APPENDIX A

Proposed Guardhouse at 4222 Columbia Highway, Cultus Lake B.C.
Geotechnical Investigation Report.
Horizon Engineering Inc, March 31 2020

HORIZON ENGINEERING INC

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March 31, 2020

Our File: 120-4701

Department of Fisheries and Ocean

Attention: Collin Douglas Gagne

Re: **Proposed Guard House at**
4222 Columbia Valley Highway, Cultus Lake, BC
Geotechnical Investigation Report

1.0 INTRODUCTION

This document provides geotechnical comments and recommendations for the proposed guard house based on the results of our subsurface investigation at the project site, our past experience within the vicinity of the site, and published information. This report is prepared in general conformance with our scope of services dated February 7, 2020 (ref. File No: P20-3116). Authorization to Proceed was received on February 24, 2020.

2.0 SITE DESCRIPTION

The proposed location for the guard house is located within the Cultus Lake laboratory facilities at 4222 Columbia Valley Highway, Cultus Lake, BC, specifically, northwest of the main gated entrance. The proposed location is bounded by the gated fence to the west, the access roadway to the south, the existing underground water reservoir to the north and landscaping vegetation (mainly lawn) to the east.

Topography in the general vicinity of the subject site is gently sloping down to the southeast.

3.0 PROPOSED DEVELOPMENT

At this stage of the project no design drawings are available. Based on the information provided by our client via email dated January 30, 2020, it is understood that the proposed development would comprise a one-storey building to be constructed at grade with approximate footprint of 3.1 metres by 3.1 metres (10.0 feet by 10.0 feet).

4.0 BACKGROUND INFORMATION

4.1 Surficial Geology

Published information from the Geological Survey of Canada (Map 1487A, Chilliwack) indicates that the surficial geology expected at the subject site consists of Sumas Drift and Sumas and Pre-Sumas Deposits.

Sumas Drift is generally described as till, glaciofluvial, and ice-contact deposits, specifically: "outwash gravel and sand up to 10+m thick." Sumas and Pre-Sumas Deposits is composed of till, glaciofluvial, glaciomarine, fluvial, and marine sediments, described as: "gravel and sand in part proglacial, may be in part fluvial, probably includes Fort Langley, Vashon, Coquitlam, and older deposits; as indicated on the map most of these deposits lie beneath Sumas till (Sf)".

4.2 Seismic Hazard

Based on published information from the 2018 edition of BC Building Code, the seismic event with a 2% probability of exceedance in 50 years at the project site would have peak ground acceleration (PGA) of 0.242, where g is the gravitational acceleration. An event with a 2% probability of exceedance in 50 years corresponds to return period of 2475 years. The peak ground acceleration is for the firm ground conditions and is assumed to have no vertical acceleration component. The 2% probability of exceedance in 50 years published spectral acceleration values for different natural periods are presented in Table 1.

Table 1: BC Building Code 2018 Spectral Accelerations (g) for 2% Probability of Exceedance in 50 Years (firm ground)

Period (s)	Sa (0.2)	Sa (0.5)	Sa (1.0)	Sa (2.0)	Sa (5.0)	Sa (10.0)
Spectral Acceleration (g)	0.539	0.448	0.277	0.174	0.062	0.021

5.0 SUBSURFACE INVESTIGATION

5.1 Subsurface Investigation

The subsurface investigation was carried out by "Adams Excavating" on March 11, 2020. Utility locate searches was conducted by "Quadra Utility Locating" to assess the proposed test hole location with respect to underground utilities. A combination of visual and electromagnetic techniques were utilized to delineate the location of the underground utilities in the immediate vicinity of the proposed test hole.

The investigation program consisted of one test pit that was advanced using a back-hoe excavator. The approximate location of the test pit is shown on Figure 2. Select soil samples were retrieved from test pit for further soil characterization.

The subsurface investigation was directed by an engineer from our office who also documented the soil stratigraphy in the test pit. The test pit was subsequently backfilled with excavated spoil. The footprint of the test pit was measured to be approximately 1.5 metres by 2.1 metres (5.0 feet by 7.0 feet).

5.2 Soil Conditions

A summary of the soil conditions encountered at the test pit is provided in this section. Detailed descriptions of the subsurface materials encountered at the test pit is provided in the test pit log attached to this report. The generalized soil stratigraphy encountered at the test pit is summarized below:

- Topsoil (dark brown) - encountered at surface, extended to depths of about 0.2 metre (8 inches); dark brown, silty sand with trace organics (roots and rootlets). The sand is fine to medium grained. This soil type was inferred to be very loose.
- Silty Sand (grey) - encountered beneath the topsoil and extended to depth of about 0.6 metre (2.0 feet); grey, silty sand with some gravel and trace organics (roots and wood fragments). The sand was fine-grained. This soil type was inferred to be loose and fill.
- Gravelly Sand (light brown) - encountered beneath grey, silty sand, extended to depth of about 0.8 metre (2.8 feet); grey mottled brown, gravelly sand with trace silt. The sand was medium to coarse grained. The gravel subangular to rounded. This soil type was inferred to be loose to compact and possible fill.
- Sand (grey mottled brown) - encountered at depths of about 0.8 metre (2.8 feet) below grade, extended to depth of at least 1.8 metres (6.0 feet), where the test pit was terminated; grey mottled brown, sand with trace silt. The sand was fine grained. This soil type was inferred to be compact.

The test pit was terminated at 1.8 metres (6.0 feet) below grade because the natural grey sand exposed at 0.8 metre (2.8 feet) below grade was consistent with the site geology and expected to extend to a depth of interest for the type of building proposed and to avoid further site disturbance due to the proximity of the test hole to the proposed building footprint.

5.3 Groundwater Conditions

Moderate groundwater seepage was observed in the test pit. It was noted that where groundwater was intercepted in the test pit, the bottom of the test pit excavation would rapidly fill with water. Groundwater was noted to be perched on the surface of the grey mottled brown fine grained sand and generally flowed from north to south which was consistent with the local topography sloping down towards the southeast. The near-surface, perched groundwater seepage was observed is typically related to the infiltration of surface water into the more permeable surficial soil. The natural, fine-grained sand is expected to be less permeable than the overlying fill and surficial soil.

6.0 GEOTECHNICAL COMMENTS AND RECOMMENDATIONS

6.1 General

From a geotechnical point of view, the subject site is considered to be suitable for the proposed development provided that the following recommendations are incorporated into the design and construction and the final design be provided to Horizon Engineering for review.

The surficial soil types including topsoil and fill are not considered suitable for supporting settlement sensitive structures such as building foundations and floor slabs. These materials are considered to be compressible and typically have significant settlement with increased surcharge loads and time. Based on the test pit investigation results, these surficial soil types may typically be in the order of 0.8 metre (2.8 feet) thick.

The grey mottled brown, fine grained sand encountered at shallow depth in the test pit is considered suitable for supporting settlement sensitive structures.

It is envisaged that unsuitable surficial materials would be stripped from proposed building areas and construction pad comprised of suitably compacted fill materials would be used to restore the grades to the proposed underside of the foundation and appurtenant structures. Buildings would be supported on this construction pad utilizing shallow foundations consisting of strip and pad type footings.

6.2 Site Preparation

It is recommended that all topsoil, organic, or unsuitable fill materials including any loosened, softened, disturbed, or otherwise deleterious material be stripped from beneath settlement-sensitive facilities such as foundations, floor slabs, and underground utilities such that the natural, undisturbed, grey mottled brown, compact fine grained is exposed. Thickness of soil stripping was estimated to be less than 0.9 metre (3.0 feet).

It is envisaged there are existing underground utilities within the proposed site preparation areas. It is recommended that a site specific review carried out by the design team to ensure that location of the proposed guard house is not in conflict with the existing utilities.

6.3 Temporary Excavation Support

Excavations are expected to encounter groundwater discharge and perched surface water flows at comparatively shallow depths of less than 0.9 metre (3.0 feet) below current grade. We envisage that most of this water flow would be managed by conventional trenches, sumps and pumping.

Grade adjacent to an excavation should be sloped to direct surface runoff away from the excavation slopes. Alternatively, any surface water should be controlled such that is does not discharge over the crest into the excavation.

It is recommended that excavated spoil and construction materials be stockpiled no closer than the greater horizontal distance of 1.8 metres (6.0 feet) or half the excavation depth to the crest of the excavation slopes.

Unshored excavation slopes in soil should be protected by a layer of 6 mil polyethylene sheeting securely tied to the ground.

It is estimated that surficial soil types encountered in the test pits could be excavated using conventional hydraulic excavation equipment in good repair. It is possible that large boulders may be encountered which may require splitting for removal. It is common that boulders with a volume in excess of 1 cubic metre are defined as "rock" for contractual purposes and typically the volumes of boulders are quantified (i.e. measured / surveyed) by the owner, or owner's agent.

In general, it is recommended that unshored excavation slopes, in soil types encountered at the test holes be no steeper than 1 vertical to 1 horizontal (45 degrees).

It is envisaged that there will be sufficient room to accommodate sloped excavations across the subject property. Should steeper excavation slope be required, site specific recommendations should be developed subsequent to on-site review of soil and ground conditions.

Excavations deeper than 1.2 metres (4.0 feet) should be reviewed by Horizon Engineering to confirm the soil and slope conditions. Therefore, Horizon Engineering should be provided with opportunities to review the soil and groundwater conditions encountered during excavation to confirm the suitability of the ground conditions with respect to excavation slope stability.

6.4 Construction Pad

Based on the aforementioned discussion, we expect that subsequent to stripping the site from topsoil and unsuitable soils, a construction pad (which would comprise of Engineered fill placed over grey mottled brown, fine grained sand) will be constructed in order to restore or raise grade to design elevations.

Typically, the bulk fill material for these construction pad would consist of well-graded, crushed rock with a gradation ranging between 25 mm to 100 mm (1 to 4 inches). This material is considered to be free-draining and would have a void ratio of more than 30 percent.

It is recommended that construction pad comprised of the aforementioned crushed rock have permanent side slopes no steeper than 1 Vertical : 2 Horizontal, as shown on Figure 3. If steeper permanent side slopes are required, these areas should be reviewed on a site specific basis and may require lowering the footings or constructing a retaining wall.

Construction pad should be capped with a minimum 0.5 metre (1.6 feet) thick, granular, well-graded, compacted road-base type, sand and gravel layer.

6.5 Fill Materials

6.5.1 Re-use of Excavation Material.

Most of the surficial materials encountered at the test hole consisted of silt and fine-grained soil. Fine-grained soils are typically not recommended for re-use as Engineered Fill due to the potential difficulty of placement and achieving suitable compaction. This fine-grained soil may be suitable for landscaping purposes and where support of settlement-sensitive structures is not required. It should be noted that fine-grained soil may be moisture sensitive and susceptible to water softening; therefore, this soil should only be placed under dry weather conditions.

6.4.2 Engineered Fill

Within the context of this report, Engineered Fill used for the construction pads should consist of select, clean, well-graded granular material with less than 5% fines content by mass and range in soil particle diameter sizes from 25mm to 100mm (1 to 42 inch). Blasted rock material should be placed in maximum 300mm (1 feet) thick loose lifts and compacted with a minimum 1000 lb, vibratory drum-roller compactor. Engineered Fill used as capping material over the construction pad fill should consist of select, clean, well-graded granular material with less than 5% fines content by mass with a maximum grain size diameter of 75mm (3 inch). Fine grained soil is defined as particles passing the US #200 sieve.

Engineered Fill should be placed and compacted within 2% of its optimum moisture content to the equivalent of at least 100% of its maximum dry density when determined in accordance with ASTM D698 (Standard Proctor).

The supplier of the material selected as engineered fill should provide written material specifications to confirm the selected fill material conforms with the recommended specifications. Fill materials should be capable of withstanding the effects of handling, spreading, and compaction without excessive degradation or production of deleterious fines. The particles should be reasonably uniform in quality and free from organic materials and deleterious matter.

Horizon Engineering should be given the opportunity to review the actual compaction level achieved using periodic field density tests. A practical method of assuring that the fill has been suitably compacted may be to place the fill in 200mm thick lifts (loose thickness) and compacted using a vibratory plate tamper until there is no noticeable "seam" between adjacent passes.

Where a testing agency is retained for density confirmation, test results should be forwarded to the Geotechnical Engineer of Record for review.

6.6 Foundation Recommendations

6.6.1 Bearing Pressure

It is envisaged that the proposed building foundation will be supported on construction pad that is overlying grey mottled brown fine grained sand with trace silt. It is recommended that a design bearing pressure of 1,500 psf be used for sizing footings supported on the construction pad fill materials under Serviceability Limit States (SLS) design provided that the fill thickness does not exceed 2.5 metres (8 feet). This maximum fill thickness would correspond with a maximum total settlement of 25mm (1 inch).

Based on the published information and our previous experience, total long-term settlement of the footings can be estimated to be in the order of 1% of the fill thickness. Therefore, the proposed structures should be designed for this range of total and differential settlements for the proposed SLS design value. We envisage that the structural design details for the proposed one storey guard house would not be significantly affected if the fill thickness exceeds 2.5 metres (8 feet). Potential differential settlements of the building foundations can be calculated based on the above approach and variation of fill thickness at each construction pad. Based on the variations of the fill thickness, we don’t expect differential settlement would exceed 50% of the total settlement across the width of the building.

The proposed SLS design value should be revised if the above assumptions (quality and thickness of Engineered Fill) are not in accordance with the recommendations provided in this report.

Foundation subgrades should be protected from freezing. In addition, groundwater and rainwater runoff should be directed to temporary sumps and footing subgrades should be kept free of standing water.

Horizon Engineering should be provided with an opportunity to review the exposed subgrade and quality of “Construction Pads” prior to footing construction.

6.6.2 Recommended Footing Characteristics - Typical

Minimum pad footing dimensions of 600 mm (2 feet) and minimum strip footing widths of 250 mm (0.8 foot) are recommended. For buildings designed in accordance with the 2018 edition of the BC Building Code Part 9, minimum footing sizes are provided in Table 9.15.3.4 of the building code document.

It is recommended that foundations be placed at least 450 mm (1.5 feet) below final exterior grades for frost protection.

Foundations should step at no more than 1.0 vertical to 2.0 horizontal.

The design underside of proposed footing elevations should be no closer than 1.0 vertical to 2.0 horizontal from the underside of adjacent conduits or underground utilities.

6.6.3 Seismic Considerations

The above design bearing pressures may be increased by 100% for short term transient loading conditions under Ultimate Limit States design, such as those induced by wind and earthquakes.

Based on the BC Building Code (2018), the subject site is judged to have a Site Class designation of “D” as indicated in Table 4.1.8.4.A in Division B, Part 4. The site coefficients for spectral acceleration, F(T), may be determined as described in Tables 4.1.8.4.B to 4.1.8.4.I of the BC Building Code (2018).

6.7 Slabs-on-Grade

It is recommended that a 150 mm (6 inches) thick drainage layer of compacted 19 mm (3/4 inch) clear crushed gravel be placed beneath any slab-on-grade. This drainage layer should be separated from the slab-on-grade by a continuous layer of 6 mil polyethylene sheeting. The under-slab drainage layer should be reviewed by Horizon Engineering prior to pouring concrete for the slab-on-grade. If the capping material is considered free-draining, the proposed underslab drainage layer may be omitted.

6.8 Foundation Drainage

It is recommended that foundation drains consist of 100 mm (4 inch) diameter, rigid, perforated, PVC pipe placed around the perimeter of the buildings. The maximum invert elevation of the drain pipe should be 100 mm (4 inch) (or more) below the elevation of the underside of the slab-on-grade (eg 200 mm (8 inches) below the slab-on-grade finished floor elevation for a 100 mm (4 inches) thick slab). The pipes should be bedded on and surrounded by a minimum of 150 mm (6 inches) of 19 mm (3/4 inch) clear crushed gravel. A layer of non-woven geotextile filter fabric (such as Propex 4545 or approved equivalent) should be placed between any adjacent soil or fill and the gravel in an effort to ensure that fine grained materials do not migrate into the drainage system. A sample of this filter fabric should be provided to the Geotechnical Engineer for review prior to construction. Foundation drains should be installed with a minimum grade of 1.0%, and collected water should be directed to a suitable disposal system. The suitability of this system should be confirmed during construction by the professional having the responsibility for site and foundation drainage.

The foundation drainage system along the north of the proposed building would also perform as a drainage feature to intercept near-surface, perched groundwater and divert it to a suitable disposal system. Based on our site observation and information provided by the client during our test pit investigations, the aforementioned drainage feature can be connected to the near-by manholes or catch basins. The details to be coordinated at later stage of the project with the civil engineer or contractor.

7.0 REVIEWS

In accordance with the 2018 edition of the BC Building Code’s, the Geotechnical Engineer of Record is obligated to carry out field reviews. For this project, geotechnical field reviews should be completed for the following items or during the following stages of construction:

<u>Geotechnical - Temporary</u>
7.1 Excavation
<u>Geotechnical - Permanent</u>
8.1 Bearing capacity of the soil
8.3 Compaction of engineered fill
8.5 Backfill

Thus, Horizon Engineering must be given the opportunity to review the stability of excavation slopes, confirm the foundation and slab-on-grade subgrades, review the suitability of engineered fill and backfill, and review the placement and compaction level of the engineered fill. Any in-situ density test results should be forwarded to Horizon Engineering for review in a timely manner.

8.0 CLOSURE

This report has been prepared for the sole use of our client, **Institute of Ocean Sciences RP&TS**, and other consultants for this project as described. Any use or reproduction of this report for other than the stated intended purpose is prohibited without the written permission of Horizon Engineering Inc.

We are pleased to be of assistance to you on this project and we trust that our comments and recommendations are both helpful and sufficient for your current purposes. If you would like further details or require clarification of the above, please do not hesitate to contact us.

For:
HORIZON ENGINEERING INC

Alisa Donnelly., P.Eng.
Geotechnical Engineer

For:
HORIZON ENGINEERING INC

PROFESSIONAL PROVINCE OF BRITISH COLUMBIA ENGINEER
K. KARIMZADEGAN
#27156

Karimzadeg May 1,

Karim Karimzadegan, M.A.Sc., P.Eng.
Principal

Attachment:	Figure 1: Site Location Plan	[1 page]
	Figure 2: Test Hole Location Plan	[1 page]
	Figure 3: Section A-A	[1 page]
	Test Hole Log	[1 page]

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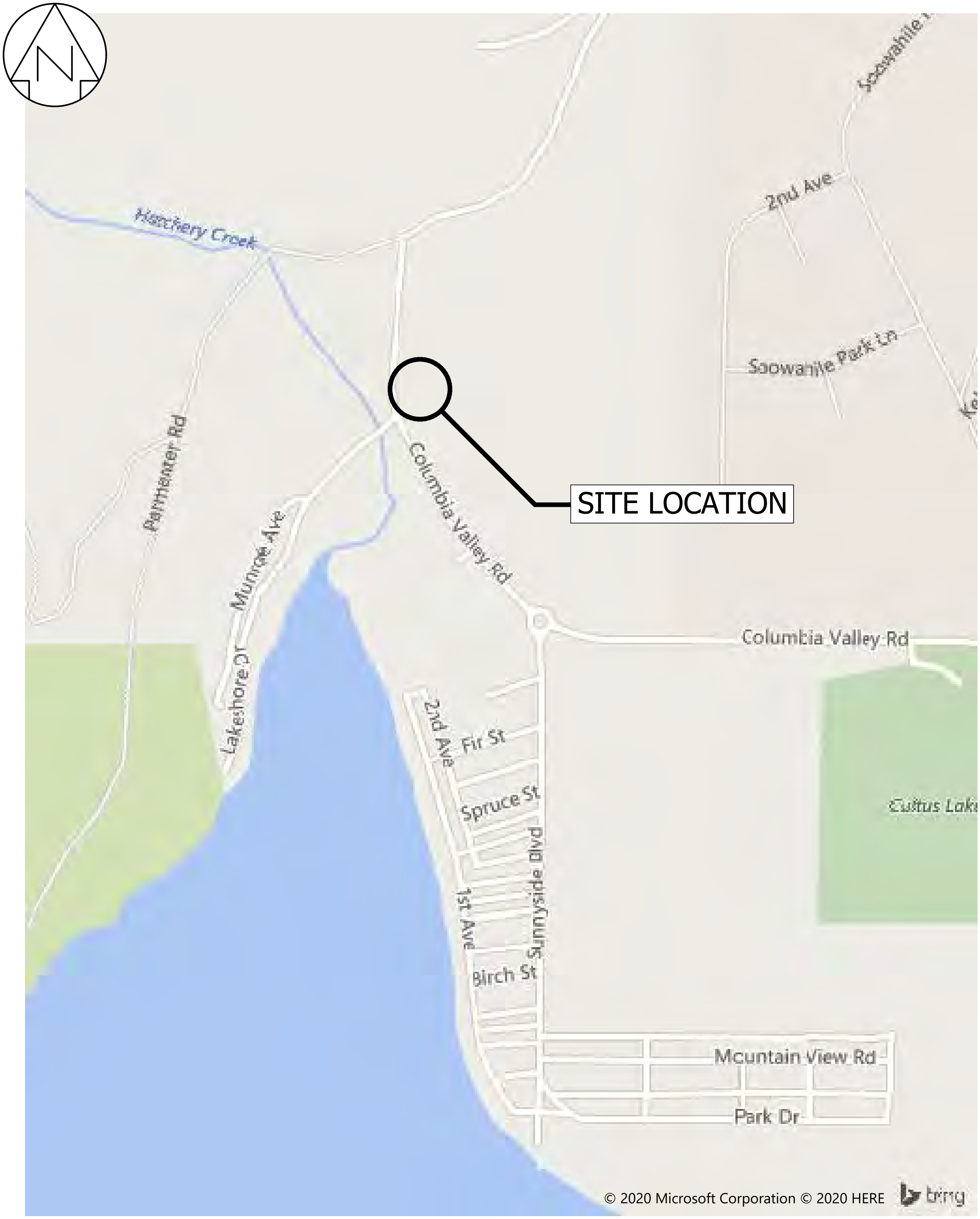

INSTITUTE OF OCEAN SCIENCES RP&TS
9860 West Saanich Road
Sidney, BC V8L 4B2

PROPOSED GUARD HOUSE
4222 Columbia Valley Hwy, Cultus Lake, BC

SITE LOCATION PLAN

HORIZON
ENGINEERING INC

Scale: NTS	File No: 120-4701	Date: MAR/2020	FIGURE: 1
Des: AD	Dwn: CT	Chk: KK	Rev:

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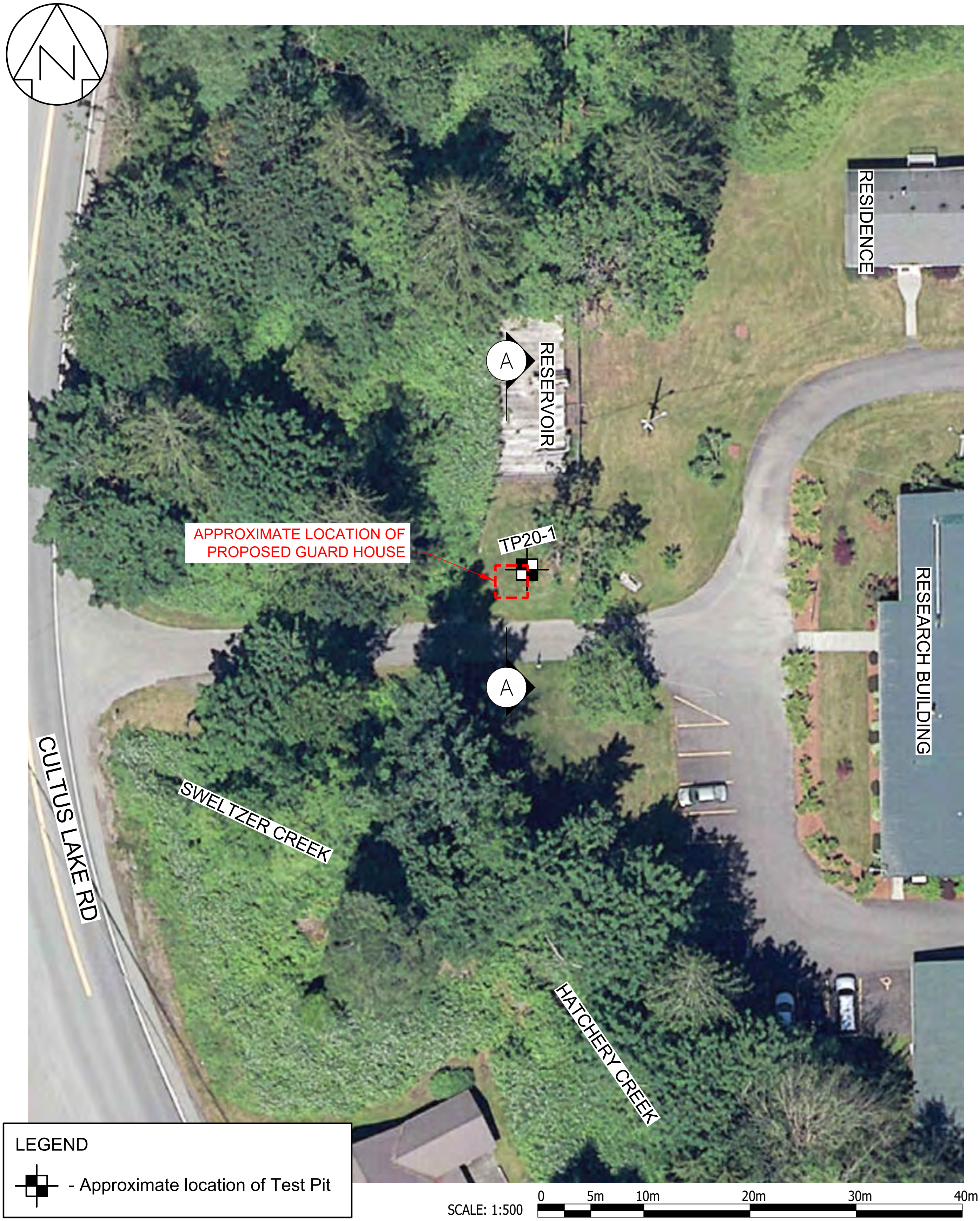

INSTITUTE OF OCEAN SCIENCES RP&TS
9860 West Saanich Road
Sidney, BC V8L 4B2

PROPOSED GUARD HOUSE
4222 Columbia Valley Hwy, Cultus Lake, BC

TEST HOLE
LOCATION PLAN

HORIZON
ENGINEERING INC

Scale:	File No:	Date:	FIGURE:
1:500	120-4701	MAR/2020	2

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AD	CT	KK	

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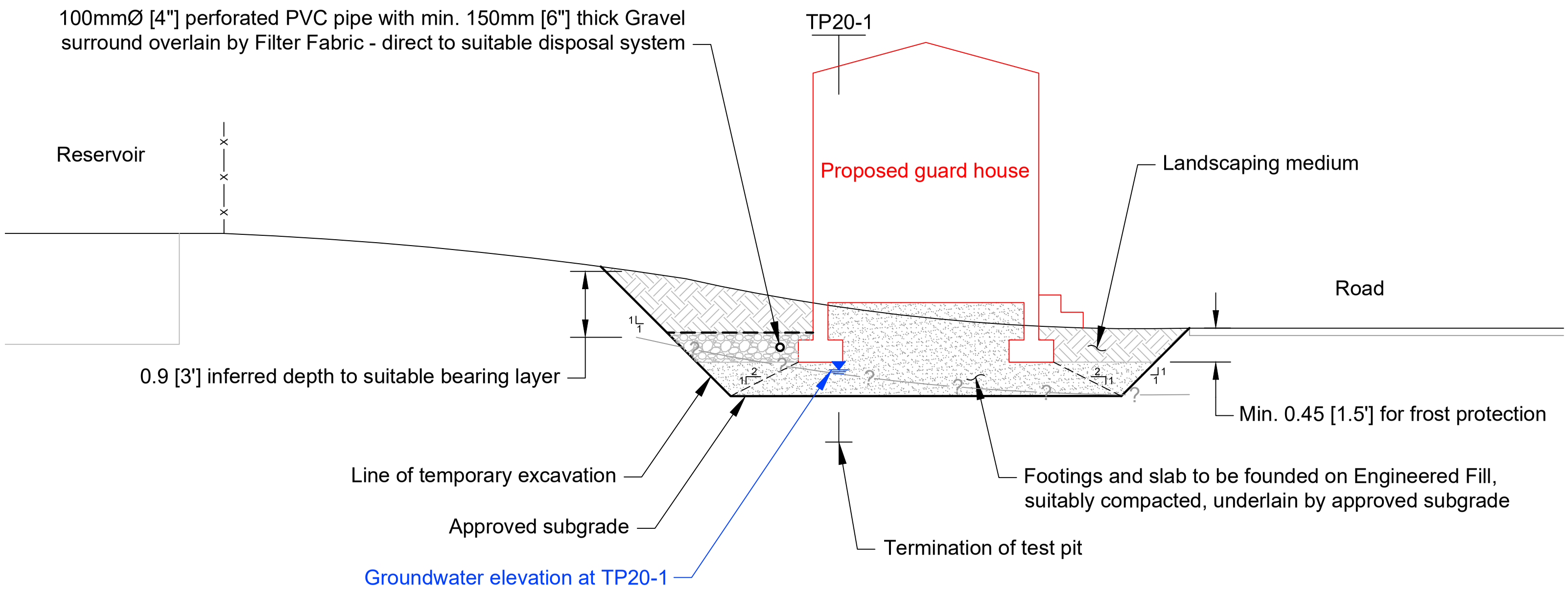

NOTES:
2. Gravel is to be clear-crushed, passing a 25mm (1") screen and retained on a 19mm (3/4") screen.
3. Filter Fabric is to be non-woven needle punch Nilex 4545, or an approved equivalent.
4. Engineered Fill is to be composed of inert, clean, tough, durable mineral particles capable of withstanding the effects of handling, spreading and compaction without excessive degradation or production of deleterious fines. The particles shall be uniform in quality and free from organic materials and deleterious matter. Suitable material would be well graded with less than 5% passing the US #200 sieve and 100% passing a 75mm (3") sieve designation. All granular fill should be placed in 200mm (8") thick lifts and compacted to greater than 100% of its maximum dry density as determined by ASTM D698 (Standard Proctor).

INSTITUTE OF OCEAN SCIENCES RP&TS
9860 West Saanich Road, Sidney, BC

PROPOSED GUARD HOUSE
4222 Columbia Valley Hwy, Cultus Lake, BC

SECTION A-A

HORIZON
ENGINEERING INC

Scale:	File No:	Date:	FIGURE:
1:100	120-4701	MAR/2020	3

Des: AD
Dwn: CT
Chk: KK
Rev:

Test Pit Log No. TP20-1

LOGGED BY: AD REVIEWER: KK DATE: 2020 / 03 / 11 ADDRESS: 4222 Columbia Valley Hwy, Cultus Lake

METHOD: Backhoe NORTHING: EASTING: ELEVATION:

Type of Test:
- ○ Dynamic Cone Penetrometer Test (DCPT)
- ● Becker Denseness Test (BDT)
- ▲ Standard Penetration (SPT)
- ■ Moisture Content (% of dry weight)
- > Plastic limit
- < Liquid limit

TYPE -- Type of sample
SPT -- Split spoon
S -- Shelby tube
G -- Grab
O -- Other (specify)

▽ Ground water level

Notes: 2020-03-11: Groundwater seepage at 2.8 ft

Depth m | ft	DESCRIPTION	Depth	SAMPLE TYPE	20 40 60 80	Piezometer / Comments / Additional Testing
0 | 0	**TOPSOIL - SILTY SAND** (dark brown) fine to medium grained, trace organics (roots and rootlets), moits - inferred to be loose				
	FILL - SILTY SAND(grey) fine grained, trace to some gravel, trace organics (roots and wood fragments), moist - inferred to be loose	0.6			
	POSSIBLE FILL - GRAVELLY SAND(grey motlled brown) medium to coarse grains, subangular to rounded gravel, trace silt, wet - inferred to be loose to compact	2			
1 5	**SAND** (grey mottled brown) fine grained, trace silt, wet - inferred to be compact	2.8	G 1		▽ Groundwater seepage at 2.8 ft
	Test Pit terminated at 6 feet	6	G 2		
2					
3					

HORIZON ENGINEERING INC

PROJECT: Proposed Gaurd House

CLIENT: Institute of Ocean Sciences RP&TS

FILE NO.: 120-4701

SHEET 1 of 1