THURBER ENGINEERING LTD.

December 21, 2020 File: 27441

Enginuity Consulting Ltd.
8059 N. Fraser Way
Burnaby, B.C.
V5J 5M8

Attention: Richardo Rivera, B.Eng.

WALLENIUS WILHELMSEN SOLUTIONS ANNACIS TERMINAL
#100, 820 DOCK ROAD, DELTA, B.C.
PROPOSED NEW PRODUCTION BUILDING
PRELIMINARY GEOTECHNICAL REPORT (REVISION 1)

Dear Richardo:

Thurber has completed a geotechnical investigation for the above project. This report summarizes the results of the geotechnical investigation and provides preliminary recommendations for design of the proposed new production building. This report was issued originally on September 28, 2020 as a desktop study. This revision of the report has been updated to include results based on a site-specific geotechnical investigation and has incorporated comments provided by Enginuity on December 17, 2020.

It is a condition of this letter that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1. INTRODUCTION

We understand that Wallenius Wilhelmsen Solutions (WWS) plans to redevelop the existing buildings within the Annacis Terminal. The redevelopment includes demolition of the existing mechanical #1 and accessory #2 buildings and construction of a new production building generally between and in very close proximity to the existing parts warehouse and accessory #1 building. The new building will be a prefabricated steel frame structure with a height of 6 m, similar to existing buildings in the area. The building footprint will be about 4,100 m^2, measuring about 60 m in length and about 55 m in width between the existing parts warehouse and accessory #1 building to about 85 m in width west of the accessory #1 building. The finished site grade will be similar to the existing.

According to Enginuity, the maximum column compression loads will be 700 kN and 300 kN under ultimate (ULS) and serviceability (SLS) limit state conditions, respectively, for design of spread footings. The equivalent uniform pressures will be 30 kPa and 22 kPa under ULS and SLS loading conditions, respectively, for design of a raft foundation.

Our scope of work in this phase of the project was to review available geotechnical information provided by WWS and in our files, conduct a geotechnical investigation and provide preliminary geotechnical recommendations for design of the new building foundations in accordance to the

2015 National Building Code of Canada (NBCC) under the normal importance category. Assessment of soil and groundwater contamination is not with included in our scope of work.

2. EXISTING CONDITIONS

The area in the vicinity of the new building is relatively flat. According to the City of Delta's GIS map, the project site is at about El. 4 m (geodetic).

The east edge of the new building will be situated about 80 m from the crest of the foreshore slope of the Annieville Channel (i.e. the Fraser River south arm) at about El. 3 m. It is noted that existing buildings for break room and lockers and administration office are situated about 25 m east of the new building and that Berth No. 2 is present offshore along the width of the new building. Berth No. 2 is a pile-supported deck that was originally constructed in 1972 and subsequently expanded in 1989. The original portion comprised about 9 rows of timber piles terminated about 6.1 m (20 ft.) to 7.6 m (25 ft.) below the mudline. The 1989 expansion comprised 15 rows of 610 mm diameter concrete piles terminated at El. -20 m to El. -24 m (chart datum).

Bathymetry data in the vicinity of Berth No. 2 was provided by the Vancouver Fraser Port Authority (VFPA) on December 11, 2020. The recent bathymetry data suggests that the toe of the foreshore slope extends about 75 m to 80 m from the crest and that the bottom of the riverbed is about 20 m below the existing site grade.

3. PROGRAM OF WORK

A geotechnical investigation comprising test hole (TH) drilling, cone penetration test (CPT) and seismic cone penetration test (SCPT) profiling was completed by Southland Drilling Co. Ltd. and Schwartz Soil Technical Inc. on September 25, 2020. The approximate locations of the completed THs, CPT and SCPT are shown on Dwg. 27441-1.

Four test holes, designated TH20-01 to TH20-04, were drilled to depths of about 6 m to 7.5 m. Prior to drilling at TH20-1 and TH20-2, SCPT20-01 and CPT20-02 were advanced to depths of 30 m and 20 m, respectively. Shear wave velocities (V_s) were measured at 1 m intervals along the entire CPT profile at SCPT20-01.

A dynamic cone penetration test (DCPT) profile was conducted at TH20-03 and TH20-04 to a depth of about 7.3 m before they were drilled. The DCPT tip is similar in size and shape to the standard penetration test split-spoon sampler and is driven using the same hammer energy. The DCPT provides a qualitative estimate of in-situ density of granular soil and is useful for identifying stiffness and strength contrasts within and between soil strata.

The soil and groundwater conditions were logged in the field by a Thurber geotechnical engineer. Disturbed soil samples were collected off the auger flights at regular intervals for laboratory testing. All soil samples were subjected to routine moisture content and visual classification testing in our laboratory. Percent passing No. 200 sieve testing was completed for two selected soil samples.

Upon completion of drilling, the test holes were backfilled with soil cuttings and sealed with bentonite chips in accordance to the B.C. groundwater protection regulations. The asphalt was restored using cold patch asphalt.

4. SOIL AND GROUNDWATER CONDITIONS

The results of the site investigation and laboratory testing are summarized on the attached test hole and CPT/SCPT logs. The soil descriptions on the logs should be used in preference to the generalized soil descriptions given below. It should be noted that soil descriptions provided in the CPT/SCPT logs are an interpretation of the CPT data using published correlations and should be considered approximate. Actual soils encountered may differ from the interpreted descriptions provided.

The soil conditions encountered within the proposed building footprint generally comprise asphalt and fill over Fraser River sand to the depths investigated. The asphalt thickness was about 50 mm to 90 mm.

Below the asphalt, predominately dredged sand fill was encountered as the project site appears to be situated within the reclaimed portion of the Annacis Island. According to the available air photos, the fill, likely comprising dredge sand originated from the Annieville Channel, was placed hydraulically circa 1949. The fill was generally in a loose to compact condition. A silt layer with variable sand content was encountered within the fill.

Below the fill, native Fraser River sand was encountered to the depth investigated. The transition of the dredged sand fill and the native Fraser River sand could not be clearly identified as they are very similar in gradation. The Fraser River sand was generally loose to compact with localized dense zones typically below a depth of 20 m. Based on our experience, the sand layer typically extends up to a depth of about 35 m and is underlain by a thick interbedded silt and sand layer that extends to a depth of 100 m or more.

Groundwater was not encountered in the open test holes. The CPT/SCPT data suggests an underlying groundwater table in the Fraser River sand with a hydrostatic head corresponding to a depth of about 4 m (about El. 0 m geodetic). Groundwater levels are expected to be heavily influenced by river levels and tidal fluctuations due to the close proximity to the Annieville Channel, as well as infiltration and drainage conditions.

5. SEISMIC ASSESSMENT

Seismic Site Classification

Based on the V_s profile measured at SCPT20-01, the average shear wave velocity in the upper 30 m depth (V_{s30}) is estimated to be 210 m/s. Therefore, without the consideration of liquefaction, the interpreted V_{s30} value of 210 m/s suggests a Site Class D classification in accordance to 2015 NBCC, especially for the fundamental period of vibration for structures below 0.5 seconds.

However, due to the presence of liquefaction susceptible soils as discussed below, the Site Class is F in accordance with the 2015 NBCC. Thurber conducted a site-specific response analysis

(SSRA) related to racking design in the vicinity of the site for WWS in 2017. The SSRA was carried out using the 2015 NBCC seismic hazard values. For a design period of less than 0.5 seconds, the results of the SSRA were significantly lower than those from the code-based values.

Recently, EGBC is proposing a draft practice advisory for SSRAs that the design spectra from SSRAs should be at least 80% of the code-based spectra. Based on our review of the 2017 SSRA results and given that the fundamental period of the new building is less than 0.5 seconds according to Enginuity, we consider that the design spectrum for the new building may be taken as 80% of the Site Class D spectrum for preliminary design.

Liquefaction Potential

A liquefaction triggering analysis was carried out using the commercial software program CLiq by Geologismiki in accordance to the CPT-based simplified approach procedures by Idriss and Boulanger (2008 and 2014). The cyclic resistance of soils, defined as the cyclic resistance ratio (CRR), was estimated using semi-empirical relationships from CPTs. The earthquake-induced cycle shear stress, defined as the cyclic stress ratio (CSR), was determined using a peak ground acceleration of 0.34g, corresponding to the 1:2,475-year return period (or a 2% probability of exceedance in 50 years) design earthquake for Site Class D soils.

The results of the CPT-based liquefaction triggering analyses are shown on Figures 1 and 2. In general, the majority of the dredged sand fill or native sand deposits below the mean groundwater level (El. 0 m), except for some dense lenses, are expected to be susceptible to liquefaction in the design earthquake.

Consequences of Liquefaction

The potential consequences of liquefaction to the proposed grade-supported building without ground improvement are listed below:

- There is insufficient non-liquefiable crust to prevent crust rupture, loss of foundation support and punching failure of conventional footings.

- Liquefaction could induce soil settlement due to dissipation of excess pore pressures generated in soils during strong ground shaking. While liquefaction extends to a significant depth, ground manifestation is typically limited to the zone of liquefaction in the upper 18 m depth according to Cetin et al (2004). Accordingly, we estimate that total and differential post-liquefaction settlements on the order of 200 mm and 100 mm could occur, respectively.

- Liquefaction could induce a lateral spreading due to the proximity to the Annieville Channel. A limit equilibrium seismic slope stability analysis was completed using the computer software program SLOPE/W for a flow slide check. The analysis was carried out using the bathymetry data provided by VFPA in conjunction with residual soil strengths for the liquefiable layers. The results suggest that the east edge of the new building will be marginally behind a potential flow slide zone (i.e. lateral displacements in excess of 1 m) as shown on Figure 3. However, using the empirical relationship by Youd et al (2002), lateral spreading of about 1 m to 2 m from the east edge of the new building could occur with differential lateral displacements between the east and west ends of the building of 200 mm to 400 mm.

Other Seismic Considerations

The next revision of the NBCC is expected to be released in 2021. Based on our understanding, the seismic hazard values in the next revision of the NBCC are expected to be greater than those in the current revision. Larger seismic deformations and inertial loading should be anticipated. This should be further reviewed during detailed design.

6. PRELIMINARY GEOTECHNICAL RECOMMENDATIONS

6.1 General

Enginuity indicated that any uneven displacements due to liquefaction may cause a brittle collapse and that ground improvement is recommended. Accordingly, preliminary recommendations for ground improvement to mitigate the effects associated with liquefaction are provided in Section 6.2.

Typically, ground improvement will extend to a depth and create a non-liquefiable zone to limit seismic deformations to tolerable levels. Hence, liquefaction susceptible soils will likely remain below the ground improvement zone. Accordingly, we recommend a structurally connected foundation system comprising a thickened-edge slab foundation system, conventional spread footings connected with grade beams or similar be used to enhance the seismic performance of the new building. Preliminary recommendations for design of shallow foundations are provided in Section 6.3.

6.2 Ground Improvement Design

Vibro-Replacement (Stone Columns)

For preliminary design purposes, we have assumed that vibro-replacement with stone columns will be used to densify the soil below the building footprint. Vibro-replacement comprises construction of gravel columns into the ground with a large diameter vibratory probe. The vibration probe compacts the gravel columns, as well as densifies the surrounding loose to compact sand. Stone columns are commonly used in the Lower Mainland to treat the Fraser River sand.

In general, stone columns are installed on a 2.5 to 3 m triangular grid spacing. For preliminary design purposes, stone columns should extend to a depth of about 20 m, a similar elevation as the bottom of the Annieville Channel. The zone of soil densification should ideally extend 10 m to 20 m beyond the edge of building. However, due to the presence of the Accessory #1 and Parts Warehouse, it is not feasible to extend the soil densification zone to the north and south of the new building. This further supports the use of a structurally connected foundation system.

Typically, the densification tender should be a performance specification with a required CPT tip resistance specified for the underlying sand. With this approach it is the contractor's responsibility to select a suitable spacing and column diameter to achieve the required CPT tip resistance to be measured in the mid-point between columns. The performance criteria for soil densification will depend on the seismic hazard and tolerable deformations which will need to be determined during detailed design.

Seismic Drains

Due to the presence of the existing structures adjacent to the new building, installation of stone columns to the edge of foundations will likely not be feasible. Hence, we recommend that seismic drains be installed where stone columns cannot be installed.

A seismic drain typically comprises a nominal 75 mm diameter perforated pipe wrapped around with geotextile filter fabric. It provides a drainage path to limit excess pore pressure build-up in soils during strong ground shaking and, hence, limit the onset of liquefaction. However, seismic drains do not mitigate post-liquefaction settlement. We anticipate that seismic drains will be installed to a similar depth of 20 m to 25 m to stone columns at about 1 m spacing.

6.3 Shallow Foundation Design

Upon completion of soil densification, we anticipate that the exposed subgrade will be regraded and compacted to a dense and unyielding condition prior to fill placement or foundation construction. Any soft, loose, wet, deleterious material or materials that do not respond to the compaction should be subexcavated and replaced with well-compacted structural fill.

A layer of granular fill is typically provided between the underside of foundations and the top of the stone columns. For preliminary design, a minimum 300 mm thick layer of well-compacted base course comprising minus 19 mm crushed sand and gravel can be used. The base course should be compacted to 98% Modified Proctor Maximum Dry Density (MPMDD).

For design of conventional footings or thickened areas below walls or columns supported on densified soils, the footings or thickenings can be designed using bearing resistances of 75 kPa and 50 kPa under ULS and SLS loading conditions, respectively. Foundations should be subject to minimum widths of 450 mm and 600 mm for wall and column footings or thickenings, respectively. A depth of cover of 450 mm to the underside of footings or thickenings below exterior grades should be provided for frost protection.

For a thickened-edge slab system, sufficient reinforcement should be provided to allow 50% of the load to be transferred to the adjacent slab and the junction between the slab and thickenings should be sloped at 30° or flatter to reduce tensile loads developed in the slab by lateral spreading (the flatter the slope, the lower the passive pressure on the thickening).

6.4 Estimated Settlement

For preliminary design purposes, we suggest the shallow foundations be designed for a total settlement of 25 mm to 50 mm under non-seismic loading conditions. Differential settlement of 1:400 may be used.

Assuming vibro-replacement with stone columns will be implemented as recommended, we suggest the shallow foundations be designed for a total settlement of 100 mm under seismic loading conditions. Differential settlement of 1:200 to 1:300 may be used for preliminary design.

Differential settlements will be higher where seismic drains must be installed to mitigate impacts to adjacent structures; this will need to be considered further during detailed design. If differential settlements between ground improvement zones of seismic drains and stone columns cannot be accommodated in the structural design (span/cantilever details), alternative ground improvements at the interface of existing buildings such as soil mixing may need to be considered instead of seismic drains.

6.5 Slab-on-Grade

Slab-on-grade should be underlain by a minimum of 150 mm thick base course of clean, well-graded, crushed gravel fill compacted to 100% SPMDD. Conventional perimeter drains and vapour barrier should be provided.

6.6 Potential Impact to Adjacent Buildings and Facilities

Installation of stone columns or excavation, backfilling and compaction operations will induce vibrations resulting in ground settlement that could affect the existing buildings and facilities adjacent to ground improvement or construction zones. For precautionary purposes, a precondition survey including a baseline survey and visual inspection of nearby existing buildings and facilities should be conducted prior to construction to understand the existing conditions of the structures. We envisage that threshold deformation tolerances will be developed by structural engineers prior to construction. A detailed monitoring program should be implemented to observe actual movements during construction. These items should be developed during detailed design.

7. CLOSURE

We trust that this information is sufficient for your needs. Should you require clarification of any item or additional information, please contact us at your convenience.

Yours truly,
Thurber Engineering Ltd.
Paul Wilson, M.Eng., P.Eng.
Review Principal

PROFESSIONAL
PROVINCE OF
C. K. LING
31250
BRITISH COLUMBIA
ENGINEER

Charles Ng, M.Eng., P.Eng.
Associate, Project Engineer

2020-12-21

Attachments:	Statement of Limitations and Conditions (1 page)
	Dwg. 27441-1 – Test Hole Location Plan (1 page)
	Symbols and Terms (1 page)
	Test Hole and CPT/SCPT Logs (8 pages)
	2015 NBCC Seismic Hazard Values for Site Class C Soils (1 page)
	Figures 1 and 2 – Results of Liquefaction Triggering Analyses (2 pages)
	Figure 3 – Seismic Slope Stability for Flow Slide Check (1 page)

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

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 Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together 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. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is 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 part of 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 THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities 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. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing 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 the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. 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. If 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 Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

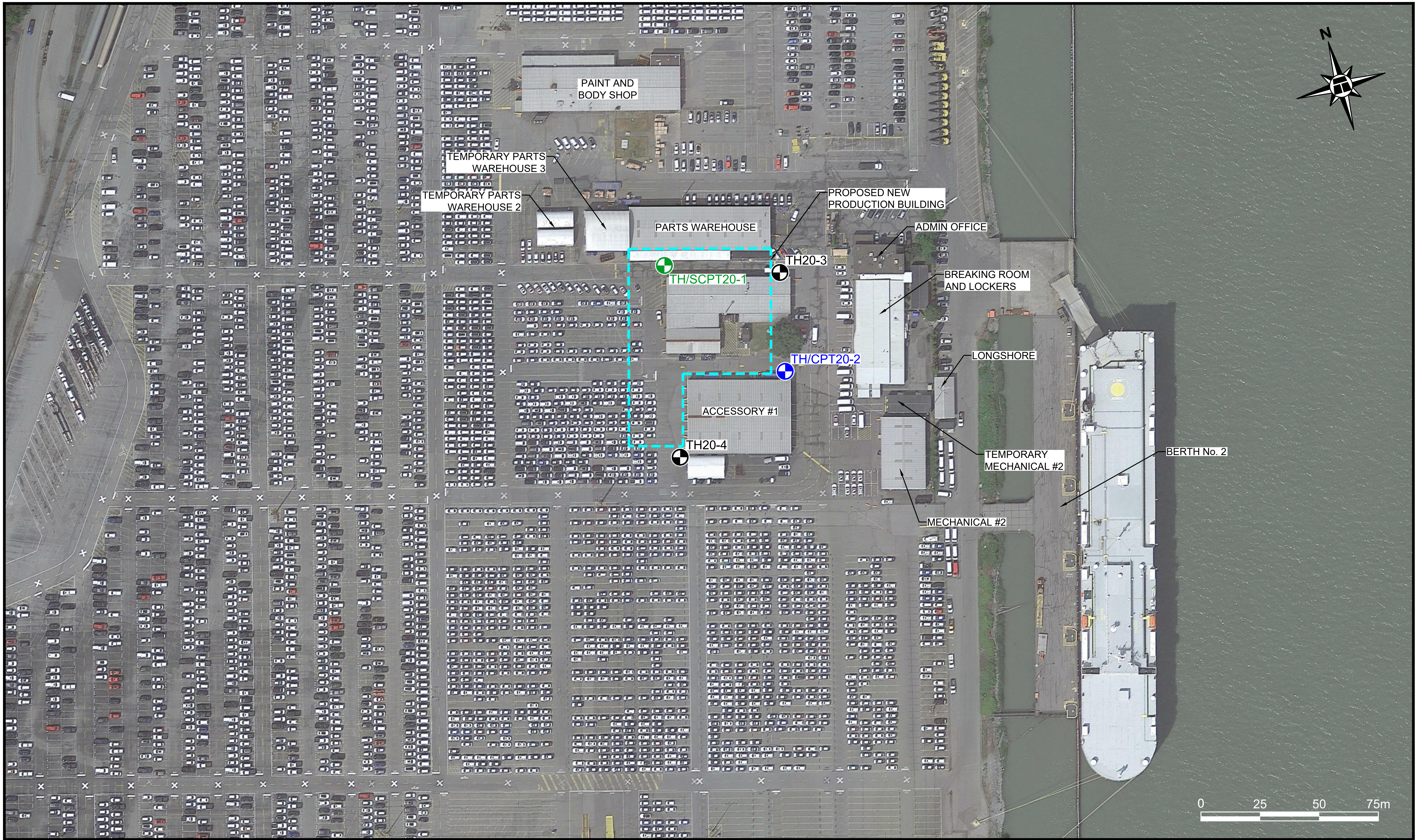
6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

Plotted: December 21, 2020



LEGEND:

◐ TEST HOLE / DCPT

◐ TEST HOLE / SCPT

◐ TEST HOLE / CPT

NOTES:
1. BASE PLAN TAKEN FROM GOOGLE EARTH.
2. TEST HOLE LOCATIONS ARE APPROXIMATE.

THURBER ENGINEERING LTD.

CLIENT
WALLENIUS WILHELMSEN SOLUTIONS

TEST HOLE LOCATION PLAN

PROPOSED NEW
PRODUCTION BUILDING
DELTA, BC

DESIGNED	DRAWN	APPROVED
AGW	MOM	

DATE	SCALE
DECEMBER 21, 2020	1:1500

PROJECT No.	DWG. No.	REV.
27441	1	0

CANCEL PRINTS BEARING EARLIER NUMBER

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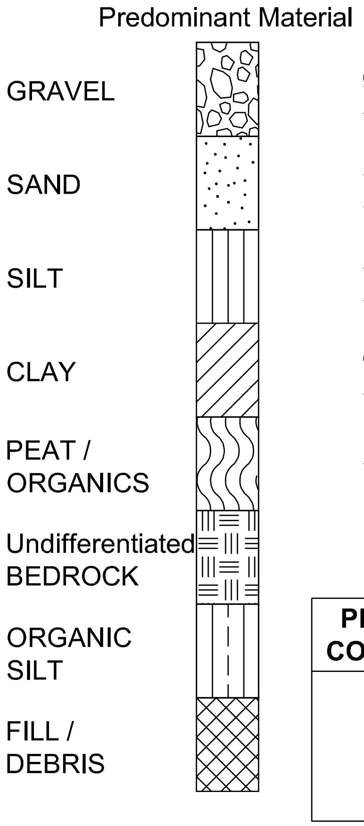
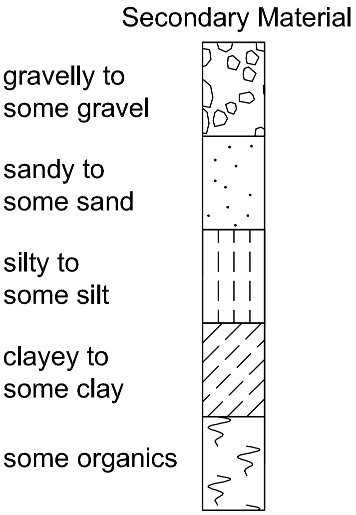
SYMBOLS AND TERMS

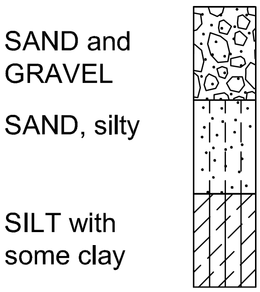
FOR SOIL DESCRIPTION AND TEST HOLE LOGS

BASIC SOIL SYMBOLS





SYMBOL VARIATIONS - EXAMPLES(1)



DENSITY OF GRANULAR SOILS

Description	SPT N (5) (6)
Very Loose	0 - 4
Loose	4 - 10
Compact	10 - 30
Dense	30 - 50
Very Dense	> 50

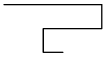
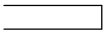
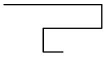
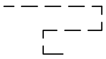
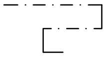
PROPORTION OF MINOR COMPONENTS BY WEIGHT (2)

and	35 - 50%
y / ey	20 - 35%
some	10 - 20%
trace	0 - 10%

CONSISTENCY OF COHESIVE SOILS

Description	Undrained Shear Strength (kPa)(6)
Very Soft	< 12
Soft	12 - 25
Firm	25 - 50
Stiff	50 - 100
Very Stiff	100 - 200
Hard	> 200

PENETRATION TESTS

Dynamic Cone Penetration	
Standard Penetration	
Becker Closed Casing	
Becker Open Casing	
Bounce Chamber Pressure	

CLASSIFICATION BY PARTICLE SIZE

		Size Range (6)		
			U.S. Standard Sieve Size	
Name		(mm)(3)	Retained	Passing
Boulders		> 200	8 inch	-
Cobbles		75 - 200	3 inch	8 inch
Gravel:	coarse	19 - 75	0.75 inch	3 inch
	fine	5 - 19	No. 4	0.75 inch
Sand:	coarse	2 - 5	No. 10	No. 4
	medium	0.4 - 2	No. 40	No. 10
	fine	0.075 - 0.4	No. 200	No. 40
Fines (Silt or Clay)(4)		< 0.075	-	No. 200

(1) Only selected examples of the possible variations or combinations of the basic symbols are illustrated.
(2) Example: SAND, silty, trace of gravel = sand with 20 to 35% silt and up to 10% gravel, by dry weight. Percentages of secondary materials are estimates based on visual and tactile assessment of samples.
(3) Approximate metric conversion.
(4) Fines are classified as silt or clay on the basis of Atterberg limits.
(5) SPT N values on test hole logs are uncorrected field values.
(6) Reference Canadian Foundation Engineering Manual 4th Edition, 2006.

THURBER

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO. 20-1

LOCATION: See DWG. 27441-1
N 5447968, E 505515 (Est.)

TOP OF HOLE ELEV: 4.8 m (Est.)

METHOD: Solid Stem Auger

DRILLING CO.: Southland Drilling Co. Ltd.

INSPECTOR: AGW

THURBER

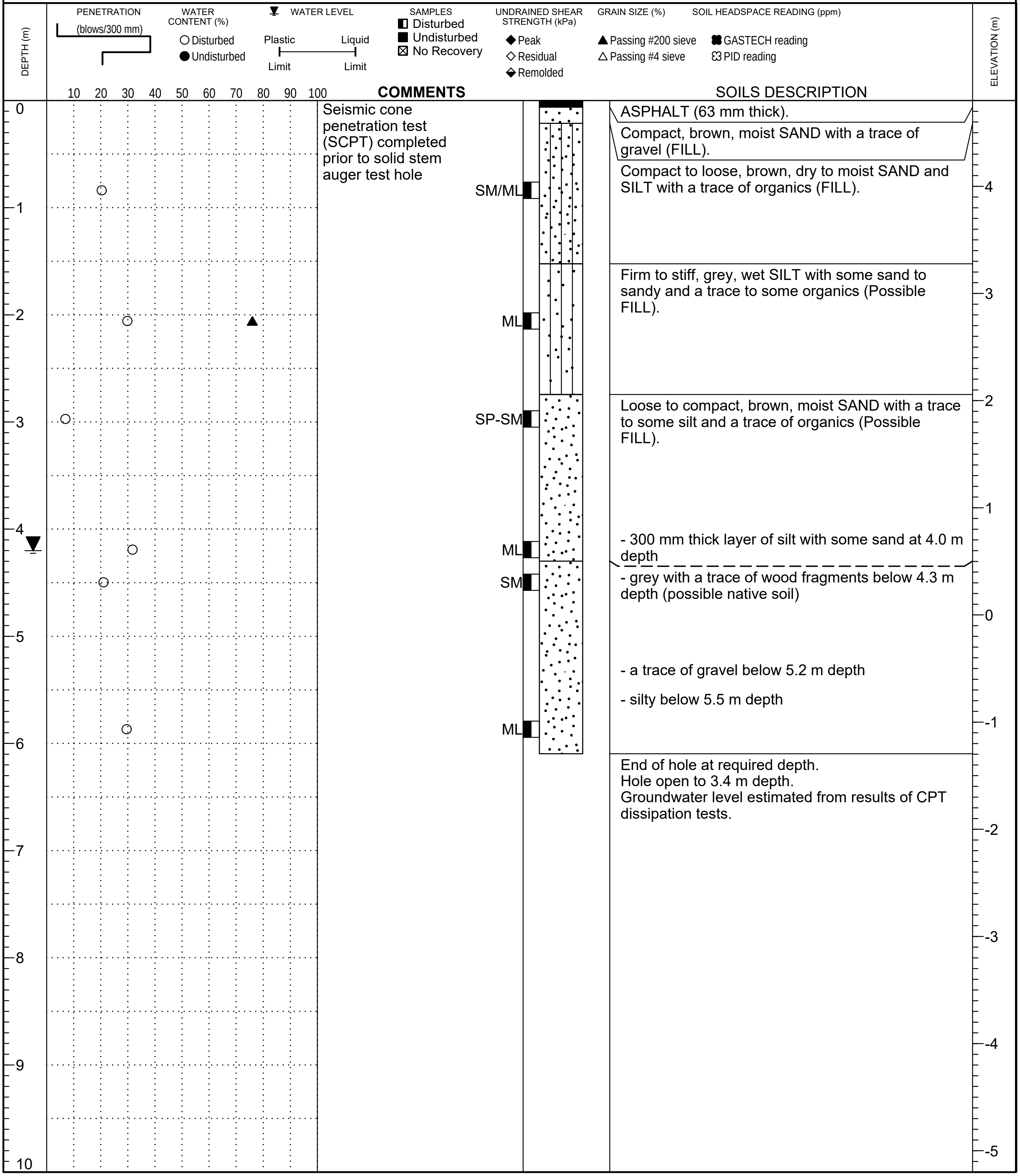
CLIENT: Wallenius Wilhalmsen Solutions

PROJECT: Proposed New Production Building

DATE: September 25, 2020

FILE NO.: 27441

REVIEWED BY: CN



COMMENTS

Seismic cone penetration test (SCPT) completed prior to solid stem auger test hole

SOILS DESCRIPTION

ASPHALT (63 mm thick).

Compact, brown, moist SAND with a trace of gravel (FILL).

Compact to loose, brown, dry to moist SAND and SILT with a trace of organics (FILL).

Firm to stiff, grey, wet SILT with some sand to sandy and a trace to some organics (Possible FILL).

Loose to compact, brown, moist SAND with a trace to some silt and a trace of organics (Possible FILL).

- 300 mm thick layer of silt with some sand at 4.0 m depth
- grey with a trace of wood fragments below 4.3 m depth (possible native soil)
- a trace of gravel below 5.2 m depth
- silty below 5.5 m depth

End of hole at required depth.
Hole open to 3.4 m depth.
Groundwater level estimated from results of CPT dissipation tests.

Sheet 1 of 1

LOG OF TEST HOLE

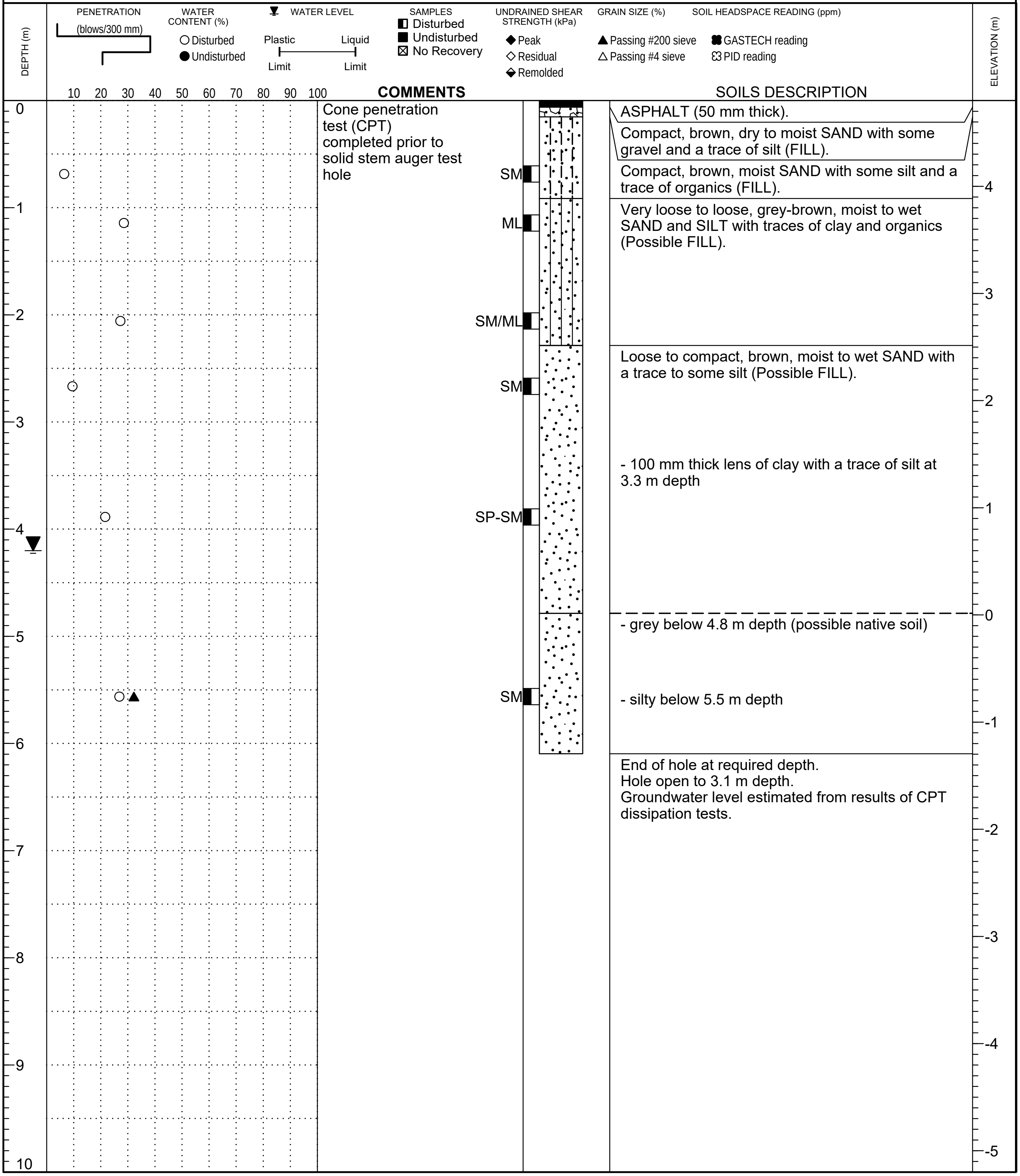
TEST HOLE NO. **20-2**

LOCATION: See DWG. 27441-1
N 5448027, E 505482 (Est.)

TOP OF HOLE ELEV: 4.8 m (Est.)
METHOD: Solid Stem Auger
DRILLING CO.: Southland Drilling Co. Ltd.
INSPECTOR: AGW

CLIENT: Wallenius Wilhalmsen Solutions
PROJECT: Proposed New Production Building

DATE: September 25, 2020
FILE NO.: 27441
REVIEWED BY: CN



COMMENTS

Cone penetration test (CPT) completed prior to solid stem auger test hole

SOILS DESCRIPTION

ASPHALT (50 mm thick).

Compact, brown, dry to moist SAND with some gravel and a trace of silt (FILL).

Compact, brown, moist SAND with some silt and a trace of organics (FILL).

Very loose to loose, grey-brown, moist to wet SAND and SILT with traces of clay and organics (Possible FILL).

Loose to compact, brown, moist to wet SAND with a trace to some silt (Possible FILL).

- 100 mm thick lens of clay with a trace of silt at 3.3 m depth

- grey below 4.8 m depth (possible native soil)

- silty below 5.5 m depth

End of hole at required depth.
Hole open to 3.1 m depth.
Groundwater level estimated from results of CPT dissipation tests.

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO.
20-3

LOCATION: See DWG. 27441-1
N 5448008, E 505527 (Est.)

TOP OF HOLE ELEV: 4.8 m (Est.)
METHOD: Solid Stem Auger
DRILLING CO.: Southland Drilling Co. Ltd.
INSPECTOR: AGW

CLIENT: Wallenius Wilhalmsen Solutions
PROJECT: Proposed New Production Building

DATE: September 25, 2020
FILE NO.: 27441
REVIEWED BY: CN

DEPTH (m)

PENETRATION (blows/300 mm)

WATER CONTENT (%)
○ Disturbed
● Undisturbed
Plastic Limit
Liquid Limit

WATER LEVEL

SAMPLES
◧ Disturbed
■ Undisturbed
☒ No Recovery

UNDRAINED SHEAR STRENGTH (kPa)
◆ Peak
◇ Residual
◆ Remolded

GRAIN SIZE (%)
▲ Passing #200 sieve
△ Passing #4 sieve

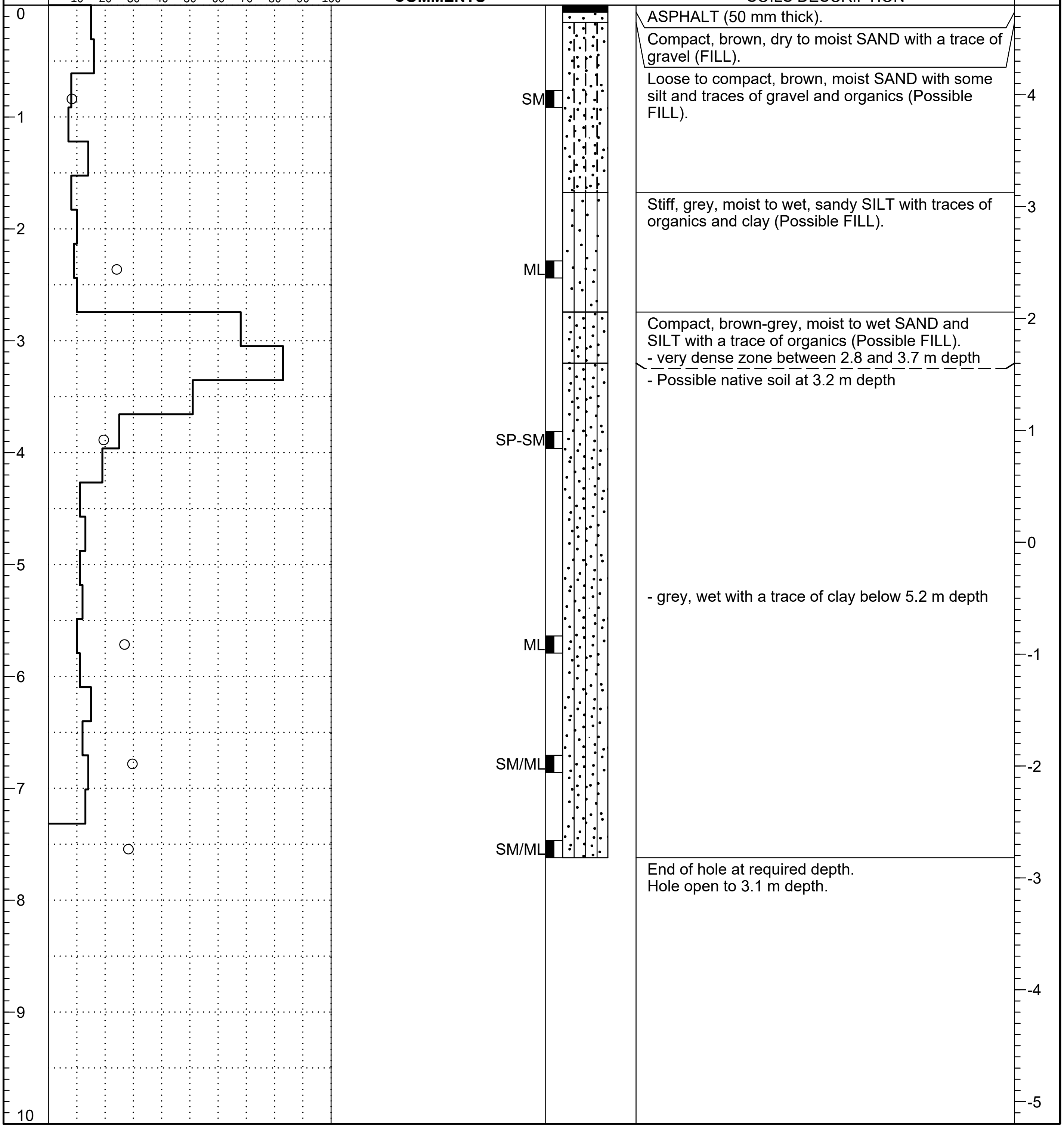
SOIL HEADSPACE READING (ppm)
✱ GASTECH reading
✳ PID reading

ELEVATION (m)

10 20 30 40 50 60 70 80 90 100

COMMENTS

SOILS DESCRIPTION



ASPHALT (50 mm thick).

Compact, brown, dry to moist SAND with a trace of gravel (FILL).

Loose to compact, brown, moist SAND with some silt and traces of gravel and organics (Possible FILL).

Stiff, grey, moist to wet, sandy SILT with traces of organics and clay (Possible FILL).

Compact, brown-grey, moist to wet SAND and SILT with a trace of organics (Possible FILL).
- very dense zone between 2.8 and 3.7 m depth
- Possible native soil at 3.2 m depth

- grey, wet with a trace of clay below 5.2 m depth

End of hole at required depth.
Hole open to 3.1 m depth.

LOG OF TEST HOLE (COORDS + EL. EST.) 27441.GPJ THURBER_MOM.GDT 21/12/20- THURBER MOM.GLB

Sheet 1 of 1

LOG OF TEST HOLE

TEST HOLE NO.
20-4

LOCATION: See DWG. 27441-1
N 5447949, E 505461 (Est.)

TOP OF HOLE ELEV: 4.8 m (Est.)
METHOD: Solid Stem Auger
DRILLING CO.: Southland Drilling Co. Ltd.
INSPECTOR: AGW

THURBER

CLIENT: Wallenius Wilhalmsen Solutions
PROJECT: Proposed New Production Building

DATE: September 25, 2020
FILE NO.: 27441
REVIEWED BY: CN

PENETRATION (blows/300 mm)

WATER CONTENT (%)
○ Disturbed
● Undisturbed

Plastic Limit ├───┤ Liquid Limit

WATER LEVEL

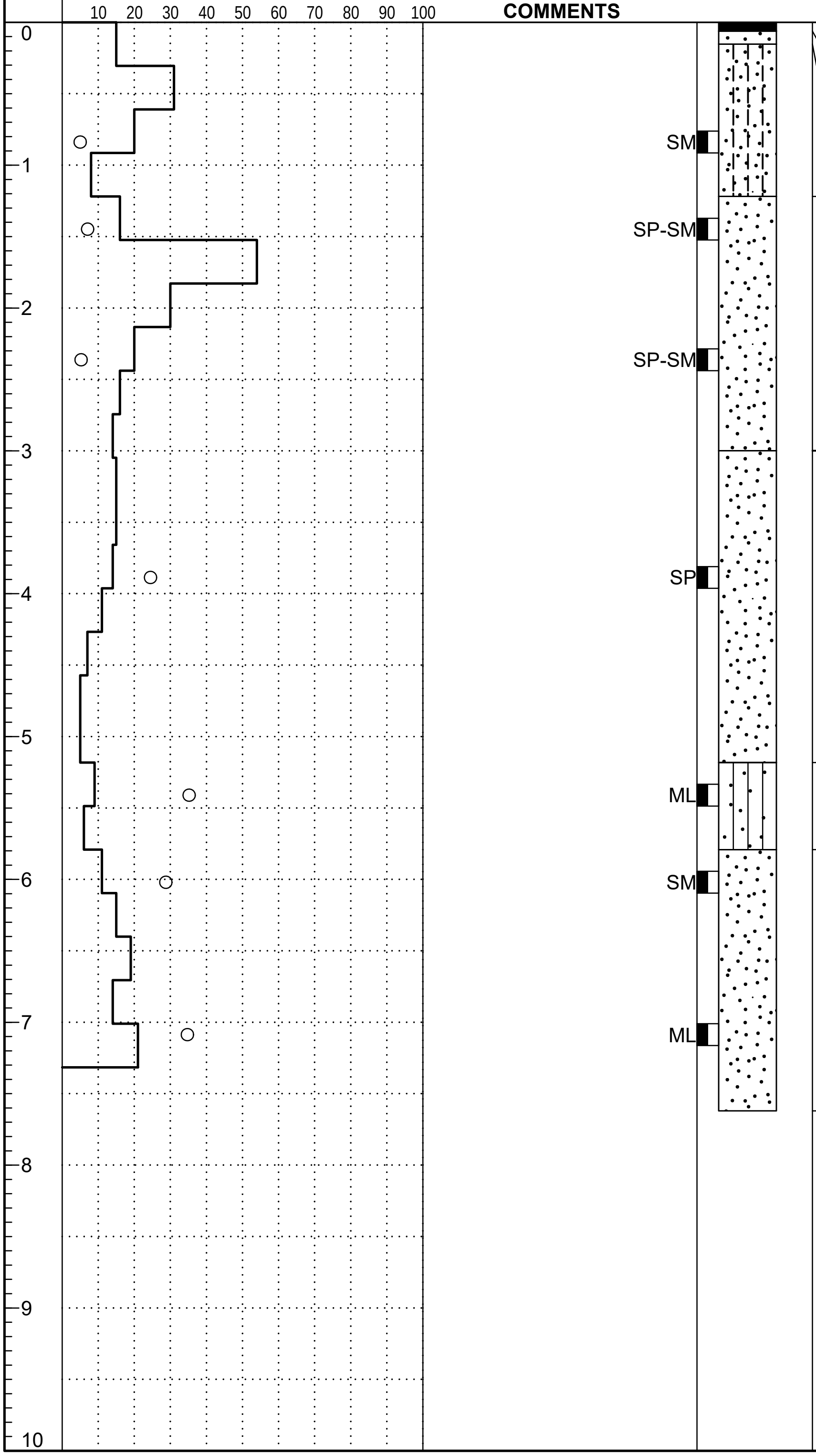
SAMPLES
◧ Disturbed
■ Undisturbed
☒ No Recovery

UNDRAINED SHEAR STRENGTH (kPa)
◆ Peak
◇ Residual
⬖ Remolded

GRAIN SIZE (%)
▲ Passing #200 sieve
△ Passing #4 sieve

SOIL HEADSPACE READING (ppm)
✱ GASTECH reading
✲ PID reading

COMMENTS



SOILS DESCRIPTION

ASPHALT (88 mm thick).

Compact, brown, moist SAND with a trace of gravel (FILL).

Compact over loose, brown, dry to moist SAND with some silt (Possible FILL).

Compact over loose, brown, moist SAND with a trace of silt (Possible FILL).
- dense zone between 1.5 and 2.1 m depth

- brown-grey below 3.0 m depth (possible native soil)

- a trace of gravel below 2.7 m depth

Grey, wet, sandy SILT.

Grey, wet SAND.

- silty below 6.6 m depth

End of hole at required depth.
Hole open to 3.8 m depth.

ELEVATION (m)
4
3
2
1
0
-1
-2
-3
-4
-5

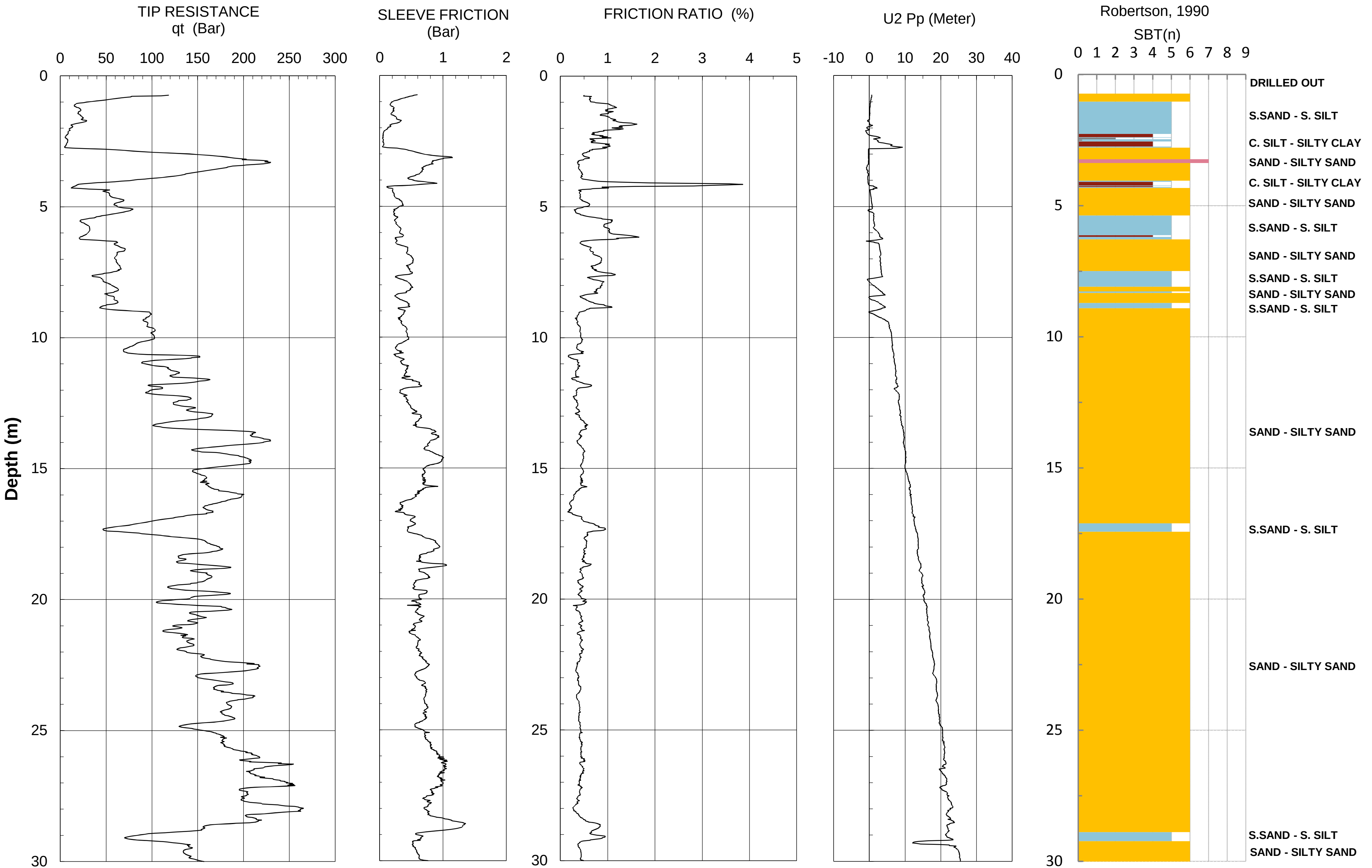
Thurber Engineering

THURBER

Operator: Schwartz Soil Technical
Sounding: SCPT20 - 01
Cone ID: DPG1428

Date: September 25, 2020
Site: WWL Production Bldg
Thurber project: 27441

Schwartz SOIL TECH



Maximum Depth = 30.00 meter
Depth increment = 0.02 meter

■ 1 SENS FINE GRAIN	■ 4 C. SILT - SILTY CLAY	■ 7 GRAVELLY SAND - SAND
■ 2 ORGANIC	■ 5 S. SAND - S. SILT	■ 8 V. STIFF CLAY SAND
🟥 3 CLAY - SILTY CLAY	🟨 6 SAND - S. SAND	🟩 9 V. STIFF FINE GRAIN

Schwartz
SOIL TECH

SHEAR WAVE VELOCITY DATA

Client: Thurber Engineering
Test: SCPT20 - 01
Site: WWL Production Bldg
Delta, BC

Date: September 25, 2020
Cone ID: DPG1428
Source offset: 0.40 m
Source: Beam

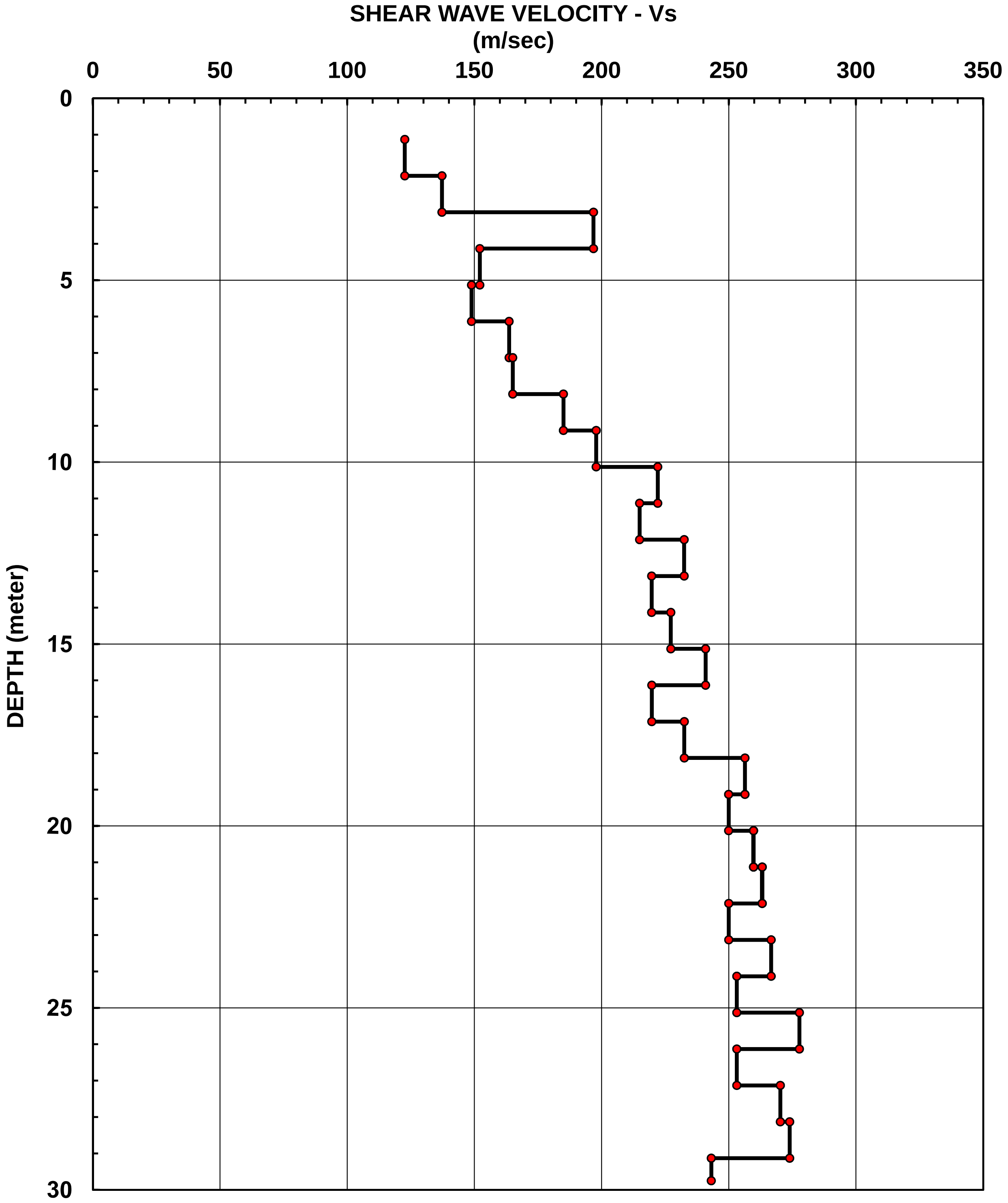
Cone tip Depth (m)	Geophone Depth (m)	Wave Path (m)	Wave Path Interval (m)	Wave Travel Time interval (ms)	Interval Velocity (m/sec)
1.38	1.13	1.20	0.97	7.90	123
2.38	2.13	2.17	0.99	7.20	137
3.38	3.13	3.16	0.99	5.05	197
4.38	4.13	4.15	1.00	6.55	152
5.38	5.13	5.15	1.00	6.70	149
6.38	6.13	6.14	1.00	6.10	164
7.38	7.13	7.14	1.00	6.05	165
8.38	8.13	8.14	1.00	5.40	185
9.38	9.13	9.14	1.00	5.05	198
10.38	10.13	10.14	1.00	4.50	222
11.38	11.13	11.14	1.00	4.65	215
12.38	12.13	12.14	1.00	4.30	232
13.38	13.13	13.14	1.00	4.55	220
14.38	14.13	14.14	1.00	4.40	227
15.38	15.13	15.14	1.00	4.15	241
16.38	16.13	16.13	1.00	4.55	220
17.38	17.13	17.13	1.00	4.30	232
18.38	18.13	18.13	1.00	3.90	256
19.38	19.13	19.13	1.00	4.00	250
20.38	20.13	20.13	1.00	3.85	260
21.38	21.13	21.13	1.00	3.80	263
22.38	22.13	22.13	1.00	4.00	250
23.38	23.13	23.13	1.00	3.75	267
24.38	24.13	24.13	1.00	3.95	253
25.38	25.13	25.13	1.00	3.60	278
26.38	26.13	26.13	1.00	3.95	253
27.38	27.13	27.13	1.00	3.70	270
28.38	28.13	28.13	1.00	3.65	274
29.38	29.13	29.13	0.62	2.55	243
30.00	29.75	29.75			

Schwartz
SOIL TECH

SHEAR WAVE VELOCITY PROFILE

Client: Thurber Engineering
Test: SCPT20 - 01
Site: WWL Production Bldg
Delta, BC

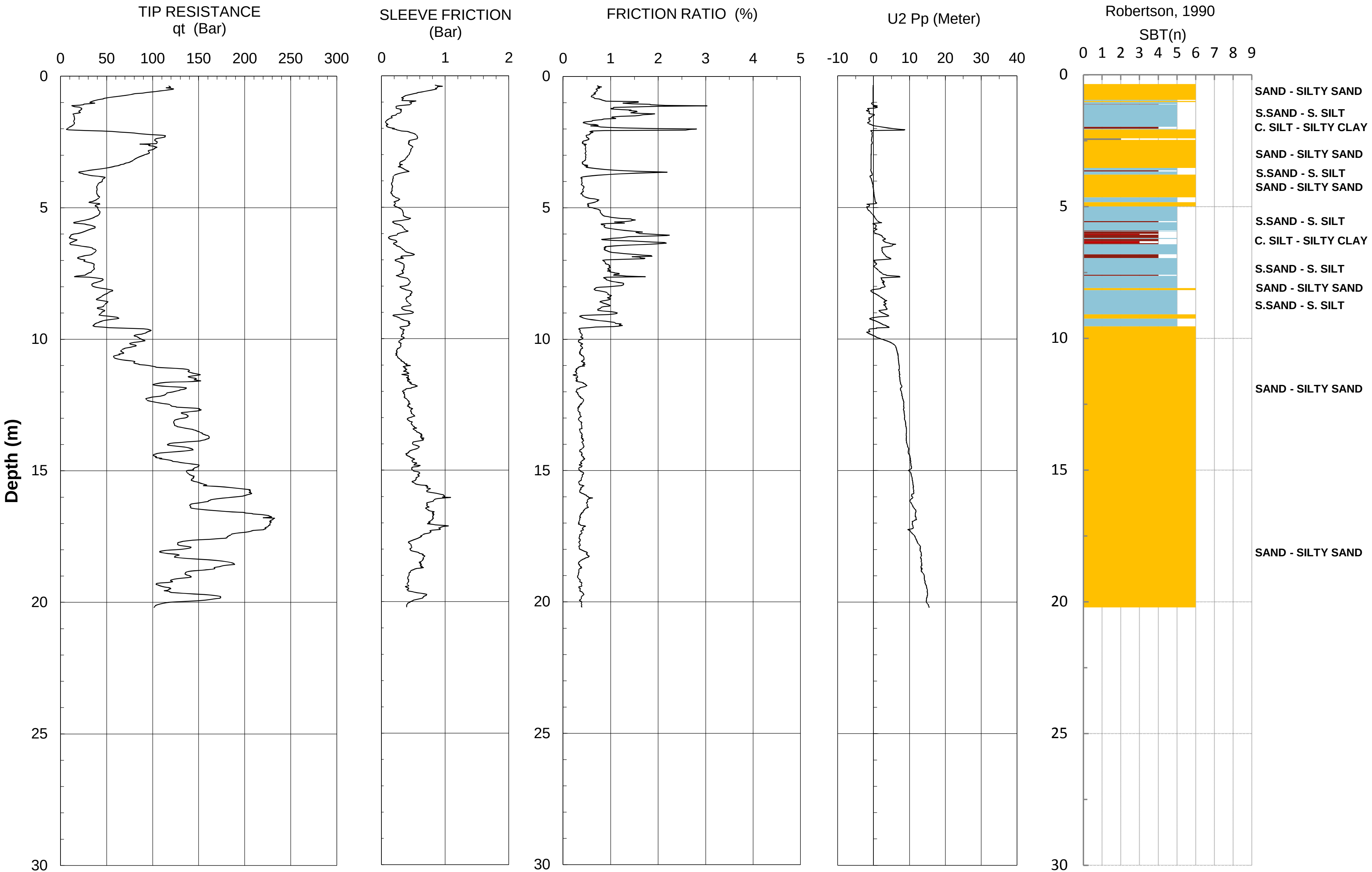
Date: Sept 25, 2020
Cone ID: DPG1428
Source offset: 0.40 m
Source: Beam



Thurber Engineering

Operator: Schwartz Soil Technical
Sounding: CPT20 - 02
Cone ID: DPG1428

Date: September 25, 2020
Site: WWL Production Bldg
Thurber project: 27441



Maximum Depth = 20.20 meter
Depth increment = 0.02 meter

■ 1 SENS FINE GRAIN
■ 2 ORGANIC
🟥 3 CLAY - SILTY CLAY
🟫 4 C. SILT - SILTY CLAY
🟦 5 S. SAND - S. SILT
🟨 6 SAND - S. SAND
■ 7 GRAVELLY SAND - SAND
🟪 8 V. STIFF CLAY SAND
🟩 9 V. STIFF FINE GRAIN

2015 National Building Code Seismic Hazard Calculation

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

Site: 49.185N 122.925W **User File Reference:** WWL Annacis Island Terminal - Proposed New Production Building

2020-09-27 23:42 UT

Requested by: Thurber Engineering Ltd.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.431	0.300	0.216	0.096
Sa (0.1)	0.655	0.457	0.331	0.148
Sa (0.2)	0.814	0.575	0.419	0.188
Sa (0.3)	0.816	0.580	0.424	0.188
Sa (0.5)	0.721	0.507	0.366	0.156
Sa (1.0)	0.408	0.281	0.197	0.078
Sa (2.0)	0.248	0.166	0.113	0.043
Sa (5.0)	0.079	0.046	0.028	0.009
Sa (10.0)	0.028	0.016	0.010	0.003
PGA (g)	0.352	0.249	0.181	0.080
PGV (m/s)	0.530	0.362	0.251	0.095

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

References

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

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

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

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

Natural Resources Canada Ressources naturelles Canada

Canada

THURBER ENGINEERING LTD.

Thurber Engineering Ltd.
Suite 900, 1281 West Georgia Street
Vancouver, BC V6E 3J7

File No. 27441
Figure 1

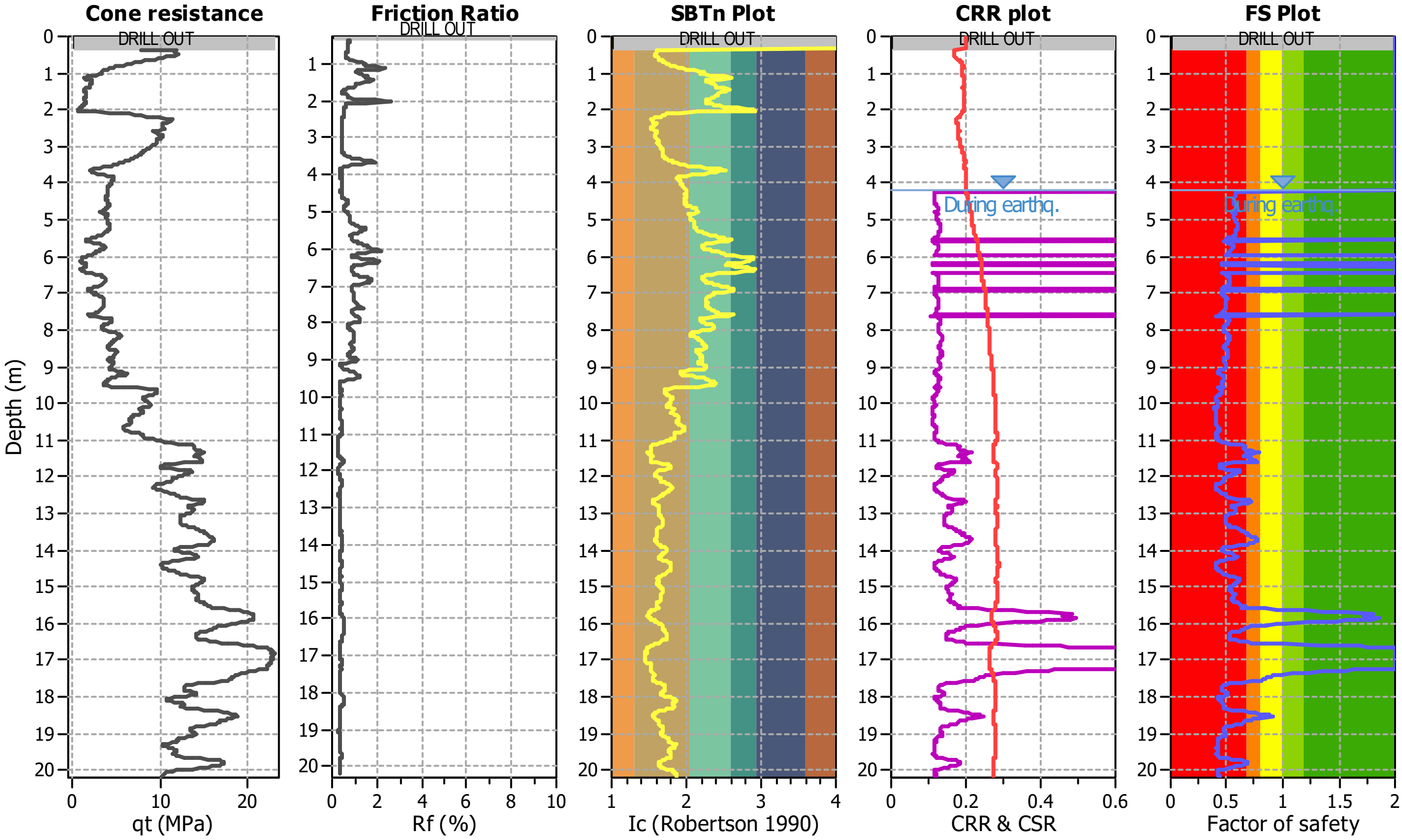
LIQUEFACTION ANALYSIS REPORT

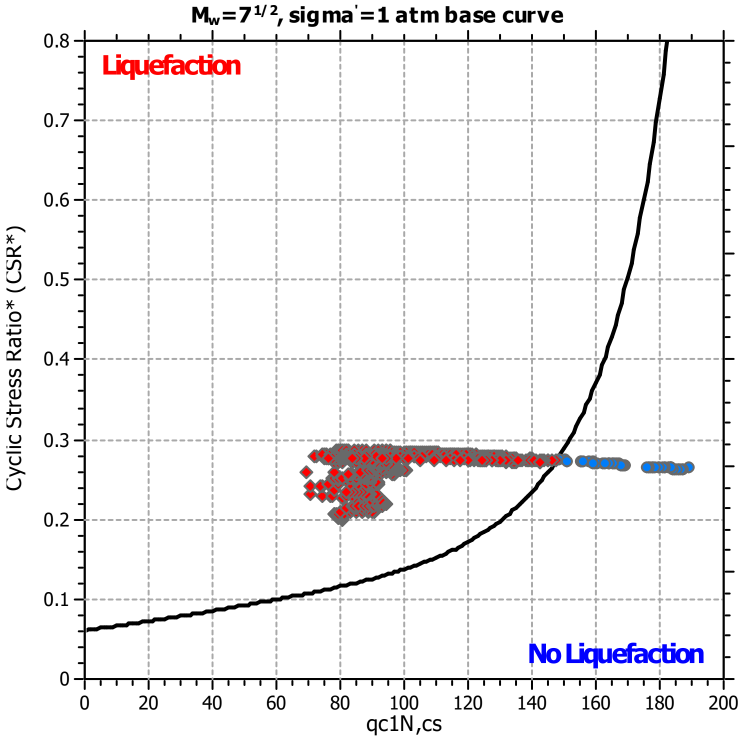
Project title : WWL Annacis Terminal Whaft **Location : Annacis Island, Delta, B.C.**

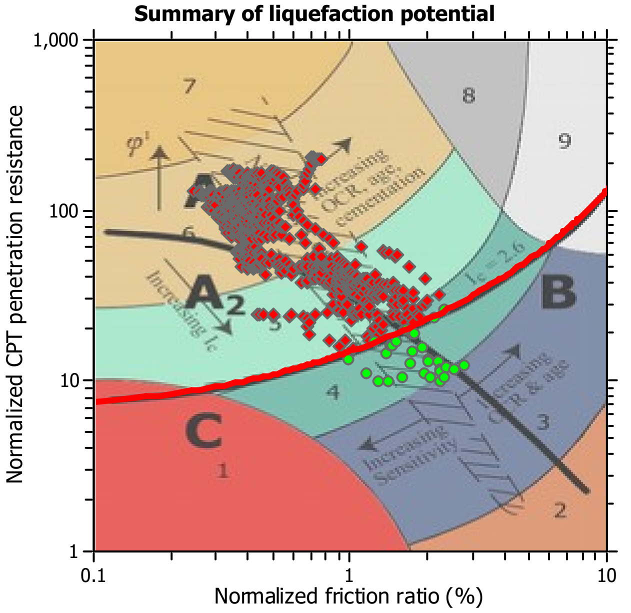
CPT file : CPT20-02

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	4.20 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	4.20 m	Fill height:	N/A		
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	No
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	N/A
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based







Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Thurber Engineering Ltd.
Suite 900, 1281 West Georgia Street
Vancouver, BC V6E 3J7

File No. 27441
Figure 2

LIQUEFACTION ANALYSIS REPORT

Project title : WWL Annacis Terminal Whaft **Location : Annacis Island, Delta, B.C.**

CPT file : SCPT20-01

Input parameters and analysis data

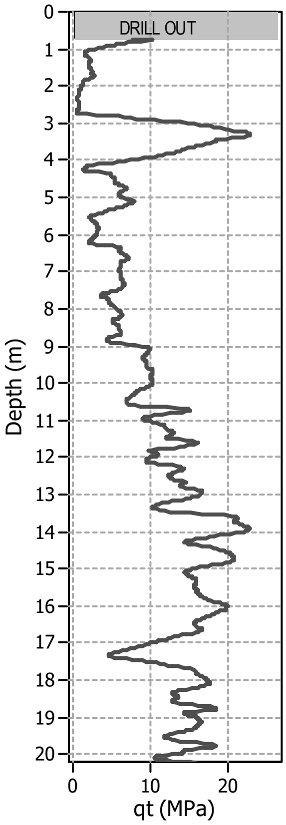
Analysis method: B&I (2014)
Fines correction method: B&I (2014)
Points to test: Based on Ic value
Earthquake magnitude M_w: 7.00
Peak ground acceleration: 0.34

G.W.T. (in-situ): 4.20 m
G.W.T. (earthq.): 4.20 m
Average results interval: 3
Ic cut-off value: 2.60
Unit weight calculation: Based on SBT

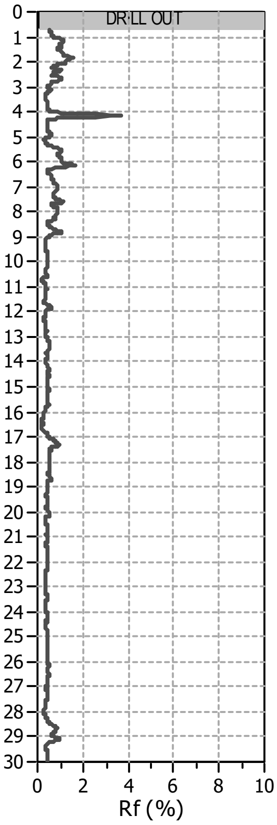
Use fill: No
Fill height: N/A
Fill weight: N/A
Trans. detect. applied: No
K_σ applied: Yes

Clay like behavior applied: Sands only
Limit depth applied: No
Limit depth: N/A
MSF method: Method based

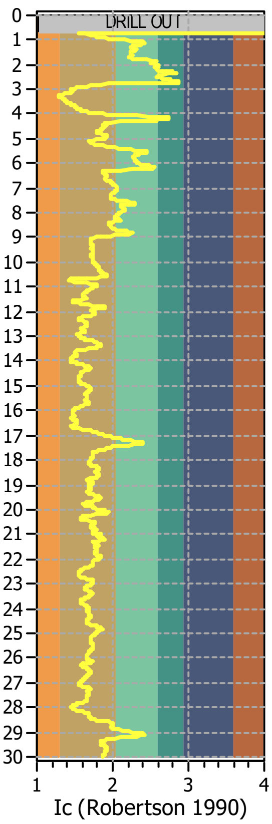
Cone resistance



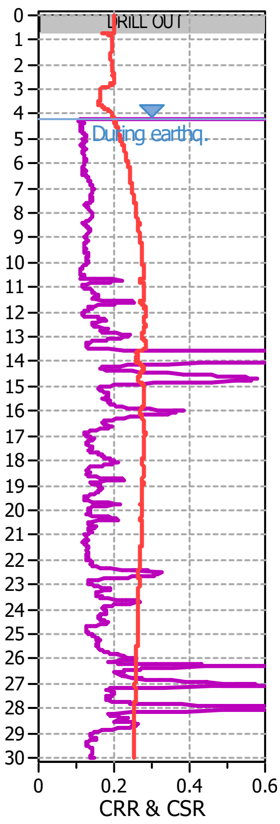
Friction Ratio



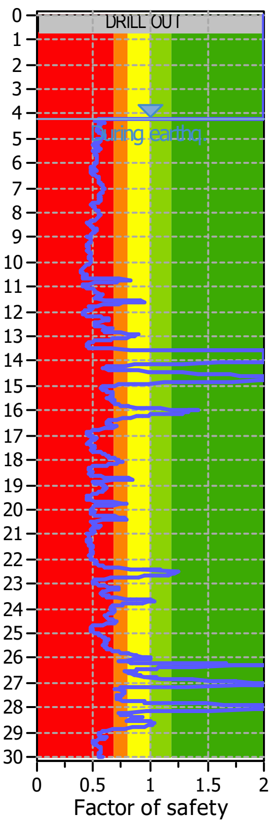
SBTn Plot



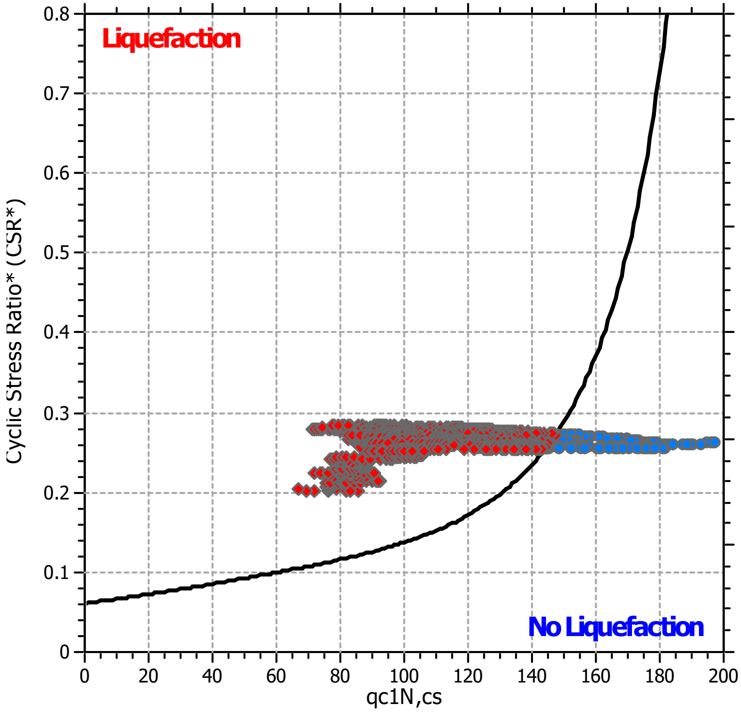
CRR plot



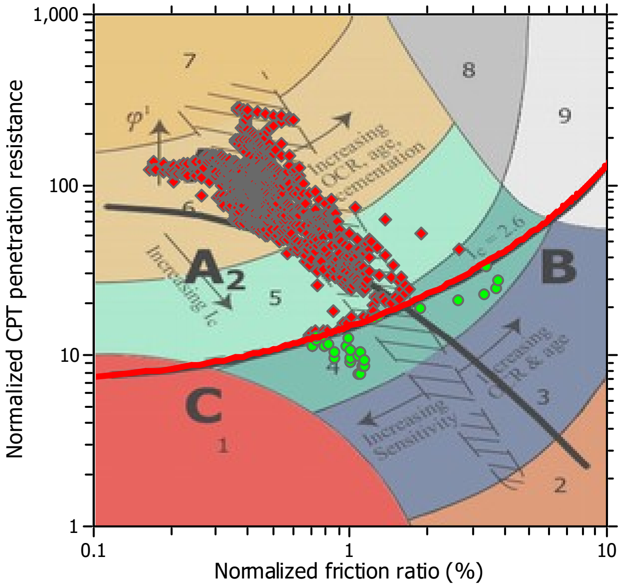
FS Plot



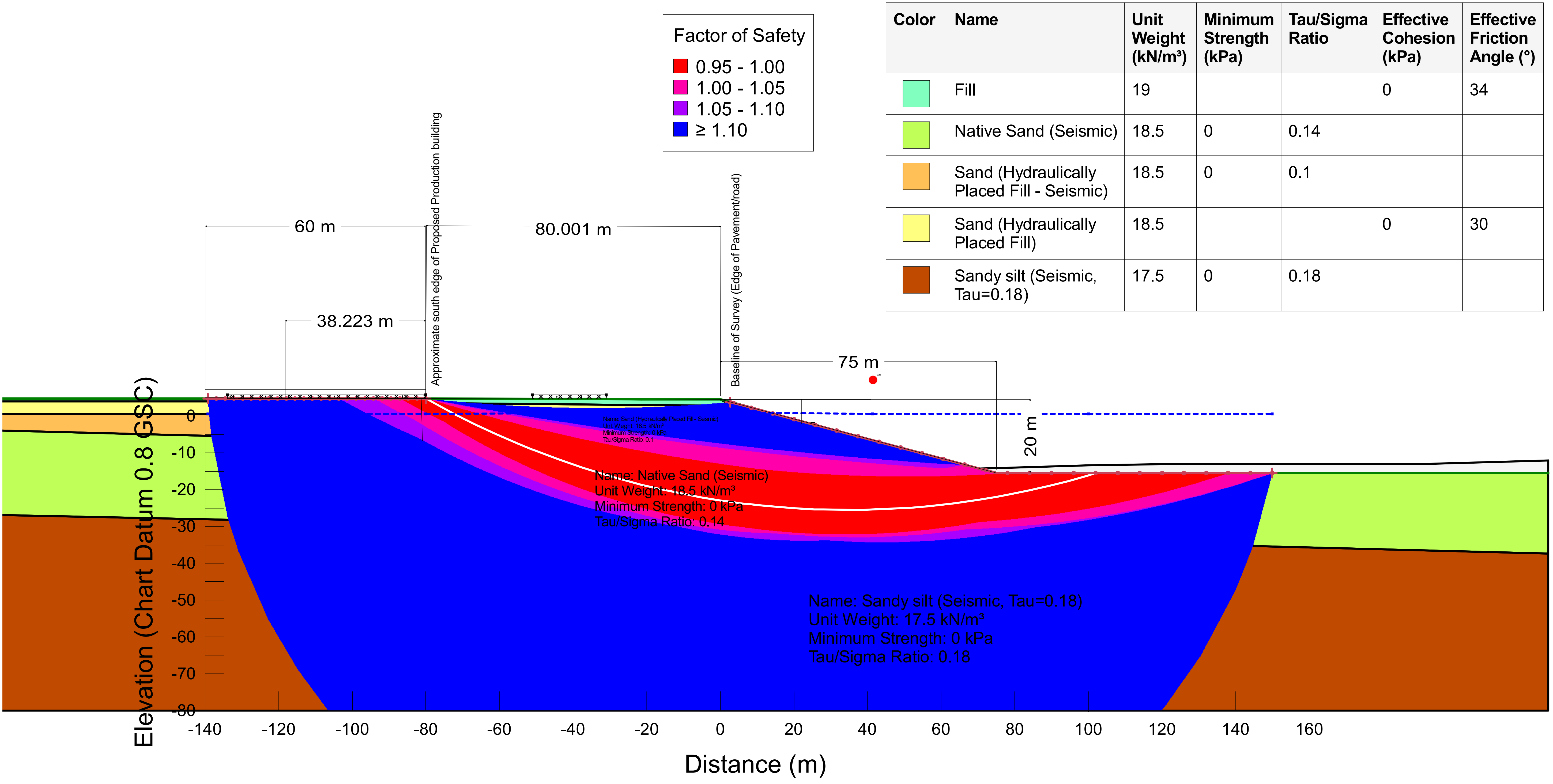
$M_w=7^{1/2}$, sigma'=1 atm base curve



Summary of liquefaction potential



Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry



Color	Name	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)
🟩	Fill	19			0	34
🟩	Native Sand (Seismic)	18.5	0	0.14		
🟧	Sand (Hydraulically Placed Fill - Seismic)	18.5	0	0.1		
🟨	Sand (Hydraulically Placed Fill)	18.5			0	30
🟫	Sandy silt (Seismic, Tau=0.18)	17.5	0	0.18		

3 Flow Slide - Liquefied Properties with Building Surcharge (2)

20201217_ckn_GI Analysis_27441.gsz

2020-12-18 1:1,100

File No. 27441
Figure 3