pit where excavation of up to 14m or more is required. CMC's proposed approach as shown in attached sketch 1419-G-63 for excavation and dewatering is considered to be a reasonable alternative approach under the given circumstances. Based on the attached sketch Option 1, the following steps are understood to be involved in the proposed excavation and dewatering process:

Step One
- Install the sheet pile wall. Sheet pile shoring would need to be embedded to sufficient depth to prevent risk of instability of the excavation base, combined with internal bracing (struts and walers) for lateral support. At least 2m embedment below the bottom of the excavation is recommended.

Step Two
- Excavate soil from enclosed sheet pile area. During excavation maintain inside and outside water level at a same level or inside water level higher than the outside water level.

Step Three
- Install "anchor" piles from the existing ground surface. Anchor piles will act to resist uplift bouncy force on a tremie slab. There will be some shear keys on the pile to interact with the tremie slab.

Step Four
- Pour tremie concrete slab to seal the bottom.

Step Five
- Dewater the contained water from within the sheet pile enclosed excavated area. Sheet pile joints would be welded to seal against leakage.

Step Six
- Cut off the unsupported portion of the anchor piles.

Step Seven
- Pour the concrete for the foundation base slab.

Step Eight
- Pour concrete for the walls.

Two more options are under review and consideration currently. Option 2 is similar to Option 1, with the main difference being use of soil anchors instead of piles. Option 3 would be the use of jet grouted shoring wall and base slab. Details will be developed after finalizing the options.

7.3 Backfill and Structural Backfill

Extraction of temporary sheet piles can cause ground disturbance. If extraction of sheet piles is required for any excavation area, the use of birdseye gravel backfill is recommended to be specified for the entire backfill as it has a greater capability of flowing to fill voids and is less susceptible to disturbance than conventional granular soil backfill. Granular backfill should be placed in lifts and compacted to achieve at least 95% Modified Proctor density (ASTM D 1557). Birdseye gravel should be placed in lifts of no more than 1m and mechanically consolidated using concrete immersion vibrators and supplemented with plate tampers wherever accessible.

7.4 Buoyancy Effect

It was understood that the railway unloading building and other below grade structures would be designed as a sealed and tanked structure. As previously indicated, the unloading building, reclaimed pit and transfer tower pits and tunnel would be established about 4 to 14m below existing ground surface, which would put most of the base well below the groundwater table. As discussed in Section 5.3.3, when designing a tanked structure for static buoyancy, it is recommended that the maximum high groundwater table be assumed at existing ground surface.

As discussed in Section 7.2, the buoyancy force for the deep unloading pit will be temporarily resisted tremie slab concrete with anchor piles. In permanent situation, the weight of the pit in combination with the anchor piles would resist the buoyancy force.

As also pointed out in Section 5.3.3, there is potential for increased buoyancy forces in the event of liquefaction which could cause floatation of the structure. If this consequence is not assessed and accounted for in the design of below grade structures, then the Owner must accept the risk of such an occurrence, along with the other consequences of liquefaction previously discussed.

7.5 Foundation Design and Subgrade Preparation

Based on the discussions with the structural engineer, raft foundation system appears to be the most appropriate for the silos foundation. Further discussion can be found in Section 6 of the report. For foundation design, ultimate axial pile capacity verses embedment depth for different sizes and types (i.e., open ended versus closed ended) of piles can be found in pile capacity graphs in Appendix E. Note that if test piles are completed and achieve set criteria and capacity requirement as confirmed by PDA at shallower depths, then the above mentioned pile embedment could be reduced. In this event, we would recommend maintaining a minimum 15m pile embedment depth.

Helical piles were also considered in the design. Helical piles having 300mm shaft diameter and 9.5mm wall thickness with 600mm helix diameter were assumed. A configuration of three helices at 1m spacing was considered. Table 5 provides capacity of helical screw pile with depth.

Table 4: Calculated Helical Pile Capacity

Shaft Diameter (mm)	Helix Diameter (mm)	Total Embedment (m)	Ultimate Compression (kN)	Ultimate Tension (kN)
300	600	10	520	435
		12	630	540
		15	780	700
		20	1050	950

Recommended resistance factor for compression and tension is 0.45 and 0.35, respectively. Recommended minimum horizontal helical pile spacing in groups is 3 helix diameters.

Possibility of using H piles was also considered in the design. HP350x108 and HP310x94 piles were assessed. Ultimate axial capacity vs depth can be found in Appendix E.

It is assumed that the unloading building, transfer tower pit base slabs and silo foundation would be designed as a reinforced raft slab type foundation which may need extra thickening to resist hydrostatic uplift. In order to provide a stable base, it is recommended that the foundation slab be constructed on a minimum 300mm thick layer of compacted 19mm clear crushed rock underlain by a layer of geotextile fabric such as Nilex 4551 or approved equivalent to act as a filter/separator. The clear crushed rock layer should extend at least 450mm beyond the footprint of the base slab. The sides of the clear crushed rock layer should have birdseye gravel between it and the sheetpile/soil on the side of the excavation and the surface of the clear crushed rock layer should have birdseye gravel between it and any soil backfill to act as a natural filter and allow the free passage of water. Prior to placement of the clear crushed rock layer, the surface of the sand subgrade should be compacted to at least 95% Modified Proctor density within at least the top 300mm.

With the above subgrade preparation, a raft slab type foundation may be designed using an allowable contact pressure of 100 kPa to 150 kPa and a modulus of subgrade reaction of 5 to 10 MN/m^3 for preliminary design. With the anticipated sand subgrade soils and likelihood of a net soil unload condition, any settlement of the unloading building should occur primarily during and shortly after load application, and long-term static settlement from dead load and live loads is expected to be less than 25mm.

Due the environmental constraints, the raft slab may be constructed on top of the existing concrete slab/asphalt. If the existing concrete slab is removed, then the foundation slab should be constructed on a minimum 150mm thick layer of compacted 19mm minus crushed granular base placed on top of compacted existing granular fill.

Grade supported light structures could be supported on footings founded on the existing sand fill soils. Such footings should be designed using a maximum allowable bearing pressure of 75 kPa. Strip and pad footings should have a minimum width of 500mm and 900mm, respectively, and should be embedded at least 450mm below adjacent finished grade for confinement and frost protection. The sand subgrade for the footings should be thoroughly compacted using a large vibratory drum roller to achieve a minimum 95% Modified Proctor maximum dry density within at least the top 300mm. With such preparation, it is anticipated that some differential settlement should be expected due to potential for silt layers beneath the sand fill. Immediate, consolidation and total settlement at different locations of the proposed structures can be found in Appendix F.

It is noted that at grade structures where the base of the structure is founded no greater than 600mm below the existing ground surface elevations do not need to be designed to resist buoyancy/flotation

The lateral surcharge from shallow footings, railway locomotives, container storage, etc. should be taken into account in the design of the below grade walls where applicable.

It is suspected that the estimated horizontal and vertical ground movements which could occur if the sub-soils were to liquefy could potentially cause a structure supported on conventional shallow footings to collapse during a major earthquake. Conventional practice would be to tie the footings together along both axes to significantly reduce the risk of collapse during a design earthquake event. It is considered that punching failure of the footings would be low if they were to be tied together given that the sand fill within the upper 2.5 to 3m above the groundwater table is unlikely to liquefy.

7.6 Lateral Earth Pressure for Foundation Wall Design

Lateral earth pressures for design of foundation walls were evaluated. Recommended design lateral pressures are shown in the Figures 10 to 13 (see Appendix G). In providing the pressure diagram for active pressure conditions, it is assumed that the walls can rotate in the order of 0.005H to 0.01H to mobilize active earth pressure condition, where H is the height of the wall below grade. The seismic component was calculated for both the 475 and 2475 year return period earthquake depending on which is to be considered. As previously discussed, it is recommended that the static case be designed for maximum high groundwater table at the existing ground surface. The seismic case can be designed assuming a groundwater table at 2.5m below existing ground surface.

Effect of lateral pressure on the reclaimed pit/trench wall from the adjacent silo foundation was estimated. Lateral pressure on the reclaimed pit/trench wall can be found in Appendix G (Figure 14).

7.7 Subgrade Review and Testing

Engineering review of subgrade preparation, excavation stability (at an Owner QA level), foundation bearing conditions, backfill materials and procedures, and monitoring and testing of sub-grade and backfill compaction should be carried out by **exp** Services Inc. during the progress of the work. Pile foundation installation will require full-time monitoring by **exp** to document installation procedures, driving resistance blow counts, and final pile set. This will allow for geotechnical aspects of the project to be verified for compliance with the geotechnical recommendations and allow for design changes during construction, as appropriate.

8.0 CLOSURE

Please be advised that the contents of this report are based on preliminary information and drawings provided to us and our understanding of the project as described in this report. **Exp** Services Inc. should be given the opportunity to review final construction plans and make any needed modifications to our geotechnical report to reflect changes in the original design assumptions. If the construction plans change, or if during construction, the soil conditions are noted to differ from those described in this report, **exp** should be notified immediately, and the recommendations regarding the geotechnical aspects of the development should be reviewed and modified, as appropriate.

This report was prepared for the exclusive use of Parrish & Hiembercker Ltd., CMC Engineering and Management Ltd., and their designated consultants/agents and may not be used by other parties without written consent of **exp** Services Inc. The attached “Interpretation & Use of Study and Report” forms an integral part of this report and must be included with any copies of this report.

We appreciate this opportunity to be of service to you. If you have any questions regarding the contents of this report, or if we can be of further assistance to you on this project, please call the undersigned.

Yours truly,

exp Services Inc.

PROFESSIONAL
PROVINCE OF
U. CHAKRABORTY
32226
BRITISH COLUMBIA
ENGINEER

April 03, 2017

Ujjal Chakraborty, P.Eng.
Geotechnical Engineer

Reviewed by:

Ben Weiss, P.Eng.
Senior Geotechnical Engineer

Enclosures:
- Interpretation & Use of Study and Report
- Figure 1 – Test Hole Location Plan
- CMC Engineering and Management Ltd. Sketch 1419-G-63 Temporary Excavation for Unloading Pit
- Appendix A – Test Hole Logs
- Appendix B – CPT Test Results
- Appendix C – Laboratory Test Results
- Appendix D – Response Spectra (Figures 2 to 5), and Results of Liquefaction Assessment (Figures 6 to 9)
- Appendix E – Pile Ultimate Axial Capacity Output
- Appendix F – Settlement Estimate Output
- Appendix G – Lateral Earth Pressure Diagrams (Figures 10 to 14)
- Appendix H - Supplemental Coring Exploration Memo
- Appendix J – 2010 National Building Code Seismic Hazard Value

L:\2014 (Starting at 0216767-A0)\0222989-A0 BW AGEX Pre-Feed Development at Bekaert Building\4.1 General Correspondence\Reports\Final Report\exp RE 2017 03 31 Geo Rpt P&H Fraser Terminal -Final.docx

INTERPRETATION & USE OF STUDY AND REPORT

1. STANDARD OF CARE

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.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT

The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS “APPROVED USERS”. The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report, or any portion thereof, available to any party without our written permission. Any use which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. We accept no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT

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.

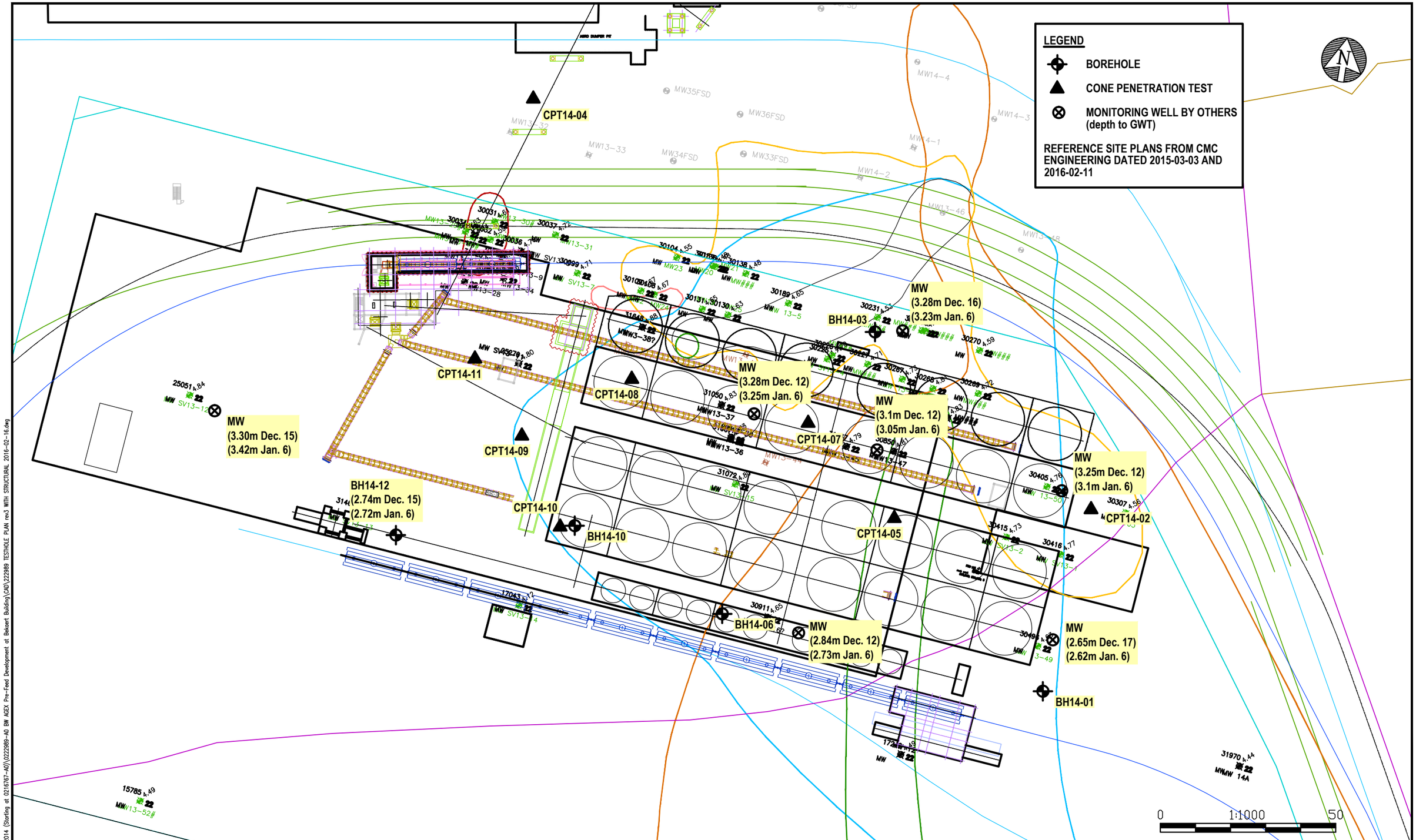
c. To avoid misunderstandings, **exp** Services Inc. (**exp**) should be retained to work with the other design professionals to explain relevant engineering findings and to review their plans, drawings, and specifications relative to engineering issues pertaining to consulting services provided by **exp**. 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.

6.0 ALTERNATE REPORT FORMAT

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**.

The Client recognizes and agrees that electronic files submitted by **exp** have been prepared and submitted using specific software and hardware systems. **Exp** makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.



exp Services Inc.
275–3001 Wayburne Drive
Burnaby, British Columbia V5G 4W3
Telephone: 604–874–1245
Fax: 604–874–2358
exp.com

DFTR.	DSGN.	CHK.
MG	RK	BW

REVISIONS

No.	DESCRIPTION	DATE
3	STRUCTURAL PLAN ADDED	2016-01-12
2	BASE PLAN REPLACED	2015-03-03
1	BASE PLAN REPLACED	2015-02-13

CLIENT: Parrish & Hiembercker Ltd.

PROJECT: Proposed P&H Fraser Terminal
Fraser Surrey Docks, Surrey, BC

PROJECT NO.: VAN-00222989-A0

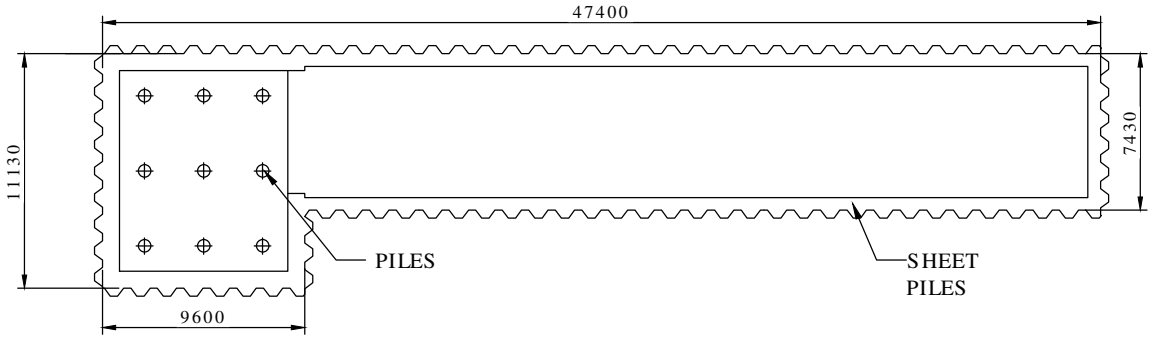
TITLE: TESTHOLE LOCATION PLAN

DATE	SCALE:	DWG NO.
2015-01-07	1:1000	FIGURE 1

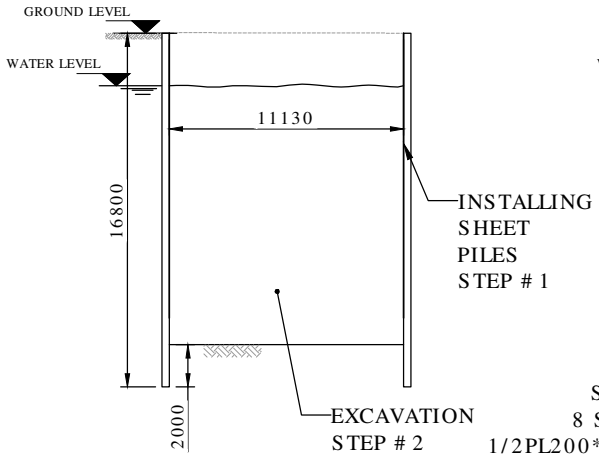
Feb 12, 2016 – 11:12am L:\2014 (Starting at 0216767–A0)\0222989–A0 BW AGSX Pre–Feed Development at Bekaert Building\CAD\222989 TESTHOLE PLAN rev3 WITH STRUCTURAL 2016–02–16.dwg

NOTE:

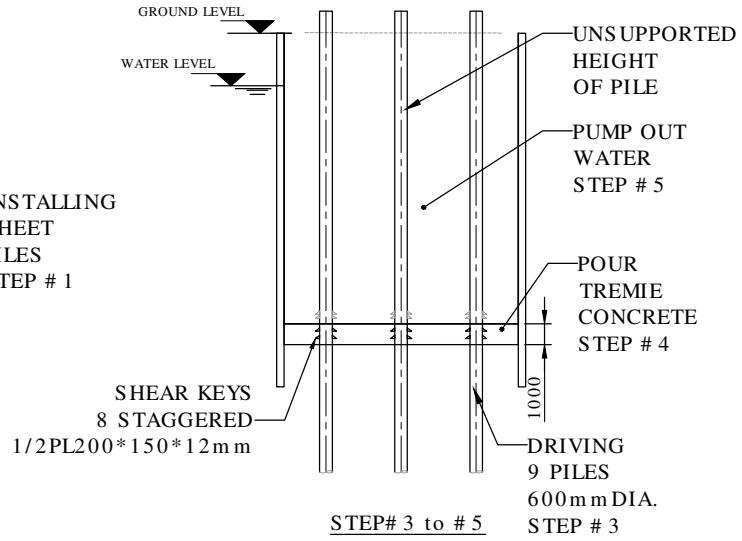
-DURING EXCAVATION WATER TABLE INSIDE THE PIT SHOULD BE SAME OR HIGHER THAN THE SURROUNDING NATURAL GROUND WATER TABLE.



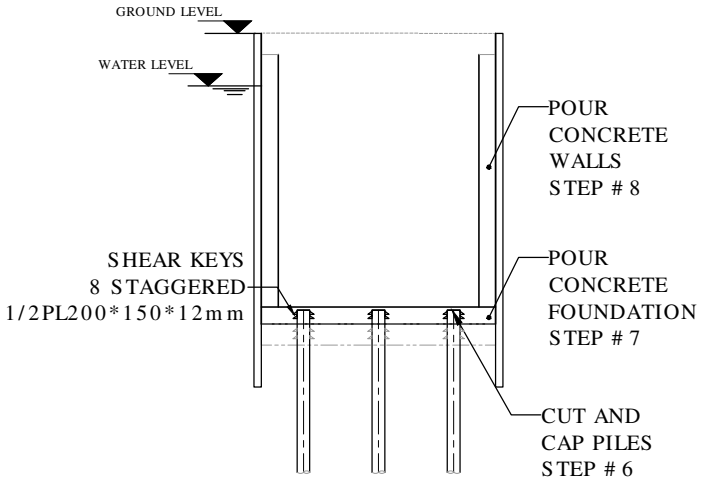
SHEET PILES AND FOUNDATION PLAN



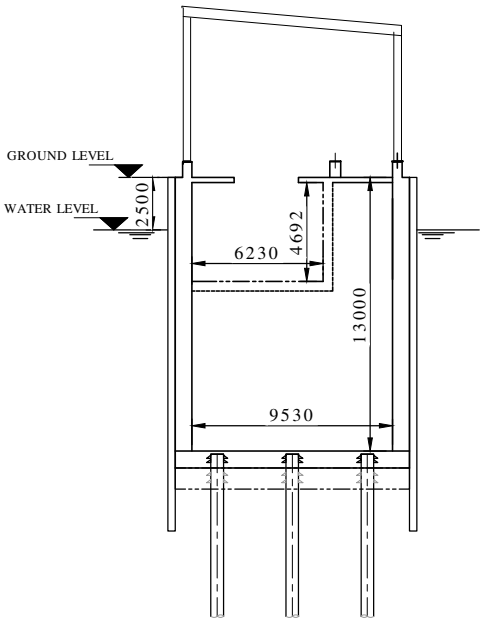
STEP# 1 & # 2



STEP# 3 to # 5



STEP# 6 TO # 8



COMPLETED SECTION OF BUILDING

CMC ENGINEERING AND MANAGEMENT LIMITED
300-1180 DOUGLAS ROAD, BURNABY, BC, CANADA V5C 4Z6
TELEPHONE: (604) 294-0483 FAX: (604) 294-0487

SKETCH 1419-G-63

Appendix A

Test Hole Logs

BH14-01, -03, -06, -10 -12

RECORD OF BOREHOLE : BH14-01

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-16 to 2014-12-17
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 2.6m (Dec. 17)
▼ **AFTER DRILLING** 2.6m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m ⌇ (20 40 60 80)	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		25mm Asphalt							
		SAND and GRAVEL, trace silt, brownish grey, damp (FILL)	0.1	S01 S02					3
		SAND, trace silt, brown, damp, fine to medium grained (compact to loose) (FILL)	0.3						
1								10	
				S03	SPT				
2									
		▼ - becomes grey and wet						7	
				S04	SPT				
3									
4								5	220
		SILT, some clay to clayey, grey, firm to stiff	4.0	S06 S05 S07	SPT				48 90
		- 0.2m thick peat organic silt layer at 4.3m							
5		FV > 50 kPa (initial), too stiff for remoulded		S08	ST				42
		- SILT, some organics						5	
		SAND, some silt to silty, grey, wet (loose)	5.5	S09	SPT				50
6									
7								6	
		- becomes interlayered organic silt and sand below 7.3m		S10	SPT				55
8									
								7	
9				S11	SPT				50
10								13	
		- becomes SAND, trace silt, grey, wet, fine grained (compact)		S12	SPT				30
11									
		- silt content decreases to none						10	
12				S13	SPT				

(Continued Next Page)

RECORD OF BOREHOLE : BH14-01

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-16 to 2014-12-17
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 2.6m (Dec. 17)
▼ **AFTER DRILLING** 2.6m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY %	SAMPLES POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m ⌇ (20 40 60 80)	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		SAND, trace silt, grey, wet, fine to medium grained (loose)							
13									
		- silt content increases to some (becomes loose)		S14	SPT			7 ▲	
		- at least 150mm of woody organics							
14									
		- trace of silt and gravel (becomes compact)		S15	SPT			21 ▲	
15									
16									
17									
18		- 50mm layer of organics		S16	SPT			12 ▲	
19									
20									
21				S17	SPT			21 ▲	

Bottom of hole at 21.3m.

RECORD OF BOREHOLE : BH14-03

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-15 to 2014-12-16
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 3.3m (Dec. 16)
▼ **AFTER DRILLING** 3.2m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m ⌇ (20 40 60 80)	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		38mm Asphalt layer	0.0	S01	GB				● 4
		GRAVEL and SAND, brown (compact) (FILL)	0.2	S02	GB				
		SAND, trace silt and gravel, brown, damp (compact to loose) (FILL)							
1		- becomes grey, moist - gravel content decreases to none		S03	SPT			▲ 10	
2									
3		- becomes brownish grey		S04	SPT			▲ 9	
		▼	3.0						
4		No Recovery		S05	SPT			▲ 6	
5									
6		SILT, trace to some sand, some clay, grey, plastic (soft to firm)	5.5	S06	SPT			▲ 6	● 39
				S07	ST			▲ 3	
7		SAND, some silt to silty, grey (very loose)	6.6						
		SILTY SAND to SANDY SILT interlayers, grey (loose/firm) - becomes some organics	7.0	S08	SPT			▲ 4	● 43
8									
9		SAND, trace silt to some silt in interlayers, grey, wet (loose)	8.5	S09	SPT			▲ 6	● 37
10		- becomes SAND, trace silt, grey, wet, fine to medium grained (compact)		S10	SPT			▲ 12	□ 10
11									
12				S11	SPT			▲ 12	

(Continued Next Page)

RECORD OF BOREHOLE : BH14-03

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-15 to 2014-12-16
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 3.3m (Dec. 16)
▼ **AFTER DRILLING** 3.2m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY %	SAMPLES POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m ⌇ (20 40 60 80)	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		SAND, trace silt, grey, wet, fine to medium grained (compact)							
13									
		- 100mm peat inclusion at 13.3m		S12	SPT			9 ▲	103 ●
14									
15		- some gravel below 15m		S13	SPT			15 ▲	
16									
17									
18		- gravel content becomes none		S14	SPT			15 ▲	
19									
20									
21				S15	SPT			16 ▲	

Bottom of hole at 21.3m.

RECORD OF BOREHOLE : BH14-06

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-11 to 2014-12-12
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: **AT TIME OF DRILLING** 2.8m (Dec. 12)
AFTER DRILLING 2.7m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m / DYNAMIC CONE BLOWS/0.3m	FINES CONTENT (%) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT (PL, MC, LL)
		177mm Concrete Slab with ~6mm void below		S01	GB				3
		GRAVELLY SAND, brown, dry, subangular gravel (FILL)	0.2						
		SAND, some fine gravel, dry, fine to medium grained (compact) (FILL)	0.5	S02 S03	SPT			24 14	
1		- gravel conent becomes none		S04	SPT				
		- becomes damp							
2									
		- becomes wet (compact to loose)		S05	SPT			10	
3									
4								8	
				S06	SPT				
5									
		CLAYEY SILT, grey, wet (soft)	5.5	S07	SPT			3	59
6									
7								5	
		SILT, some sand to sandy (firm)	7.0	S08	SPT				50
8									
		SILT with fine sand, trace to some organics, grey, non-plastic (firm)	8.5	S09	SPT			5	44
9									
		FV = 48 kPa (initial), 2 kPa (remoulded)		S10	ST				
10									
		SILTY SAND, grey, wet, sand is fine grained (loose)	10.1	S11	SPT			5	47
		SAND, some silt, with fiberous organics/peat	10.5						
11		Interlayered SILTY SAND and ORGANICS and CLAYEY SILT, trace fine sand (firm) FV > 50 kPa (initial), too stiff for remoulded	10.6	S12	ST				
		SILTY SAND, some organics, grey, wet (compact)	11.6					10	
12		- Organics content decreases to none below 11.8m	11.6	S13	SPT				63

(Continued Next Page)

RECORD OF BOREHOLE : BH14-06

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-11 to 2014-12-12
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 2.8m (Dec. 12)
▼ **AFTER DRILLING** 2.7m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	FINES CONTENT (%) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT (PL MC LL) (20 40 60 80)
		SILTY SAND, some organics, grey, wet (compact) *(continued)*							
13									
				S14	SPT			16	
14									
		SAND, trace silt and gravel, grey, wet, fine grained (compact)	14.6						
15				S15	SPT			16	
16									
				S16	SPT			22	6
17									
18				S17	SPT			14	
19									
				S18	SPT			13	
20									
21		- sand becomes fine to medium grained		S19	SPT			15	
22									
				S20	SPT			19	
23									
24				S21	SPT			22	

(Continued Next Page)

RECORD OF BOREHOLE : BH14-06

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-11 to 2014-12-12
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 2.8m (Dec. 12)
▼ **AFTER DRILLING** 2.7m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY %	SAMPLES POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m ⌇ (20 40 60 80)	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		SAND, trace silt and gravel, grey, wet, fine grained (compact) *(continued)*							
25									
		CLAYEY SILT, wet, grey (firm to stiff)	25.3	S22	SPT			8 ▲	32 ●
				S23	SPT				29 ●
26		SAND, grey, wet, fine grained (compact)	25.8						
27		- becomes some to trace silt		S24	SPT			14 ▲	30 ●
		- organics lense							
28									
		Interlayered SILTY SAND and SILT (compact/stiff)	28.3	S25	SPT			12 ▲	33 ●
29		SAND, trace silt, grey, wet, sand is fine grained (dense)	28.7	S26	SPT			31 ▲	32 ●
30									

Bottom of hole at 30.5m.

RECORD OF BOREHOLE : BH14-10

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-17 to 2014-12-17
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Solid Stem Auger to 7.6m, Mud Rotary below
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 3.3m inferred
▼ **AFTER DRILLING** ---

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m ⌇ (20 40 60 80)	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		140mm CONCRETE SLAB							
		SAND, trace silt, brown, dry, fine to medium grained (FILL)	0.1						
1				S01	GB				
		- becomes damp to moist							
2									
				S02	GB				
3									
		▽ - becomes wet							
		- siilt content becomes trace to some		S03	GB				9
4									
5									
				S04	GB				5
6									
		- 25mm organic lense							
		- 100mm organic lense		S05	GB				48
7		- 152mm organic lense							
		SILT, trace clay to clayey, grey, moist, plastic	7.3	S06	GB				46
8				S07	ST				43
		FV > 50 kPa (initial), 15 kPa (remoulded)							
9									
				S08	SPT			3	40
10									
		SILT, some organics to orgnic silt, trace silt, grey, wet, firm	10.1						
		SAND, some silt to silty, grey, wet (loose to compact)	10.2						
		- 50mm SILT lense						10	
11				S09	SPT				

Bottom of hole at 11.3m.

RECORD OF BOREHOLE : BH14-12

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-12 to 2014-12-15
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 2.7m (Dec. 15)
▼ **AFTER DRILLING** 2.7m (Jan. 6)

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	FINES CONTENT (%) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT (PL MC LL) (20 40 60 80)
		190mm Concete Slab (No rebar found)		S01	GB				
		SAND, trace silt, brown, damp, fine to medium grained (compact to loose) (FILL)	0.2						
1				S02	SPT			11	
2									
3		- becomes wet - silt content becomes trace to some		S03	SPT			8	
4		- silt content becomes trace		S04	SPT			8	6
5									
6		SILT, some sand to sandy, grey, wet, fine to medium grained (firm to stiff)	5.5	S05	SPT			4	40
7		- 127mm layer of SILT, some sand to sandy, some organics		S06	SPT			9	35
8									
9		SILTY SAND, grey wet, loose - organics content becomes some - No recovery	8.5	S07	SPT			4	37
				S08	ST				
10		SAND, some silt, grey, wet, fine grained sand (loose to compact)	10.1	S09	SPT			7	36
11									
12		- Silt content decreases to trace		S10	SPT			10	8

(Continued Next Page)

RECORD OF BOREHOLE : BH14-12

exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-12 to 2014-12-15
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK **CHECKED BY** BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF DRILLING** 2.7m (Dec. 15)
▼ **AFTER DRILLING** 2.7m (Jan. 6)

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	FINES CONTENT (%) (20 40 60 80) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT (PL MC LL 20 40 60 80)
		SAND, some silt, grey, wet, fine grained (compact)							
13									
		- Silt content decreases to trace to some		S11	SPT			14	
14									
		- Silt content decreases to trace, becomes fine to medium grained with trace fine gravel (compact)		S12	SPT			18	
15									
16									
				S13	SPT			19	
17									
		- Silt content increases some silt to silty		S14	SPT	75		20	
18									
19									
		- Silt content decreases to trace to some silt		S15	SPT			15	
20									
		- trace silt		S16	SPT			24	
21									

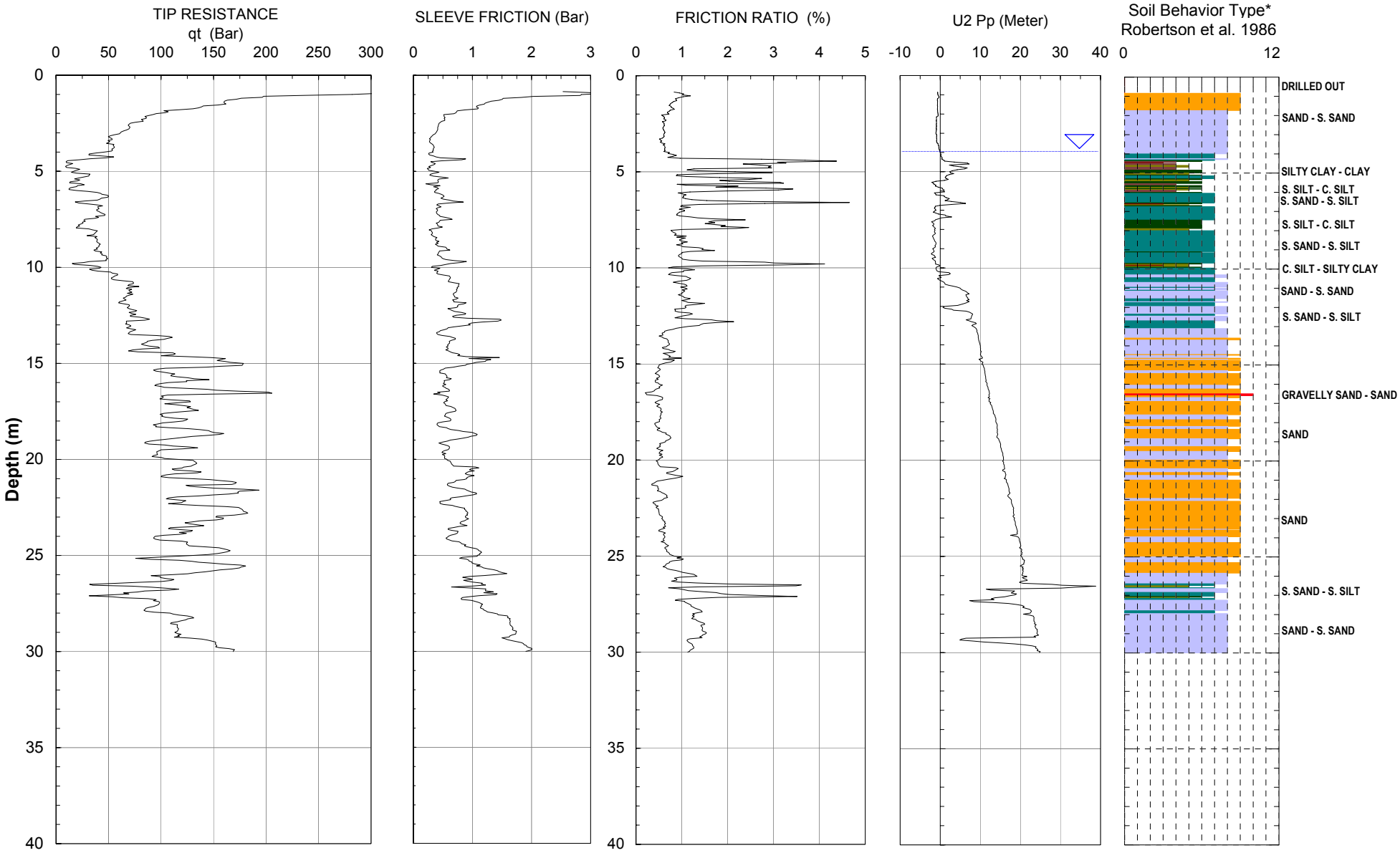
Bottom of hole at 21.3m.

Appendix B

CPT Test Results

Operator: Schwartz Soil Technical
Sounding: CPT14 - 02
Cone Id: DPG1236 10 Ton

Date: December 9 - 11, 2014
Site: Bekaert, F.S.D.
Exp Project No: 222989



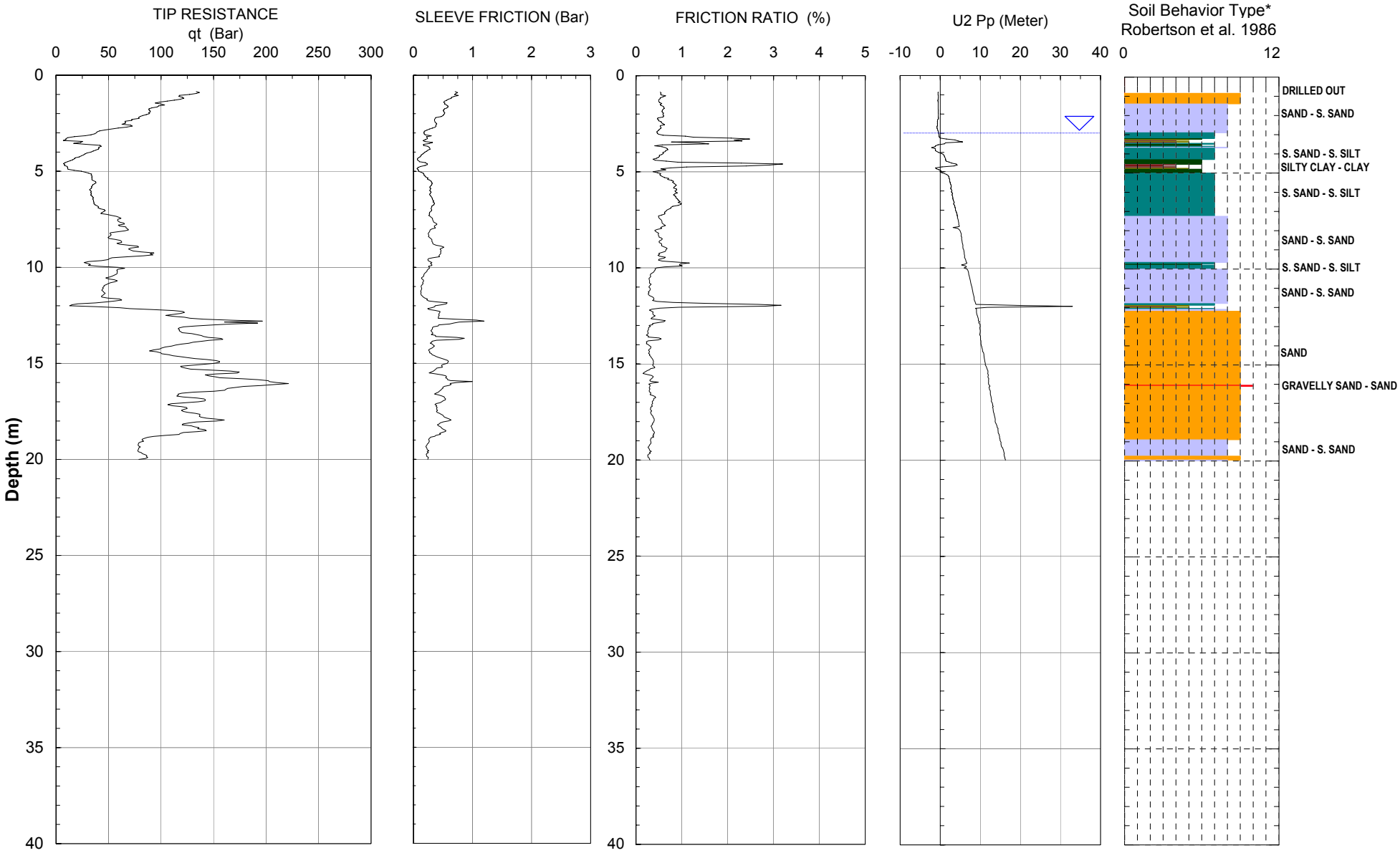
Maximum Depth = 30.00 meter

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Operator: Schwartz Soil Technical
Sounding: CPT14 - 04
Cone Id: DPG1236 10 Ton

Date: December 9 - 11, 2014
Site: Bekaert, F.S.D.
Exp Project No: 222989



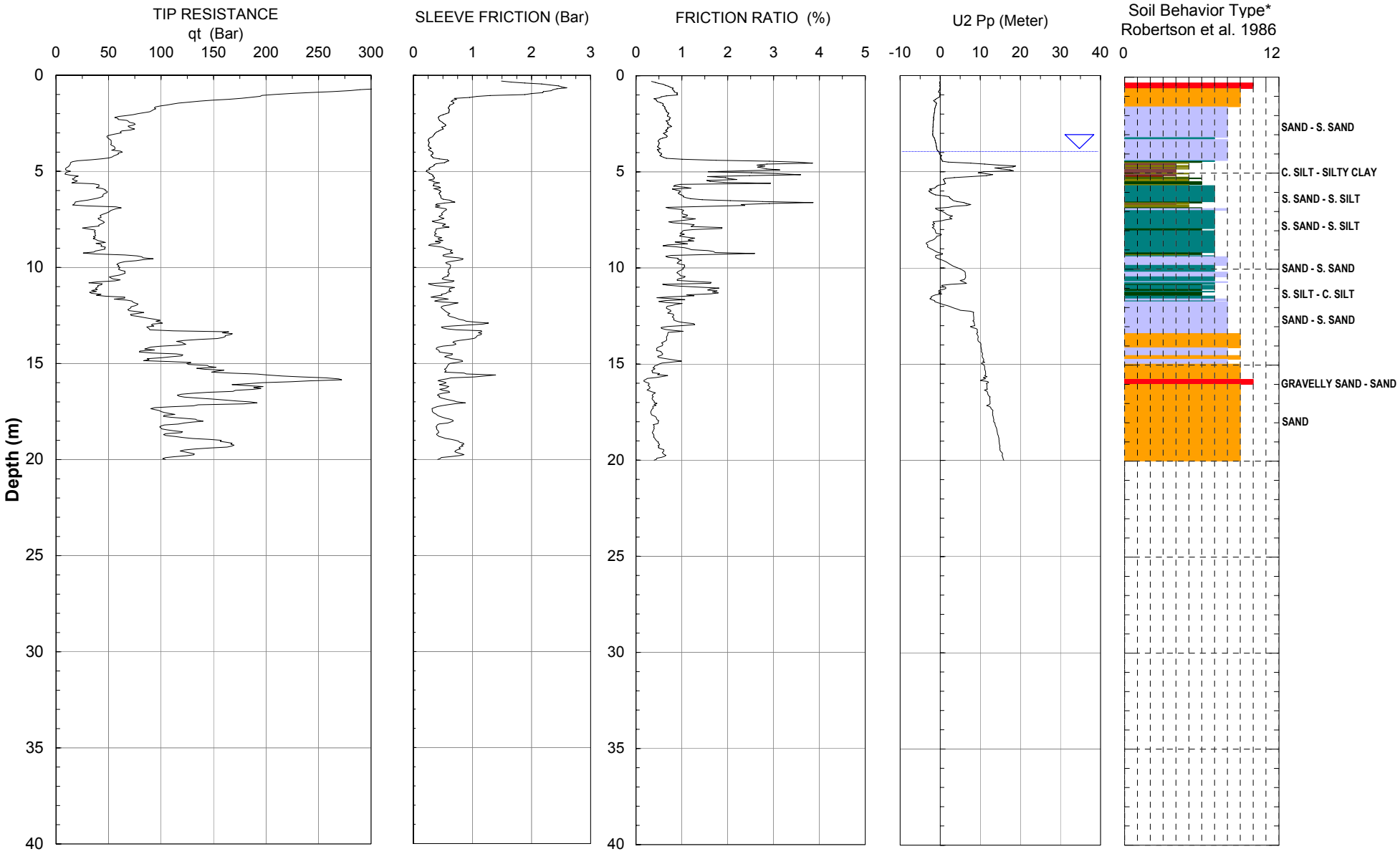
Maximum Depth = 20.00 meter

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Operator: Schwartz Soil Technical
Sounding: CPT14 - 05
Cone Id: DPG1236 10 Ton

Date: December 9 - 11, 2014
Site: Bekaert, F.S.D.
Exp Project No: 222989



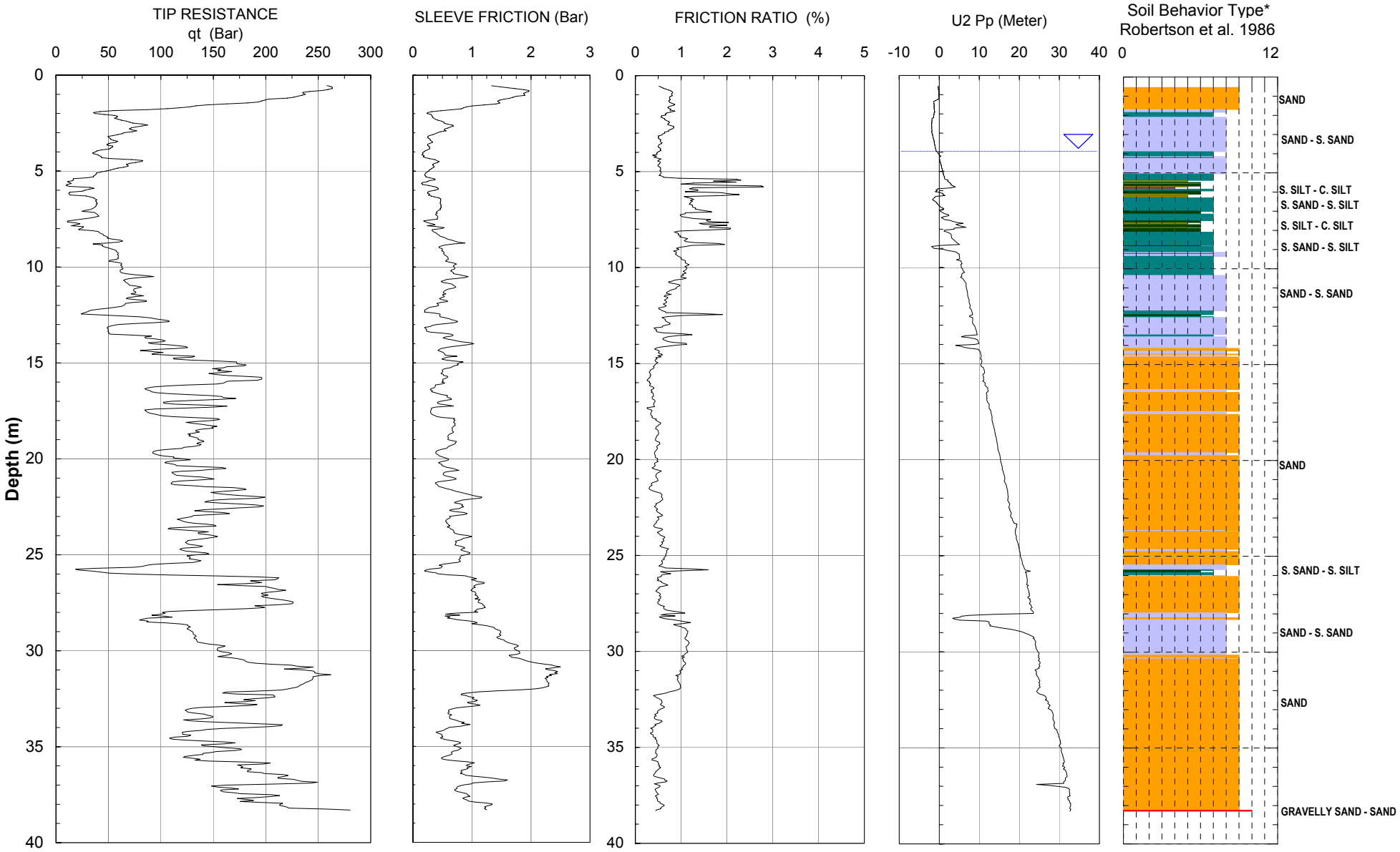
Maximum Depth = 20.00 meter

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Operator: Schwartz Soil Technical
Sounding: CPT14 - 07
Cone Id: DPG1236 10 Ton

Date: December 9 - 11, 2014
Site: Bekaert, F.S.D.
Exp Project No: 222989



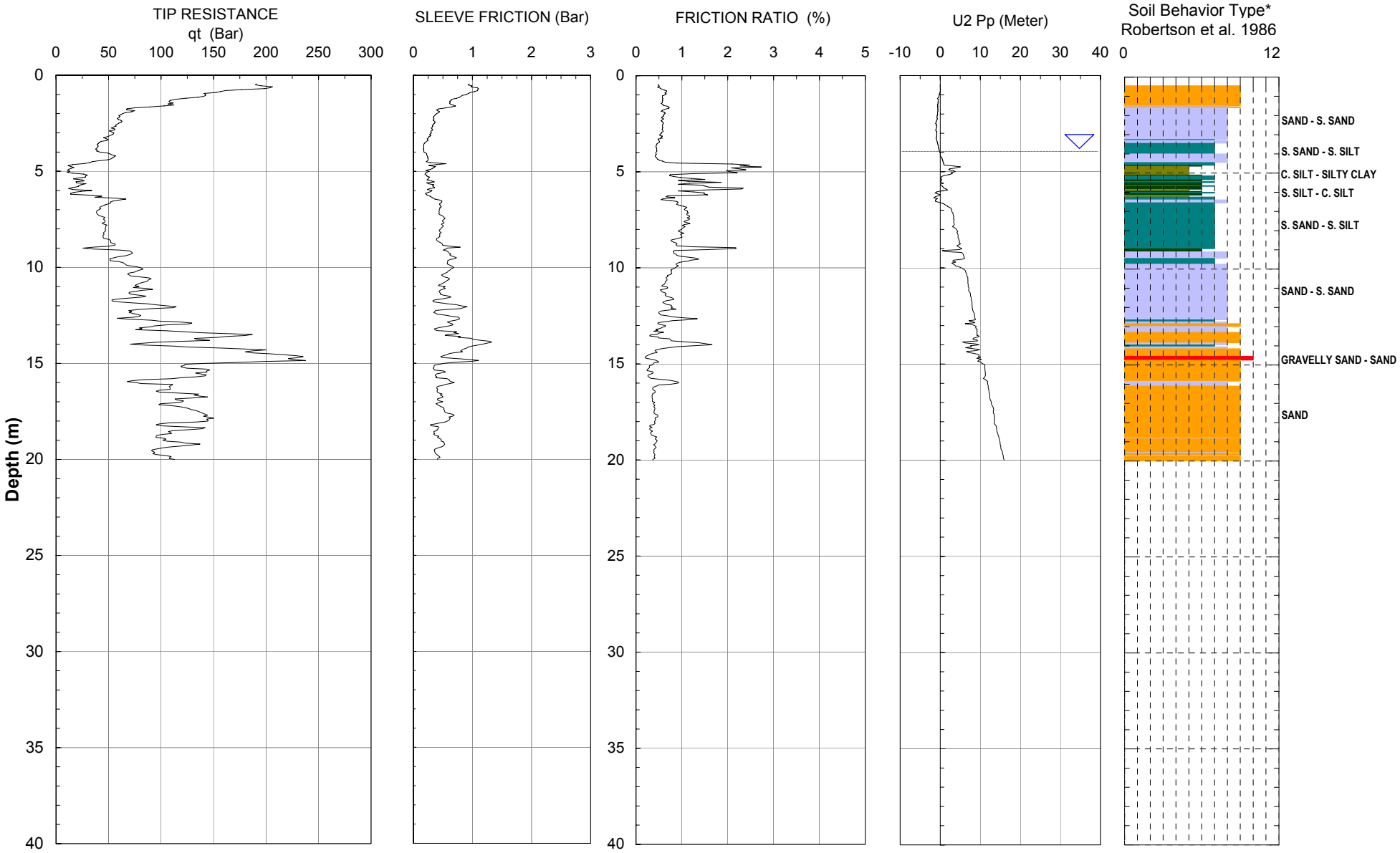
Maximum Depth = 38.30 meter

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Operator: Schwartz Soil Technical
Sounding: CPT14 - 08
Cone Id: DPG1236 10 Ton

Date: December 9 - 11, 2014
Site: Bekaert, F.S.D.
Exp Project No: 222989



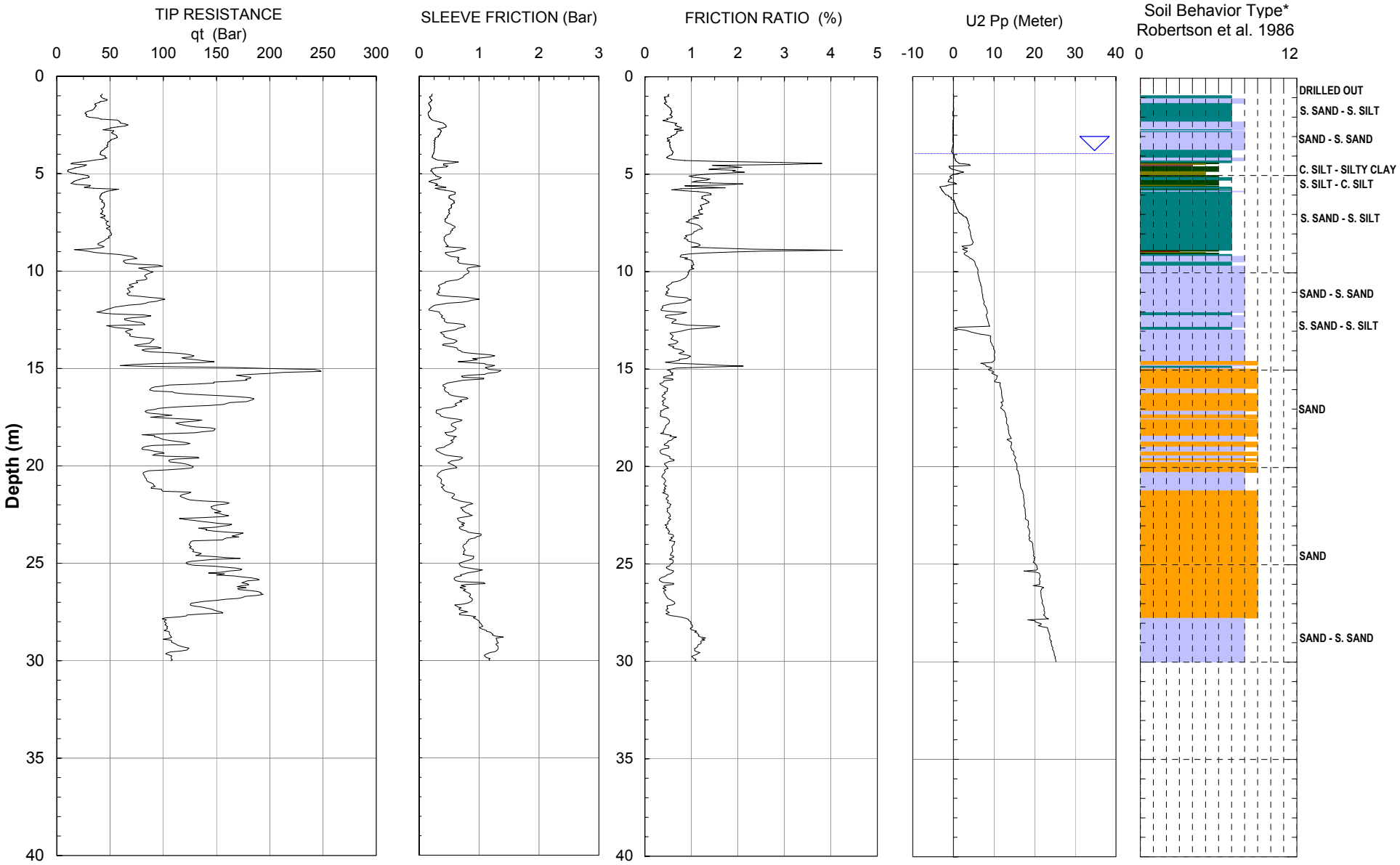
Maximum Depth = 20.00 meter

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Operator: Schwartz Soil Technical
Sounding: CPT14 - 09
Cone Id: DPG1236 10 Ton

Date: December 9 - 11, 2014
Site: Bekaert, F.S.D.
Exp Project No: 222989



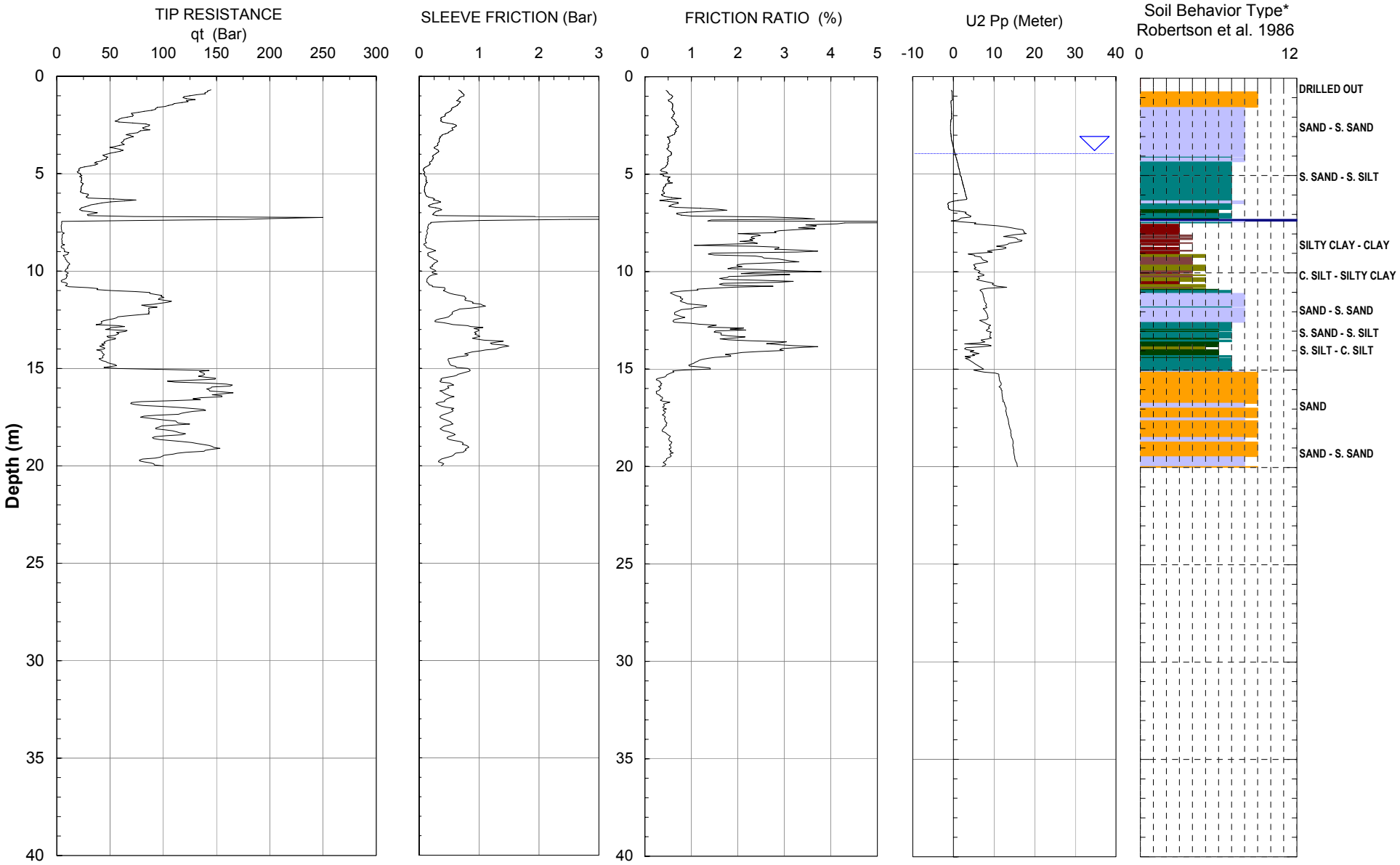
Maximum Depth = 30.00 meter

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Operator: Schwartz Soil Technical
Sounding: CPT14 - 10
Cone Id: DPG1236 10 Ton

Date: December 9 - 11, 2014
Site: Bekaert, F.S.D.
Exp Project No: 222989



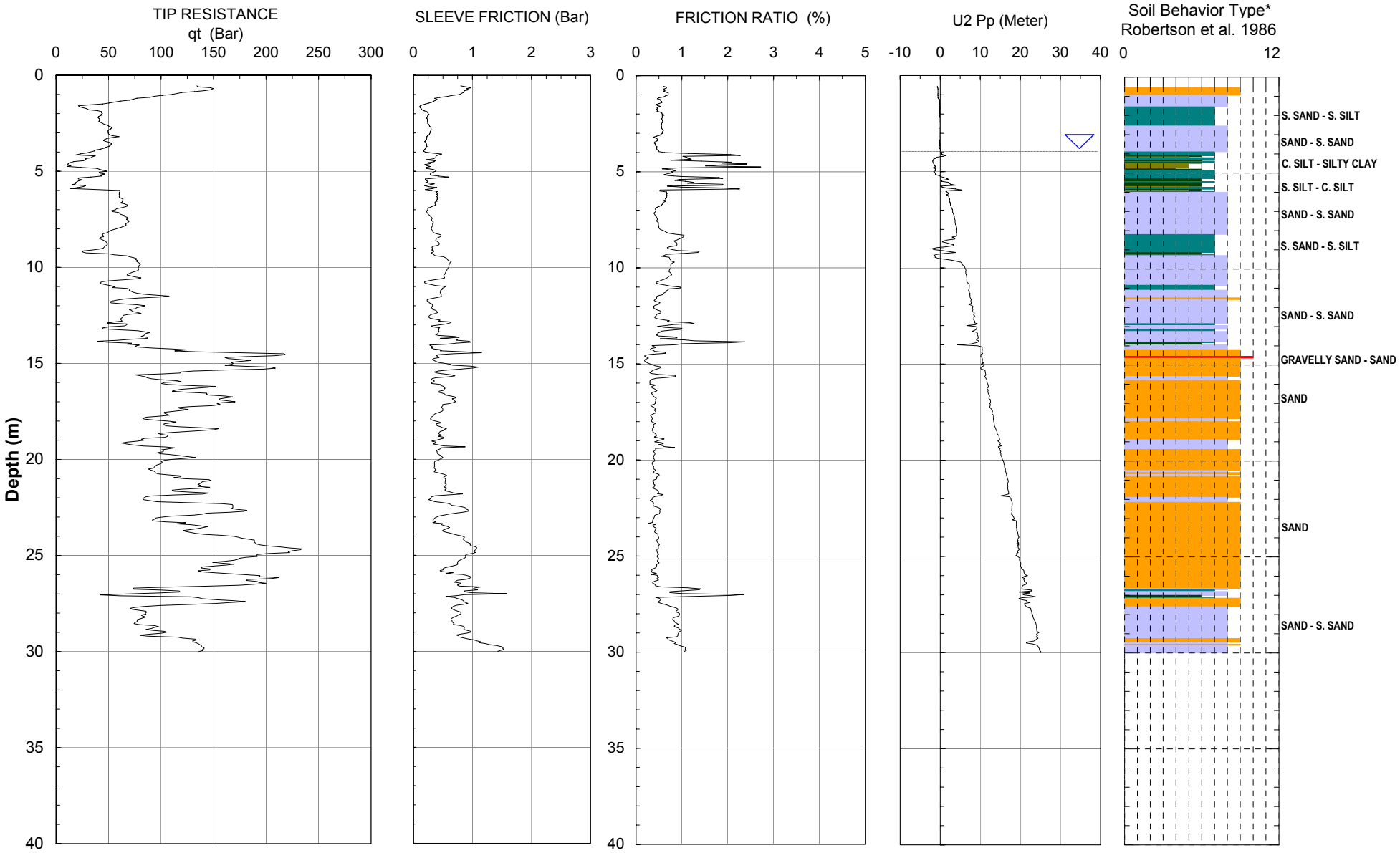
Maximum Depth = 20.00 meter

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Operator: Schwartz Soil Technical
Sounding: CPT14 - 11
Cone Id: DPG1236 10 Ton

Date: December 9 - 11, 2014
Site: Bekaert, F.S.D.
Exp Project No: 222989



Maximum Depth = 30.00 meter

Depth Increment = 0.05 meters

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Appendix C

Laboratory Test Results

Sieve Analysis Reports
Test No. 1 to 6

Atterberg Limits
3 Tests

Consolidation Test Results
3 Sheets

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
250-372-5321

CERTIFIED TESTING LABORATORY

SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

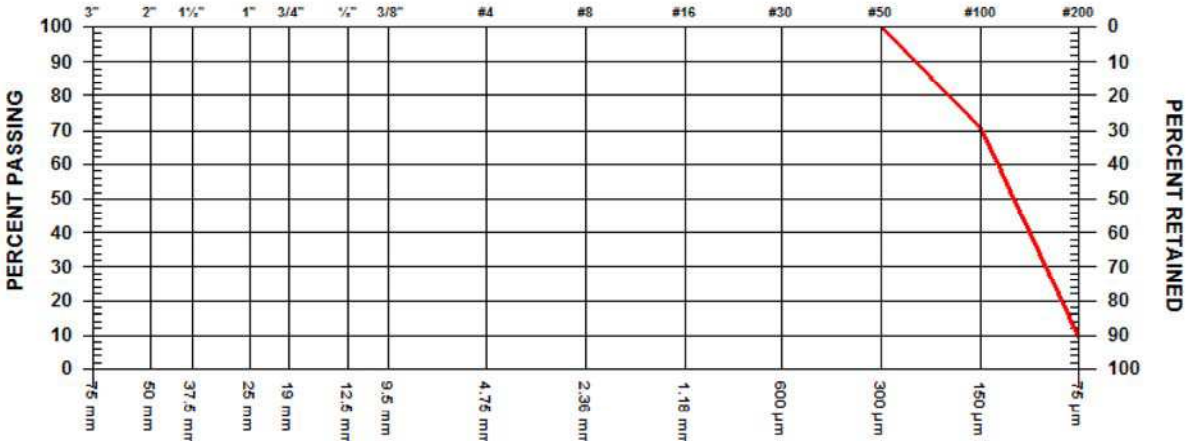
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 1 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 16,2014

SUPPLIER SITE
SOURCE TH14-03, SPT @ 33'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT

SAMPLED BY R. KORHONEN
TESTED BY H. WU
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm		
No. 8	2.36 mm		
No. 16	1.18 mm		
No. 30	600 µm	100.0	
No. 50	300 µm	99.9	
No. 100	150 µm	70.6	
No. 200	75 µm	9.6	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
250-372-5321

CERTIFIED TESTING LABORATORY

SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

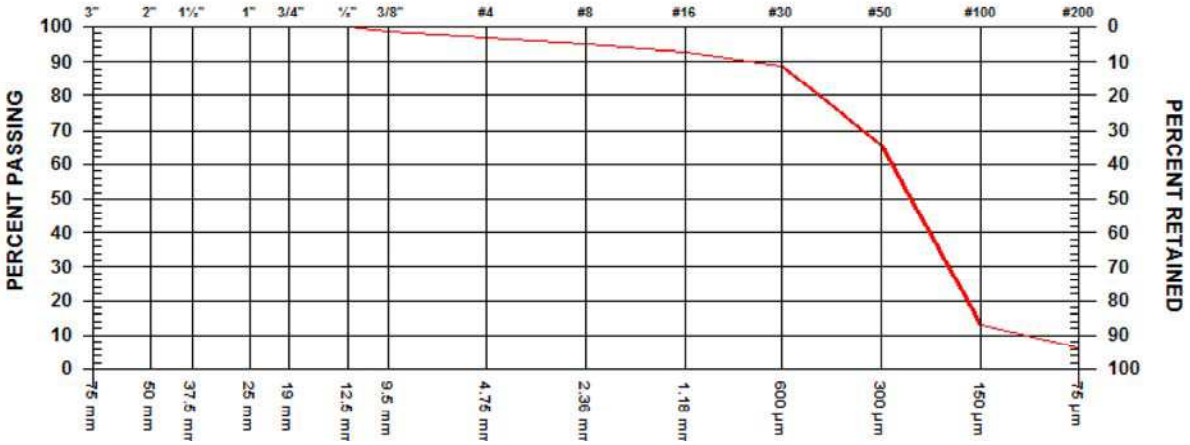
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 2 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 15,2014

SUPPLIER SITE
SOURCE TH14-06, SPT @ 53'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT, TRACE GRAVEL

SAMPLED BY R. KORHONEN
TESTED BY L. JEAN, AScT
TEST METHOD WASHED



GRAVEL SIZES			PERCENT PASSING	GRADATION LIMITS
3"	75	mm		
2"	50	mm		
1 1/2"	37.5	mm		
1"	25	mm		
3/4"	19	mm		
1/2"	12.5	mm	100.0	
3/8"	9.5	mm	98.5	

SAND SIZES AND FINES			PERCENT PASSING	GRADATION LIMITS
No. 4	4.75	mm	96.8	
No. 8	2.36	mm	95.0	
No. 16	1.18	mm	92.7	
No. 30	600	µm	88.7	
No. 50	300	µm	65.9	
No. 100	150	µm	12.9	
No. 200	75	µm	6.1	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
250-372-5321

CERTIFIED TESTING LABORATORY

SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

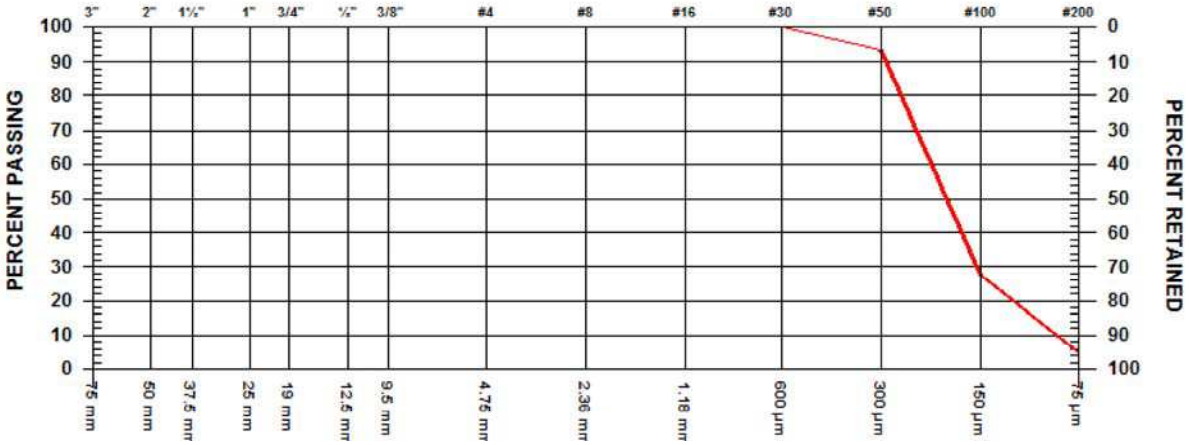
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 3 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 17,2014

SUPPLIER SITE
SOURCE TH14-10, SPT @ 17'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT

SAMPLED BY R. KORHONEN
TESTED BY L. JEAN, AScT
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm		
No. 8	2.36 mm		
No. 16	1.18 mm	100.0	
No. 30	600 µm	99.8	
No. 50	300 µm	93.4	
No. 100	150 µm	27.7	
No. 200	75 µm	4.8	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
250-372-5321

CERTIFIED TESTING LABORATORY

SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

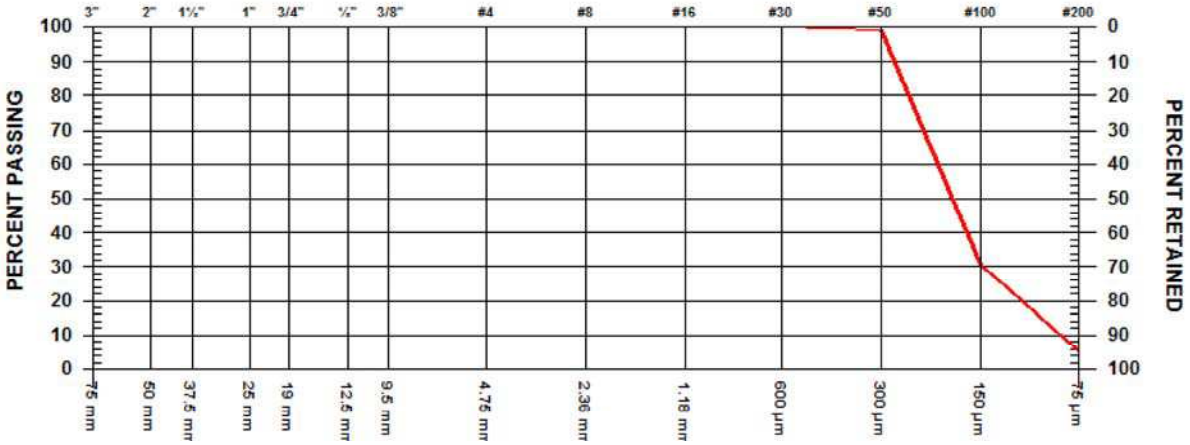
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 4 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 15,2014

SUPPLIER SITE
SOURCE TH14-12, SPT @ 13'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT

SAMPLED BY R. KORHONEN
TESTED BY L. JEAN, AScT
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm		
No. 8	2.36 mm		
No. 16	1.18 mm	100.0	
No. 30	600 µm	99.9	
No. 50	300 µm	98.9	
No. 100	150 µm	30.7	
No. 200	75 µm	5.5	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
250-372-5321

CERTIFIED TESTING LABORATORY

SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

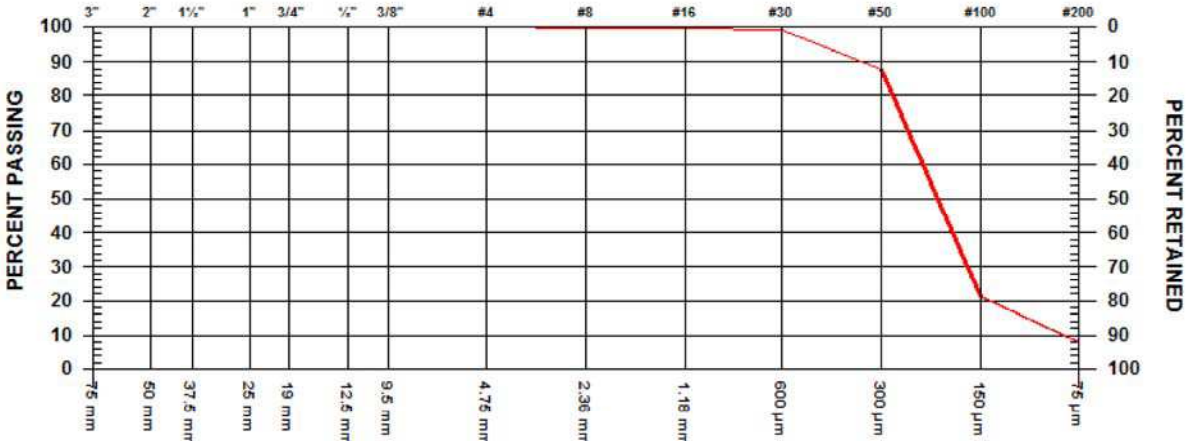
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 5 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 15,2014

SUPPLIER SITE
SOURCE TH14-12, SPT @ 38'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT, TRACE GRAVEL

SAMPLED BY R. KORHONEN
TESTED BY L. JEAN, AScT
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	100.0	
No. 8	2.36 mm	99.6	
No. 16	1.18 mm	99.5	
No. 30	600 µm	99.0	
No. 50	300 µm	88.0	
No. 100	150 µm	21.3	
No. 200	75 µm	8.0	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
250-372-5321

CERTIFIED TESTING LABORATORY

SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

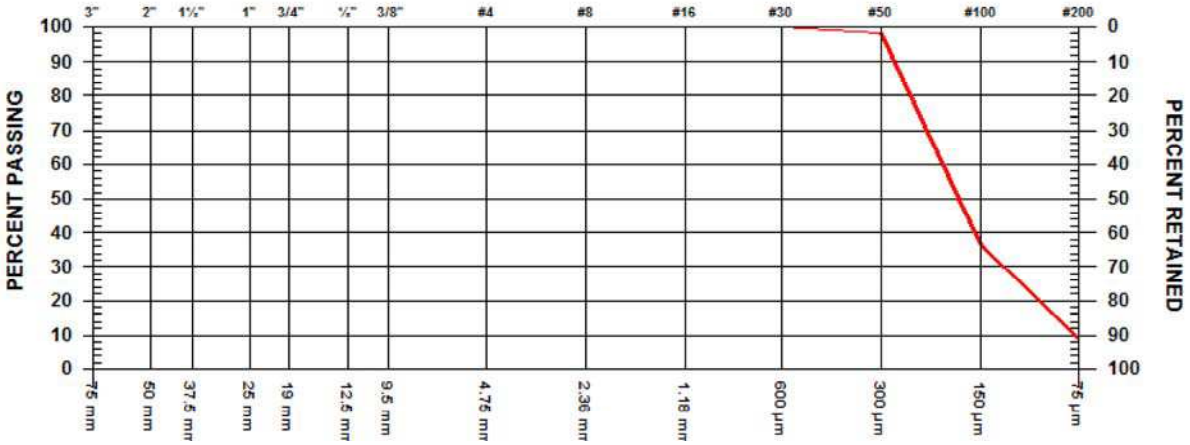
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 6 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 17,2014

SUPPLIER SITE
SOURCE TH14-10, SPT @ 12.5'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT

SAMPLED BY R. KORHONEN
TESTED BY H. WU
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm		
No. 8	2.36 mm	100.0	
No. 16	1.18 mm	99.9	
No. 30	600 µm	99.8	
No. 50	300 µm	98.4	
No. 100	150 µm	36.7	
No. 200	75 µm	9.1	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp Services Inc.
Parrish and Heimbecker Ltd.

Atterberg Limits ASTM D4318
AGEX Pre-Feed Development at
Bekaert Building
Fraser Surrey Docks

VAN-00222989-A0
January 06, 2015

(1)
Sample Source: BH1 @ 16.5'
Sample ID: grey clay

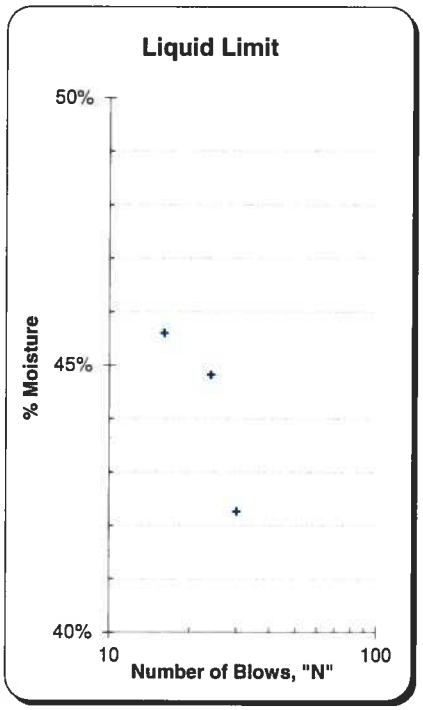
Liquid Limit Determination

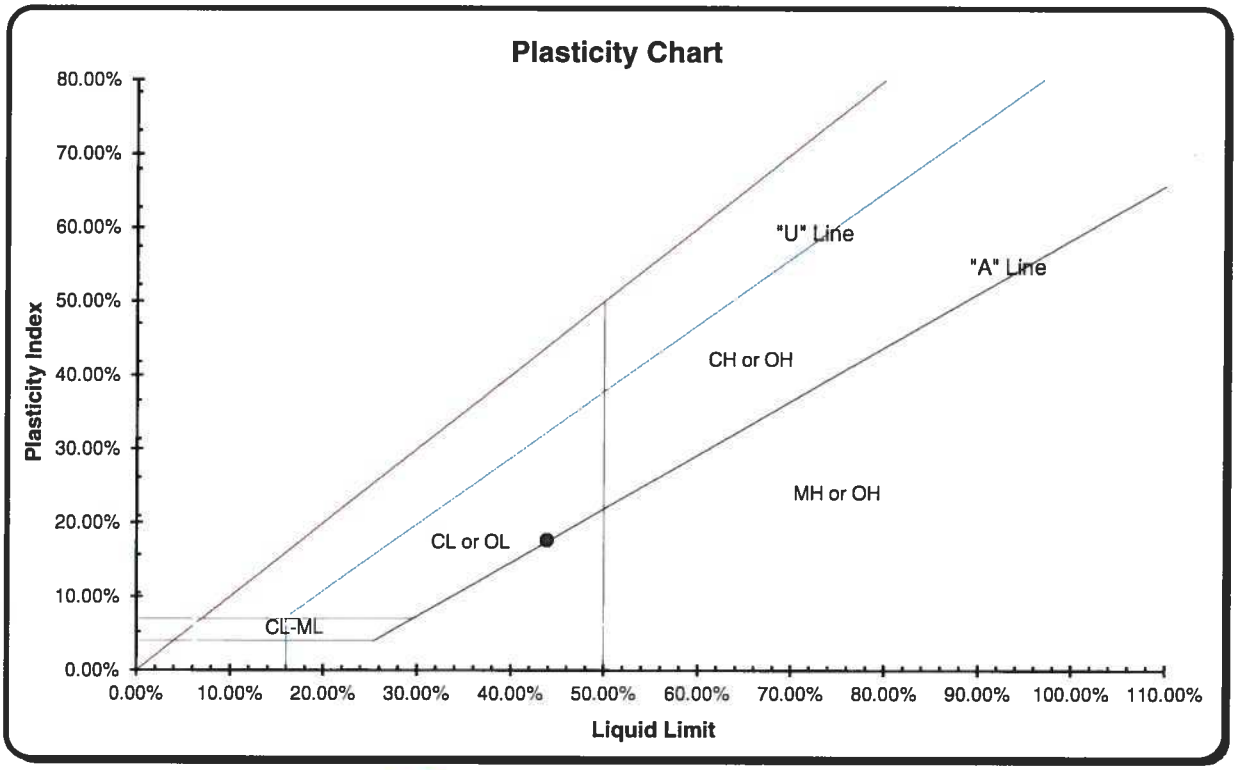
	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	27.09	20.90	104.17			
Weight of Dry Soils + Pan:	23.62	17.96	101.41			
Weight of Pan:	16.01	11.40	94.88			
Weight of Dry Soils:	7.61	6.56	6.53			
Weight of Moisture:	3.47	2.94	2.76			
% Moisture:	45.60%	44.82%	42.27%			
N:	16	24	30			

Liquid Limit @ 25 Blows:	43.85%
Plastic Limit:	26.20%
Plasticity Index, I_P:	17.65%
Moisture Content, M_C:	41.50%

Plastic Limit Determination

	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	98.88	103.25				
Weight of Dry Soils + Pan:	97.05	100.96				
Weight of Pan:	90.05	92.24				
Weight of Dry Soils:	7.00	8.72				
Weight of Moisture:	1.83	2.29				
% Moisture:	26.14%	26.26%				





Reported by: Kevin Bowyer, CTech

Reviewed by: Brian Gray, AScT

exp Services Inc.
Parrish and Heimbecker Ltd.

Atterberg Limits ASTM D4318
AGEX Pre-Feed Development at
Bekaert Building
Fraser Surrey Docks

VAN-00222989-A0
January 06, 2015

(2)
Sample Source: BH3 @ 21.5'
Sample ID: grey clay silt

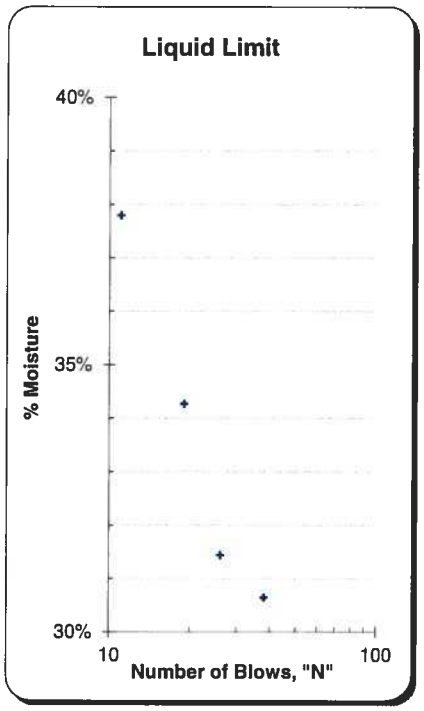
Liquid Limit Determination

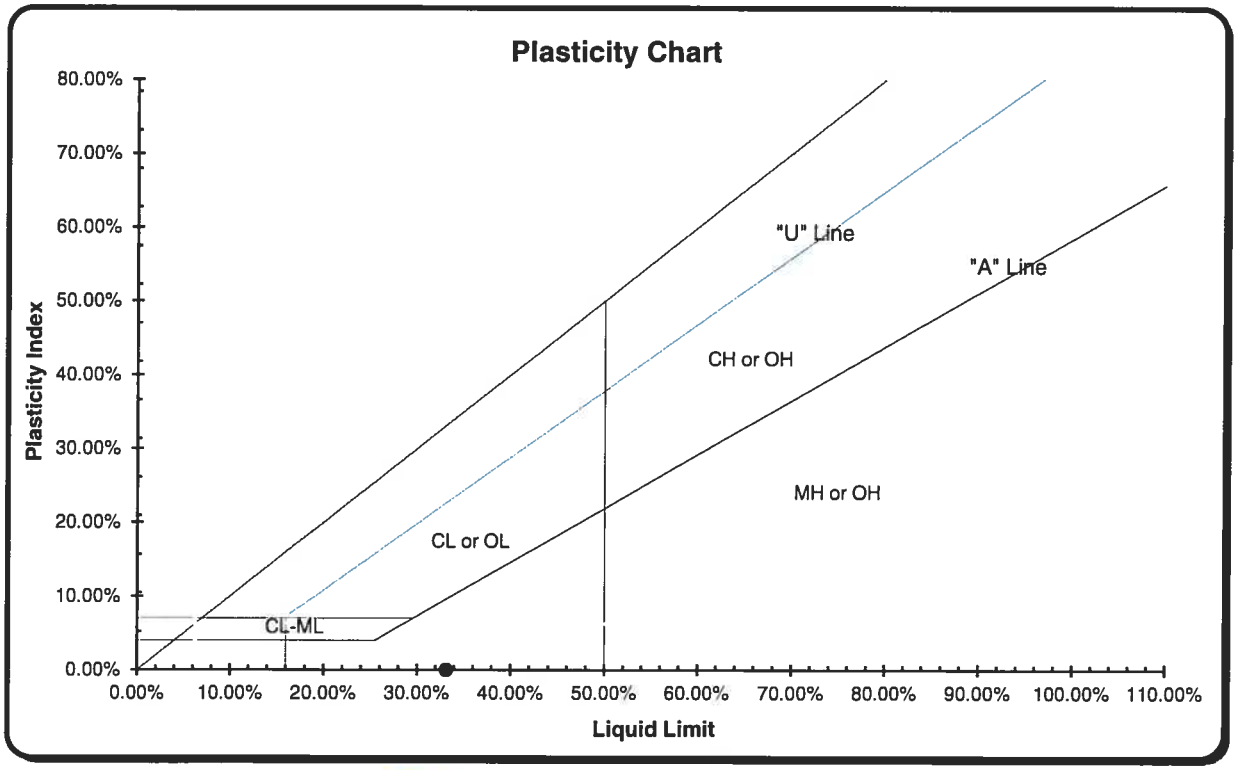
	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	99.17	107.77	106.14	102.16		
Weight of Dry Soils + Pan:	95.55	104.84	103.81	99.04		
Weight of Pan:	85.97	96.29	96.40	88.86		
Weight of Dry Soils:	9.58	8.55	7.41	10.18		
Weight of Moisture:	3.62	2.93	2.33	3.12		
% Moisture:	37.79%	34.27%	31.44%	30.7 %		
N:	11	19	26	38		

Liquid Limit @ 25 Blows: 33.14%
Plastic Limit: N/A
Plasticity Index, I_P: N/A
Moisture Content, M_C: 42.20%

Plastic Limit Determination

	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:						
Weight of Dry Soils + Pan:						
Weight of Pan:						
Weight of Dry Soils:						
Weight of Moisture:						
% Moisture:						





Reported by: Kevin Bowyer, CTech

Reviewed by: Brian Gray, AScT

exp Services Inc.
Parrish and Heimbecker Ltd.

Atterberg Limits ASTM D4318
AGEX Pre-Feed Development at
Bekaert Building
Fraser Surrey Docks

VAN-00222989-A0
January 06, 2015

(3)
Sample Source: BH10 @ 27'
Sample ID: grey clay

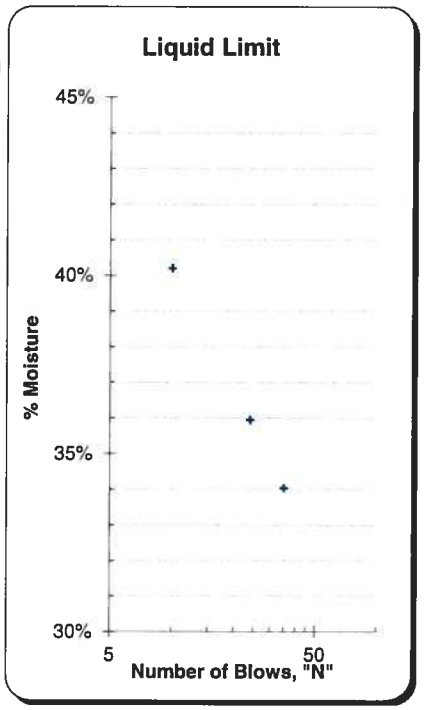
Liquid Limit Determination

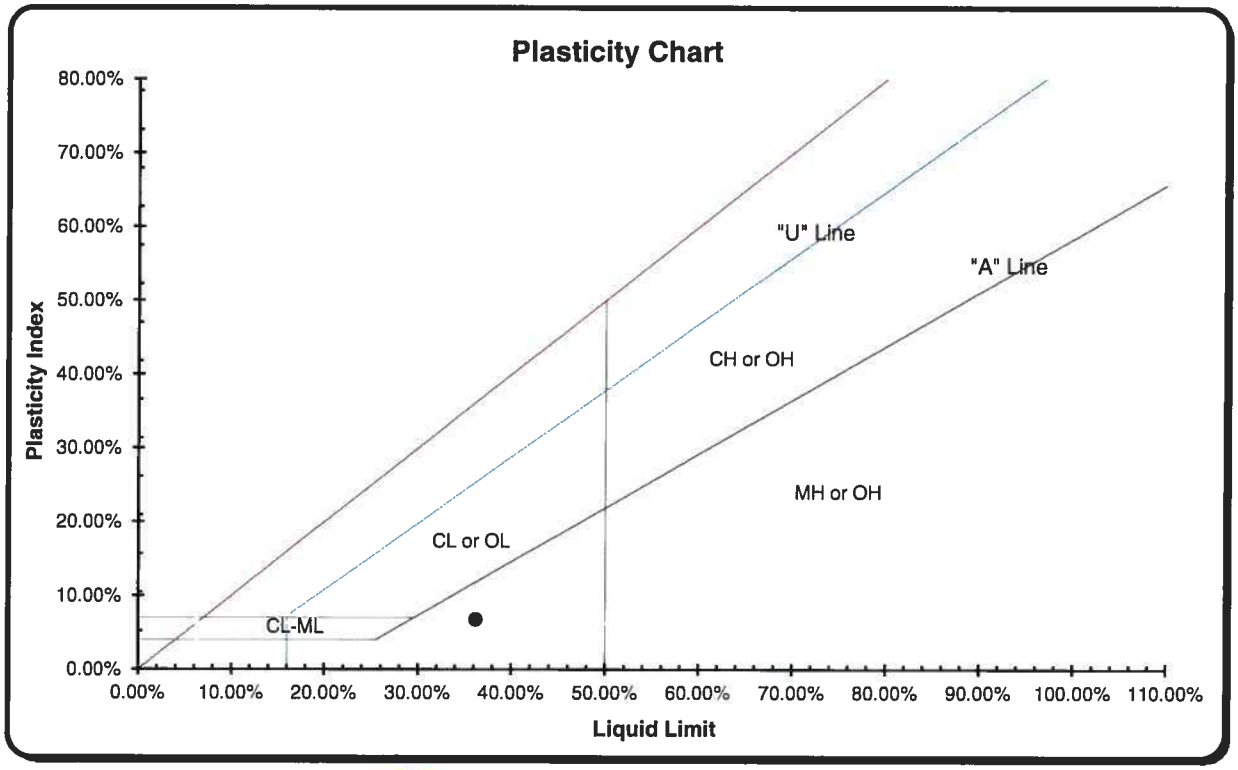
	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	20.34	103.47	103.21			
Weight of Dry Soils + Pan:	17.94	100.81	100.65			
Weight of Pan:	11.97	93.41	93.13			
Weight of Dry Soils:	5.97	7.40	7.52			
Weight of Moisture:	2.40	2.66	2.56			
% Moisture:	40.20%	35.95%	34.04%			
N:	10	24	35			

Liquid Limit @ 25 Blows: 36.23%
Plastic Limit: 29.42%
Plasticity Index, I_P: 6.81%
Moisture Content, M_C: 43.40%

Plastic Limit Determination

	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	110.41	107.07				
Weight of Dry Soils + Pan:	107.64	104.42				
Weight of Pan:	98.27	95.37				
Weight of Dry Soils:	9.37	9.05				
Weight of Moisture:	2.77	2.65				
% Moisture:	29.56%	29.28%				





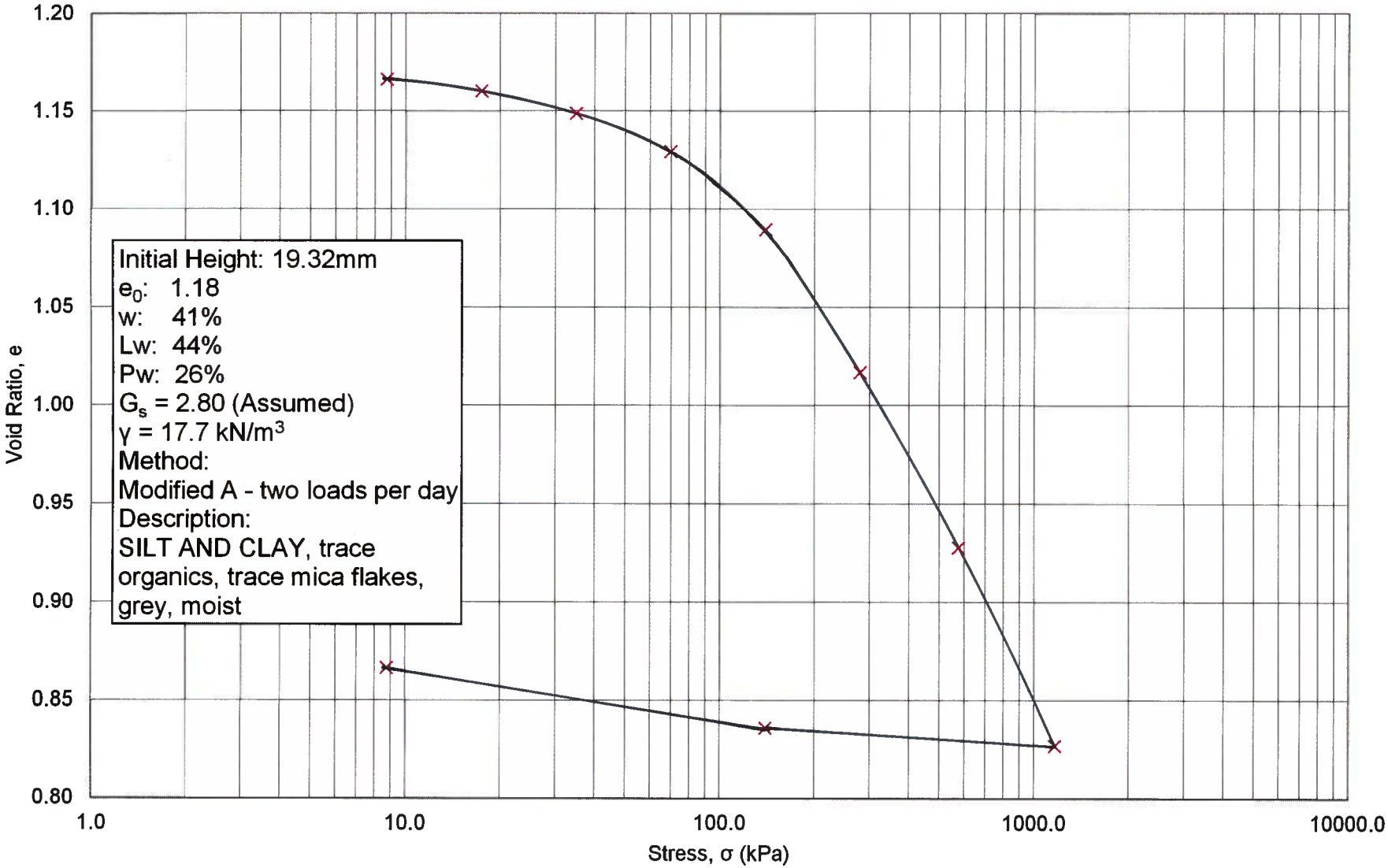
Reported by: Kevin Bowyer, CTech

Reviewed by: Brian Gray, AScT

VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

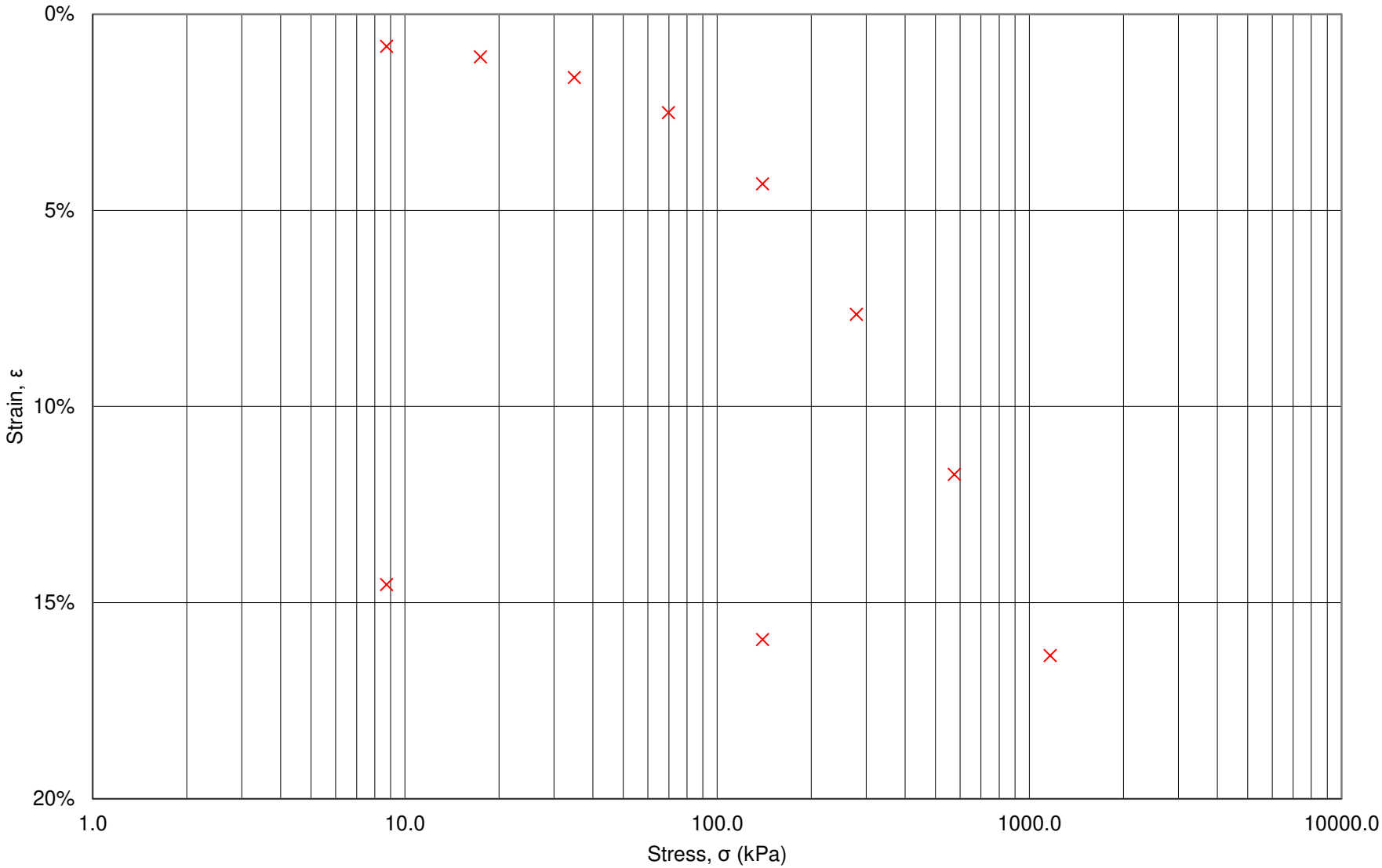
BH14-01, 5.03m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Strain v. Applied Stress

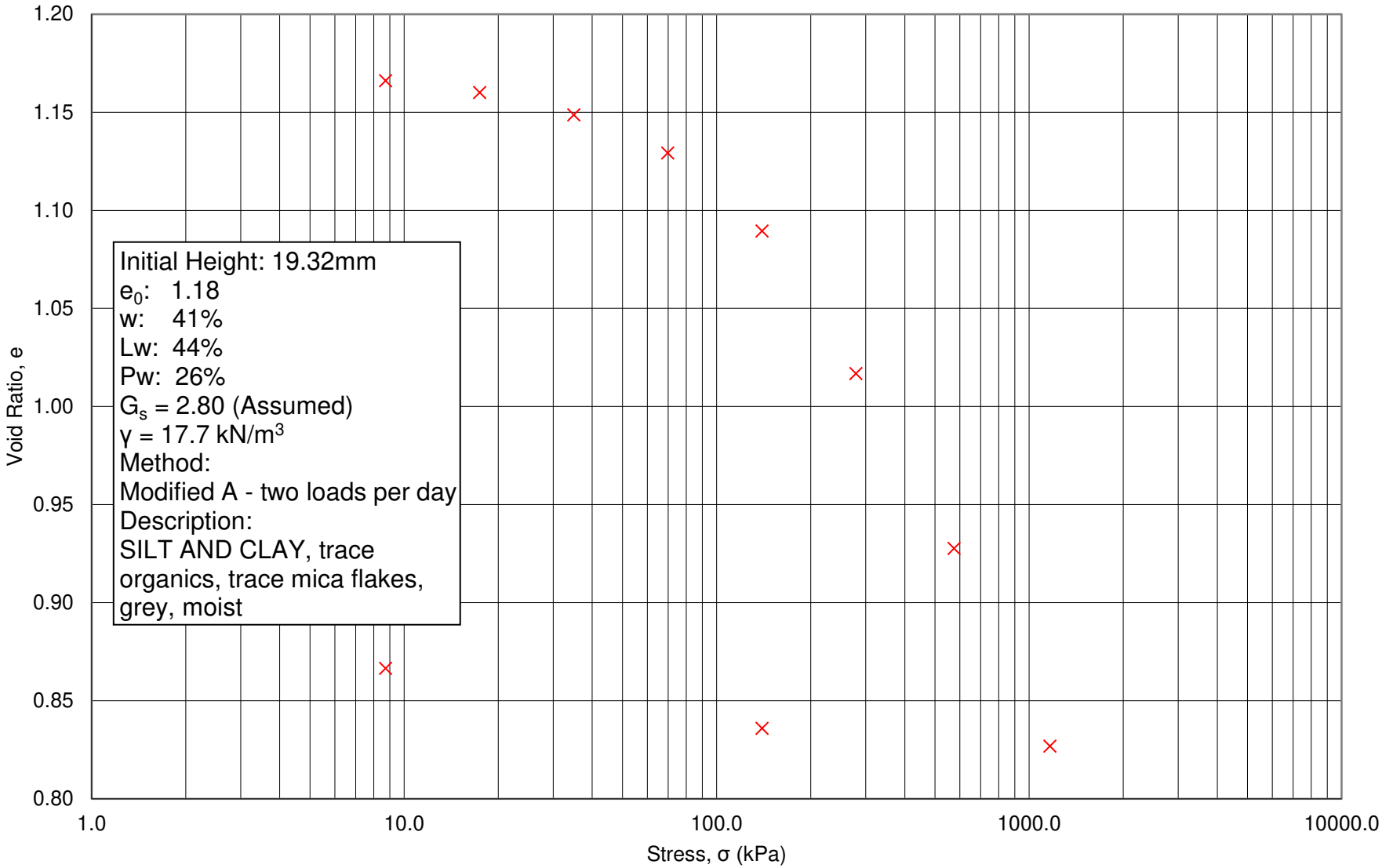
BH14-01, 5.03m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

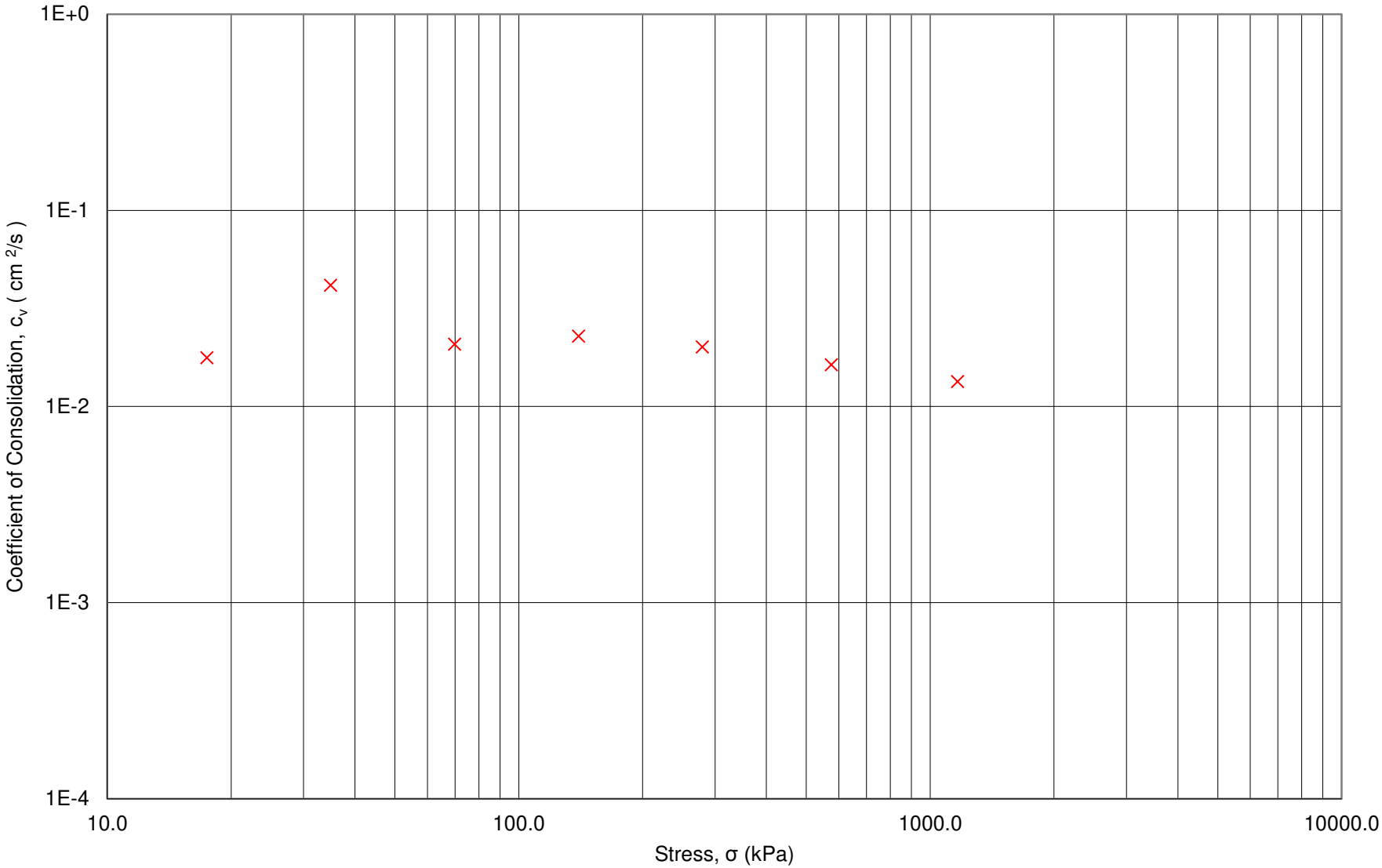
BH14-01, 5.03m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Coefficient of Consolidation v. Applied Stress

BH14-01, 5.03m



VAN-0222989-A0
2015-01-15 SCD

Consolidation Data Sheet

BH14-01, 5.03m

Sample Dimensions	
H_o =	19.32 mm
D_o =	63.36 mm
A =	31.53 cm²
V_o =	60.92 cm³
G_s =	2.80
H_s =	8.85 mm

Moisture Content of Specimen	(Initial)	(End)
Wet Soil + Tare	244.76 g	385.41 g
Dry Soil + Tare	212.94 g	359.61 g
Water	31.82 g	25.80 g
Tare	134.84	281.97 g
Wet Soil	109.92 g	103.44 g
Dry Soil	78.10 g	77.64 g
w(%)	40.74%	33.23%
Saturation	0.96	

Moisture Content of Cuttings			
Tare #	114	79	134
Wet Soil + Tare	280.79 g	292.68 g	304.56 g
Dry Soil + Tare	243.78 g	250.17 g	259.08 g
Water	37.01 g	42.51 g	45.48 g
Tare	150.27 g	149.04 g	147.11 g
Wet Soil	130.52 g	143.64 g	157.45 g
Dry Soil	93.51 g	101.13 g	111.97 g
w(%)	39.58%	42.04%	40.62%

Total Load (kg)	Pressure (kPa)	Correction (mm)	Deformation* (mm)	delta-H (mm)	Strain %	H (H_o - delta-H)	$H-H_s$	e $(H-H_s)/H_s$	t_{90} (min) for Cv	Cv (cm^2/s)
			0	0.000	0.0%	19.32	10.474	1.18		
0.375	8.7	0.000	0.159	0.159	0.8%	19.161	10.315	1.17	0.25	5.23E-02
0.75	17.5	0.002	0.213	0.212	1.1%	19.109	10.262	1.16	0.73	1.77E-02
1.5	34.9	0.011	0.323	0.313	1.6%	19.007	10.161	1.15	0.31	4.14E-02
3.0	69.8	0.020	0.505	0.485	2.5%	18.835	9.989	1.13	0.61	2.07E-02
6.0	139.8	0.031	0.867	0.836	4.3%	18.484	9.637	1.09	0.54	2.28E-02
12.0	279.6	0.043	1.522	1.479	7.7%	17.841	8.994	1.02	0.58	2.01E-02
24.7	575.8	0.061	2.328	2.267	11.7%	17.053	8.206	0.93	0.66	1.63E-02
50.1	1167.4	0.069	3.229	3.159	16.4%	16.161	7.314	0.83	0.73	1.34E-02
6.0	139.8	0.031	3.110	3.080	15.9%	16.241	7.394	0.84		
0.375	8.7	0.000	2.809	2.809	14.5%	16.511	7.665	0.87		

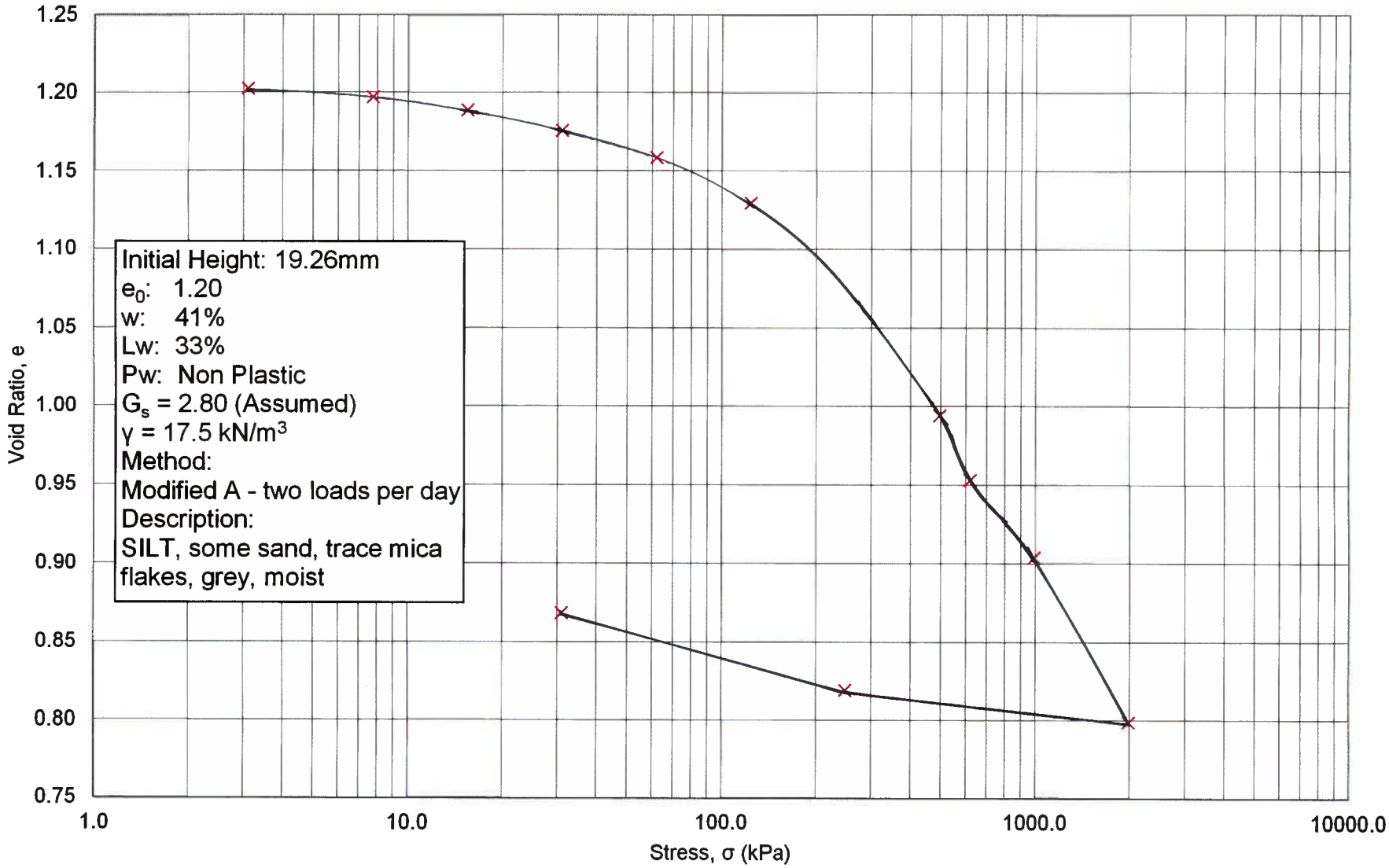
Notes
* Deformation at end of each load increment

Consolidometer: B **Linear Voltmeter:** J15192
Method: Modified A - two loads per day
Comments:

VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

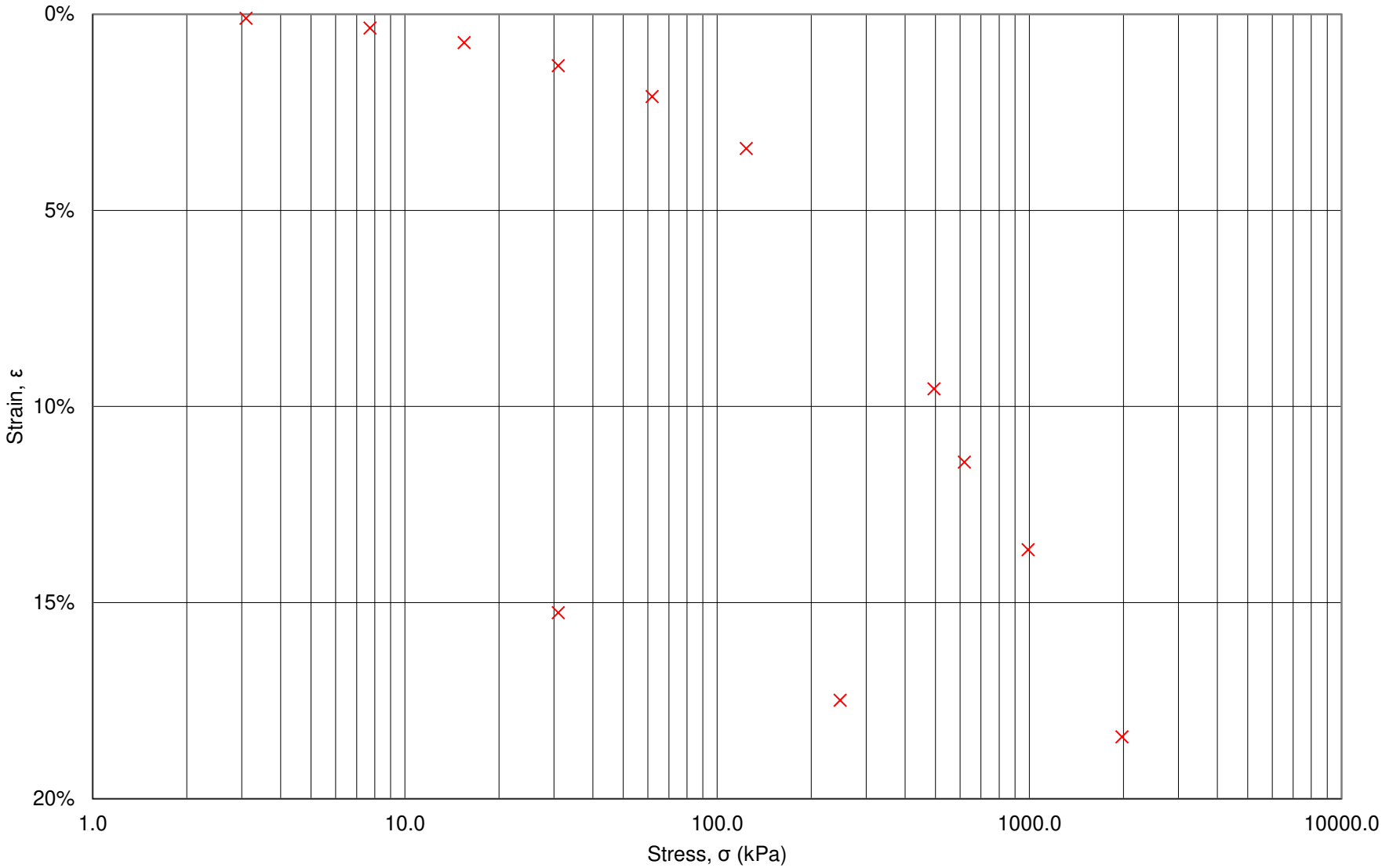
BH14-03, 6.54m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Strain v. Applied Stress

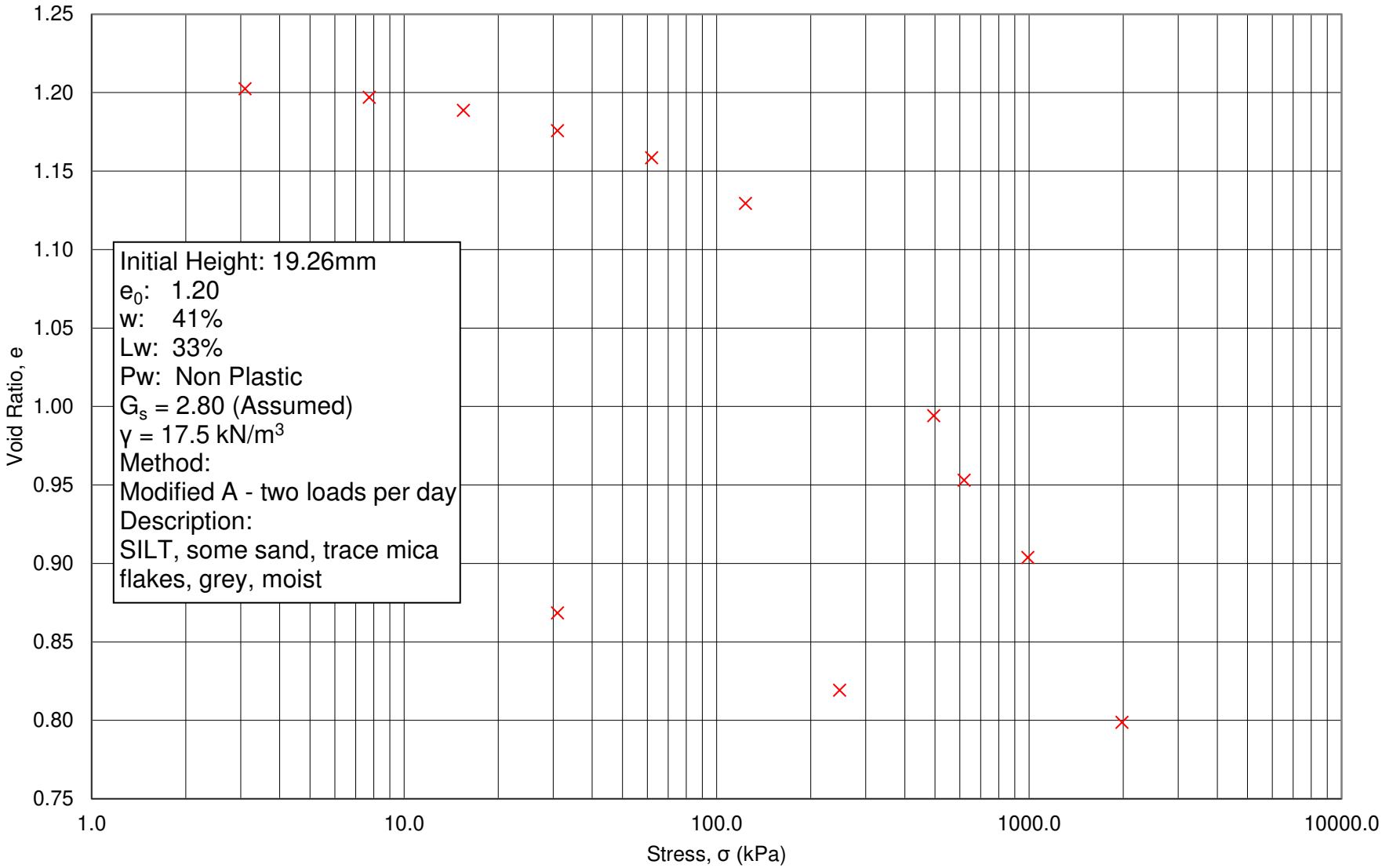
BH14-03, 6.54m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

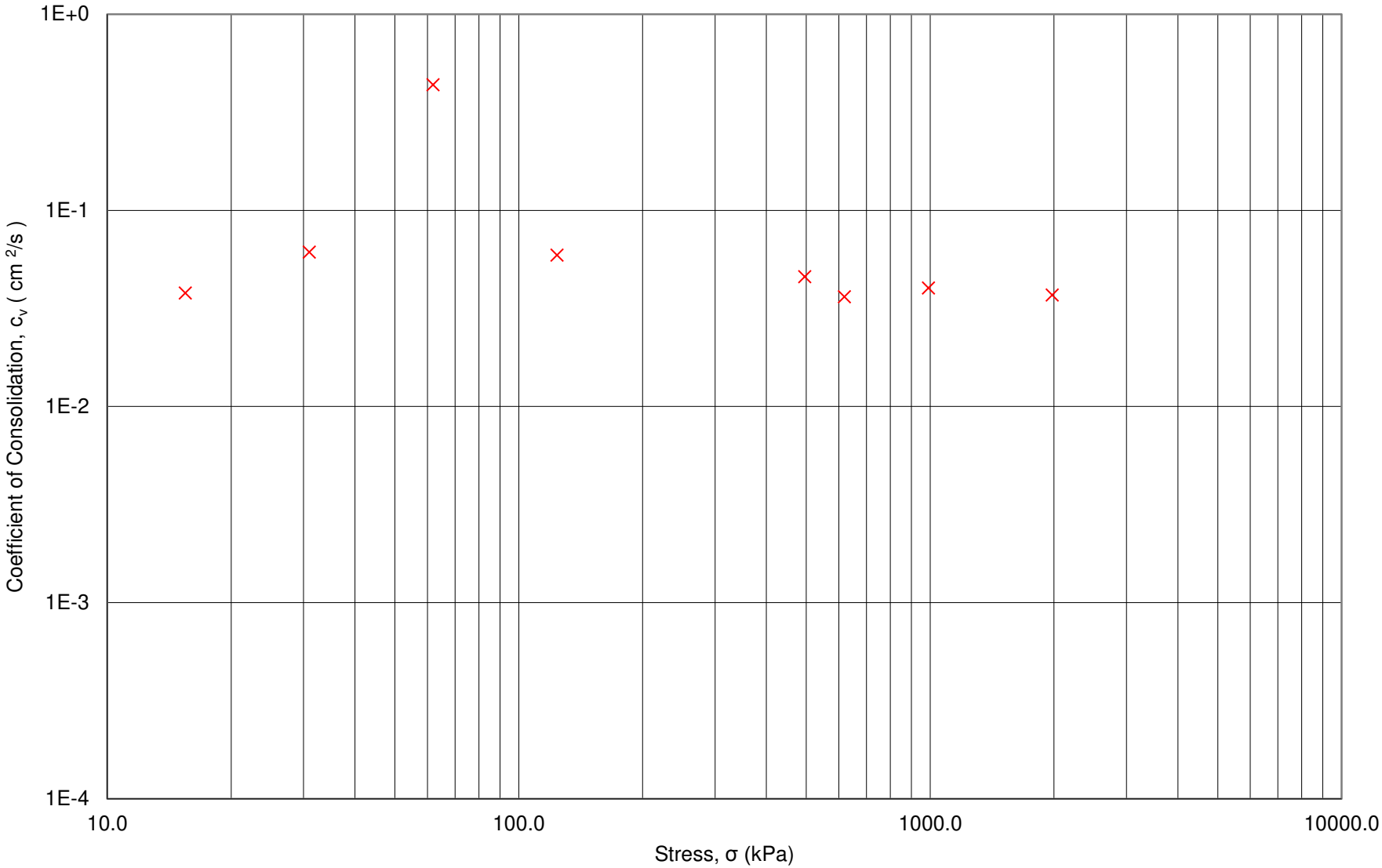
BH14-03, 6.54m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Coefficient of Consolidation v. Applied Stress

BH14-03, 6.54m



VAN-0222989-A0
2015-01-15 SCD

Consolidation Data Sheet

BH14-03, 6.54m

Sample Dimensions	
H_o =	19.26 mm
D_o =	63.48 mm
A =	31.65 cm²
V_o =	60.96 cm³
G_s =	2.80
H_s =	8.74 mm

Moisture Content of Specimen		
	(Initial)	(End)
Wet Soil + Tare	241.73 g	399.64 g
Dry Soil + Tare	210.26 g	373.23 g
Water	31.47 g	26.41 g
Tare	132.85	298.08 g
Wet Soil	108.88 g	101.56 g
Dry Soil	77.41 g	75.15 g
w(%)	40.65%	35.14%
Saturation	0.94	

Moisture Content of Cuttings			
Tare #	123	140	135
Wet Soil + Tare	322.99 g	336.66 g	347.34 g
Dry Soil + Tare	273.05 g	280.62 g	294.09 g
Water	49.94 g	56.04 g	53.25 g
Tare	149.38 g	144.46 g	162.29 g
Wet Soil	173.61 g	192.20 g	185.05 g
Dry Soil	123.67 g	136.16 g	131.80 g
w(%)	40.38%	41.16%	40.4 %

Total Load (kg)	Pressure (kPa)	Correction (mm)	Deformation* (mm)	delta-H (mm)	Strain %	H (H_o - delta-H)	$H-H_s$	e $(H-H_s)/H_s$	t_{90} (min) for Cv	Cv (cm^2/s)
			0	0.000	0.0%	19.26	10.524	1.20		
0.1	3.1	0.000	0.021	0.021	0.1%	19.239	10.504	1.20	0.12	1.12E-01
0.25	7.7	0.000	0.068	0.068	0.4%	19.192	10.456	1.20	0.23	5.77E-02
0.5	15.5	0.000	0.141	0.141	0.7%	19.119	10.384	1.19	0.34	3.78E-02
1.0	31.0	0.017	0.271	0.254	1.3%	19.006	10.270	1.18	0.21	6.11E-02
2.0	62.0	0.025	0.430	0.405	2.1%	18.855	10.120	1.16	0.03	4.37E-01
4.0	123.9	0.035	0.694	0.659	3.4%	18.601	9.865	1.13	0.21	5.90E-02
16.0	495.6	0.065	1.905	1.840	9.6%	17.420	8.684	0.99	0.25	4.58E-02
20.0	619.5	0.069	2.268	2.199	11.4%	17.061	8.325	0.95	0.29	3.62E-02
32.0	991.3	0.083	2.712	2.629	13.7%	16.631	7.895	0.90	0.25	4.01E-02
64.0	1982.5	0.111	3.658	3.548	18.4%	15.712	6.977	0.80	0.25	3.70E-02
8.0	247.8	0.049	3.418	3.369	17.5%	15.891	7.156	0.82		
1.0	31.0	0.017	2.955	2.938	15.3%	16.322	7.586	0.87		

Notes

* Deformation at end of each load increment

Consolidometer: C **Linear Voltmeter:** J15192

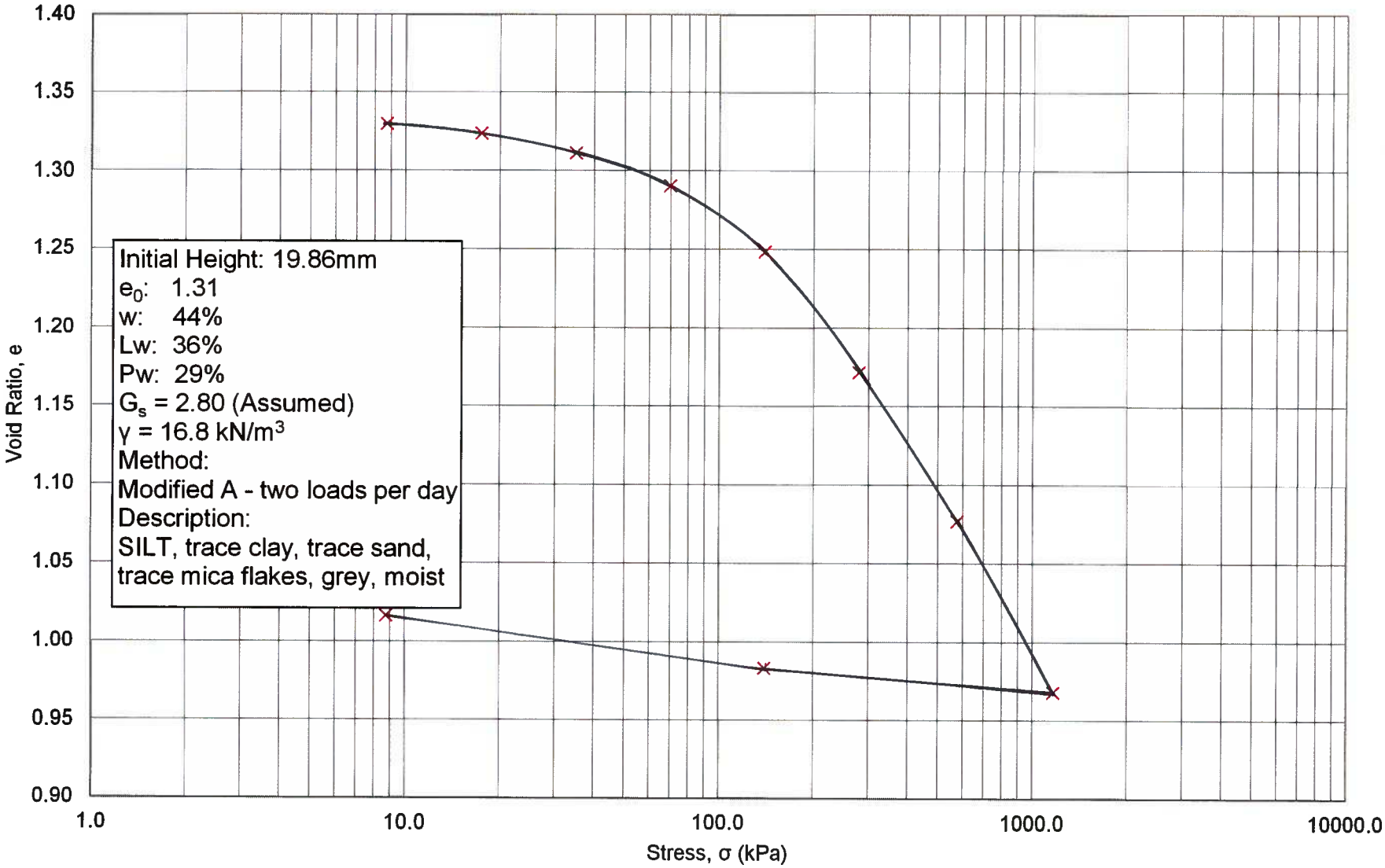
Method: Modified A - two loads per day

Comments:

VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

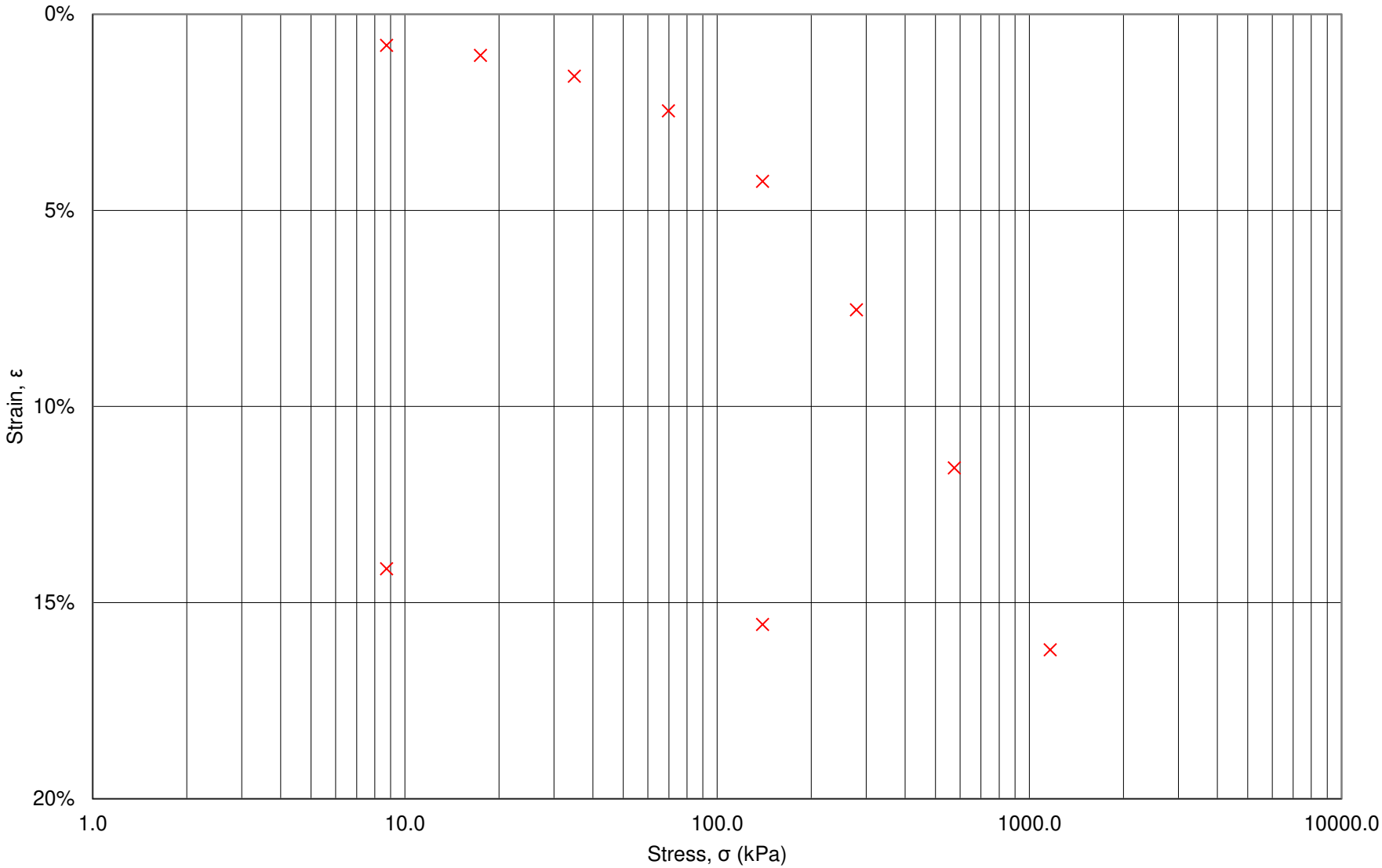
BH14-10, 8.23m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Strain v. Applied Stress

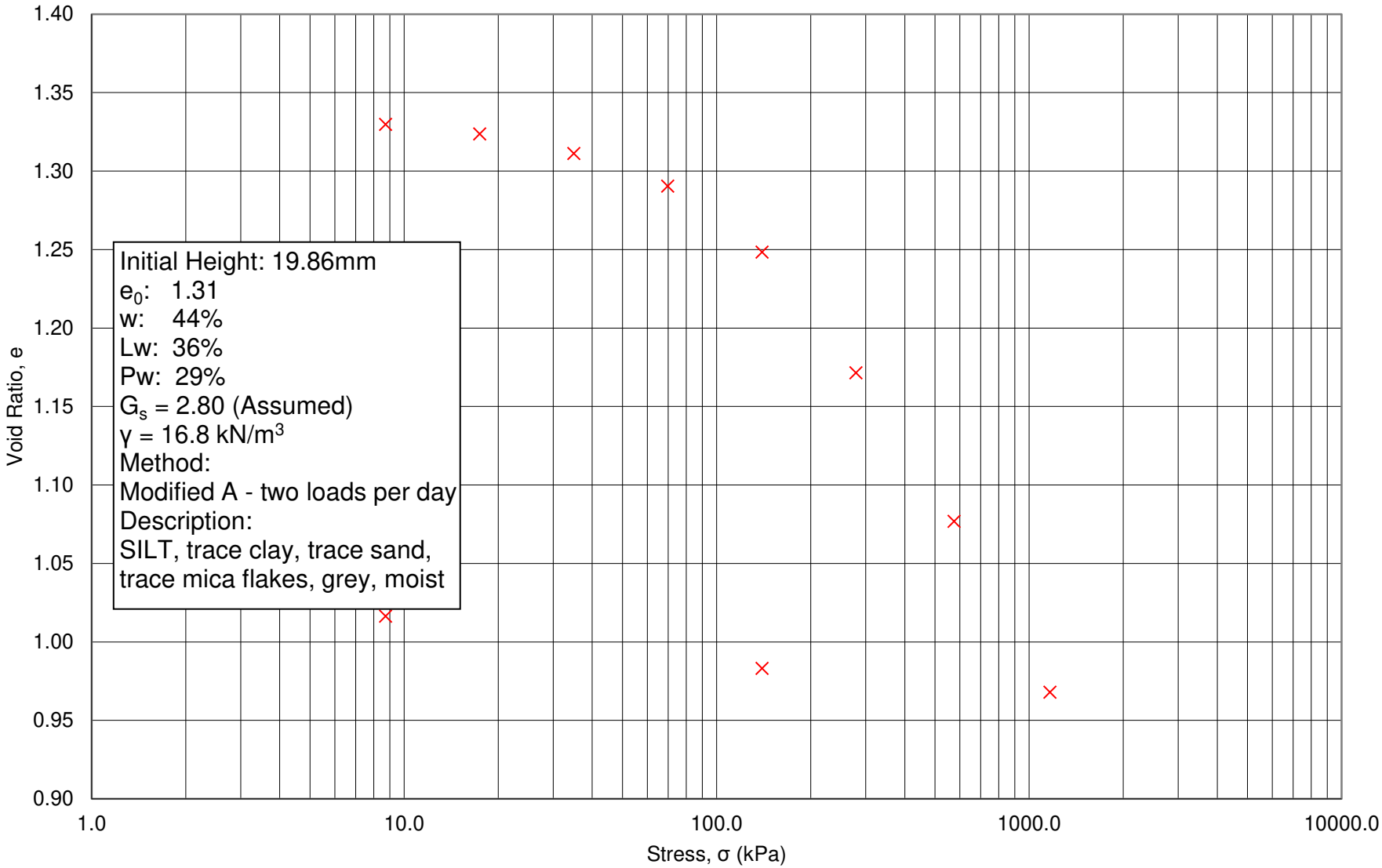
BH14-10, 8.23m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

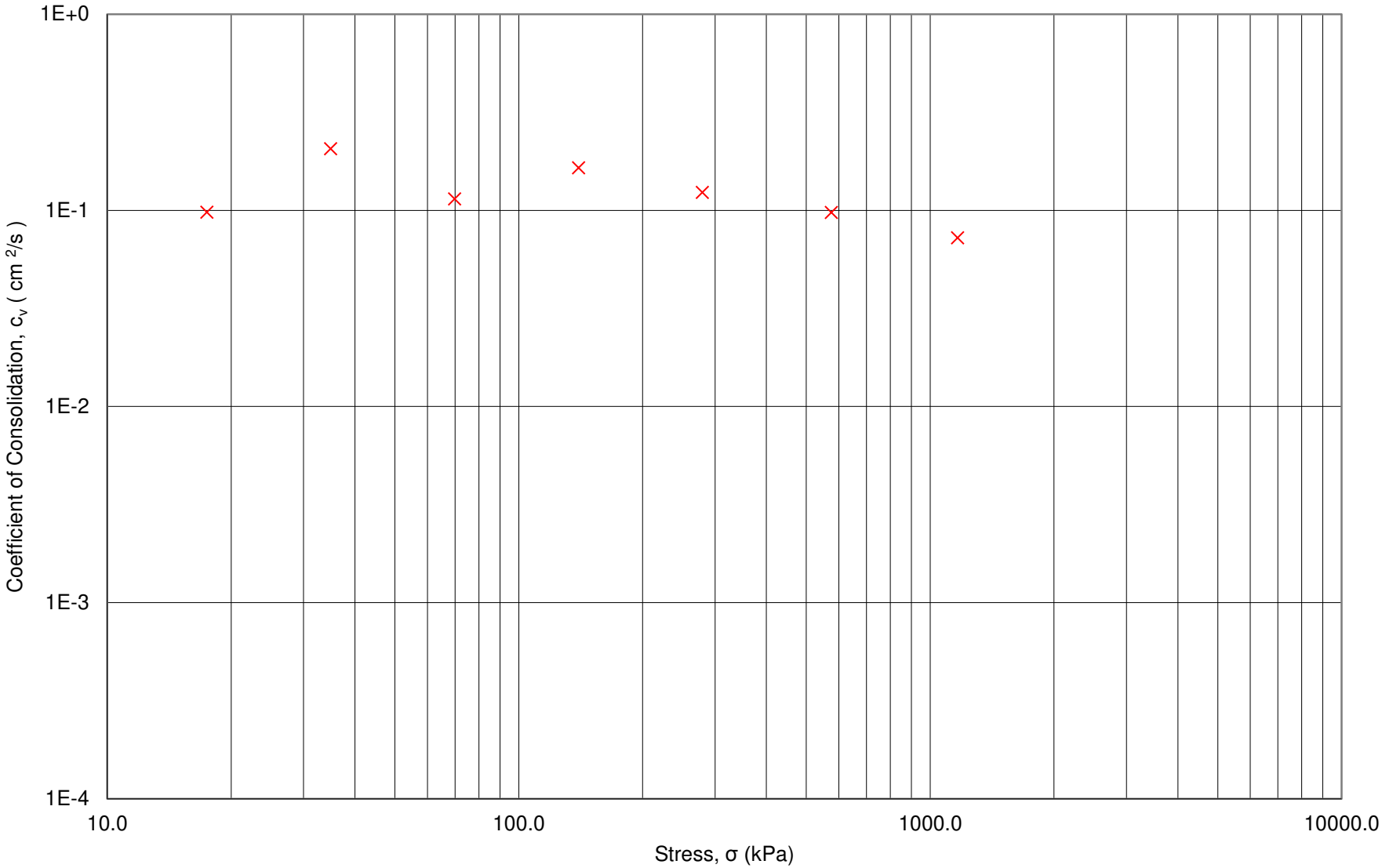
BH14-10, 8.23m



VAN-0222989-A0
2013-09-21

Consolidation: Coefficient of Consolidation v. Applied Stress

BH14-10, 8.23m



VAN-0222989-A0
2015-01-15 SCD

Consolidation Data Sheet

BH14-10, 8.23m

Sample Dimensions	
H_o =	19.86 mm
D_o =	63.00 mm
A =	31.17 cm²
V_o =	61.91 cm³
G_s =	2.80
H_s =	8.46 mm

Moisture Content of Specimen	(Initial)	(End)
Wet Soil + Tare	235.81 g	379.07 g
Dry Soil + Tare	203.43 g	352.52 g
Water	32.38 g	26.55 g
Tare	129.61	279.85 g
Wet Soil	106.20 g	99.22 g
Dry Soil	73.82 g	72.67 g
w(%)	43.87%	36.54%
Saturation	0.91	

Moisture Content of Cuttings			
Tare #	114	79	134
Wet Soil + Tare	248.39 g	250.33 g	340.29 g
Dry Soil + Tare	200.77 g	203.41 g	282.62 g
Water	47.62 g	46.92 g	57.67 g
Tare	92.44 g	96.65 g	150.67 g
Wet Soil	155.95 g	153.68 g	189.62 g
Dry Soil	108.33 g	106.76 g	131.95 g
w(%)	43.96%	43.95%	43.71%

Total Load (kg)	Pressure (kPa)	Correction (mm)	Deformation* (mm)	delta-H (mm)	Strain %	H (H_o - delta-H)	H-H_s	e (H-H_s)/H_s	t_{90} for Cv	Cv (cm²/s)
			0	0.000	0.0%	19.86	11.403	1.35		
0.375	8.7	0.002	0.160	0.158	0.8%	19.702	11.245	1.33	0.04	3.46E-01
0.75	17.5	0.004	0.213	0.210	1.1%	19.651	11.193	1.32	0.14	9.77E-02
1.5	34.9	0.009	0.323	0.315	1.6%	19.546	11.088	1.31	0.07	2.06E-01
3.0	69.8	0.015	0.505	0.490	2.5%	19.370	10.913	1.29	0.12	1.14E-01
6.0	139.8	0.021	0.867	0.846	4.3%	19.014	10.557	1.25	0.08	1.65E-01
12.0	279.6	0.025	1.522	1.497	7.5%	18.363	9.906	1.17	0.10	1.23E-01
24.7	575.8	0.031	2.328	2.297	11.6%	17.563	9.106	1.08	0.12	9.74E-02
50.1	1167.4	0.036	3.254	3.218	16.2%	16.642	8.185	0.97	0.14	7.23E-02
6.0	139.8	0.021	3.110	3.089	15.6%	16.771	8.313	0.98		
0.375	8.7	0.002	2.809	2.808	14.1%	17.052	8.595	1.02		

Notes
* Deformation at end of each load increment

Consolidometer: A **Linear Voltmeter:** J15192
Method: Modified A - two loads per day
Comments:

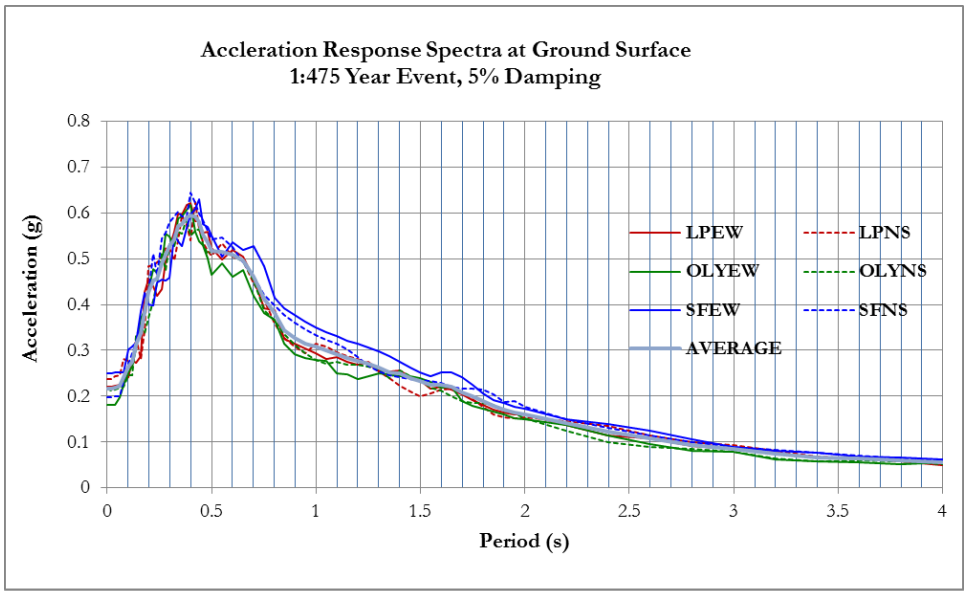
Appendix D

Response Spectra

Figures 2 to 5

Results of Liquefaction Assessment

Figures 6 to 9



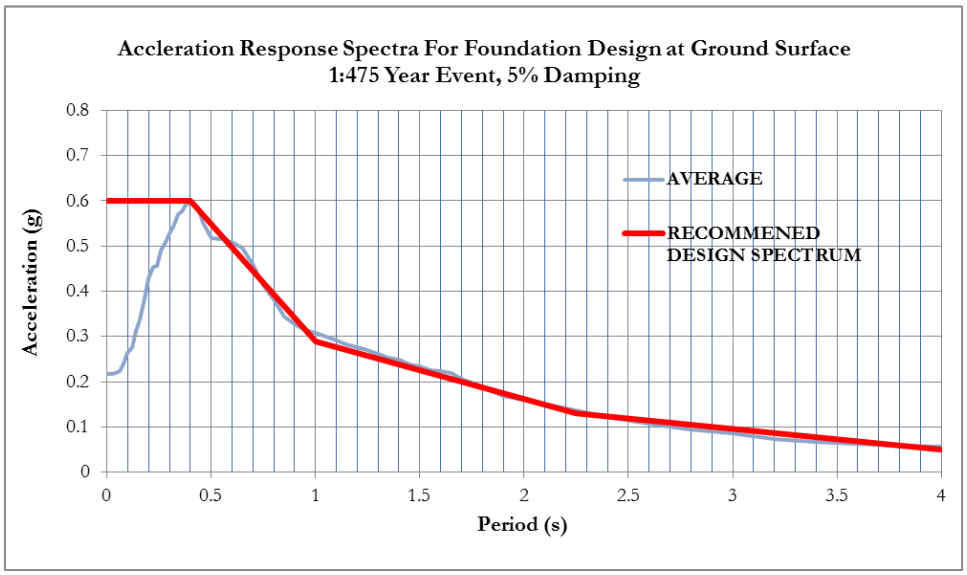
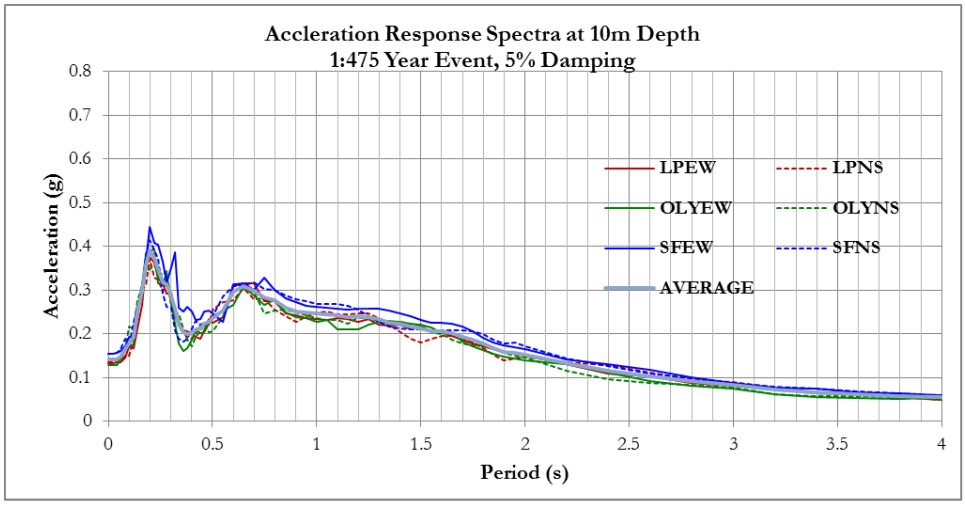


Figure 2: Response Spectra at Ground Surface 475 Earthquake



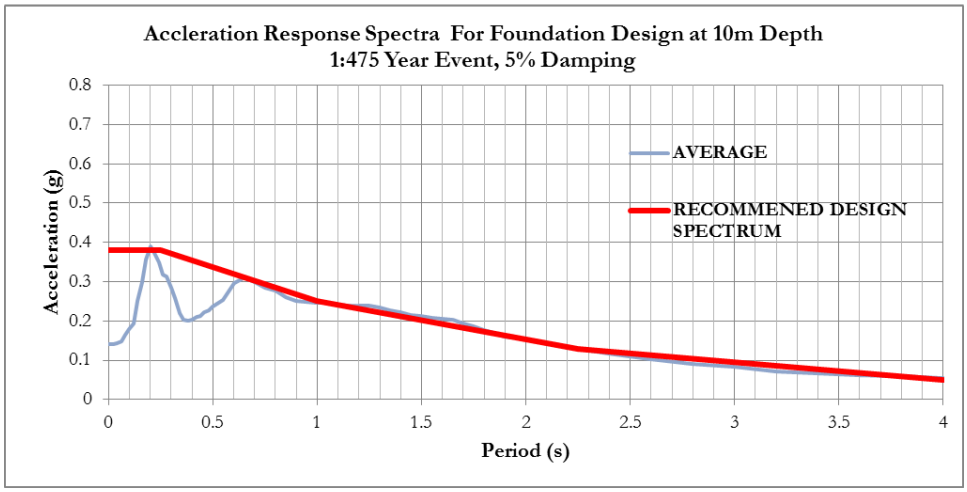
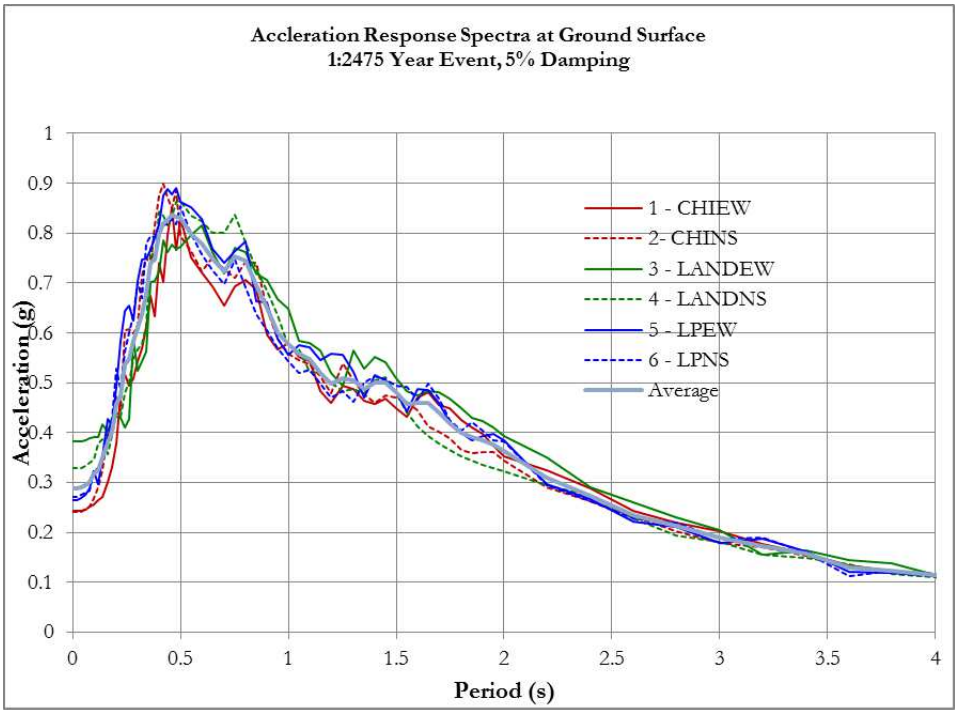


Figure 3: Response Spectra at 10m Below Ground Surface 475 Earthquake



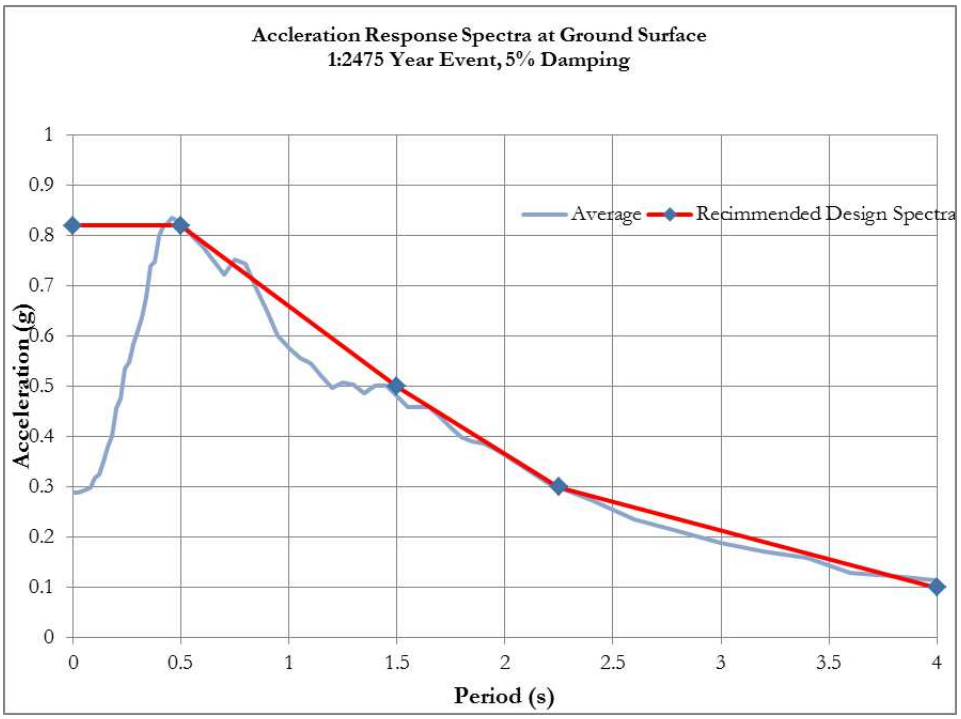
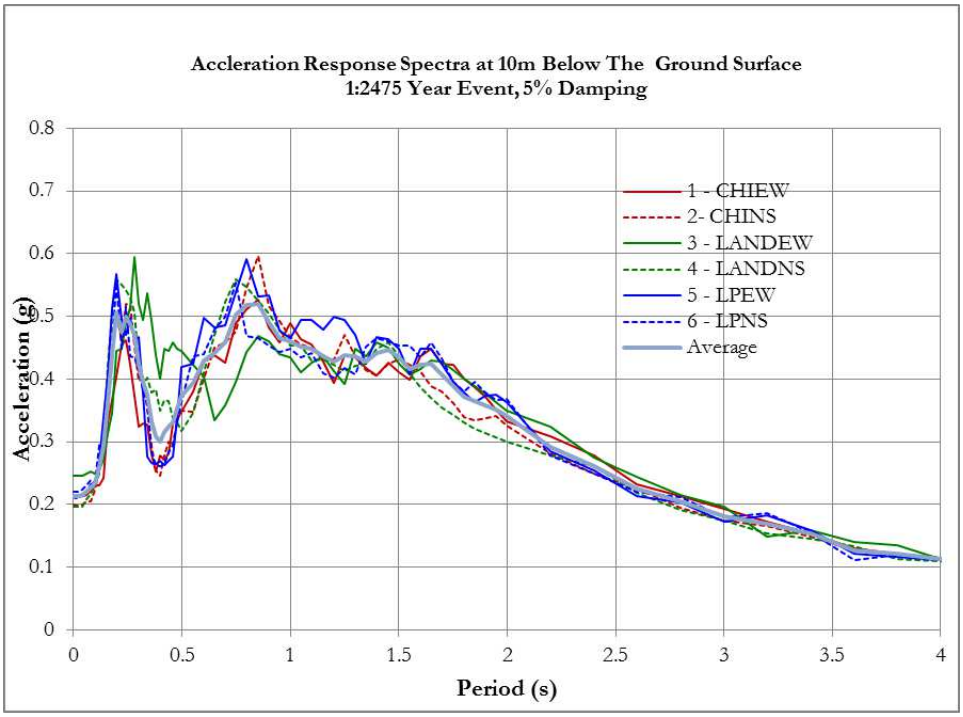


Figure 4: Response Spectra at Ground Surface 2475 Earthquake



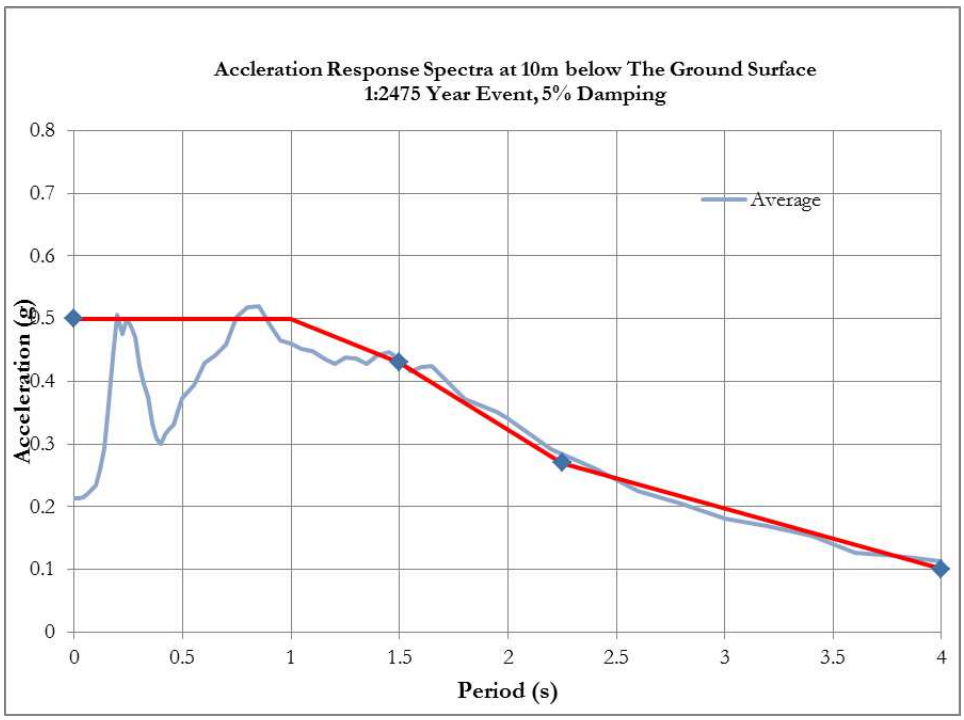
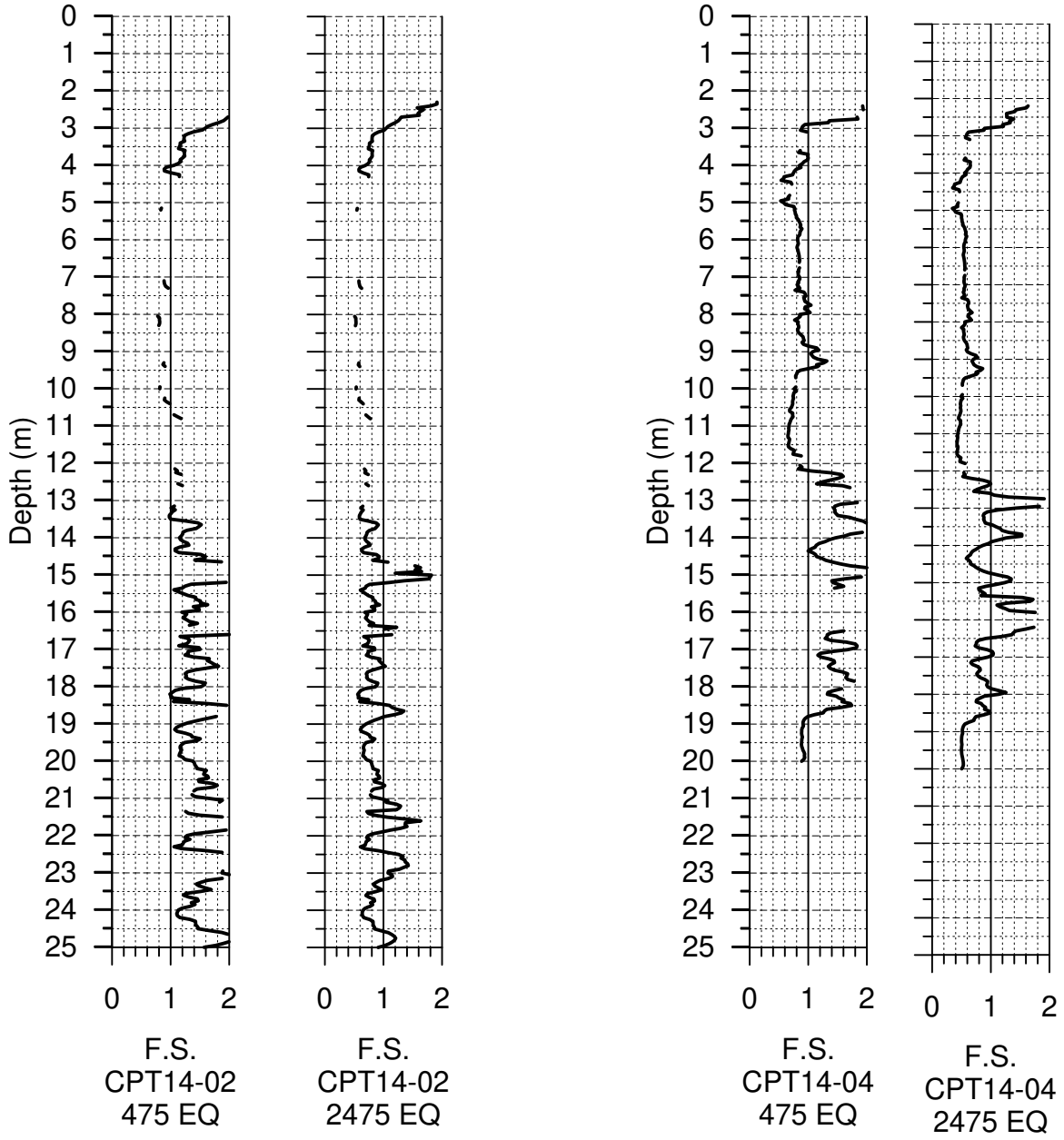


Figure 5: Response Spectra at 10m Below Ground Surface 2475 Earthquake

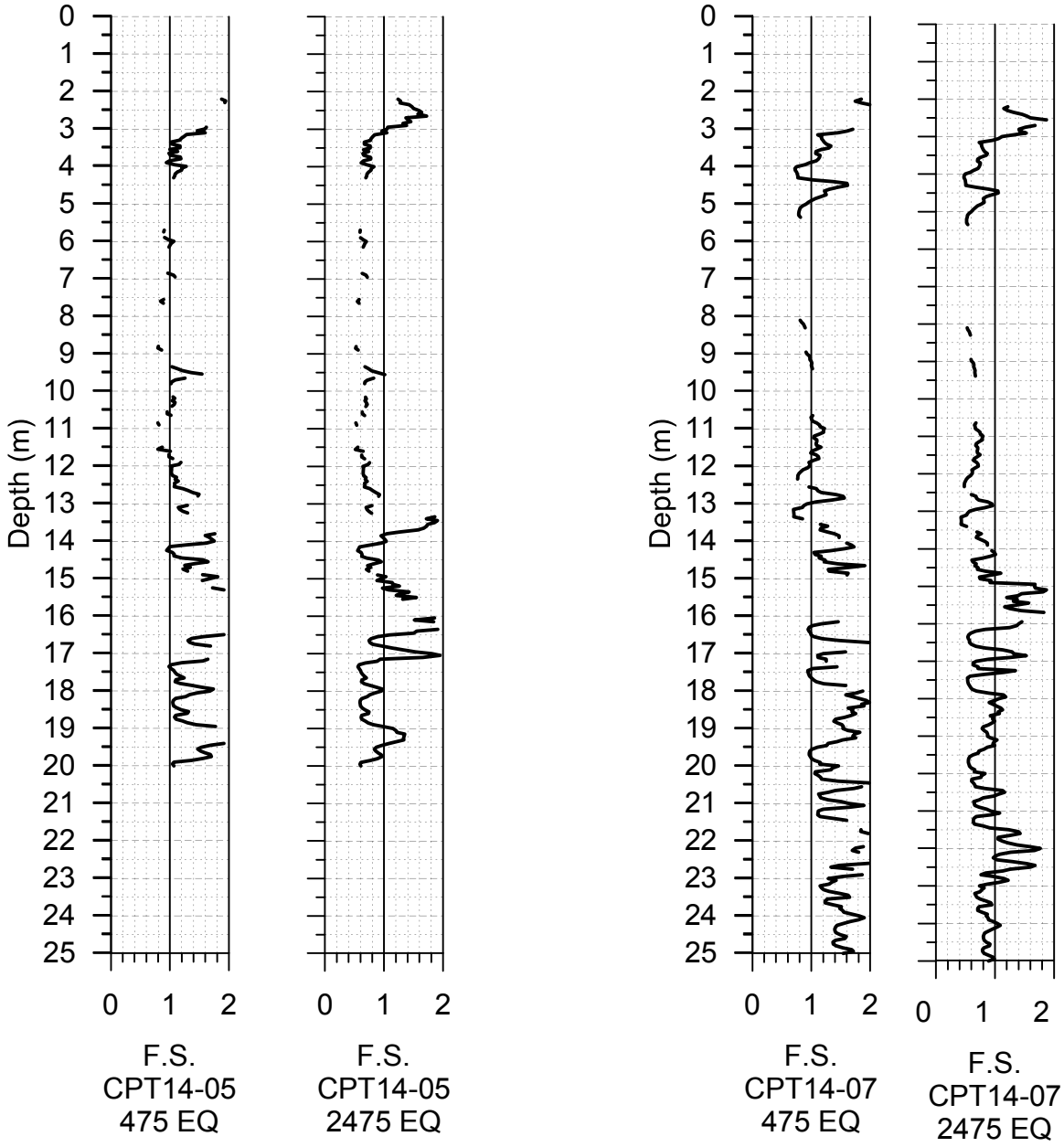


Depth is from the grade at time of driling.
F.S. was calculated based on Youd et al (2001) procedure for CPT data.

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, B.C., V5G 4W3
Tel.: 604-874-1245
Fax: 604-874-2358
exp.com

CLIENT	TITLE
PARRISH AND HIEMBERCKER LTD.	**FACTOR OF SAFETY AGAINST LIQUEFACTION, F.S. FOR 1:475 EVENT, M=6.7 FOR 1:2475 EVENT, M=7**
PROJECT **PROPOSED P&H FRASER TERMINAL SURREY, BC**	

PROJECT No.	DFTR.	DSGN.	CHK.	DATE	SCALE	FIGURE No.
0222989		**UC**	**BW**	**JANUARY, 2015**		**FIGURE 6**

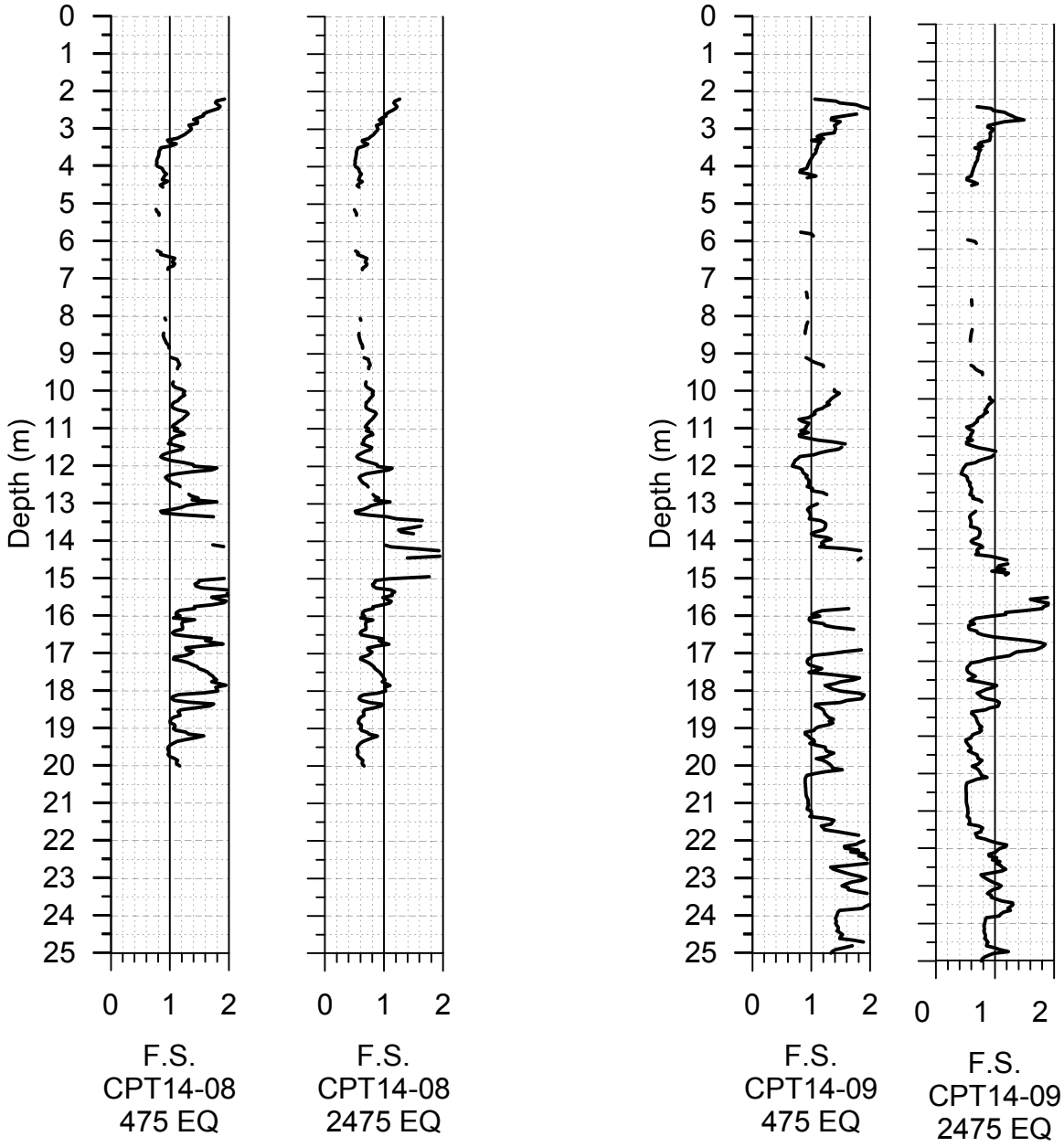


Depth is from the grade at time of driling.
F.S. was calculated based on Youd et al (2001) procedure for CPT data.

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, B.C., V5G 4W3
Tel.: 604-874-1245
Fax: 604-874-2358
exp.com

CLIENT	TITLE
PARRISH AND HIEMBERCKER LTD.	**FACTOR OF SAFETY AGAINST LIQUEFACTION, F.S. FOR 1:475 EVENT, M=6.7 FOR 1:2475 EVENT, M=7**
PROJECT **PROPOSED P&H FRASER TERMINAL, SURREY, BC**	

PROJECT No.	DFTR.	DSGN.	CHK.	DATE	SCALE	FIGURE No.
0222989		**UC**	**BW**	**JANUARY, 2015**		**FIGURE 7**

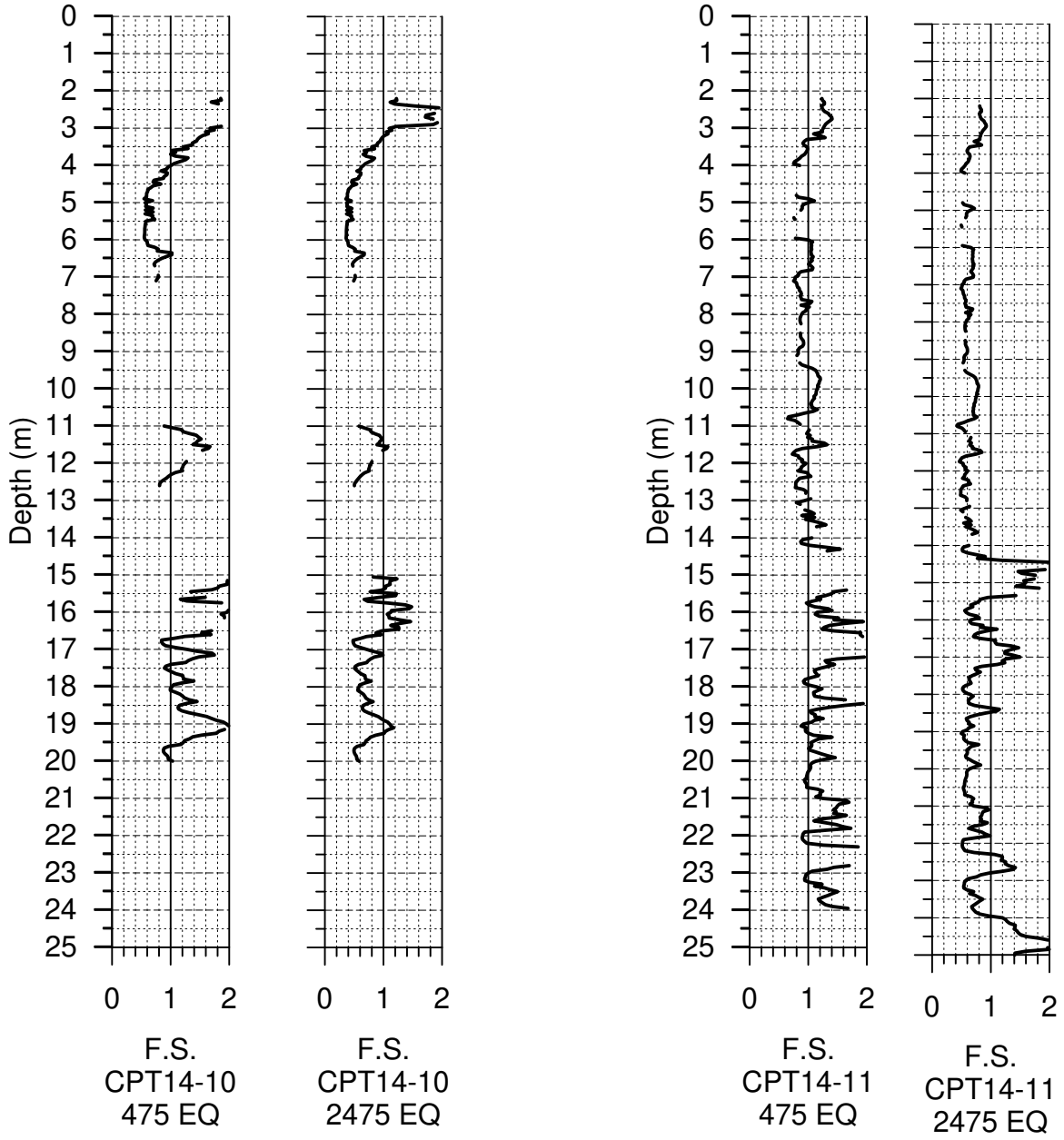


Depth is from the grade at time of driling.
F.S. was calculated based on Youd et al (2001) procedure for CPT data.

exp Services Inc.
275-3001 Wayburne Drive
Burnaby, B.C., V5G 4W3
Tel.: 604-874-1245
Fax: 604-874-2358
exp.com

CLIENT	TITLE
PARRISH AND HIEMBERCKER LTD.	**FACTOR OF SAFETY AGAINST LIQUEFACTION, F.S. FOR 1:475 EVENT, M=6.7 FOR 1:2475 EVENT, M=7**
PROJECT **PROPOSED P&H FRASER TERMINAL, SURREY, BC**	

PROJECT No.	DFTR.	DSGN.	CHK.	DATE	SCALE	FIGURE No.
0222989		**UC**	**BW**	**JANUARY, 2015**		**FIGURE 8**



Depth is from the grade at time of driling.
F.S. was calculated based on Youd et al (2001) procedure for CPT data.

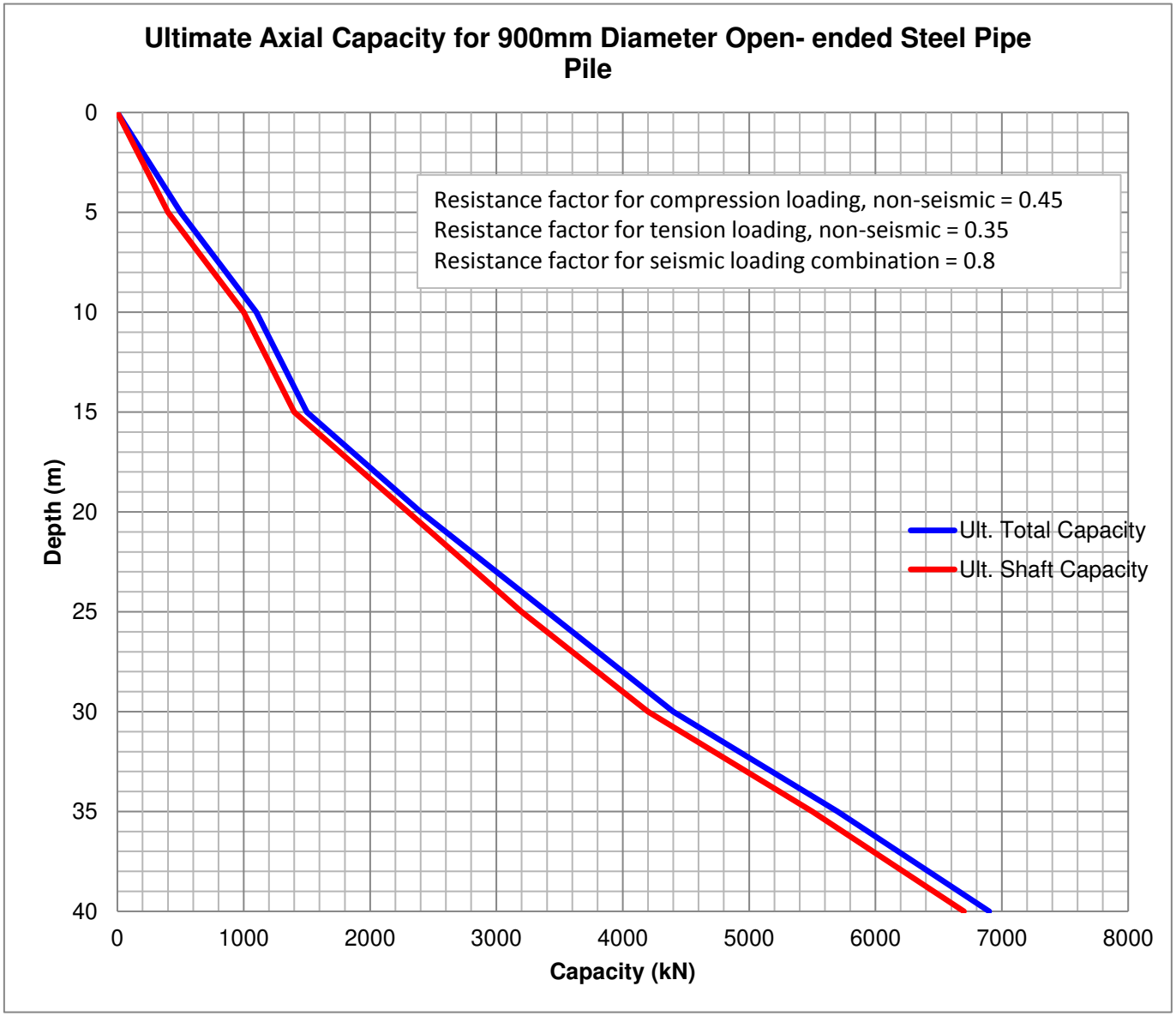
exp Services Inc.
275-3001 Wayburne Drive
Burnaby, B.C., V5G 4W3
Tel.: 604-874-1245
Fax: 604-874-2358
exp.com

CLIENT	TITLE
PARRISH AND HIEMBERCKER LTD	**FACTOR OF SAFETY AGAINST LIQUEFACTION, F.S. FOR 1:475 EVENT, M=6.7 FOR 1:2475 EVENT, M=7**
PROJECT **PROPOSED P&H FRASER TERMINAL SURREY, BC**	

PROJECT No.	DFTR.	DSGN.	CHK.	DATE	SCALE	FIGURE No.
0222989		**UC**	**BW**	**JANUARY, 2015**		**FIGURE 9**

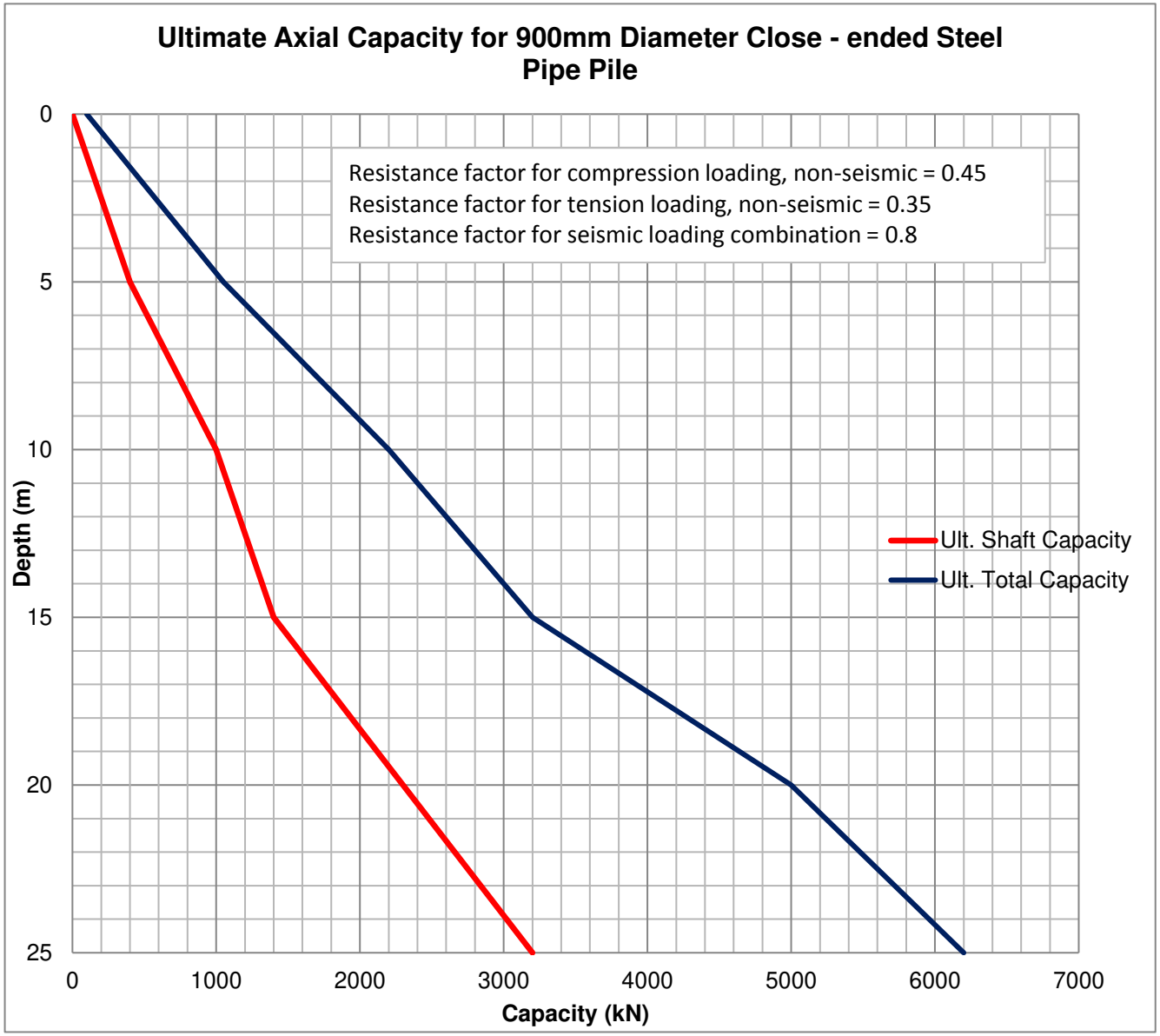
Appendix E

Pile Ultimate Axial Capacity Output



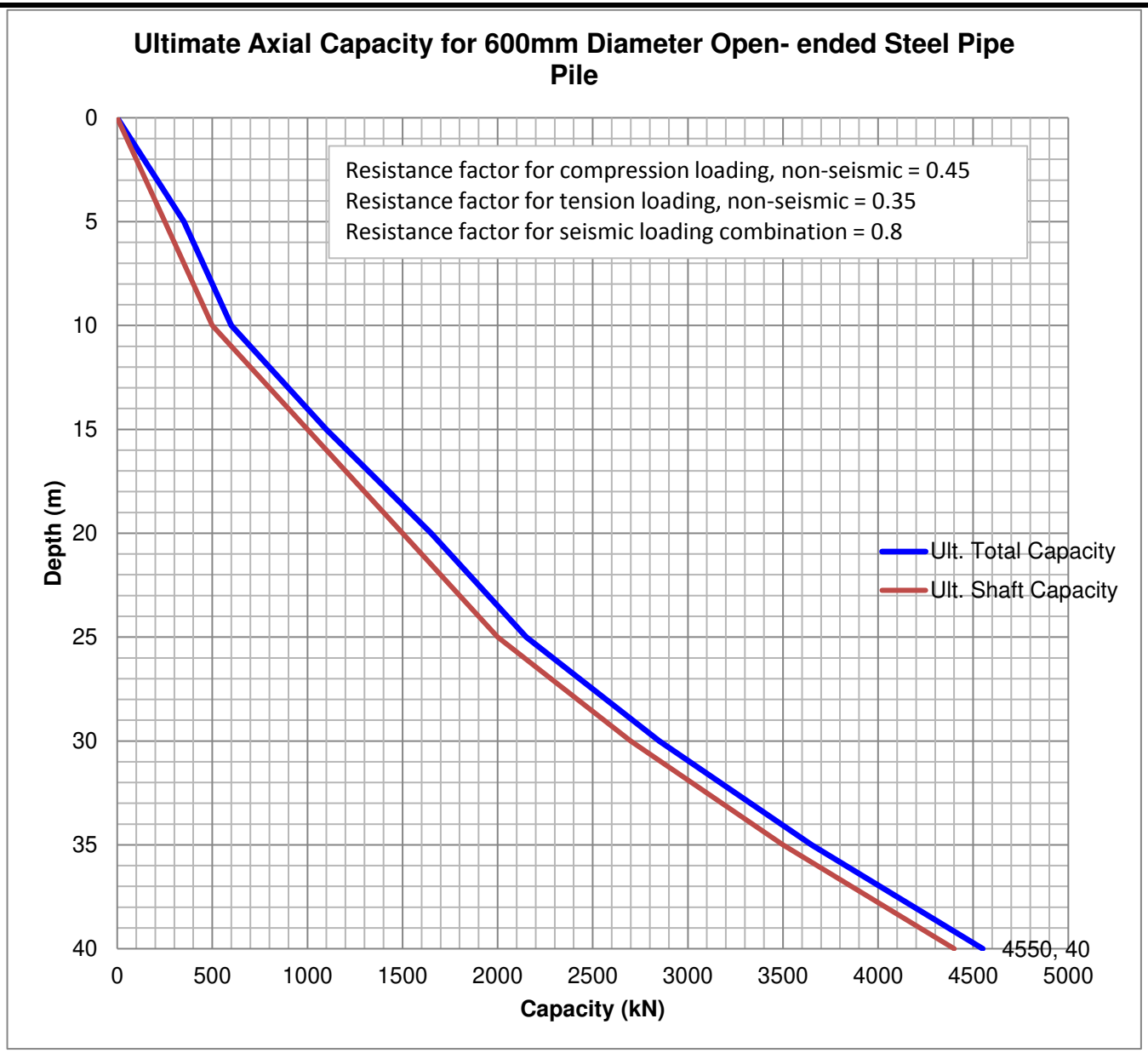
exp Services Inc.
275 - 3001 Wayburne Drive
Burnaby, BC V5G 4W3
Tel: 604.874.1245 / Fax: 604.874.2358

Title:	**Ultimate Axial Capacity for 900mm Diameter Open-Ended Steel Pipe Pile**				
Project:	Proposed P&H Fraser Terminal , Fraser Surrey Docks, Surrey, BC				
Client:	CMC	Project #:	VAN-00222989	Date:	20-Feb-15



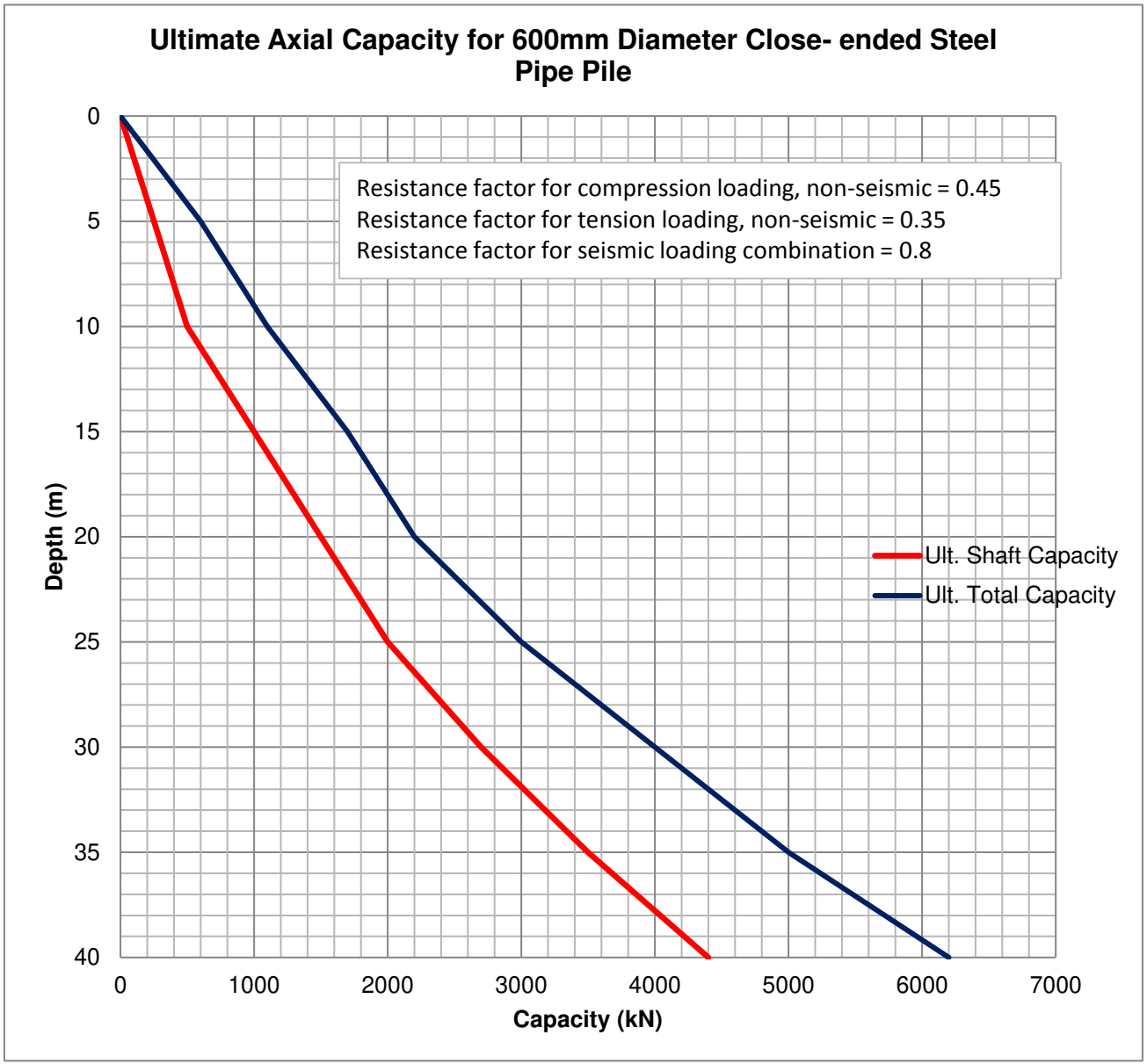
exp Services Inc.
275 - 3001 Wayburne Drive
Burnaby, BC V5G 4W3
Tel: 604.874.1245 / Fax: 604.874.2358

Title:	**Ultimate Axial Capacity for 900mm Diameter Close-Ended Steel Pipe Pile**				
Project:	Proposed P&H Fraser Terminal , Fraser Surrey Docks, Surrey, BC				
Client:	CMC	Project #:	VAN-00222989	Date:	20-Feb-15



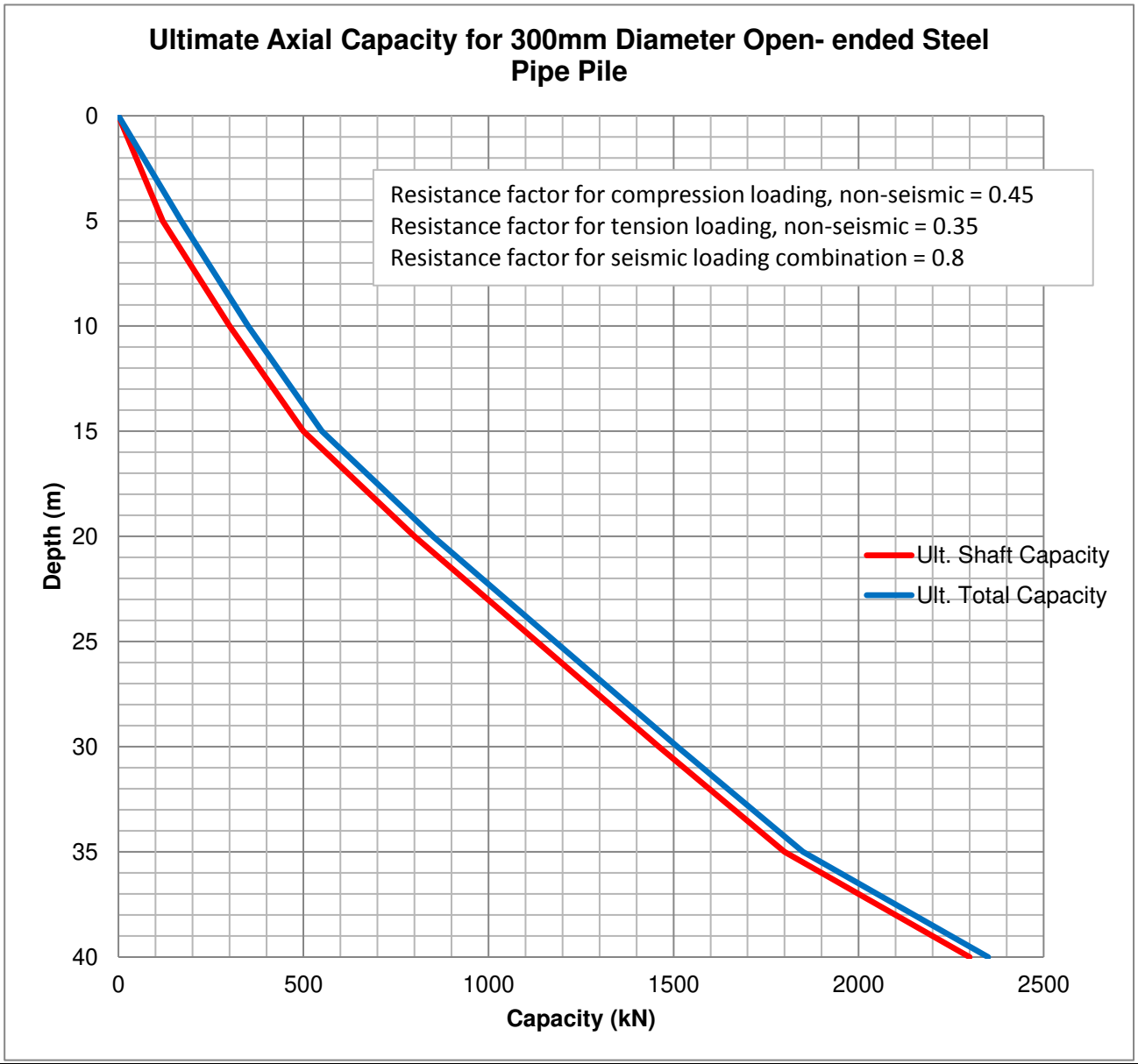
exp Services Inc.
275 - 3001 Wayburne Drive
Burnaby, BC V5G 4W3
Tel: 604.874.1245 / Fax: 604.874.2358

Title:	**Ultimate Axial Capacity for 600mm Diameter Open-Ended Steel Pipe Pile**				
Project:	Proposed P&H Fraser Terminal , Fraser Surrey Docks, Surrey, BC				
Client:	CMC	Project #:	VAN-00222989	Date:	20-Feb-15



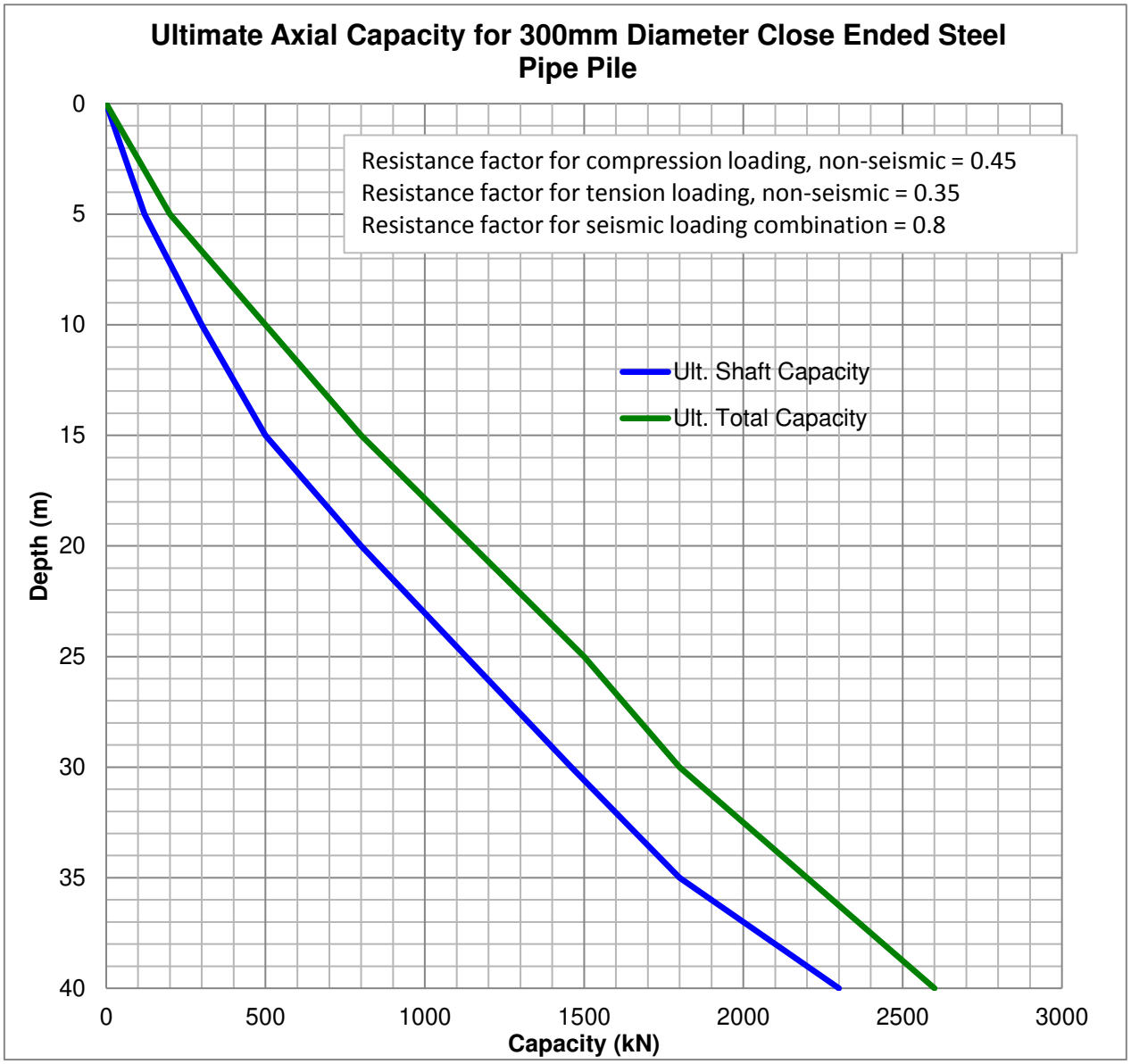
exp Services Inc.
275 - 3001 Wayburne Drive
Burnaby, BC V5G 4W3
Tel: 604.874.1245 / Fax: 604.874.2358

Title:	**Ultimate Axial Capacity for 600mm Diameter Close-Ended Steel Pipe Pile**				
Project:	Proposed P&H Fraser Terminal , Fraser Surrey Docks, Surrey, BC				
Client:	CMC	Project #:	VAN-00222989	Date:	20-Feb-15



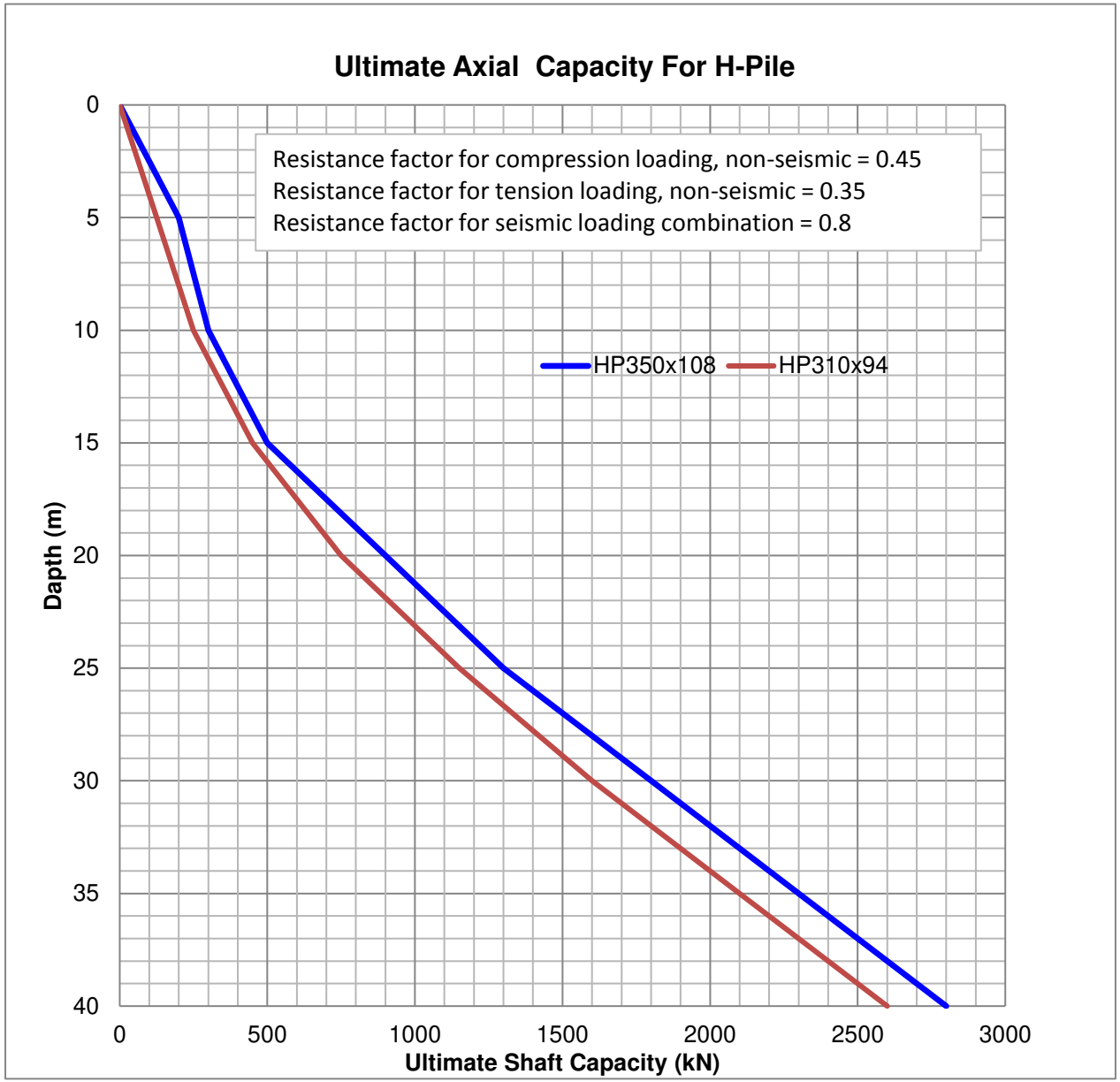
exp Services Inc.
275 - 3001 Wayburne Drive
Burnaby, BC V5G 4W3
Tel: 604.874.1245 / Fax: 604.874.2358

Title:	**Ultimate Axial Capacity for 300mm Diameter Open-Ended Steel Pipe Pile**				
Project:	Proposed P&H Fraser Terminal , Fraser Surrey Docks, Surrey, BC				
Client:	CMC	Project #:	VAN-00222989	Date:	20-Feb-15



exp Services Inc.
275 - 3001 Wayburne Drive
Burnaby, BC V5G 4W3
Tel: 604.874.1245 / Fax: 604.874.2358

Title:	**Ultimate Axial Capacity for 300mm Diameter Close-Ended Steel Pipe Pile**				
Project:	Proposed P&H Fraser Terminal , Fraser Surrey Docks, Surrey, BC				
Client:	CMC	Project #:	VAN-00222989	Date:	20-Feb-15

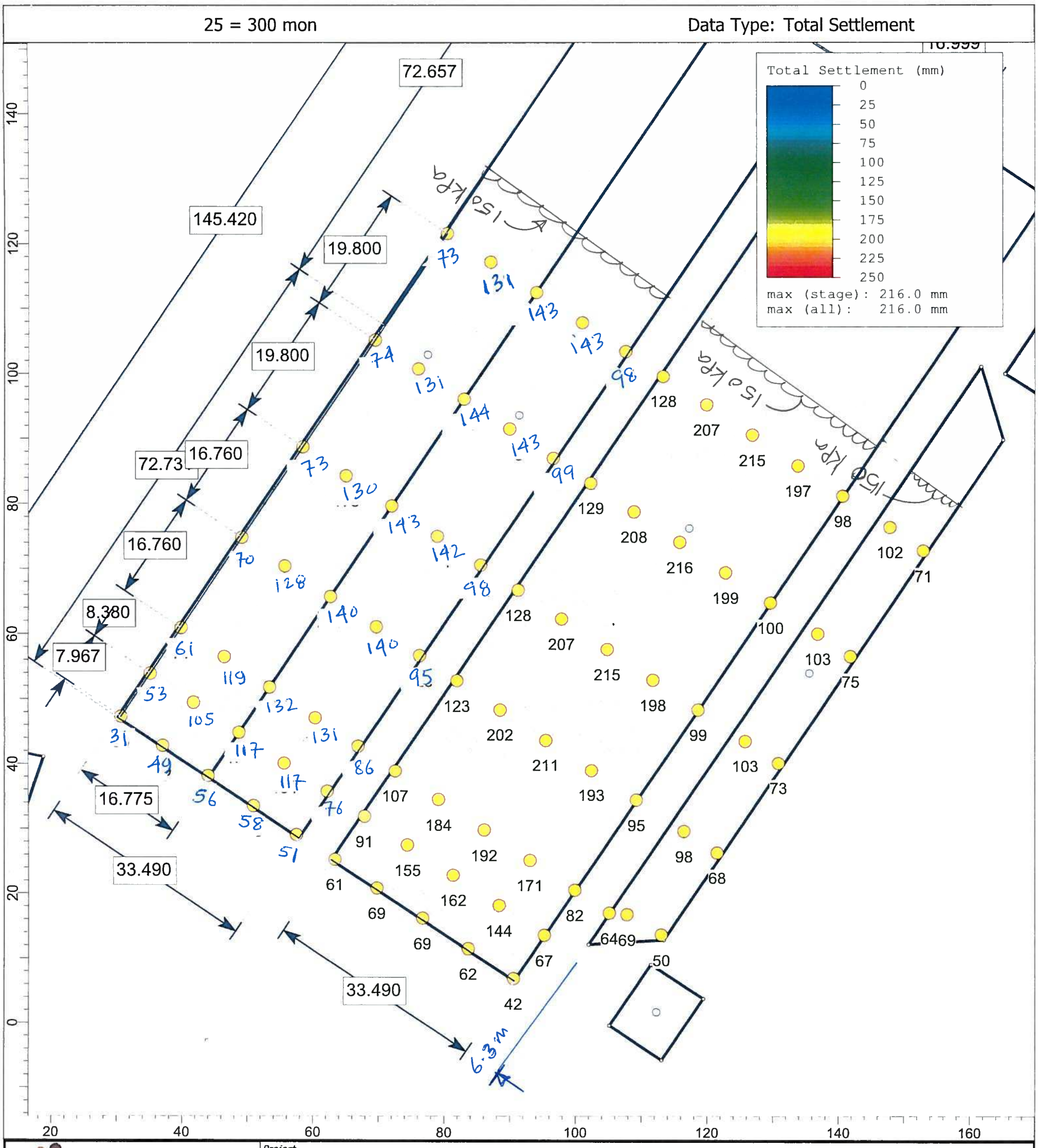


exp Services Inc.
275 - 3001 Wayburne Drive
Burnaby, BC V5G 4W3
Tel: 604.874.1245 / Fax: 604.874.2358

Title:	**Ultimate Axial Capacity for H-Pile Pile**				
Project:	Proposed P&H Fraser Terminal , Fraser Surrey Docks, Surrey, BC				
Client:	CMC	Project #:	VAN-00222989	Date:	20-Feb-15

Appendix F

Settlement Estimate Output

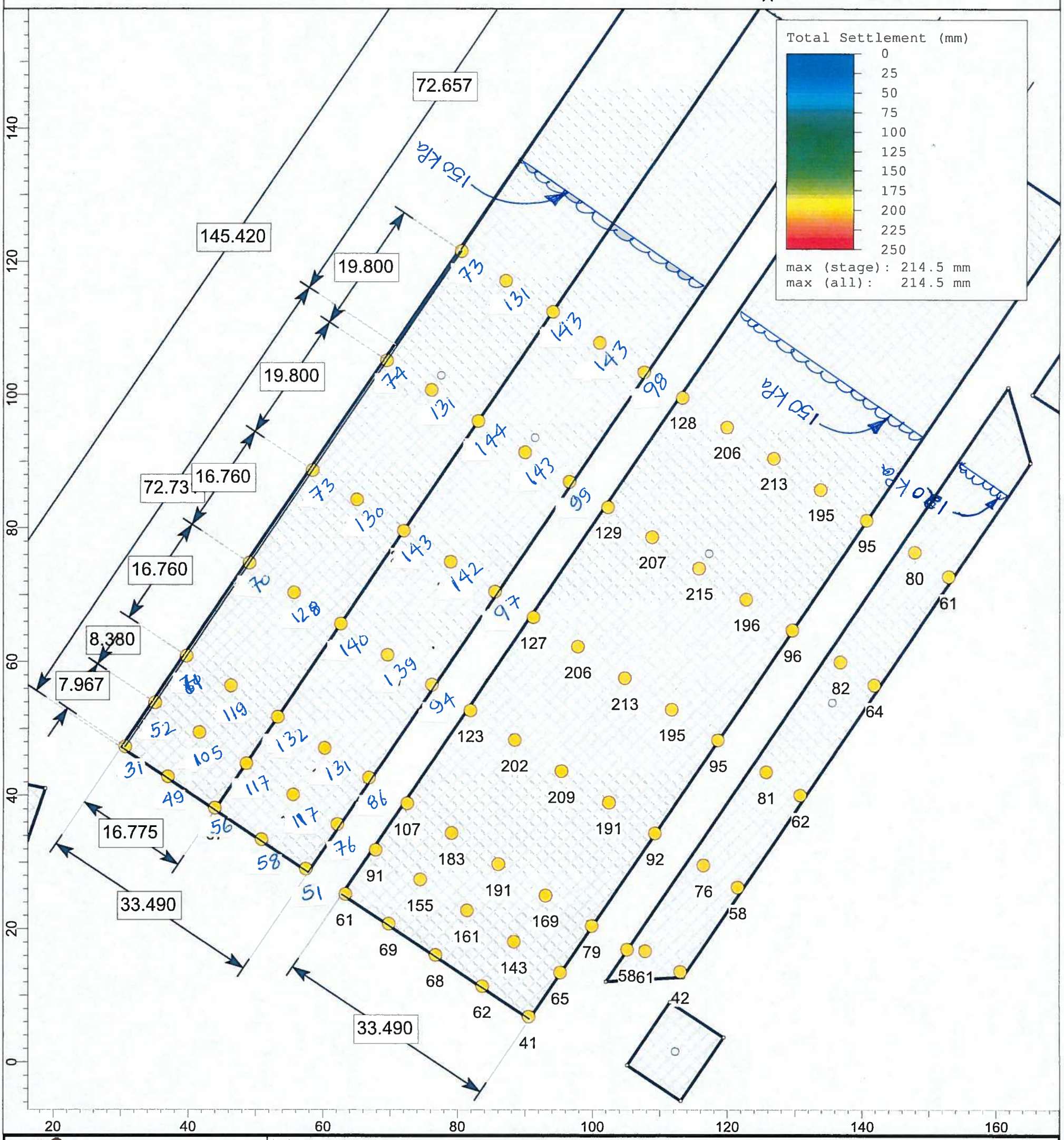


exp.	Project	0222989-A0 AGEX Pre-Feed Development at Bekaert Building	
	Analysis Description	Long Term Settlement under NEW PLAN (` 2015-09-28	
	Drawn By	MH/MAK	Company exp
SETTLE3D 2.018	Date	9/28/2015	File Name Soil Profile 150kPa Unifrom Load (2015-09-28)- MAK.s3z

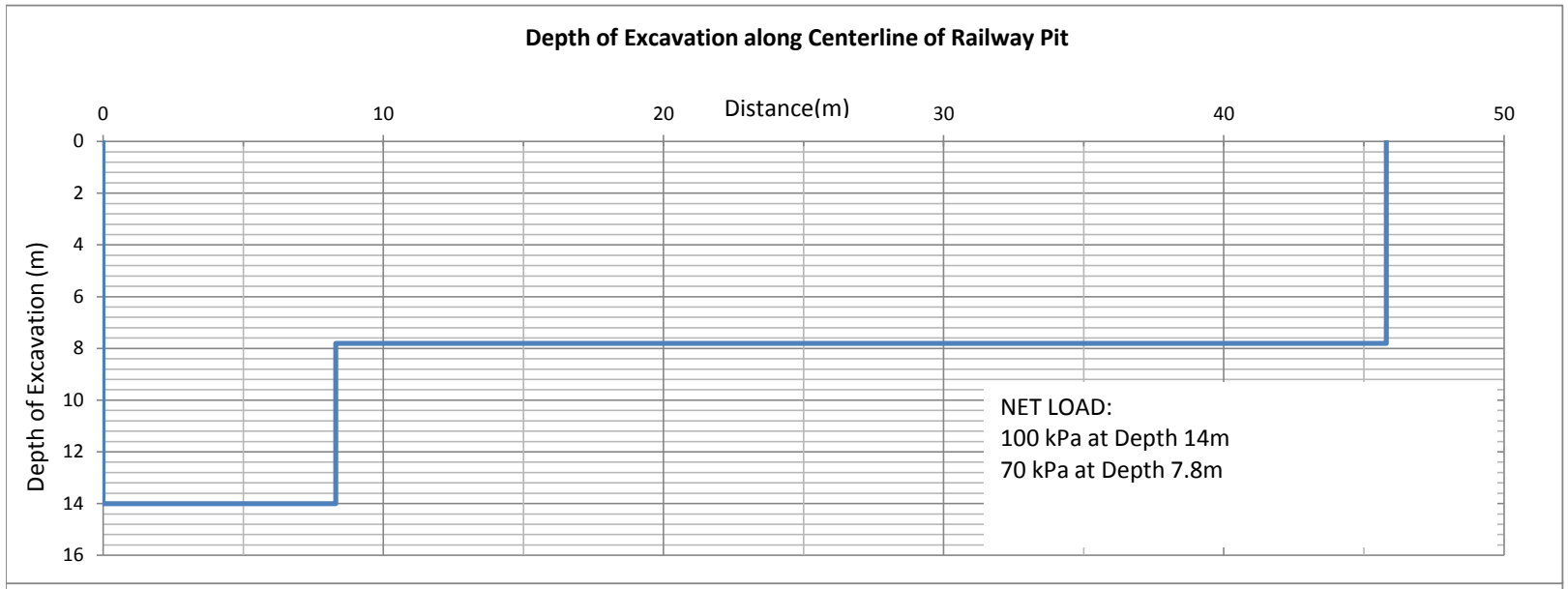
30/09/2015
UC

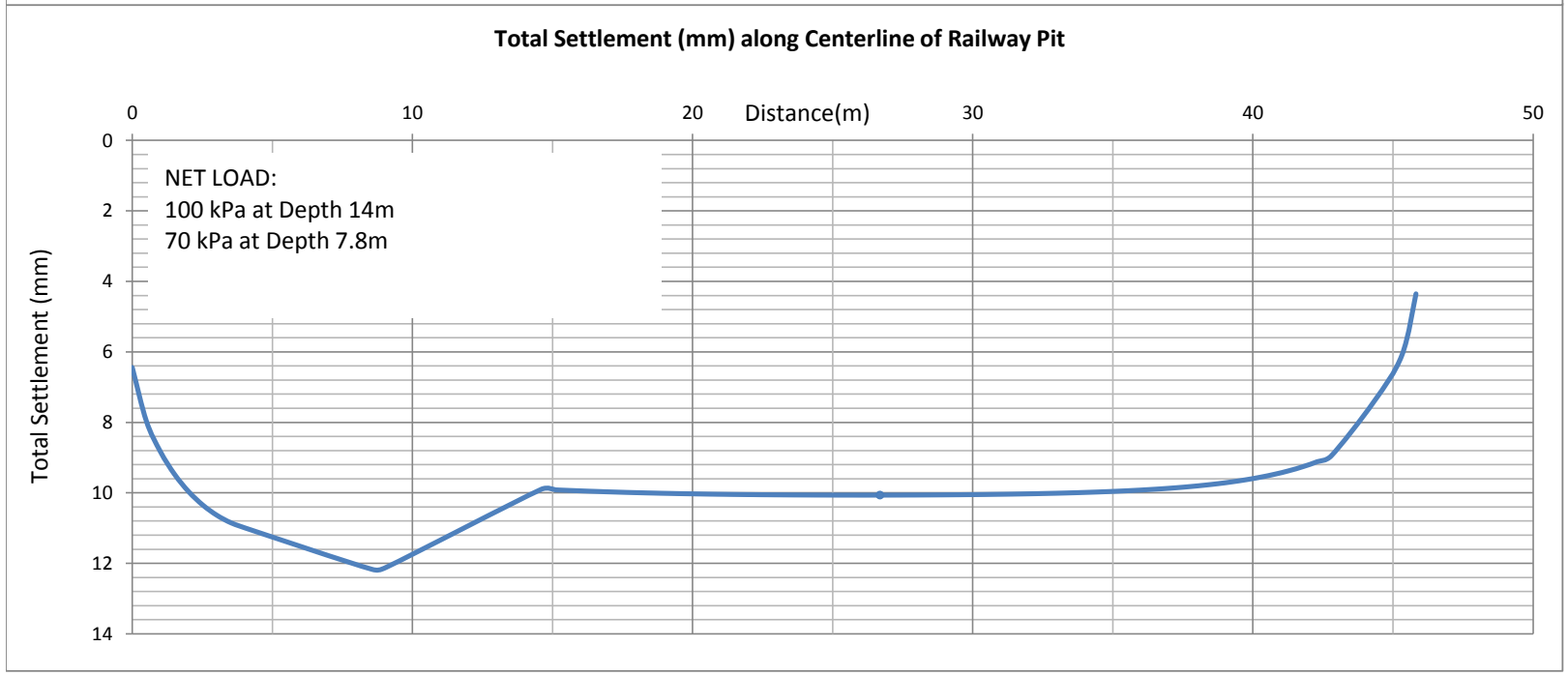
25 = 300 mon

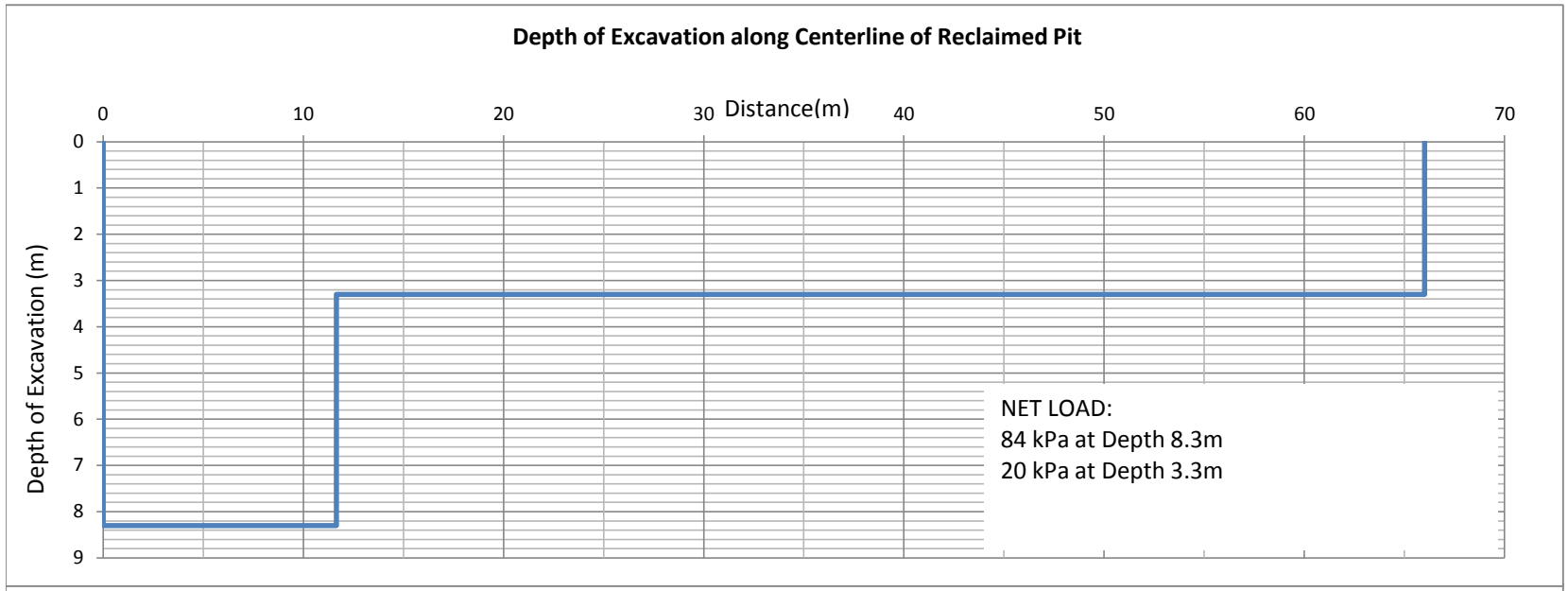
Data Type: Total Settlement

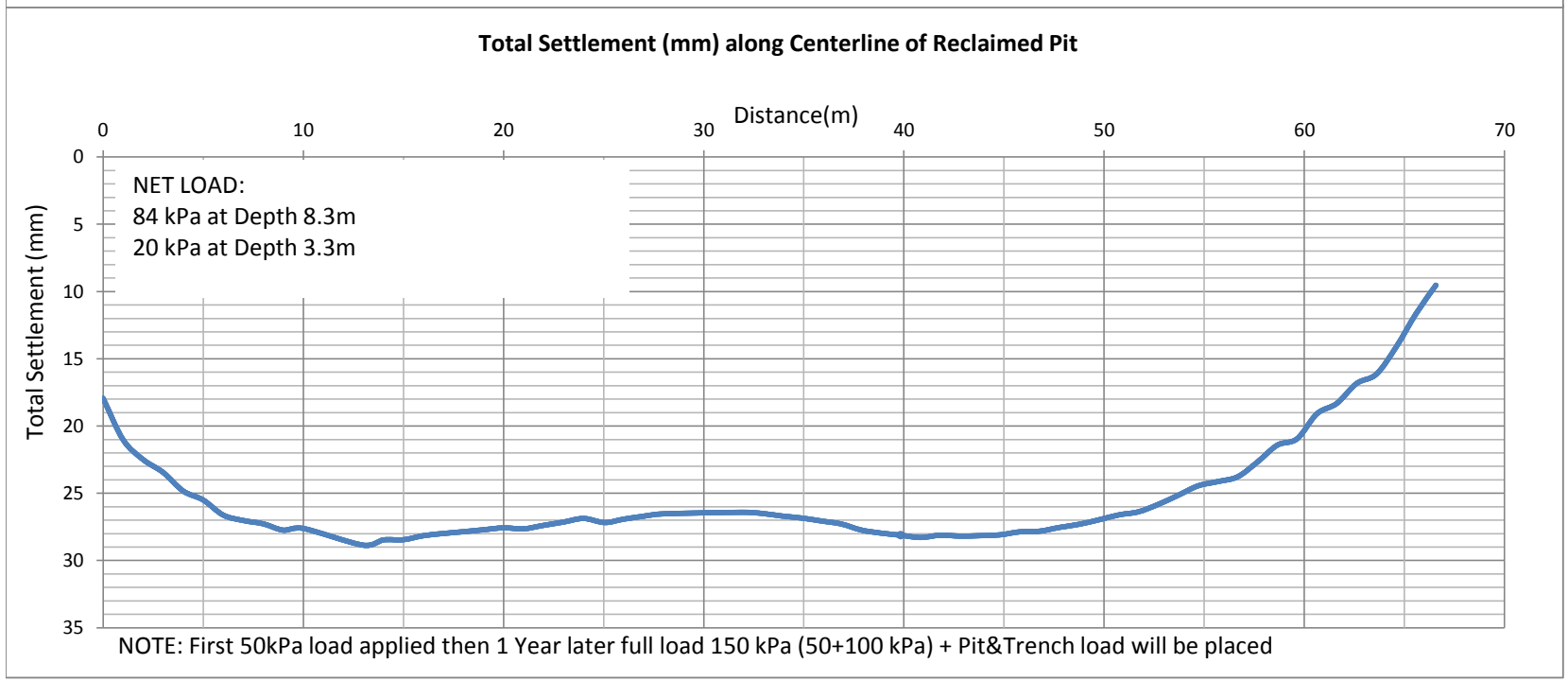


exp.	Project	0222989-A0 AGEX Pre-Feed Development at Bekaert Building	
	Analysis Description	Long Term Settlement under NEW PLAN ( ) 2015-09-28	
	Drawn By	MH/MAK	Company: exp
SETTLE3D 2.018	Date	9/28/2015	File Name: Soil Profile 150-120 kPa Unifrom Load (2015-09-28)- MAK.s3z


Depth of Excavation along Centerline of Railway Pit
Distance(m)
0
10
20
30
40
50
Depth of Excavation (m)
0
2
4
6
8
10
12
14
16
NET LOAD:
100 kPa at Depth 14m
70 kPa at Depth 7.8m


Total Settlement (mm) along Centerline of Railway Pit
Distance(m)
0
10
20
30
40
50
Total Settlement (mm)
0
2
4
6
8
10
12
14
NET LOAD:
100 kPa at Depth 14m
70 kPa at Depth 7.8m



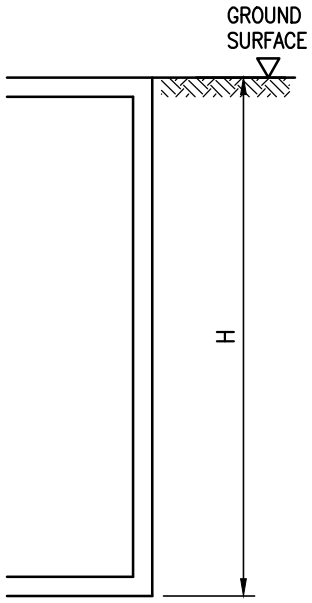


NOTE: First 50kPa load applied then 1 Year later full load 150 kPa (50+100 kPa) + Pit&Trench load will be placed

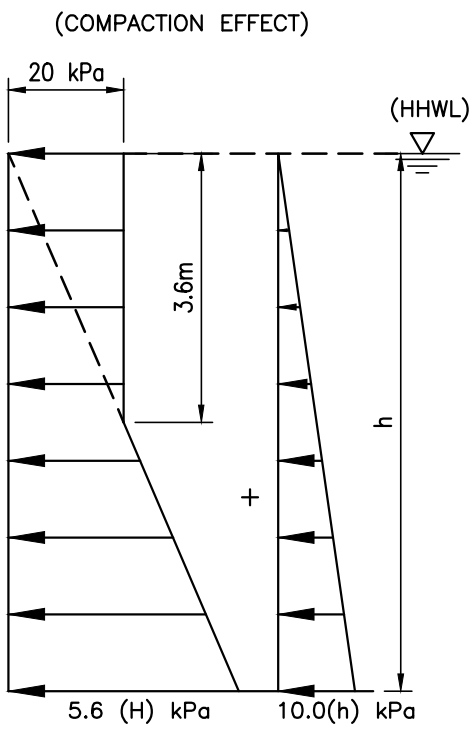
Appendix G

Lateral Earth Pressure Diagrams

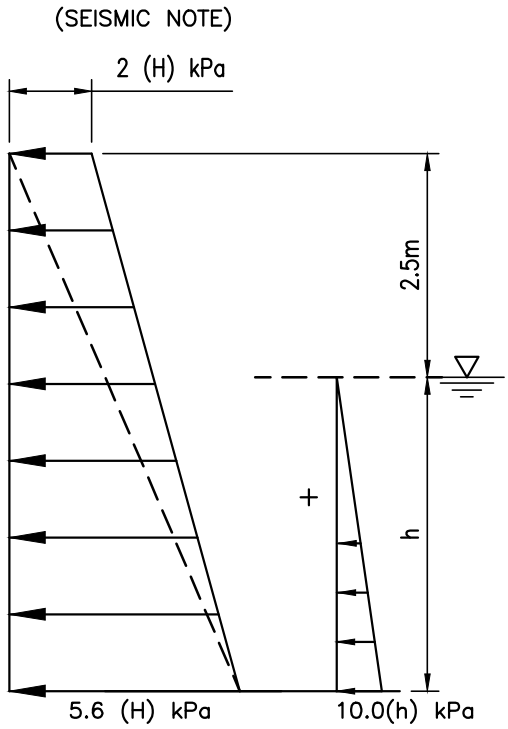
Figures 10 to 14



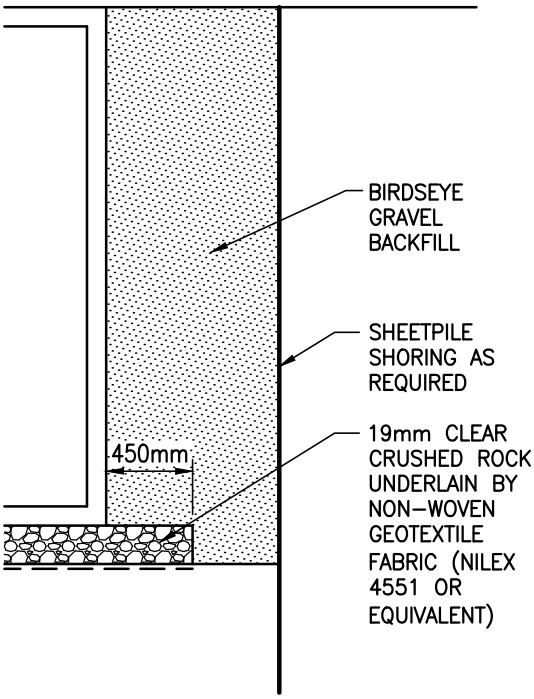
TYPICAL FOUNDATION WALL



STATIC + WATER PRESSURE



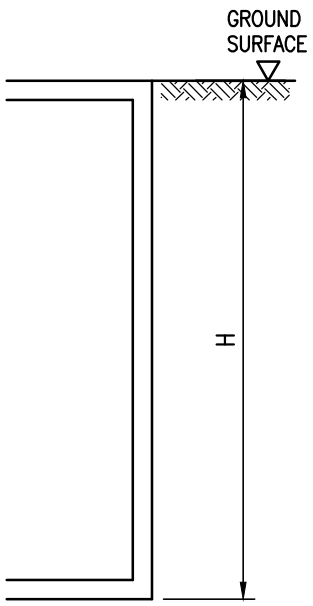
SEISMIC+STATIC + WATER PRESSURE



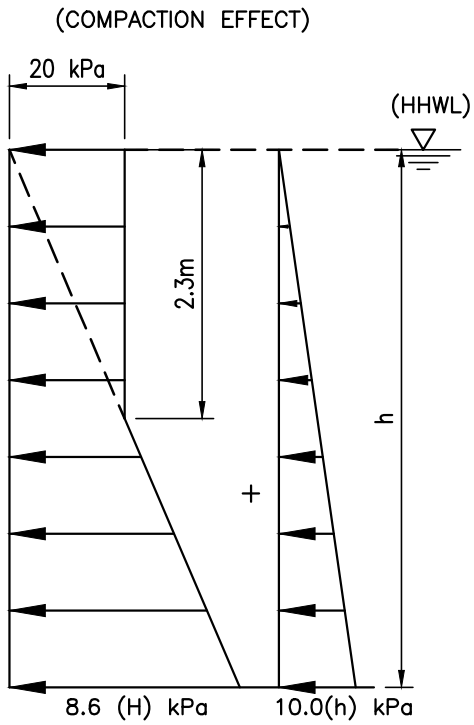
NOTES:

- ALL METRIC UNITS IN (m) AND (kPa)
- ACTIVE PRESSURE IS CALCULATED BASED ON ϕ=33 DEGREE AND γ =19kN/m3
- ACTIVE PRESSURE COEFFICIENT Ka = 0.29
- THE PRESSURES GIVEN IN THIS DIAGRAM ARE UNFACTORED. USE APPROPRIATE LOAD FACTORS.
- SEISMIC COMPONENT BASED ON:
  Kh = $\frac{3}{4}$XPGA = $\frac{3}{4}$x0.21= 0.157

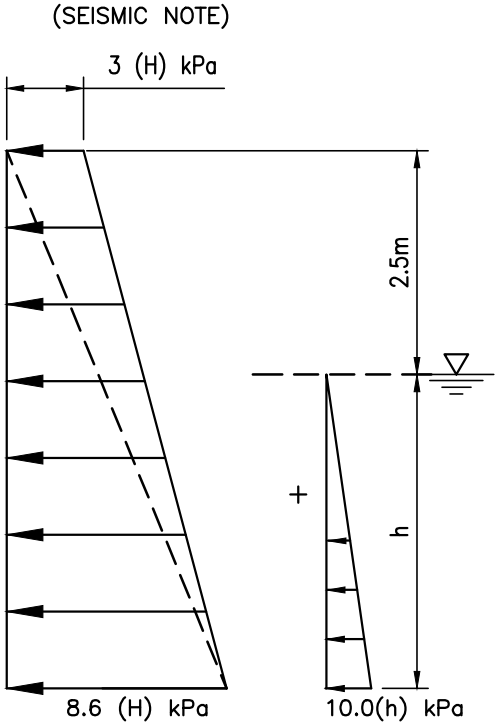
exp.	CLIENT: Parrish & Hiembercker Ltd.			TITLE: LATERAL EARTH PRESSURE ON YIELDING WALLS, 475 EQ		
	PROJECT: Proposed P&H Fraser Terminal Fraser Surrey Docks, Surrey, BC					
	PROJECT NO. VAN-00222989-A0	DFTR. MG	DSGN. UC	CHK. BW	DATE 2015-02-13	SCALE: NTS	DWG NO. FIGURE 10



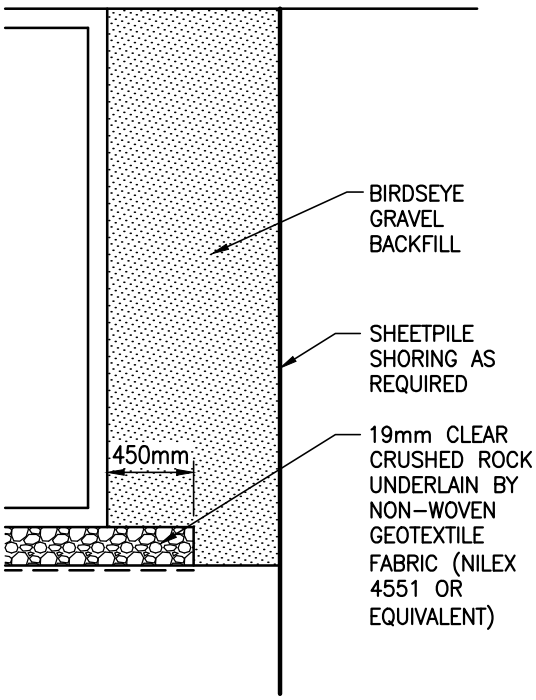
TYPICAL FOUNDATION WALL



STATIC + WATER PRESSURE



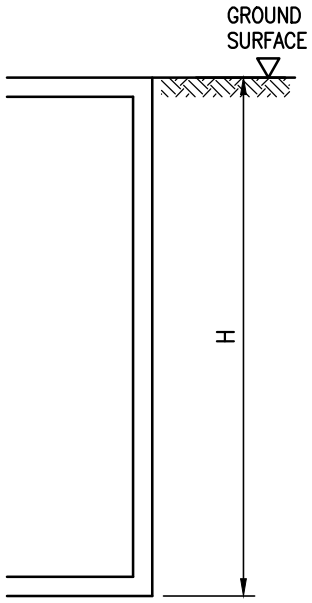
SEISMIC+STATIC + WATER PRESSURE



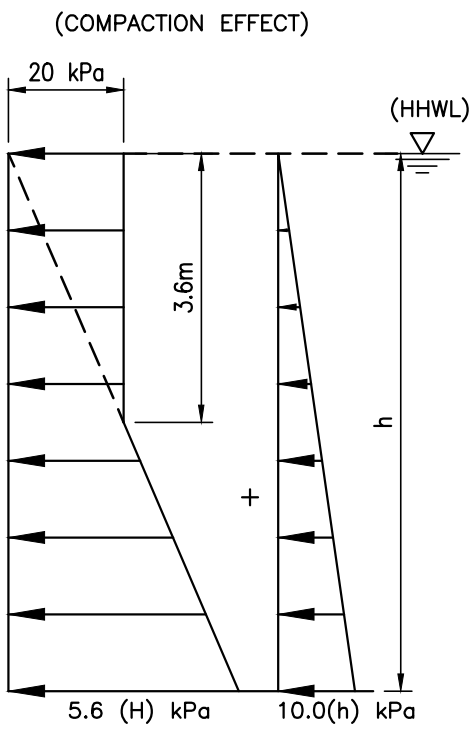
NOTES:

- ALL METRIC UNITS IN (m) AND (kPa)
- ACTIVE PRESSURE IS CALCULATED BASED ON ϕ=33 DEGREE AND γ =19kN/m3
- EARTH PRESSURE AT REST COEFFICIENT Ko = 0.45
- THE PRESSURES GIVEN IN THIS DIAGRAM ARE UNFACTORED. USE APPROPRIATE LOAD FACTORS.
- SEISMIC COMPONENT BASED ON:
  Kh = PGA = 0.21

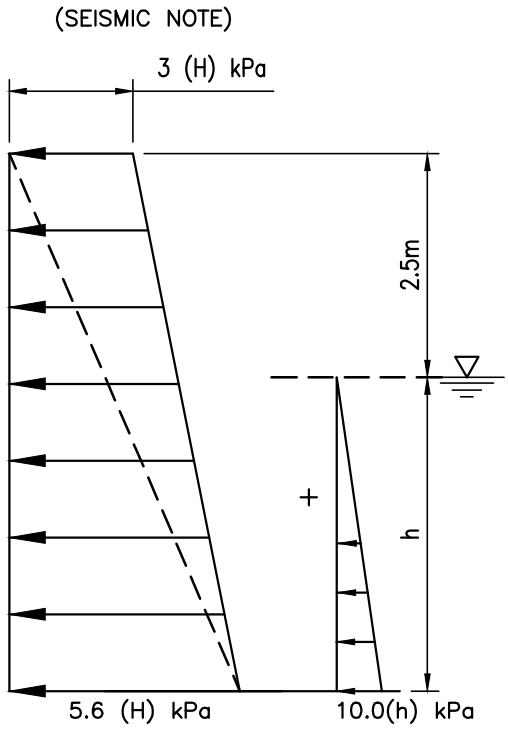
exp.	CLIENT: Parrish & Hiembercker Ltd.			TITLE: LATERAL EARTH PRESSURE ON RIGID NON-YIELDING WALLS, 475 EQ		
	PROJECT: Proposed P&H Fraser Terminal Fraser Surrey Docks, Surrey, BC					
	PROJECT NO. VAN-00222989-A0	DFTR. MG	DSGN. UC	CHK. BW	DATE 2015-02-13	SCALE: NTS	DWG NO. FIGURE 11



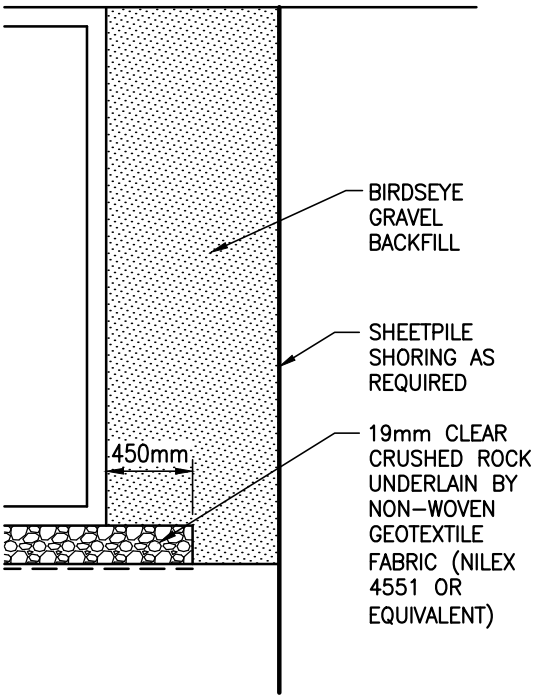
TYPICAL FOUNDATION WALL



STATIC + WATER PRESSURE



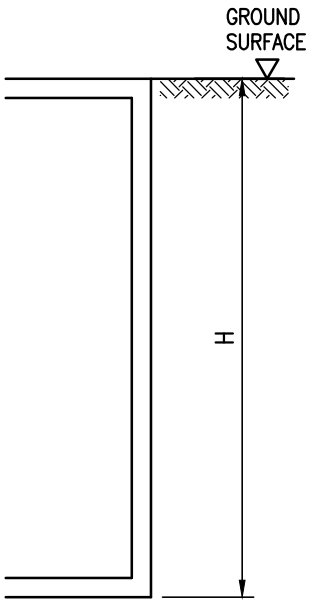
SEISMIC+STATIC + WATER PRESSURE



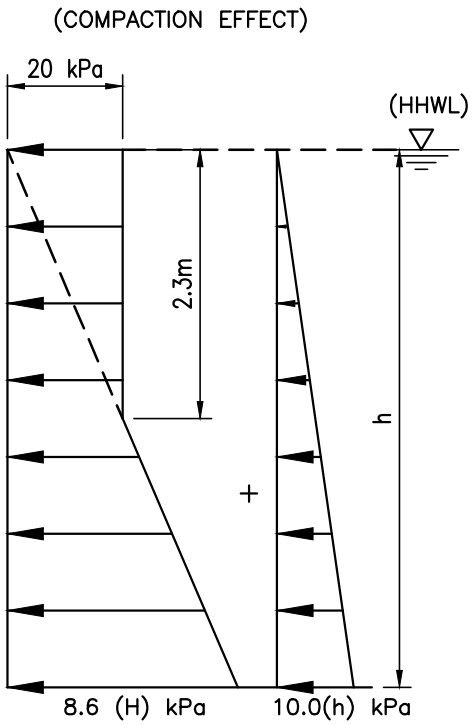
NOTES:

- ALL METRIC UNITS IN (m) AND (kPa)
- ACTIVE PRESSURE IS CALCULATED BASED ON ϕ=33 DEGREE AND γ =19kN/m3
- ACTIVE PRESSURE COEFFICIENT Ka = 0.29
- THE PRESSURES GIVEN IN THIS DIAGRAM ARE UNFACTORED. USE APPROPRIATE LOAD FACTORS.
- SEISMIC COMPONENT BASED ON:
  Kh = $\frac{3}{4}$XPGA =$\frac{3}{4}$x.29= 0.22

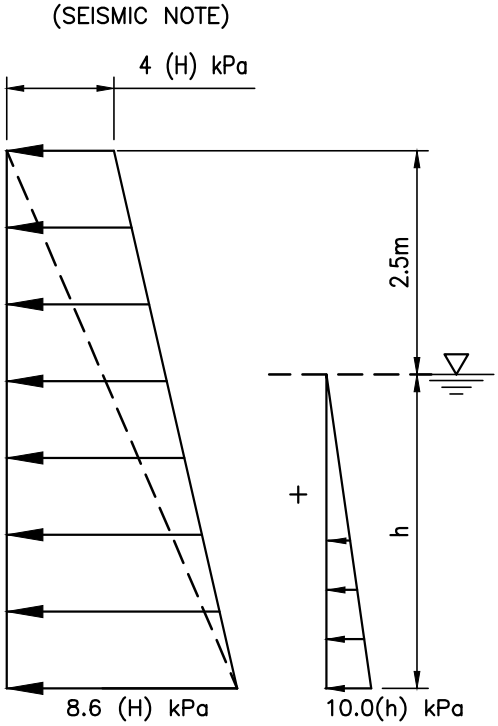
exp.	CLIENT: Parrish & Hiembercker Ltd.			TITLE: LATERAL EARTH PRESSURE ON YIELDING WALLS, 2475 EQ		
	PROJECT: Proposed P&H Fraser Terminal Fraser Surrey Docks, Surrey, BC					
	PROJECT NO. VAN-00222989-A0	DFTR. MG	DSGN. UC	CHK. BW	DATE 2015-02-13	SCALE: NTS	DWG NO. FIGURE 12



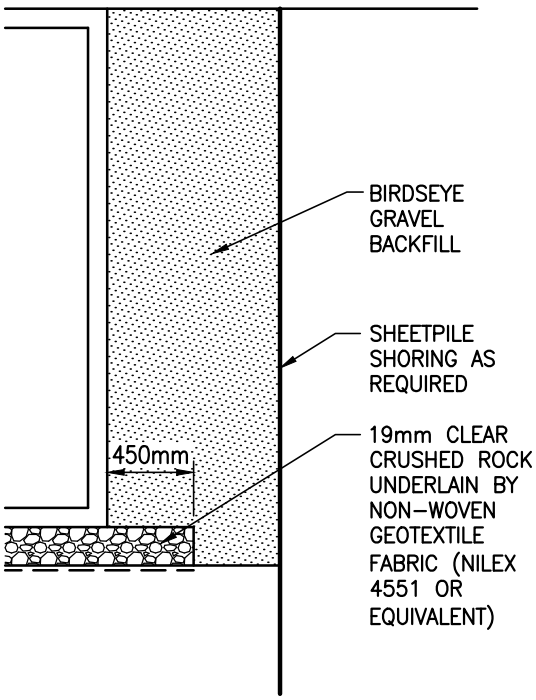
TYPICAL FOUNDATION WALL



STATIC + WATER PRESSURE



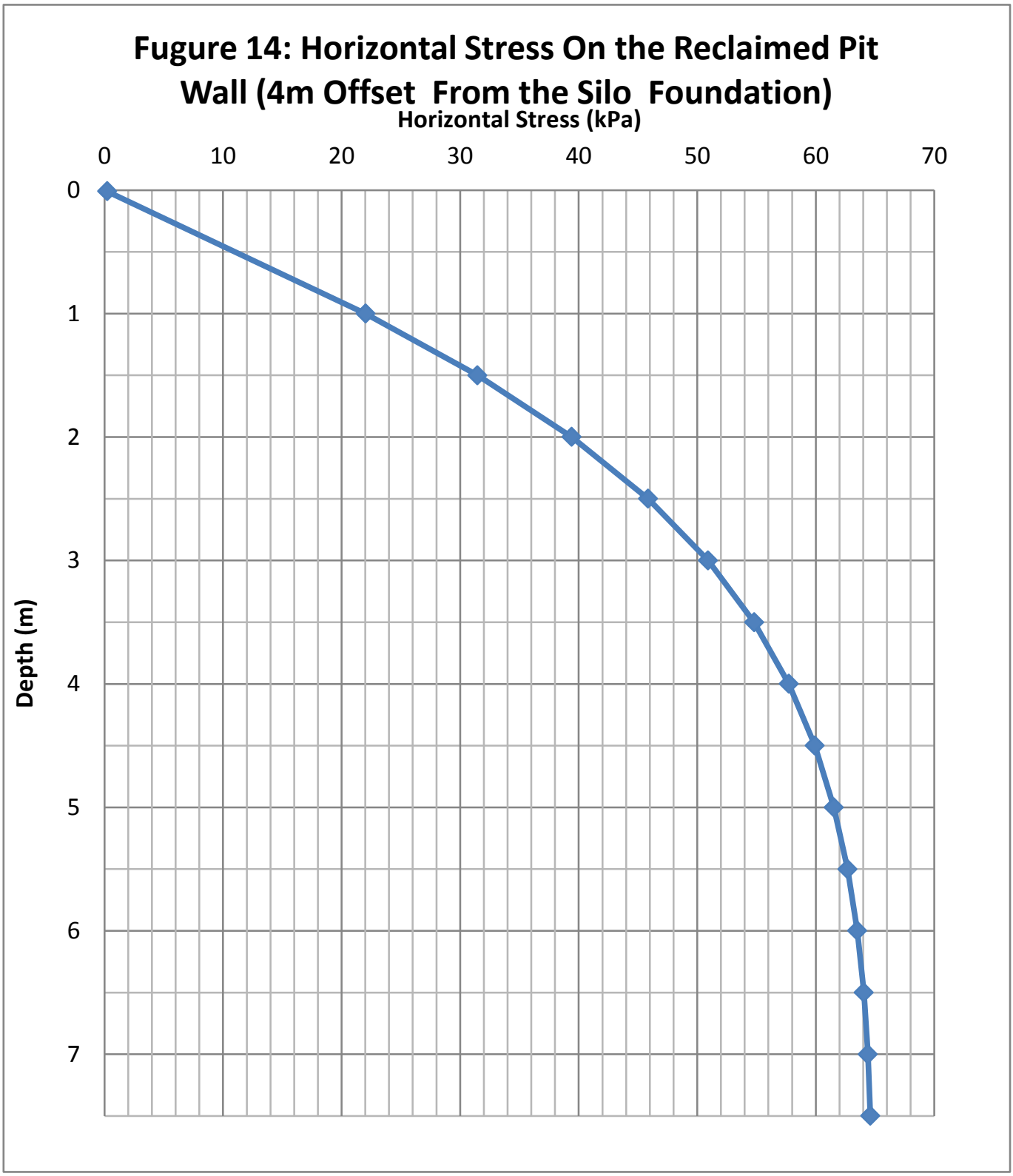
SEISMIC+STATIC + WATER PRESSURE



NOTES:

- ALL METRIC UNITS IN (m) AND (kPa)
- ACTIVE PRESSURE IS CALCULATED BASED ON ϕ=33 DEGREE AND γ =19kN/m3
- EARTH PRESSURE AT REST COEFFICIENT Ko = 0.45
- THE PRESSURES GIVEN IN THIS DIAGRAM ARE UNFACTORED. USE APPROPRIATE LOAD FACTORS.
- SEISMIC COMPONENT BASED ON:
  Kh = PGA = 0.29

exp.	CLIENT: Parrish & Hiembercker Ltd.			TITLE: LATERAL EARTH PRESSURE ON RIGID NON-YIELDING WALLS, 2475 EQ		
	PROJECT: Proposed P&H Fraser Terminal Fraser Surrey Docks, Surrey, BC					
	PROJECT NO. VAN-00222989-A0	DFTR. MG	DSGN. UC	CHK. BW	DATE 2015-02-13	SCALE: NTS	DWG NO. FIGURE 13


Fugure 14: Horizontal Stress On the Reclaimed Pit Wall (4m Offset From the Silo Foundation)
Horizontal Stress (kPa)
0
10
20
30
40
50
60
70
Depth (m)
0
1
2
3
4
5
6
7

Appendix H

Appendix H - Supplemental Coring Exploration Memo

exp Services Inc.
275 – 3001 Wayburne Drive
Burnaby, BC V5G 4W3
Telephone 604.874.1245
Fax 604.874.2358

ENGINEERING MEMO

DATE:	October 15, 2015	**FILE NO.**	VAN-00222989-A0
TO:	Michel Vander Noot, P.Eng.	mvandernoot@cmcengineering.com	
FROM:	Ujjal Chakraborty, P.Eng.	**CLIENT:**	Parrish & Heimbecker, c/o CMC Engineering and Management Ltd.
cc:		**PAGES:**	3 + Attachment
SUBJECT:	**Supplemental Coring and Hand Auger Exploration**		
LOCATION:	**Proposed AGEX Pre-Feed Development** **P & H Fraser Terminal, Surrey, BC**		

REVISION No.	Date Issued	Revision Description
0	October 15, 2015	Original Memorandum

MESSAGE/INSTRUCTIONS:

As authorized, **exp** Services Inc. (**exp**) has completed a supplemental geotechnical exploration in accordance with **exp**'s proposal dated September 24, 2015. The scope of services was limited to measuring existing concrete slab and asphalt pavement thickness at core locations, characterizing underlying shallow soil conditions, and to provide geotechnical comments with respect to the findings. Environmental or chemical assessment of soil and groundwater at the site was not part of our work scope.

The field work was carried out between October 7, 2015 and October 8, 2015 and included the following:

- Twenty (20) concrete and asphalt core holes with hand augers to 0.5 to 1.07m depths below the core holes;
- Suggested location of the core holes were provided by CMC;
- Two representatives from **exp** conducted the coring and hand augering work; and,
- Following completion of coring and hand augering, the holes were backfilled with concrete.

Attached sketch shows the location of the core holes.

Table 1 shows the summary of the core hole logs.

ENGINEERING MEMO

Table 1 - Summary of Coring and Hand Auger

Test Hole No.	Description of Soil	Remarks
TH1	152mm thick Concrete followed by dry, grey, compact to dense fine to medium grained sand. Refusal at 1.07m depth ***(with hand auger)***.	No gap observed between the concrete and the sand.
TH2	51mm thick Asphalt followed by 100mm thick sand and gravel road base then grey, dry, compact to dense fine to medium grained sand. Refusal at 1.07m depth.	
TH3	152mm thick Asphalt followed by 250mm thick sand and gravel road base then grey, dry, compact to dense sand with trace gravel. Refusal at 0.91m depth.	
TH4	75mm thick Asphalt followed by sand and gravel road base. Refusal at 0.3m depth.	
TH5	178mm thick Asphalt followed by 50mm thick sand and gravel road base then grey, dry, compact to dense sand with trace gravel. Refusal at 0.76m depth.	
TH6	152mm thick Concrete followed by 75mm thick dry, compact to dense sand and gravel then dense fine to medium grained sand. Refusal at 1.07m depth.	No gap observed between the concrete and the sand.
TH7	75mm thick Asphalt followed by 150mm thick sand and gravel road base then grey, dry, compact to dense fine to medium grained sand. Refusal at 0.91m depth.	
TH8	127mm thick Asphalt followed by 50mm thick sand and gravel road base then grey, dry, compact to dense fine to medium grained sand. Refusal at 1.07m depth.	
TH9	75mm thick Asphalt followed by 75mm thick sand and gravel road base then grey, dry, compact to dense fine to medium grained sand. Refusal at 0.91m depth	
TH10	127mm thick Concrete followed by 50mm thick dry, dense sand and gravel then compact to dense fine to medium grained sand. Refusal at 1.07m depth.	No gap observed between the concrete and the sand.
TH11	75mm thick Asphalt followed by 75mm thick sand and gravel road base then grey, dry, compact to dense fine to medium grained sand. Refusal at 0.91m depth.	
TH12	114mm thick Asphalt followed by 228mm thick sand and gravel road base then grey, dry, compact to dense fine to medium grained sand. Refusal at 1.07m depth.	
TH13	150mm thick concrete followed by dry, grey, compact to dense fine to medium grained sand, trace gravel. Refusal at 0.76m depth	No gap observed between the concrete and the sand.
TH14	178mm thick Concrete followed by 75mm thick sand and gravel road base then grey, dry, compact to dense fine to medium grained sand. Refusal at 0.76m depth.	No gap observed between the concrete and the sand.

ENGINEERING MEMO

Test Hole No.	Description of Soil	Remarks
TH15	152mm thick Concrete followed by grey, dry, compact to dense fine to medium sand, trace gravel. Refusal at 0.76m depth.	No gap observed between the concrete and the sand.
TH16	50mm thick Asphalt followed by 25mm sand and gravel road base then 50mm thick Asphalt followed by compact to dense sand and gravel. Refusal at 381mm depth.	
TH17	65mm thick Asphalt followed by crushed rock. Refusal at 250mm depth.	
TH18	480mm thick Concrete followed by dry, grey, compact to dense fine to medium grained sand, trace gravel. Refusal at 1m depth	No gap observed between the concrete and the sand.
TH19	310mm thick Concrete followed by dry, grey, compact to dense fine to medium grained sand, trace gravel. Refusal at 1m depth.	No gap observed between the concrete and the sand.
TH20	150mm thick Concrete followed by dry, grey, compact to dense fine to medium grained sand, trace gravel. Refusal at 1m depth.	No gap observed between the concrete and the sand.

Based on the review of core logs and previous deep test holes, it appears that there are no visible gaps between the existing concrete slab and foundation fill. Foundation soil under the existing concrete was consistently dry, grey compact to dense fine to medium grained sand. Based on the review, it is our opinion that the proposed silo foundation raft slab on top of the existing concrete slab is feasible. For the asphalt pavement areas, it is recommended to remove the existing asphalt and compact the exposed granular base to 95% Modified Proctor Dry density using a large ride-on type vibratory drum roller before placing any new fill or foundation. Following compaction, the exposed base should be proof-rolled with a fully loaded dump truck under review by **exp** geotechnical engineer. Any unsuitable soil/weak zones should be removed as required and backfilled with compacted granular soil.

exp Services Inc.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
U. CHAKRABORTY
32226

15 OCT, 2015

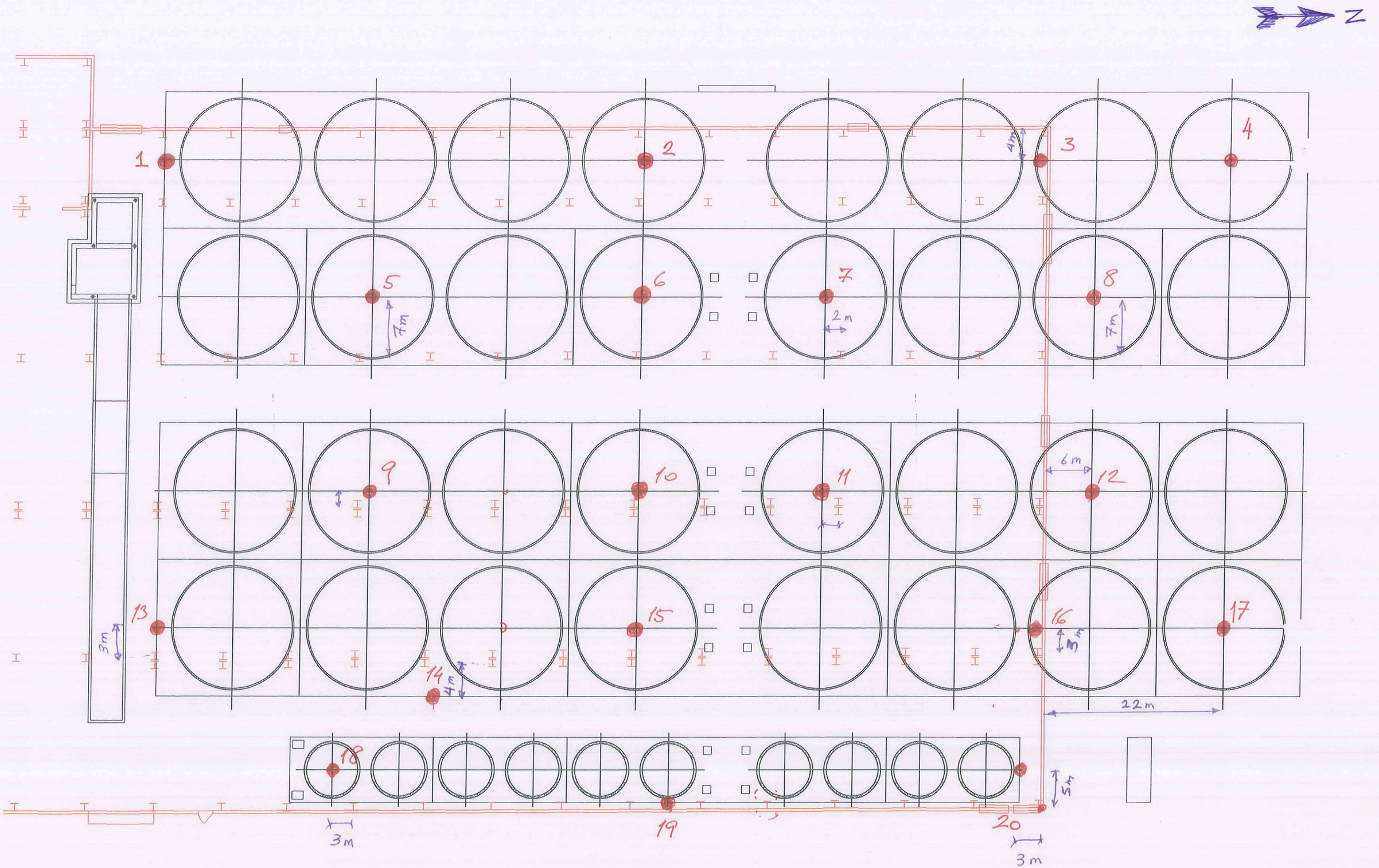
Ujjal Chakraborty, P.Eng.
Geotechnical Engineer

Reviewed by

Ben Weiss, P.Eng.
Senior Geotechnical Engineer

Attachment: Sketch of Core Hole Locations

L:\2014 (Starting at 0216767-A0)\0222989-A0 BW AGEX Pre-Feed Development at Bekaert Building\4.1 General Correspondence\Reports\exp EM 2015 10 15 Supplemental Coring Exploration.docx


N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
4m
7m
2m
7m
6m
3m
4m
3m
22m
5m
3m
3m

Appendix J

2010 National Building Code Seismic Hazard Value

2010 National Building Code Seismic Hazard Calculation

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

Requested by: Ujjal, exp — January 21, 2015

Site Coordinates: 49.1805 North 122.9152 West

User File Reference: Proposed P&H Fraser Terminal

National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
1.020	0.680	0.332	0.172	0.506

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. ***These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.*** Warning: You are in a region which considers the hazard from a deterministic Cascadia subduction event for the National Building Code. Values determined for high probabilities (0.01 per annum) in this region do not consider the hazard from this type of earthquake.

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.240	0.534	0.730
Sa(0.5)	0.156	0.350	0.481
Sa(1.0)	0.080	0.172	0.234
Sa(2.0)	0.040	0.087	0.120
PGA	0.124	0.270	0.364

References

National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

User's Guide - NBC 2010, Structural Commentaries NRCC no. 53543 (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File xxxx
Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2010 National Building Code of Canada (in preparation)

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

Aussi disponible en français