# Geohazard Assessment of Lands

*As pertaining to land parcel:*

PID 009-555-706

235 QUARRY DRIVE, SALT SPRING ISLAND

LOT 1, SECTIONS 6 AND 7, RANGE 1 WEST, NORTH SALT SPRING ISLAND, COWICHAN DISTRICT, VIP46155

# Report for Coastal Erosion Mitigation

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| Developed for: | Heidi Kuhrt, David Kuhrt (Landowners) |
| | 235 Quarry Drive |
| | Salt Spring Island, BC V8K 1J2 |


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| Developed by: | Thomas R Elliot PhD P.Geo P.Ag |
| | TRE Environmental Services |
| | tom@elliot.org |

TRE Environmental Services

# 1. Synopsis

The subject land parcel, with PID 009-555-706 and legal description of Lot 1, Plan VIP46155 (Site), is situated on the lower southwest-facing flank of a slope which terminates to the Salt Spring Island ocean-shoreline in a coastal bluff. The Site is proposed to undergo coastal erosion mitigation development activities within the Shoreline Development Permit Area[1] (DPA 3) of the Islands Trust (IT), which prompted this geohazard assessment to identify mechanisms contributing to erosion of the coastal bluff that would create hazardous conditions for existing single-family dwelling (SFD) and the natural environment.

The Site consists of a moderate-steep benching bedrock slope with a veneer to mantle of stoney sandy loam to loamy sand. There is a veneer of colluvial boulders to stones accumulated below bedrock outcropping. The slope descends from a ~58m above sea level (asl) elevation regional northwest-southeast aligned bedrock ridge. The bedrock ridge is sandstone at elevation and transitions to shale and metamorphic deposits of the Nanaimo Sedimentary Group closer to sea level. At ~10m asl elevation, a metamorphic-rock coastal bluff rises above the natural boundary and is capped with a 2 – 4m thick mantle of gravelly sandy loam.

While there is no ephemeral or permanent surface watercourse observed at Site, the presence of near-surface groundwater is apparent where bedrock outcrops force phreatic water to surface.

The erosion and sediment mass-wasting observed on Site primarily consists of two concurrent processes:

Wave action — a culmination of mechanical wave-action, daily sunlight-driven thermal oscillation, and saturating water-spray promotes decomposition and failure of fine-grained metamorphic bedrock situated in the lower 6 - 7m of coastal bluff. This results in toe erosion which, over time, destabilizes the portion of coastal bluff above.

Pore water — sufficient pore water pressure below the phreatic surface can acts as a destabilizing factor to overcome cohesion, friction angle and soil weight – entirely independent of toe erosion. While the majority of episodic pore water pressure erosion occurs during the rainy season, localized increases in pore water pressure can also lead to instability during otherwise drought conditions.

Through assessment of the Site subject to Shoreline DPA, Thomas R Elliot PhD P.Geo P.Ag has determined a Low risk of landslide geohazard impacting the SFD. However, there is a High risk of erosional geohazard impacting marine environment in an ongoing and progressive manner.

[1] IT Bylaw 488 - https://islandstrust.bc.ca/wp-content/uploads/2020/10/SS-BL-434_2020-10_OCP_Vol1-2.pdf

This determination is based on geophysical indicators on Site, regional frequency of historic landslide in the area, as well as assessment of Site surficial materials, hydrologic regime, topography and slope failure mechanics, as detailed through this report.

The proposed erosion mitigation development activities do not increase the hazard rating to the existing SFD or occupancy of Site.

# 2. Introduction

Development activity within the IT is being pursued on the subject land parcel with PID 009-555-706 (the 'Site', see Figure 1 – Appendix 1). The R (Rural) zoned land parcel is located on a southwest-facing flank of a slope which terminates to a coastal bluff ocean-shoreline. The Site is accessible via Quarry Road arriving from the north, at top of the slope, where a private roadway has been established.

This report includes assessment of pre-existing and field-gathered data which informs a geohazard risk assessment and guides proposed erosion mitigation measures.

There exists DPA 3 requirements for non-exempt development activities within 10m landward and 300m seaward of the marine-shoreline natural boundary. Due to land parcel configuration there is currently 10m setback from the natural boundary and existing SFD, resulting in a requirement to obtain DP if proposed erosion mitigation activities are occurring in this setback. Therefore, proposed landward erosion mitigation activities will be considered in context of existing structures, near-surface water management and erosion processes observed at the coastal bluff.

This report is a cumulative evaluation of existing and field-based data toward determining risk to SFD and natural environment associated with geohazards present on Site, and impact of proposed erosion mitigation measures on identified geohazards.

## 2.1. Author Qualifications

Thomas R Elliot PhD is a Qualified Professional (QP) Geoscientist [# 43570] and Professional Agrologist [# 3045] registered within the Province of British Columbia and in good standing with both professional associations. The QP has 16 years of geohazard, soil science, near surface groundwater and aquifer hydrogeology practice. In the last 9 years, Thomas R Elliot has primarily worked on Vancouver Island and the Lower Mainland of British Columbia in the practice areas of [Geoscience]: Hydrogeology, Geohazard mitigation assessments, Soils/Groundwater management; and [Agrology] Soil science, Agriculture, and Contaminant detection, mitigation and remediation.

# 3. Scope, Context & Motivation

The proposed development activities are erosion mitigation measures for identified geohazards toward reducing risk to the existing SFD and natural environment on Site.

This report does not determine the specific erosion mitigation activities due to a requirement for comprehensive assessment of near shore environments prior to identification of suitable measures. A comprehensive assessment includes this geohazard report in addition to an evaluation of beach and wave characteristics that will collectively inform suitable erosion mitigation activities through the Marine Shoreline Design Guidelines[2] that have been broadly adopted by Province of BC and Federal Department of Fisheries and Oceans.

The motivation to produce this report is to provide IT record of existing geohazard conditions on Site; predicted impact of proposed development activities; and if the proposed development activities – in context of existing or novel geohazards – allows for safe Rural-residential use of the land, as intended.

# 4. Regulatory Context

This section is dedicated to review of applicable Regulations and Acts, as governing legislation for individual and group risk of harm/death related to land use, as well as general permitting and authorization requirements of intended land use and proposed erosion mitigation development activities.

Further, the Department of Fisheries and Oceans would also be requested to conduct review of proposed activities in conjunction with the local IT DPA 3 permitting requirements.

## 4.1. IT Shoreline DPA

The geohazard assessment for the proposed works is warranted under MA Section 879 (1)(a) and (b) which prompts IT to protect the natural environment and to protect development from hazardous conditions; as specifically governed by IT Bylaw 434, V 2, S E.3 Development Permit Area 3 – Shoreline (enacted through IT Bylaw 488).

IT Bylaw 488, DPA 3 – Shoreline requires development permit applications be submitted for activities occurring 10m landward in areas where the marine environment has been identified as being particularly sensitive to development impacts.

If the proposed erosion mitigation works are to include: breakwater, weir, groin or jetty; bulkheads; placement of fill; removal of trees with diameter greater than 20cm OR removal of vegetation that results in the exposure of a total area of bare soil more than 9m$^2$ in area – then there is requirement for IT approved Development Permitting.

[2] Johannessen, J.[1], A. MacLennan[1], A. Blue[1], J. Waggoner[1], S. Williams[1], W. Gerstel[2], R. Barnard[3], R. Carman[3], and H. Shipman[4]. 2014. Marine Shoreline Design Guidelines. Washington Department of Fish and Wildlife, Olympia, Washington. **1** Coastal Geologic Services Inc.; **2** Qwg Applied Geology; **3** Washington State Department of Fish and Wildlife; **4** Washington State Department of Ecology

### 4.2. DFO Authorization

Pursuant to the *Fisheries Act*, should a requested DFO project review determine that proposed development activities are likely to cause the death of fish and/or harmful alteration, disruption or destruction of fish habitat – then authorization would be required.

Since the development activity (i.e. erosion mitigation measures) are currently undefined, this report is unable to establish whether DFO authorization will be required.

## 5. Site Conditions: Existing and Field Data

### 5.1. Slope, Geology, Soils & Surficial Materials

At shoreline, the Site has a ~8 – 12m coastal bluff consisting of siltstone and shale at base and capped with 1 – 2m of surficial material. Above which there are three distinct slope sections of the Site. The lowest is a gently sloping (~5 - 15%) bench above the coastal bluff where the SFD on Site exists, above which is a bedrock-controlled section of 30 – 35%. This second benching section does not exceed the angle of repose for local loamy soils, above which local sediment has increased likelihood of instability. The last slope section crests at a ridge-top and drops in elevation to Quarry Drive.

Soil associations on Site were previously mapped[3] in elevation-limited bands which correspond to the changes in slope, which is consequent to change in sea level during glaciation and inter-glacial periods. Starting at present day marine shoreline and ascending up slope, the soil associations present on Site include a typically <2m thick veneer of well drained loam Galiano soil, which are derived from colluvium[4], on the lowest slope.

At higher elevation, a band of thin <2m veneer of Saturna well draining sandy loam soils with prominent bedrock outcropping ascend to an elevation of ~58m asl. This portion of the land parcel is the source of boulders and other large loose rock masses which form sparse accumulations at lower elevations.

At upper elevations, Haslam well draining sandy loam soils are prevalent and functionally attenuate precipitation as it infiltrates to near surface bedrock.

The bedrock on Site was mapped as belonging to the Nanaimo Group[5], with sparse details on the surficial rock type in existing records. On Site, the mid and upper elevation presented sandstone at surface, while at lower elevations a change from shale transitioning to siltstone

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[3] Soil Information Finder Tool. https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=cc25e43525c5471ca7b13d639bbcd7aa

[4] Soils of Southern Vancouver Island. MOE Technical Report 17. https://sis.agr.gc.ca/cansis/publications/surveys/bc/bc44/index.html

[5] Vancouver Island Geology. https://www.gac-cs.ca/publications/FT_Geology_of_Vancouver_Island.pdf

at coastal bluff occurred. The rock types identified on Site are characteristically found in the Nanaimo Group.

### 5.2. Surface & Groundwater

There are no identified or observed watercourse on Site. However, accumulation of rainwater and drainage from the access road does present areas of increased surface water discharge to forest floor. These areas are demarcated by accumulation of debris moved by the flow of surface water, increased annual vegetation growth, and an infiltrative surface – the extent of which is related to volume of accumulated rainwater.

Infiltration of each soil association on Site is unrestricted by soil texture, meaning that in areas where water does accumulate at surface there is a low-permeability limiting layer (i.e. bedrock) which prevents continuous downward migration. Instead, as infiltrating water reaches bedrock, lateral dispersion becomes dominant and results in a phreatic surface (i.e. perched groundwater table) establishing within the thin <2m veneer of surficial earth materials.

Where bedrock outcrops to surface, the veneer of surface material thins and 'pinches out', resulting in emergence of phreatic water. These 'weeps' or 'springs' are not to be conflated with artesian conditions, as these waters do not enter a confined aquifer and pore water pressure does not exceed atmospheric pressure. While not individually significant to Site surface hydrology, the irregular bedrock surface accumulates these phreatic weeps to a subsurface non-contiguous perched water table within the veneer of well-draining surface material.

Due to this accumulation mechanism, there is an increased depth of perched water table at lower elevations of the Site. Therefore, it is warranted to conduct specific geohazard assessment of areas where surficial materials convey the accumulated depth of perched water table due to an increased pore water pressure forcing erosion at the coastal bluff.

## 6. Geohazard Assessment

This landslide risk assessment was largely conducted according to the Engineers and Geoscientists of BC document *Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC*[6]. The landslide risk assessment methods that were utilized includes all aspects of landslide hazard analysis, such as regional frequency and historic evidence to inform current and future landslide hazards; as well as evaluation of hazard likelihood, and consequence of landslide impact, to formulate a relative risk matrix which is comparable with levels of landslide safety adopted by the approving jurisdiction.

[6] EGBC Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC. https://www.egbc.ca/getmedia/5d8f3362-7ba7-4cf4-a5b6-e8252b2ed76c/APEGBC-Guidelines-for-Legislated-Landslide-Assessments.pdf.aspx

The assessment was restricted to the Site, as indicated in Figure 1, and specifically includes bedrock of the coastal bluff.

## 6.1. Investigation of Historic Failures in Area & Seismic Compliance

A review of historic aerial imagery was conducted on the surrounding area to determine frequency and spatial distribution of natural and induced landslides.

There were no mid-slope landslide scarps, transport paths, or deposit zones identified in proximity to Site or on similar colluvium slopes within the region within historical aerial imagery.

Through this lack of landslide evidence, and the existing evidentiary record of significant seismic events over the past ~500 years, there is no suggestion that natural slopes on Site would fail under seismic disturbances.

For example, a seismic event occurred at 10:13 a.m. on Sunday June 23, 1946 which measured at 7.3 on the richter scale, and was considered a significant seismic event which exceeds the 2% in 50 years magnitude. Therefore, as the Site and surrounding slopes exhibits no evidence of displacement consequent to ground motion, this historic record demonstrates compliance with seismic design at existing or proposed slopes of lower angle.

The presence of loose boulders (up to 1.2m in diameter were observed) on mid-slopes above the non-habitated (i.e. driveway, not SFD) lower slope on Site does suggest an increased likelihood of injury or death of an individual (i.e. consequence) while posing no likelihood for harm to the natural environment. However, the likelihood co-location of an individual within the increased consequence pathway is very remote and therefore does not contribute to overall risk considered herein.

## 6.2. Field Investigation

On Sept 17th, 2023 Thomas R Elliot PhD P.Geo P.Ag attended to Site as a QP with declared competency in geohazards, hydrology and soil science to evaluate the geohazards, ground and surface waters present on Site.

Field data was acquired according to, and through the implements noted in Table 1 below.

***Table 1 – Summary of Field Work***

| | | | |
|---|---|---|---|
| **Project ID:** | 2023.900 | **Project Name:** | Baker Beach Erosion Mitigation |
| **Project Type:** | Erosion Mitigation (Geohazard) | **Lead Investigator:** | Thomas R Elliot PhD P.Geo P.Ag |
| | | | |
| **Client:** | Aurora Professional Group | **Client Contact:** | Brad Fossen P.Eng |
| **Site Boundary Type:** | Land Parcel | **Site Common Address:** | 235 Quarry Drive |

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| **Site Legal Description:** | VIP46155, LOT 1 | **Site PID #** | 009-555-706 |
| **Site Land Use:** | Rural residential | **Site Condition:** | Secondary growth |
| | | | |
| **Development Activity:** | Erosion mitigation measures | **Project Stage:** | Assessment |
| **DPA:** | DPA3 – Shoreline | **Provincial/Federal:** | DFO review |
| **Equipment Used:** | - Clinometer<br>- Compass<br>- Engineer's tape<br>- GPS tracking | - Field soils kit<br>- Range finder<br>- Shovel and hand tools<br>- Soil probe<br>- Camera | |
| **Summary of Site Activities:** | • Site and Soils Assessments<br>• Evaluate Terrain Stability & Geohazard<br>• Document visible erosion mechanisms, ground and surface water | | |

## 6.3. Geohazard Units

Based on self-similar geophysical and hydrologic characteristics of the Site, a number of Geohazard Units (GU) were defined by the attending QP. Each GU has been assigned a respective Geohazard, or relative likelihood of a landslide event occurring, based on the documented geophysical and hydrologic characteristics.

The incremental change in Geohazard within a GU consequent to the proposed Development Activity is evaluated by the QP in order to arrive at impact of said Development Activity. The subsequent QP interpretation and recommendations are intended to fulfil requirements of the IT Shoreline DPA.

## 6.4. Wave Action and Erosion Hazard

Along the coastal bluff in proximity to Site there were numerous small-scale mass-wasting scarps consequent to erosion. Of those observed on Site, those occurring at base of the coastal bluff also had ongoing erosion of the sediment cap at top of the coastal bluff – suggesting a classic toe erosion mechanism. The bedrock toe erosion is driven by a combination of mechanical factors (e.g. wave-impact, thermal expansion, wedging/sediment jacking of fractures, etc.) and chemical factors (e.g. dissolution of binding carbonates, salt/crystal growth, etc.). The most prevalent of which appears to be wave-impact, which – due to orientation of metamorphic rock laminae and wave-direction – peels the friable bedrock during storm events.

Otherwise, erosion occurring at mid or upper portion of the coastal bluff was based in surficial material – the mechanism of which is explored in the Groundwater and Erosion Hazard section of this report.

## 6.5. Groundwater and Erosion Hazard

There exists a transient erosion hazard consequent to high pore water pressure conditions within the veneer of surficial Galiano soils at base of the slope on Site, as a component of the failing coastal bluff.

Under adverse climatic conditions, this hazard would result in a limited mass wasting failure which would mobilize and entrain the full depth of surficial material. With standard climatic conditions, this mechanism is not as likely to result in such mass failure – instead, punctuated failure events will see progressive steepening and erosion at base of the surficial material cap atop the coastal bluff. This steepening will progress until a larger landslide failure event re-establishes at angle of repose – migrating the erosion front landward, toward the SFD.

Therefore, since the erosion of surficial material – over the long term – could impact the SFD, there are recommended mitigation measures which can be found is Section 7 of this report.

## 6.6. Hazard Rating

There was no pre-existing geohazard rating established through QP assessment and reporting, to the awareness of the author at time of writing.

The Site natural slopes were less than the angle of repose for moist gravelly sandy loam to loamy sand colluvium earth materials (35 - 45% or 19° - 24°)[7] above which slope-failure becomes more probable.

The landslide hazard rating for the entire Site was lower due to strong bedrock control at upper elevations, with shallow depth to bedrock for the remainder of Site, and therefore limited surficial material which would mobilize.

However, the surface sediments capping the coastal bluff have an increased erosional hazard due to presence of a perched water table in the lower slopes.

Consequent to these observations and slope gradients, GU on Site were assigned a VERY LOW to LOW hazard ratings outside of the coastal bluff, which classified as HIGH.

As per Appendix 2 – Geohazards and Risk, the GU defined on Site are summarized in Table 2, below.

Map imagery of GU delineation is found in Appendix 2 and is a recommended reading accompaniment to this section.

[7] H. Al-Hashemi, O. Al-Amoudi. A review on the angle of repose of granular materials. Powder Technology Volume 330, 1 May 2018, Pages 397-417. https://doi.org/10.1016/j.powtec.2018.02.003

***Table 2 – GU Hazard Rating and Risk***

| Geohazard Unit | Hazard Rating and Risk | | | |
|---|---|---|---|---|
| | *Slope Characteristics* | *Hazard Rating* | *Consequence* | *Incremental Risk Rating* |
| 1 | **Cv \| Br benching ± 35 - 40%** | **VERY LOW** | **LOW** | **Very Low** |
| 2 | **Cv / Br planar ±25 – 35%** | **LOW–MODERATE** | **LOW** | **Very Low** |
| 3 | **Cm planar ±5 – 15%** | **VERY LOW** | **LOW** | **Very Low** |
| 4 | **Cv / Br planar ±150 – 180%** | **HIGH** | **HIGH** | **High** |

Geohazard Shorthand Notation

**Br** – Bedrock
**C** – Colluvium
**A** – Aeolian
**L** – Lacustrine
**GF** – Glaciofluvial
**GT** – Glacial till
**M** – Marine

**v** – veneer (.1 – 2m)
**m** – mantle (2 – 5m)
**b** – blanket (>5m)
/ - overlying
| - equal surface exposure
**benching** – slope interrupted by bedrock
**planar** – linear slope

## 6.7. Consequence of Geohazard Event

The Consequence of a geohazard incident was evaluated by the QP based on downslope receptors, predicted size and volume of geohazard event, and a simplistic Farböschung assessment – as detailed in Appendix 2 – Geohazards and Risk.

The most active failure mechanism on Site is punctuated landslide erosion of surficial materials at the coastal bluff (GU 4). The mobilized material would deposit directly to the marine environment, resulting in HIGH consequence.

Outside of which, the second likely failure mechanism on Site would be a mid-slope (GU 2) failure within a colluvium filled relic bedrock draw where a perched water table decreases shear resistance. However, due to the veneer of surficial material in the initiation area, any landslide would impact a limited area due to lack of transportable surficial materials from the initiating area or on low gradient receiving slope (GU 3). The low gradient receiving slope has sufficient width to retain mobilized material, resulting in a LOW consequence.

Summarily, the most likely geohazard results in a HIGH consequence while the remainder of Site has a LOW consequence.

### 6.8. Incremental Risk Imposed by Development Activity

The purpose of proposed erosion mitigation development activities is to reduce the geohazard risk of GU 4. This report has identified the active failure mechanisms resulting in erosion of the coastal bluff, from which mitigation measures can be evaluated.

### 6.9. Suitability of Lands for Use Intended (SFD)

There are no up-slope hazards likely to impact the SFD location.

While GU 4 has a High risk rating, the progressive-over-time nature of failure mechanisms for this area would provide opportunity to conduct more specific geotechnical review, and/or implement mitigation or emergency measures prior to impacting the SFD and ~3m of surrounding liveable space.

With no off-Site hazards and a LOW likelihood of failure above an existing SFD – the building location is **SAFE FOR THE USE INTENDED** (Residential Single Family Dwelling).

## 7. Geohazard Mitigation Recommendations

Due to the HIGH incremental risk of geohazards for GU 4, there are mitigation recommendations intended to reduce the risk to LOW.

### 7.1. Erosion and Sediment Control

All proposed activities will require Erosion and Sediment Control planning which meets IT regulatory requirements. Any such plan should be developed toward acquiring a Development Permit from the IT for the proposed activities and shall be submitted alongside any additional required paperwork.

There are two identified erosion mechanisms:

**Pore water** sufficient pore water pressure below the phreatic surface can acts as a destabilizing factor to overcome cohesion, friction angle and soil weight – entirely independent of toe erosion. While the majority of episodic pore water pressure erosion occurs during the rainy season, localized increases in pore water pressure can also lead to instability during otherwise drought conditions.

Mitigation options include, but are not limited to:

- Annual monitoring of erosional regression of surficial materials at the coastal bluff;
- Groundwater intercept and redirection to non-erosive receiving environment;

- Bioengineering and selective planting of native species toward increasing shear strength of surficial materials;
- Re-contour of the surficial materials to allow for emergence of groundwater without erosion;
- Selective removal of shoreline trees deemed hazardous due to toe erosion.

**Wave action** a culmination of mechanical wave-action, daily sunlight-driven thermal oscillation, and saturating water-spray promotes decomposition and failure of fine-grained metamorphic bedrock situated in the lower 6 - 7m of coastal bluff. This results in toe erosion which, over time, destabilizes the portion of coastal bluff above.

Mitigation options include, but are not limited to:

- Monitoring rate of erosion so as to establish a predictive timeline of coastal bluff regression;
- Bioengineering and selective planting of native species toward dissipated wave-impact on coastal bluff face;
- Wave deflection within intertidal area;
- Beach nourishment to dissipate wave energy;

The suitability, efficacy and ease of implementation and maintenance of these recommended mitigation options should be carefully considered in context of Marine Shoreline Design Guidelines which will require an integrated assessment of geohazards (this report), wave and beach dynamics, and ecosystem characteristics.

# 8. Safety and Suitability

This report has been prepared in accordance with standard geotechnical hazard assessment practices, and at the expense of Heidi and David Kuhrt. Thomas R Elliot PhD P.Geo P.Ag has not acted for or as agent of the Islands Trust in the preparation of this report.

Thomas R Elliot PhD P.Geo P.Ag certifies that the land is safe for the use intended (Residential Single Family Dwelling and Driveway) if the land is used in accordance with the conditions specified in this report.

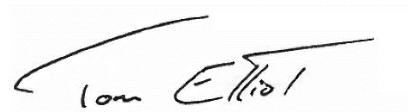
Thomas R Elliot PhD P.Geo P.Ag acknowledges that this report may be used by the Islands Trust as a precondition to the issuance of a permit and that this report and any conditions contained in this report may be included in a restrictive covenant and filed against the title to this subject property.

# 9. Summary

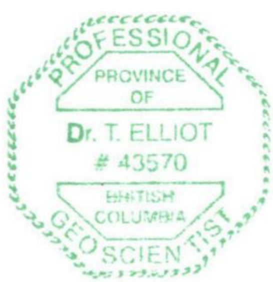
The land parcel with PID 009-555-706 situated on the southwest flank of a bedrock ridge forming a benching slope down to a coastal bluff is proposed to undergo permissible Development Activities within the Shoreline DPA of the IT.

Through assessment of these DPA requirements, Thomas R Elliot PhD P.Geo P.Ag as a QP capable of conducting the works, has determined a **High Risk of erosion geohazard** impacting the local environment. This determination is based on geophysical indicators on Site and regional frequency of historic landslide in the area.

The proposed development activities do not increase the Risk, however specific design of erosion mitigation measures will have to be completed prior to establishing a post-development Risk. There are sufficient pre-existing long term erosional processes on Site to warrant mitigation measures.

| | | |
|---|---|---|
| Qualified Professional of Record | THOMAS R. ELLIOT PhD P.Geo, P.Ag<br>Name | <br>Sign |

Thomas R Elliot PhD P.Geo. P.Ag.




Digital reproduction, original available upon request.

Date: November 6, 2023

# 10.Closure and Limitations

The QP signatory to this assessment and report assures accuracy of existing and field observation, and evaluation of technical geohazard according to best practices of the Engineers and Geoscientists of BC. The content of this report are applicable to the subject land parcel, and specifically the Site as defined in this report. Any extension of the evaluation to areas outside of the defined area assessed are not valid.

The report has been conducted according to guidelines and reporting standards of similarly qualified professionals, given similar time and budget. At time of writing, the report meets due diligence and investigatory reporting requirements to provide QP recommendations with declared competency in the subject areas. Therefore, the author of this report does not maintain liability insurance for actions taken based on the reporting, and only accepts error and omission liability up to the value of this report. The receipt, utilization and any planning, further studies or development actions undertaken by the recipient of this report are based on their acceptance of their own liability therein.

# Appendix I

## Maps and Figures

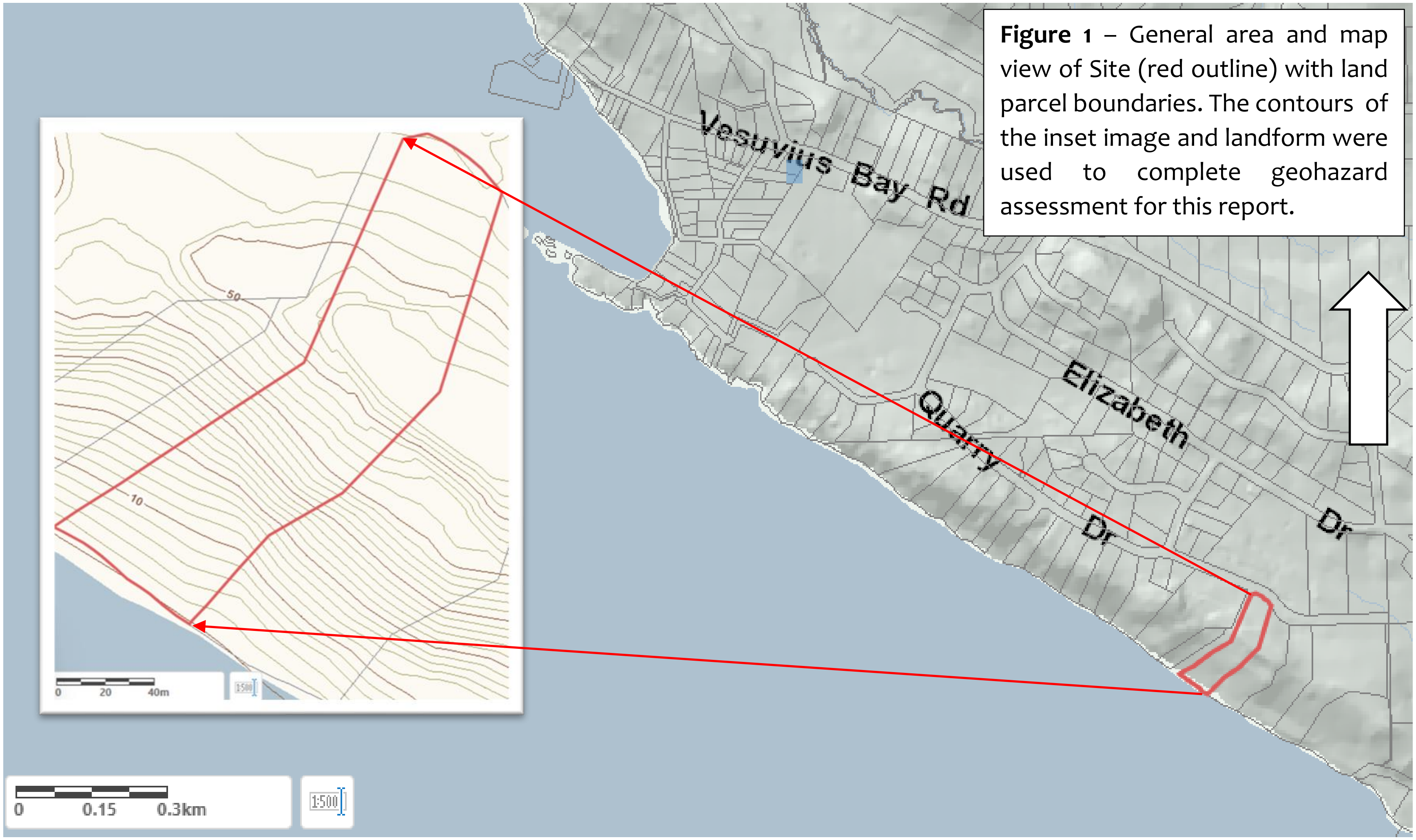



**Figure 1** – General area and map view of Site (red outline) with land parcel boundaries. The contours of the inset image and landform were used to complete geohazard assessment for this report.

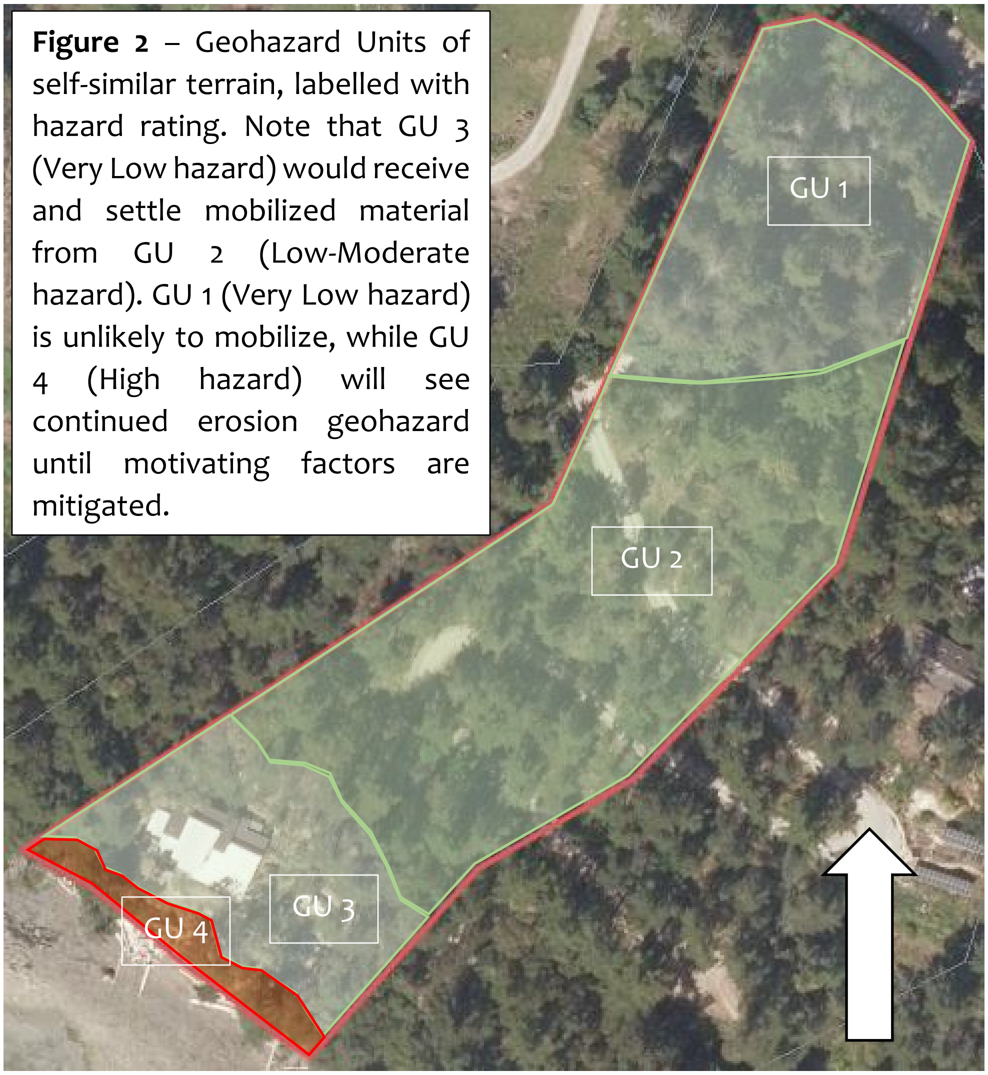



**Figure 2** – Geohazard Units of self-similar terrain, labelled with hazard rating. Note that GU 3 (Very Low hazard) would receive and settle mobilized material from GU 2 (Low-Moderate hazard). GU 1 (Very Low hazard) is unlikely to mobilize, while GU 4 (High hazard) will see continued erosion geohazard until motivating factors are mitigated.

# Appendix II

## Geohazards and Risk

## Geohazards

This assessment is partially based on local historic rates of landslide failure. The rating hazard of failures occurring in a given area under the classification system shown in Table II_a, below. By determining the likelihood of historic failures based on spatial density, the number of failures per unit area can be predicted. The likelihood of historic failures is determined through review of historic aerial imagery and general area observations while on the way to or from Site.

By establishing failure spatial density in the local area, in conjunction with Table II, the hazard rating can be estimated for areas undergoing development activities that impact terrain stability.

The hazard ratings were defined based on pre-existing practice by geoscientists and engineers for the natural resources sector, and adapted to best suit development activities governed by responsible municipal partners toward meeting those partner-organization risk tolerance policies.

Please note that, differing from resource sector terrain stability assessments, this evaluation of hazard includes failures smaller than 0.05 ha area (initiation, transport and deposit area). This is consequent to resource sector activities, and typically remote locations, being more tolerant of small-scale geohazard events. For this location, due to proximity to populated areas, and responsibility to meet municipal risk tolerance policies, the total area of a failure may be less than 0.05 ha in order to contribute to the hazard rating.

**Table II_a: Definitions of hazard categories**

| Hazard Category | # of failures per geohazard unit size |
|---|---|
| VERY HIGH | >1 failure per 2 ha |
| HIGH | 1 failure per 2 to 10 ha |
| MODERATE | 1 failure per 10 to 50 ha |
| LOW-MODERATE | 1 failure per 50 to 250 ha |
| LOW | 1 failure per 250 to 1250 ha |
| VERY LOW | <1 failure per 1250 ha |

Once the natural hazard of landslide for the area has been established, the probability of at least one failure occurring in a geohazard unit can be determined from Figure II_A.

Figure II_1 is based on the assumption that the probability of a specified number of failures occurring within a polygon is related to the size of the polygon by a cumulative normal distribution.

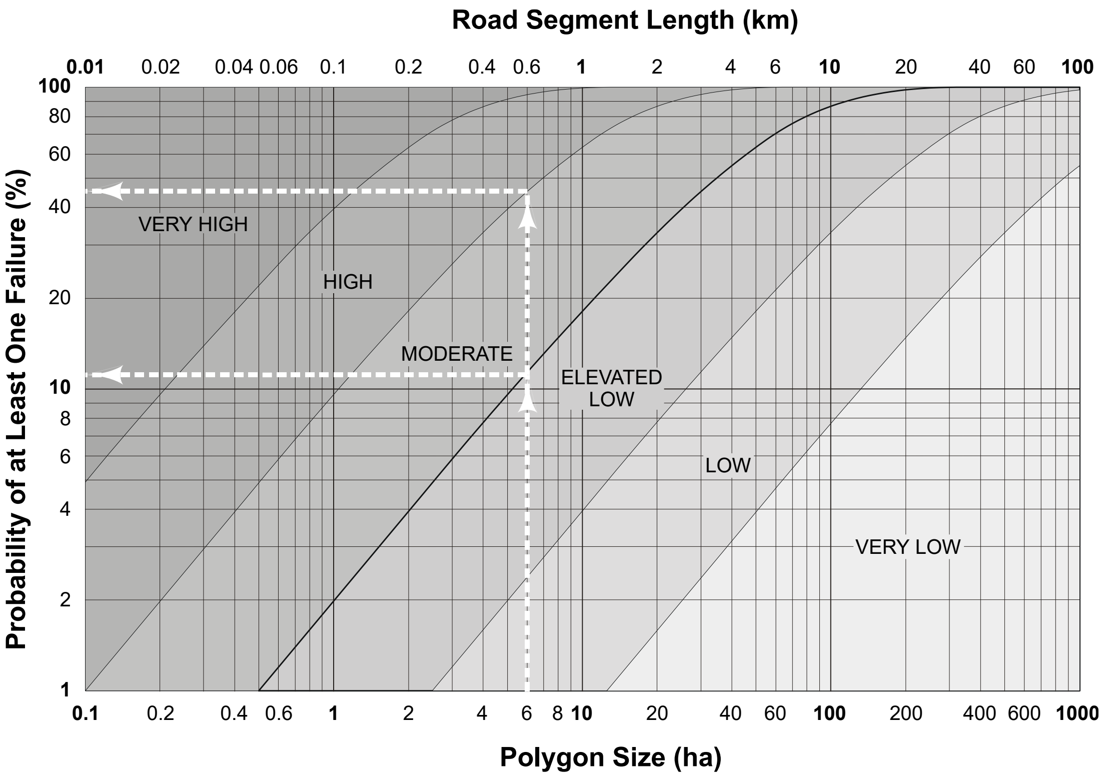



Figure II_1 – Probability of at least one failure based on a geohazard unit (GU) assessment area size or road length. This figure has been adopted from BC Forestry practices and is based on a single forestry harvest cycle, typically lasting 60 years within Coastal BC.

*Figure II_1 has an example sketched with dashed white lines. The example indicates probability of failure for a **6 ha** geohazard unit area with a **moderate** hazard rating. The probability of at least one failure occurring within the assessed geohazard unit area over the period of one forestry harvest cycle is between ~12 – 45%.*

## Consequence

### Simplistic Farböschung Evaluation

Whether or not a Site will be impacted by a geohazard is a component of determining consequence to potential landslide failures and/or debris flows. A simplistic assessment of transport and deposition zone locations can be accomplished through a 'Farböschung' evaluation. This is best exemplified through Figure II_B, which demonstrates how a sliding

mass (block on right hand side) has potential to transport some distance from point of initiation based on a simplistic assignment of Farböschung angle.

For this assessment, a Farböschung angle of 45% was used based on heuristic practice for these coastal environments and gravelly loam surficial material. By standing on Site at highest point of initiation, the QP was able to establish the approximate run-out distance to edge of the deposit zone.

A more Site specific example is provided in Figure II_C, which shows a benching bedrock terrain where a thin veneer of surface material is mobilized, and has limited transport and deposit distances based on the Farböschung angle.

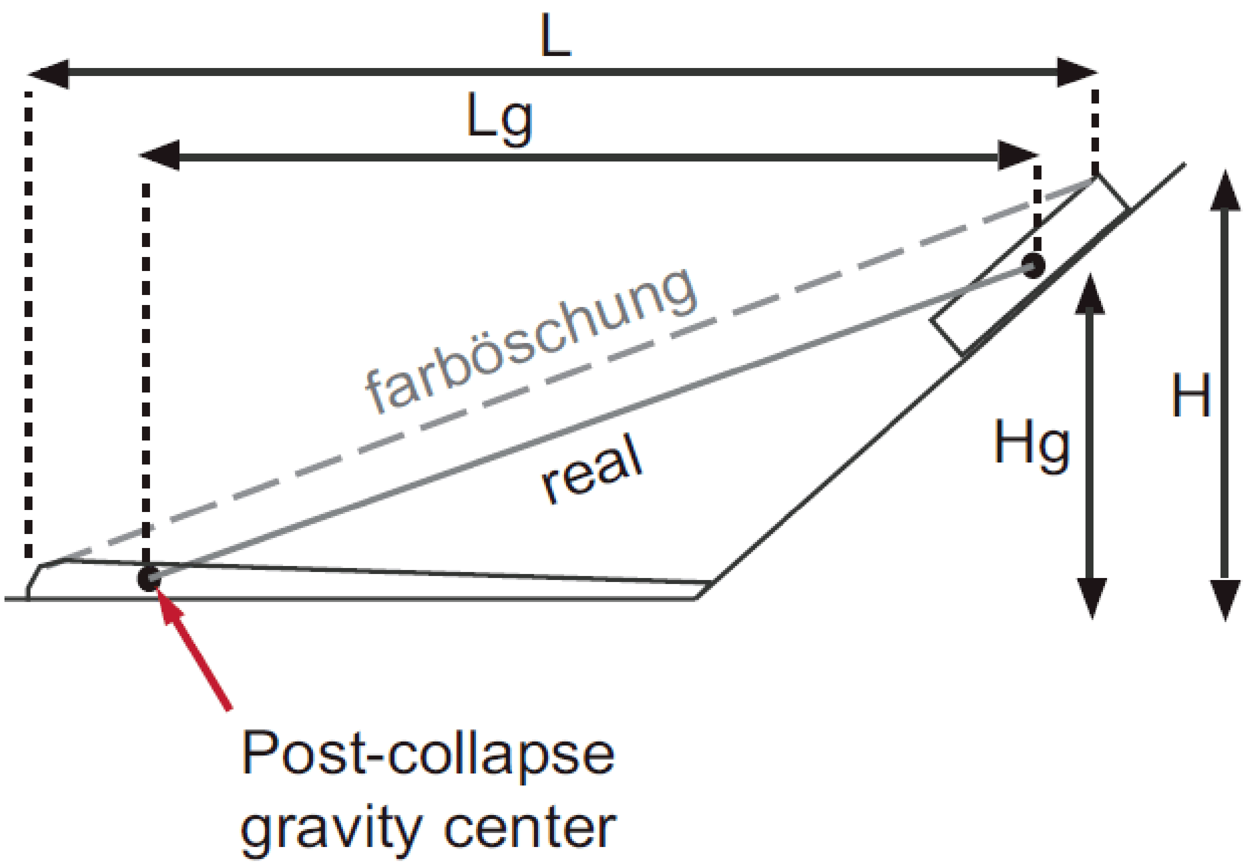



**Figure II_B** – Farböschung angle functionality for sliding masses on a slope. The specific mathematics of which are not supplied here for brevity.

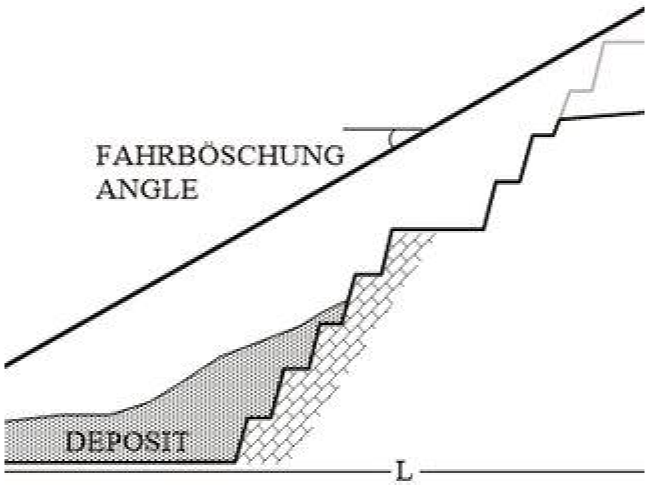



**Figure II_C** – An example of landslide runout and deposit area of potential geohazards on Site based on simplistic Farböschung assessment.

**Table II_b: Consequence**

| Consequence | Criteria |
|---|---|
| HIGH | Landslide material would directly enter fish habitat (stream, lake, or marine waters); water intake for domestic consumption; jeopardize lives of the public; impact major public infrastructure; or other property owner.<br><br>Landslide would enter non-fish stream within 500 m of fish habitat. |
| MODERATE | Landslide material enters non-fish stream > 500 m and < 3000 m from fish habitat, OR there is a slope < 20% for < 100 m below landslide to fish habitat; potable water intake; a public area; or other property owner. |
| LOW | Run-out slope < 20% for 100-200 m below landslide deposit area. At time of event, suspended sediment may reach fish habitat; potable water intake; public area, or other property owner |
| VERY LOW | Run-out slope < 20% for > 200 m below landslide. Landslide material is unlikely to reach stream or potable water intake at time of event. A landslide would not be a public safety concern; would not impact any infrastructure nor other property owner. |

## Post Development Activities Summary Table of Geohazards, Consequence and Risk on Site

### Risk

| Very Low | Low | GEOHAZARD | | | | |
|---|---|---|---|---|---|---|
| Moderate | High | VERY LOW | LOW | LOW - MODERATE | MODERATE | HIGH |
| GEOMORPHIC CONSEQUENCE | VERY LOW | | | | | |
| | LOW | *1* | *3* | 2 | | |
| | MODERATE | | | | | |
| | HIGH | | | | | *4* |

# Geohazard Assessment of Lands

*As pertaining to land parcel:*

PID 009-555-731

239 QUARRY DRIVE, SALT SPRING ISLAND

LOT 3, SECTIONS 6 AND 7, RANGE 1 WEST, NORTH SALT SPRING ISLAND, COWICHAN DISTRICT, VIP46155

# Report for Coastal Erosion Mitigation

Developed for: Trish Sanders, Bruce Sanders (Landowners)
239 Quarry Drive
Salt Spring Island, BC V8K 1J2


Developed by: Thomas R Elliot PhD P.Geo P.Ag
TRE Environmental Services
tom@elliot.org


TRE Environmental Services

# 1. Synopsis

The subject land parcel, with PID 009-555-731 and legal description of Lot 3, Sections 6 and 7, Range 1 west, North Salt Spring Island, Cowichan District, VIP46155 (Site), is situated on the lower southwest-facing flank of a slope which terminates to the Salt Spring Island ocean-shoreline in a coastal bluff. The Site is proposed to undergo coastal erosion mitigation development activities within the Shoreline Development Permit Area[1] (DPA 3) of the Islands Trust (IT), which prompted this geohazard assessment to identify mechanisms contributing to erosion of the coastal bluff that would create hazardous conditions for existing single-family dwelling (SFD) and the natural environment.

The Site consists of a moderate-steep benching bedrock slope with a veneer to mantle of stoney sandy loam to loamy sand. There is a veneer of colluvial boulders to stones accumulated below bedrock outcropping. The slope descends from a ~58m above sea level (asl) elevation regional northwest-southeast aligned bedrock ridge. The bedrock ridge is sandstone at elevation and transitions to shale and metamorphic siltstone deposits of the Nanaimo Sedimentary Group closer to sea level. At ~8m asl elevation, a shale coastal bluff rises above the natural boundary and is capped with a 2 – 3m thick mantle of gravelly sandy loam.

While there is no ephemeral or permanent surface watercourse observed at Site, the presence of near-surface groundwater is apparent where the thinning veneer of surficial sediment forces phreatic water to surface. These seepages in proximity to the existing SFD are managed by constructed catchbasin and ditching.

The erosion and sediment mass-wasting observed on Site primarily consists of two concurrent processes:

Wave action — a culmination of mechanical wave-action, daily sunlight-driven thermal oscillation, and saturating water-spray promotes decomposition and failure of fine-grained metamorphic bedrock situated in the lower 3 - 5m of coastal bluff. This results in toe erosion which, over time, destabilizes the portion of coastal bluff above. Destabilization of the bedrock is of particular significance due to the number of large trees growing on the coastal bluff.

Pore water — sufficient pore water pressure below the phreatic surface (i.e. perched water table) can acts as a destabilizing factor to overcome cohesion, friction angle and soil weight – entirely independent of toe erosion. While the majority of episodic pore water pressure erosion occurs during the rainy season, localized increases in pore water pressure can also lead to instability during otherwise drought conditions.

[1] IT Bylaw 488 - https://islandstrust.bc.ca/wp-content/uploads/2020/10/SS-BL-434_2020-10_OCP_Vol1-2.pdf

Through assessment of the Site subject to Shoreline DPA, Thomas R Elliot PhD P.Geo P.Ag has determined a Very Low risk of landslide geohazard impacting the SFD. However, there is a High risk of erosional geohazard impacting marine environment in an ongoing and progressive manner.

This determination is based on geophysical indicators on Site, regional frequency of historic landslide in the area, as well as assessment of Site surficial materials, hydrologic regime, topography and slope failure mechanics, as detailed through this report.

The proposed erosion mitigation development activities do not increase the hazard rating to the existing SFD or occupancy of Site.

# 2. Introduction

Development activity within the IT is being pursued on the subject land parcel with PID 009-555-731 (the 'Site', see Figure 1 – Appendix 1). The R (Rural) zoned land parcel is located on a southwest-facing flank of a slope which terminates to a coastal bluff ocean-shoreline. The Site is accessible via Quarry Road arriving from the west, where a private roadway has been established cross two other land parcels.

This report includes assessment of pre-existing and field-gathered data which informs a geohazard risk assessment and guides proposed erosion mitigation measures.

There exists DPA 3 requirements for non-exempt development activities within 10m landward and 300m seaward of the marine-shoreline natural boundary. Due to land parcel configuration there is currently 10m setback from the natural boundary and existing SFD, resulting in a requirement to obtain DP if proposed erosion mitigation activities are occurring in this setback. Therefore, proposed landward erosion mitigation activities will be considered in context of existing structures, near-surface water management and erosion processes observed at the coastal bluff.

This report is a cumulative evaluation of existing and field-based data toward determining risk to SFD and natural environment associated with geohazards present on Site, and impact of proposed erosion mitigation measures on identified geohazards.

## 2.1. Author Qualifications

Thomas R Elliot PhD is a Qualified Professional (QP) Geoscientist [# 43570] and Professional Agrologist [# 3045] registered within the Province of British Columbia and in good standing with both professional associations. The QP has 16 years of geohazard, soil science, near surface groundwater and aquifer hydrogeology practice. In the last 9 years, Thomas R Elliot has primarily worked on Vancouver Island and the Lower Mainland of British Columbia in the practice areas of [Geoscience]: Hydrogeology, Geohazard mitigation assessments, Soils/Groundwater management; and [Agrology] Soil science, Agriculture, and Contaminant detection, mitigation and remediation.

# 3. Scope, Context & Motivation

The proposed development activities are erosion mitigation measures for identified geohazards toward reducing risk to the existing SFD and natural environment on Site.

This report does not determine the specific erosion mitigation activities due to a requirement for comprehensive assessment of near shore environments prior to identification of suitable measures. A comprehensive assessment includes this geohazard report in addition to an evaluation of beach and wave characteristics that will collectively inform suitable erosion mitigation activities through the Marine Shoreline Design Guidelines[2] that have been broadly adopted by Province of BC and Federal Department of Fisheries and Oceans.

The motivation to produce this report is to provide IT record of existing geohazard conditions on Site; predicted impact of proposed development activities; and if the proposed development activities – in context of existing or novel geohazards – allows for safe Rural-residential use of the land, as intended.

# 4. Regulatory Context

This section is dedicated to review of applicable Regulations and Acts, as governing legislation for individual and group risk of harm/death related to land use, as well as general permitting and authorization requirements of intended land use and proposed erosion mitigation development activities.

Further, the Department of Fisheries and Oceans would also be requested to conduct review of proposed activities in conjunction with the local IT DPA 3 permitting requirements.

## 4.1. IT Shoreline DPA

The geohazard assessment for the proposed works is warranted under MA Section 879 (1)(a) and (b) which prompts IT to protect the natural environment and to protect development from hazardous conditions; as specifically governed by IT Bylaw 434, V 2, S E.3 Development Permit Area 3 – Shoreline (enacted through IT Bylaw 488).

IT Bylaw 488, DPA 3 – Shoreline requires development permit applications be submitted for activities occurring 10m landward in areas where the marine environment has been identified as being particularly sensitive to development impacts.

If the proposed erosion mitigation works are to include: breakwater, weir, groin or jetty; bulkheads; placement of fill; removal of trees with diameter greater than 20cm OR removal

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[2] Johannessen, J.[1], A. MacLennan[1], A. Blue[1], J. Waggoner[1], S. Williams[1], W. Gerstel[2], R. Barnard[3], R. Carman[3], and H. Shipman[4]. 2014. Marine Shoreline Design Guidelines. Washington Department of Fish and Wildlife, Olympia, Washington. **1** Coastal Geologic Services Inc.; **2** Qwg Applied Geology; **3** Washington State Department of Fish and Wildlife; **4** Washington State Department of Ecology

of vegetation that results in the exposure of a total area of bare soil more than 9m$^2$ in area – then there is requirement for IT approved Development Permitting.

### 4.2. DFO Authorization

Pursuant to the *Fisheries Act*, should a requested DFO project review determine that proposed development activities are likely to cause the death of fish and/or harmful alteration, disruption or destruction of fish habitat – then authorization would be required.

Since the development activity (i.e. erosion mitigation measures) are currently undefined, this report is unable to establish whether DFO authorization will be required.

## 5. Site Conditions: Existing and Field Data

### 5.1. Slopes, Soils & Surficial Materials

At shoreline, the Site has a ~6 – 8m coastal bluff consisting of siltstone and shale at base and capped with a 2 – 3m mantle of surficial material. Above which there are three distinct slope sections of the Site. The lowest is a gently sloping (~5 - 15%) bench above the coastal bluff where the SFD on Site exists, above which is a bedrock-controlled section of 35 – 40%. This second benching section does not exceed the angle of repose for local loamy soils, above which local sediment has increased likelihood of instability. The last slope section crests at a ridge-top and drops in elevation to Quarry Drive.

Soil associations on Site were previously mapped[3] in elevation-limited bands which correspond to the changes in slope, which is consequent to change in sea level during glaciation and inter-glacial periods. Starting at present day marine shoreline and ascending up slope, the soil associations present on Site include a typically >2m thick mantle of well drained loam Galiano soil, which are derived from colluvium[4], on the lowest slope.

At higher elevation, a band of thin <2m veneer of Saturna well draining sandy loam soils with prominent bedrock outcropping ascend to an elevation of ~58m asl. This portion of the land parcel is the source of boulders and other large loose rock masses which form sparse accumulations at lower elevations.

At upper elevations, Haslam well draining sandy loam soils are prevalent and functionally attenuate precipitation as it infiltrates to near surface bedrock.

The bedrock on Site was mapped as belonging to the Nanaimo Group[5], with sparse details on the surficial rock type in existing records. On Site, the mid and upper elevation presented

[3] Soil Information Finder Tool. https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=cc25e43525c5471ca7b13d639bbcd7aa

[4] Soils of Southern Vancouver Island. MOE Technical Report 17. https://sis.agr.gc.ca/cansis/publications/surveys/bc/bc44/index.html

[5] Vancouver Island Geology. https://www.gac-cs.ca/publications/FT_Geology_of_Vancouver_Island.pdf

sandstone at surface, while at lower elevations a change from shale transitioning to siltstone at coastal bluff occurred. The rock types identified on Site are characteristically found in the Nanaimo Group.

## 5.2. Surface & Groundwater

There are no identified or observed watercourse on Site. However, accumulation of rainwater and drainage from the access road does present areas of increased surface water discharge to forest floor. These areas are demarcated by accumulation of debris moved by the flow of surface water, increased annual vegetation growth, and an infiltrative surface – the extent of which is related to volume of accumulated rainwater. One such example of accumulation and discharge to forest floor is at the western property boundary, below the private roadway, where both vegetation type and upslope morphology suggest conveyance of surface water, accumulated by interceding road, to a localized area of infiltration.

Infiltration of each soil association on Site is unrestricted by soil texture, meaning that in areas where water does accumulate (and infiltrate) at surface there is a low-permeability limiting layer (i.e. bedrock) which prevents continuous downward migration. Instead, as infiltrating water reaches bedrock, lateral dispersion becomes dominant and results in a phreatic surface (i.e. perched groundwater table) establishing within the thin >2m mantle of surficial earth materials.

On higher elevation slopes, where bedrock outcrops to surface, the veneer of surface material thins and 'pinches out', resulting in emergence of phreatic water. These 'weeps' or 'springs' are not to be conflated with artesian conditions, as these waters do not enter a confined aquifer and pore water pressure does not exceed atmospheric pressure. While not individually significant to Site surface hydrology, the irregular bedrock surface accumulates these phreatic weeps to a non-contiguous subsurface perched water table within the mantle and veneer of well-draining surface material.

Due to this accumulation mechanism, there is an increased depth of perched water table at lower elevations of the Site. Therefore, it is warranted to conduct specific geohazard assessment of areas where surficial materials convey the accumulated depth of perched water table due to an increased pore water pressure forcing erosion at the coastal bluff.

Of the built environment on Site, there is a shallow intercept trench on the upslope side which re-directs near surface waters to either side of the SFD. This, in combination with surface road-runoff catchbasins and seepage management, has reduced the pore water pressure of surficial material downslope of the SFD – thus mitigating a significant factor contributing to erosion observed on the coastal bluff.

Irregularity of bedrock surface (e.g. small 'dips' which are infilled with sediment) at the coastal bluff sees variable depth of surficial material in limited areas – whereby, due to the subsurface accumulation mechanism noted earlier, pore water pressure is increased regardless of existing mitigation measures.

# 6. Geohazard Assessment

This landslide risk assessment was largely conducted according to the Engineers and Geoscientists of BC document *Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC*[6]. The landslide risk assessment methods that were utilized includes all aspects of landslide hazard analysis, such as regional frequency and historic evidence to inform current and future landslide hazards; as well as evaluation of hazard likelihood, and consequence of landslide impact, to formulate a relative risk matrix which is comparable with levels of landslide safety adopted by the approving jurisdiction.

The assessment was restricted to the Site, as indicated in Figure 1, and specifically includes bedrock of the coastal bluff.

## 6.1. Investigation of Historic Failures in Area & Seismic Compliance

A review of historic aerial imagery was conducted on the surrounding area to determine frequency and spatial distribution of natural and induced landslides.

There were no mid-slope landslide scarps, transport paths, or deposit zones identified in proximity to Site or on similar colluvium slopes within the region within historical aerial imagery.

Through this lack of landslide evidence, and the existing evidentiary record of significant seismic events over the past ~500 years, there is no suggestion that natural slopes on Site would fail under seismic disturbances.

For example, a seismic event occurred at 10:13 a.m. on Sunday June 23, 1946 which measured at 7.3 on the richter scale, and was considered a significant seismic event which exceeds the 2% in 50 years magnitude. Therefore, as the Site and surrounding slopes exhibits no evidence of displacement consequent to ground motion, this historic record demonstrates compliance with seismic design at existing or proposed slopes of lower angle.

The presence of loose boulders (up to 1.2m in diameter were observed) on mid-slopes above the non-habitated (i.e. driveway, not SFD) lower slope on Site does suggest an increased likelihood of injury or death of an individual (i.e. consequence) while posing no likelihood for harm to the natural environment. However, the likelihood co-location of an individual within the increased consequence pathway is very remote and therefore does not contribute to overall risk considered herein.

[6] EGBC Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC. https://www.egbc.ca/getmedia/5d8f3362-7ba7-4cf4-a5b6-e8252b2ed76c/APEGBC-Guidelines-for-Legislated-Landslide-Assessments.pdf.aspx

## 6.2. Field Investigation

On Sept 17th, 2023 Thomas R Elliot PhD P.Geo P.Ag attended to Site as a QP with declared competency in geohazards, hydrology and soil science to evaluate the geohazards, ground and surface waters present on Site.

Field data was acquired according to, and through the implements noted in Table 1 below.

***Table 1 – Summary of Field Work***

| | | | |
|---|---|---|---|
| **Project ID:** | 2023.900 | **Project Name:** | Baker Beach Erosion Mitigation |
| **Project Type:** | Erosion Mitigation (Geohazard) | **Lead Investigator:** | Thomas R Elliot PhD P.Geo P.Ag |
| | | | |
| **Client:** | Aurora Professional Group | **Client Contact:** | Brad Fossen P.Eng |
| **Site Boundary Type:** | Land Parcel | **Site Common Address:** | 239 Quarry Drive |
| **Site Legal Description:** | VIP46155, LOT 3 | **Site PID #** | 009-555-731 |
| **Site Land Use:** | Rural residential | **Site Condition:** | Secondary growth |
| | | | |
| **Development Activity:** | Erosion mitigation measures | **Project Stage:** | Assessment |
| **DPA:** | DPA3 – Shoreline | **Provincial/Federal:** | DFO review |
| **Equipment Used:** | - Clinometer<br>- Compass<br>- Engineer's tape<br>- GPS tracking | - Field soils kit<br>- Range finder<br>- Shovel and hand tools<br>- Soil probe<br>- Camera | |
| **Summary of Site Activities:** | • Site and Soils Assessments<br>• Evaluate Terrain Stability & Geohazard<br>• Document visible erosion mechanisms, ground and surface water | | |

## 6.3. Geohazard Units

Based on self-similar geophysical and hydrologic characteristics of the Site, a number of Geohazard Units (GU) were defined by the attending QP. Each GU has been assigned a respective Geohazard, or relative likelihood of a landslide event occurring, based on the documented geophysical and hydrologic characteristics.

The incremental change in Geohazard within a GU consequent to the proposed Development Activity is evaluated by the QP in order to arrive at impact of said Development Activity. The subsequent QP interpretation and recommendations are intended to fulfil requirements of the IT Shoreline DPA.

## 6.4. Wave Action and Erosion Hazard

Along the coastal bluff in proximity to Site there were numerous small-scale mass-wasting scarps consequent to erosion. Of those observed on Site, those occurring at base of the coastal bluff also had ongoing erosion of the sediment cap at top of the coastal bluff – suggesting a classic toe erosion mechanism. The bedrock toe erosion is driven by a combination of mechanical factors (e.g. wave-impact, thermal expansion, wedging/sediment jacking of fractures, etc.) and chemical factors (e.g. dissolution of binding carbonates, salt/crystal growth, etc.). The most prevalent of which appears to be wave-impact, which – due to orientation of metamorphic rock laminae and wave-direction – peels the friable bedrock during storm events.

Wave action and toe erosion are primary geohazard factors when evaluating methods of managing ‘hazard trees’ along the coastal bluff. A ‘hazard tree’ failure has considerably more impact to the receiving environment consequent to an increased volume of surficial material that is mobilized during failure. Additionally, due to the highly friable nature of the metamorphic bedrock at base of the coastal bluff, it is anticipated that continued wave action driven erosion will steadily increase geohazard. In order to mitigate an increasing likelihood of geohazard event, there will be recommendations to mitigate this erosion mechanism.

Otherwise, erosion occurring at mid or upper portion of the coastal bluff was based in surficial material – the mechanism of which is explored in the Groundwater and Erosion Hazard section of this report.

## 6.5. Groundwater and Erosion Hazard

There exists a transient erosion hazard consequent to high pore water pressure conditions within the veneer of surficial Galiano soils at base of the slope on Site, as a component of the failing coastal bluff.

Under adverse climatic conditions, this hazard would result in a limited mass wasting failure which would mobilize and entrain the full depth of surficial material. With standard climatic conditions, this mechanism is not as likely to result in such mass failure – instead, punctuated failure events will see progressive steepening and erosion at base of the surficial material cap atop the coastal bluff. This steepening will progress until a larger landslide failure event re-establishes at angle of repose – migrating the erosion front landward, toward the SFD.

Therefore, since the erosion of surficial material – over the long term – could impact the SFD, there are recommended mitigation measures which can be found is Section 7 of this report.

## 6.6. Hazard Rating

There was no pre-existing terrain hazard rating established through QP assessment and reporting, to the awareness of the author at time of writing.

The Site natural slopes were less than the angle of repose for moist gravelly sandy loam to loamy sand colluvium earth materials (35 - 45% or 19° - 24°)[7] above which slope-failure becomes more probable.

The landslide hazard rating for the entire Site was lower due to strong bedrock control at upper elevations, with shallow depth to bedrock for the remainder of Site, and therefore limited surficial material which would mobilize.

However, the surface sediments capping the coastal bluff have an increased erosional hazard due to presence of a perched water table in the lower slopes.

Consequent to these observations and slope gradients, GU on Site were assigned a VERY LOW to LOW hazard ratings outside of the coastal bluff, which classified as HIGH.

As per Appendix 2 – Geohazards and Risk, the GU defined on Site are summarized in Table 2, below.

Map imagery of GU delineation is found in Appendix 2 and is a recommended reading accompaniment to this section.

[7] H. Al-Hashemi, O. Al-Amoudi. A review on the angle of repose of granular materials. Powder Technology Volume 330, 1 May 2018, Pages 397-417. https://doi.org/10.1016/j.powtec.2018.02.003

***Table 2 – GU Hazard Rating and Risk***

| *Terrain Unit* | **Hazard Rating and Risk** | | | |
|---|---|---|---|---|
| | *Slope Characteristics* | *Hazard Rating* | *Consequence* | *Incremental Risk Rating* |
| 1 | Cv \| Br benching ± 25 - 40% | VERY LOW | LOW | Very Low |
| 2 | Cv / Br planar ±35 – 40% | LOW– MODERATE | LOW | Very Low |
| 3 | Cm planar ±5 – 15% | VERY LOW | LOW | Very Low |
| 4 | Cv / Br planar ±150 – 180% | HIGH | HIGH | High |

Geohazard Shorthand Notation

**Br** – Bedrock
**C** – Colluvium
**A** – Aeolian
**L** – Lacustrine
**GF** – Glaciofluvial
**GT** – Glacial till
**M** – Marine

**v** – veneer (.1 – 2m)
**m** – mantle (2 – 5m)
**b** – blanket (>5m)
/ - overlying
| - equal surface exposure
**benching** – slope interrupted by bedrock
**planar** – linear slope

## 6.7. Consequence of Geohazard Event

The Consequence of a geohazard event was evaluated by the QP based on downslope receptors, predicted size and volume of geohazard event, and a simplistic Farböschung assessment – as detailed in Appendix 2 – Geohazards and Risk.

The most active failure mechanism on Site is punctuated landslide erosion of surficial materials at the coastal bluff (GU 4) which can be motivated by multiple erosion mechanism. The mobilized material would deposit directly to the marine environment, resulting in HIGH consequence.

Outside of which, the second likely failure mechanism on Site would be a mid-slope (GU 2) failure within a colluvium filled relic bedrock draw where a perched water table decreases shear resistance. However, due to the veneer of surficial material in the initiation area, any landslide would impact a limited area due to lack of transportable surficial materials from the initiating area or on low gradient receiving slope (GU 3). The low gradient receiving slope has sufficient width to retain mobilized material, resulting in a LOW consequence.

Summarily, the most likely geohazard results in a HIGH consequence while the remainder of Site has a LOW consequence.

### 6.8. Incremental Risk Imposed by Development Activity

The purpose of proposed erosion mitigation development activities is to reduce the geohazard risk of GU 4, which currently has a High incremental Risk. This report has identified the active failure mechanisms resulting in erosion of the coastal bluff (GU 4), from which a variety of mitigation measures can be evaluated.

### 6.9. Suitability of Lands for Use Intended (SFD)

There are no up-slope hazards likely to impact the SFD location within GU 3.

While GU 4 has a High risk rating, the progressive-over-time nature of failure mechanisms for this area would provide opportunity to conduct more specific geotechnical review, and/or implement mitigation or emergency measures prior to impacting the SFD and ~3m of surrounding liveable space.

With no off-Site hazards and a LOW likelihood of failure above an existing SFD – the building location is **SAFE FOR THE USE INTENDED** (Residential Single Family Dwelling).

## 7. Geohazard Mitigation Recommendations

Due to the HIGH incremental risk of geohazards for GU 4, there are mitigation recommendations intended to reduce the risk to LOW.

### 7.1. Erosion and Sediment Control

All proposed activities will require Erosion and Sediment Control planning which meets IT regulatory requirements. Any such plan should be developed toward acquiring a Development Permit from the IT for the proposed activities and shall be submitted alongside any additional required paperwork.

There are two identified erosion mechanisms:

**Pore water** sufficient pore water pressure below the phreatic surface can acts as a destabilizing factor to overcome cohesion, friction angle and soil weight – entirely independent of toe erosion. While the majority of episodic pore water pressure erosion occurs during the rainy season, localized increases in pore water pressure can also lead to instability during otherwise drought conditions.

Mitigation options include, but are not limited to:

- Annual monitoring of erosional regression of surficial materials at the coastal bluff, and particularly in the soils and bedrock which is currently supporting overhanging trees;
- Groundwater intercept and redirection to non-erosive receiving environment;
- Bioengineering and selective planting of native species toward increasing shear strength of surficial materials;
- Re-contour of the surficial materials to allow for emergence of groundwater without erosion;
- Selective removal of shoreline trees deemed hazardous due to toe erosion.

**Wave action** a culmination of mechanical wave-action, daily sunlight-driven thermal oscillation, and saturating water-spray promotes decomposition and failure of fine-grained metamorphic bedrock situated in the lower 6 - 7m of coastal bluff. This results in toe erosion which, over time, destabilizes the portion of coastal bluff above.

Mitigation options include, but are not limited to:

- Monitoring rate of erosion so as to establish a predictive timeline of coastal bluff regression;
- Bioengineering and selective planting of native species toward dissipated wave-impact on coastal bluff face;
- Wave deflection within intertidal area;
- Beach nourishment to dissipate wave energy;

The suitability, efficacy and ease of implementation and maintenance of these recommended mitigation options should be carefully considered in context of Marine Shoreline Design Guidelines[2] which will require an integrated assessment of geohazards (this report), wave and beach dynamics, and ecosystem characteristics.

# 8. Safety and Suitability

This report has been prepared in accordance with standard geotechnical hazard assessment practices, and at the expense of Trish Sanders and Bruce Sanders. Thomas R Elliot PhD P.Geo P.Ag has not acted for or as agent of the Islands Trust in the preparation of this report.

Thomas R Elliot PhD P.Geo P.Ag certifies that the land is safe for the use intended (Residential Single Family Dwelling and Driveway) if the land is used in accordance with the conditions specified in this report.

Thomas R Elliot PhD P.Geo P.Ag acknowledges that this report may be used by the Islands Trust as a precondition to the issuance of a permit and that this report and any conditions contained in this report may be included in a restrictive covenant and filed against the title to this subject property.

## 9. Summary

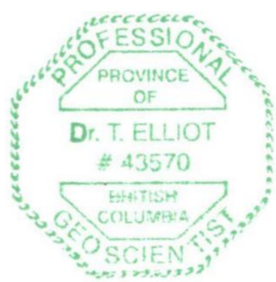
The land parcel with PID 009-555-731 situated on the southwest flank of a bedrock ridge forming a benching slope down to a coastal bluff is proposed to undergo permissible Development Activities within the Shoreline DPA of the IT.

Through assessment of these DPA requirements, Thomas R Elliot PhD P.Geo P.Ag as a QP capable of conducting the works, has determined a **High Risk of erosion geohazard** impacting the local environment. This determination is based on geophysical indicators on Site and regional frequency of historic landslide in the area.

The proposed development activities do not increase the Risk, however specific design of erosion mitigation measures will have to be completed prior to establishing a post-development Risk. There are sufficient pre-existing long term erosional processes on Site to warrant mitigation measures.

| | | |
|---|---|---|
| Qualified Professional of Record | THOMAS R. ELLIOT PhD P.Geo, P.Ag<br>Name | Sign |

Thomas R Elliot PhD P.Geo. P.Ag.




Digital reproduction, original available upon request.

Date: November 6, 2023

# 10.Closure and Limitations

The QP signatory to this assessment and report assures accuracy of existing and field observation, and evaluation of technical geohazard according to best practices of the Engineers and Geoscientists of BC. The content of this report are applicable to the subject land parcel, and specifically the Site as defined in this report. Any extension of the evaluation to areas outside of the defined area assessed are not valid.

The report has been conducted according to guidelines and reporting standards of similarly qualified professionals, given similar time and budget. At time of writing, the report meets due diligence and investigatory reporting requirements to provide QP recommendations with declared competency in the subject areas. Therefore, the author of this report does not maintain liability insurance for actions taken based on the reporting, and only accepts error and omission liability up to the value of this report. The receipt, utilization and any planning, further studies or development actions undertaken by the recipient of this report are based on their acceptance of their own liability therein.

# Appendix I

## Maps and Figures

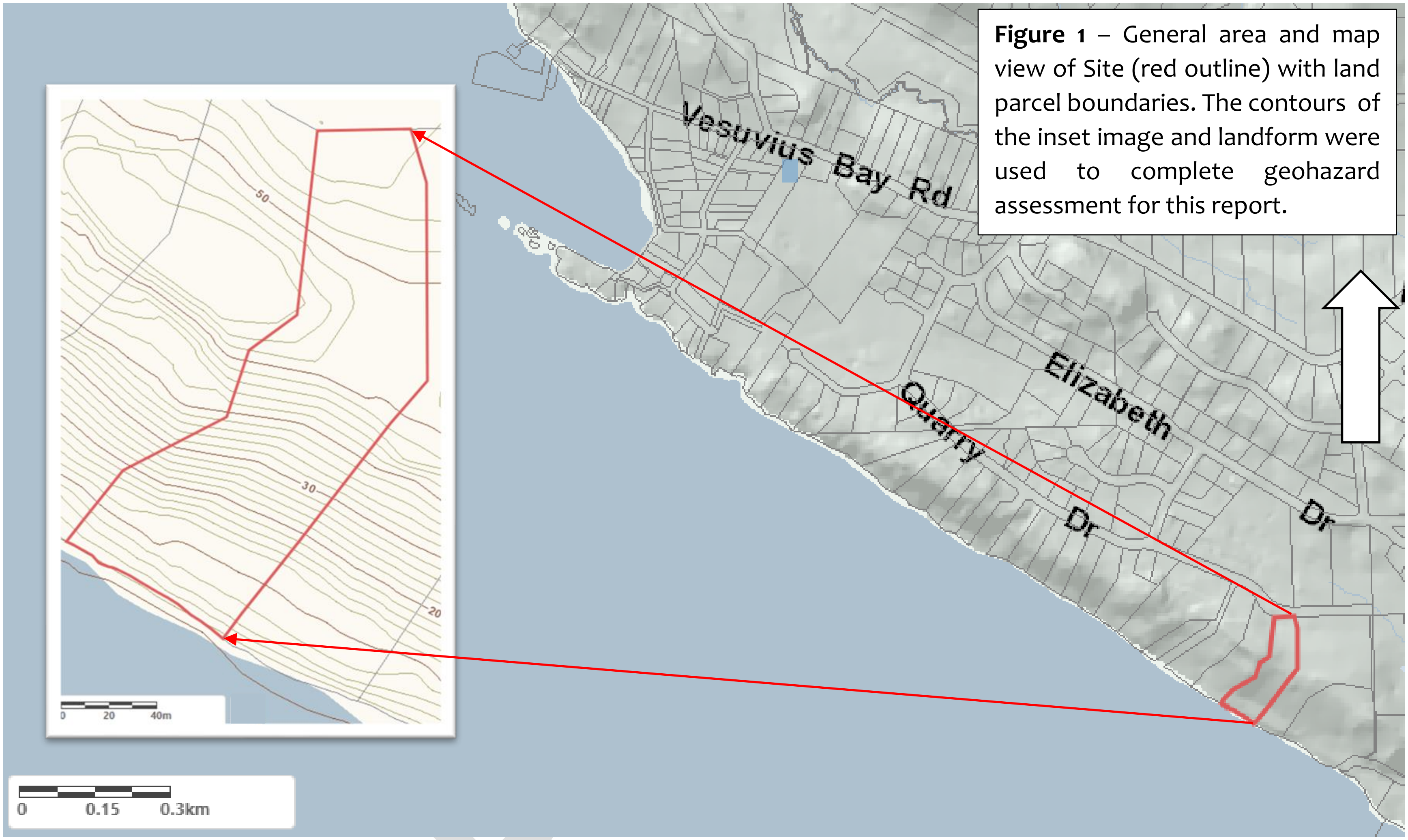



**Figure 1** – General area and map view of Site (red outline) with land parcel boundaries. The contours of the inset image and landform were used to complete geohazard assessment for this report.

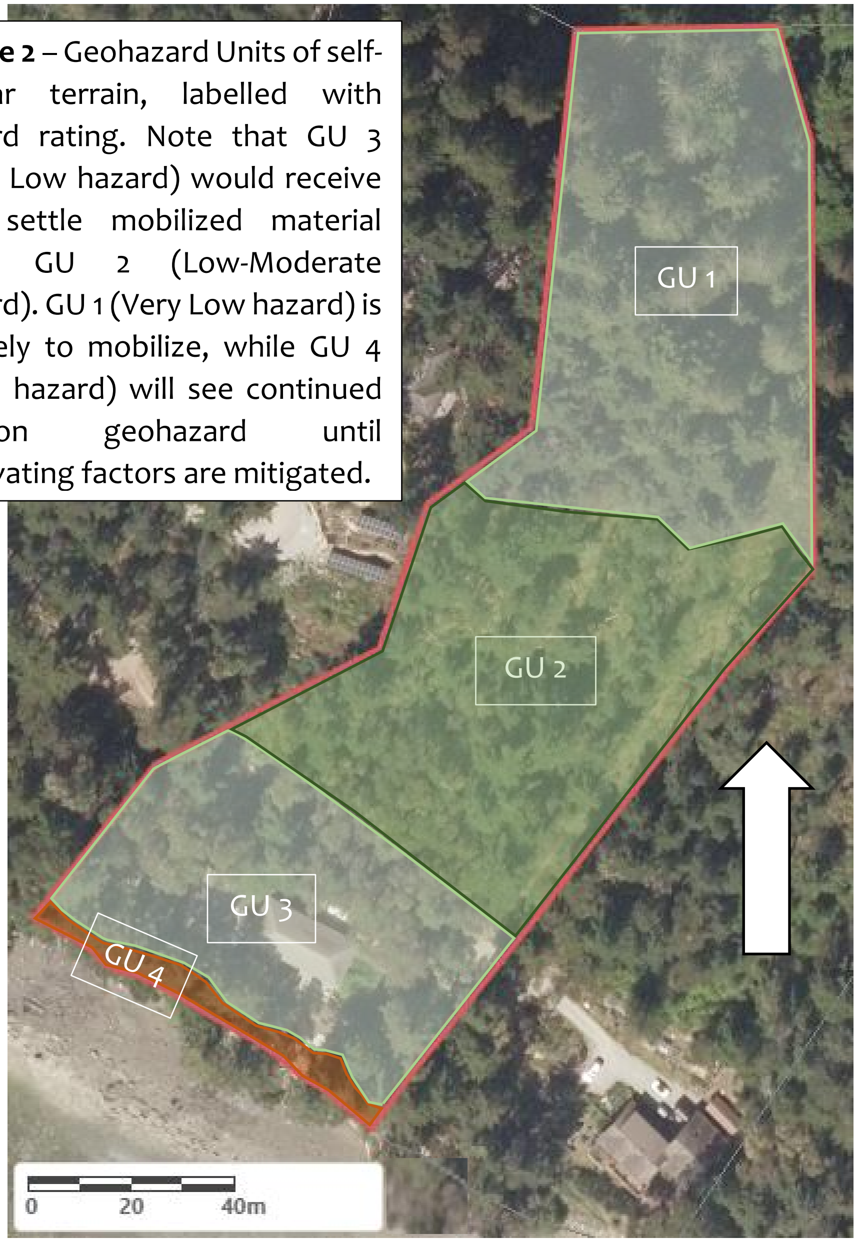



**Figure 2** – Geohazard Units of self-similar terrain, labelled with hazard rating. Note that GU 3 (Very Low hazard) would receive and settle mobilized material from GU 2 (Low-Moderate hazard). GU 1 (Very Low hazard) is unlikely to mobilize, while GU 4 (High hazard) will see continued erosion geohazard until motivating factors are mitigated.

# Appendix II

## Geohazards and Risk

## Geohazards

This assessment is partially based on local historic rates of landslide failure. The rating hazard of failures occurring in a given area under the classification system shown in Table II_a, below. By determining the likelihood of historic failures based on spatial density, the number of failures per unit area can be predicted. The likelihood of historic failures is determined through review of historic aerial imagery and general area observations while on the way to or from Site.

By establishing failure spatial density in the local area, in conjunction with Table II, the hazard rating can be estimated for areas undergoing development activities that impact terrain stability.

The hazard ratings were defined based on pre-existing practice by geoscientists and engineers for the natural resources sector, and adapted to best suit development activities governed by responsible municipal partners toward meeting those partner-organization risk tolerance policies.

Please note that, differing from resource sector terrain stability assessments, this evaluation of hazard includes failures smaller than 0.05 ha area (initiation, transport and deposit area). This is consequent to resource sector activities, and typically remote locations, being more tolerant of small-scale geohazard events. For this location, due to proximity to populated areas, and responsibility to meet municipal risk tolerance policies, the total area of a failure may be less than 0.05 ha in order to contribute to the hazard rating.

**Table II_a: Definitions of hazard categories**

| **Hazard Category** | **# of failures per terrain unit size** |
|---|---|
| VERY HIGH | >1 failure per 2 ha |
| HIGH | 1 failure per 2 to 10 ha |
| MODERATE | 1 failure per 10 to 50 ha |
| LOW-MODERATE | 1 failure per 50 to 250 ha |
| LOW | 1 failure per 250 to 1250 ha |
| VERY LOW | <1 failure per 1250 ha |

Once the natural hazard of landslide for the area has been established, the probability of at least one failure occurring in a terrain unit can be determined from Figure II_A.

Figure II_1 is based on the assumption that the probability of a specified number of failures occurring within a polygon is related to the size of the polygon by a cumulative normal distribution.

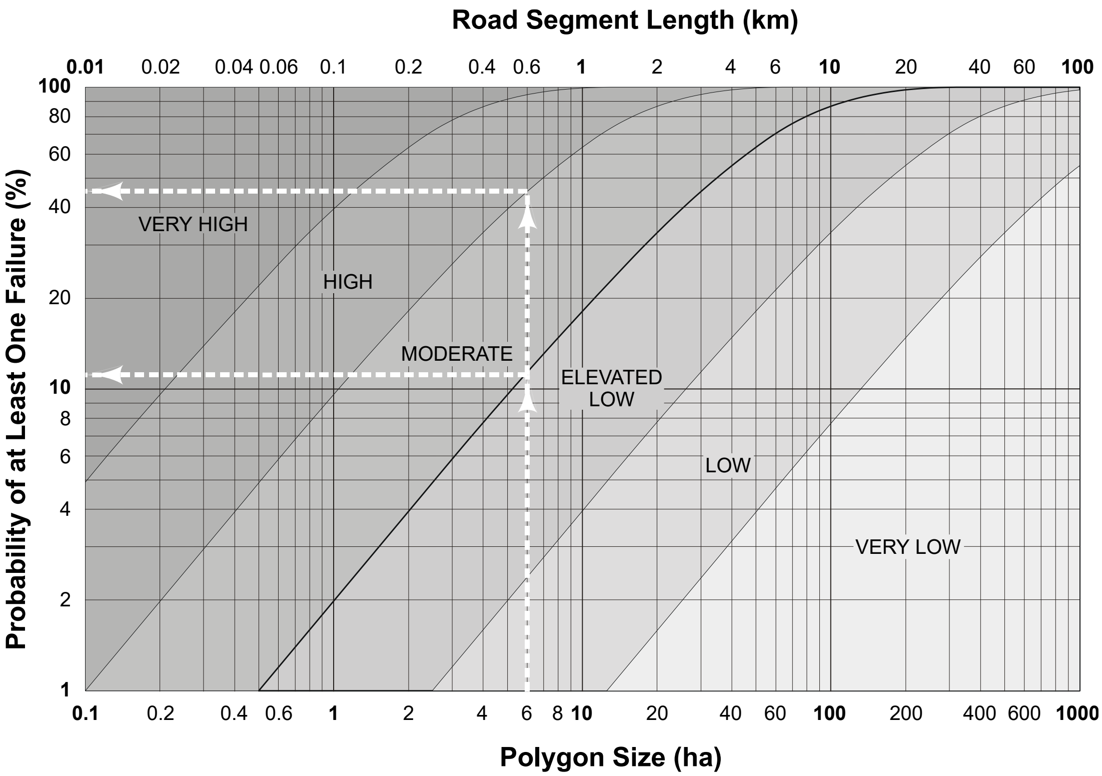



Figure II_1 – Probability of at least one failure based on a geohazard unit (GU) assessment area size or road length. This figure has been adopted from BC Forestry practices and is based on a single forestry harvest cycle, typically lasting 60 years within Coastal BC.

*Figure II_1 has an example sketched with dashed white lines. The example indicates probability of failure for a **6 ha** terrain unit area with a **moderate** hazard rating. The probability of at least one failure occurring within the assessed terrain unit area over the period of one forestry harvest cycle is between ~12 – 45%.*

## Consequence

### Simplistic Farböschung Evaluation

Whether or not a Site will be impacted by a geohazard is a component of determining consequence to potential landslide failures and/or debris flows. A simplistic assessment of transport and deposition zone locations can be accomplished through a 'Farböschung' evaluation. This is best exemplified through Figure II_B, which demonstrates how a sliding

mass (block on right hand side) has potential to transport some distance from point of initiation based on a simplistic assignment of Farböschung angle.

For this assessment, a Farböschung angle of 45% was used based on heuristic practice for these coastal environments and gravelly loam surficial material. By standing on Site at highest point of initiation, the QP was able to establish the approximate run-out distance to edge of the deposit zone.

A more Site specific example is provided in Figure II_C, which shows a benching bedrock terrain where a thin veneer of surface material is mobilized, and has limited transport and deposit distances based on the Farböschung angle.

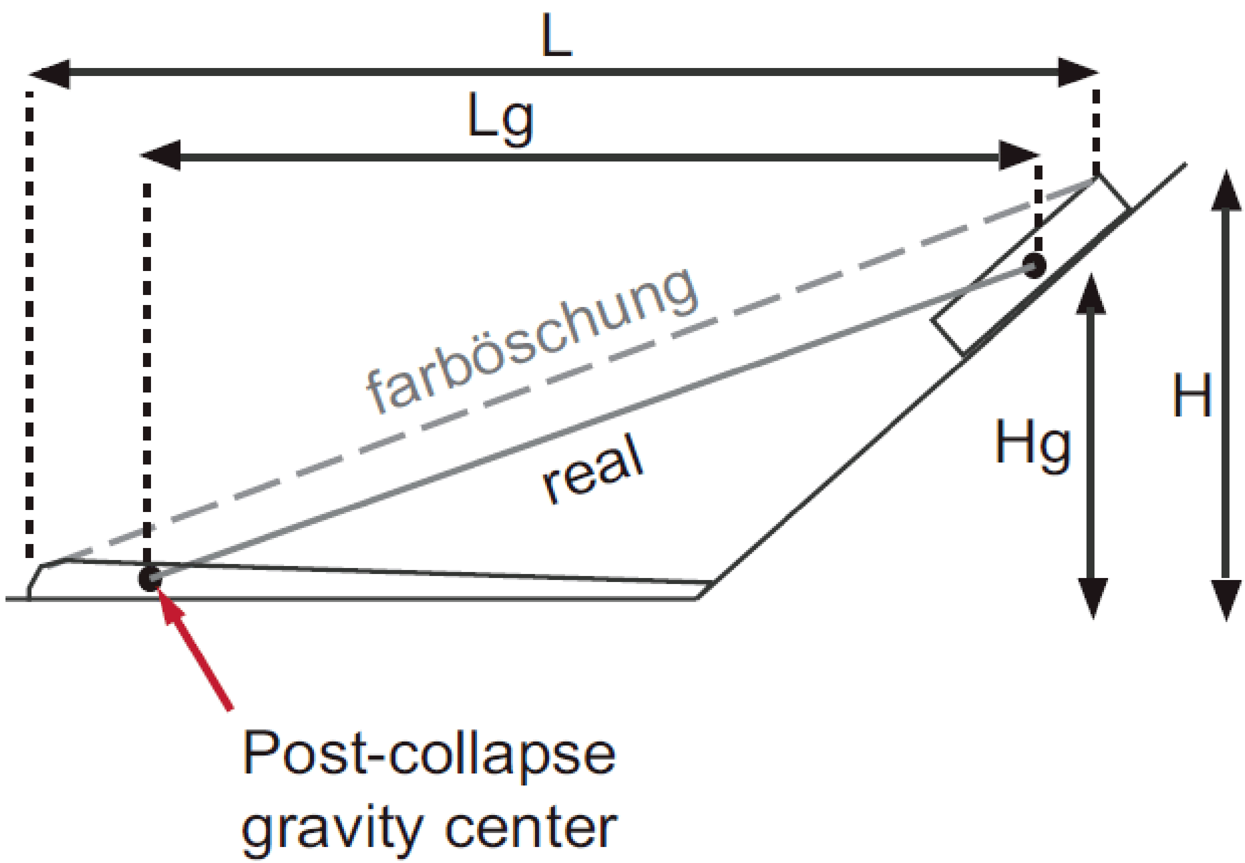



**Figure II_B** – Farböschung angle functionality for sliding masses on a slope. The specific mathematics of which are not supplied here for brevity.

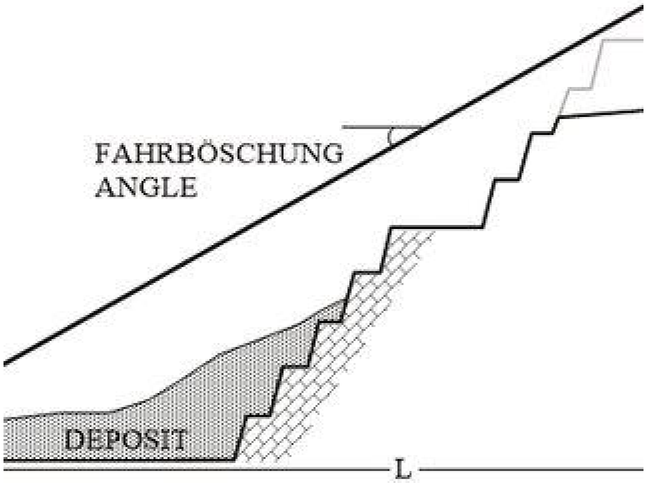



**Figure II_C** – An example of landslide runout and deposit area of potential geohazards on Site based on simplistic Farböschung assessment.

**Table II_b: Consequence**

| Consequence | Criteria |
|---|---|
| HIGH | Landslide material would directly enter fish habitat (stream, lake, or marine waters); water intake for domestic consumption; jeopardize lives of the public; impact major public infrastructure; or other property owner.<br><br>Landslide would enter non-fish stream within 500 m of fish habitat. |
| MODERATE | Landslide material enters non-fish stream > 500 m and < 3000 m from fish habitat, OR there is a slope < 20% for < 100 m below landslide to fish habitat; potable water intake; a public area; or other property owner. |
| LOW | Run-out slope < 20% for 100-200 m below landslide deposit area. At time of event, suspended sediment may reach fish habitat; potable water intake; public area, or other property owner |
| VERY LOW | Run-out slope < 20% for > 200 m below landslide. Landslide material is unlikely to reach stream or potable water intake at time of event. A landslide would not be a public safety concern; would not impact any infrastructure nor other property owner. |

## Post Development Activities Summary Table of Geohazards, Consequence and Risk on Site

### Risk

| Very Low | Low | GEOHAZARD | | | | |
|---|---|---|---|---|---|---|
| Moderate | High | VERY LOW | LOW | LOW - MODERATE | MODERATE | HIGH |
| GEOMORPHIC CONSEQUENCE | VERY LOW | | | | | |
| | LOW | 1, 3 | | 2 | | |
| | MODERATE | | | | | |
| | HIGH | | | | | 4 |

# Geohazard Assessment of Lands

*As pertaining to land parcel:*

PID 009-555-781

434 BAKER ROAD, SALT SPRING ISLAND

LOT 5, SECTIONS 6, RANGE 1 WEST, NORTH SALT SPRING ISLAND, COWICHAN DISTRICT, VIP46155

# Report for Coastal Erosion Mitigation

Developed for: Ethan Wilding (Landowner)
434 Baker Road
Salt Spring Island, BC V8K 2N6


Developed by: Thomas R Elliot PhD P.Geo P.Ag
TRE Environmental Services
tom@elliot.org


TRE Environmental Services

# 1. Synopsis

The subject land parcel, with PID 009-555-781 and legal description of Lot 5, Sections 6, Range 1 West, North Salt Spring Island, Cowichan District, VIP46155 (Site), is situated on the lower southwest-facing flank of a slope which terminates to the Salt Spring Island ocean-shoreline in a coastal bluff. The Site is proposed to undergo coastal erosion mitigation development activities within the Shoreline Development Permit Area[1] (DPA 3) of the Islands Trust (IT), which prompted this geohazard assessment to identify mechanisms contributing to erosion of the coastal bluff that would create hazardous conditions for existing single-family dwelling (SFD) and the natural environment.

The Site consists of a moderate-steep benching bedrock slope with a veneer to mantle of stoney sandy loam to loamy sand. There is a veneer of colluvial boulders to stones accumulated below bedrock outcropping. The slope descends from a ~58m above sea level (asl) elevation regional northwest-southeast aligned bedrock ridge. The bedrock ridge is sandstone at elevation and transitions to shale and metamorphic deposits of the Nanaimo Sedimentary Group closer to sea level. Up to ~7m asl elevation, a metamorphic-rock coastal bluff rises above the natural boundary and is capped with a 1 – 2m thick veneer of gravelly sandy loam.

While there is no ephemeral or permanent surface watercourse observed at Site, the presence of near-surface groundwater is apparent where bedrock outcrops force phreatic water to surface.

The erosion and sediment mass-wasting observed on Site primarily consists of two concurrent processes:

| | |
|---|---|
| Wave action | a culmination of mechanical wave-action, daily sunlight-driven thermal oscillation, and saturating water-spray promotes decomposition and failure of fine-grained metamorphic bedrock situated in the lower 6 - 7m of coastal bluff. This results in toe erosion which, over time, destabilizes the portion of coastal bluff above. |
| Pore water | sufficient pore water pressure below the phreatic surface can acts as a destabilizing factor to overcome cohesion, friction angle and soil weight – entirely independent of toe erosion. While the majority of episodic pore water pressure erosion occurs during the rainy season, localized increases in pore water pressure can also lead to instability during otherwise drought conditions. |

[1] IT Bylaw 488 - https://islandstrust.bc.ca/wp-content/uploads/2020/10/SS-BL-434_2020-10_OCP_Vol1-2.pdf

Through assessment of the Site subject to Shoreline DPA, Thomas R Elliot PhD P.Geo P.Ag has determined a Low risk of landslide geohazard impacting the SFD. However, there is a High risk of erosional geohazard impacting marine environment in an ongoing and progressive manner.

This determination is based on geophysical indicators on Site, regional frequency of historic landslide in the area, as well as assessment of Site surficial materials, hydrologic regime, topography and slope failure mechanics, as detailed through this report.

The proposed erosion mitigation development activities do not increase the hazard rating to the existing SFD or occupancy of Site.

# 2. Introduction

Development activity within the IT is being pursued on the subject land parcel with PID 009-555-781 (the 'Site', see Figure 1 – Appendix 1). The R (Rural) zoned land parcel is located on a southwest-facing flank of a slope which terminates to a coastal bluff ocean-shoreline. The Site is accessible via Quarry Road arriving from the north, at top of the slope, where a private roadway has been established.

This report includes assessment of pre-existing and field-gathered data which informs a geohazard risk assessment and guides proposed erosion mitigation measures.

There exists DPA 3 requirements for non-exempt development activities within 10m landward and 300m seaward of the marine-shoreline natural boundary. Due to land parcel configuration there is currently 10m setback from the natural boundary and existing SFD. Therefore, proposed landward erosion mitigation activities will be considered in context of existing structures, near-surface water management and erosion processes observed at the coastal bluff.

Therefore, this report is a cumulative evaluation of existing and field-based data toward determining risk to SFD and natural environment associated with geohazards present on Site, and impact of proposed erosion mitigation measures on identified geohazards.

## 2.1. Author Qualifications

Thomas R Elliot PhD is a Qualified Professional (QP) Geoscientist [# 43570] and Professional Agrologist [# 3045] registered within the Province of British Columbia and in good standing with both professional associations. The QP has 16 years of geohazard, soil science, near surface groundwater and aquifer hydrogeology practice. In the last 9 years, Thomas R Elliot has primarily worked on Vancouver Island and the Lower Mainland of British Columbia in the practice areas of [Geoscience]: Hydrogeology, Geohazard mitigation assessments, Soils/Groundwater management; and [Agrology] Soil science, Agriculture, and Contaminant detection, mitigation and remediation.

# 3. Scope, Context & Motivation

The proposed development activities are erosion mitigation measures for identified geohazards toward reducing risk to the existing SFD and natural environment on Site.

This report does not determine the specific erosion mitigation activities due to a requirement for comprehensive assessment of near shore environments prior to identification of suitable measures. A comprehensive assessment includes this geohazard report in addition to an evaluation of beach and wave characteristics that will collectively inform suitable erosion mitigation activities through the Marine Shoreline Design Guidelines[2] that have been broadly adopted by Province of BC and Federal Department of Fisheries and Oceans.

There are DPA requirements which apply to the Site, including the Shoreline DPA 3 which necessitates any non-exempt development activities within 10m landward and 300m seaward of the natural boundary be subject to development permitting.

The motivation to produce this report is to provide IT record of existing hazard conditions on Site; predicted impact of proposed development activities; and if the proposed development activities – in context of existing or novel hazards – allows for safe Rural-residential use of the land, as intended.

# 4. Regulatory Context

This section is dedicated to review of applicable Regulations and Acts, as governing legislation for individual and group risk of harm/death related to land use, as well as general permitting and authorization requirements of intended land use and proposed erosion mitigation development activities.

Further, the Department of Fisheries and Oceans would also be requested to conduct review of proposed activities in conjunction with the local IT DPA 3 permitting requirements.

## 4.1. IT Shoreline DPA

The geohazard assessment for the proposed works is warranted under MA Section 879 (1)(a) and (b) which prompts IT to protect the natural environment and to protect development from hazardous conditions; as specifically governed by IT Bylaw 434, V 2, S E.3 Development Permit Area 3 – Shoreline (enacted through IT Bylaw 488).

IT Bylaw 488, DPA 3 – Shoreline requires development permit applications be submitted for activities occurring 10m landward in areas where the marine environment has been identified as being particularly sensitive to development impacts.

---

[2] Johannessen, J.[1], A. MacLennan[1], A. Blue[1], J. Waggoner[1], S. Williams[1], W. Gerstel[2], R. Barnard[3], R. Carman[3], and H. Shipman[4]. 2014. Marine Shoreline Design Guidelines. Washington Department of Fish and Wildlife, Olympia, Washington. **1** Coastal Geologic Services Inc.; **2** Qwg Applied Geology; **3** Washington State Department of Fish and Wildlife; **4** Washington State Department of Ecology

If the proposed erosion mitigation works are to include: breakwater, weir, groin or jetty; bulkheads; placement of fill; removal of trees with diameter greater than 20cm OR removal of vegetation that results in the exposure of a total area of bare soil more than $9m^2$ in area – then there is requirement for IT approved Development Permitting.

### 4.2. DFO Authorization

Pursuant to the *Fisheries Act*, should a requested DFO project review determine that proposed development activities are likely to cause the death of fish and/or harmful alteration, disruption or destruction of fish habitat – then authorization would be required.

Since the development activity (i.e. erosion mitigation measures) are currently undefined, this report is unable to establish whether DFO authorization will be required.

## 5. Site Conditions: Existing and Field Data

### 5.1. Slopes, Soils & Surficial Materials

At shoreline, the Site has a ~7 – 9m coastal bluff consisting of siltstone and shale at base and capped with 1 – 2m of surficial material. Above which there are two distinct slope sections of the Site. The lowest is a gently sloping (~5 - 15%) bench above the coastal bluff where the SFD on Site exists, above which is a bedrock-controlled section of 30 – 35%. This second benching section does not exceed the angle of repose for local loamy soils, above which local sediment has increased likelihood of instability.

Soil associations on Site were previously mapped[3] in elevation-limited bands which correspond to the changes in slope, which is consequent to change in sea level during glaciation and inter-glacial periods. Starting at present day marine shoreline and ascending up slope, the soil associations present on Site include a typically <2m thick veneer of well drained loam Galiano soil, which are derived from colluvium[4], on the lowest slope.

At higher elevation, a band of thin <2m veneer of Saturna well draining sandy loam soils with prominent bedrock outcropping ascend to an elevation of ~58m asl. This portion of the land parcel is the source of boulders and other large loose rock masses which form sparse accumulations at lower elevations.

At upper elevations, a small amount of Haslam well draining sandy loam soils are present and functionally attenuate precipitation as it infiltrates to near surface bedrock at top of slope.

[3] Soil Information Finder Tool.
https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=cc25e43525c5471ca7b13d639bbcd7aa
[4] Soils of Southern Vancouver Island. MOE Technical Report 17.
https://sis.agr.gc.ca/cansis/publications/surveys/bc/bc44/index.html

The bedrock on Site was mapped as belonging to the Nanaimo Group[5], with sparse details on the surficial rock type in existing records. On Site, the mid and upper elevation presented sandstone at surface, while at lower elevations a change from shale transitioning to siltstone at coastal bluff occurred. The rock types identified on Site are characteristically found in the Nanaimo Group.

### 5.2. Surface & Groundwater

There are no identified or observed watercourse on Site. However, accumulation of rainwater and drainage from the access road does present areas of increased surface water discharge to forest floor. These areas are demarcated by accumulation of debris moved by the flow of surface water, increased annual vegetation growth, and an infiltrative surface – the extent of which is related to volume of accumulated rainwater.

Infiltration of each soil association on Site is unrestricted by soil texture, meaning that in areas where water does accumulate at surface there is a low-permeability limiting layer (i.e. bedrock) which prevents further downward migration. Instead, as infiltrating water reaches bedrock, lateral dispersion becomes dominant and results in a phreatic surface (i.e. perched groundwater table) establishing within the thin <2m veneer of surficial earth materials.

Where bedrock outcrops to surface, the veneer of surface material thins and 'pinches out', resulting in emergence of phreatic water. These 'weeps' or 'springs' are not to be conflated with artesian conditions, as these waters do not enter a confined aquifer and pore water pressure does not exceed atmospheric pressure. While not individually significant to Site surface hydrology, the irregular bedrock surface accumulates these phreatic weeps to a subsurface non-contiguous perched water table within the veneer of well-draining surface material.

Due to this accumulation mechanism, there is an increased depth of perched water table at lower elevations of the Site. Therefore, it is warranted to conduct specific geohazard assessment of areas where surficial materials convey the accumulated depth of perched water table due to an increased pore water pressure forcing erosion at the coastal bluff.

## 6. Geohazard Assessment

This landslide risk assessment was largely conducted according to the Engineers and Geoscientists of BC document *Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC*[6]. The landslide risk assessment methods that were utilized includes all aspects of landslide hazard analysis, such as regional frequency and historic evidence to inform current and future landslide hazards; as well as evaluation of hazard

[5] Vancouver Island Geology. https://www.gac-cs.ca/publications/FT_Geology_of_Vancouver_Island.pdf

[6] EGBC Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC. https://www.egbc.ca/getmedia/5d8f3362-7ba7-4cf4-a5b6-e8252b2ed76c/APEGBC-Guidelines-for-Legislated-Landslide-Assessments.pdf.aspx

likelihood, and consequence of landslide impact, to formulate a relative risk matrix which is comparable with levels of landslide safety adopted by the approving jurisdiction.

The assessment was restricted to the Site, as indicated in Figure 1, and specifically includes bedrock of the coastal bluff.

## 6.1. Investigation of Historic Failures in Area & Seismic Compliance

A review of historic aerial imagery was conducted on the surrounding area to determine frequency and spatial distribution of natural and induced landslides.

There were no mid-slope landslide scarps, transport paths, or deposit zones identified in proximity to Site or on similar colluvium slopes within the region within historical aerial imagery.

Through this lack of landslide evidence, and the existing evidentiary record of significant seismic events over the past ~500 years, there is no suggestion that natural slopes on Site would fail under seismic disturbances.

For example, a seismic event occurred at 10:13 a.m. on Sunday June 23, 1946 which measured at 7.3 on the richter scale, and was considered a significant seismic event which exceeds the 2% in 50 years magnitude. Therefore, as the Site and surrounding slopes exhibits no evidence of displacement consequent to ground motion, this historic record demonstrates compliance with seismic design at existing or proposed slopes of lower angle.

The presence of loose boulders (up to 1.2m in diameter were observed) on mid-slopes above the habitated (i.e. SFD) lower slope on Site does suggest an increased likelihood of injury or death of an individual (i.e. consequence) while posing no likelihood for harm to the natural environment. However, the likelihood co-location of an individual within the increased consequence pathway is very remote and therefore does not contribute to overall risk considered herein.

## 6.2. Field Investigation

On Sept 17$^{th}$, 2023 Thomas R Elliot PhD P.Geo P.Ag attended to Site as a QP with declared competency in geohazards, hydrology and soil science to evaluate the geohazards, ground and surface waters present on Site.

Field data was acquired according to, and through the implements noted in Table 1 below.

***Table 1 – Summary of Field Work***

| | | | |
|---|---|---|---|
| **Project ID:** | 2023.900 | **Project Name:** | Baker Beach Erosion Mitigation |
| **Project Type:** | Erosion Mitigation (Geohazard) | **Lead Investigator:** | Thomas R Elliot PhD P.Geo P.Ag |
| | | | |
| **Client:** | Aurora Professional Group | **Client Contact:** | Brad Fossen P.Eng |
| **Site Boundary Type:** | Land Parcel | **Site Common Address:** | 434 Baker Road |
| **Site Legal Description:** | Lot 5, Sections 6, Range 1 West, North Salt Spring Island, Cowichan District, VIP46155 | **Site PID #** | 009-555-781 |
| **Site Land Use:** | Rural residential | **Site Condition:** | Secondary growth |
| | | | |
| **Development Activity:** | Erosion mitigation measures | **Project Stage:** | Assessment |
| **DPA:** | DPA3 – Shoreline | **Provincial/Federal:** | DFO review |
| **Equipment Used:** | - Clinometer<br>- Compass<br>- Engineer's tape<br>- GPS tracking | - Field soils kit<br>- Range finder<br>- Shovel and hand tools<br>- Soil probe<br>- Camera | |
| **Summary of Site Activities:** | • Site and Soils Assessments<br>• Evaluate Terrain Stability & Geohazard<br>• Document visible erosion mechanisms, ground and surface water | | |

## 6.3. Geohazard Units

Based on self-similar geophysical and hydrologic characteristics of the Site, a number of Geohazard Units (GU) were defined by the attending QP. Each GU has been assigned a respective Geohazard, or relative likelihood of a landslide event occurring, based on the documented geophysical and hydrologic characteristics.

The incremental change in Geohazard within a GU consequent to the proposed Development Activity is evaluated by the QP in order to arrive at impact of said Development Activity. The subsequent QP interpretation and recommendations are intended to fulfil requirements of the IT Shoreline DPA.

## 6.4. Wave Action and Erosion Hazard

Along the coastal bluff in proximity to Site there were numerous small-scale mass-wasting scarps consequent to erosion. Of those observed on Site, those occurring at base of the coastal bluff also had ongoing erosion of the sediment cap at top of the coastal bluff – suggesting a classic toe erosion mechanism. The bedrock toe erosion is driven by a combination of mechanical factors (e.g. wave-impact, thermal expansion, wedging/sediment jacking of fractures, etc.) and chemical factors (e.g. dissolution of binding carbonates, salt/crystal growth, etc.). The most prevalent of which appears to be wave-impact, which – due to orientation of metamorphic rock laminae and wave-direction – peels the friable bedrock during storm events.

Otherwise, erosion occurring at mid or upper portion of the coastal bluff was based in surficial material – the mechanism of which is explored in the Groundwater and Erosion Hazard section of this report.

## 6.5. Groundwater and Erosion Hazard

There exists a transient erosion hazard consequent to high pore water pressure conditions within the veneer of surficial Galiano soils at base of the slope on Site, as a component of the failing coastal bluff.

Under adverse climatic conditions, this hazard would result in a limited mass wasting failure which would mobilize and entrain the full depth of surficial material. With standard climatic conditions, this mechanism is not as likely to result in such mass failure – instead, punctuated failure events will see progressive steepening and erosion at base of the surficial material cap atop the coastal bluff. This steepening will progress until a larger landslide failure event re-establishes at angle of repose – migrating the erosion front landward, toward the SFD.

Therefore, since the erosion of surficial material – over the long term – could impact the SFD, there are recommended mitigation measures which can be found is Section 7 of this report.

## 6.6. Hazard Rating

There was no pre-existing geohazard rating established through QP assessment and reporting, to the awareness of the author at time of writing.

The Site natural slopes were less than the angle of repose for moist gravelly sandy loam to loamy sand colluvium earth materials (35 - 45% or 19° - 24°)[7] above which slope-failure becomes more probable.

[7] H. Al-Hashemi, O. Al-Amoudi. A review on the angle of repose of granular materials. Powder Technology Volume 330, 1 May 2018, Pages 397-417. https://doi.org/10.1016/j.powtec.2018.02.003

The landslide hazard rating for the entire Site was lower due to strong bedrock control at upper elevations, with shallow depth to bedrock for the remainder of Site, and therefore limited surficial material which would mobilize.

However, the surface sediments capping the coastal bluff have an increased erosional hazard due to presence of a perched water table in the lower slopes.

Consequent to these observations and slope gradients, GU on Site were assigned a VERY LOW to LOW hazard ratings outside of the coastal bluff, which classified as HIGH.

As per Appendix 2 – Geohazards and Risk, the GU defined on Site are summarized in Table 2, below.

Map imagery of GU delineation is found in Appendix 2 and is a recommended reading accompaniment to this section.

***Table 2 – GU Hazard Rating and Risk***

| ***Geohazard Unit*** | **Hazard Rating and Risk** | | | |
|---|---|---|---|---|
| | ***Slope Characteristics*** | ***Hazard Rating*** | ***Consequence*** | ***Incremental Risk Rating*** |
| **1** | **Cv \| Br**<br>**benching**<br>**± 35 - 40%** | **LOW-MODERATE** | **LOW** | **Very Low** |
| **2** | **Cm**<br>**planar**<br>**±5 – 15%** | **VERY LOW** | **LOW** | **Very Low** |
| **3** | **Cv / Br**<br>**planar**<br>**±150 – 180%** | **HIGH** | **HIGH** | **High** |

Geohazard Shorthand Notation

**Br** – Bedrock
**C** – Colluvium
**A** – Aeolian
**L** – Lacustrine
**GF** – Glaciofluvial
**GT** – Glacial till
**M** – Marine

**v** – veneer (.1 – 2m)
**m** – mantle (2 – 5m)
**b** – blanket (>5m)
**/** - overlying
**|** - equal surface exposure
**benching** – slope interrupted by bedrock
**planar** – linear slope

## 6.7. Consequence of Geohazard Event

The Consequence of a geohazard incident was evaluated by the QP based on downslope receptors, predicted size and volume of geohazard event, and a simplistic Farböschung assessment – as detailed in Appendix 2 – Geohazards and Risk.

The most active failure mechanism on Site is punctuated landslide erosion of surficial materials at the coastal bluff (GU 3). The mobilized material would deposit directly to the marine environment, resulting in HIGH consequence.

Outside of which, the second likely failure mechanism on Site would be a mid-slope (GU 1) failure within a colluvium filled relic bedrock draw where a perched water table decreases shear resistance. However, due to the veneer of surficial material in the initiation area, any landslide would impact a limited area due to lack of transportable surficial materials from the initiating area or on low gradient receiving slope (GU 2). The low gradient receiving slope has sufficient width to retain mobilized material, resulting in a LOW consequence.

Summarily, the most likely geohazard results in a HIGH consequence while the remainder of Site has a LOW consequence.

### 6.8. Incremental Risk Imposed by Development Activity

The purpose of proposed erosion mitigation development activities is to reduce the geohazard risk of GU 3. This report has identified the active failure mechanisms resulting in erosion of the coastal bluff, from which mitigation measures can be evaluated.

### 6.9. Suitability of Lands for Use Intended (SFD)

There are no up-slope hazards likely to impact the SFD location.

While GU 3 has a High risk rating, the progressive-over-time nature of failure mechanisms for this area would provide opportunity to conduct more specific geotechnical review, and/or implement mitigation or emergency measures prior to impacting the SFD and ~3m of surrounding liveable space.

<u>With no off-Site hazards and a LOW likelihood of failure above an existing SFD – the building location is **SAFE FOR THE USE INTENDED** (Residential Single Family Dwelling)</u>.

## 7. Geohazard Mitigation Recommendations

Due to the HIGH incremental risk of geohazards for GU 3, there are mitigation recommendations intended to reduce the risk to LOW.

### 7.1. Erosion and Sediment Control

All proposed activities will require Erosion and Sediment Control planning which meets IT regulatory requirements. Any such plan should be developed toward acquiring a Development Permit from the IT for the proposed activities and shall be submitted alongside any additional required paperwork.

There are two identified erosion mechanisms:

**Pore water** sufficient pore water pressure below the phreatic surface can acts as a destabilizing factor to overcome cohesion, friction angle and soil weight –

entirely independent of toe erosion. While the majority of episodic pore water pressure erosion occurs during the rainy season, localized increases in pore water pressure can also lead to instability during otherwise drought conditions.

Mitigation options include, but are not limited to:

- Annual monitoring of erosional regression of surficial materials at the coastal bluff;
- Groundwater intercept and redirection to non-erosive receiving environment;
- Bioengineering and selective planting of native species toward increasing shear strength of surficial materials;
- Re-contour of the surficial materials to allow for emergence of groundwater without erosion;
- Selective removal of shoreline trees deemed hazardous due to toe erosion.

**Wave action** a culmination of mechanical wave-action, daily sunlight-driven thermal oscillation, and saturating water-spray promotes decomposition and failure of fine-grained metamorphic bedrock situated in the lower 6 - 7m of coastal bluff. This results in toe erosion which, over time, destabilizes the portion of coastal bluff above.

Mitigation options include, but are not limited to:

- Monitoring rate of erosion so as to establish a predictive timeline of coastal bluff regression;
- Bioengineering and selective planting of native species toward dissipated wave-impact on coastal bluff face;
- Wave deflection within intertidal area;
- Beach nourishment to dissipate wave energy;

The suitability, efficacy and ease of implementation and maintenance of these recommended mitigation options should be carefully considered in context of Marine Shoreline Design Guidelines[2] which will require an integrated assessment of geohazards (this report), wave and beach dynamics, and ecosystem characteristics.

## 8. Safety and Suitability

This report has been prepared in accordance with standard geotechnical hazard assessment practices, and at the expense of Ethan Wilding. Thomas R Elliot PhD P.Geo P.Ag has not acted for or as agent of the Islands Trust in the preparation of this report.

Thomas R Elliot PhD P.Geo P.Ag certifies that the land is safe for the use intended (Residential Single Family Dwelling and Driveway) if the land is used in accordance with the conditions specified in this report.

Thomas R Elliot PhD P.Geo P.Ag acknowledges that this report may be used by the Islands Trust as a precondition to the issuance of a permit and that this report and any conditions contained in this report may be included in a restrictive covenant and filed against the title to this subject property.

## 9. Summary

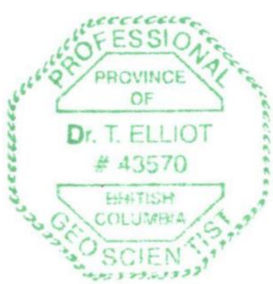
The land parcel with PID 009-555-781 situated on the southwest flank of a bedrock ridge forming a benching slope down to a coastal bluff is proposed to undergo permissible Development Activities within the Shoreline DPA of the IT.

Through assessment of these DPA requirements, Thomas R Elliot PhD P.Geo P.Ag as a QP capable of conducting the works, has determined a **High Risk of erosion geohazard** impacting the local environment. This determination is based on geophysical indicators on Site and regional frequency of historic landslide in the area.

The proposed development activities do not increase the Risk, however specific design of erosion mitigation measures will have to be completed prior to establishing a post-development Risk. There are sufficient pre-existing long term erosional processes on Site to warrant mitigation measures.

| | | |
|---|---|---|
| Qualified Professional of Record | THOMAS R. ELLIOT PhD P.Geo, P.Ag<br>Name | Tom Elliot<br>Sign |

Thomas R Elliot PhD P.Geo. P.Ag.




Digital reproduction, original available upon request.

Date: November 6, 2023

# 10.Closure and Limitations

The QP signatory to this assessment and report assures accuracy of existing and field observation, and evaluation of technical geohazard according to best practices of the Engineers and Geoscientists of BC. The content of this report are applicable to the subject land parcel, and specifically the Site as defined in this report. Any extension of the evaluation to areas outside of the defined area assessed are not valid.

The report has been conducted according to guidelines and reporting standards of similarly qualified professionals, given similar time and budget. At time of writing, the report meets due diligence and investigatory reporting requirements to provide QP recommendations with declared competency in the subject areas. Therefore, the author of this report does not maintain liability insurance for actions taken based on the reporting, and only accepts error and omission liability up to the value of this report. The receipt, utilization and any planning, further studies or development actions undertaken by the recipient of this report are based on their acceptance of their own liability therein.

# Appendix I

Maps and Figures

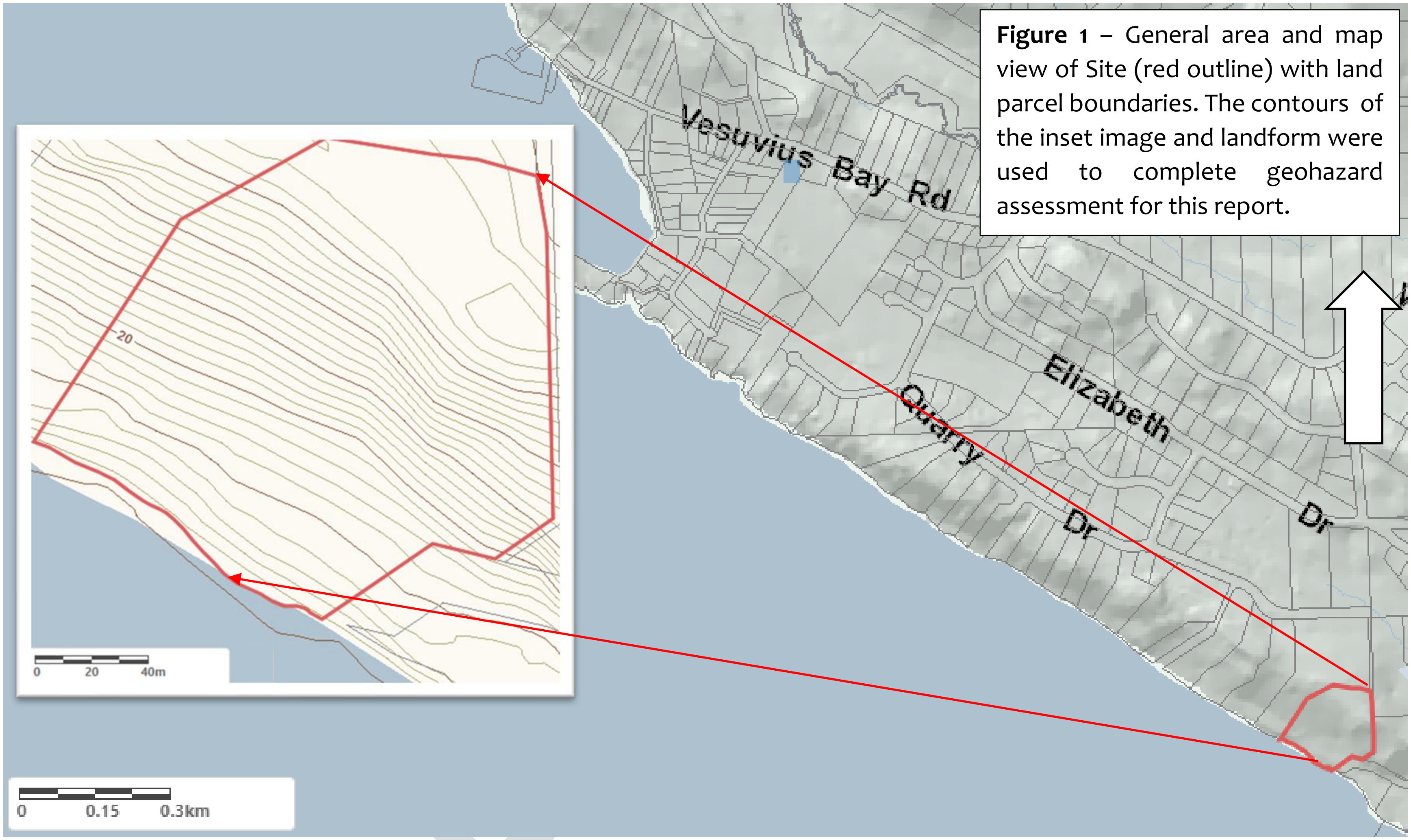



**Figure 1** – General area and map view of Site (red outline) with land parcel boundaries. The contours of the inset image and landform were used to complete geohazard assessment for this report.


**Figure 2** – Geohazard Units of self-similar terrain, labelled with hazard rating. Note that GU 2 (Very Low hazard) would receive and settle mobilized material from GU 1 (Low-Moderate hazard). GU 3 (High hazard) will see continued erosion geohazard until motivating factors are mitigated.

# Appendix II

Geohazards and Risk

## Geohazards

This assessment is partially based on local historic rates of landslide failure. The rating hazard of failures occurring in a given area under the classification system shown in Table II_a, below. By determining the likelihood of historic failures based on spatial density, the number of failures per unit area can be predicted. The likelihood of historic failures is determined through review of historic aerial imagery and general area observations while on the way to or from Site.

By establishing failure spatial density in the local area, in conjunction with Table II, the hazard rating can be estimated for areas undergoing development activities that impact terrain stability.

The hazard ratings were defined based on pre-existing practice by geoscientists and engineers for the natural resources sector, and adapted to best suit development activities governed by responsible municipal partners toward meeting those partner-organization risk tolerance policies.

Please note that, differing from resource sector terrain stability assessments, this evaluation of hazard includes failures smaller than 0.05 ha area (initiation, transport and deposit area). This is consequent to resource sector activities, and typically remote locations, being more tolerant of small-scale geohazard events. For this location, due to proximity to populated areas, and responsibility to meet municipal risk tolerance policies, the total area of a failure may be less than 0.05 ha in order to contribute to the hazard rating.

**Table II_a: Definitions of hazard categories**

| Hazard Category | # of failures per geohazard unit size |
|---|---|
| VERY HIGH | >1 failure per 2 ha |
| HIGH | 1 failure per 2 to 10 ha |
| MODERATE | 1 failure per 10 to 50 ha |
| LOW-MODERATE | 1 failure per 50 to 250 ha |
| LOW | 1 failure per 250 to 1250 ha |
| VERY LOW | <1 failure per 1250 ha |

Once the natural hazard of landslide for the area has been established, the probability of at least one failure occurring in a geohazard unit can be determined from Figure II_A.

Figure II_1 is based on the assumption that the probability of a specified number of failures occurring within a polygon is related to the size of the polygon by a cumulative normal distribution.

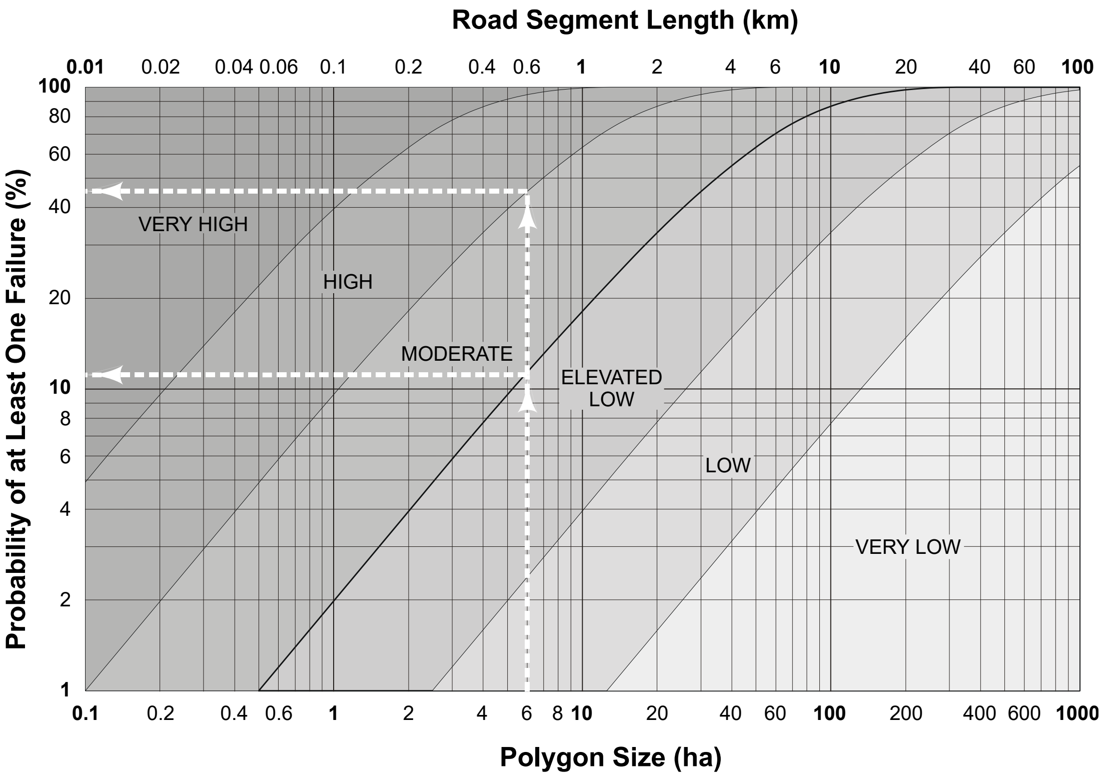



Figure II_1 – Probability of at least one failure based on a geohazard unit (GU) assessment area size or road length. This figure has been adopted from BC Forestry practices and is based on a single forestry harvest cycle, typically lasting 60 years within Coastal BC.

*Figure II_1 has an example sketched with dashed white lines. The example indicates probability of failure for a* ***6 ha*** *geohazard unit area with a* ***moderate*** *hazard rating. The probability of at least one failure occurring within the assessed geohazard unit area over the period of one forestry harvest cycle is between ~12 – 45%.*

## Consequence

### Simplistic Farböschung Evaluation

Whether or not a Site will be impacted by a geohazard is a component of determining consequence to potential landslide failures and/or debris flows. A simplistic assessment of transport and deposition zone locations can be accomplished through a 'Farböschung' evaluation. This is best exemplified through Figure II_B, which demonstrates how a sliding

mass (block on right hand side) has potential to transport some distance from point of initiation based on a simplistic assignment of Farböschung angle.

For this assessment, a Farböschung angle of 45% was used based on heuristic practice for these coastal environments and gravelly loam surficial material. By standing on Site at highest point of initiation, the QP was able to establish the approximate run-out distance to edge of the deposit zone.

A more Site specific example is provided in Figure II_C, which shows a benching bedrock terrain where a thin veneer of surface material is mobilized, and has limited transport and deposit distances based on the Farböschung angle.

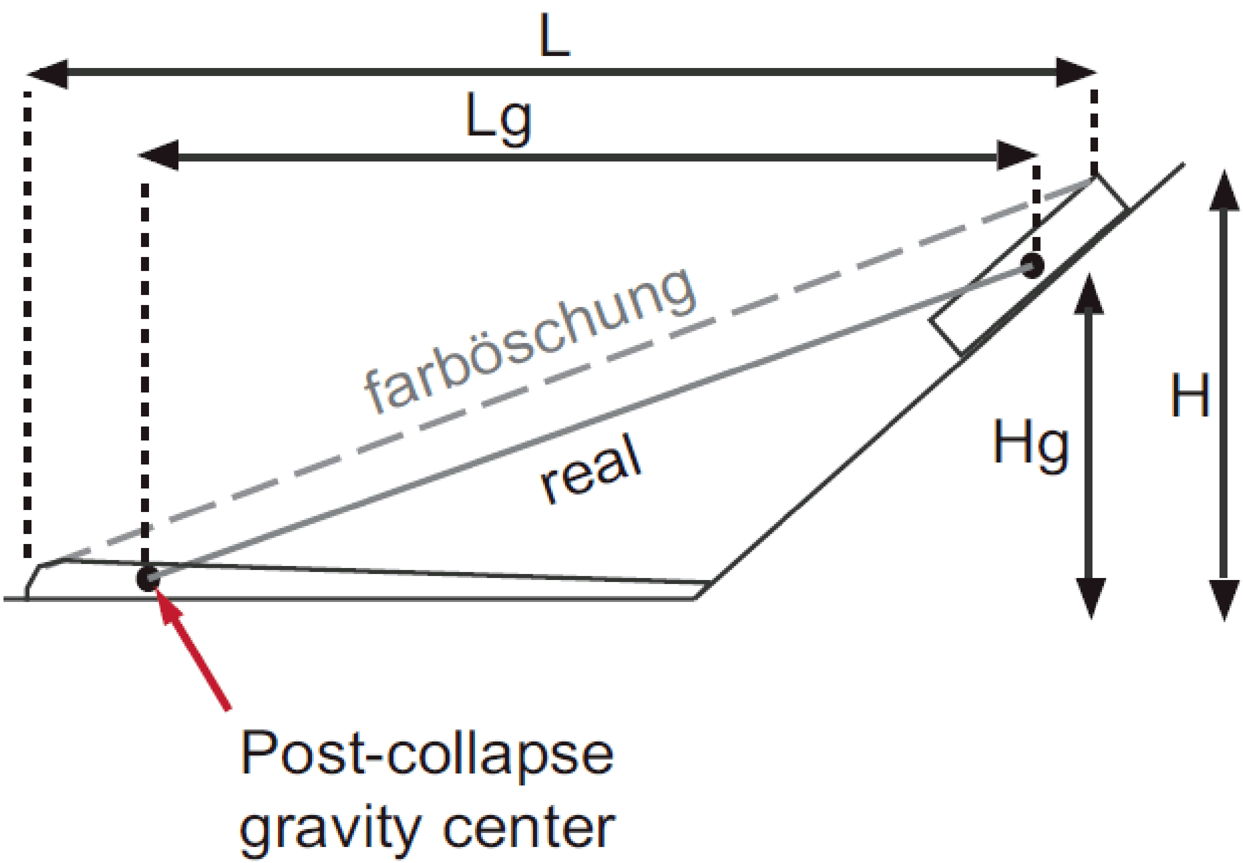



**Figure II_B** – Farböschung angle functionality for sliding masses on a slope. The specific mathematics of which are not supplied here for brevity.

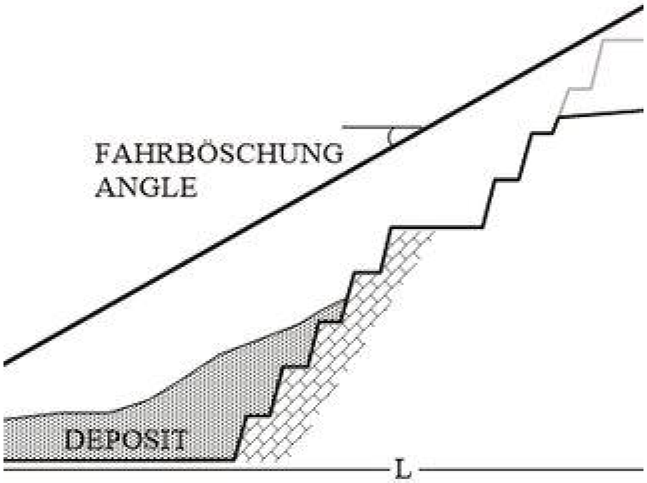



**Figure II_C** – An example of landslide runout and deposit area of potential geohazards on Site based on simplistic Farböschung assessment.

**Table II_b: Consequence**

| Consequence | Criteria |
|---|---|
| HIGH | Landslide material would directly enter fish habitat (stream, lake, or marine waters); water intake for domestic consumption; jeopardize lives of the public; impact major public infrastructure; or other property owner.<br><br>Landslide would enter non-fish stream within 500 m of fish habitat. |
| MODERATE | Landslide material enters non-fish stream > 500 m and < 3000 m from fish habitat, OR there is a slope < 20% for < 100 m below landslide to fish habitat; potable water intake; a public area; or other property owner. |
| LOW | Run-out slope < 20% for 100-200 m below landslide deposit area. At time of event, suspended sediment may reach fish habitat; potable water intake; public area, or other property owner |
| VERY LOW | Run-out slope < 20% for > 200 m below landslide. Landslide material is unlikely to reach stream or potable water intake at time of event. A landslide would not be a public safety concern; would not impact any infrastructure nor other property owner. |

## Post Development Activities Summary Table of Geohazards, Consequence and Risk on Site

### Risk

| Very Low | Low | GEOHAZARD | | | | |
|---|---|---|---|---|---|---|
| Moderate | High | VERY LOW | LOW | LOW - MODERATE | MODERATE | HIGH |
| GEOMORPHIC CONSEQUENCE | VERY LOW | | | | | |
| | LOW | 2 | | 1 | | |
| | MODERATE | | | | | |
| | HIGH | | | | | 3 |

# Geohazard Assessment of Lands

*As pertaining to land parcel:*

PID 000-014-656

431 BAKER ROAD, SALT SPRING ISLAND

AMENDED LOT 2 (DD 251903I) SECTION 6 RANGE 1 WEST NORTH SALT SPRING ISLAND COWICHAN DISTRICT PLAN 7144 EXCEPT PART IN PLAN 40042

# Report for Coastal Erosion Mitigation

Developed for: Jeremy Sicherman (Landowner)
431 Baker Road
Salt Spring Island, BC V8K 2N6

Developed by: Thomas R Elliot PhD P.Geo P.Ag
TRE Environmental Services
tom@elliot.org

TRE Environmental Services

# 1. Synopsis

The subject land parcel, with PID 000-014-656 and legal description of Amended Lot 2 (DD251903l), Section 6, Range 1, West North Salt Spring Island, Cowichan District Plan 7144 Except part in Plan 40042 (Site), is situated on the lower southwest-facing flank of a slope which terminates to the Salt Spring Island ocean-shoreline in a coastal bluff. The Site is proposed to undergo coastal erosion mitigation development activities within the Shoreline Development Permit Area[1] (DPA 3) of the Islands Trust (IT), which prompted this geohazard assessment to identify mechanisms contributing to erosion of the coastal bluff that would create hazardous conditions for existing single-family dwelling (SFD) and the natural environment.

The Site consists of a low benching slope with a mantle of gravelly sandy loam to loamy sand. The slope descends from a ~14m above sea level (asl) elevation at the north of Site, collocated with bedrock outcrop below the access road. Bedrock in the area is sandstone at elevation and transitions to shale and metamorphic siltstone deposits of the Nanaimo Sedimentary Group closer to sea level. At the western property line there is a ~2m metamorphic-rock coastal bluff rising above the natural boundary, and is capped with a 2 – 3m thick mantle of gravelly sandy loam.

There is no ephemeral or permanent surface watercourse observed at Site, although the presence of near-surface groundwater is apparent at the coastal bluff where phreatic water is forced to surface.

The erosion and sediment mass-wasting observed on Site primarily consists of two concurrent processes:

Wave action: a culmination of mechanical wave-action, daily sunlight-driven thermal oscillation, and saturating water-spray promotes decomposition and failure of fine-grained metamorphic bedrock situated in the lower 2m of coastal bluff. This results in toe erosion which, over time, destabilizes the portion of coastal bluff above.

Where the bedrock does not exist, from the central to east of Site, wave action works directly on coastal sediments (gravelly loam) which is largely retained in place by vegetation root-reinforcement. This results in undercutting of vegetated banks, which leads to periodic collapse and mass wasting.

Pore water: sufficient pore water pressure below the phreatic surface can acts as a destabilizing factor to overcome cohesion, friction angle and soil weight – entirely independent of toe erosion. While the majority of episodic pore water

[1] IT Bylaw 488 - https://islandstrust.bc.ca/wp-content/uploads/2020/10/SS-BL-434_2020-10_OCP_Vol1-2.pdf

pressure erosion occurs during the rainy season, localized increases in pore water pressure can also lead to instability during otherwise drought conditions.

Through assessment of the Site subject to Hazard Lands DPA, Thomas R Elliot PhD P.Geo P.Ag has determined a Low risk of landslide geohazard impacting the SFD. However, there is a Moderate risk of erosional geohazard impacting marine environment in an ongoing and progressive manner.

This determination is based on geophysical indicators on Site, regional frequency of historic landslide in the area, as well as assessment of Site surficial materials, hydrologic regime, topography and slope failure mechanics, as detailed through this report.

The proposed erosion mitigation development activities do not increase the hazard rating to the existing SFD or occupancy of Site.

# 2. Introduction

Development activity within the IT is being pursued on the subject land parcel with PID 000-014-656 (the 'Site', see Figure 1 – Appendix 1). The R (Rural) zoned land parcel is located on a southeast-facing flank of a slope which terminates to a coastal bluff ocean-shoreline. The Site is accessible via Baker Drive arriving from the west, where a public roadway exists.

This report includes assessment of pre-existing and field-gathered data which informs a geohazard risk assessment and guides proposed erosion mitigation measures.

There exists DPA 3 requirements for non-exempt development activities within 10m landward and 300m seaward of the marine-shoreline natural boundary. Due to land parcel configuration there is currently 10m setback from the natural boundary and existing SFD. As such, proposed landward erosion mitigation activities will be considered in context of existing structures, near-surface water management and erosion processes observed at the coastal bluff.

Therefore, this report is a cumulative evaluation of existing and field-based data toward determining risk to SFD and natural environment associated with geohazards present on Site, and impact of proposed erosion mitigation measures on identified geohazards.

## 2.1. Author Qualifications

Thomas R Elliot PhD is a Qualified Professional (QP) Geoscientist [# 43570] and Professional Agrologist [# 3045] registered within the Province of British Columbia and in good standing with both professional associations. The QP has 16 years of geohazard, soil science, near surface groundwater and aquifer hydrogeology practice. In the last 9 years, Thomas R Elliot has primarily worked on Vancouver Island and the Lower Mainland of British Columbia in the practice areas of [Geoscience]: Hydrogeology, Geohazard mitigation assessments, Soils/Groundwater management; and [Agrology] Soil science, Agriculture, and Contaminant detection, mitigation and remediation.

# 3. Scope, Context & Motivation

The proposed development activities are erosion mitigation measures for identified geohazards toward reducing risk to the existing SFD and natural environment on Site.

This report does not determine the specific erosion mitigation activities due to a requirement for comprehensive assessment of near shore environments prior to identification of suitable measures. A comprehensive assessment includes this geohazard report in addition to an evaluation of beach and wave characteristics that will collectively inform suitable erosion mitigation activities through the Marine Shoreline Design Guidelines[2] that have been broadly adopted by Province of BC and Federal Department of Fisheries and Oceans.

There are DPA requirements which apply to the Site, including the Shoreline DPA 3 which necessitates any non-exempt development activities within 10m landward and 300m seaward of the natural boundary be subject to development permitting.

The motivation to produce this report is to provide IT record of existing hazard conditions on Site; predicted impact of proposed development activities; and if the proposed development activities – in context of existing or novel hazards – allows for safe Rural-residential use of the land, as intended.

# 4. Regulatory Context

This section is dedicated to review of applicable Regulations and Acts, as governing legislation for individual and group risk of harm/death related to land use, as well as general permitting and authorization requirements of intended land use and proposed erosion mitigation development activities.

Further, the Department of Fisheries and Oceans would also be requested to conduct review of proposed activities in conjunction with the local IT DPA 3 permitting requirements.

## 4.1. IT Shoreline DPA

The geohazard assessment for the proposed works is warranted under MA Section 879 (1)(a) and (b) which prompts IT to protect the natural environment and to protect development from hazardous conditions; as specifically governed by IT Bylaw 434, V 2, S E.3 Development Permit Area 3 – Shoreline (enacted through IT Bylaw 488).

IT Bylaw 488, DPA 3 – Shoreline requires development permit applications be submitted for activities occurring 10m landward in areas where the marine environment has been identified as being particularly sensitive to development impacts.

---

[2] Johannessen, J.[1], A. MacLennan[1], A. Blue[1], J. Waggoner[1], S. Williams[1], W. Gerstel[2], R. Barnard[3], R. Carman[3], and H. Shipman[4]. 2014. Marine Shoreline Design Guidelines. Washington Department of Fish and Wildlife, Olympia, Washington. **1** Coastal Geologic Services Inc.; **2** Qwg Applied Geology; **3** Washington State Department of Fish and Wildlife; **4** Washington State Department of Ecology

If the proposed erosion mitigation works are to include: breakwater, weir, groin or jetty; bulkheads; placement of fill; removal of trees with diameter greater than 20cm OR removal of vegetation that results in the exposure of a total area of bare soil more than 9m$^2$ in area – then there is requirement for IT approved Development Permitting.

### 4.2. DFO Authorization

Pursuant to the *Fisheries Act*, should a requested DFO project review determine that proposed development activities are likely to cause the death of fish and/or harmful alteration, disruption or destruction of fish habitat – then authorization would be required.

Since the development activity (i.e. erosion mitigation measures) are currently undefined, this report is unable to establish whether DFO authorization will be required.

## 5. Site Conditions: Existing and Field Data

### 5.1. Slopes, Soils & Surficial Materials

At shoreline, the Site has a ~2 – 3m coastal bluff at the western property line consisting of siltstone and shale at base and capped with 1 – 2m of surficial material. Approximately central and east of the shoreline boundary the dipping bedrock is no longer visible at the natural boundary, and instead a sediment bluff of 1 – 2m in height is held upright by root reinforcement of heavy brush.

Above the shoreline, there is a singular slope on Site rising gently (~5 – 10%) from the natural boundary. The SFD on Site exists within this portion of Site, and is set back by ~12 - 15m from the natural boundary.

Soil associations on Site were previously mapped[3] in a single elevation-limited band which correspond to slope changes in the area. Starting at present day marine shoreline and ascending up slope, the soil associations present on Site include a typically <2m veneer of well drained gravelly sandy loam Mexicana soil, which are derived from colluvium[4], on the lowest slope.

For the remainder of Site, a thin <2m veneer of Galiano well draining sandy loam soils underlie the SFD and built environment.

The bedrock on Site was mapped as belonging to the Nanaimo Group[5], with sparse details on the surficial rock type in existing records. On Site, there is shale and siltstone represented

[3] Soil Information Finder Tool. https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=cc25e43525c5471ca7b13d639bbcd7aa
[4] Soils of Southern Vancouver Island. MOE Technical Report 17. https://sis.agr.gc.ca/cansis/publications/surveys/bc/bc44/index.html
[5] Vancouver Island Geology. https://www.gac-cs.ca/publications/FT_Geology_of_Vancouver_Island.pdf

within the western coastal bluff. The rock types identified on Site are characteristically found in the Nanaimo Group.

### 5.2. Surface & Groundwater

There are no identified or observed watercourse on Site. However, accumulation of rainwater and drainage from the access road and impermeable surfaces does result in areas with increased surface water discharge to ground for infiltration. These areas are demarcated by accumulation of debris moved by the flow of surface water, increased annual vegetation growth, and an infiltrative surface – the extent of which is related to volume of accumulated rainwater.

Infiltration of each soil association on Site is unrestricted by soil texture, meaning that in areas where water does accumulate at surface there is a low-permeability limiting layer (i.e. bedrock) which prevents further downward migration. Instead, as infiltrating water reaches bedrock, lateral dispersion becomes dominant and results in a phreatic surface (i.e. perched groundwater table) establishing within the thin <2m veneer of surficial earth materials.

Where bedrock outcrops to surface – such as at the western property boundary, the veneer of surface material thins and 'pinches out', resulting in emergence of phreatic water. These 'weeps' or 'springs' are not to be conflated with artesian conditions, as these waters do not enter a confined aquifer and pore water pressure does not exceed atmospheric pressure. While not individually significant to Site surface hydrology, the irregular bedrock surface accumulates these phreatic weeps to a subsurface non-contiguous perched water table within the veneer of well-draining surface material.

Due to this accumulation mechanism, there is an increased depth of perched water table at lower elevations of the Site. Therefore, it is warranted to conduct specific geohazard assessment of areas where surficial materials convey the accumulated depth of perched water table due to an increased pore water pressure forcing erosion.

## 6. Geohazard Assessment

This landslide risk assessment was largely conducted according to the Engineers and Geoscientists of BC document *Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC*[6]*.* The landslide risk assessment methods that were utilized includes all aspects of landslide hazard analysis, such as regional frequency and historic evidence to inform current and future landslide hazards; as well as evaluation of hazard likelihood, and consequence of landslide impact, to formulate a relative risk matrix which is comparable with levels of landslide safety adopted by the approving jurisdiction.

[6] EGBC Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC. https://www.egbc.ca/getmedia/5d8f3362-7ba7-4cf4-a5b6-e8252b2ed76c/APEGBC-Guidelines-for-Legislated-Landslide-Assessments.pdf.aspx

The assessment was restricted to the Site, as indicated in Figure 1, and specifically includes bedrock of the coastal bluff.

## 6.1. Investigation of Historic Failures in Area & Seismic Compliance

A review of historic aerial imagery was conducted on the surrounding area to determine frequency and spatial distribution of natural and induced landslides.

There were no mid-slope landslide scarps, transport paths, or deposit zones identified in proximity to Site or on similar colluvium slopes within the region within historical aerial imagery.

Through this lack of landslide evidence, and the existing evidentiary record of significant seismic events over the past ~500 years, there is no suggestion that natural slopes on Site would fail under seismic disturbances.

For example, a seismic event occurred at 10:13 a.m. on Sunday June 23, 1946 which measured at 7.3 on the richter scale, and was considered a significant seismic event which exceeds the 2% in 50 years magnitude. Therefore, as the Site and surrounding slopes exhibits no evidence of displacement consequent to ground motion, this historic record demonstrates compliance with seismic design at existing or proposed slopes of lower angle.

The presence of loose boulders (up to 1.2m in diameter were observed) on mid-slopes above the non-habitated (i.e. driveway, not SFD) lower slope on Site does suggest an increased likelihood of injury or death of an individual (i.e. consequence) while posing no likelihood for harm to the natural environment. However, the likelihood co-location of an individual within the increased consequence pathway is very remote and therefore does not contribute to overall risk considered herein.

## 6.2. Field Investigation

On Sept 17th, 2023 Thomas R Elliot PhD P.Geo P.Ag attended to Site as a QP with declared competency in geohazards, hydrology and soil science to evaluate the geohazards, ground and surface waters present on Site.

Field data was acquired according to, and through the implements noted in Table 1 below.

***Table 1 – Summary of Field Work***

| | | | |
|---|---|---|---|
| **Project ID:** | 2023.900 | **Project Name:** | Baker Beach Erosion Mitigation |
| **Project Type:** | Erosion Mitigation (Geohazard) | **Lead Investigator:** | Thomas R Elliot PhD P.Geo P.Ag |
| | | | |
| **Client:** | Aurora Professional Group | **Client Contact:** | Brad Fossen P.Eng |

| | | | |
|---|---|---|---|
| **Site Boundary Type:** | Land Parcel | **Site Common Address:** | 431 Baker Road |
| **Site Legal Description:** | VIP46155, LOT 1 | **Site PID #** | 000-014-656 |
| **Site Land Use:** | Rural residential | **Site Condition:** | Secondary growth |
| | | | |
| **Development Activity:** | Erosion mitigation measures | **Project Stage:** | Assessment |
| **DPA:** | DPA3 – Shoreline | **Provincial/Federal:** | DFO review |
| **Equipment Used:** | - Clinometer<br>- Compass<br>- Engineer's tape<br>- GPS tracking | - Field soils kit<br>- Range finder<br>- Shovel and hand tools<br>- Soil probe<br>- Camera | |
| **Summary of Site Activities:** | • Site and Soils Assessments<br>• Evaluate Terrain Stability & Geohazard<br>• Document visible erosion mechanisms, ground and surface water | | |

## 6.3. Geohazard Units

Based on self-similar geophysical and hydrologic characteristics of the Site, a number of Geohazard Units (GU) were defined by the attending QP. Each GU has been assigned a respective Geohazard, or relative likelihood of a landslide event occurring, based on the documented geophysical and hydrologic characteristics.

The incremental change in Geohazard within a GU consequent to the proposed Development Activity is evaluated by the QP in order to arrive at impact of said Development Activity. The subsequent QP interpretation and recommendations are intended to fulfil requirements of the IT Shoreline DPA.

## 6.4. Wave Action and Erosion Hazard

Along the shoreline in proximity to Site there were numerous small-scale mass-wasting scarps consequent to erosion. Of those observed on Site, those occurring at base of the coastal bluff also had ongoing erosion of the sediment cap at top of the coastal bluff – suggesting a classic toe erosion mechanism. The bedrock toe erosion is driven by a combination of mechanical factors (e.g. wave-impact, thermal expansion, wedging/sediment jacking of fractures, etc.) and chemical factors (e.g. dissolution of binding carbonates, salt/crystal growth, etc.). Whereas, undercutting of sediment shoreline are mechanical and pore water pressure mechanisms.

Of mechanical forces, the most prevalent appears to be wave-impact, which – due to orientation of metamorphic rock laminae and wave-direction – peels the friable bedrock during storm events or mobilizes sediment retained by root reinforcement.

Otherwise, erosion occurring at mid or upper portion of the shoreline was based in surficial material – the mechanism of which is explored in the Groundwater and Erosion Hazard section of this report.

## 6.5. Groundwater and Erosion Hazard

There exists a transient erosion hazard consequent to high pore water pressure conditions within the veneer of surficial Galiano soils on Site, as a component of the failing shoreline.

Under adverse climatic conditions, this hazard would result in a limited mass wasting failure which would mobilize and entrain surficial material. With standard climatic conditions, this mechanism is not as likely to result in such mass failure – instead, punctuated failure events will see progressive undercutting and erosion at base of the surficial material. This undercutting will progress until a larger landslide failure event re-establishes a new scarp – migrating the erosion front landward, toward the SFD.

Therefore, since the erosion of surficial material – over the long term – could impact the SFD, there are recommended mitigation measures which can be found is Section 7 of this report.

## 6.6. Hazard Rating

There was no pre-existing geohazard rating established through QP assessment and reporting, to the awareness of the author at time of writing.

The Site natural slopes were less than the angle of repose for moist gravelly sandy loam to loamy sand colluvium earth materials (35 - 45% or 19° - 24°)[7] above which slope-failure becomes more probable.

The landslide hazard rating for the entire Site was lower due to strong bedrock control, with shallow depth to bedrock for the Site, and therefore limited surficial material which would mobilize.

However, the shoreline sediments have an increased erosional hazard due to presence of a perched water table in the lower slopes.

Consequent to these observations and slope gradients, GU on Site were assigned a VERY LOW hazard ratings outside of the coastal bluff, which classified as LOW-MODERATE hazard due to frequency of observed failures on similar shorelines within proximity to Site.

As per Appendix 2 – Geohazards and Risk, the GU defined on Site are summarized in Table 2, below.

Map imagery of GU delineation is found in Appendix 2 and is a recommended reading accompaniment to this section. Please note that some of GU 2 is outside of Site and that

[7] H. Al-Hashemi, O. Al-Amoudi. A review on the angle of repose of granular materials. Powder Technology Volume 330, 1 May 2018, Pages 397-417. https://doi.org/10.1016/j.powtec.2018.02.003

suitable permissions from regulatory agencies are required prior to engaging in works for these lands.

***Table 2 – GU Hazard Rating and Risk***

| ***Geohazard Unit*** | **Hazard Rating and Risk** | | | |
|---|---|---|---|---|
| | ***Slope Characteristics*** | ***Hazard Rating*** | ***Consequence*** | ***Incremental Risk Rating*** |
| **1** | **Cm planar ± 5 - 10%** | **VERY LOW** | **VERY LOW** | **Very Low** |
| **2** | **Cv / Br planar ±150 – 180%** | **LOW – MODERATE** | **HIGH** | **Moderate** |

Geohazard Shorthand Notation

**Br** – Bedrock
**C** – Colluvium
**A** – Aeolian
**L** – Lacustrine
**GF** – Glaciofluvial
**GT** – Glacial till
**M** – Marine

**v** – veneer (.1 – 2m)
**m** – mantle (2 – 5m)
**b** – blanket (>5m)
/ - overlying
| - equal surface exposure
**benching** – slope interrupted by bedrock
**planar** – linear slope

## 6.7. Consequence of Geohazard Event

The Consequence of a geohazard incident was evaluated by the QP based on downslope receptors, predicted size and volume of geohazard event, and a simplistic Farböschung assessment – as detailed in Appendix 2 – Geohazards and Risk.

The most active failure mechanism on Site is punctuated landslide erosion of surficial materials at the shoreline (GU 2). The mobilized material would deposit directly to the marine environment, resulting in HIGH consequence.

Outside of which, the veneer of surficial material across the Site would result in a lack of transportable surficial materials from the initiating area from low gradient slope of GU 1. The low gradient slope and lack of mobilized material volume results in a VERY LOW consequence.

Summarily, the most likely geohazard (shoreline mass wasting) results in a HIGH consequence while the remainder of Site has a VERY LOW consequence.

## 6.8. Incremental Risk Imposed by Development Activity

The purpose of proposed erosion mitigation development activities is to reduce the geohazard risk of GU 2. This report has identified the active failure mechanisms resulting in erosion of the coastal bluff, from which mitigation measures can be evaluated.

## 6.9. Suitability of Lands for Use Intended (SFD)

There are no up-slope hazards likely to impact the SFD location.

While GU 2 has a Moderate risk rating, the progressive-over-time nature of failure mechanisms for this area would provide opportunity to conduct more specific geotechnical review, and/or implement mitigation or emergency measures prior to impacting the SFD and ~3m of surrounding liveable space.

With no off-Site hazards and a VERY LOW likelihood of failure above an existing SFD – the building location is **SAFE FOR THE USE INTENDED** (Residential Single Family Dwelling).

# 7. Geohazard Mitigation Recommendations

Due to the Moderate incremental risk of geohazards for GU 2, there are mitigation recommendations intended to reduce the risk to Low.

## 7.1. Erosion and Sediment Control

All proposed activities will require Erosion and Sediment Control planning which meets IT regulatory requirements. Any such plan should be developed toward acquiring a Development Permit from the IT for the proposed activities and shall be submitted alongside any additional required paperwork.

There are two identified erosion mechanisms:

**Pore water** sufficient pore water pressure below the phreatic surface can acts as a destabilizing factor to overcome cohesion, friction angle and soil weight – entirely independent of toe erosion. While the majority of episodic pore water pressure erosion occurs during the rainy season, localized increases in pore water pressure can also lead to instability during otherwise drought conditions.

Mitigation options include, but are not limited to:

- Annual monitoring of erosional regression of surficial materials at the coastal bluff;
- Groundwater intercept and redirection to non-erosive receiving environment;
- Bioengineering and selective planting of native species toward increasing shear strength of surficial materials;
- Re-contour of the surficial materials to allow for emergence of groundwater without erosion;

- Selective removal of shoreline trees deemed hazardous due to undercutting erosion.

**Wave action** a culmination of mechanical wave-action, daily sunlight-driven thermal oscillation, and saturating water-spray promotes decomposition and failure of fine-grained metamorphic bedrock situated in the lower 2m of coastal bluff. This results in toe erosion which, over time, destabilizes the portion of coastal bluff above.

Where the bedrock does not exist, from the central to east of Site, wave action works directly on coastal sediments (gravelly loam) which is largely retained in place by vegetation root-reinforcement. This results in undercutting of vegetated banks, which leads to periodic collapse and mass wasting.

Mitigation options include, but are not limited to:

- Monitoring rate of erosion so as to establish a predictive timeline of shoreline regression;
- Bioengineering and selective planting of native species toward dissipated wave-impact on coastal bluff face;
- Wave deflection within intertidal area;
- Beach nourishment to dissipate wave energy;

The suitability, efficacy and ease of implementation and maintenance of these recommended mitigation options should be carefully considered in context of Marine Shoreline Design Guidelines which will require an integrated assessment of geohazards (this report), wave and beach dynamics, and ecosystem characteristics.

# 8. Safety and Suitability

This report has been prepared in accordance with standard geotechnical hazard assessment practices, and at the expense of Jeremy Sicherman. Thomas R Elliot PhD P.Geo P.Ag has not acted for or as agent of the Islands Trust in the preparation of this report.

Thomas R Elliot PhD P.Geo P.Ag certifies that the land is safe for the use intended (Residential Single Family Dwelling and Driveway) if the land is used in accordance with the conditions specified in this report.

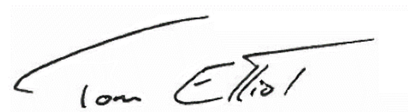
Thomas R Elliot PhD P.Geo P.Ag acknowledges that this report may be used by the Islands Trust as a precondition to the issuance of a permit and that this report and any conditions contained in this report may be included in a restrictive covenant and filed against the title to this subject property.

## 9. Summary

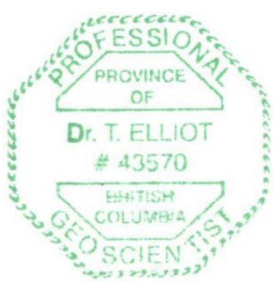
The land parcel with PID 000-014-656 situated on the southwest flank of a gentle slope leading to marine shoreline is proposed to undergo permissible Development Activities within the Shoreline DPA of the IT.

Through assessment of these DPA requirements, Thomas R Elliot PhD P.Geo P.Ag as a QP capable of conducting the works, has determined a **Moderate Risk of erosion geohazard** impacting the local environment. This determination is based on geophysical indicators on Site and regional frequency of historic landslide in the area.

The proposed development activities do not increase the Risk, however specific design of erosion mitigation measures will have to be completed prior to establishing a post-development Risk. There are sufficient pre-existing long term erosional processes on Site to warrant mitigation measures.

| | | |
|---|---|---|
| Qualified Professional of Record | THOMAS R. ELLIOT PhD P.Geo, P.Ag<br>Name | <br>Sign |

Thomas R Elliot PhD P.Geo. P.Ag.




Digital reproduction, original available upon request.

Date: November 6, 2023

# 10.Closure and Limitations

The QP signatory to this assessment and report assures accuracy of existing and field observation, and evaluation of technical geohazard according to best practices of the Engineers and Geoscientists of BC. The content of this report are applicable to the subject land parcel, and specifically the Site as defined in this report. Any extension of the evaluation to areas outside of the defined area assessed are not valid.

The report has been conducted according to guidelines and reporting standards of similarly qualified professionals, given similar time and budget. At time of writing, the report meets due diligence and investigatory reporting requirements to provide QP recommendations with declared competency in the subject areas. Therefore, the author of this report does not maintain liability insurance for actions taken based on the reporting, and only accepts error and omission liability up to the value of this report. The receipt, utilization and any planning, further studies or development actions undertaken by the recipient of this report are based on their acceptance of their own liability therein.

# Appendix I

## Maps and Figures

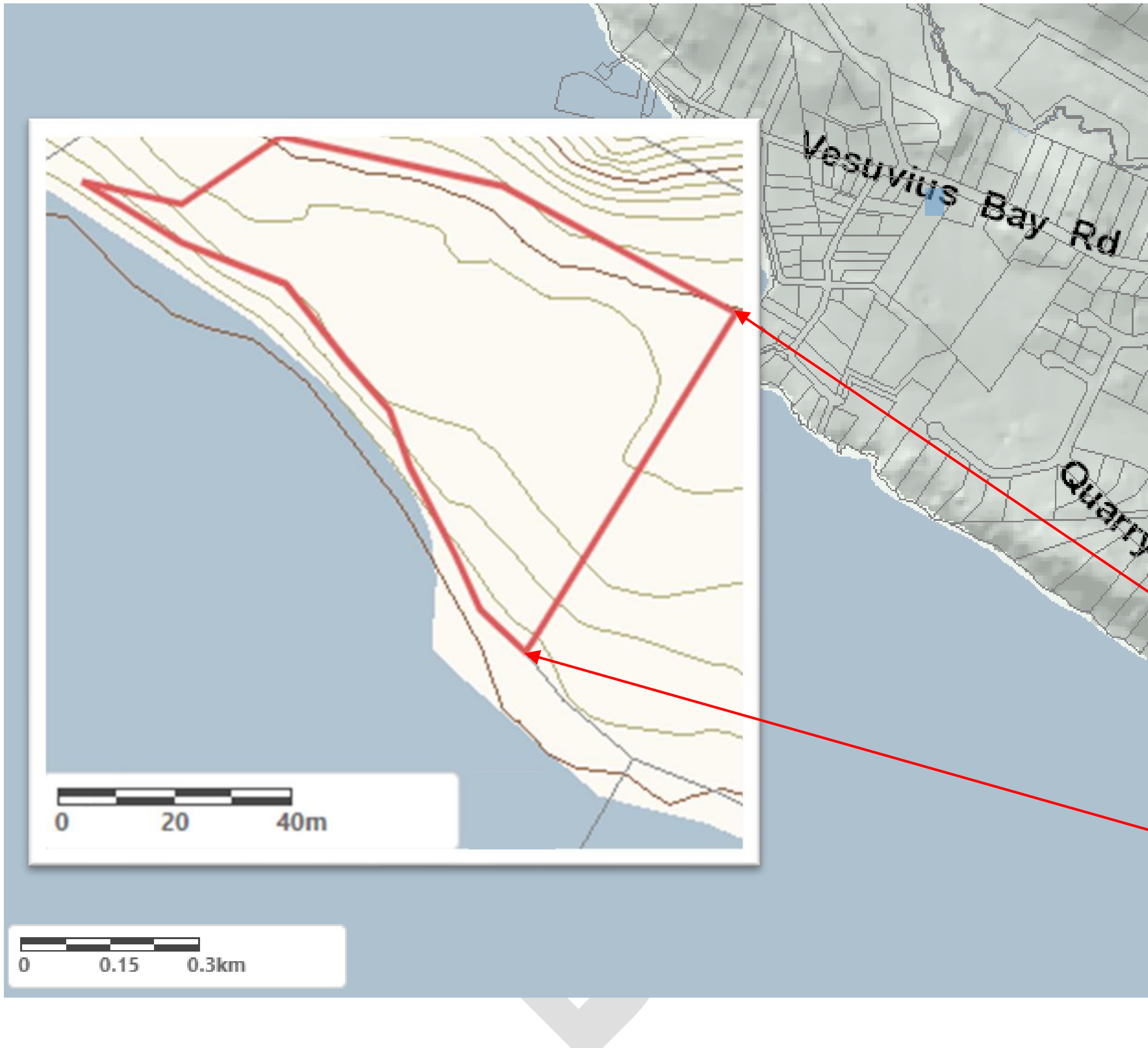



**Figure 1** – General area and map view of Site (red outline) with land parcel boundaries. The contours of the inset image and landform were used to complete geohazard assessment for this report.

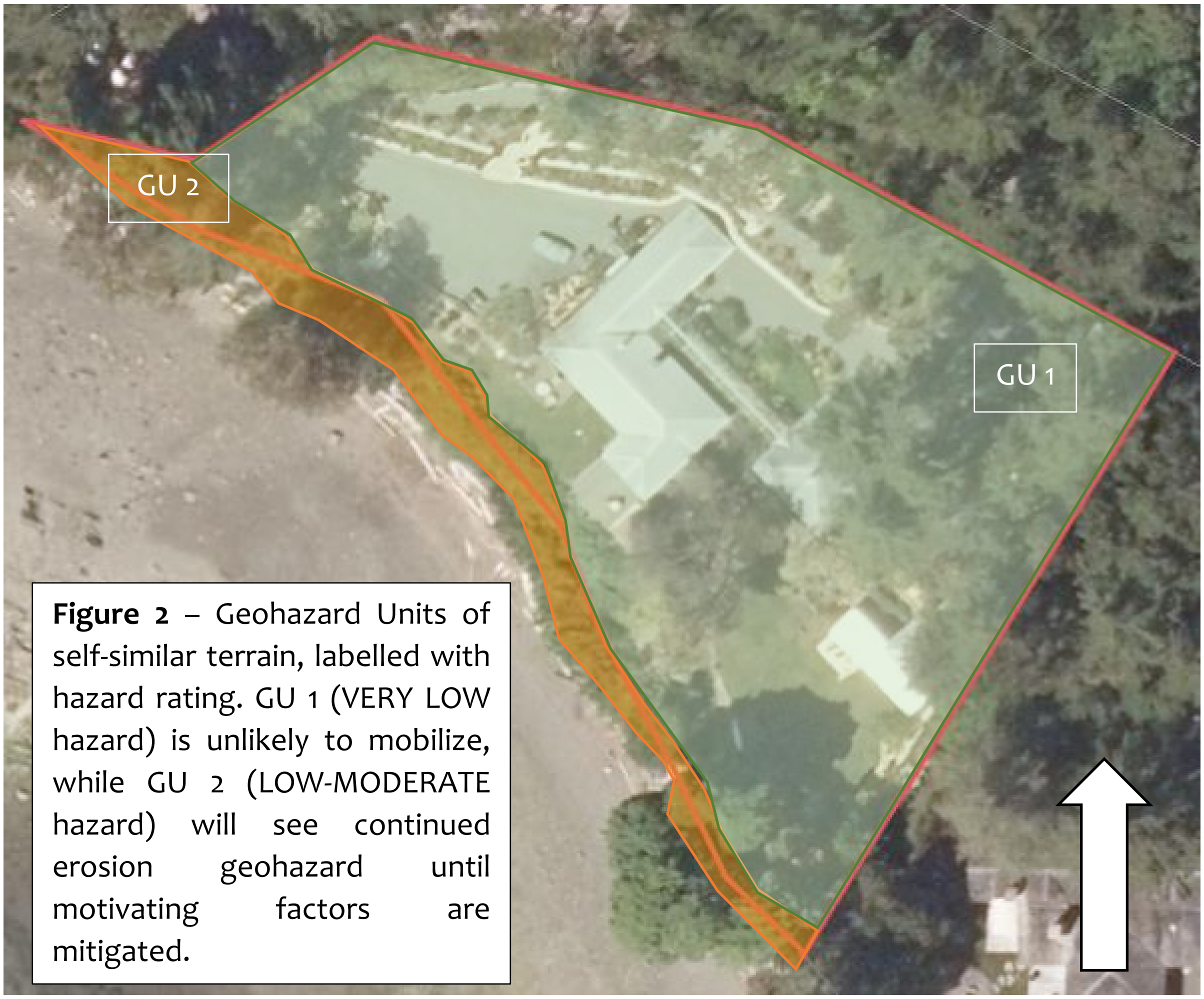



**Figure 2** – Geohazard Units of self-similar terrain, labelled with hazard rating. GU 1 (VERY LOW hazard) is unlikely to mobilize, while GU 2 (LOW-MODERATE hazard) will see continued erosion geohazard until motivating factors are mitigated.

# Appendix II

## Geohazards and Risk

## Geohazards

This assessment is partially based on local historic rates of landslide failure. The rating hazard of failures occurring in a given area under the classification system shown in Table II_a, below. By determining the likelihood of historic failures based on spatial density, the number of failures per unit area can be predicted. The likelihood of historic failures is determined through review of historic aerial imagery and general area observations while on the way to or from Site.

By establishing failure spatial density in the local area, in conjunction with Table II, the hazard rating can be estimated for areas undergoing development activities that impact terrain stability.

The hazard ratings were defined based on pre-existing practice by geoscientists and engineers for the natural resources sector, and adapted to best suit development activities governed by responsible municipal partners toward meeting those partner-organization risk tolerance policies.

Please note that, differing from resource sector terrain stability assessments, this evaluation of hazard includes failures smaller than 0.05 ha area (initiation, transport and deposit area). This is consequent to resource sector activities, and typically remote locations, being more tolerant of small-scale geohazard events. For this location, due to proximity to populated areas, and responsibility to meet municipal risk tolerance policies, the total area of a failure may be less than 0.05 ha in order to contribute to the hazard rating.

**Table II_a: Definitions of hazard categories**

| Hazard Category | # of failures per geohazard unit size |
|---|---|
| VERY HIGH | >1 failure per 2 ha |
| HIGH | 1 failure per 2 to 10 ha |
| MODERATE | 1 failure per 10 to 50 ha |
| LOW-MODERATE | 1 failure per 50 to 250 ha |
| LOW | 1 failure per 250 to 1250 ha |
| VERY LOW | <1 failure per 1250 ha |

Once the natural hazard of landslide for the area has been established, the probability of at least one failure occurring in a geohazard unit can be determined from Figure II_A.

Figure II_1 is based on the assumption that the probability of a specified number of failures occurring within a polygon is related to the size of the polygon by a cumulative normal distribution.

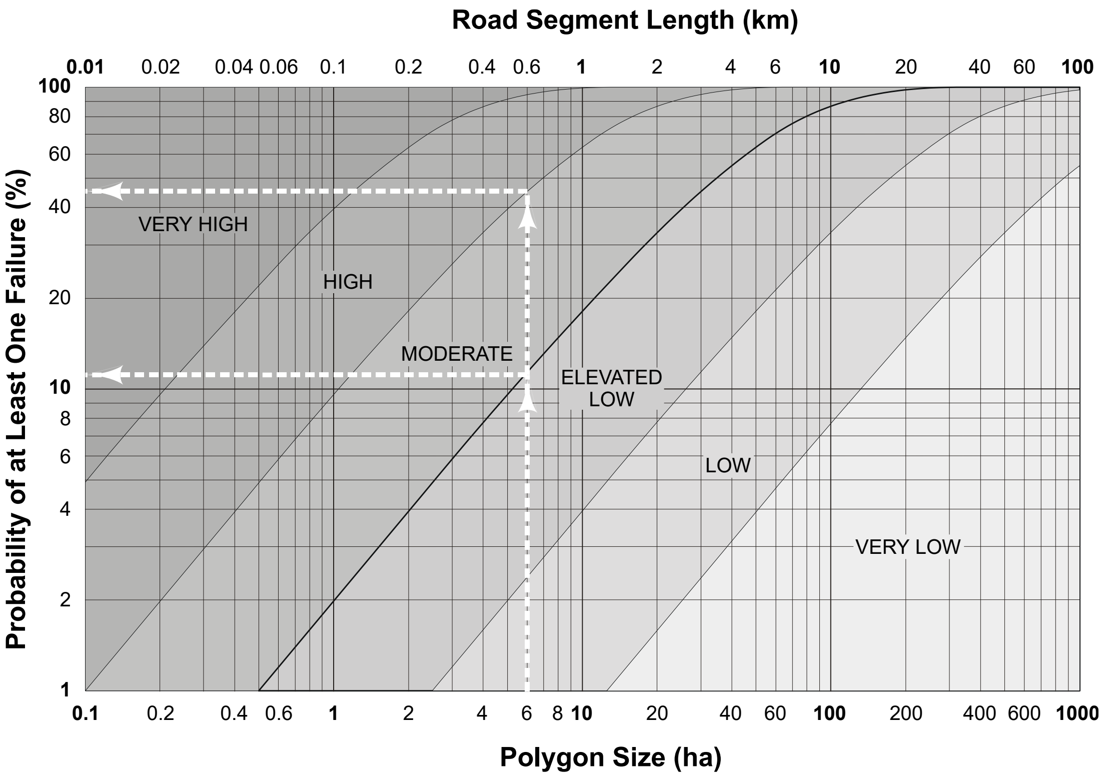



Figure II_1 – Probability of at least one failure based on a geohazard unit (GU) assessment area size or road length. This figure has been adopted from BC Forestry practices and is based on a single forestry harvest cycle, typically lasting 60 years within Coastal BC.

*Figure II_1 has an example sketched with dashed white lines. The example indicates probability of failure for a **6 ha** geohazard unit area with a **moderate** hazard rating. The probability of at least one failure occurring within the assessed geohazard unit area over the period of one forestry harvest cycle is between ~12 – 45%.*

## Consequence

### Simplistic Farböschung Evaluation

Whether or not a Site will be impacted by a geohazard is a component of determining consequence to potential landslide failures and/or debris flows. A simplistic assessment of transport and deposition zone locations can be accomplished through a 'Farböschung' evaluation. This is best exemplified through Figure II_B, which demonstrates how a sliding

mass (block on right hand side) has potential to transport some distance from point of initiation based on a simplistic assignment of Farböschung angle.

For this assessment, a Farböschung angle of 45% was used based on heuristic practice for these coastal environments and gravelly loam surficial material. By standing on Site at highest point of initiation, the QP was able to establish the approximate run-out distance to edge of the deposit zone.

A more Site specific example is provided in Figure II_C, which shows a benching bedrock terrain where a thin veneer of surface material is mobilized, and has limited transport and deposit distances based on the Farböschung angle.

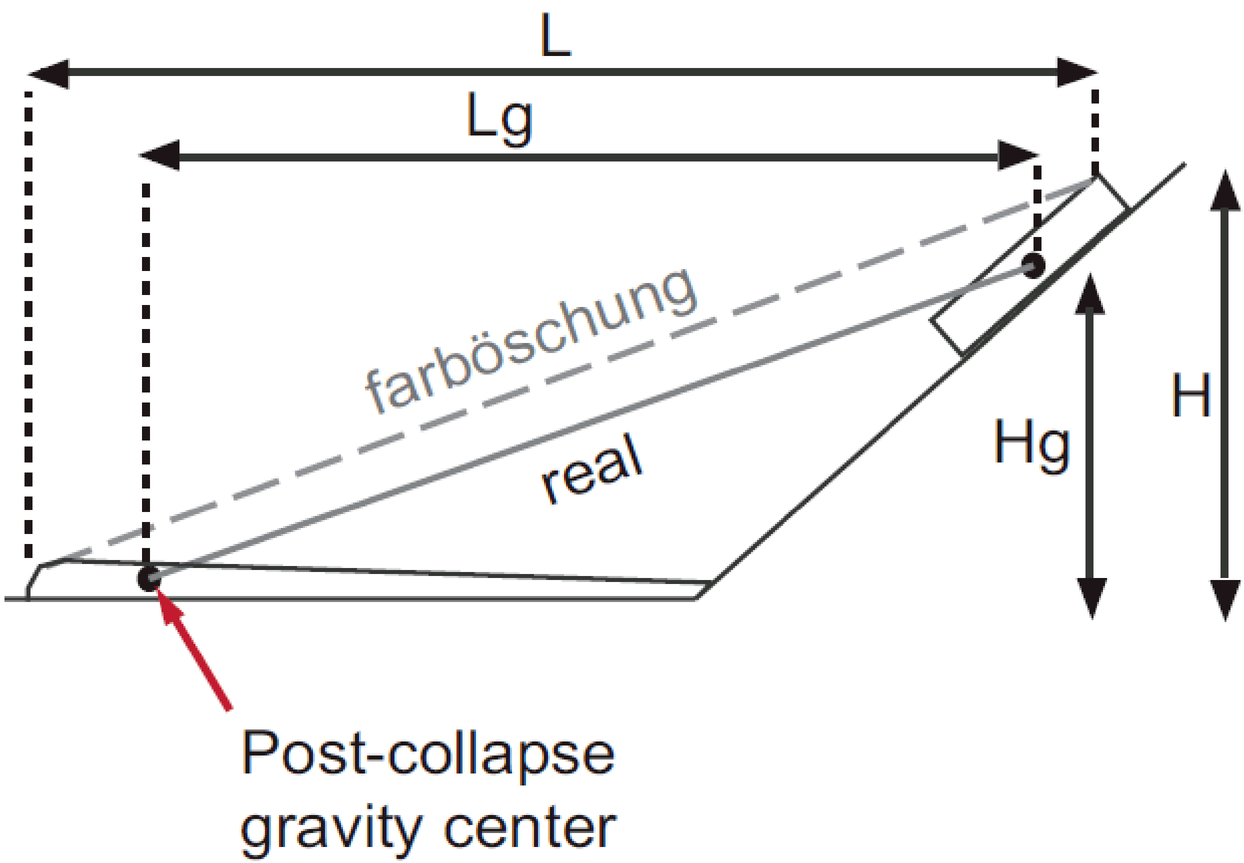



**Figure II_B** – Farböschung angle functionality for sliding masses on a slope. The specific mathematics of which are not supplied here for brevity.

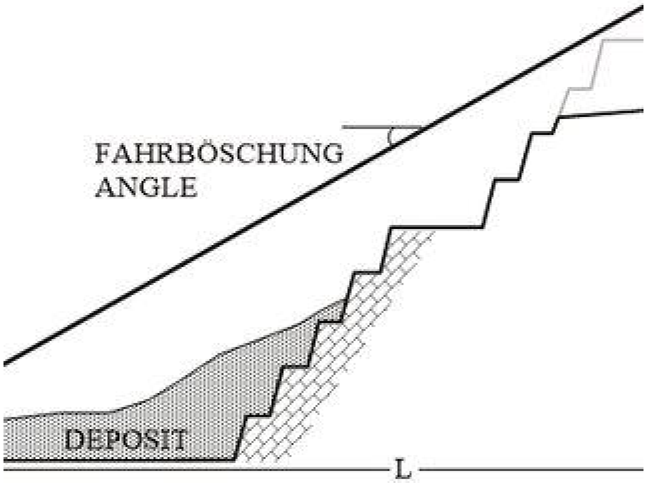



**Figure II_C** – An example of landslide runout and deposit area of potential geohazards on Site based on simplistic Farböschung assessment.

**Table II_b: Consequence**

| Consequence | Criteria |
|---|---|
| HIGH | Landslide material would directly enter fish habitat (stream, lake, or marine waters); water intake for domestic consumption; jeopardize lives of the public; impact major public infrastructure; or other property owner.<br><br>Landslide would enter non-fish stream within 500 m of fish habitat. |
| MODERATE | Landslide material enters non-fish stream > 500 m and < 3000 m from fish habitat, OR there is a slope < 20% for < 100 m below landslide to fish habitat; potable water intake; a public area; or other property owner. |
| LOW | Run-out slope < 20% for 100-200 m below landslide deposit area. At time of event, suspended sediment may reach fish habitat; potable water intake; public area, or other property owner |
| VERY LOW | Run-out slope < 20% for > 200 m below landslide. Landslide material is unlikely to reach stream or potable water intake at time of event. A landslide would not be a public safety concern; would not impact any infrastructure nor other property owner. |

## Post Development Activities Summary Table of Geohazards, Consequence and Risk on Site

### Risk

| Very Low | Low | GEOHAZARD | | | | |
|---|---|---|---|---|---|---|
| Moderate | High | VERY LOW | LOW | LOW - MODERATE | MODERATE | HIGH |
| GEOMORPHIC CONSEQUENCE | VERY LOW | *1* | | | | |
| | LOW | | | | | |
| | MODERATE | | | | | |
| | HIGH | | | **2** | | |

# Assessment of Marine Shoreline Characteristics

*As pertaining to areas seaward of land parcels:*

235 Quarry Drive PID 009-555-706
239 Quarry Drive PID 009-555-731
434 Baker Road PID 009-555-781
431 Baker Road PID 000-014-656

SALT SPRING ISLAND

# Report for Coastal Erosion Mitigation

Developed for: Aurora Professional Group
c/o Bradley Fossen P.Eng
338 Lower Ganges Rd UNIT 202
Salt Spring Island, BC V8K 2V3

Developed by: Thomas R Elliot PhD P.Geo P.Ag
TRE Environmental Services
tom@elliot.org

TRE Environmental Services

## 1. Synopsis

This assessment of marine shoreline was conducted using field, analytic and existing data to determine wave and sediment dynamics associated with erosion management of the coastline, as well as transport control of mobile sediments. These determinations are used to inform size distribution for sediment suitable for beach nourishment methods of erosion mitigation and transport control.

There are ~670m of hard armouring, or ~28.5% of the 2,350m shoreline within the drift-cell. Within the study area, there are ~70m of riprap and concrete, creating a ~14% hard-armoured coastline within the Site. This amount is considered to be moderate, where further erosion mitigation hard armouring would be discouraged by regulatory authorities.

There were two zones with distinct sediment size characteristics spread across the Site, for which there were sediment/gravel mixtures identified as being suitable for beach nourishment.

Lastly, the suitability of erosion mitigation and sediment transport control in context of Site factors and dynamics was evaluated. This evaluation encourages both continued monitoring and beach nourishment as suitable activities to pursue as part of erosion mitigation and sediment transport control.

## 2. Introduction

Landowners of four parcels adjacent to Baker Beach on Salt Spring Island have observed increased occurrence of punctuated erosion (e.g. landslide and landslip/tree-topple) and progressive erosion (e.g. plucking, thermal-jacking, or overland flow sediment mobilization). These landowners requested an assessment of the ~40m x 600m Site (Figure 1 – Appendix A), including existing foreshore and backshore characteristics, which informs sediment and wave dynamics. The assessment of foreshore and backshore dynamics will generate a drift-cell model for the Site. The drift-cell model will be used to evaluate suitability of proposed erosion mitigation measures at the end of this report.

This report is applicable to the foreshore and backshore seaward of the following land parcels:

| Common Address | Parcel Identification |
|---|---|
| **235 Quarry Drive** | PID 009-555-706 |
| **239 Quarry Drive** | PID 009-555-731 |
| **434 Baker Road** | PID 009-555-781 |
| **431 Baker Road** | PID 000-014-656 |

This report was written using existing and field-based data that provides spatial layout of the Baker Beach foreshore and backshore, generalized coastal zone sediment budget, beach particle size assessment and a drift-cell model summary.

### 2.1. Author Qualifications

Thomas R Elliot PhD is a Qualified Professional (QP) Geoscientist [# 43570] and Professional Agrologist [# 3045] registered within the Province of British Columbia and in good standing with both professional associations. The QP has 16 years of geohazard, soil science, near surface groundwater and hydrology. In the last 9 years, Thomas R Elliot has primarily worked on Vancouver Island and the Lower Mainland of British Columbia in the practice areas of [Geoscience]: Hydrogeology, Geohazard mitigation assessments, Soils/Groundwater management; and [Agrology] Soil science, Agriculture, and Contaminant detection, mitigation and remediation.

## 3. Standards of Practice for Marine Shorelines Management

The marine shorelines of British Columbia are subject to overlapping jurisdictional claims from municipal, provincial and federal government agencies. Despite the regulatory oversight, there are few guidance documents produced from Canadian sources that demonstrate best management practices from an integrated perspective which includes geophysical, ecologic and social/land use.

Some governmental agencies, such as Islands Trust (IT), who have adopted customized or standard guidance documents from Washington State Department of Fish and Wildlife[1]. Other non-governmental organizations have supported investigatory methods for detecting vulnerabilities and existing health status of shoreline environments[2].

This Assessment relies on existing guidance and approach methods that have been referenced by governmental agencies as being suitable for development planning and implementation practices within the BC coastal marine environment. Specifically, the determination and classification of marine shoreline and coastline dynamics, and consequentially which mitigation opportunities are suitable – is from the Marine Shore Design Guidelines[3]. Additionally, assessment and mitigation pathways identified have been considered in context of a Coastal Marine Strategy for British Columbia Policy Intentions

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[1] Your Marine Waterfront (Canadian Edition): https://islandstrust.bc.ca/document/your-marine-waterfront-guide-2023/ Accessed 11/2023.

[2] BC Parks Shoreline Sensitivity to Sea Level Rise Model: User Guide: https://a100.gov.bc.ca/pub/acat/documents/r42825/BCPark_SS_user_guide_1403632673820_3629261453.pdf

supported by the SeaChange Marine Conservation Society (https://seachangesociety.com/resources/). Accessed 11/2023.

[3] Washington Department of Fish & Wildlife Marine Shore Design Guidelines: https://wdfw.wa.gov/publications/01583. Accessed: 09/2023

Paper issued in December 2022[4]. In this report, the six outcomes identified in the Intentions Paper informed the assessment and mitigation options considered.

## 4. Scope, Context & Motivation

The purpose of this assessment is characterization of shoreline that will inform suitable marine coastline erosion mitigation measures which can be pursued on Site.

The motivation for this evaluation is to use sediment analysis and a drift-cell model in conjunction with reporting on ecology and geohazards to guide planning of erosion mitigation measures. The planning will be provided in subsequent reporting.

Additionally, there exists IT DPA 3 – Shoreline requirements for non-exempt development activities within 10m landward and 300m seaward of the marine-shoreline natural boundary. Therefore, if erosion mitigation recommendations are to occur within this DPA 3 area, there is a requirement to conduct characterization of existing conditions alongside demonstrably supportable recommendations for erosion mitigation.

The motivation to produce this report is to provide IT record of existing shoreline conditions, in partial or completion of IT DPA – 3 Shoreline requirements.

## 5. Shoreline Terminology, Site Delineation and Erosion Mechanisms

The shoreline area, as per IT DPA 3 definition, consists of a 300m coastal zone from the coastline, above which it extends into 10m of the uplands.

The Site includes the area of Baker Beach, as bracketed by public access, in addition to self-similar shoreline at both extents for a total ~600m of coastline (Figure 1 – Appendix A).

To best align this document with existing map products of shoreline delineation by IT, such as Saltspring Is. North Map 1 of 3: Distribution of Shoreline Types, Figure 3 was generated with identical classification and colour scheme.

Of the erosion mechanisms identified on Site from previous geohazard reports, the following are of note:

- Pore pressure/Groundwater Seepage from surficial soils, reducing cohesion and resulting in landward progression of the crest through continuous or punctuated mobilization of sediment.

[4] A Coastal Marine Strategy for British Columbia. https://engage.gov.bc.ca/app/uploads/sites/121/2022/12/Coastal-Marine-Strategy-Intentions-Paper.pdf. Accessed 11/2023.

- Toe-erosion of bedrock, or undercutting of shoreline sediment, which decreases stability of all materials above, often resulting in narrow failures from crest to base of coastal bluff.
- Landslip/Tree-topple is occurring on Site wherein trees near, or overhanging, the coastal bluff mobilize consequent to soil creep, pore pressure or toe-erosion. These failures result in a larger volume of surficial sediment during failure than toe-erosion instability reaching the crest. Consequent to root reinforcement or friability of bedrock, landslip is likely to mobilize underlying shale and siltstone.
- Landslide is a moderate to large scale failure event which can mobilize bedrock and overlying surficial sediment. Coastal landslide are often consequent to a history of toe-erosion, bedrock fracture and an increase in pore pressure (i.e. saturated soils & rock-fractures during a storm event) which has destabilized the coastal bluff in that area.

## 6. Shoreline Characteristics and Dynamics

This section presents details on the existing composition and quantifiable characteristics of the assessed marine shoreline. The following is a summary table of global characteristics, acquired from previous geohazard reporting[5], while details of each area are reviewed in subsequent relevant sections. Field assessment methods provided in Appendix A of this report.

**TABLE 1. GENERAL SHORELINE CHARACTERISTICS FROM PREVIOUS REPORTING**

| **Geology & Geomorphology** | |
|---|---|
| Geology | Siltstone to mudstone in upland, sandstone within coastal zone, of the Nanaimo group – which is an elevation-banded sedimentary and metamorphic rock assemblage. |
| Surficial Sediment | Well to rapidly drained sandy loam to loam belonging to the Galiano soil association is present at the coastline. |
| Landslide/Landslip activity frequency | Concentrated within areas of accelerated erosion, with a Site wide occurrence of 1 per ~40m of coastline. |
| Shore & beach type and beach features | *Shore type:* Rocky coastline bluff with variable elevation bedrock resulting in low rock/boulders, boulder/cobble and sea cliff natural coastline. There are structurally altered (i.e. hard armour) coastline up-drift, within and downdrift of the assessment area.<br>*Beach type:* The presence of bedrock within the coastal bluff and foreshore results in the Site being typified as a high tide reflective beach face fronted by intertidal rock flats (i.e. bedrock low-tide terrace). |

[5] Geohazard assessment for each land parcel, completed by TRE Environmental Services under separate cover. For reference and details, please refer to those reports.

| | |
|---|---|
| | *Features:* There exist two bedrock outcropping, nearly 40 – 50m from coastline at seaward extent of the low-tide terrace, which are in line with two ridges descending from uplands and consistent with the benching morphology of this shoreline geology. |
| **Ground and Surface Water** | |
| Watershed conditions | Single benching slope above the assessment area results in small-scale flow accumulations.<br>There are no identified streams, albeit there was some evidence of overland flow associated with high volume precipitation events. |
| Groundwater | Limited infiltration to bedrock results in perched water table within the veneer to mantle of surficial materials.<br>Perched water table causes increase pore water pressure at soil interface with air, decreasing soil stability. |

## 6.1. Hard Armouring

At respective distances of 115m and 490m northwest of Site, there are ~200m of groyne and ~300m of coastline-riprap hard armouring installations. Of these anthropogenic foreshore modifications, the groynes may be encouraging some sediment accumulation along the beach face by diffracting wave energy, albeit that poor installation has resulted in low sediment retention; while the riprap has reduced kinetic wave action on the shale and siltstone coastline, reducing supply from upland to the local coastal zone sediment system.

Down-drift from Site is ~80m of coastline-riprap on a sediment bar at the mouth of Booth Inlet. This hard-armouring restricts both progressive and punctuated sediment mobilization from the area by constricting flow to a narrowed channel, thus reducing fine-sediment supply to local shoreline.

There are three additional sections of hard armouring within Site: coastline-riprap placed at the northwest (10m) and southeast (30m) CRD access points, as well as along the coastline of 241 Quarry Rd (30m) – creating a ~14% hard-armoured coastline within the Site.

In total, the ~2,350m long drift-cell (see Section 6) – extending from Vesuvius Bay to the mouth of Booth Inlet – has ~670m of hard armouring, or ~28.5% of the local area shoreline.

## 6.2. Backshore

Indicators of a backshore are the presence of accumulated fine sediment and clasts, large littoral debris, sparse vegetation, and an area that is dry under normal conditions but exposed to wave action during storm events coinciding with high-tide. With this criterion, the backshore on Site was determined to have limited extent, often less than 1m in width and non-existent in some areas where there is continuous bedrock outcrop to the coastal bluff.

The backshore does not have sufficient width to create dunes or other geomorphic sediment accumulations. However, there exists minor clastic terrace deposits above the wrack line in sections of backshore that were contiguous with the beach face. There is sparse littoral and flotsam debris accumulated within the backshore, which is in contrast with the common to frequent presence of accumulated debris along up-drift sections of shoreline which have been historically armoured by rock groynes.

Sediment supply from uplands is principally delivered to the backshore as progressive erosion of coastline bedrock bluff. Sediment deposits from punctuated toe-erosion, landslip and landslide failures were also present in the backshore – some of which hosted perennial salt-tolerant vegetation, suggesting a multi-year existence. The persistence of these deposits through prior year storm-season (i.e. high wave energy and storm events) is a component of continuous sediment supply to Baker Beach.

## 6.3. Foreshore

The bedrock transition from shorerise to a ~3° gradient low-tide terrace is notably marked by the presence of two bedrock rises which present as 'barrier islands' for a portion of Baker Beach (see Figure 1). Under high tide conditions, these outcrops are fully submerged. The low-tide terrace is a wave-cut rock platform in siltstone and shale bedrock. The wave-cut platform has been created over the most recent eustatic sea level, in existence since the end of the last ice age ~8,000ybp.

Within the low-tide terrace there is a mixture of sediment and bedrock coverage, as shown in Figures 3 & 4 – Appendix A. The accumulation of sediment is facilitated by undulating bedrock surface, with depressions readily infilled. The infill presented cobbles and gravel surface armouring, with fine sediments captured and retained underneath. There is a typical progressive reduction in the amount of mobile gravel toward the seaward extent of low-tide terrace.

The 10 – 25m width of ~5° gradient continuous beach face across the Site is demarcated by a grading of accumulated sediment, from sparse cobbles and coarse gravel atop sand at the low-tide terrace interface, to fine gravel and sand at the backshore interface. Generally, there is a surface layer of mobile gravel which accumulates to greater depths toward the backshore interface. There is a wrack layer at the upper extent of the beach face, with accumulation of littoral debris by normal wave and tide-action.

The beach sediment is a broad mixture of boulder erratics emerging from sedimentary bedrock or upland surficial material through weathering, to gravel, coarse sand and limited fines. Further information on beach sediment is found in the Section 5.5 – Beach sediment analysis.

## 6.4. Wave dynamics

Wind-driven wave generation is largest in the west to northwest direction, creating acute incidence of approach. However, windrose diagrams (Figure 4) demonstrate a predominantly southwest to southeast winds that reach moderate velocity (≥6.0m/s). These predominant winds would form waves over a maximum 4.6km fetch. There are rarely occurring strong northerly to northwesterly winds recorded for the autumn period which would incur the maximum possible 13.5km fetch for the Site. The reference marine shoreline development guidelines recommend differentiating between Low, Moderate and High energy waves when fetch exceeds 1.6km & 8.0km (respectively) – therefore wind-driven wave energy on Site is determined to be Moderate.

Vessel-wake wave energy is predominantly from the most transited paths through the Sansum Narrows, and the regular Vesuvius-Crofton ferry. While there is large cargo vessel traffic to the nearby Crofton Mill, the lower frequency and low-speed manoeuvring does not contribute significantly to wave-energy delivered to Baker Beach. Due to the predominant angle of incidence, the vessel-wake do contribute to alongshore drift, moving fine sediment within the Drift cell.

Using equation 3 from Appendix B, typical wave velocity at high-tide across the rising low-tide terrace is determined to be 1.98m/s (7.12 km/h) resulting in a surging breaker classification. Surging breaker waves involve a progressive transfer of potential to kinetic energy across the coastal zone of Site.

Under storm event conditions where wind energy increases wave speed, wave type shifts to plunging breakers at steep shorerise, with the resulting whitewater traveling across the low-tide terrace and beach face as turbulent motion.

Based on sediment deposition patterns and distance from deep water, tidal currents do not have an apparent influence on wave dynamics at Site. Further, Booth Inlet – immediately east of the Site – is an ebb-tide delta with observable fine sediment accumulation. There is little evidence of increased fine sediment accumulation from the ebb-tide delta within the Site, demonstrated through beach sediment analysis, reinforcing that the drift-cell transports alongshore from northwest to southeast.

## 6.5. Beach sediment analysis and Beach Nourishment Sizing

Sediment analysis of the coastal zone samples were evaluated for size fraction (See Appendix C). Sediment analysis provides distribution across distinct size ranges for samples from the following delineated coastal zones: Coastline, Backshore terrace, Backshore face/wrack, Foreshore beach, and Nearshore crest.

Within the study area, the most consistent sediment size-composition (Graph C1) was found across the well sorted foreshore beach face (Figure 2). After which, the backshore face and backshore terrace demonstrate good size consistency (Graph C2, C3) across the Site. There is a clustered distribution of sediment composition for the nearshore samples (Graph C4), which demonstrate a zonation along the drift cell.

To better understand the zonation, sediment size was charted for each property (Graph C5 – C9) to determine if there are alongshore effects to be accounted for in beach nourishment sizing. This identified grouping of sediment sizes between property 1 and 5, as well as 3 and 6; suggesting similar wave action and resulting sediment transport processes in these areas.

Generalized Sediment Budget

The Site is of limited spatial area, and therefore can only receive sediment from a limited section of the coastline and intertidal terrace erosion. While there is some alongshore sediment transport within the drift-cell, the mobile size fraction – being fine sand to silts – was most prevalent in the nearshore adjacent land parcels further along in the drift-cell. This distribution indicates a fine sediment deposition zone in the eastern portion of the Site, which agrees well with geomorphic factors – such as the nearby confluence of Booth Inlet.

Coarse sand to stones are most readily supplied to Site by erosion of surficial materials in the coastline and uplands, accomplished through overland transport or failure of the coastal bluff. These sediment sources are limited in volume prior to when their transport to beach would encroach on built structure geohazard setbacks. As such, we can state that there will be a decrease in sediment supply from uplands, trending to zero in the long term, should safe use of the built structures be prioritized.

Sparse gravel coverage along the low tide terrace and beach face demonstrates a low supply and low loss environment. The deposits present were found to be armoured at surface with large clasts, finding sand and silt content deeper within the sediment profile. This suggests there is reworking of sediment within the drift-cell, but there does not appear to be sufficient force to transport the larger size range of sediment present out of the drift-cell.

In context, the drift-cell generalized sediment budget is low input/output, with primary loss – being fine sands to silts – through evacuation to off-shore. There is reworking of gravel present, although observed armouring and stratification of beach sediment profile indicates a heavily conserved higher clastic fragment size range.

From this generalized sediment budget, beach nourishment planning can be better focused on the larger sediment size ranges to ensure conservation of materials while including coarse sand to help stratification and armouring processes occurring on the beach face.

Beach Nourishment Sizing

Determining sediment size suitable for beach nourishment within the Site becomes more complex in context of a drift cell, where materials deposited to a portion of the Coastal Zone (Figure 2.) will disperse to adjacent zones and alongshore within the drift cell. This is a factor in determining both target-zone, and size range for beach nourishment. One suitable approach is to determine sediment size composition for beach nourishment through averaging of existing sediment within zones that will ultimately receive the material, weighted for the target deposition area.

Based on Client motivation, the target deposition area within Site would be the backshore face, where it is anticipated that there will be transport to backshore terrace and foreshore beach face. Additionally, there is no intention of placing easily transportable material – meaning that there will be no purposeful addition of silt to the beach nourishment, and coarse sand will be the smallest size fraction identified for placement.

Due to the previously identified zonation, there are two size ranges suitable for beach nourishment at the backshore face – as follows:

**Zone 1: Property 1 & 5**

| Percent Composition | Size Range | Common Name |
|---|---|---|
| 60% | 4.8mm+ | (30%) 20mm washed drain rock, (40%) 40mm washed crushed rock, (25%) 60mm washed crushed rock, (5%) 10 - 20cm round cobbles |
| 20% | 1.8mm to 4.7mm | 10mm washed rounded gravel |
| 20% | 1.7mm- | Fine to coarse sand |

**Zone 2: Property 3 & 6**

| Percent Composition | Size Range | Common Name |
|---|---|---|
| 45% | 4.8mm+ | (30%) 20mm washed drain rock, (40%) 40mm washed crushed rock, (25%) 60mm washed crushed rock, (5%) 10 - 20cm round cobbles |
| 20% | 1.8mm to 4.7mm | 10mm washed rounded gravel |
| 35% | 1.7mm- | Fine to coarse sand |

## 7. Drift Cell Model - Interpretation and Summary of Marine Shoreline Dynamics

The drift-cell of Baker Beach extends 2,350m from the rocky outcrops at south Vesuvius Bay to the mouth of Booth Inlet. This drift-cell is designated based on a common alongshore drift-current that transport sediments and has been generated by consistent waves approaching at oblique angles to the shoreline.

Baker Beach is currently supply limited, resulting in discontinuous sections of beach face, with long-term coastline retreat driven by wave, water and weathering erosion mechanisms. The beach features a bedrock intertidal terrace, over which a moderate alongshore drift-cell current provides low-volume sediment transport.

Consequently, the primary source of sediment for Baker Beach are sections of the adjacent upland coastal bluff, which contribute silt, sand, gravel and limited larger clastics up to boulders.

The delivery of sediment is through progressive erosion mechanisms and punctuated erosion mechanisms. Bedrock erosion produces angular to sub-angular coarse to fine gravel which is highly susceptible to further breakdown due to the fissility of shale – the predominant bedrock type. A variable mantle of ~0.5 – 3m of surficial material contributes sandy to silty loams, with clastic fragment (e.g. gravel, cobbles, stones) content up to 20% by volume. There are sparse stones to boulders on the beach which have weathered out of bedrock during formation of the low-tide terrace, or through erosion of the surficial uplands sediment mantle.

Sediment discharge from the drift-cell includes evacuation of mobilized sediment to off-shore depths, and limited wind-driven loss of fine sediment fraction from the backshore and uplands.

Alongshore sediment movement is facilitated by the low-tide terrace having a gentle slope and predominantly bedrock surface. Outside of the submerged low-tide terrace, alongshore sediment movement is very limited.

## 8. Suitability of Erosion Mitigation and Sediment Transport Management Recommendations

Previous reporting on geohazards[5] identified erosion mechanisms and developed recommendations for mitigation. This report has assessed shoreline and sediment processes, culminating in a drift-cell model which differentiates between prevalent kinetic forces (i.e. wave, wind, current & weathering) and results in a generalized sediment budget for Baker Beach.

In this section, the recommended erosion mitigation options are evaluated for suitability in context of existing conditions and drift-cell model. Suitability is a high, moderate and low ranking based on evidence gathered through this and preceding reporting.

The following table is evaluation of activity suitability for mitigation of erosion and management of sediment transport in the Site foreshore.

**TABLE 2. SUITABILITY OF EROSION MITIGATION AND SEDIMENT TRANSPORT RECOMMENDATIONS MADE UNDER PREVIOUS GEOHAZARD REPORTING.**

| | Suitability | | | |
|---|---|---|---|---|
| **Mitigation or Management Activity** | **Foreshore** | **Backshore** | **Wave Dynamics** | **Sediment Supply** |
| **Monitoring rate of erosion** | High<br>Monitoring captures multi-seasonal natural cycles. | High<br>Monitoring captures multi-seasonal natural cycles. | High<br>Direct capture of data. | High<br>Capture seasonal fluctuation in sediment transport. |
| **Bioengineering and selective planting** | Low<br>Very challenging establishment conditions. | Moderate<br>Shelter and stabilization of sloughed surficial material and bedrock. Challenging establishment conditions. | Moderate<br>Bioengineered and root reinforcement of sedimentary coastline. Overhanging vegetation would shelter bedrock from weathering. | Low<br>Mitigation activity would reduce primary sediment supply to beach. |
| **Wave deflection** | Moderate<br>Reduces incident wave energy reaching backshore. Close placement to be uniformly effective. | Low<br>Would constitute hard armouring in coverage required to be effective. | Moderate<br>Moderate energy wave conditions and presence of discontinuous backshore de-prioritizes this option. | Moderate<br>Reduces incident wave energy reaching backshore. Reduces amount of sediment supplied to beach. |
| **Beach Nourishment** | High<br>Post-placement in the backshore, natural transport of sediment would supply the foreshore. | High<br>Placement in the backshore would reduce wave energy reaching coastline. | Moderate<br>Moderate wave energy would evacuate some of placed sediment. | Moderate<br>Subsidize existing natural supply, reduces natural sediment supply. Would need re-supply in future. |

The interaction with Site ecology, efficacy and ease of implementation and maintenance of these recommended mitigation options should be carefully considered in context of Marine Shoreline Design Guidelines.

## 9. Summary

This assessment of Baker Beach and surrounding area marine shoreline has characterized shoreline, wave dynamics, erosion and sediment supply of the area which constitutes a drift-cell. Within Site, detailed foreshore and backshore characteristics were established from field and existing data.

Analysis of beach sediments has identified a zonated drift-cell with deposition of fine sediments in the eastern portion of the Site. The drift-cell generalized sediment budget is low input/output, with primary loss – being fine sands to silts – through evacuation to off-shore. There were two distinct sediment-size distributions identified that would be suitable for beach nourishment activities.

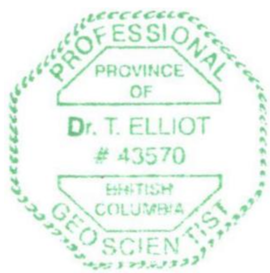
A drift-cell model was developed for the Site, which establishes sediment supply and transport mechanisms present. Using the drift-cell model, a suitability evaluation of erosion mitigation and transport management activities was undertaken for the Site with explanatory rationale demonstrating whether particular recommendations would be viable in context.

Despite moderate energy wave conditions on Site, a limited sediment supply exists due to the low amount of global sediment movement brought about by tidal currents and lack of up-drift sediment sources.

A comparison of activity suitability from this assessment with a similar suitability evaluation based on geohazards and ecology would be instrumental when applying the reference Marine Shoreline Development Guidelines.

| | | |
|---|---|---|
| Qualified Professional of Record | THOMAS R. ELLIOT PhD P.Geo, P.Ag<br>Name | Sign |

Thomas R Elliot PhD P.Geo. P.Ag.




Date: December 18, 2023

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# *Closure and Limitations*

The QP signatory to this assessment and report assures accuracy of existing and field observation, and evaluation of technical geohazard according to best practices of the Engineers and Geoscientists of BC. The content of this report are applicable to the subject land parcels, and specifically the Site as defined in this report. Any extension of the evaluation to areas outside of the defined area assessed are not valid.

The report has been conducted according to guidelines and reporting standards of similarly qualified professionals, given similar time and budget. At time of writing, the report meets due diligence and investigatory reporting requirements to provide QP recommendations with declared competency in the subject areas. Therefore, the author of this report does not maintain liability insurance for actions taken based on the reporting, and only accepts error and omission liability up to the value of this report. The receipt, utilization and any planning, further studies or development actions undertaken by the recipient of this report are based on their acceptance of their own liability therein.

# *Appendix A*

## Maps and Figures

**Figure 1. Assessment area**

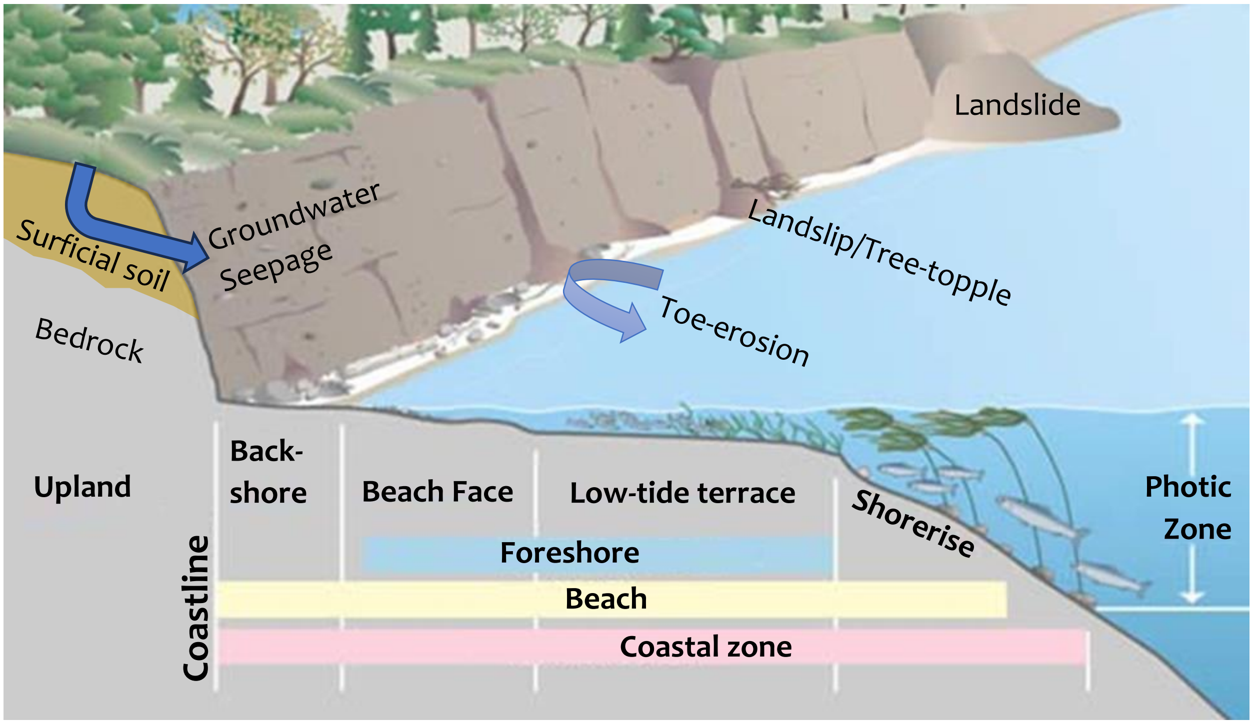
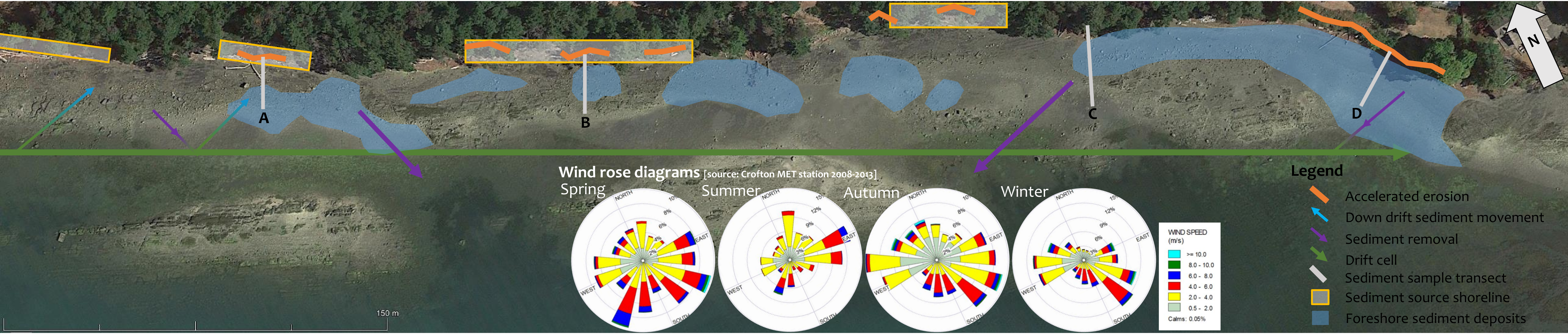



**FIGURE 2. CONTEXTUAL DELINEATION OF THE SITE WITH RELEVANT TERMINOLOGY TO ASSIST WITH READING OF THIS REPORT. THE COMPONENTS OF THE COASTAL ZONE AND UPLANDS ARE INDICATED ALONG WITH ACTIVE EROSION MECHANISMS. ADAPTED FROM: KING COUNTY NEARSHORE ENVIRONMENTS, CENTRAL PUGET SOUND, WASHINGTON STATE.**

## Figure 3. Shoreline types, sediment transects and bedrock outcroppings

## Figure 4. Sediment dynamics, drift-cell current, and windrose diagrams



# *Appendix B*

Methods and Rationale

# *Field and Analytic Methods*

**Field Methods**

Two field days were used to characterize the Site.

Day One: Characterization of geology, geomorphology, wave dynamics, sediment dynamics, and documentation of soil and bedrock erosion/evidence of groundwater.

Day Two: foreshore delineation and beach sediment sampling along Transects A – D, as shown in Figure 3 & 4.

Beach sediment sampling

Sediment samples were collected using appropriate tools, ensuring they represent the area of interest accurately.

A 250mL silicon container was used to collect uniform volume of trowel-excavated (to a depth of 10cm where existent) grab samples from beach sediments at specific locations, as follows: backshore, beach face, low-tide terrace, and shorerise.

The distance from coastline to each sample location was measured alongside multiple GPS enabled photographs which are used to document the precise location.

Each sample was codified, and placed in a sample bag.

The samples were retained in a cool environment until analytic testing (see below).

**Analytic Methods**

The process of drying and fractioning sediment typically involves the following standard methods:

Drying: The collected sediment samples are spread out in thin layers and set to air dry at a low temperature (usually around 105°C). This process removes moisture from the samples without significantly altering the composition.

Sieving: Dried sediment is sieved through various mesh sizes to fractionate the particles based on their size. This can range from very fine sieves for clay particles to coarser sieves for sand and gravel fractions.

Particle Size Analysis: After sieving, the fractions are weighed and analyzed to determine the percentage of different particle sizes in each fraction. This analysis may involve techniques such as sedimentation, laser diffraction, or microscopic examination to precisely determine particle size distribution.

Organic Matter and Mineral Content Analysis: Sediment fractions were not evaluated for organic content. Mineral composition was determined by hand-lens heuristic assessment to general rock type.

Data Interpretation: The results obtained from these analyses are used to characterize the sediment, understand its properties, and make inferences about its origin, quality, and potential uses or impacts in various contexts.

# *Rationale*

**Wave Dynamics**

Wave generation proximal to Site is by two mechanisms: wind and vessel-wake. Wind-generated waves are formed off-shore, above deeper water, oriented in the predominant wind direction of the area, which is shown for Site in Figure 4 seasonal windrose diagrams[6].

Vessel-wake waves are generated by marine traffic, forming short-period, steep sided wave-trains with moderate height that move quickly across open waters. Larger vessels initiate wave-trains that compound to amplify height, which can exceed wind-generated waves in areas with short-fetch.

Waves generated by wind above deep water are typically short-period, with steep sides, with relatively tall height that move slower during wind-driven generation. Transition to swell waves occurs as the proto-waves concatenate in the orientation of predominant wind as modified by any coastal-reflection. Swell waves are longer, faster and uniformly spaced as they approach coastal environments, whereupon contact with the rising bedrock causes them to shoal and break. The contact with bedrock in shallow waters also starts to re-orients the incoming swell waves to be more perpendicular to the coastline due to refractive waves.

The potential energy contained within swell waves are released as kinetic energy through this shoal and break mechanism. Typically, the wave height (H, trough to crest), period (T, time for crest to crest to pass), length (L), and velocity (C) are related to each other through the following equations:

[6] It should be noted that the weather-station which acquired wind data for the windrose diagrams shown in Figure 4 is situated at the coastline of Crofton, on the west side of Sansum Narrows – opposite to Site at a distance of 3.8km, and as such the weather-station location will be subject to a wind regime modified by local topography that over-represents winds coming from off-shore – although general trends in wind direction would be consistent for both the meteorological station and Baker Beach.

| | | |
|---|---|---|
| **Eq. 1** | L = 1.56 T | wave length |
| **Eq. 2** | C = 1.56 $T^2$ | off-shore wave velocity |
| **Eq. 3** | C = sq.rt.(g*d) | near-shore wave velocity, where g is gravitational constant, d is depth of water |

wherefrom velocity can be used as general proxy for mechanical energy conveyed by waves.

Transferral of wave potential energy to kinetic energy at the foreshore and coastline is, in part, dependent on the angle of incidence ($\alpha$), as the measurement of wave alignment to perpendicular from coastline. When waves enter the break and swash zone at oblique angles, the momentum gradient in the alongshore direction produces an alongshore current typically known as a drift current. This current advects sediment mobilized by a combination of wave motion and turbulent motion in the alongshore direction. The alongshore current forms the fundamental component of a Drift Cell, which is a representation of wave, current, tidal and transport processes – ultimately determining distribution of sediment within the Site.

Tides influence waves and kinetic energy delivered to coastlines by altering the shoal and break mechanism through adjustment of the water depth in the foreshore (i.e. high vs. low tide). Exceptionally high tides, typically corresponding to full or new moons, are contributory to backshore composition and configuration due to this increased depth and concurrent wave activity which can reach the backshore.

Tidal currents are critical to supply of fine sediment for drift cells, and within regional proximity to Site there are Department of Fisheries and Oceans current predictions[7] which indicate a low to moderate tidal effect throughout the Gulf Islands on the east coast of Vancouver Island. Due to Site being off-set from a main tidal channel, the influence on sediment budget is anticipated to have a lesser effect than a similar site more exposed to tidal current.

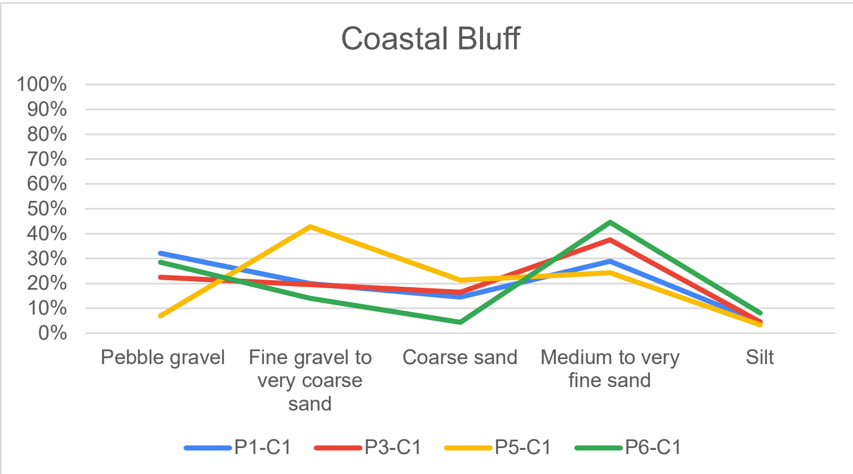
The angle of waves incidental to Site is such that a considerable amount of wave-energy is reflected, or disrupted, from Baker Beach during high tide – resulting in a reduction to incoming moderate wave energy and therefore less kinetic erosion on bedrock and sediment coastline, as well as lower energy evacuation of water from the shoreline. During low-tide conditions, the shoreline bedrock terrace is above sea level, restricting the amount of kinetic energy transferred to the bedrock and sediment coastline.

[7] Canada Department of Fisheries and Oceans. Current Predictions by Station: https://tides.gc.ca/en/current-predictions-station utilizing Gabriola Passage [43km distant], Porlier Pass [17km distant] as indicators. Accessed October 2023.

# *Appendix C*

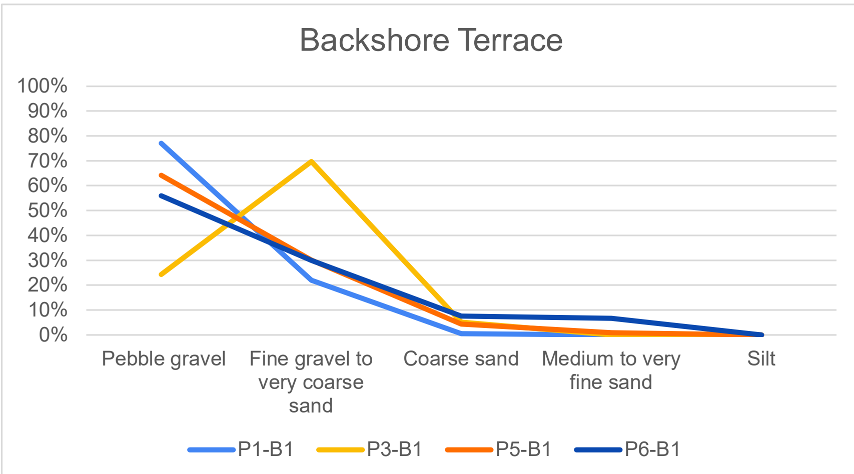
## Sediment Analysis

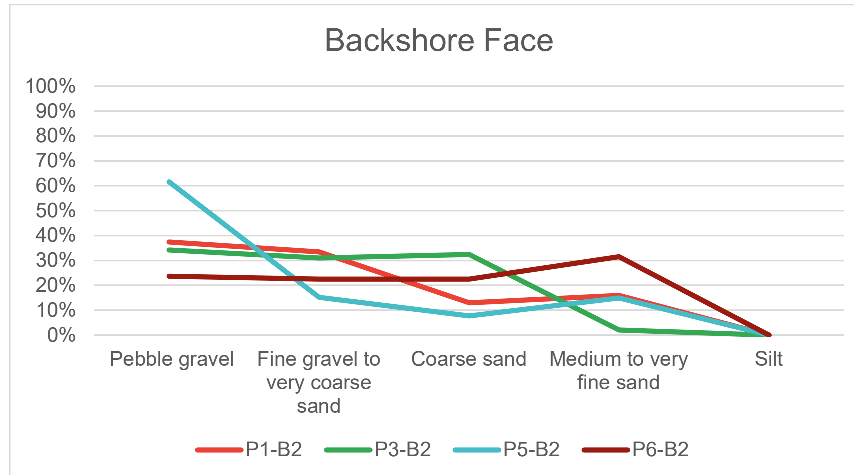
| Date | Sector | m | Wet Weigl | Dry Weigh | XL(g) | Pebble gr | L (g) | Fine grave | M(g) | Coarse sa | S(g) | Medium tc | XS(g) | Silt | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1-C1 | n/a | 221 | 221 | 71 | 32% | 44 | 20% | 32 | 14% | 64 | 29% | 10 | 5% | |
| | P3-C1 | n/a | 204 | 200 | 45 | 23% | 39 | 20% | 33 | 17% | 75 | 38% | 9 | 5% | |
| | P5-C1 | n/a | 280 | 271 | 19 | 7% | 116 | 43% | 58 | 21% | 66 | 24% | 9 | 3% | |
| | P6-C1 | n/a | 193 | 186 | 53 | 28% | 26 | 14% | 8 | 4% | 83 | 45% | 15 | 8% | |



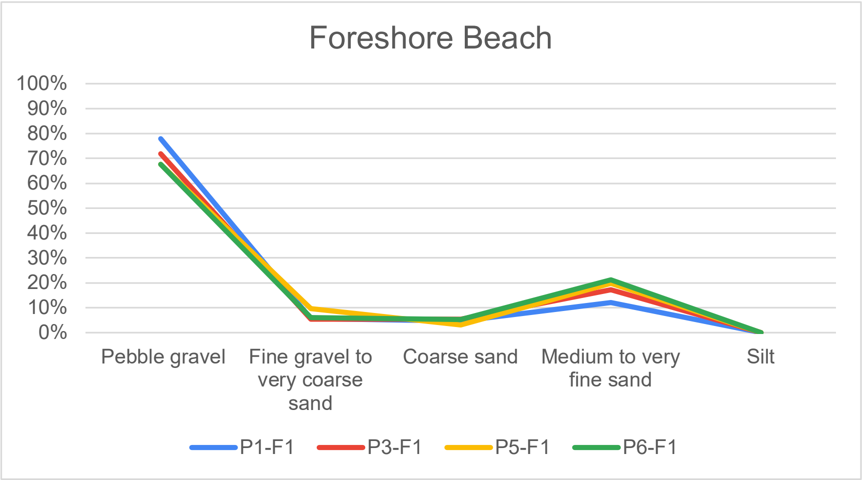

| | Size Range (mm) | | Wentworth Classification |
|---|---|---|---|
| XL | | 4.7498 | Pebble Gravel |
| L | 4.7497 | 1.8288 | Granule Gravel to Very Coarse Sand |
| M | 1.8287 | 0.762 | Coarse Sand |
| S | 0.7619 | 0.0737 | Medium sand to very fine sand |
| XS | 0.0736 | | Silt |

| Date | Sector | m | Wet Weigh | Dry Weight | XL(g) | Pebble gra | L (g) | Fine gravel | M(g) | Coarse sar | S(g) | Medium to | XS(g) | Silt | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1-B1 | 0.65 | 322 | 322 | 248 | 77% | 71 | 22% | 2 | 1% | 0 | 0% | 0 | 0% | |
| | P1-B2 | 2.9 | 352 | 337 | 126 | 37% | 113 | 34% | 44 | 13% | 54 | 16% | 0 | 0% | |
| | P3-B1 | 2.26 | 367 | 367 | 89 | 24% | 256 | 70% | 19 | 5% | 0 | 0% | 0 | 0% | |
| | P3-B2 | 5.09 | 346 | 333 | 114 | 34% | 103 | 31% | 108 | 32% | 7 | 2% | 0 | 0% | |
| | P5-B1 | 1.71 | 316 | 316 | 203 | 64% | 95 | 30% | 14 | 4% | 3 | 1% | 0 | 0% | |
| | P5-B2 | 4.54 | 375 | 375 | 231 | 62% | 57 | 15% | 29 | 8% | 56 | 15% | 0 | 0% | |
| | P6-B1 | 1.71 | 355 | 343 | 192 | 56% | 103 | 30% | 26 | 8% | 23 | 7% | 0 | 0% | |
| | P6-B2 | 4.66 | 332 | 317 | 75 | 24% | 71 | 22% | 71 | 22% | 100 | 32% | 0 | 0% | |

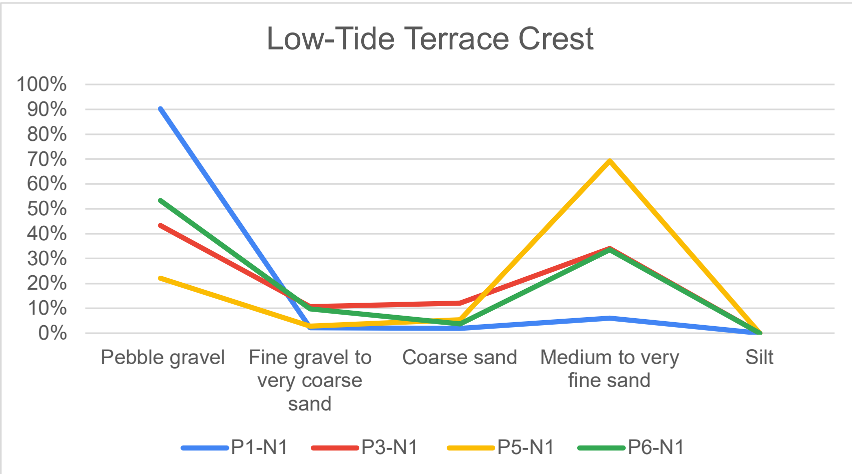


| Date | Sector | m | Wet Weigh | Dry Weight | XL(g) | Pebble gra | L (g) | Fine gravel | M(g) | Coarse sar | S(g) | Medium to | XS(g) | Silt | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1-F1 | 9.63 | 424 | 404 | 315 | 78% | 23 | 6% | 19 | 5% | 49 | 12% | 0 | 0% | |
| | P3-F1 | 8.64 | 462 | 442 | 318 | 72% | 24 | 5% | 24 | 5% | 76 | 17% | 0 | 0% | |
| | P5-F1 | 10.95 | 408 | 390 | 264 | 68% | 38 | 10% | 12 | 3% | 77 | 20% | 0 | 0% | |
| | P6-F1 | 10.88 | 482 | 457 | 309 | 68% | 28 | 6% | 24 | 5% | 97 | 21% | 0 | 0% | |



| Date | Sector | m | Wet Weigh | Dry Weigh | XL(g) | Pebble gra | L (g) | Fine gravel | M(g) | Coarse sar | S(g) | Medium to | XS(g) | Silt | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1-N1 | 15.7 | 569 | 556 | 502 | 90% | 12 | 2% | 11 | 2% | 33 | 6% | 0 | 0% | |
| | P3-N1 | 17.98 | 465 | 422 | 183 | 43% | 45 | 11% | 51 | 12% | 144 | 34% | 0 | 0% | |
| | P5-N1 | 15.18 | 353 | 284 | 63 | 22% | 8 | 3% | 15 | 5% | 197 | 69% | 0 | 0% | |
| | P6-N1 | 18.87 | 466 | 439 | 234 | 53% | 43 | 10% | 16 | 4% | 147 | 33% | 0 | 0% | |



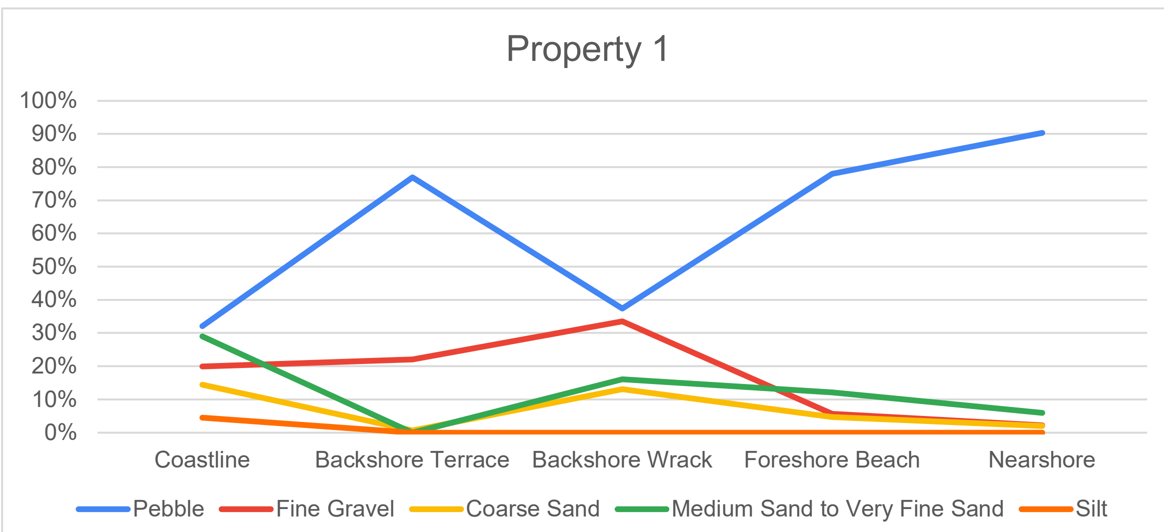
| | | |
|---|---|---|
| **Deposit Area Weighting Scheme:** | Weight | Areas impacted by deposit |
| | 10 | Backshore Terrace |
| | 60 | Backshore Face |
| | 30 | Foreshore Beach Face |

| **Aggregate Mix #1 (Property 1 & 5)** | | |
|---|---|---|
| 59% | 4.8mm+ | Drain |
| 20% | 1.8 to 4.7mm | pea |
| 22% | fine to coarse sand | fine to coarse sand |

## Property 1

| | Coastline | Backshore | Backshore | Foreshore | Nearshore |
|---|---|---|---|---|---|
| Pebble | 32% | 77% | 37% | 78% | 90% |
| Fine Gravel | 20% | 22% | 34% | 6% | 2% |
| Coarse Sand | 14% | 1% | 13% | 5% | 2% |
| Medium Sand to Very Fine Sand | 29% | 0% | 16% | 12% | 6% |
| Silt | 5% | 0% | 0% | 0% | 0% |

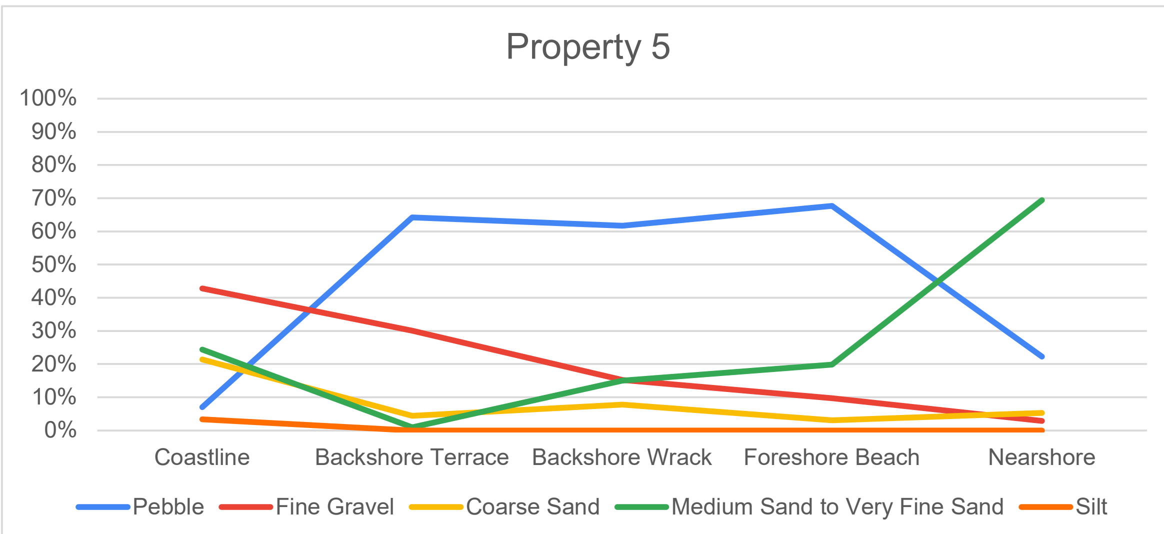
| Recommended Composition | |
|---|---|
| Pebble | 54% |
| Fine Gravel | 24% |
| Coarse Sand | 9% |
| Medium Sand to Very Fine Sand | 13% |
| Silt | 0% |



## **Property 5**

| | Coastline | Backshore | Backshore | Foreshore | Nearshore |
|---|---|---|---|---|---|
| Pebble | 7% | 64% | 62% | 68% | 22% |
| Fine Gravel | 43% | 30% | 15% | 10% | 3% |
| Coarse Sand | 21% | 4% | 8% | 3% | 5% |
| Medium Sand to Very Fine Sand | 24% | 1% | 15% | 20% | 69% |
| Silt | 3% | 0% | 0% | 0% | 0% |

| Recommended Composition | |
|---|---|
| Pebble | 64% |
| Fine Gravel | 15% |
| Coarse Sand | 6% |
| Medium Sand to Very Fine Sand | 15% |
| Silt | 0% |



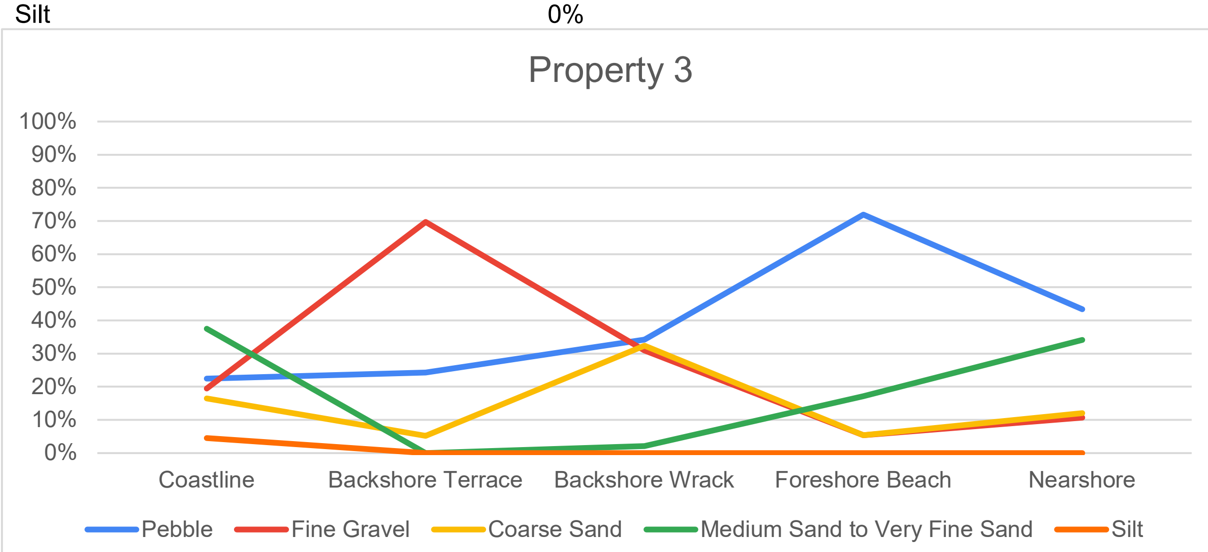
| Sediment Size Range (mm) | | Wentworth Classification |
|---|---|---|
| + | 4.7498 | Pebble Gravel |
| 4.7497 | 1.8288 | Granule Gravel to Very Coarse Sand |
| 1.8287 | 0.762 | Coarse Sand |
| 0.7619 | 0.0737 | Medium sand to very fine sand |
| 0.0736 | - | Silt |

| Aggregate Mix #2 (Property 3 & 6) | | |
|---|---|---|
| 42% | 4.8mm+ | Drain |
| 23% | 1.8 to 4.7mm | pea |
| 35% | fine to coarse sand | fine to coarse sand |

## Property 3

| | Coastline | Backshore | Backshore | Foreshore | Nearshore |
|---|---|---|---|---|---|
| Pebble | 23% | 24% | 34% | 72% | 43% |
| Fine Gravel | 20% | 70% | 31% | 5% | 11% |
| Coarse Sand | 17% | 5% | 32% | 5% | 12% |
| Medium Sand to Very Fine Sand | 38% | 0% | 2% | 17% | 34% |
| Silt | 5% | 0% | 0% | 0% | 0% |

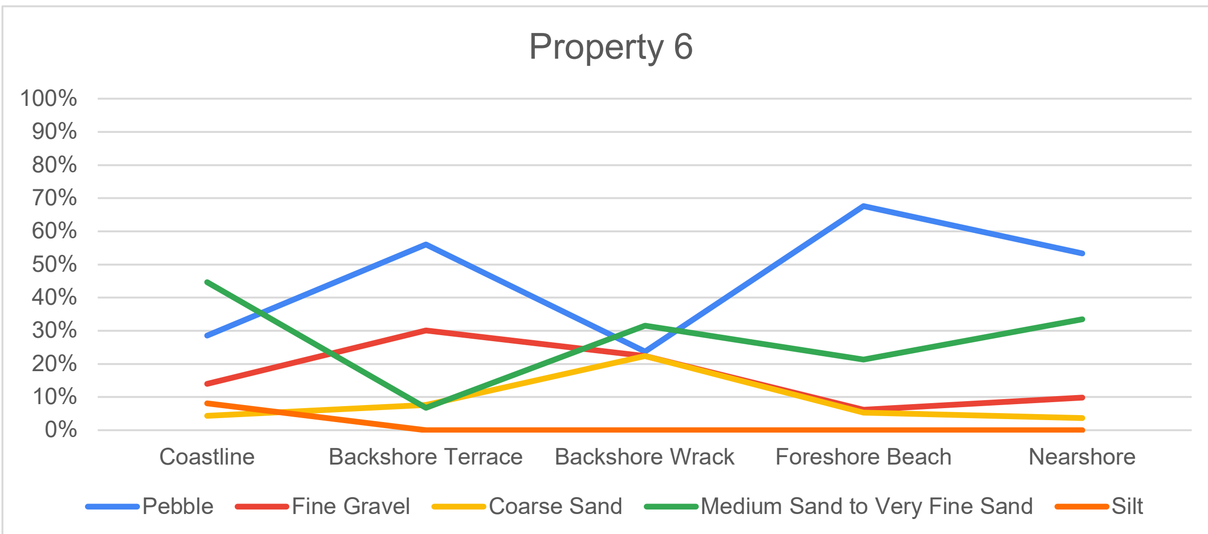
| Recommended Composition | |
|---|---|
| Pebble | 45% |
| Fine Gravel | 27% |
| Coarse Sand | 22% |
| Medium Sand to Very Fine Sand | 6% |
| Silt | 0% |



## **Property 6**

| | Coastline | Backshore | Backshore | Foreshore | Nearshore |
|---|---|---|---|---|---|
| Pebble | 28% | 56% | 24% | 68% | 53% |
| Fine Gravel | 14% | 30% | 22% | 6% | 10% |
| Coarse Sand | 4% | 8% | 22% | 5% | 4% |
| Medium Sand to Very Fine Sand | 45% | 7% | 32% | 21% | 33% |
| Silt | 8% | 0% | 0% | 0% | 0% |

| Recommended Composition | |
|---|---|
| Pebble | 40% |
| Fine Gravel | 18% |
| Coarse Sand | 16% |
| Medium Sand to Very Fine Sand | 26% |
| Silt | 0% |




**235 Quarry Drive:**

Progressive sloughing of surficial soil, driven by stormwater seepage.

Minor toe erosion of friable bedrock present at this location.


## 239 Quarry Drive:

Bedrock at coastline has dipped, as shown by dashed line, exposing surficial soil to wave action and spray-erosion, under-cutting protective root-masses. Presence of large woody debris is a benefit, but transient.


## 434 Baker Road:

*Background*: surficial soil vulnerable to wave erosion rising from bedrock. Undercut root-masses overhanging.

*Foreground*: Presence of a natural ‘rock cluster’, which has been recommended to be reproduced during the proposed beach nourishment program.


## 431 Baker Road:

Lack of bedrock at surface in this location allows for undercutting of root mass which constitutes the shoreline along this property. Some undercuts were observed to be greater than 1.0m in depth.

| ADDRESS | OWNERS |
|---|---|
| 235 QUARRY DRIVE | HEIDI KUHRT & DAVID KUHRT |
| 239 QUARRY DRIVE | TRISH SANDERS & BRUCE SANDERS |
| 434 BAKER ROAD | ETHAN WILDING |
| 431 BAKER ROAD | JEREMY & CLAIRE SICHERMAN |

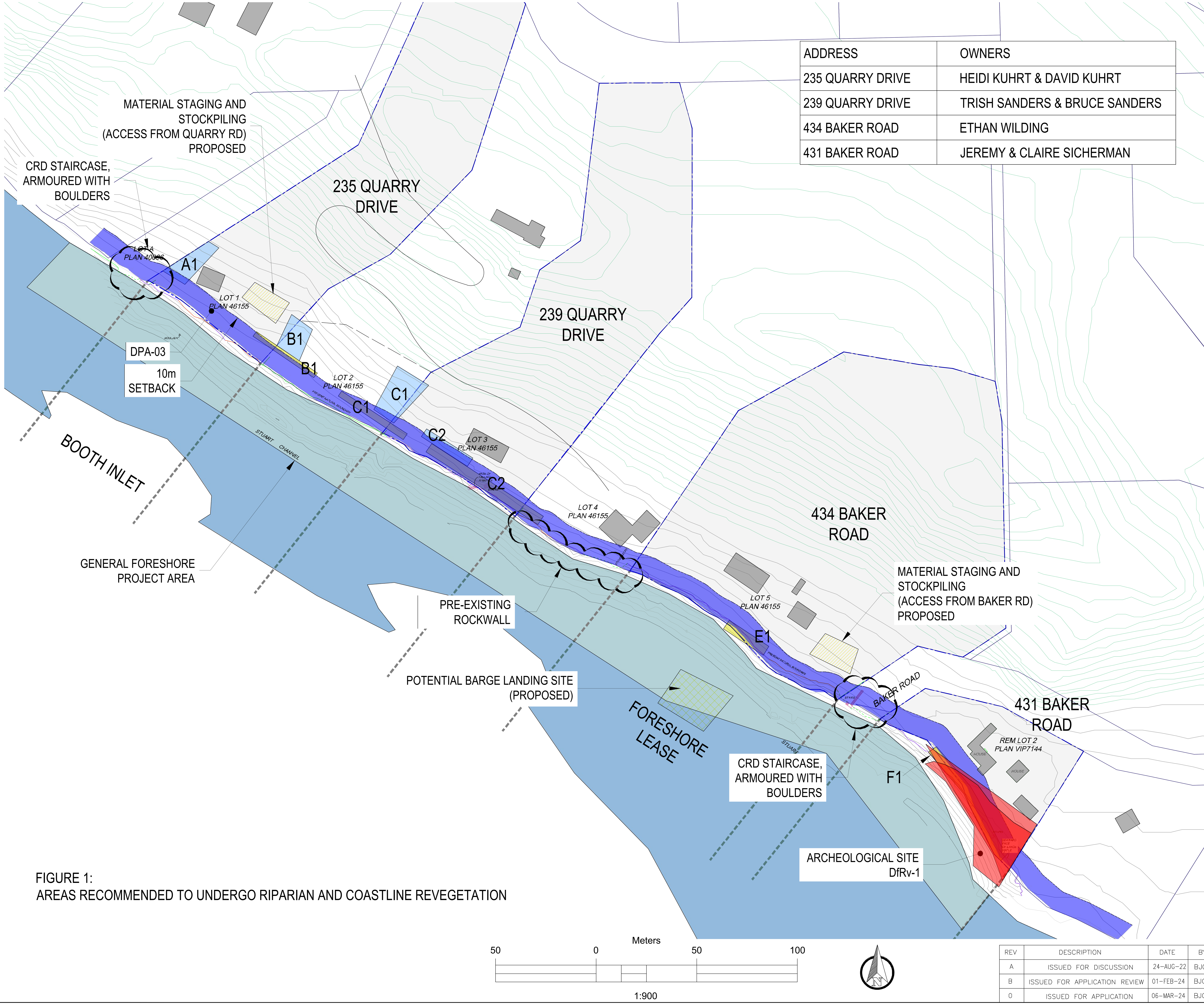



FIGURE 1:
AREAS RECOMMENDED TO UNDERGO RIPARIAN AND COASTLINE REVEGETATION

GENERAL NOTES:
1) DIMENSIONS IN METRES UNLESS STATED OTHERWISE.

DESIGN NOTES:

LEGENDS:
- RE-VEGETATION & BIOENGINEERING AREAS
- UPLAND RIPARIAN RE-VEGETATION AREAS
- DPA-03
- GENERAL FORESHORE PROJECT AREA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thinkpg.com / +1 250-930-2426

EGBC PERMIT TO PRACTICE NO: 100204


PROJECT TITLE:
BEACH EROSION PROJECT
2022.68 QUARRY DRIVE

CLIENT:
QUARRY / BAKER BEACH OWNERS GROUP

PROJECT LOCATION:
QUARRY / BAKER BEACH
SALT SPRING ISLAND, BC

DRAWING NO:
2022.68-46-LAY-001

| REV | DESCRIPTION | DATE | BY |
|---|---|---|---|
| A | ISSUED FOR DISCUSSION | 24-AUG-22 | BJGF |
| B | ISSUED FOR APPLICATION REVIEW | 01-FEB-24 | BJGF |
| 0 | ISSUED FOR APPLICATION | 06-MAR-24 | BJGF |

| | |
|---|---|
| PERMIT NO: | TBC |
| STAMP | |
| DATE: | 6-Mar-24 |
| DESIGN BY: | TRE |
| DRAWN BY: | VBB |
| SIZE: | A1 |
| SCALE: | 1:900 |
| REVIEWED BY: | TRE |
| SHEET: | 1OF5 |

| ADDRESS | OWNERS |
|---|---|
| 235 QUARRY DRIVE | HEIDI KUHRT & DAVID KUHRT |
| 239 QUARRY DRIVE | TRISH SANDERS & BRUCE SANDERS |
| 434 BAKER ROAD | ETHAN WILDING |
| 431 BAKER ROAD | JEREMY & CLAIRE SICHERMAN |

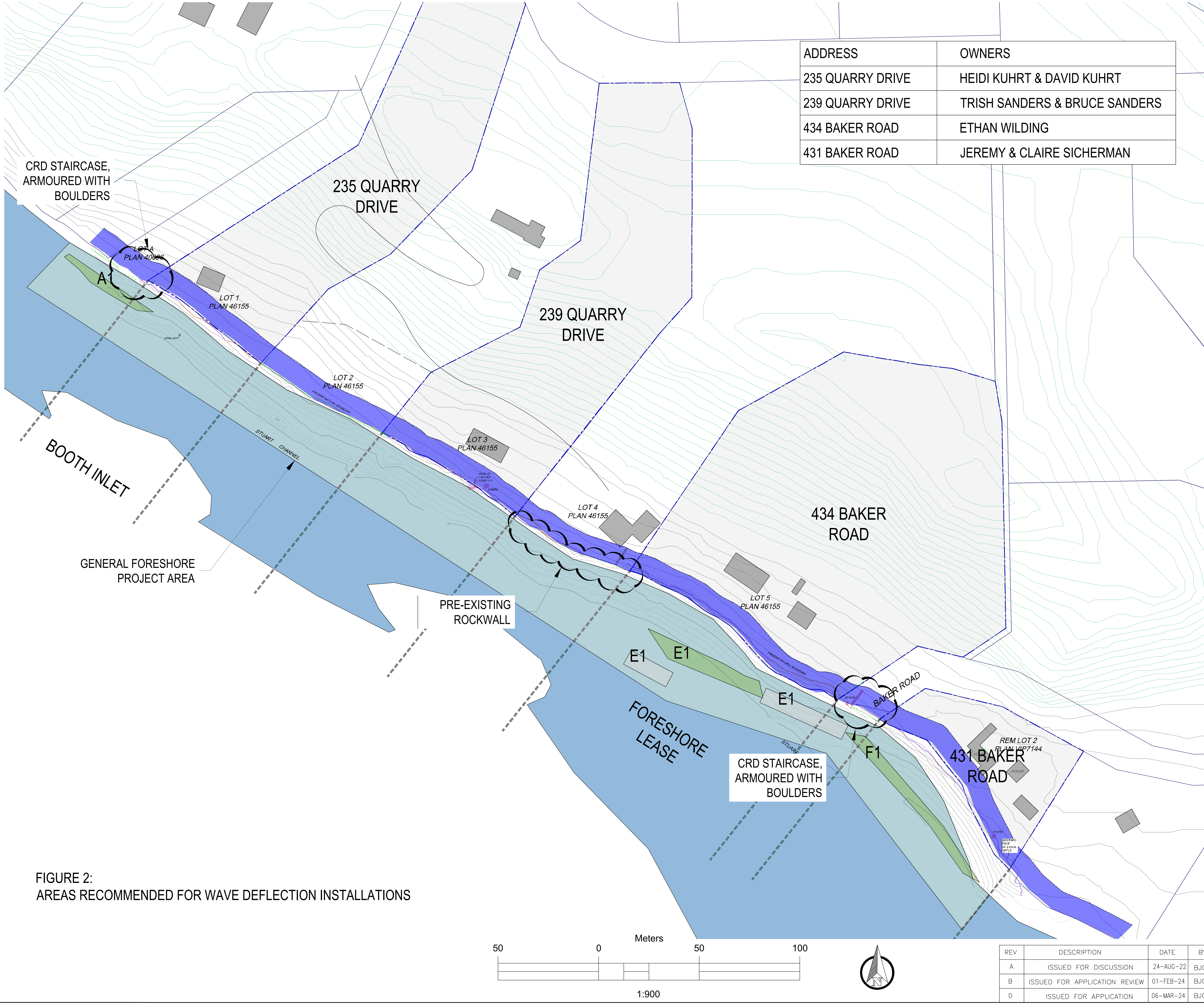


FIGURE 2:
AREAS RECOMMENDED FOR WAVE DEFLECTION INSTALLATIONS

GENERAL NOTES:
1) DIMENSIONS IN METRES UNLESS STATED OTHERWISE.

DESIGN NOTES:

LEGENDS:
- RECOMMENDED WAVE DEFLECTION AREAS
- EXISTING NATURAL WAVE DEFLECTION AREAS
- DPA-03
- GENERAL FORESHORE PROJECT AREA

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EGBC PERMIT TO PRACTICE NO: 100204

PROJECT TITLE:
BEACH EROSION PROJECT
2022.68 QUARRY DRIVE

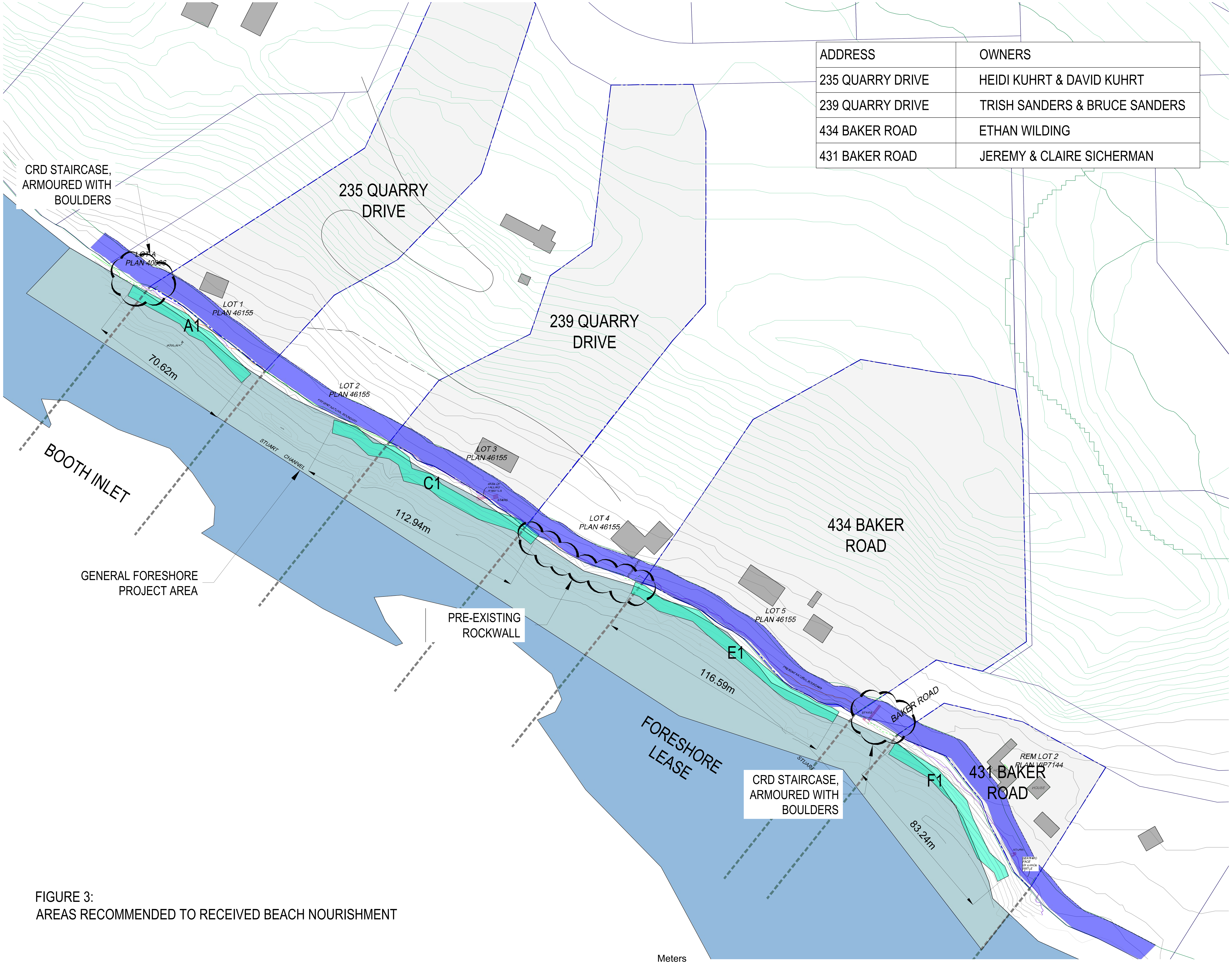
CLIENT:
QUARRY / BAKER BEACH OWNERS GROUP

PROJECT LOCATION:
QUARRY / BAKER BEACH
SALT SPRING ISLAND, BC

DRAWING NO:
2022.68-46-LAY-002

| REV | DESCRIPTION | DATE | BY |
|---|---|---|---|
| A | ISSUED FOR DISCUSSION | 24-AUG-22 | BJGF |
| B | ISSUED FOR APPLICATION REVIEW | 01-FEB-24 | BJGF |
| 0 | ISSUED FOR APPLICATION | 06-MAR-24 | BJGF |

| | | | |
|---|---|---|---|
| PERMIT NO: | TBC | DATE: | 6-Mar-24 |
| STAMP | | DESIGN BY: | TRE |
| | | DRAWN BY: | VBB |
| | | SIZE: | A1 |
| | | SCALE: | 1:900 |
| | | REVIEWED BY: | BJGF |
| | | SHEET: | 2OF5 |




| ADDRESS | OWNERS |
|---|---|
| 235 QUARRY DRIVE | HEIDI KUHRT & DAVID KUHRT |
| 239 QUARRY DRIVE | TRISH SANDERS & BRUCE SANDERS |
| 434 BAKER ROAD | ETHAN WILDING |
| 431 BAKER ROAD | JEREMY & CLAIRE SICHERMAN |

FIGURE 3:
AREAS RECOMMENDED TO RECEIVED BEACH NOURISHMENT

Meters
50 0 50 100
1:900

| REV | DESCRIPTION | DATE | BY |
|---|---|---|---|
| A | ISSUED FOR DISCUSSION | 24–AUG–22 | BJGF |
| B | ISSUED FOR APPLICATION REVIEW | 01–FEB–24 | BJGF |
| 0 | ISSUED FOR APPLICATION | 06–MAR–24 | BJGF |

GENERAL NOTES:
1) DIMENSIONS IN METRES UNLESS STATED OTHERWISE.

DESIGN NOTES:

LEGENDS:
- BEACH NOURISHMENT APPLICATION AREAS
- DPA–03
- GENERAL FORESHORE PROJECT AREA

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EGBC PERMIT TO PRACTICE NO: 100204

PROJECT TITLE:
BEACH EROSION PROJECT
2022.68 QUARRY DRIVE

CLIENT:
QUARRY / BAKER BEACH OWNERS GROUP

PROJECT LOCATION:
QUARRY / BAKER BEACH
SALT SPRING ISLAND, BC

DRAWING NO:
2022.68-46-LAY-003

| | | | |
|---|---|---|---|
| PERMIT NO: | TBC | DATE: | 6–Mar–24 |
| STAMP | | DESIGN BY: | TRE |
| | | DRAWN BY: | VBB |
| | | SIZE: | A1 |
| | | SCALE: | 1:900 |
| | | REVIEWED BY: | BJGF |
| | | SHEET: | 3OF5 |

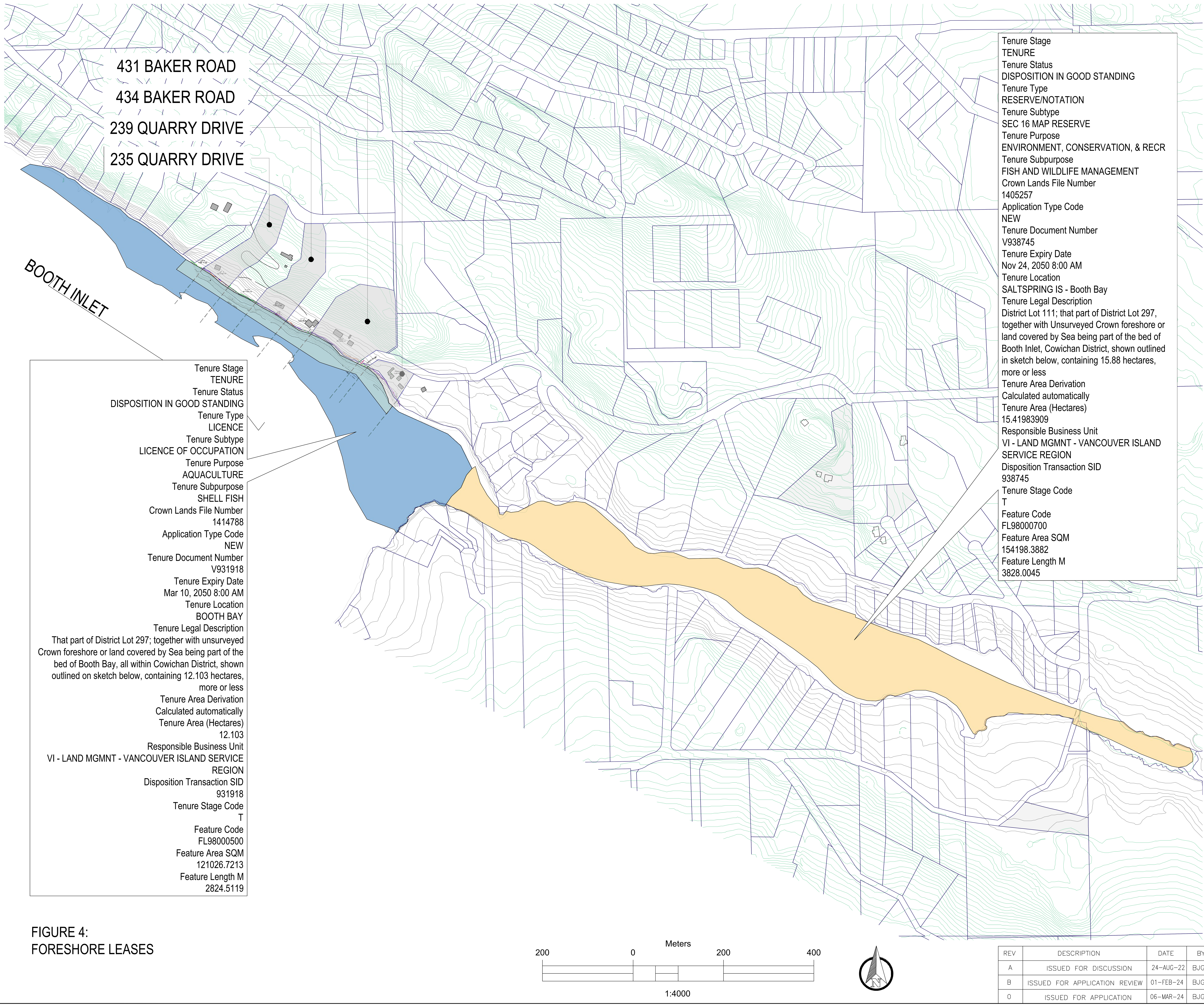


FIGURE 4:
FOREWHORE LEASES

GENERAL NOTES:
1) DIMENSIONS IN METRES UNLESS STATED OTHERWISE.

DESIGN NOTES:

LEGENDS:

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EGBC PERMIT TO PRACTICE NO: 100204

PROJECT TITLE:
BEACH EROSION PROJECT
2022.68 QUARRY DRIVE

CLIENT:
QUARRY / BAKER BEACH OWNERS GROUP

PROJECT LOCATION:
QUARRY / BAKER BEACH
SALT SPRING ISLAND, BC

DRAWING NO:
2022.68-46-LAY-004

| REV | DESCRIPTION | DATE | BY |
|---|---|---|---|
| A | ISSUED FOR DISCUSSION | 24-AUG-22 | BJGF |
| B | ISSUED FOR APPLICATION REVIEW | 01-FEB-24 | BJGF |
| 0 | ISSUED FOR APPLICATION | 06-MAR-24 | BJGF |

| | |
|---|---|
| PERMIT NO: | TBC |
| STAMP | |
| DATE: | 6-Mar-24 |
| DESIGN BY: | TRE |
| DRAWN BY: | VBB |
| SIZE: | A1 |
| SCALE: | As Shown |
| REVIEWED BY: | BJGF |
| SHEET: | 4OF5 |

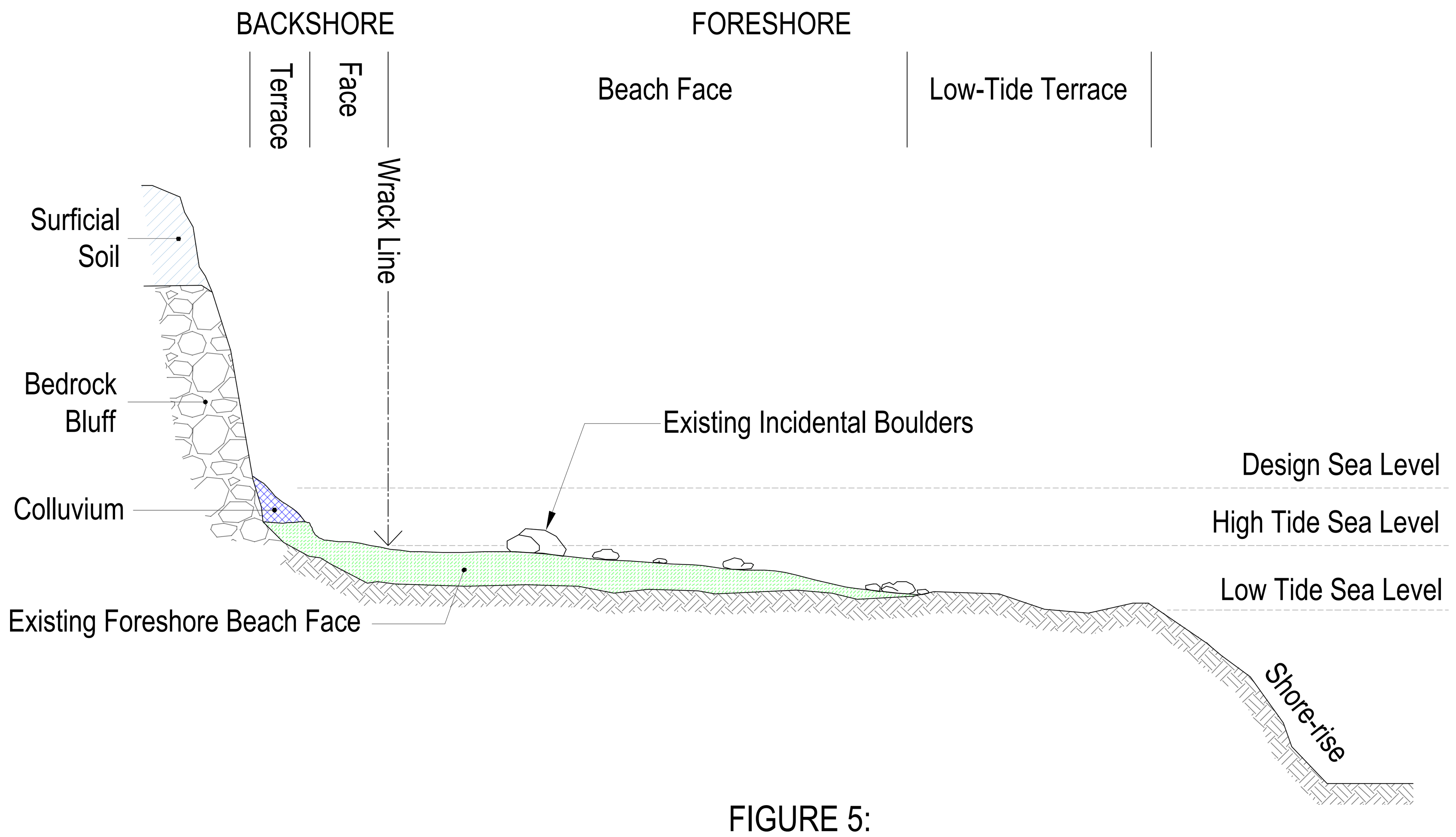


FIGURE 5:
NOMINAL CROSS-SECTION OF A PROJECT AREA
CURRENT CONDITION

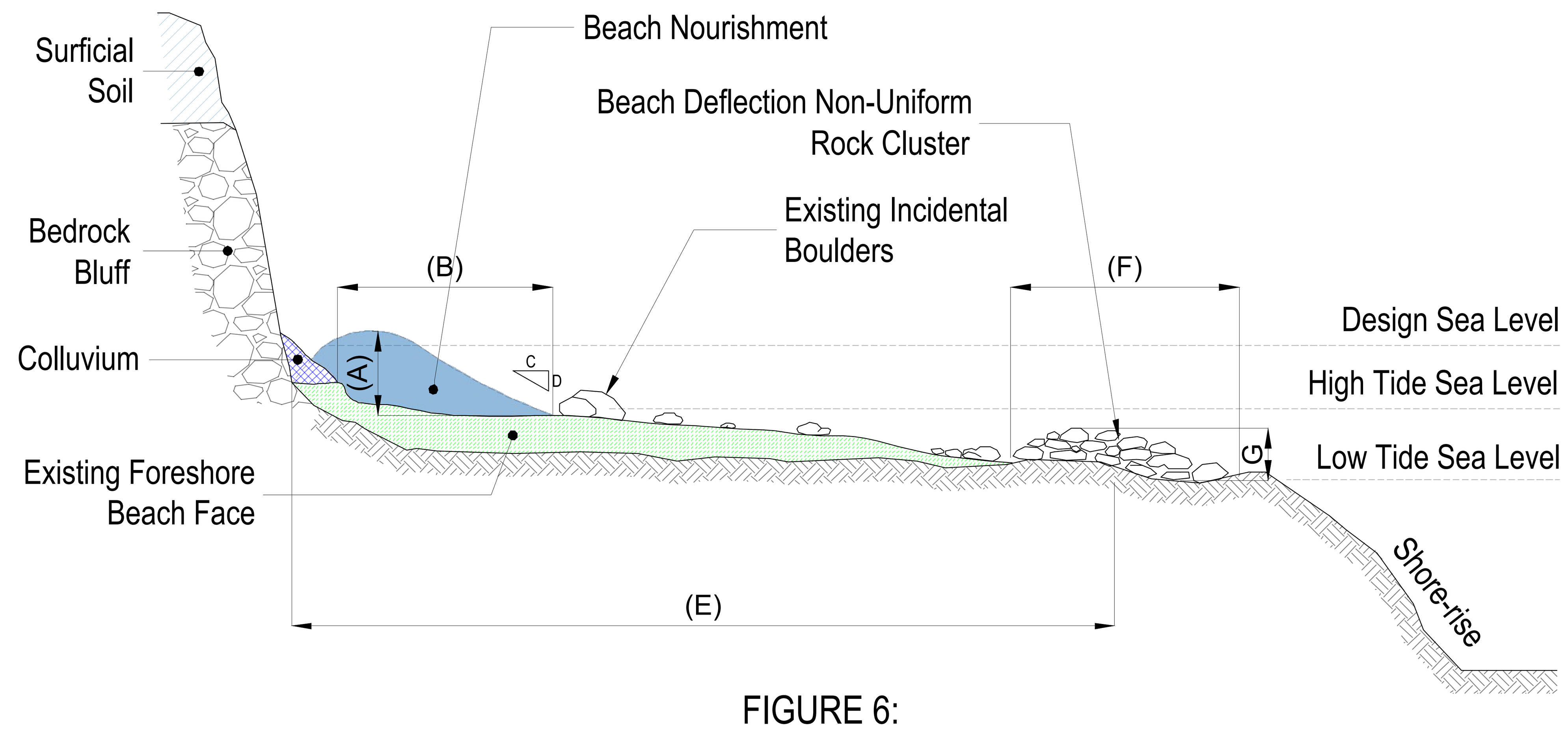


FIGURE 6:
NEAR-TERM CROSS-SECTION

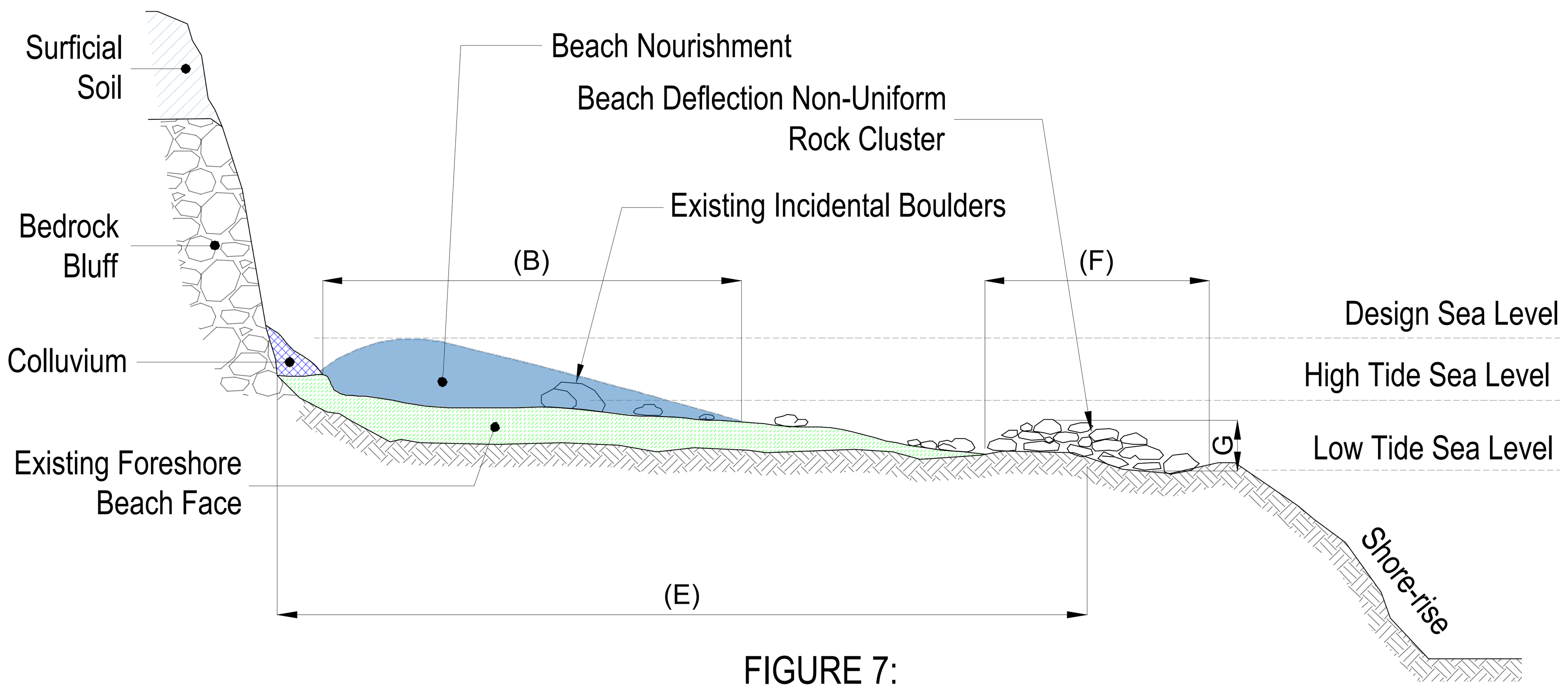


FIGURE 7:
5 YEAR CROSS-SECTION

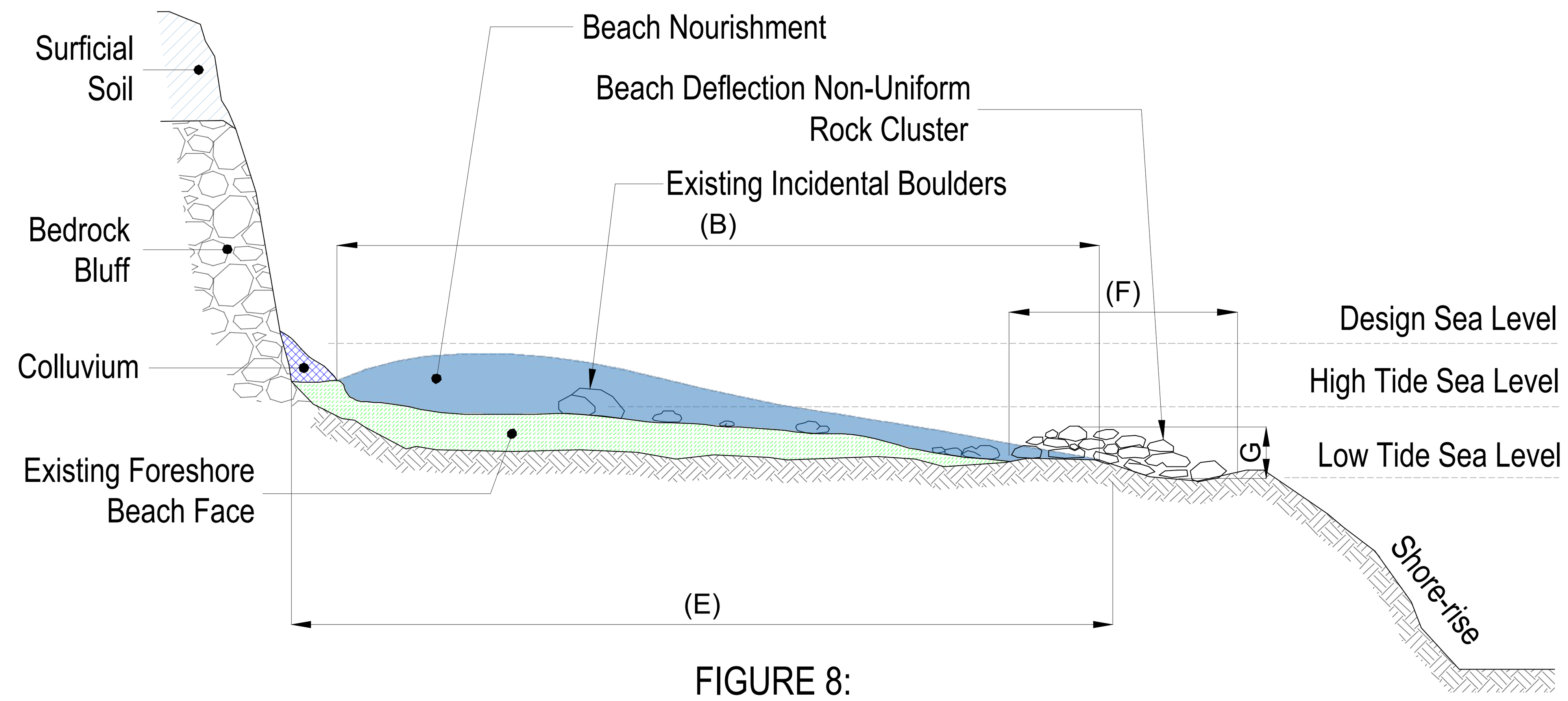


FIGURE 8:
15 YEAR CROSS-SECTION

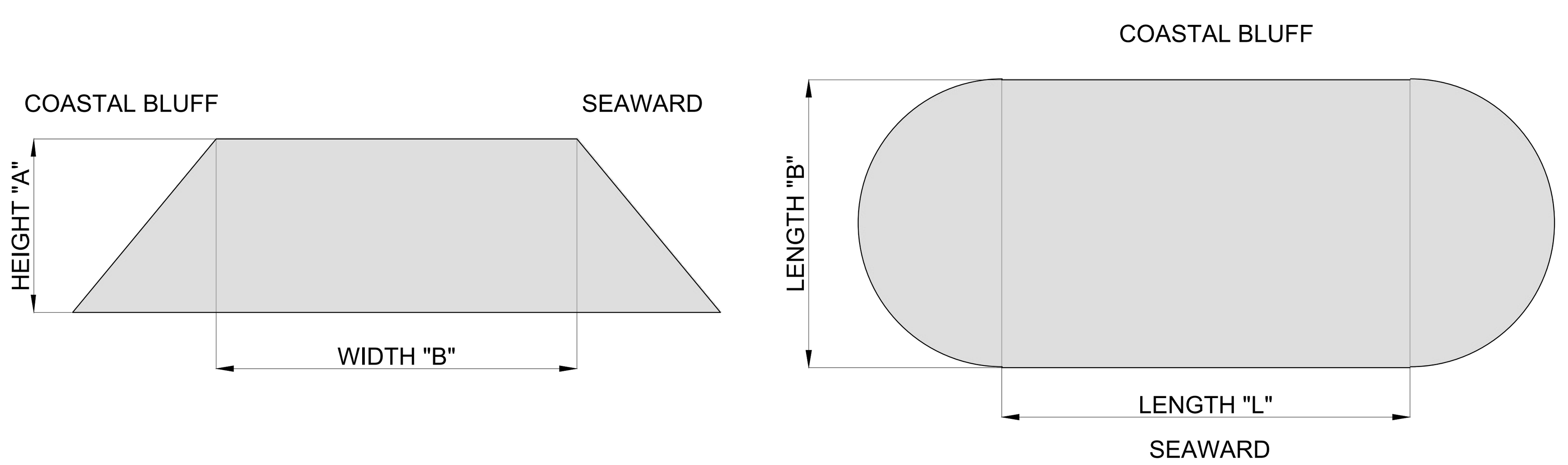


FIGURE 9:
INSTALL PROFILE
(MASS PLACEMENT)

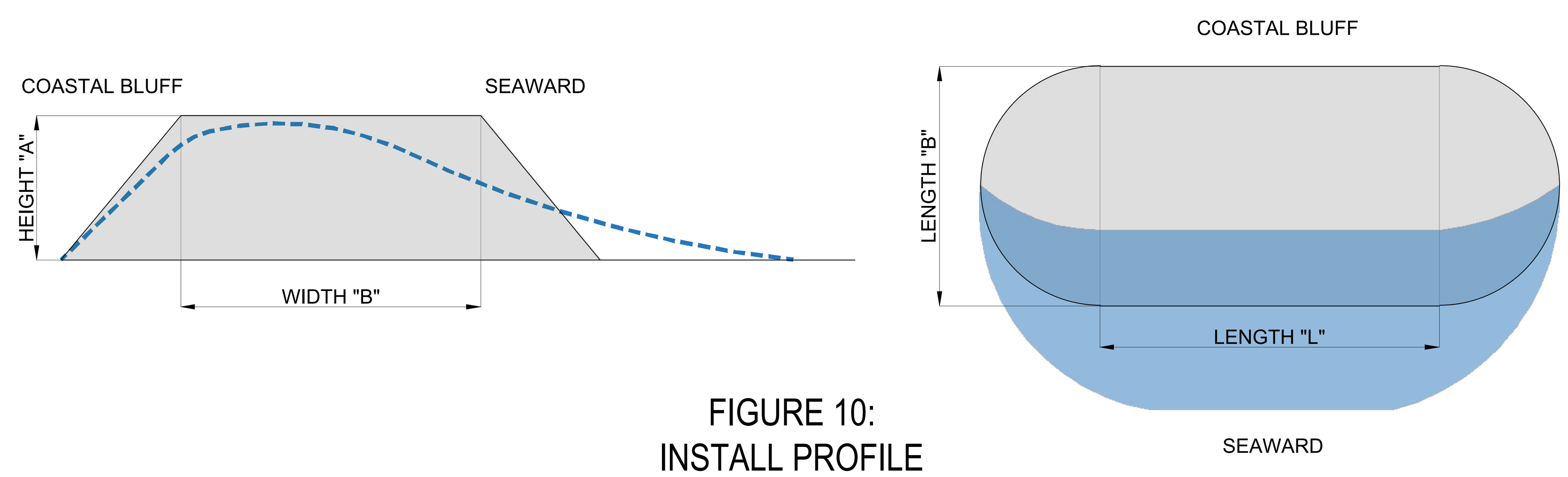


FIGURE 10:
INSTALL PROFILE
(SHAPING)

| REV | DESCRIPTION | DATE | BY |
|---|---|---|---|
| A | ISSUED FOR DISCUSSION | 24-AUG-22 | BJGF |
| B | ISSUED FOR APPLICATION REVIEW | 01-FEB-24 | BJGF |
| 0 | ISSUED FOR APPLICATION | 06-MAR-24 | BJGF |

GENERAL NOTES:
1) DIMENSIONS IN METRES UNLESS STATED OTHERWISE.

DESIGN NOTES:

LEGENDS:
- Beach Nourishment
- Existing Foreshore Beach Face
- Colluvium
- Surficial Soil
- Bedrock Bluff

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EGBC PERMIT TO PRACTICE NO: 100204

PROJECT TITLE:
BEACH EROSION PROJECT
2022.68 QUARRY DRIVE

CLIENT:
QUARRY / BAKER BEACH OWNERS GROUP

PROJECT LOCATION:
QUARRY / BAKER BEACH
SALT SPRING ISLAND, BC

DRAWING NO:
2022.68-46-LAY-005

| | |
|---|---|
| PERMIT NO: TBC | DATE: 6-Mar-24 |
| STAMP | DESIGN BY: TRE |
| | DRAWN BY: VBB |
| | SIZE: A1 |
| | SCALE: NTS |
| | REVIEWED BY: BJGF |
| | SHEET: 5OF5 |

# Summary of Baker Beach Shoreline Erosion Mitigation Recommendations

*As pertaining to areas seaward of land parcels:*

235 Quarry Drive PID 009-555-706
239 Quarry Drive PID 009-555-731
434 Baker Road PID 009-555-781
431 Baker Road PID 000-014-656

SALT SPRING ISLAND

Developed for: Aurora Professional Group
c/o Bradley Fossen P.Eng
338 Lower Ganges Rd UNIT 202
Salt Spring Island, BC V8K 2V3


Developed by: Thomas R Elliot PhD P.Geo P.Ag
TRE Environmental Services
tom@elliot.org


TRE Environmental Services

## 1. Introduction

This summary report and preceding investigations were conducted within the intentions of A Coastal Marine Strategy for British Columbia[1], and we specifically acknowledge that our work spans Halalt and Penelakut Tribe First Nation territories. We are grateful for the knowledge, teachings and holistic worldviews contained within. These holistic worldviews were, and are, foundational to how First Nation Peoples steward the lands, water, seabed, air and resources that sustain them.

This summary report presents climate resilient shoreline erosion mitigation opportunities for Bakers Beach, Salt Spring Island. The existing geohazards, ecologic, and marine characteristics of Bakers Beach and surrounding area have been assessed in previous reporting which is the result of field and desktop investigations. Those investigations have guided the identification of suitable and effective mitigation measures for the area in context of local shoreline processes.

The suitability of mitigation measures was guided by the Stewardship Centre for British Columbia Green Shores for Homes[2] program, including the assessment approach and our best practices for erosion management. Suitability is based on site characteristics evaluated during assessment of upland geohazards and surface hydrology[3]; shoreline and coastal sediment dynamics[4]; and Environmental Assessment[5].

The recommendations within this report are generalized, with Site specific design pending support of concept by participating property owners and local government.

## 2. Shoreline and Upland Characteristics

There were no significant geohazards identified within upland of the assessed areas, ensuring no overriding natural hazard would affect the recommended mitigation measures. There is both natural and ditched concentration of stormwater flow to pre-existing natural catchments. A consistent upland terrace across the assessed area has sparse areas where stormwater flow concentrates, creating localized soil wetness, fostering wet-soil vegetation

[1] A Coastal Marine Strategy for British Columbia Policy Intentions Paper (December 2022). https://engage.gov.bc.ca/app/uploads/sites/121/2022/12/Coastal-Marine-Strategy-Intentions-Paper.pdf Accessed 11/2023
[2] Stewardship Centre of BC. Green Shores for Homes. 2023. https://stewardshipcentrebc.ca/PDF_docs/greenshores/Resources/GSHCreditsandRatingsGuide.pdf
[3] Geohazard Assessment of Lands. Pertaining to upland area from the shoreline of 235, 239 Quarry Drive and 431, 434 Baker Rd. TRE Environmental Services. File: 2023.900_A – D
[4] Assessment of Marine Shoreline Characteristics: Report for Coastal Erosion Mitigation. TRE Environmental Services. File: 2023.900_E
[5] Environmental Assessment: 235, 239 QUARRY DRIVE & 434, 431 BAKER ROAD SALT SPRING ISLAND. Corvidae Environmental Consulting Inc.

and affecting downslope coastal bluff erosion. Vegetation of the upland terrace and slopes above are typic of the red-listed Douglas-fir – arbutus ecological community, which is at risk of being lost in BC.

The coastal bluff trends from bedrock-dominant in the northwest, downward (dipping) to the southeast whereby the low gradient backshore and coastline is predominantly fine gravel and sand (respectively). Vegetation along the coastal bluff was characterized by Douglas-fir – arbutus woodland species, with lesser amounts of shore pine and Garry oak. Understory species included pink (hairy) honeysuckle, grasses, weeds, evergreen huckleberry, and numerous invasive species. The shoreline and uplands are habitat for river otter, belted kingfisher, and a variety of yellow listed bird species.

The majority of foreshore area is dominated by a low-tide terrace, which results in retention of the sediment that forms the beach face and backshore sediment terrace. The beach face is predominantly gravel and sands with frequent cobble to boulder coarse fragments. The southeastern foreshore, in front of 431 Baker Road is dominated by the beach face, which trends toward finer sediment with sparse stones and boulders. The backshore has limited grasses, with minor occurrence of landslip depositing sufficient mineral soil on the backshore terrace to foster salt tolerant woody species – although these deposits are at risk of removal under unmitigated storm wave-action.

There are areas of the foreshore mapped as surf smelt and Pacific sand lance spawning habitat. Off-shore, there are mapped eelgrass beds which support herring and forage fish. Additionally, there are known plainfin midshipman rearing grounds off-shore – which draws raptors and sea-birds to the annual food source. Intersecting these off-shore area is a mollusc lease parcel, which has seen intermittent operation in recent history.

Any recommended mitigation options will maintain critical awareness of these habitat to maintain a healthy and productive coast that sustains ecosystems with abundant fisheries and marine wildlife.

## 3. Summary of Management and Mitigation Options

One of the easiest and most effective management options is monitoring the rate of erosion. A suitable method for monitoring is static-location imagery, with conscious effort to reproduce both location and visibility-conditions to provide comparable results. Timing of monitoring should be once per year at minimum, with updated imagery after significant storm events so as to capture occurrence of punctuated erosion.

## 3.1. Bioengineering and Revegetation

Bioengineering and selective planting of the backshore, coastline and upland terrace are recommended in the areas indicated in Figure 1 of this document. Each shading colour in Figure 1 indicates differing goals and motivation for planting, as follows:

- Backshore planting: Primarily planting grasses and sedge due to a lack of accumulated mineral soil that would support larger woody species. Planting would intend to create ‘clumps’ on the backshore terrace to encourage sediment accumulation.
- Coastline planting: Planting is viable in the upper surficial materials which cap the bedrock coastal bluff. The coarse soil texture and south-facing exposure results in an anticipated attrition of planting-stock due to drought conditions, or consistent irrigation during drought season. Where appropriate along the coastal bluff implementing a succession tree-planting program would benefit the relatively even-aged population of existing trees. There is opportunity for pole planting of salt-tolerant woody species along the southeastern coastline fronting 431 Baker Road. Invasive management is recommended for the coastline of 431 Baker Road as part of the revegetation process.
- Upland terrace planting: Planting of wetted soils would increase evapotranspiration, reducing long-term groundwater erosion of the coastal bluff. In these areas, it would be suitable to plant hydrophilic species common to the Douglas-fir – arbutus woodland species understory. Extending additional deeper-rooted plantings from these wetted areas to the coastal bluff would increase soil cohesion of the area likely to fail.

## 3.2. Wave Deflection

Wave deflection is recommended, in areas shown in Figure 2, to disperse the persistent wake from vessel traffic, which contributes to sediment loss from the foreshore. An effective way to accomplish wave deflection is by sparse placement of boulders along the low-tide terrace so as to provide relatively uniform coverage from the predominant wave direction (west, for vessel wake). These boulders would be submerged at high tide, and as such would assist in disrupting plunging breaker wave action, prompting transition to surging breaker wave which better distributes (i.e. lessen the peak) erosion forces. The shoreline already has sparse coverage of large glacial erratics, weathered nodular boulders emerging from bedrock, and stones to boulders from upland till and bedrock exposures. Placement of boulders would look to mimic and enhance this natural process to accomplish erosion mitigation goals.

## 3.3. Beach Nourishment

Beach nourishment, as a concept, is an exaggeration of existing natural sediment supply processes which primarily uses coarse sediment due to mobility – and therefore loss – of fine sand and smaller particles. The installation of sediment for beach nourishment also attenuates with natural conditions through localized re-distribution within the backshore, foreshore beach face and low-tide terrace.

The intention of a beach nourishment program for the assessed area is to increase the width and elevation of backshore terrace, as shown in Figure 3, approaching the coastal bluff in most areas. This supplement to the sediment budget is intended to dissipate incoming wave energy by changing the plunging breaker wave type (higher erosion) occurring under storm event conditions to a surging breaker wave type (lower erosion).

The beach nourishment program will supplement long-term sediment deficiency resulting from hard armouring within the drift-cell and coastal bluff erosion mitigation activities. As the preceding assessments have accounted for our changing climate and sea level rise[6], the recommended beach nourishment meets a number of climate change resilience objectives as explored through the following sections of this document.

## 4. Applicable Potential Green Shores Credits Scoring

The following evaluates the recommended measures and associated activities under the Green Shores for Homes credit scheme, wherefrom categories which have no applicability have been excluded from the following table.

| **Green Shore for Homes Credit Categories** | **Possible Score** | **Potential Project Score** |
|---|---|---|
| **Shoreline physical processes** | | |
| 1.2 Setback/Impact Avoidance (110m/600m does not qualify) | 9 | 7 |
| 1.5 Nature-Based Erosion and Flood Management | 13 | 13 |
| **Shoreline habitat** | | |
| 2.1 Enhance Bird Habitat Stewardship | 8 | 8 |
| 2.2 Riparian and Emergent Vegetation | 13 | 13 |
| 2.3 Trees and Snags | 5 | 4 |
| 2.4 Invasive Plants | 4 | 2 |
| 2.5 Organic Material | 6 | 5 |
| 2.6 Overwater Structures | 6 | 4 |
| **Water Quality** | | |
| 3.2 Reduce and Treat Runoff | 9 | 7 |
| 3.5 Aesthetic Vegetation Chemical Control | 3 | 3 |
| 3.6 On-Site Sewage Treatment | 4 | 3 |
| **Shoreline stewardship** | | |

[6] Natural Resources Canada. James *et al.* 2021. Relative sea-level projections for Canada based on the IPCC Fifth Assessment Report and the NAD83v70VG national crustal velocity model. https://geoscan.nrcan.gc.ca/text/geoscan/fulltext/of_8764.pdf

| | | |
|---|---|---|
| 4.1 Shoreline Collaboration | 8 | 8 |
| 4.2 Public Information and Education | 3 | 3 |
| 4.3 Conservation Easement or Covenant | 6 | 2 |
| 4.4 Shoreline Stewardship Participation | 2 | 2 |
| **Total** | **99** | **84** |

Of note is that Potential Project Score is optimal, and performance should be based on the Project aspiring to secure all 84 credits while recognizing that the Green Shores for Homes Gold rating is a minimum 40 points, of which a minimum 20 points (collectively) are acquired from Shoreline Process and Shoreline Habitat credit categories.

## 5. BC Marine Strategy Intentions

In this section, the recommended mitigation measures are generally evaluated under the 30 intentions of the BC Marine Strategy – as presented in the table below with the following ranking method:

**Intention Met** **No Reasonable Affect** **Detracts from Intention**

| BC Marine Strategy Intention | Bioengineering and Revegetation | Wave Deflection | Beach Nourishment |
|---|---|---|---|
| **Healthy and Productive Coast** | | | |
| A-1 Wild salmon | | | |
| A-2 Monitor health | | | |
| A-3 Prevent pollution | | | |
| A-4 Protect habitat | | | |
| A-5 Recover S.A.R. | | | |
| **Resilience to Climate Change** | | | |
| B-1 Safe communities | | | |
| B-2 Support seafood | | | |
| B-3 Nature-based solutions | | | |
| B-4 Mitigate acidification | | | |
| B-5 Protect carbon sinks | | | |
| **Trusting, Respectful Relationships** | | | |
| C-1 Respect FN rights | | | |
| C-2 Engage British Columbians | | | |
| C-3 Collaborative stewardship | | | |
| C-4 Coastal legislation | | | |
| **Holistic Learning and Knowledge Sharing** | | | |
| D-1 Weave Traditional and Western | | | |
| D-2 Value the Ocean | | | |

| | | | |
|---|---|---|---|
| D-3 Enhance spatial data | | | |
| D-4 Improve data access | | | |
| **Community Well-Being** | | | |
| E-1 Create steady employment | | | |
| E-2 Diverse workforce | | | |
| E-3 Support FN cultural revitalization | | | |
| E-4 Improve community resilience | | | |
| E-5 Develop marine use plans | | | |
| E-6 Improve access to nature | | | |
| **A Sustainable, Thriving Ocean Economy** | | | |
| F-1 Invest and Diversify | | | |
| F-2 Co-develop FN opportunities | | | |
| F-3 Support marine fisheries | | | |
| F-4 Advance sustainable aquaculture | | | |
| F-5 Support regenerative marine tourism | | | |
| F-6 Manage cumulative effects | | | |

Broadly, the recommended erosion mitigation is meeting the intentions of the BC Marine Strategy, with areas of Community Well-Being and Sustainable, Thriving Ocean Economy remaining challenging intentions to meet through the limited size of this project.

## 6. Conclusion and Next Steps

Due to the low-tide terrace and low gradient foreshore beach-face within the assessed area, there is an opportunity to manage the consequence of sea level rise through a hybrid soft-shores erosion mitigation program that includes upland water management and riparian vegetation enhancement.

The scoped mitigation program includes three distinct options: Bioengineering and revegetation; Wave deflection; and Beach nourishment which can be implemented in the areas indicated in Figures 1 - 3.

The evaluation of the recommended measures was conducted under the Green Shores for Homes credit scheme, wherefrom a score of 84/99 possible credits was determined to be reasonably accomplished. Additionally, the alignment with BC's Marine Strategy Intentions was determined to be meeting most intentions or having no affect. There was no adverse impact to BC Marine Strategy Intentions consequent to the recommended mitigation measures identified through this evaluation.

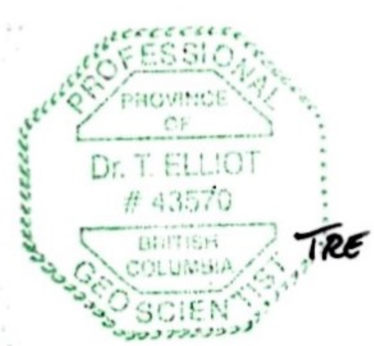
The next steps in this process are to work under the Shoreline Stewardship credit categories as well as Intentions C – D (as shown above) to secure local government, stewardship, community and First Nation support. With support, permit applications will be required prior to implementation. Additional technical detail beyond what has been provided in this report, including detailed survey and cross-sections of proposed alterations, will be necessary for permit applications.

## 7. Closure

The undersigned certifies that the above recommendations are based on best practices, guidance and professional experience to the capacity of the qualified professional of record – under similar constraints. There is reasonable expectation of professional product to be of sufficient quality and accuracy to be acceptable by receiving landowners, agency and governments. However, revision is an acceptable practice – one that I encourage and embrace. Should any requests for changes be made, please contact the undersigned.

| | | |
|---|---|---|
| Qualified Professional of Record | THOMAS R. ELLIOT PhD<br>P.Geo, P.Ag<br>Name | Tom Elliot<br>Signature |

Thomas R Elliot PhD P.Geo. P.Ag.

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Date: January 5 2024

## Limitations

The QP signatory to this assessment and report assures accuracy of existing and field observation, and evaluation of technical geohazard according to best practices of the Engineers and Geoscientists of BC. The content of this report are applicable to the subject land parcels, and specifically the Site as defined in this report. Any extension of the evaluation to areas outside of the defined area assessed are not valid.

The report has been conducted according to guidelines and reporting standards of similarly qualified professionals, given similar time and budget. At time of writing, the report meets due diligence and investigatory reporting requirements to provide QP recommendations with declared competency in the subject areas. Therefore, the author of this report does not maintain liability insurance for actions taken based on the reporting, and only accepts error and omission liability up to the value of this report. The receipt, utilization and any planning, further studies or development actions undertaken by the recipient of this report are based on their acceptance of their own liability therein.

**Figure 1. Areas recommend to undergo riparian and coastline revegetation**

**Figure 2. Areas recommended for wave deflection installations**

## Figure 3. Areas recommended to receive beach nourishment

# Rationale for Design Sea Level and Calculation of Baker Beach Nourishment Volumes

*As pertaining to areas seaward of land parcels:*

235 Quarry Drive PID 009-555-706
239 Quarry Drive PID 009-555-731
434 Baker Road PID 009-555-781
431 Baker Road PID 000-014-656

SALT SPRING ISLAND

# Report for Coastal Erosion Mitigation

Developed for: Aurora Professional Group
c/o Bradley Fossen P.Eng
338 Lower Ganges Rd UNIT 202
Salt Spring Island, BC V8K 2V3


Developed by: Thomas R Elliot PhD P.Geo P.Ag
TRE Environmental Services
tom@elliot.org


TRE Environmental Services

# 1. Introduction

Global sea level is anticipated to rise consequent to environmental change resulting in less snow pack at elevation on all continents, decreased duration/volume/extent of sea ice in Arctic waters, and melt of ice-sheet of Antarctica. This anticipated global sea-level change is commonly thought of as the average amount of sea-level change relative to the centre of the Earth – referred to as 'absolute' sea-level change. Local, or relative, sea-level change is more complex as there are regional factors affecting the solid surface of the Earth in relation to the absolute sea-level change.

Sea level change can result in increased coastal flooding (increased sea level), erosion (both increased and decreased sea level), as well as introducing novel navigation hazards and pressure on coastal ecologic resources. To determine what relative sea-level change will occur, a number of factors that function across different regional to global scales need to be considered.

# 2. Approach

Land tectonic uplift, primarily through isostatic rebound consequent to the last episode of glacial coverage, is a primary factor of relative sea level change in the Canadian Pacific Northwest. In the Pacific Northwest there is also some land subsidence as various tectonic plates undergo subduction to less-dense continental accretion belts and oceanic plates. Additional factors of sea level change include: temperature and heating of the oceans resulting in regionally increased volume, altered ocean circulation resulting in 'mounding' of water against land, regional melting of land ice from glaciers and ice caps causing 'mounding' of water surrounding the outwash deltas, and regional changes to the hydrologic cycle which affect the seasonality and periodicity of sea level. Human activity can have a direct influence of relative sea level in the form of land subsidence when coastal groundwater resources are over-produced, resulting in decreasing elevation as the aquifers compact without the support of *in situ* water.

When considering erosion mitigation and coastline protection activities, the predicted sea level for future use scenarios will largely dictate necessity and extent of said activities. There is a positive linear, if not exponential, relationship between predicted sea level and amount of erosion mitigation and coastline protection installations – higher sea level, more extensive and robust installations. As such, the Design Sea Level (DSL) is important for ensuring successful implementation and cost-management for erosion mitigation and coastline protection activities.

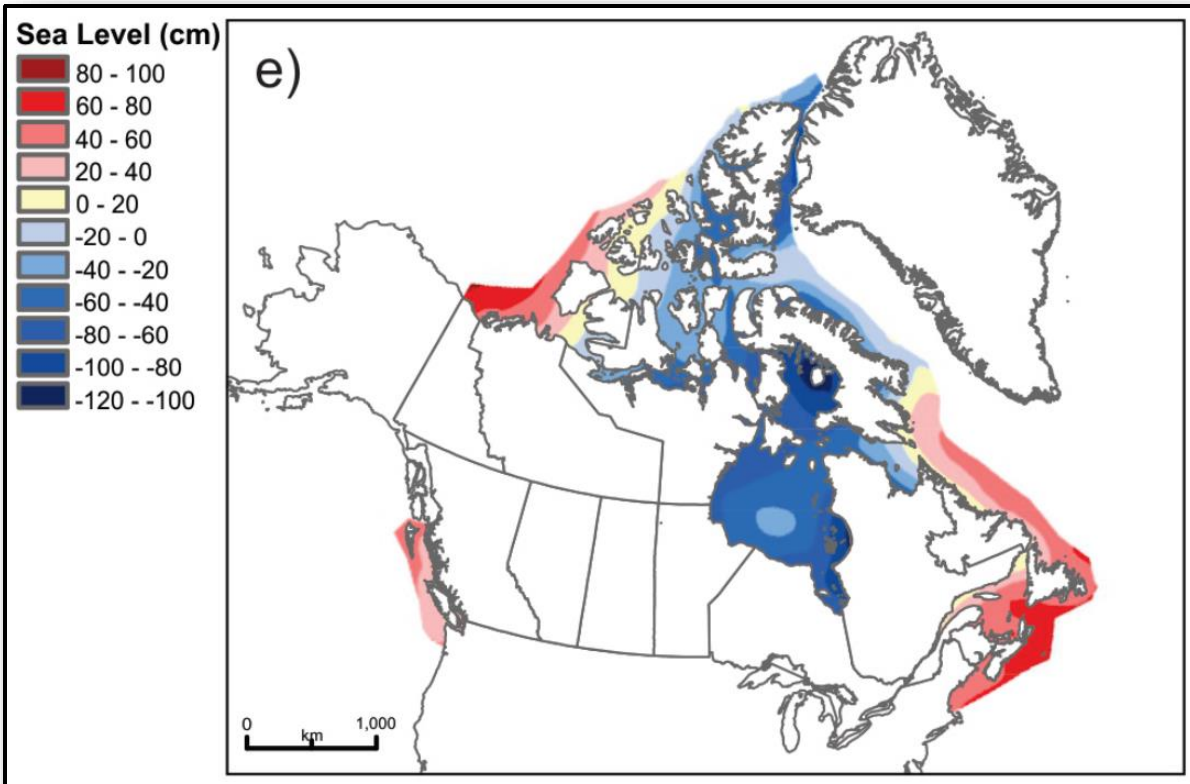
The factors considered for determining DSL for the proposed Baker Beach erosion mitigation follow the *Relative sea-level projections for Canada based on the IPCC Fifth Assessment Report* *and the NAD83v70VG national crustal velocity model*[1]. From which, the following assumptions are made:

- Representative Concentration Pathways (RCP) from the fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) are presented as the low (RCP2.6) and moderate (RCP4.5) emission scenarios. An additional RCP8.5 high emission scenario is mentioned but not included in the determination of DSL.
- RCP2.6 and RCP4.5 scenarios present immediate and progressive (respectively) curtailment of greenhouse gas emissions.
- RCP8.5 presents unabated global greenhouse gas emissions where continuation of existing emission trends proceed globally.
- The meltwater from Antarctic ice sheet reduction across all scenarios are included as a precautionary approach to determination of DSL.
- Discretized regional estimates of sea level change are of sufficient resolution to be reasonably accurate for the limited spatial extent of the Baker Beach project area.
- The reference sea level is based on average conditions between 1986 – 2005 within Canada and it's coastal waters.
- Contribution from the Antarctica ice sheet for RCP2.6 and RCP4.5 in year 2100 was established by median values from the publication *Projecting Antarctica's contribution to future sea level rise from basal ice shelf melt using linear response functions of 16 ice sheet models (LARMIP-2)*[2].
- The project DSL is calculated to match the lifespan of existing structures, which is 75 years for single family dwellings in British Columbia. As such, predictions of sea level change for the year 2100 are considered for this rationale.

## 3. Determination of Design Sea Level

The following map-product (Figure 1) illustrates the calculated west coast relative seal level values for year 2100 under RCP2.6 and RCP4.5. Figure 2 presents sea level change for the west coast of British Columbia in year 2050 under RCP8.5, which is the highest rate of climate-forcing which affects sea level change.

[1] James, T.S., Robin, C., Henton, J.A., and Craymer, M., 2021. Relative sea-level projections for Canada based on the IPCC Fifth Assessment Report and the NAD83v70VG national crustal velocity model; Geological Survey of Canada, Open File 8764, 1 .zip file, https://doi.org/10.4095/327878
[2] Earth Syst. Dynam., 11, 35–76, 2020 https://doi.org/10.5194/esd-11-35-2020



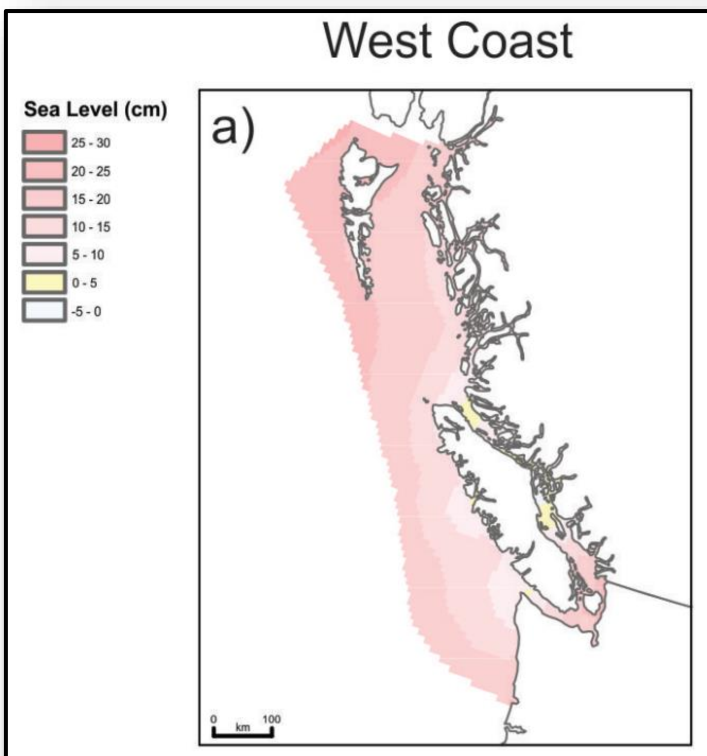




**Figure 1.** [ABOVE] Relative sea level change for coastal environments of Canada in year 2100 under RCP4.5 (median values).[1]

**Figure 2.** [LEFT] Relative sea level rise in year 2050 under RCP8.5 (high values) for the Juan de Fuca and Georgia Straight, and continuing north along coastal British Columbia.[1]

The estimated rate of additional sea level rise contributed by melt of Antarctica ice sheets is shown in Figure 3 below, with the maximum value being extracted to demonstrate a precautionary principle when determining DSL.

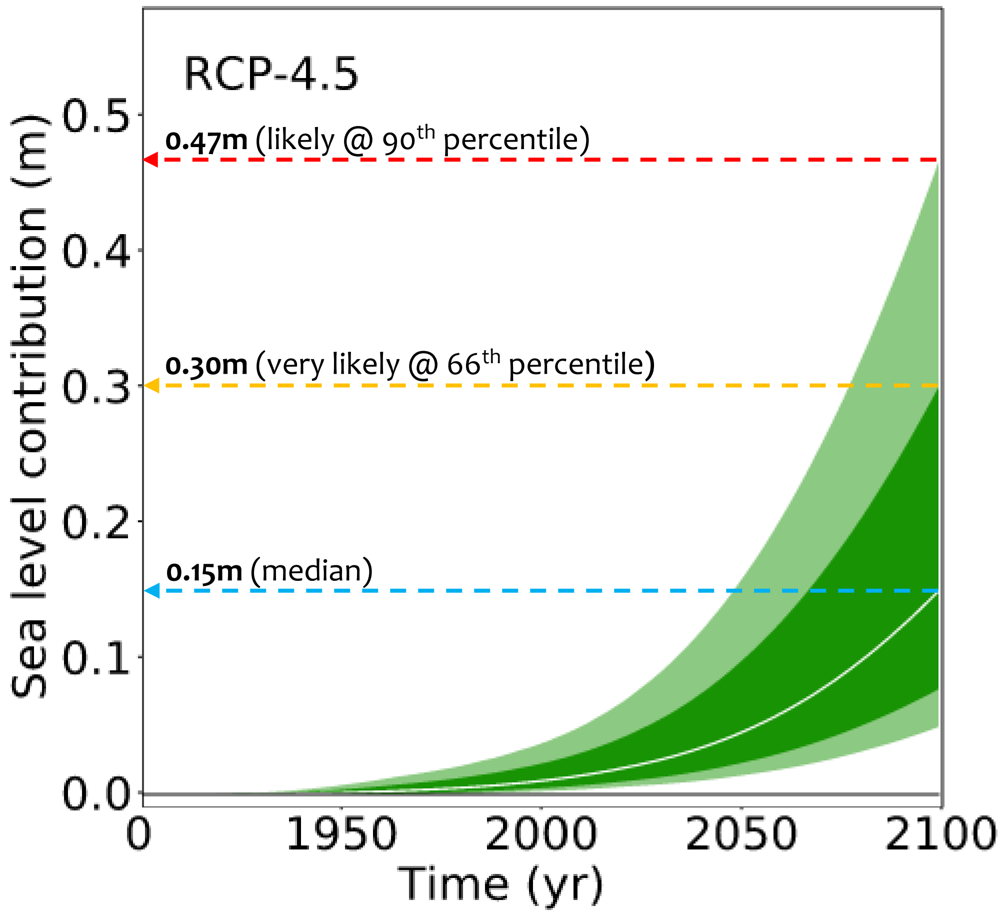



**Figure 3.** Contribution to sea level by meltwater from the Antarctica ice sheet, as determined in LARMIP-2 modeling[2].

From the above Figure 1 map product and supporting data (not shown, please see references and source material) the likely relative sea level change in year 2100 for the west coast of Salt Spring Island is +0.87m under RCP4.5 with accounting of Antarctica ice sheet meltwater.

The DSL is therefore the sum of 0.40m from sea level change and 0.47m of Antarctica ice sheet meltwater, resulting in 0.87m above current average sea level, as established by high-tide geomorphic features.

## 4. Beach Nourishment Sediment Sizing

Beach nourishment with consideration of a changing climate requires placement of sediment with suitable size and gradation to match increased energy and tidal forces consequent to an

0.87m increase in relative sea level. Consequently, the previously established size-ranges for existing Baker Beach sediment should be increased proportional to depth of wave profile arriving to the beach at that distance from shore.

However, since beach nourishment requires replenishment at periodic intervals that are dependent on the beach sediment cell and alongshore and evacuation transport, the estimated sea level change in a shorter time-frame should be considered. Figure 2, presenting year 2050 under RCP8.5 should be considered for size-scaling of existing sediment for the beach nourishment sediment size distribution.

The discretized mapping shown in Figure 2 demonstrates a 0.20m increase in relative sea level in year 2050 under RCP8.5. Increase in sea level results in more depth of water further up on the backshore where average existing sea level does not reach unless under storm surge. As such, any increase in average existing sea level for an area currently not covered will result in a proportional increase of wave-energy. For example, in year 2050 a 0.20m increase will result in up to a 20% increase in transport energy, resulting in a coarsened sediment distribution across size-ranges, which should be considered when determining beach nourishment sediment size.

For example, previously established aggregate mixture (#1) is adjusted for increased wave energy as follows:

| Grain Size | Existing composition | 2050 RCP8.5 Sea level change composition |
|---|---|---|
| 4.8mm+ | 59% | 71% |
| 1.8 to 4.7mm | 20% | 24% |
| Fine to coarse sand | 22% | 5% |

Whereby reduced fine to coarse sand content is balanced by increasing the amount of coarse and fine aggregate, when considered under increased sea level for year 2050.

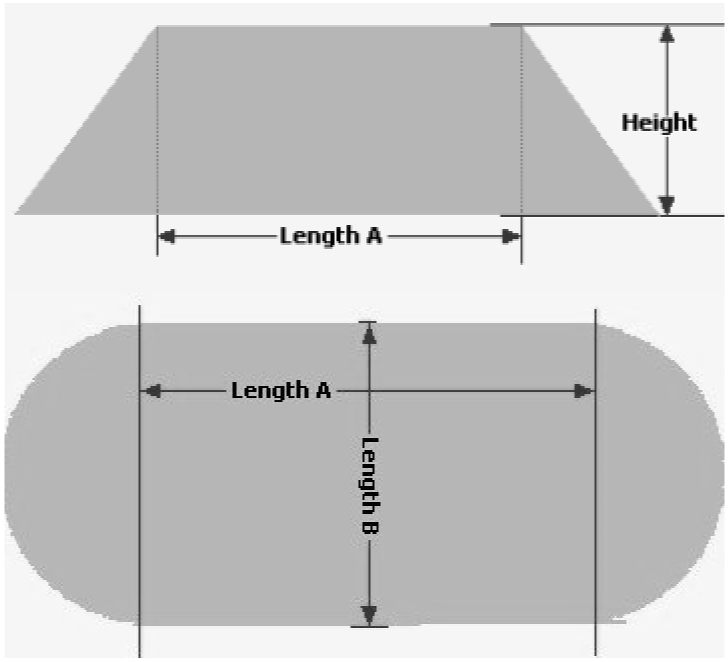
# 5. Design Sea Level and Proposed Beach Nourishment Volumes

Installed beach nourishment volumes will accommodate surveyed local topography, with current projected volumes based on DSL and the average expected slump of sediment mixtures when deposited in a trapezoid pile.

There are discrete areas recommended to receive beach nourishment, with the goal of establishing a backshore elevation at or below the DSL.

Basing this calculation on a cumulative ~300m of shoreline recommended to receive beach nourishment, the placement of aggregate to a height above the DSL will ensure entrainment and re-distribution by natural forces in the recommended areas of Baker Beach. Initial placement will be ‘loaf’ shaped to a height of 1.00m above existing grade, with an average width of 5m to encompass the transition from backshore beach and foreshore beach face.

Calculation of the loaf volume is based on the following schematic:




This results in approximately 770m$^3$ (~1,000 yards) of aggregate material required for the recommended beach nourishment segments on Baker Beach.

A central tenet of beach nourishment is to mimic natural processes for sediment-limited coastal systems. To which, the placed materials will be graded toward open-waters, mimicking the profile of a natural landslide deposit into the receiving coastal environment. Precise form is dependent on placement location within the study area, albeit expected that wave and alongshore sediment movement in the coastal zone will naturally redistribute the placed beach nourishment volume. The redistributed volume of beach nourishment is anticipated to meet or be at lower elevation than the DSL.

## 6. Closure and Limitations

This investigation of predicted sea level change for the west coast of Salt Spring Island accounts for best available data and methods suitable for coastal western Canada. From which, the year 2100 prediction of sea level rise is 0.40m under median (RCP4.5) climate-forcing conditions resulting from progressive global implementation of greenhouse gas mitigation measures. Using a precautionary approach, the addition of meltwater from the Anatarctica ice sheet was considered to be contributory – resulting in an additional 0.47m of sea level rise by year 2100.

Therefore the DSL is 0.87m above current relative sea level along the west coast of Salt Spring Island.

To adequately account for increased forces applied to the coastline consequent to sea level rise, the fractional grain-size distribution of existing sediment was increased proportional to a medium-term high rate of climate forcing (RCP8.5). The RCP8.5 scenario, as presented in Figure 2, was selected consequent to a projected lack of progress on implementing greenhouse gas mitigation measures by the year 2050 – which is accounted for in the year 2100 RCP4.5 scenario.

The preceding rationale relies on existing IPCC AR5 assessments, data, global circulation models, and nationalistic human behaviour when faced by climate-driven global socioeconomic challenges. The calculations remain valid insofar as the data and policy upon which they rely is regarded as representative of best available knowledge.

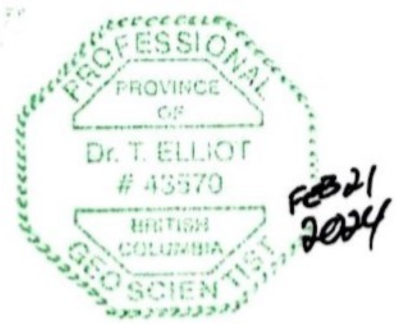
As such, this report is limited to the proposed beach nourishment and erosion mitigation activities for the study area – Baker Beach and upland areas – on Salt Spring Island, British Columbia Canada. Utilization of the DSL, or other calculated data from this report, for areas outside of the study area is not suitable.

## 7. Certification and sign-off

The undersigned certifies that this Assessment conforms to EGBC guidance and best practice for evaluating Site hydrology under similar time and monetary constraints.

| | | |
|---|---|---|
| Qualified Professional of Record | THOMAS R. ELLIOT PhD<br>P.Geo, P.Ag<br>Name | Signature |

Thomas R Elliot PhD P.Geo. P.Ag.

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Date: February 21, 2024