Photo source: Derek Ray (NHC)

Haida Gwaii Coastal Flood and Erosion Study Community Summary Report: The Village of Port Clements

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1 INTRODUCTION

This report summarizes the coastal flood and erosion hazards identified for the community of the Village of Port Clements (Port Clements) and Juskatla on Haida Gwaii. The objectives of the study were to predict the potential future effects from two independent natural hazards – coastal flooding from storm waves and tsunamis – when sea levels are expected to be higher. The results of the study are intended to inform communities as they make long-term community planning and governance decisions.

2 COASTAL STORM FLOOD HAZARD RESULTS

NHC has prepared maps for this study that characterize local conditions with both 1 metre (m) and 2 m of relative sea-level rise (also referred to as SLR in this report). The following figures (Figure 2.1 to Figure 2.4) show the extents and elevations of the coastal storm flood hazard resulting from a 1-in-200-year[1] storm event with 1 m of SLR for select areas along the Port Clements shoreline. The maps show the coastal flood construction level (or FCL) in each location, which is the minimum elevation needed for the underside of a building's wooden floor or the top of a concrete slab to protect living spaces and areas used for storing goods that could be damaged by floodwaters. The yellow, orange, and red lines on the maps indicate the flood risk, from low (yellow) to moderate (orange) to high (red). Further explanation of the maps is provided in section 0.

Key findings from the analysis include the following:

- Waves are generally small (compared to the open ocean), and wave effects are limited to areas near the shorelines.
- At the north end of Port Clements, there are additional backshore coastal flood risks in low areas as noted in the dark blue shaded areas on the maps (Figure 2.1).
- The shoreline areas on the western side of the peninsula near the small marina at Tingley Street have higher wave exposure, but the upland areas are generally above the coastal flood hazard zone from storm waves in this area (Figure 2.2).
- In the central part of the Port Clements study area, the low area near the intersection of Bayview Drive and Jasper Street is at risk of coastal flooding (without wave effects) from a designated coastal flood with 1 m of SLR (Figure 2.3). A coastal storm flood at this intersection would require community access to be re-routed to the highway along Dyson Street.
- The highway is at risk of flooding with 1 m of SLR as it passes near the head of the small inlet just east of Port Clements (Figure 2.4).

[1] A 1-in-200-year event corresponds to an annual exceedance probability of 0.5%.

- The coastal storm flood hazard at Juskatla is limited in extent, affecting only areas immediately adjacent to the shoreline from wave runup or select low-lying areas near the shoreline (Figure 2.5).

Figure 2.1 A portion of the map showing the coastal FCL for the north area of the Port Clements shoreline with 1 m of SLR.

Figure 2.2 A portion of the map showing the coastal FCL for the populated area of the Port Clements shoreline with 1 m of SLR. Note, the wave effects are reduced on the eastern side of the peninsula, resulting in a lower shoreline FCL.

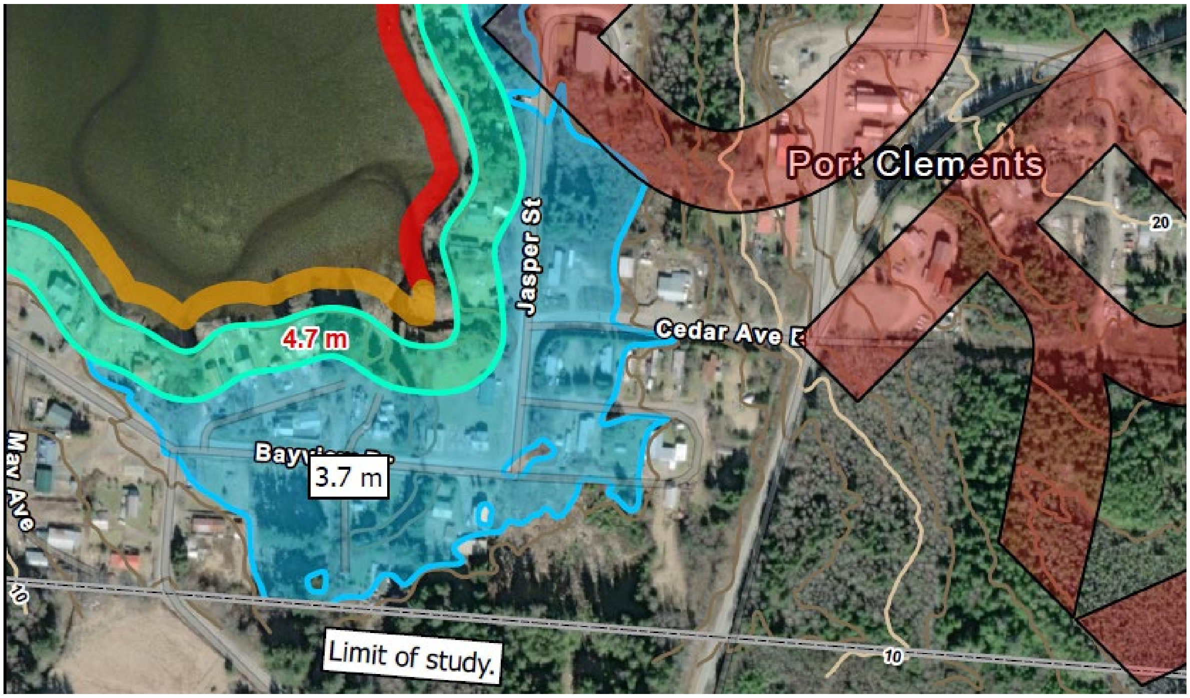

Figure 2.3 **A portion of the map showing the coastal FCL for the central area of the Port Clements shoreline with 1 m of SLR.**

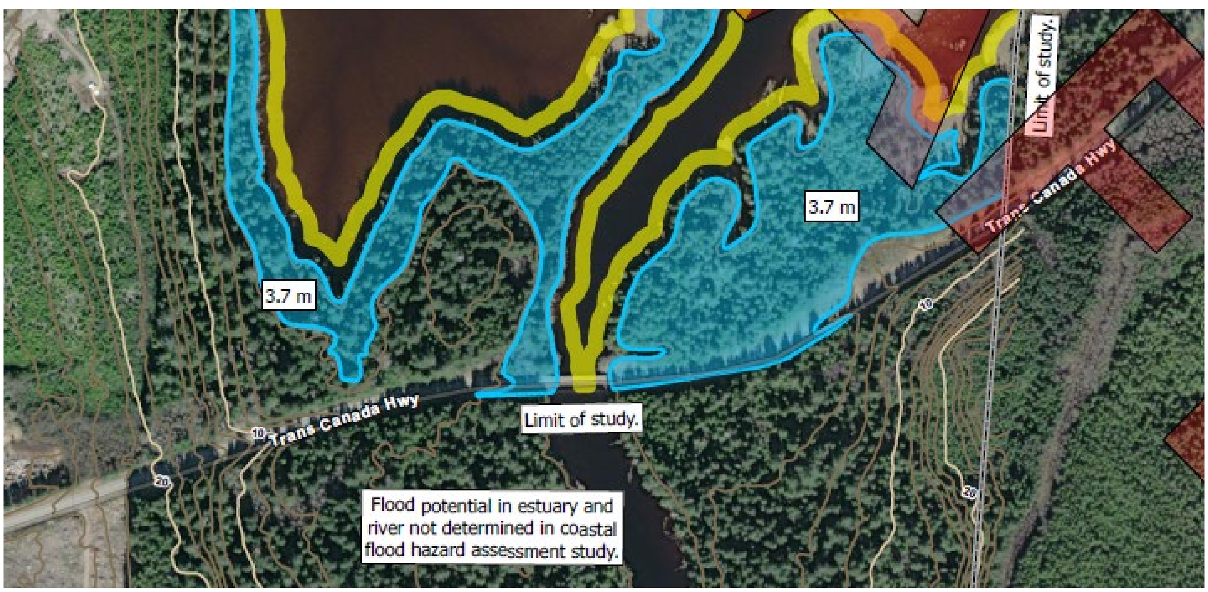

Figure 2.4 **A portion of the map showing the coastal FCL for the eastern area of the Port Clements shoreline with 1 m of SLR. Note study limit is at the highway, but flooding extents beyond the study limit were not mapped.**

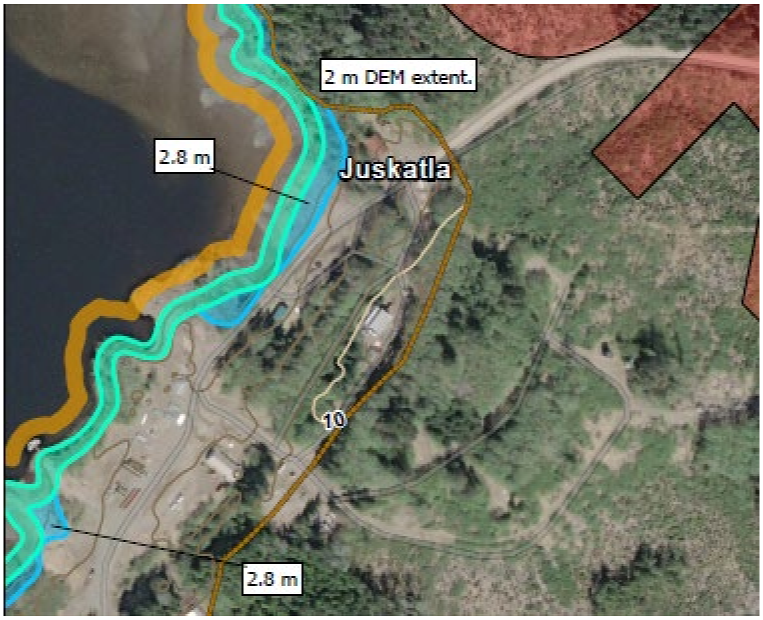

Figure 2.5 A portion of the map showing the coastal FCL for the eastern area of the Juskatla shoreline with 1 m of SLR.

The following Figure 2-6 shows wave patterns along the Port Clements and Juskatla shorelines from an analysis of storm force winds across different fetch directions in Masset Inlet. Large storm waves over 2 m in significant wave height[2] (denoted by H_s) can occur in this area during such storms. Wave heights reduce as the waves approach and break on the shallow foreshore; however, at periods of high tide and storm surge, the water is sufficiently deep in the nearshore area to result in wave runup and overtopping at the shorelines.

[2] Significant wave height corresponds to the mean height of the highest one-third of all waves.

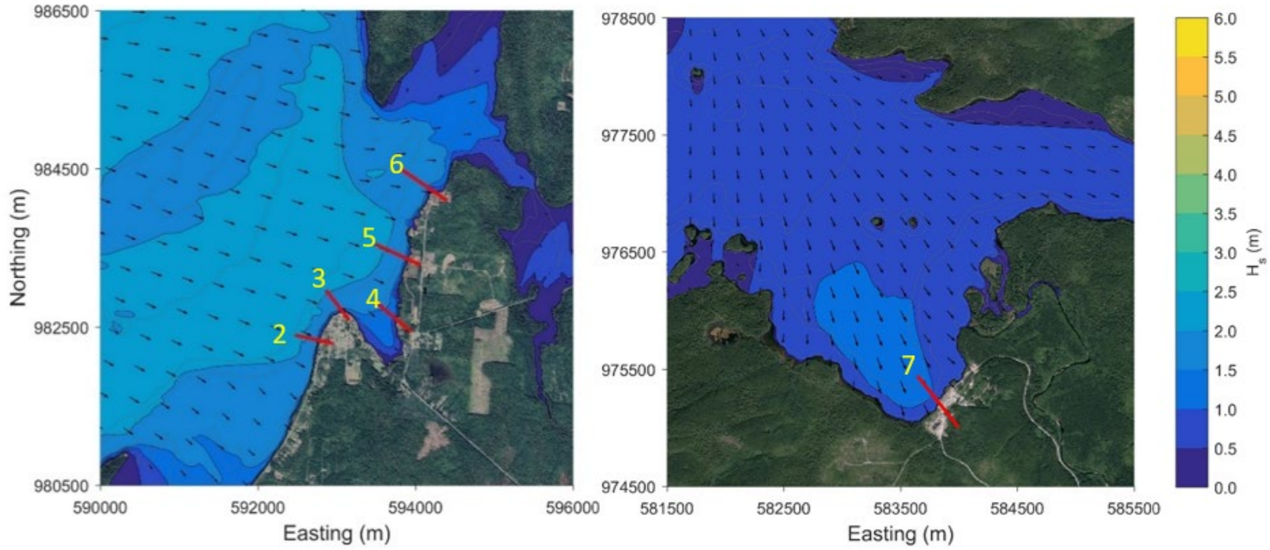

Figure 2-6. The pattern of wave propagation at Port Clements from westerly storm winds (left, Port Clements) and from northwesterly winds (right, Juskatla). The colour contours on these images are given for the significant wave height (H_s), while the arrows show the direction of wave propagation. The red lines indicate transects along which wave runup was estimated for representative shoreline reaches.

3 EROSION SUSCEPTIBILITY

The study area includes three separate zones: Juskatla, Ferguson Bay, and the main community of Port Clements. The following figures (Figure 3-1 to Figure 3-3) show the varying classification of erosion susceptibility along the study area shoreline, with many areas identified as highly susceptible to erosion. Further explanation of the erosion susceptibility classification is provided in section 0.

Shorelines in Juskatla are classified as moderately susceptible to erosion (Figure 3-1) due to a combination of relatively low wave exposure within Mammin Bay; the presence of tidal flats formed by the Mammin River, which drains to the bay at the eastern end of the Juskatla shoreline; and the dominance of gravelly material in the shoreline. The shorelines in Ferguson Bay (Figure 3-2) are classified as medium to low susceptibility to erosion. Although Ferguson Bay is on the southern shore of Masset Inlet and so exposed to larger waves than Juskatla, the orientation of the bay and the presence of rock breakwaters at each end of the bay moderate the wave exposure. Shoreline materials are gravel and cobble except in the most protected part of the bay where materials are finer (gravel and sand).

Figure 3-1. Map of erosion susceptibility for the Juskatla portion of the study area.

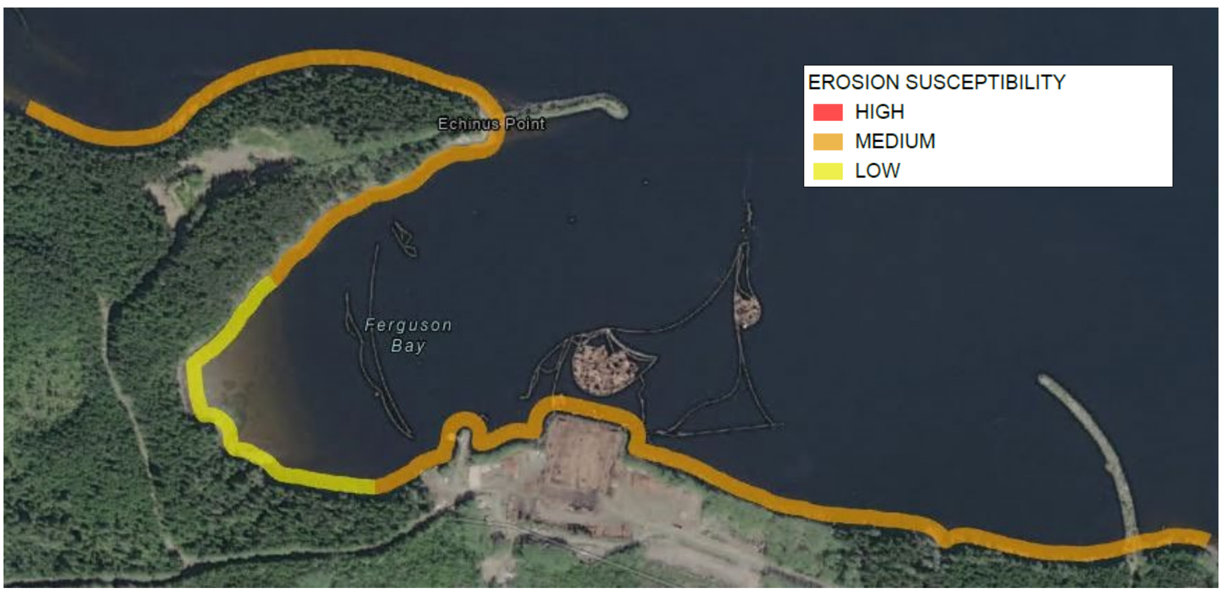

Figure 3-2. Map of erosion susceptibility for the Ferguson Bay portion of the study area.

Shorelines in the main Port Clements study area vary between low susceptibility within the protected environment of the Kumdis River estuary, to high susceptibility along much of the main shoreline exposed to waves from Masset Inlet (Figure 3-3). At the southern end of the study area, the shoreline is partially protected by the accumulation of sediments at the mouth of the Yakoun River, which has formed extensive tidal flats offshore. The extent of shoreline that benefits from this feature is mapped as having a medium susceptibility to erosion. This effect declines with the distance to the north from the Yakoun River. The main community of Port Clements is located on a point of land that separates Stewart

Bay to the east from the main body of Masset Inlet. The west and north sides of the point of land are fully exposed to waves from Masset Inlet, while the west side of Stewart Bay is somewhat sheltered.

Figure 3-3. Map of erosion susceptibility for the main study area.

The following series of photographs presented in Figure 3-4 to Figure 3-10 show the variability and complexity of the shorelines within the study area and illustrate the range of active coastal processes that define this area. The main portion of the study area is book-ended by relatively large river systems that deliver sediment to Masset Inlet – the Kumdis River in the north and the Yakoun River in the south. The accumulation of sediment in the form of offshore tidal flats provides some protection to the shoreline, while the middle part of the study area receives waves more directly.

At most locations the shore is composed of gravel and cobble sediments, with localized accumulations of finer material depending on relative wave exposure and proximity to one of the main sediment sources. Instability is mostly apparent in the upper shore face, caused by wave cutting. In some cases, the height of the upper shore appears to be increased by imported fill material. Non-standard rock protection has been installed at many locations to mitigate shoreline erosion.

Figure 3-4. The typical shoreline condition in the more exposed part of Ferguson Bay. The beach is dominated by coarse gravel and cobble. The presence of rockweed (*Fucus sp.*) indicates relative beach stability. Mature terrestrial vegetation is established just above the typical high tide line, indicating long-term stability of the shoreline.

Figure 3-5. Aerial image of the northeastern shoreline in Juskatla. Mature vegetation growing to the typical high tide line indicates a generally stable shore, and shallow waters offshore offer some protection from waves.

Figure 3-6. The shoreline along the southern portion of the Port Clements study area is partially protected by the shallow waters offshore from sediments delivered by the Yakoun River. The collection of logs and fine sediment indicate an accreting or rising shoreline.

Figure 3-7. Erosion of the upper shoreline is evident in this photo, as are efforts to protect the shore with non-standard rock.

Figure 3-8. The west side of Stewart Bay at Port Clements is protected from the largest storm waves that form in Masset Inlet. The foreshore is stable, with rockweed (*Fucus sp.*) present and evidence of the accumulation of fine sediments. Much of the upper shoreline is protected by non-standard rock revetments[3], presumably to address wave cutting at high tide.

[3] A revetment is the addition of impact-resistant material applied to a shore to protect it from erosion.

Figure 3-9. The shoreline along the northern portion of the Port Clements study area is fronted by relatively shallow water and a steeper beach, backed by semi-mature vegetation. This shore is highly exposed to waves from Masset Inlet yet is relatively stable at present.

Figure 3-10. The protected shoreline and fine sediment accumulation within the Kumdis River estuary portion of the Port Clements study area.

4 TSUNAMI HAZARD RESULTS

NHC produced overland inundation (i.e., flood) maps for the most adverse scenario between tsunamis originating from the Alaska-Aleutian and the Cascadia subduction zones. While both modelled tsunamis have similar effects, a tsunami from the Alaska-Aleutian subduction zone is predicted to be more adverse with greater tsunami amplitude. The extent of inundation shown on the maps corresponds to

1 m and 2 m of SLR. The coverage of the maps includes shorelines extending from Kumdis Bay to Yakoun Bay in Port Clements, as well as in Ferguson Bay and at Juskatla. While simulations were undertaken for current-day sea level, these simulations are not mapped.

Following are the key findings of the assessment:

- Low-lying areas at the head of Stewart Bay would experience significant flooding (Figure 4-1).
- For most of Port Clements, tsunami flooding is generally limited to areas closer to the shoreline. The elevation of the road in most places is high enough to not experience tsunami flood hazard, except for the Stewart Bay area and Bayview Drive in the village centre (Figure 4-2).
- The Highway 16 bridge at Kumdis River is at risk of being inundated or damaged by the effects of a tsunami. Flooding in this area could affect access and delivery of supplies to and from the Village of Masset.
- At Ferguson Bay, tsunami inundation would be limited to areas closer to the shoreline.
- The flood hazard associated with tsunami effects is low at Juskatla.

The arrival time[4] of a distant tsunami at Port Clements is between three and four hours after the triggering earthquake, although maximum inundation is predicted to occur approximately eight hours after the earthquake. Effects of tsunamis in coastal areas can last several hours and even days.

[4] Tsunami arrival time is defined as the time of the first maximum height of the first tsunami wave; flooding may begin before this moment is reached.

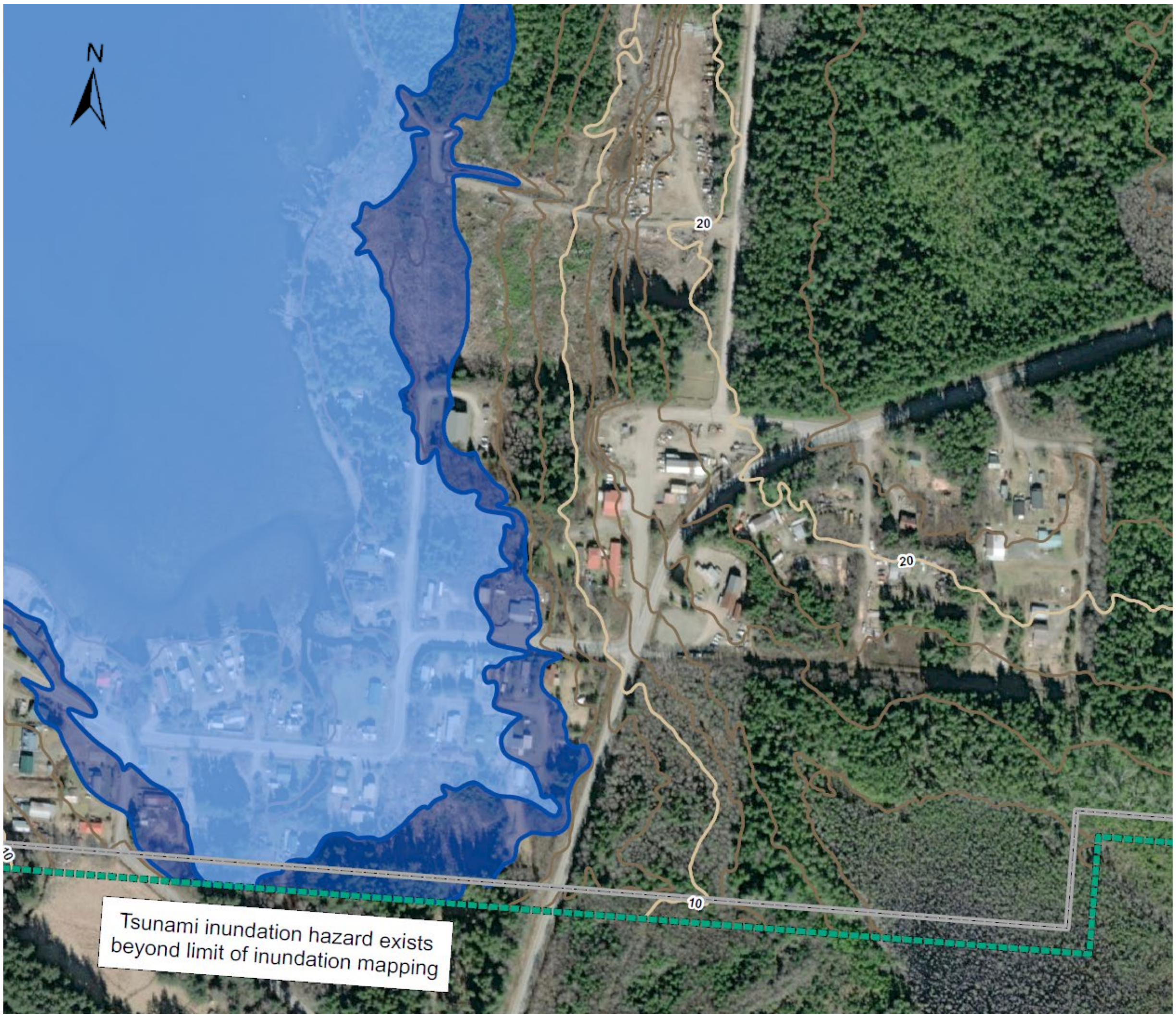

Figure 4-1. Tsunami inundation predicted in Port Clements at Stewart Bay with 1 m (light blue) and 2 m (dark blue) of relative sea-level rise.

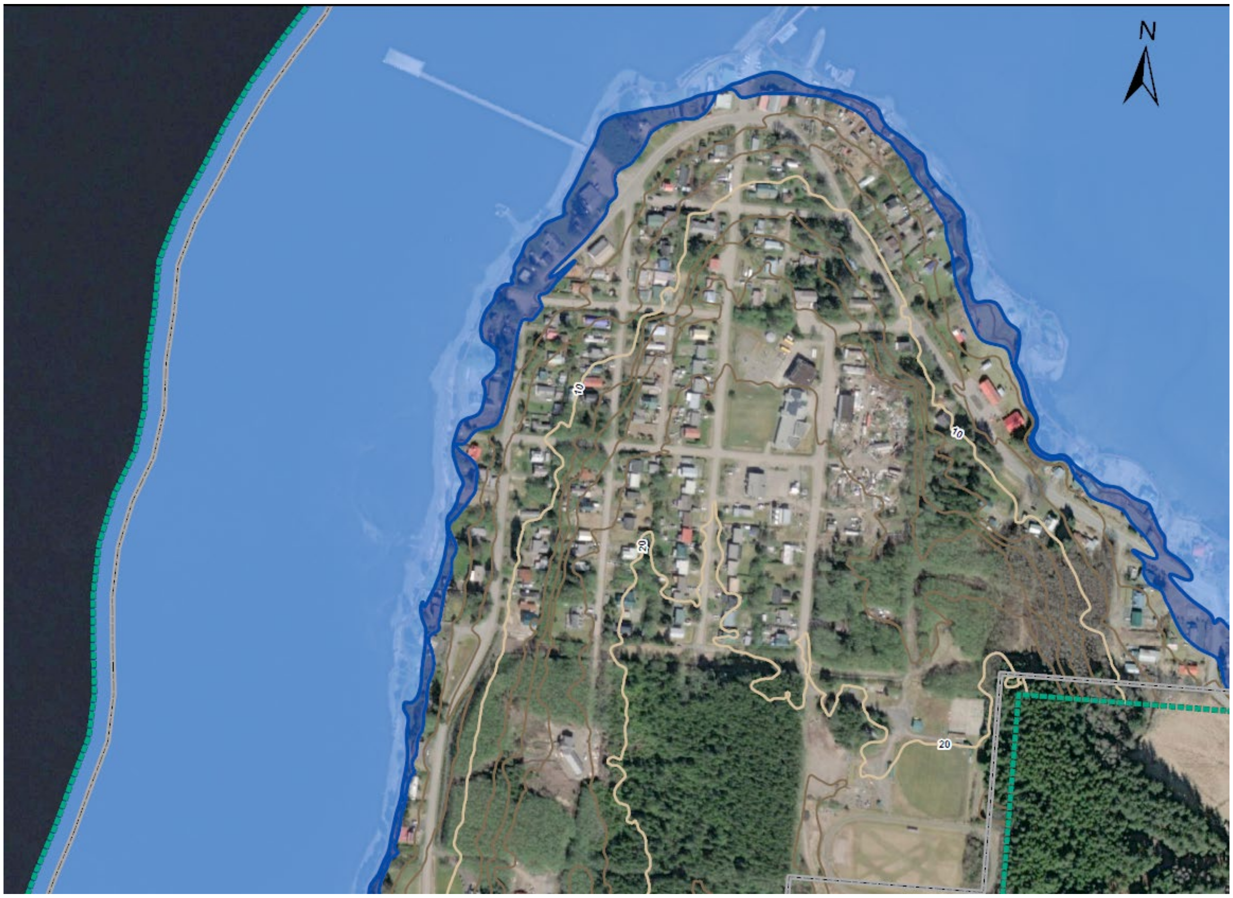

Figure 4-2. Tsunami inundation predicted at Port Clements with 1 m (light blue) and 2 m (dark blue) of relative sea-level rise.

5 BACKGROUND AND DISCUSSION

This section presents a summary of the project background along with a discussion of the findings of the effects of sea-level rise on the community of Port Clements. In addition, this section provides guidance on how to interpret the maps from the data that have been gathered and developed as part of this assessment.

5.1 Sea-level Rise

The hazards shown on the maps are influenced by SLR and expected to increase over time in the future. The project's main report provides a discussion of the background science on sea-level rise and the uncertainty that presently exists in the scientific analysis and SLR predictions. Following are the most important findings to consider during community planning discussions and decision-making:

- The sea level is expected to rise by 1 m during the next 80 to 150 years. Although the timing remains uncertain on when the 1 m of SLR will occur, the timing will ultimately depend on the actions of major emitting countries in the future (IPCC WGI, 2021).
- Up to 2 m of SLR may occur under worst-case emission scenarios as soon as year 2100 if rapid ice loss occurs in the Greenland and Antarctic ice sheets during the second half of this century, although the likelihood of this scenario is estimated to be low at this time (IPCC WGI, 2021).
- The BC government is recommending that communities plan for 1 m of SLR in year 2100 and 2 m of SLR by year 2200 (MFLNRORD, 2018). These planning levels remain consistent with the estimates developed in the latest scientific reports on climate change.

5.2 Interpreting the Maps

This section presents a discussion of the maps that have been developed for this project, which depict the coastal storm flood hazards, erosion susceptibility, and tsunami hazards. Guidance is also provided on how to interpret the map details to best understand the coastal flood, erosion, and tsunami hazards for Port Clements.

5.2.1 Coastal Storm Flood Hazards

The portion of map depicted in Figure 5-1 provides an overview of the horizontal extents of the hazard zones for Port Clements. The flood construction levels (or FCLs) are presented as red numbers on the maps and depict the elevations following the CGVD2013[5] reference datum. The schematic drawing shown in Figure 5-2 illustrates the components of the physical hazard that are considered in defining the FCL.

[5] Short for Canadian Geodetic Vertical Datum for 2013, CGVD2013 is the reference standard for heights across Canada. This height reference system replaced the Canadian Geodetic Vertical Datum of 1928 and is defined by a surface of equal gravitational potential, which represents, by convention, the coastal mean sea level for North America.

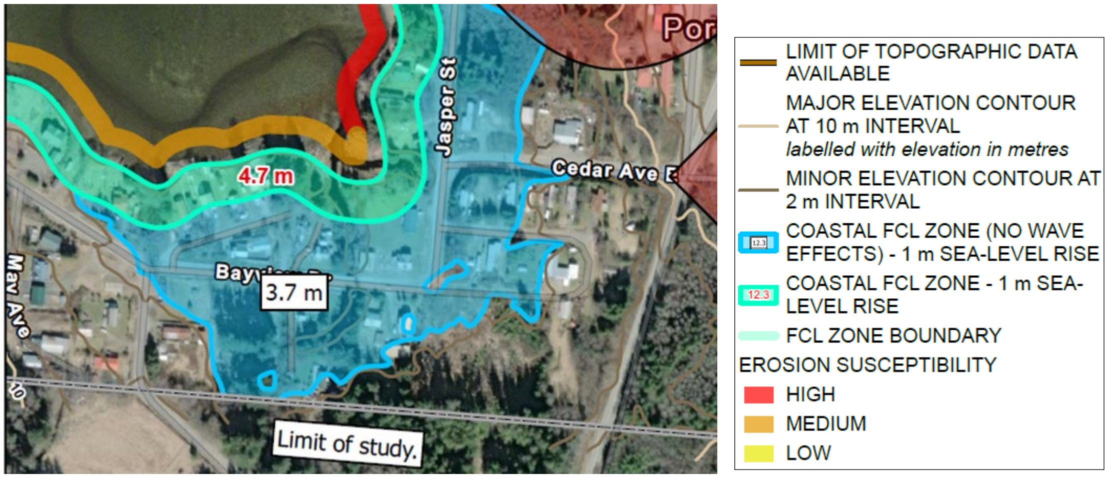

Figure 5-1. Example of a hazard zone on the map showing the FCL at Port Clements. The area outlined in blue shows the coast FCL zone with a 1 m SLR with no wave effects. The area outlined in green shows the coastal FCL zone with a 1 m SLR, which includes wave effects. Erosion susceptibility is medium and high, as shown by the coloured line that parallels the shoreline.

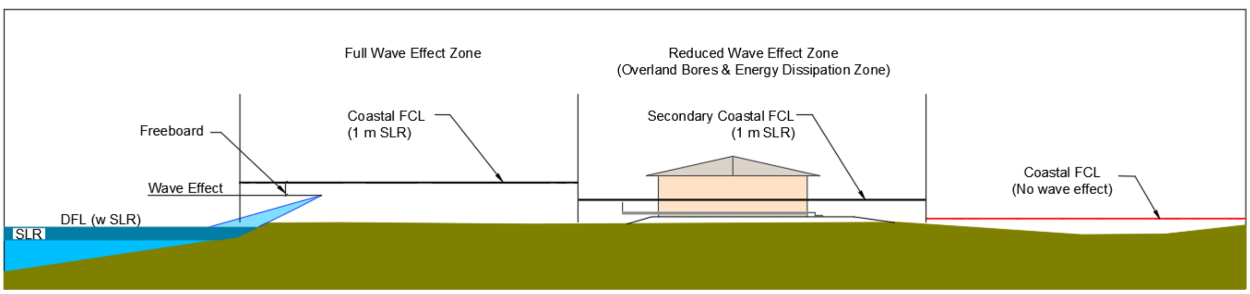

Figure 5-2. This schematic drawing shows the predicted FCL levels in profile view, which are depicted in the coastal storm hazard maps produced for the project. In some areas where the land is flat, two FCL zones are presented with wave effects of different elevations where wave overtopping rates at the shoreline are high enough to propagate in the form of overland bores[6] in low-lying areas. Further inland where wave energy has dissipated, an FCL zone is shown with no wave effects.

5.2.2 Erosion Susceptibility

The project study team developed a shoreline erosion susceptibility rating system to provide additional context for the coastal storm hazard maps, highlighting how the relative rate of shoreline retreat may intensify the flood hazard. The methods adopted for this classification system (presented in **Error! Reference source not found.**) enable relatively rapid classification of extensive segments of the

[6] A hydraulic bore is a wave with a steep and turbulent front moving across standing waters or dry land. It can result from the breaking of ocean waves.

shoreline, so that similar shoreline types can be grouped into reaches rather than having to sub-divide the shoreline to accommodate highly localized changes in conditions. The system is not intended to predict future conditions, but it must still consider the time scales associated with future sea-level changes. Large-scale geomorphic processes[7] will adjust to the gradual increase in sea level in the future, which in many cases will result in drastic alterations of the shoreline system. The study team took a conservative approach to classifying erosion susceptibility to avoid the potential of present-day erosion rates unduly influencing the assessment.

Table 5-1. Definitions of ratings for the shoreline erosion susceptibility classification system.

Rating	Description
Low	Shoreline types that are classified as having a *low* potential for erosion are typically dominated by highly resistant materials or have very low exposure to coastal processes such as wind-driven waves. The presence of shoreline protection structures does not generally place the shoreline in the low category. Often, such structures point to past erosion activity that required active intervention. Similarly, the term *low* does not mean non-erodible, nor does it mean that the shoreline will not be modified by large storms in the future.
Medium	The *medium* designation is applied to shorelines that display characteristics of either a *high* or a *low* susceptibility to erosion and feature one or more key characteristics that indicate the need to lower or raise the classification, depending on the characteristic.
High	Shoreline types that are classified as having a *high* potential for erosion are typically dominated by small-calibre or loose materials that are easily transported by coastal processes and exposed to highly energetic coastal processes. Typically, there are no mitigating features along the shoreline or backshore to slow the rate of shoreline erosion.

5.2.3 Tsunami Hazards

Tsunamis pose a risk anywhere near the shoreline as well as over water, whereas an overland tsunami hazard varies across the study area depending on local topography in conjunction with exposure to incoming waves. The tsunami hazards mapped in this study include flood hazards (e.g., overland inundation) in localized areas, as well as overwater hazards, such as maximum tsunami wave amplitude and maximum tsunami-induced current velocity.

5.2.3.1 Overland Tsunami Inundation Maps

An example of a tsunami inundation map is shown in Figure 5-3. The map shows inundation extents for both 1 m and 2 m of relative SLR as well as elevation contours for reference. These extents are for the purpose of emergency planning, and a safety factor is included to account for the uncertainties in the

[7] Geomorphic processes are processes associated with the form of a landscape and its relationship with surrounding natural features.

analysis. However, neither a vertical freeboard or a horizontal setback were applied to the tsunami inundation estimated as part of this study.

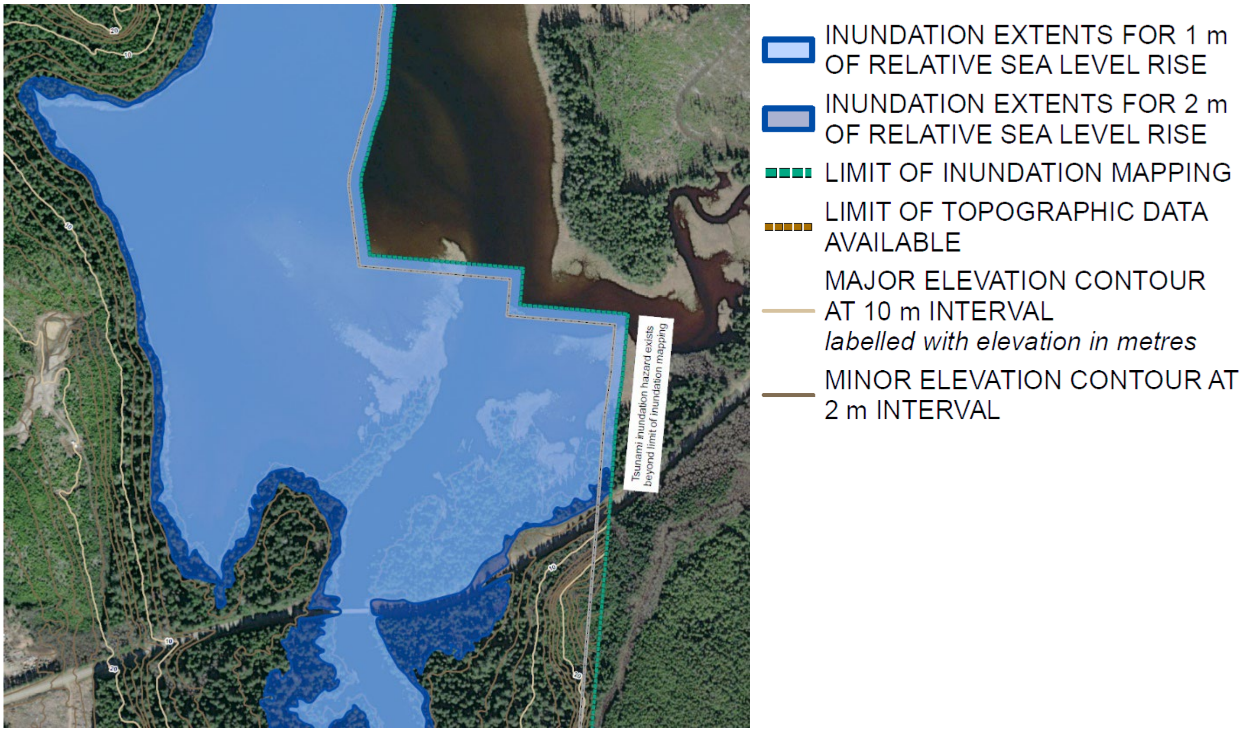

Figure 5-3. Example of a tsunami inundation map for Port Clements near the Highway 16 crossing at the Kumdis River.

5.2.3.2 Overwater Tsunami Hazard Maps

Figure 5-4 and Figure 5-5 show examples of maximum tsunami wave amplitude and maximum tsunami-induced current velocity, respectively. Neither a safety factor or freeboard were applied to the results plotted on the overwater hazard maps. Any overland inundation or overland tsunami flow velocity visible on these maps corresponds to information as approximated by the numerical model without any adjustment and should not be relied upon without an additional site-specific assessment. Also, the amplitudes reported on the maximum tsunami amplitude maps are reported according to a reference plane that corresponds to the water level considered for the tsunami simulations. For this study the water level corresponds to higher high-water, mean tide[8].

[8] Higher high-water, mean tide is the average of the higher high-water height of each tidal day observed over a tidal epoch, as defined by the Canadian Hydrographic Service in Canada.

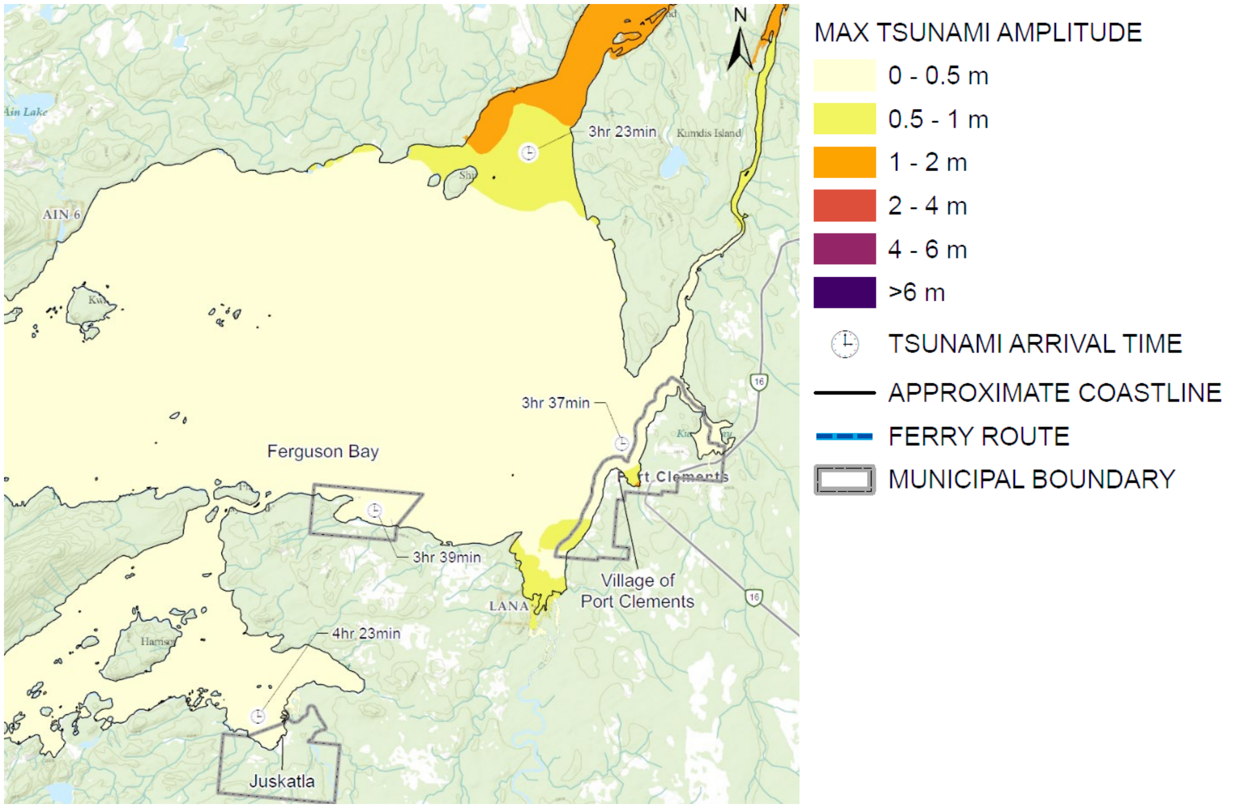

Figure 5-4. Example of maximum tsunami amplitude map in Masset Inlet.

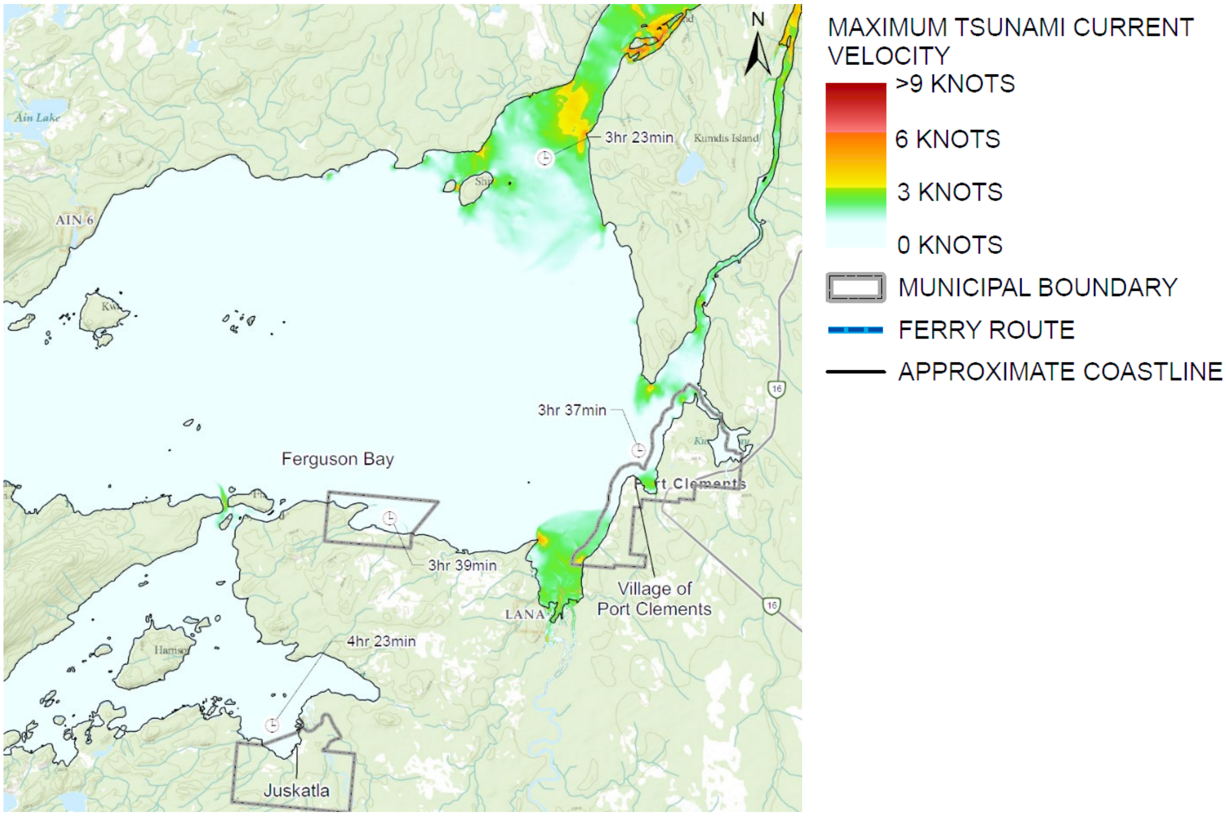

Figure 5-5. Example of maximum tsunami current velocity map in Masset Inlet.

6 FINDINGS AND RECOMMENDATIONS

6.1 Key Findings

Following is a summary of the key findings of the of coastal flood hazard and erosion study:

- Shoreline areas in Port Clements are at a risk from coastal storm flood hazards and erosion.
- High winds across Masset Inlet that coincide with high tide conditions will cause localized flooding in low-lying areas. With future SLR, this wave energy will produce more frequent impacts on the upper beach and erodible shoreline.
- Individual properties on the shoreline are at risk from both erosion and coastal flooding.
- A small section of the Highway is at risk of flooding in the future with SLR as it leaves the community heading toward Masset.
- Tsunami hazards exist for low-lying areas of Port Clements and anywhere close to the shoreline.

The existing strategy of armouring the shoreline to protect the highway infrastructure has only been partially successful, and this armouring requires ongoing repairs and maintenance following storm events. This strategy is unlikely to sufficiently protect the highway as sea level increases.

6.2 Recommendations

The project study team has developed the following recommendations for Port Clements residents and community planners to consider during future planning initiatives.

1. As SLR occurs, the rate of shoreline erosion in Port Clements is expected to accelerate as existing shorelines become more frequently exposed to wave action, and for longer periods during a given tidal cycle. Specific planning is recommended to account for expected future erosion, including increased setbacks for future development from areas with a medium and high susceptibility to erosion.
2. Building seawalls and rock armour revetments or stone facings could offer protection against erosion for the community. However, these structures may also cause harm by accelerating erosion along beaches, thus affecting aquatic habitat. The potential benefits and impacts of building revetments and seawalls should be studied during the next 10 to 15 years to inform community planning decisions on where this mitigation option is feasible, and where it may cause harms.
3. New construction should adhere to FCL levels in any areas of exposed risk for coastal storm flooding. Critical community infrastructure, such as emergency service facilities and community centres should be built outside of the tsunami hazard zone, unless these structures are specifically designed to withstand tsunami loads and effects and are sufficiently tall to provide refuge from tsunami inundation.
4. The risk of tsunami propagation presents an immediate hazard, although this hazard has a low probability of occurrence at any given time. The following important considerations apply to the community of Port Clements when considering and planning for this hazard:
    a. For a person caught in a tsunami the chance of survival is low, mainly due to the strong flow momentum and the floating debris that is often carried in the water during such an event. For planning purposes, NHC assumes that people exposed to tsunami hazards will experience an extreme risk to survival if they are unable to evacuate safely.

    b. Low-lying areas of the community are at direct risk of inundation from a tsunami. Emergency planning exercises should include evaluation of the inundation maps and arrival times so evacuation procedures can be refined for various parts of the community.

    c. At Port Clements Highway 16 is generally not exposed to a tsunami hazard except for the bridge crossing the Kumdis River, which is at risk of being inundated or damaged by the effects of a tsunami. This could affect access and delivery of supplies to and from the Village of Masset and transportation between Masset area and other communities on Haida Gwaii.

    d. Marine facilities for small boats could be severely damaged in a tsunami, while tsunami conditions may be unsafe for mariners in shallow water areas near to the Masset area due to potential wave breaking and strong currents.

    e. The community should evaluate the potential consequences if infrastructure in neighbouring communities of Masset, Daajing Giids, and Sandspit is damaged to the point that no ferry or airport services would be available for brief or extended periods following a tsunami event, thus preventing delivery of supplies or access to emergency services.

7 REFERENCES

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nhc 50 YEARS

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