District of Ucluelet Coastal Flood Mapping

Appendix B: Coastal Erosion Preliminary Data Review

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1 Introduction

As part of the District of Ucluelet Coastal Flood Mapping project, the District of Ucluelet (DOU) wishes to better understand the implications of coastal erosion hazard on landuse planning. This document first provides a brief background on coastal erosion hazard, including observations from a field visit, and the regulatory context. This is followed by a review of data that would be relevant to complete an erosion hazard assessment for the DOU. The review focusses on an existing dataset produced by BC Parks. Data gaps and useful local information are also discussed. At the end of this document we provide recommendations for next steps. The findings from this document complement the detailed coastal storm and tsunami flood hazard mapping presented in the main report.

1.1 What is Coastal Erosion Hazard

Coastal erosion occurs when there is a loss of coastal lands due to the net removal of sediments or bedrock from the shoreline. Globally, over the period 1984-2015, the overall surface of eroded land (28,000 km^2) was estimated to be about twice the surface of gained land (Mentaschi *et al.*, 2018). This study found that, human-caused factors are dominant drivers of the changes. Activities that range from building coastal structures to clearing coastal ecosystems lead to increasing movement of sediment, which causes the net loss of land. Other important drivers of coastal erosion are natural coastal flood hazards such as tsunamis and extreme storms, as well as sea level rise (SLR) caused by climate change[1]. Coastal erosion hazard is therefore highly interconnected with other human and natural coastal processes.

1.1.1 Shorelines in Ucluelet

Shorelines within the boundaries of the DOU are diverse. Rocky shores dominate and are interspersed by pocket beaches with flat sandy areas and marshes. The Ebbwater project team conducted a site visit on March 3-4, 2020 to gain an appreciation for, and document, this diversity. The team was accompanied by staff from the DOU to discuss storm and tsunami hazard issues, including coastal erosion. General observations from example areas are shown in Figure 1 (images a to f). The full set of images from the site visit is included within the data package transferred to the DOU as part of this project.

a) The Ucluelet Small Craft Harbour has a variety of infrastructure including boats and docks that interact with the shoreline. Photo taken on 3 March 2020.

b) Inundated areas of this marsh, which is located on the Southern Peninsula at the end of Kimoto Dr., vary substantially according to the tides. Photo taken on 3 March 2020.

[1] Coastal erosion hazard and risk assessment. United Nations Office for Disaster Risk Reduction. Weblink: https://www.undrr.org/publication/coastal-erosion-hazard-and-risk-assessment#:~:text=Coastal%20erosion%20(or%20shoreline%20retreat,or%20bedrock%20from%20the%20shoreline. Accessed 2 June 2020.

c) Big Beach has a rocky outer shore and finer grained material near the backshore zone. Photo taken on 3 March 2020.

d) Located at the tip of the Ucluth Peninsula, Amphitrite Point has a rocky and mildly-sloped foreshore. It is exposed to the winds and waves of the Pacific Ocean. Photo taken on 4 March 2020.

e) This rocky/sandy inlet near Terrace Beach is representative of the many inlets around Ucluelet. Photo taken 4 March 2020.

f) Driftwood on Little Beach shows how wave action can transport material during coastal storm events. Photo taken 3 March 2020.

Figure 1: General observations of shoreline areas within the DOU.

Characterizing the erosion hazard at the local scale requires an understanding of the diverse coastal geomorphological processes and shoreline ecosystems that are present. Modelling these dynamic processes is challenging, which is an important limitation in coastal erosion management.

1.2 Managing Changing Erosion Hazard

From a regulatory perspective, guidance on coastal erosion hazard can be found in the *Provincial Guidelines*, which are discussed in the main report in the context of flood hazard. The Provincial Flood Hazard Area Land Use Management Guidelines (FHALUMG) specify distance requirements for setbacks in coastal areas depending on a building site's location relative to geographic features (e.g., erodible beach, coastal bluff, natural bedrock) and the natural boundary of the sea. The natural boundary can be defined simply as the natural limit of permanent terrestrial vegetation; however, it contains important nuances[2] (Figure 2). One important nuance is that coastal and sea level rise processes are dynamic leading to constant changes in coastal vegetation and—with it—the natural boundary. These processes are responsible for "coastal squeeze" of shoreline vegetation (Mills *et al.*, 2015).

The concept of a dynamic natural boundary is captured within Sea Level Rise Planning Areas of the FHALMUG (Figure 2). SLR Planning Areas reach from the natural boundary of the sea landward to the contour elevation of the future Flood Construction Level, which itself can be tied to future sea levels (see the main report for discussion).

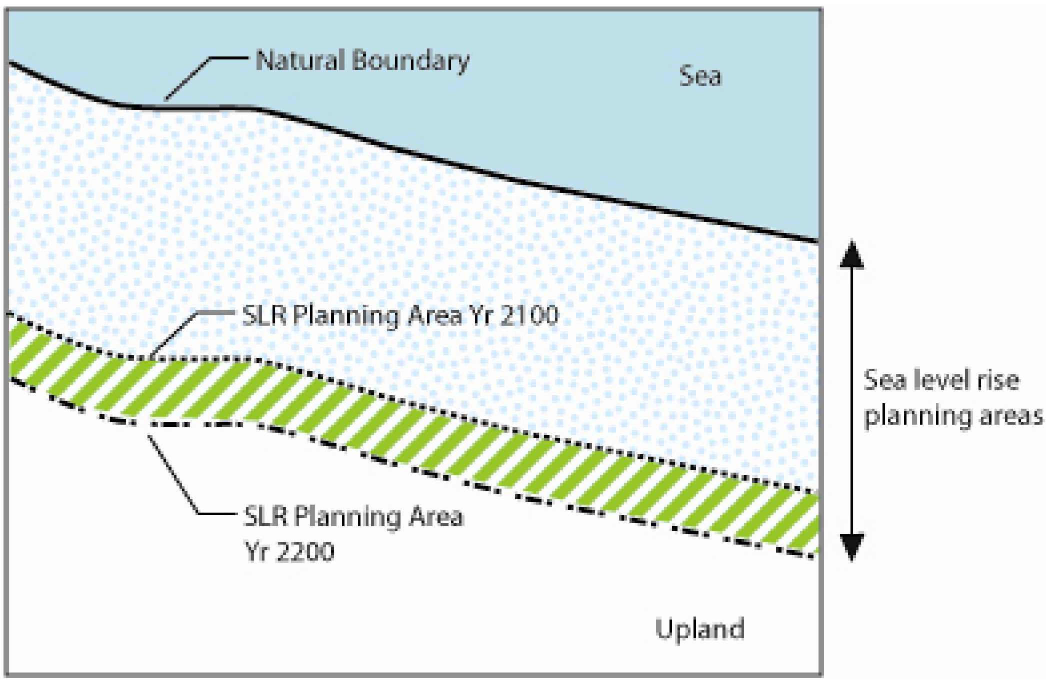

Figure 2: Sea Level Rise Planning Area example (Figure from Ausenco Sandwell 2011a, 2011b, 2011c).

SLR Planning Area extents vary depending upon the shoreline and backshore terrain. Steeper areas will experience less sea level rise impacts compared to flatter areas (see Figure 3). SLR Planning Areas are used to show the change in flood extent over time and may be designated by local governments, by bylaw, as flood hazard areas.

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[2] The natural boundary is defined in the *Provincial Guidelines* as "The visible high watermark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river, stream or other body of water a character distinct from that of the banks, thereof, in respect to vegetation, as well as in respect to the nature of the soil itself. For coastal areas, the natural boundary shall include the natural limit of permanent terrestrial vegetation. In addition, the natural boundary includes the best estimate of the edge of dormant or old side channels and marsh areas."

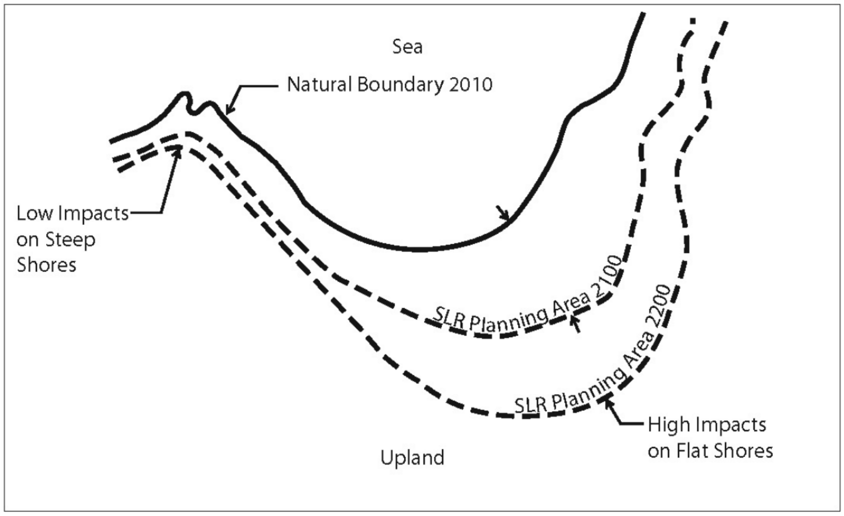

Figure 3: Concept plan of SLR Planning Area varying with terrain (Ausenco-Sandwell, 2011).

In practice, implementing coastal erosion guidelines is challenging and these issues are introduced in the next section.

1.3 Erosion Hazard Assessment

There is a clear consensus about the linkages between dynamic coastal processes, SLR, and potential erosion hazard. This is based on the recognition that hazard increases from gravel and estuarine settings to sandy shorelines, and that these increase with wind and wave action. It is also understood that the rate of land retreat resulting from erosion is highly dependent on site material of the foreshore and backshore (Ausenco-Sandwell, 2011).

However, guidance in BC on how to conduct appropriate hazard assessments is currently only available at a high-level. Basic coastal geomorphology information that would be used for site-characterizations is most often unavailable for use in technical studies. Secondly, key technical components such as wave run-up estimates are usually based upon simplified shoreline geometry using a 1-dimensional (1D) transects approach (see Appendix A for details on how this was achieved for this project). Therefore, more detailed 2D modelling, based on high-resolution coastal geomorphology information, would be required to obtain a more fulsome understanding of erosion hazard through time. The next section contains a review of relevant information that was found to reach this objective for the DOU; data gaps will be highlighted and further discussed in Section 2.2.

2 Data Review

A preliminary data review was conducted to evaluate the information that was available for the project area to support an erosion hazard assessment. We focused the review on the BC Parks Model, as it was a source of information that was consistent, relevant, and covered the project area.

2.1 BC Parks Model

BC Parks developed a model that rates marine and terrestrial segments of the BC coastline. The model was developed to assist managers, planners, and others who require knowledge of the relative sensitivity of shorelines to develop an appropriate set of adaptation and mitigation responses (Biffard and Stevens, no date). The model rating system defines the sensitivity to sea level rise using a five-point scale. The data are available in shapefile and kmz format, including attribute tables[3]. The sensitivity ratings were determined by rating shoreline units based on their foreshore and backshore components. The datasets that were combined to develop the ratings are summarized in Table 1.

Table 1: Summary of BC Parks Model data sets.

Zone	Name and Reference	Description	Resolution
Foreshore	ShoreZone (Howes, Harper and Owens, 1997)[4].	Mapping of the physical characteristics of shoreline areas.	High (1:20,000)
Backshore	Broad Ecosystem Inventory (BEI)[5]	Spatial layer showing the distribution of ecosystems and their value to wildlife.	(Low) 1:250,000
Backshore	HectaresBC[6].	Mapping of terrain characteristics including slope, based on digital elevation models.	High (unspecified)[7]

Based on the low resolution of the BEI, we placed little confidence in this dataset and it was not explored further. However, the relatively high resolution of the HectaresBC data suggested that the slope information could be used for interpretation with relatively high confidence. Similarly, we placed higher confidence in the Shorezone data's high resolution; this dataset was explored further.

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[3] BC Parks Sensitivity to Sea Level Rise Model data Weblink: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=42825. Accessed 15 January 2020.
[4] Strait of Georgia Data Centre. British Columbia ShoreZone Map. Weblink: http://sogdatacentre.ca/interactive-map/shorezone_map/shorezone_map.html. Accessed 27 May 2020.
[5] Broad Ecosystem Inventory Specification Layer. BC Ministry of Environment. 2013. Weblink: https://catalogue.data.gov.bc.ca/dataset/broad-ecosystem-inventory-classification-spatial-layer. Accessed 4 June 2020.
[6] Hectares BC. https://hectaresbc.org/app/habc/HaBC.html. Accessed 4 June 2020.
[7] The current gridded DEM specification on the Hectares website currently contains a broken link to its metadata. However, based on professional judgement the DEM resolution used at the time the BC Parks Model was developed was conservatively less than 50 m.

2.1.1 Shorezone Data

The physical characteristics of DOU areas of were explored to gain a better appreciation for the underlying information in the Shorezone dataset. Figure 4 shows results for wind exposure. As expected, areas located on the western and southern sides of the Ucluth Peninsula are either exposed or semi-exposed to waves (i.e., see red and orange lines). Areas on the inlet side of the DOU are classed as protected (i.e., see blue lines).

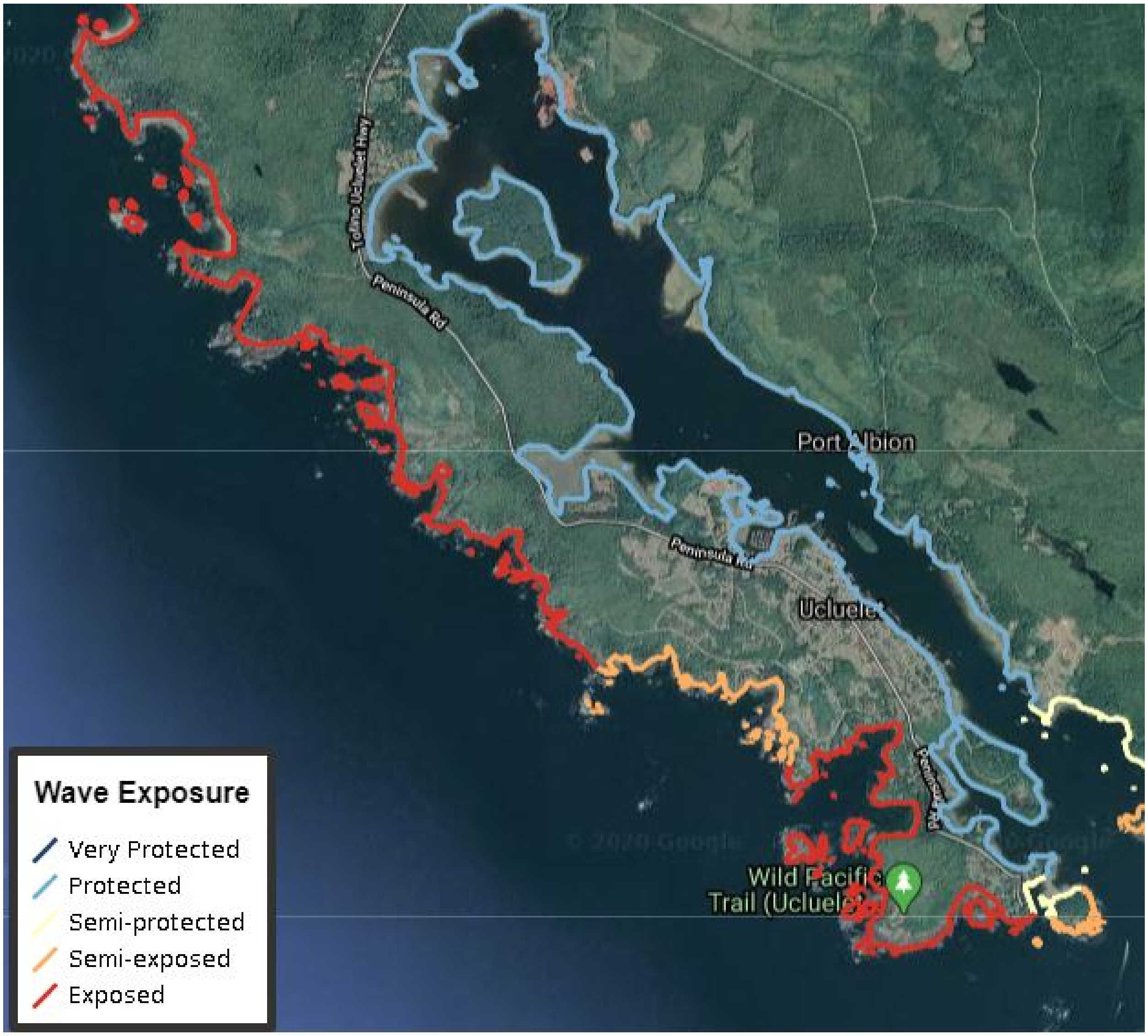

Figure 4: BC ShoreZone Map showing wave exposure classes for the Ucluelet area (from Howes, Harper and Owens, 1997)**.**

The results from Figure 4 closely resemble the pattern of results obtained from the coastal storm modelling presented in this project's main report. Figure 5, taken from the main report, shows the difference in modelled water depths between frequent and rare coastal storm flood events.

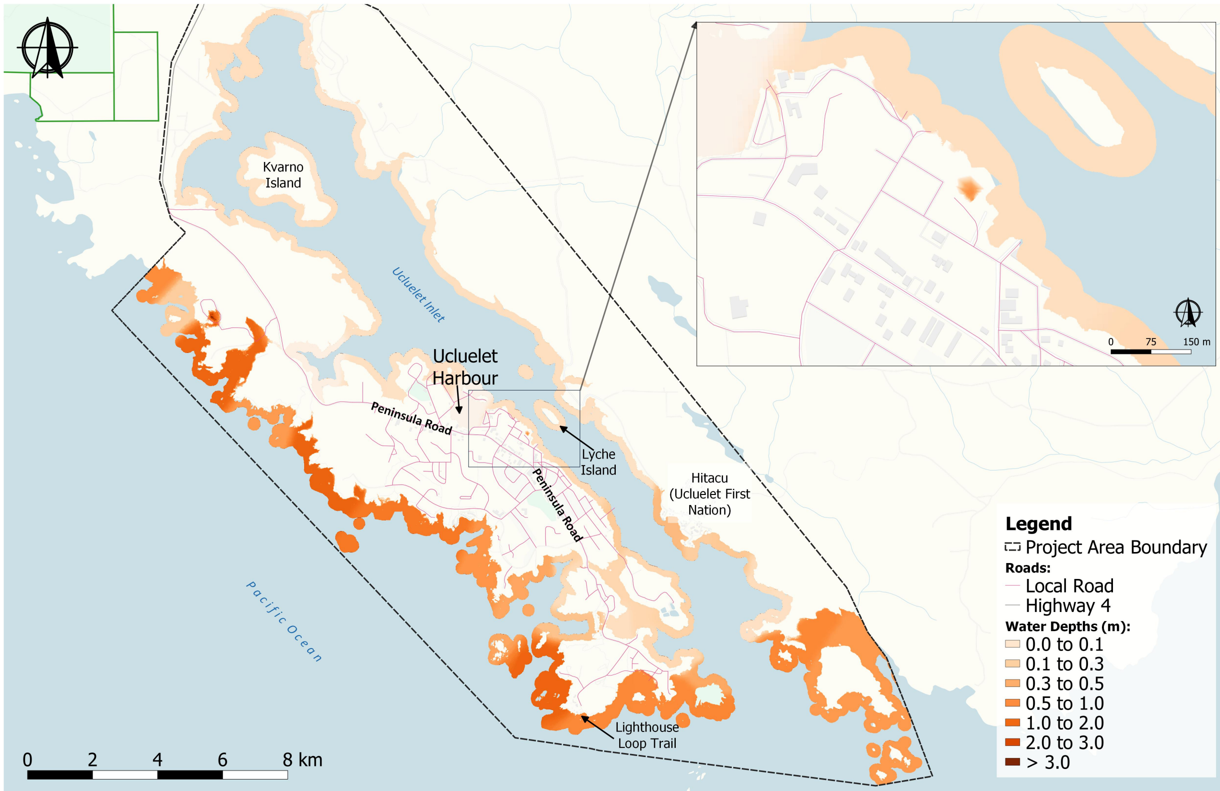

Figure 5. Modelled water depth difference between frequent and rare coastal storm events.

In Figure 4, the protected areas match the pattern of areas showing the smallest difference between frequent (i.e., low magnitude; 6.67% AEP) and rare (i.e., high magnitude; 0.2% AEP) floods shown in Figure 5 (i.e., areas with light orange in the inlet). This illustrates the strong influence that the wave effect component has in determining water depth for different sizes of coastal storms in the Ucluelet area. The comparison between Figure 4 and Figure 5 provides two insights:

1) The results from this project's localized modelling are consistent with the wave exposure data used in the BC Parks Model.
2) Wave exposure corresponds to greater water depths, highlighting areas of potential erosion.

Coastal processes such as wave effects alone, however, are not sufficient to increase erosion. Sediment abundance and mobility are also required. The Shorezone dataset contains information on sediment abundance; however, there is no data for the Ucluelet area (Figure 6). An alternate high resolution source of data on sediment abundance was not found; more discussion on this topic is in Section 2.2.

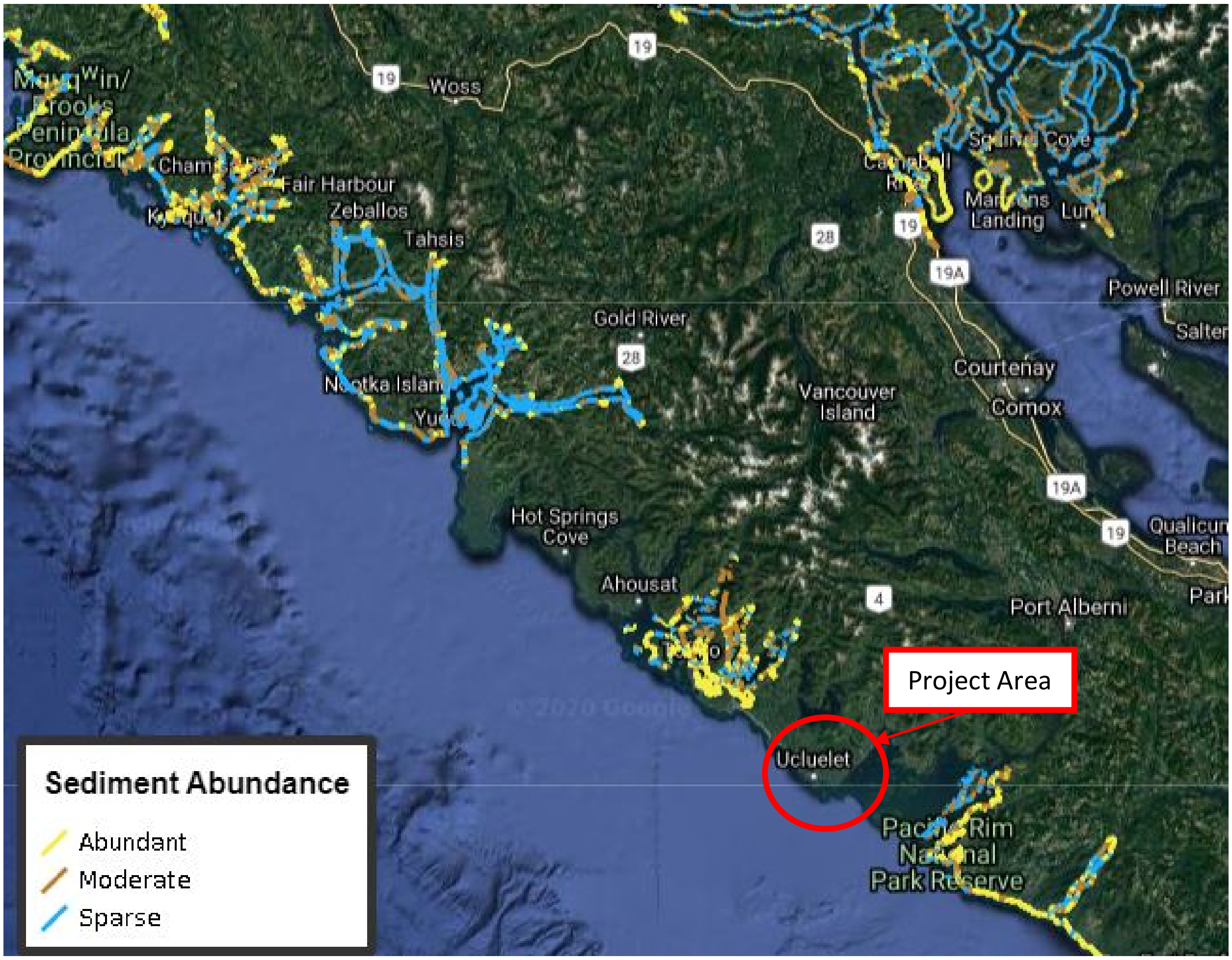

Figure 6: British Columbia ShoreZone Map showing sediment abundance for areas of Vancouver Island; however, data exclude the Ucluelet area.

2.1.2 Preliminary Findings

The BC Parks Model data were analyzed recognizing the data availability limitations for the project area. Figure 7 shows the Model's results, which show sensitivity to sea level rise as one of five colour-coded categories: red is very high sensitivity, orange is high sensitivity, yellow is moderate sensitivity, light green is low sensitivity and dark green is very low sensitivity. Figure 7 includes annotations for example shorelines having high or very high ratings. The annotations explain the factors that led to their very high and high sensitivity ratings. Bold text highlights the key factors in each of the high rating areas that are annotated; these are shoreline type, exposure, and slope.

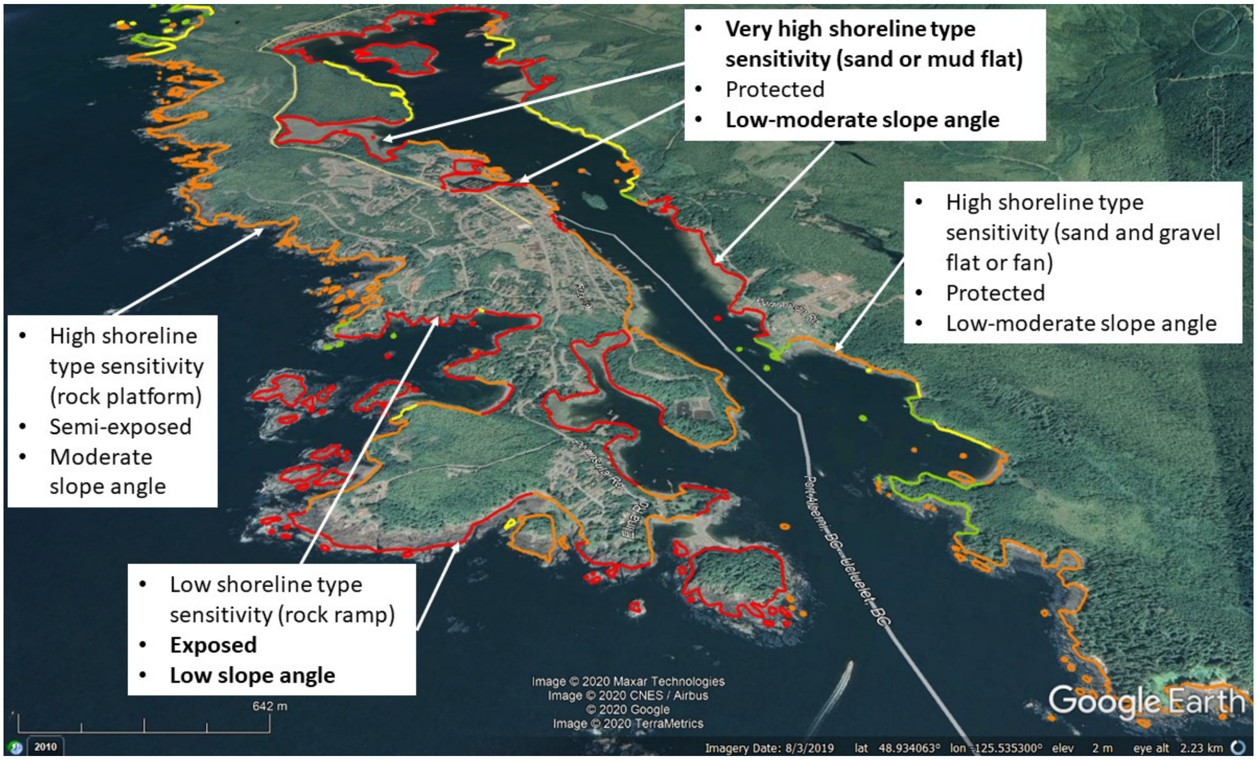

Figure 7: BC Parks Shoreline Sensitivity to Sea Level Rise Model, with annotations for the Ucluelet Area.

Based on the BC Parks Model results, the project area may be broadly divided into two areas, and the potential for erosion hazard in these areas is explained at a high level as follows:

- **Areas on the ocean side of the peninsula.** These are more exposed to waves, increasing the erosion potential. However, these areas generally consist of rocky shorelines that are less likely to erode. Even where slopes are high, erosion is less likely to occur due to the dominance of rock (in contrast to sediment and sand).
- **Areas in the inlet.** These areas are protected from wave exposure. However, flat sandy areas are susceptible to changes in sea level rise and erosion of sediment along the foreshore zone.

The BC Parks Model dataset and findings provide an initial high-level understanding of erosion potential in the project area. The sensitivity ratings may be used to guide more detailed investigations into potential erosion areas of concern for the DOU. The more important data gaps that were highlighted within the Model are discussed below.

2.2 Data Gaps

Based on the preliminary data review, the key data gaps to address erosion hazard in the DOU are related to characterizing surficial geology and soils, as well as ecosystems, of the shoreline areas. The following sections broadly discuss the literature related to these gaps.

2.2.1 Surficial Geology and Soils

Several sources were reviewed for information on surficial geology and soils, which could be used to better understand sediment abundance and mobility. Baker (1974) completed an assessment of soil resources in the Tofino area for land-use planning and management purposes. The study reported that the high total precipitation (and ions present in the precipitation) of the area influences the function and morphology of local soils. Other important factors include the depth to bedrock and the depth to the water table. While these high-level conclusions likely apply to the Ucluelet area, the study did not contain data collection and specific results for the DOU.

The BC Ministry of Mines and Petroleum Resources maintains a surficial geology map index for the province[8]. However, no information is available for the Ucluelet area. Other relevant surficial geology data sources were generally found to consist of broad-scale studies with low-resolution data. The Surficial Materials of Canada[9] map, for example, has a resolution of 1:5,000,000. This data appears to be the basis for the surficial geology data within the newer CanCoast Coastal Materials Version 2.0[10] dataset. This dataset consists of baseline mapping of coastal characteristics and understanding of the dynamic response of coastal sensitivity to environmental changes.

2.2.2 Ecosystems

Further understanding is also required related to shoreline vegetation and structure; erosion hazards vary in marshlands compared to barren rock or forest ecosystems. As noted in Section 2.1.1, the BEI data available in the BC Parks Model has a very low resolution (i.e., 1:250,000). The BC Parks Model manual states that if available for specific study areas, updated Terrain Ecosystem Mapping[11], produced by the BC Ministry of Environment, could be used in conjunction with the BC Parks Model.

2.3 Useful Local Information

Once key data gaps are filled, hydrodynamic modelling outputs that were produced as part of this flood mapping project, such as wave velocities (see Appendix A for details), could be used as input to an erosion model. This approach is being taken as part of a coastal adaptation plan currently being conducted by the neighbouring Toquaht First Nation[12]. The assessment includes an erosion analysis that is based on

[8] British Columbia surficial geology map index. H. Arnold and T. Ferbey. Weblink: http://cmscontent.nrs.gov.bc.ca/geoscience/PublicationCatalogue/OpenFile/BCGS_OF2019-03.pdf. Accessed 29 May 2020.

[9] Fulton, R.J., 1995. Surficial materials of Canada. Geological Survey of Canada, Map 1880A, 1:5,000,000 scale. Weblink: https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=205040. Accessed 29 May 2020.

[10] CanCoast – Coastal Materials Version 2.0. Natural Resources Canada. Weblink: https://open.canada.ca/data/en/dataset/73714ed4-a795-a7ae-7e93-36100ce7c242. Accessed 29 May 2020.

[11] Terrain Ecosystem Mapping. BC Ministry of Environment. Accessed 29 May 2020.

[12] Robin Parker. Kerr Wood Leidal. Comprehensive Coastal Flood Group (CCFG) meeting of 29 April 2020. This was also confirmed by phone conversations between Ebbwater staff and Noah Plonka (Manager Business Operations, Tel.: 250-522-0201) through email on 28-Feb-2020 and Rick Shafer (contractor, Tel.: 250-715-6201) in a phone conversation in February 2020, both of Toquaht First Nation.

hydrodynamic modelling that was managed by Indigenous Services Canada (ISC) to complete flood and tsunami hazard mapping[13].

The DOU should also follow-up with the Ucluelet First Nation to access drone footage that has reportedly been obtained for shoreline areas. The footage could have potential use in calibrating an erosion model[14].

3 Recommendations

This section discusses recommended next steps for the DOU to manage coastal erosion hazard. Recommendations on conducting an erosion hazard assessment and implementing no-regrets management practices are provided.

3.1 Conduct Coastal Erosion Hazard Assessment

Based on international best practice from UNDRR (2017), a variety of methods can be considered to conduct a coastal erosion hazard assessment. In considering the data gaps discussed in Section 2.2, the key steps to conduct an assessment include:

- **Consider the spatial and temporal scale.** The spatial scale could follow the same scale used for the flood mapping project. The timescale should include short-term analyses to better understand coastal behaviour across the seasonal weather cycle. It should also include long-term considerations to assess the influences of climate variability and change. Geologic timescales are also relevant to consider the influence of uplift within the context of sea level rise. This has already been considered in the flood mapping project by incorporating the concept of relative sea level rise.
- **Define the governing flood hazards.** The drivers for erosion (i.e., human-caused activities, tsunami, storm, and sea level rise) need to be defined. Scenario outputs from the coastal flood mapping report may be selected for this step. Defining these drivers will help characterize erosional processes, which can be used within a sediment budget.
- **Identify available data and modelling approaches.** Baseline data collection can be valuable in establishing rates of shoreline change. Surficial geology, LiDAR, satellite imagery, and coastal infrastructure maps can all be used in conjunction with models to understand coastal processes. Key questions may be answered such as "how far would the shoreline need to erode to affect the FCL or SLR Planning Area?" and "what is the probability of various levels of shoreline retreat", and "what is the uncertainty of these estimates?". As previously mentioned, some of the base data is now available as a result of the coastal flood mapping project.

Recent guidance from the United States, such as the Guidance for Flood Risk Analysis and Mapping – Coastal Erosion (FEMA, 2018) should also be considered in the completion of an erosion hazard assessment.

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[13] The Coastal Vulnerability Studies (CVS) for Vancouver Island are being managed by ISC and completed by Parsons, and Robin Fenn and Associates.
[14] John Towgood. Planner I, District of Ucluelet. Personal communication, 4 March 2020.

Once a hazard assessment has been completed, a risk assessment should be considered to frame mitigation options within the context of risk reduction. This would include an analysis of likelihood of erosion, as well as the exposed assets that are located within erosion hazard areas. The exposure components of the erosion risk assessment would be very similar to those determined for a coastal flood risk assessment (that assessment is one of the recommendations provided in the main report).

3.2 Solicit Services from a Suitably Qualified Professionals

As outlined throughout this document, knowledge of coastal erosion requires an understanding of complex and interconnected processes. A multi-disciplinary team of professionals, which combine technical and non-technical knowledge within engineering, planning, and environmental science fields, should be assembled within the DOU and its consultants. Key knowledge areas for professionals should include coastal geomorphology and biology. These professionals should be registered with one of the five professional regulators for engineering and geoscience, forestry, agrology, applied biology, and applied science technology.

3.3 Implement No-Regrets Best Management Practices

There are clear steps that the DOU could take today to reduce erosion potential. High-level best management practices that could be integrated into its landuse planning initiatives include (Biffard and Stevens, no date):

- Enhance and restore ecosystems in sensitive areas.
- Reconfigure land use to protect sensitive areas.
- Prevent or minimize damage to areas of human occupation.
- Protect or relocate existing developments of concern.

4 Conclusion

This document has provided background and supporting information on coastal erosion hazard for the DOU. A preliminary review of a dataset was completed, which helped to identify data gaps that should be filled prior to completing a hazard assessment. The information complements findings on coastal flood hazard contained in the main report; it can be used to build upon future coastal flood hazard and risk assessments in the DOU.

5 References

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