Regional District of Nanaimo
Sea Level Rise Adaptation Program
Coastal Floodplain Mapping (Revision 1)
Overview

Photo: High tide in Parksville, December 26, 2018.

28 June 2021

Disclaimer

This document has been prepared by Ebbwater Consulting Inc. and its partner Cascadia Coast Research Ltd. for the exclusive use and benefit of the Regional District of Nanaimo. It has been developed in accordance with generally accepted engineering practices and with full understanding of applicable flood mapping guidelines in the province of British Columbia. The contents may be used and relied upon by the officers and employees of the Regional District of Nanaimo. However, Ebbwater Consulting Inc. and Cascadia Coast Research Ltd. deny any liability to other parties who access and use this report.

This report provides a short overview of the work. Please refer to the full report (Ebbwater Consulting Inc. and Cascadia Coast Research Ltd. 2021: Regional District of Nanaimo Coastal Floodplain Mapping Final Report) for full discussion of methods, results, and limitations.

Introduction

The Regional District of Nanaimo (RDN)'s beautiful coastal landscape also means that it is exposed to flood hazards caused by coastal storms. These hazards are further increased by climate change and rising sea levels.

The RDN has recognized the importance of better understanding coastal flood hazards, especially in the context of changing sea levels, to support planning and emergency management. Flood hazard maps are a foundational tool to support this; a good understanding of where and how deep water might be in a flood event provides the basis for sound decisions on flood management.

To support the RDN in becoming more resilient to future flooding, Ebbwater Consulting Inc. and its partner Cascadia Coast Research Ltd. assessed coastal flood hazards from storms considering sea level rise in accordance with British Columbia Provincial guidelines.

Specifically, in this study, we asked:

1. Where and how deep might it flood during different coastal storm events? And how does this change with sea level rise?
2. What is a suitable elevation for new residential construction in coastal zones that incorporates allowances for sea level rise?

Study Area

This study focused on the Regional District of Nanaimo on Vancouver Island from Deep Bay in the north to Cassidy in the south, including Gabriola Island (not including the City of Nanaimo), as can be seen in Figure 1.

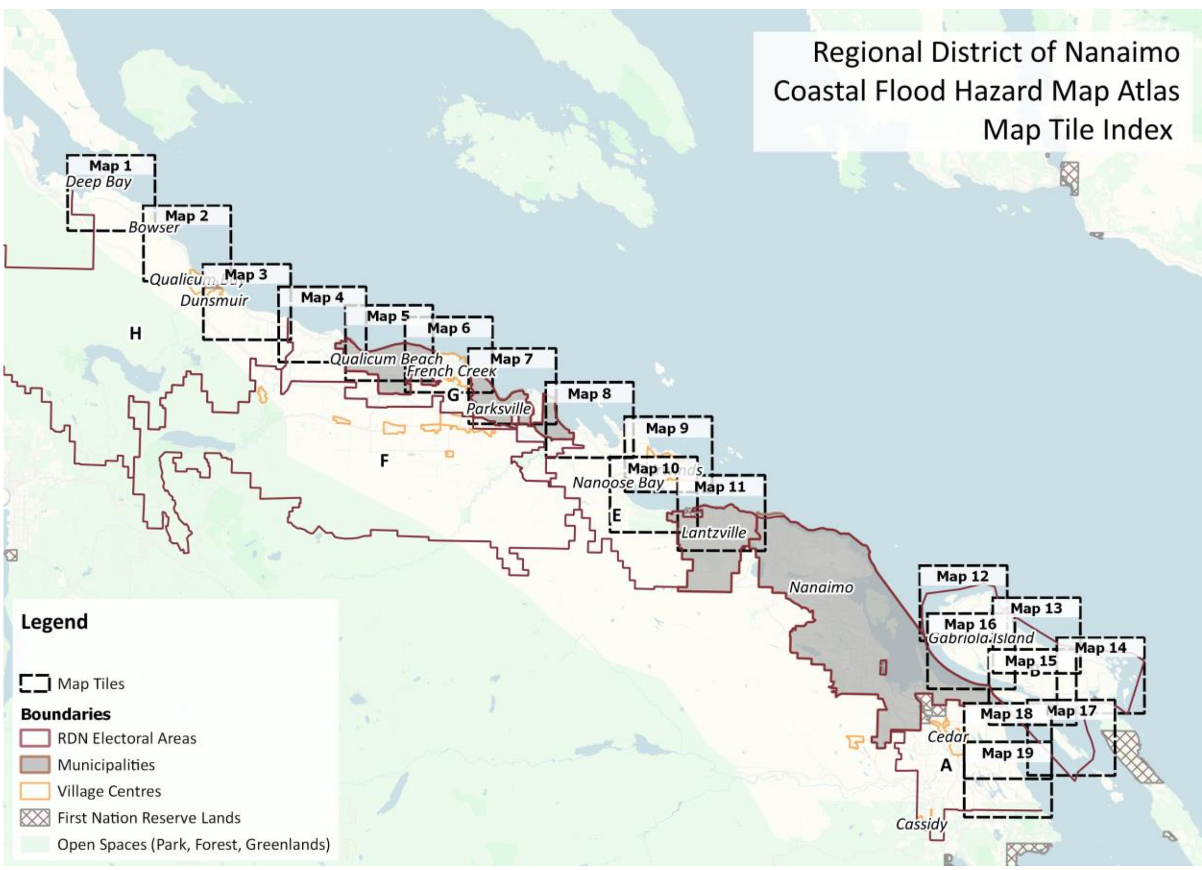

Figure 1: Study area of the coastal floodplain mapping project in the RDN, showing flood map tiles.

What is a Coastal Flood Hazard?

Coastal storm-driven flood hazards arise when ocean water levels are higher than normal in the Strait of Georgia as a result of storm activities. Water levels in the ocean off the coast are a function of many components. Some of these are predictable (deterministic), such as tides. Other components are less predictable (probabilistic); these are factors that increase water levels as a result of storm events and include storm surge, wind set-up, and wave setup and effects (Figure 2). These processes have varying likelihoods of occurrence and require detailed analyses of specific events to quantify the resultant combined effect on total water levels.

Coastal Storm Flood Hazard Method

Storm flooding was assessed using a "designated storm approach", where a series of different storm conditions are analyzed using records of local coastal weather patterns. We assessed different combinations of storm surge heights and wind and wave effects, and looked at the historic record to determine how frequently these conditions occurred. From this analysis, we estimated how likely particular events are to occur in future. This was done based on **Annual Exceedance Probabilities (AEPs).** The AEP describes the probability than an event will occur in any given year and is written as a percentage.

Another way to think about flood probability is through the use of **encounter probabilities**, which is the probability of encountering an event of a given size over a defined time period — for example, the length of an average mortgage (25 years) (Table 1).

Storms with different probabilities vary in magnitude and will have different impacts on the coastline. To understand the range of impacts (ranging from relatively small, relatively common storms to very large, much rarer storms), 5 different AEPs were determined (Table 1).

Table 1: AEPs and corresponding encounter probabilities for the flood likelihoods assessed in this project.

Annual Exceedance Probability (AEP)	Encounter Probability of Occurrence			
	In 25 years	in 50 years	In 75 years	in 100 years
6.67%	82%	97%	99%	100%
2%	40%	64%	78%	87%
1%	22%	39%	53%	63%
0.5%	12%	22%	31%	39%
0.2%	5%	10%	14%	18%

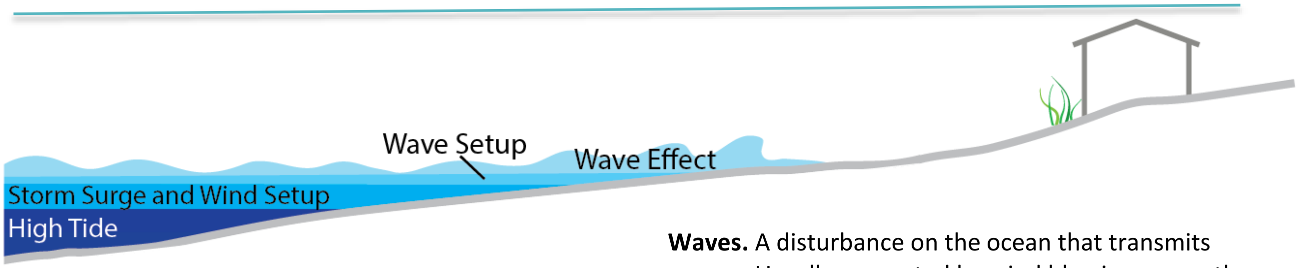

Figure 2: Components of total water level.

<u>Probabilistic (Unpredictable Components)</u>

Storm Surge. A rise above normal water level on the open coast due to a change in atmospheric pressure and wind stress on the water surface**.**

Wind Set-up. Increase in water level near the shore due to on-shore winds blowing over shallow water pushing it up.

Waves. A disturbance on the ocean that transmits energy. Usually generated by wind blowing across the ocean's surface. Waves breaking on the beach cause a static increase in water level (**wave set-up**) and dynamic variation in water level (**wave effects**).

<u>Deterministic (Predictable Components)</u>

Tide. A periodic rise and fall of the ocean surface due principally to the gravitation interactions between the moon, sun and earth.

Changing Climate and Sea Levels

Around the world, sea levels are rising due to warming seas and the melting of ice caps and glaciers with climate change. Variations in local sea level rise occur due to differences in topography, gravitational forces, and ocean currents; the west coast of North America generally experiences lower than average global sea level rise rates.

In the RDN, sea level rise is partially offset by a rise in ground level (land uplift). In southwest BC, it occurs due to tectonic activity and the slow decompression of soils that were compressed by the weight of glaciers during the last ice age, and is also known as isostatic rebound (Figure 3). **Relative Sea Level Rise (RSLR)** describes the rise in sea level compared to vertical changes of the ground level.

RSLR is critical to understanding how the hazard will change over time. In this study, we looked at an RSLR of 0 m, 0.5 m, 1 m, and 2 m for each of the 5 AEP scenarios (20 scenarios in total). The effect of these scenarios on flooding vary along the coastline, as the local topography (i.e., the shape of the land surface) and bathymetry (i.e., the shape of the ocean ground) affects how water moves onshore.

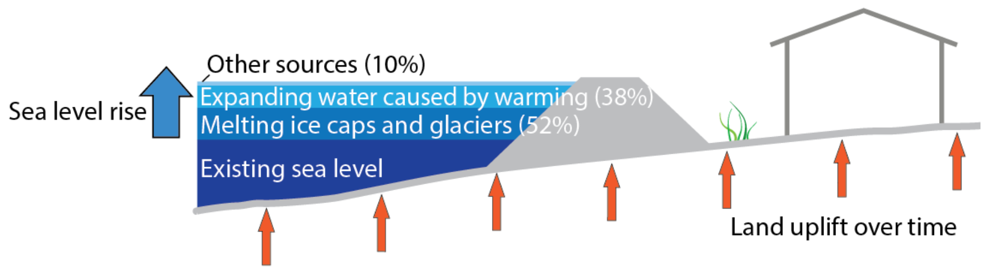

Figure 3: Drivers of RSLR including components of SLR and land uplift.

Flood Maps

To better understand coastal flood hazards under sea level rise, flood maps are produced from hydraulic computer models and calculations to represent the extent of flooding under different scenarios. Simple regulatory maps that include Flood Construction Levels (FCLs) were developed to support planning and building controls.

Flood Inundation Maps

Flood inundation maps are used to represent the total water depth and extents for storm events, as shown in the figures on the next page — the darker shades of blue represent deeper water. Two example maps are provided for an area of the RDN for the 0.5% AEP[1] and 0 m RSLR scenario (Figure 4) and the 0.5% AEP and 1 m RSLR scenario (Figure 5). Water depths and extents increase with **sea level rise** and vary based on topography as the flood waters move inland. According to these examples, low lying areas are more subject to change, see the darker blues on the map with 1.0 m RSLR (Figure 5) in comparison to the first map (Figure 4) with 0 m RSLR.

[1] The 0.5% AEP flood event is the recommended Provincial standard. See Page 3 and Table 1 for AEP definition.

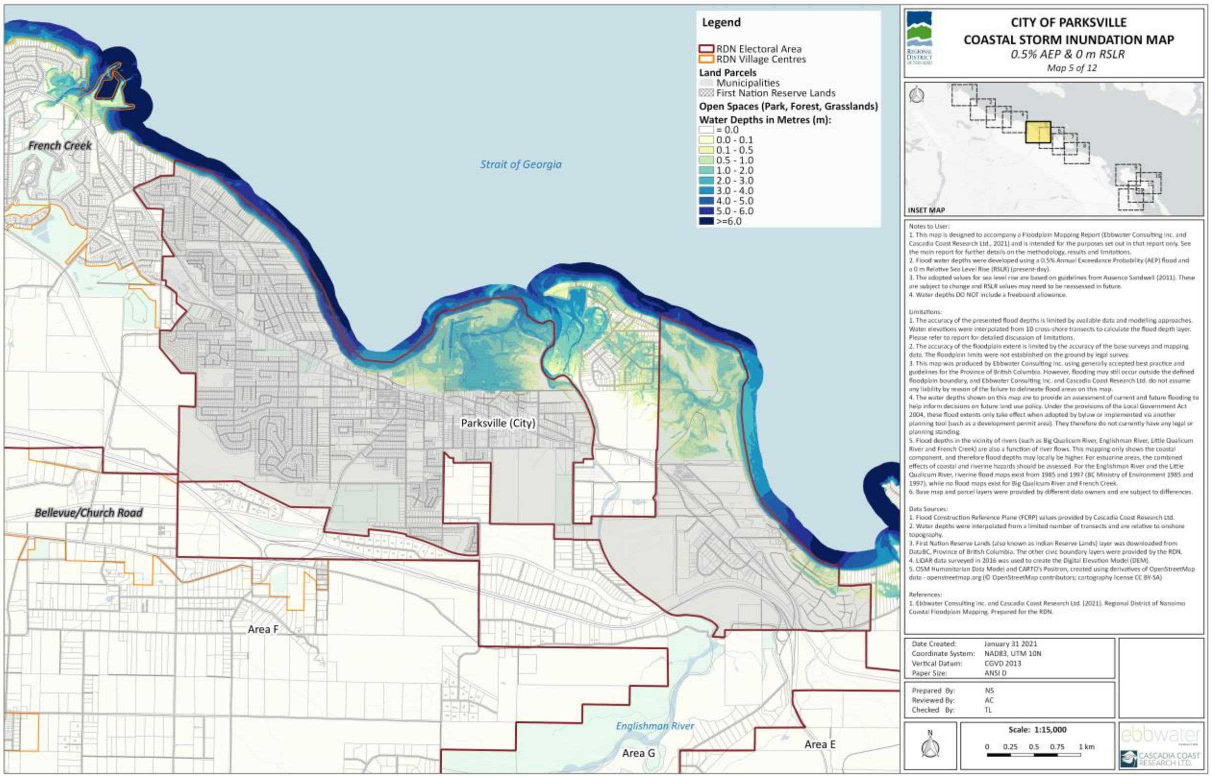

Figure 4: Example 1 – Present-day: 0.5% AEP flood and 0 m RSLR.

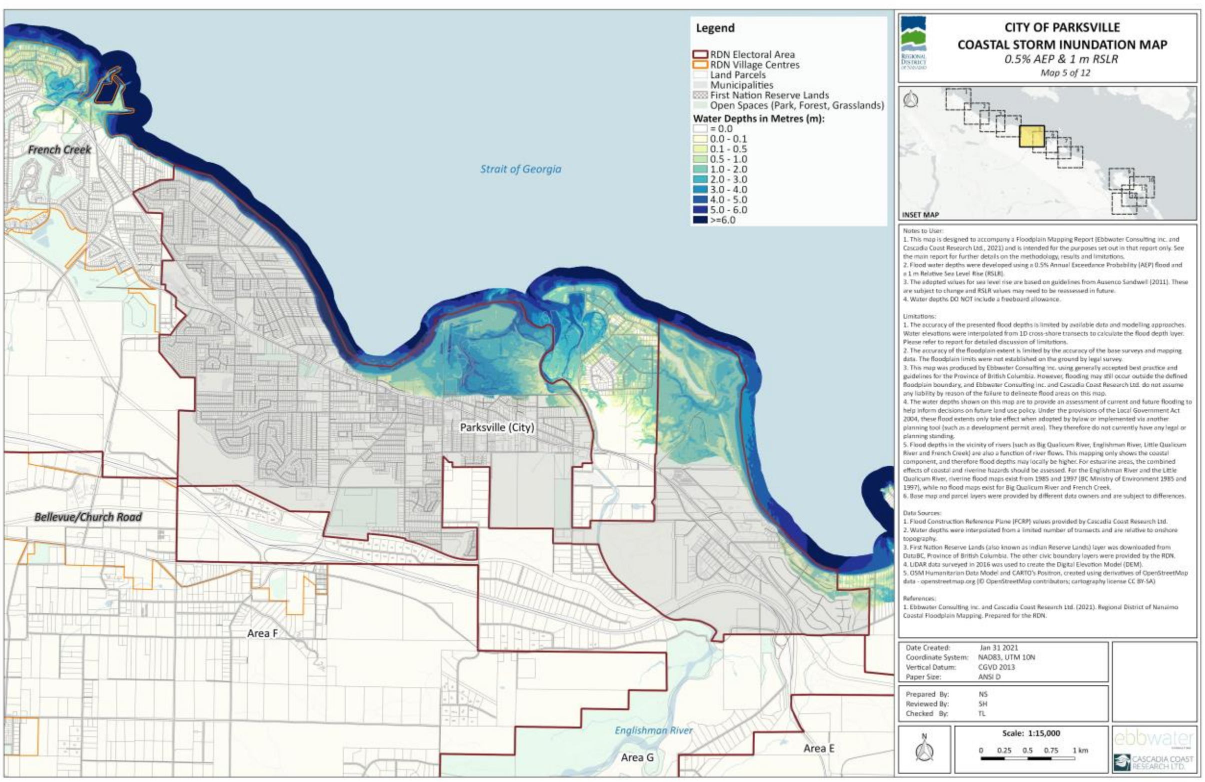

Figure 5: Example 2 – With future sea level rise: 0.5% AEP and 1 m RSLR.

How does flood mapping affect me?

Determining Flood Construction Levels

Flood maps are used in many ways to reduce the impacts of flooding on people, property and infrastructure. One key way is to identify affected areas and to define a **Flood Construction Level** (FCL). The FCL is the elevation of a floor system of a habitable building, which new buildings are required to achieve to minimize damages from flooding.

The Province provides guidelines[2] on how FCLs should be determined and how they can be used in local policy and regulations. The guidelines state that requirements for buildings and zoning should allow for sea level rise (SLR) to the year 2100. The FCL is defined as the total vertical water elevation above a geodetic datum (mean sea level)[3] at the shore (including tide, storm surge, wind and wave effects, and sea level rise), plus an uncertainty factor called freeboard (Figure 6). The FCL in the RDN is determined for the 0.5% AEP storm event, which is the provincial standard[1].

The FCL is extended from the shoreline horizontally landward, until the land surface elevation reaches the FCL. All land with an elevation below the FCL landward of the shoreline is considered within the FCL extent. It is important to note that the FCL always refers to an elevation above a geodetic datum; for this project, the Canadian Geodetic Vertical Datum (CGVD) 2013[4] was used.

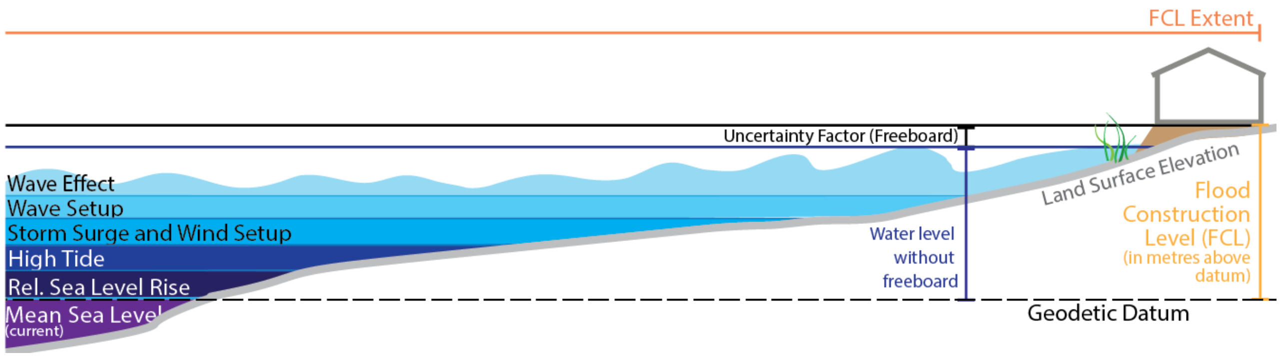

Figure 6: The Flood Construction Level (FCL) is composed of relative sea level rise, high tide, storm surge, wind setup, wave setup, wave effects and an uncertainty factor (freeboard) and is reported in metres above geodetic datum (mean sea level).

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[2] Provincial guidelines: Ausenco Sandwell (2011). Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use - Guidelines for Management of Coastal Flood Hazard Land Use. Prepared for BC Ministry of Environment.
EGBC (2017). Flood Mapping in BC - EGBC Professional Practice Guidelines - V1.0. Association of Professional Engineers and Geoscientists of British Columbia.

[3] A geodetic datum is a reference point or surface that ties an abstract coordination system to Earth. It serves to provide a known location to begin surveys and to create maps.

[4] The Canadian Geodetic Vertical Datum (CGVD) of 2013 is defined by a reference surface that represents the coastal mean sea level for North America, and it replaces the former CGVD28 from 1928. Vertical elevation is reported relative to this datum.

The shoreline characteristics play a major role in how high the FCLs are. For instance, wave runup is typically much higher along steep rocky shores than on low-sloping sandy beaches (as can be observed in storms when waves crash high into steep rocky shores). While FCLs at steep shorelines are generally higher than on sandy beaches, the land surface elevations inland of steep cliffs are also typically higher than inland of sandy beaches. Thus, even though the FCL might seem high, it may in practice not require a much higher building construction above land surface elevation.

Shoreline orientation (i.e., if the coast is facing southeast or northeast, etc.) also plays an important role in terms of local wind and wave effects and may lead to differences in the FCLs.

Flood Construction Levels in the RDN

With 1 m of RSLR, the FCLs in the RDN area range from 4.88 m to 12.1 m elevation. From Deep Bay to Parksville, the shoreline is characterized by low-sloping sandy beaches, and along this long stretch of coastline the estimated FCLs are 4.9 to 7.7 m. South of Parksville to Nanoose Bay, low-sloping sandy shores are interspersed with higher-sloped rocky shores. Through this area, the range of FCLs is very large, about 4.9 m to 10.2 m. Outer Gabriola Island is characterized by steep rocky shores, coastal bluffs and a few sandy pocket beaches. Here, the FCLs range from 5.0 m to 11.3 m, with the largest values occurring at exposed coastal bluffs. The more protected southern coast of Gabriola Island has FCLs from 5.9 to 11 m. South of Nanaimo in Electoral Area A, FCLs range from 5.1 m to 8.5 m.

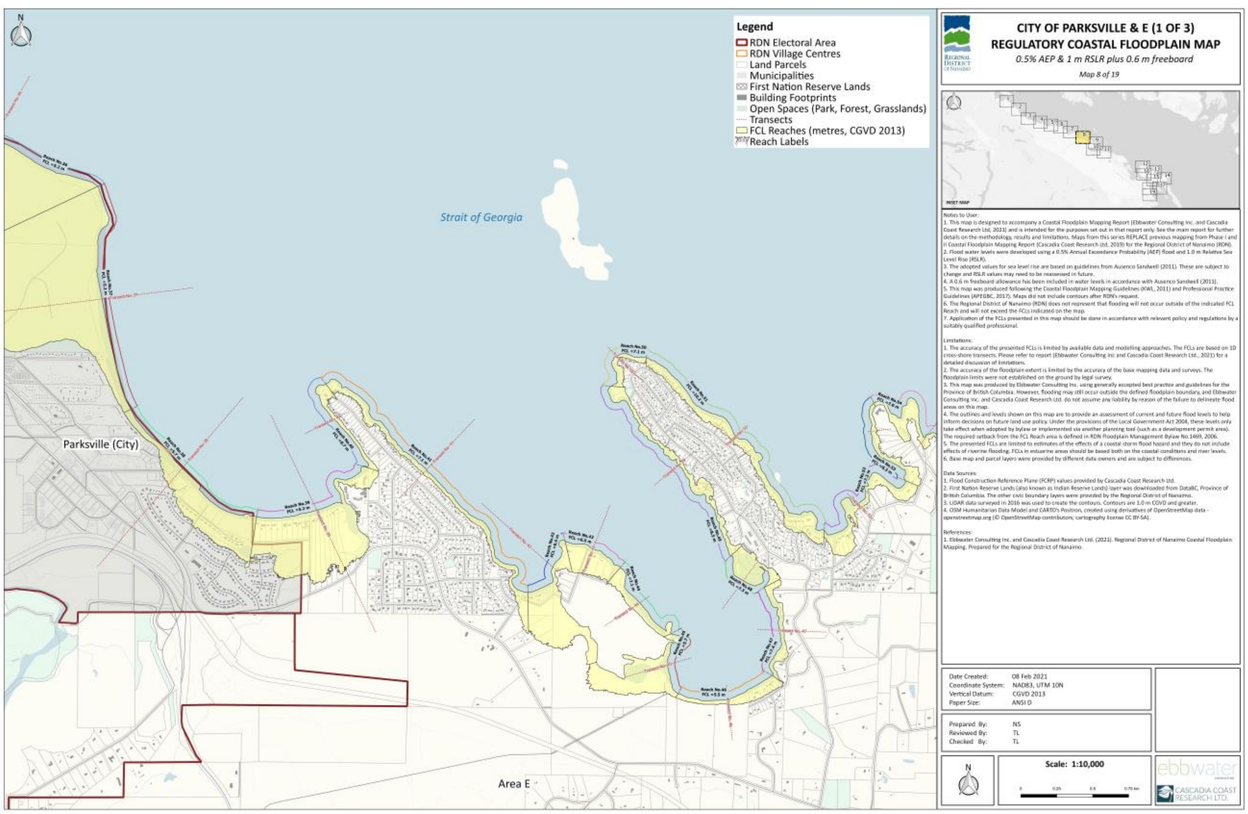

Figure 7: Example 3: FCL for the RDN for RSLR = 1 m and 0.5% AEP plus 0.6 m freeboard. FCLs are presented relative to CGVD2013[4].

Zoomed-in FCL maps for the RDN are provided in the form of FCL reach maps, see an example in Figure 7 (the full set of FCL maps is provided in the RDN Coastal Flood Hazard Map Atlas). FCL reaches describe areas of similar shoreline characteristics that are all defined by the same FCL.

Limitations

As with any study of this type, many uncertainties exist, and coastal modelling and flood mapping can only provide a simplified representation of a complex reality. This section summarizes some of the limitations and uncertainties from this study. Please refer to the final report (Ebbwater Consulting Inc. and Cascadia Coast Research Ltd., 2021) for full discussion of limitations.

Storm hazard modelling was limited by the available historical data, and uncertainty is high especially for large storm events. As new information becomes available, especially on climate change impacts and the rate of sea level rise, the values used in this study should be reassessed.

The coastline of the RDN is varied with a steep shore and long beaches. While the modelling and mapping approach addressed these variations, the nature of the analysis also means that some of the details may not be represented in the results. Where assumptions had to be made, these were done in a conservative manner. For instance, for the definition of the FCL reaches, the highest (worst-case) water elevation within a reach was chosen.

FCL Map Use

The FCL maps should be consulted in the application of the mapping information for a single dwelling unit. In cases of subdivision or rezoning, or higher levels of use (e.g., multi-residential, commercial, mixed used, industrial, institutional), contact the RDN.

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Photo: High tide at Rathtrevor Beach Provincial Park, December 26, 2018.