Comox Valley Regional District Coastal Flood Adaptation Strategy Phase 2: Flood Risk and Options Assessments

Appendix B: Flood Hazard Layer Sensitivity Analysis

Contents

1 Introduction

The Comox Valley Regional District (CVRD) completed a Coastal Flood Adaptation Strategy (CFAS) to assess and mitigate coastal flood hazards. In the project's Phase 1, Kerr Wood Leidal Associates (KWL) completed comprehensive coastal storm and sea level rise mapping for approximately 200 km of the CVRD coastline (floodplain mapping was also completed for the Oyster River). The methods and the GIS-based coastal flood hazard results were summarized in KWL (2021). KWL mapped a range of flood characteristics (e.g. flood extent and depth layers) using different processing methods and algorithms, depending on the intended purpose of the outputs. Given the size of the project, the available data and methods, and schedule and resources, KWL made justified assumptions and simplifications to deliver the project.

Ebbwater was retained by the CVRD to complete Phase 2 of the CFAS, which focused on flood risk and preliminary mitigation options assessment. The coastal flood hazard layers produced in Phase 1 were the basis for the flood risk assessment. Given the importance of the hazard data to the outcome of the risk assessment, it was important to understand how assumptions or simplifications in the hazard data sets would affect the results of the risk assessment work.

This document outlines and presents a high-level sensitivity analysis of the coastal flood extent and depth layers, highlighting the differences between the two types of data. The analysis shows how the use of the different layers affects risk assessment results for two focus areas within the project area. Based on the results, we provide a justification for the layers that were used in the risk assessment in Phase 2.

2 Phase 1 Coastal Flood Hazard Layers

In this section, we briefly introduce the data produced by KWL in terms of planning range scenarios, two types of GIS data (raw data and processed data), and why a sensitivity analysis was required for Phase 2 of the project.

2.1 Scenarios

In the project's Phase 1, KWL conducted flood mapping for 4 sea level rise (SLR) scenarios (0 m, 0.5 m, 1 m, 2 m) and 5 annual exceedance probability (AEP) flood scenarios (10%, 5%, 1%, 0.5%, 0.2%). For the 1%, 0.5%, and 0.2% AEP events, dike breach scenarios were additionally provided for the Oyster River, but these scenarios are not relevant for Phase 2 and are not considered in this document. The 20 scenarios relevant to Phase 2 are summarized in Table 2-1. Among the 20 scenarios, three scenarios were selected for the Phase 2 assessment (Table 2-2); the justification for this is provided in the main report. The 10% annual exceedance probability was selected for short-term planning (together with 0.0 m SLR). The 0.5% annual exceedance probability was selected for mid-term planning (with 0.5 m SLR) and long-term planning (with 1.0 m SLR).

Table 2-1: Phase 1 scenario combinations relevant to Phase 2.

Scenario Variables	Scenario Combinations
Sea Level Rise (m)	0, 0.5, 1, 2
Annual Exceedance Probability (AEP)	10%, 5%, 1%, 0.5, 0.2%

Table 2-2. Scenarios used in Phase 2 of the project.

Planning Range Scenario	Annual Exceedance Probability	Indicative Return Period	Sea Level Rise
Short-term	10%	10-year	0 m
Mid-term	0.5%	200-year	0.5 m
Long-term	0.5%	200-year	1.0 m

2.2 Raw and Processed Data

In Phase 1, KWL produced water depth and water level raw raster data ("raw data") for all scenarios. The water depth data depict the maximum water depth and also incorporate wave effects Figure 2-1. Although the raster format of the raw data is a suitable choice to store information such as depth and elevation, vector data are better suited to store spatial information related to extent. As a result, the scenario flood extents ("processed data") were derived from the raw data and provided in a vector format (Figure 2-1). The vector layers were simplified by removing any dry "islands" (areas that were surrounded by flood) that were smaller than 1000 m^2 or were less than 3 m above the surrounding flood level on average. These filling criteria were applied to assume that the small, low-lying areas would flood due to the surrounding flood conditions. These types of approaches to clean the data are common, however the thresholds used by KWL are significantly larger than those used in other similar projects (e.g. Lower Fraser River hydraulic modelling and mapping).

The information of the data we used in the project is summarized in Table 2-3, and more details can be found in KWL (2021).

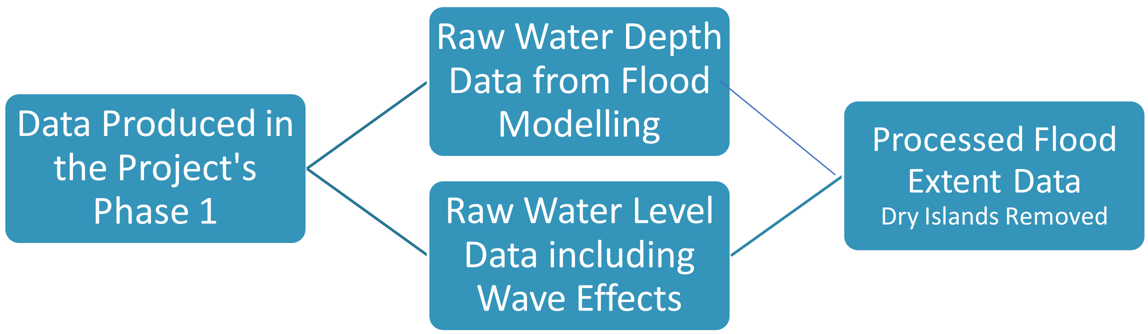


Figure 2-1: Brief summary of the flood layer data produced by KWL.

Table 2-3. Overview of the Phase 1 data used in Phase 2.

Description	Data Type	Included Wave Effects	Included in the Sensitivity Analysis
Raw water depth	Raster	No	No
Raw water level	Raster	Yes	Yes
Processed flood extent	Vector	Yes	Yes

2.3 Differences in the Raw and Processed Data

As mentioned in Section 2.2, the main difference between the flooded areas shown in the raw data and processed data is that the raw data contain islands, whereas the islands were removed in the processed data. Figure 2-2 demonstrates the differences between the raw and processed data at Saratoga Beach for the 0.0 m SLR, 10% AEP flood scenario. The areas marked by black diagonal lines represent the islands that were filled (i.e., shown as being flooded) as depicted by the processed data layer. Filling in some of the islands appears realistic, especially when those islands represent areas of lower elevation and small extent. Islands with those characteristics have most likely been generated by computational artefacts. However, many of the large and higher elevation islands that were filled-in may not be prone to flood in practice. We note that the KWL filling criteria (i.e., fill areas smaller than 1000 km^2 or with elevation less than 3 m above the surrounding flood level on average) did not change the outline of the flooded areas. However, it made the processed data more conservative as more areas within the outline were considered flooded.

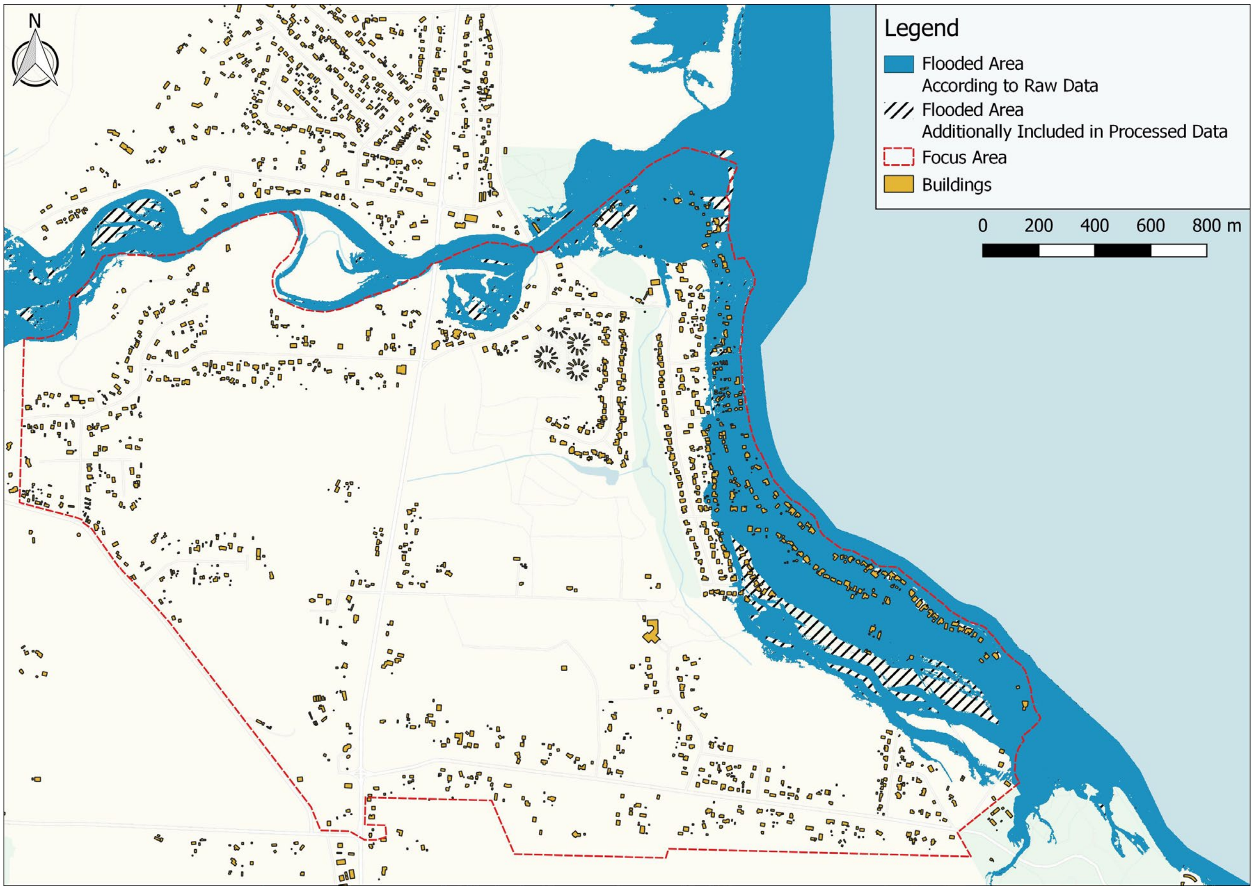


Figure 2-2. Differences between the raw and processed data shown by an example (Saratoga Beach for the 0.0 m SLR, 10% AEP flood scenario). Areas shown in blue define the flood extents according to the raw data, whereas the black diagonal lines show the additional areas included in the processed data.

Figure 2-2 shows the boundary of the Saratoga Beach focus area. This area is based on the jurisdictional boundaries of the Settlement Node, which has been designated by the CVRD as an area for growth potential (see main report for details).

The difference between the raw and processed data raises two interrelated questions:

1. How different are the processed and raw data?
2. How would the differences affect the risk assessment in Phase 2?

The answer to those questions is determined by evaluating the characteristics of the dry islands. As discussed, whether or not a dry island should be removed is based on its local conditions (e.g., local topography, connectivity, conditions of surrounding areas, topographic evolution). However, it is not practically possible to examine all the dry islands within the project area. Therefore, directly using either raw or processed data will yield some uncertainty. To quantify the uncertainty related to the difference between the raw and processed data at a high level, we utilized a sensitivity analysis consisting of qualitative and quantitative investigations.

3 Sensitivity Analysis

The sensitivity analysis included a visual investigation for five focus areas and a quantitative investigation for two selected focus areas, where a sensitivity analysis describes the process of comparing relative results (in this case from a risk assessment) given different inputs to the assessment (in this case the two-layer types).

To streamline our investigation, specific sections of the coast were analysed in this sensitivity analysis. In the first instance a visual inspection of the data layers was conducted to establish likely areas where the relative difference related to the two types of hazard data would be most marked. Second, a detailed quantitative spatial analysis was conducted on two areas to understand the expected worst-case implication of choosing one layer over another.

3.1 Visual Inspection

During the preparation of engagement Round 1, we selected five focus areas (Saratoga Beach, Little River, Union Bay, Comox Road, and Goose Spit). Although Little River was subsequently removed for consideration as a focus area, it was retained for the purposes of this analysis.

We mapped all three scenarios for the five focus areas and, based on visual analysis, found that Saratoga Beach and Little River (Figure 3-1 and Figure 3-2) had more profound and complex differences between the raw and processed data. The difference between the raw and processed data (areas covered by dashed lines) is not marked for the Union Bay and Comox Road focus areas (Figures A1 and A2, in Attachment 1, respectively). For Goose Spit, the flood extent is confined and less complex than for other focus areas (Figure A3, in Attachment 1). Based on the maps, we found the discrepancy at Goose Spit was relatively large for the short-term planning range scenario. However, the discrepancy is significantly reduced for larger floods.

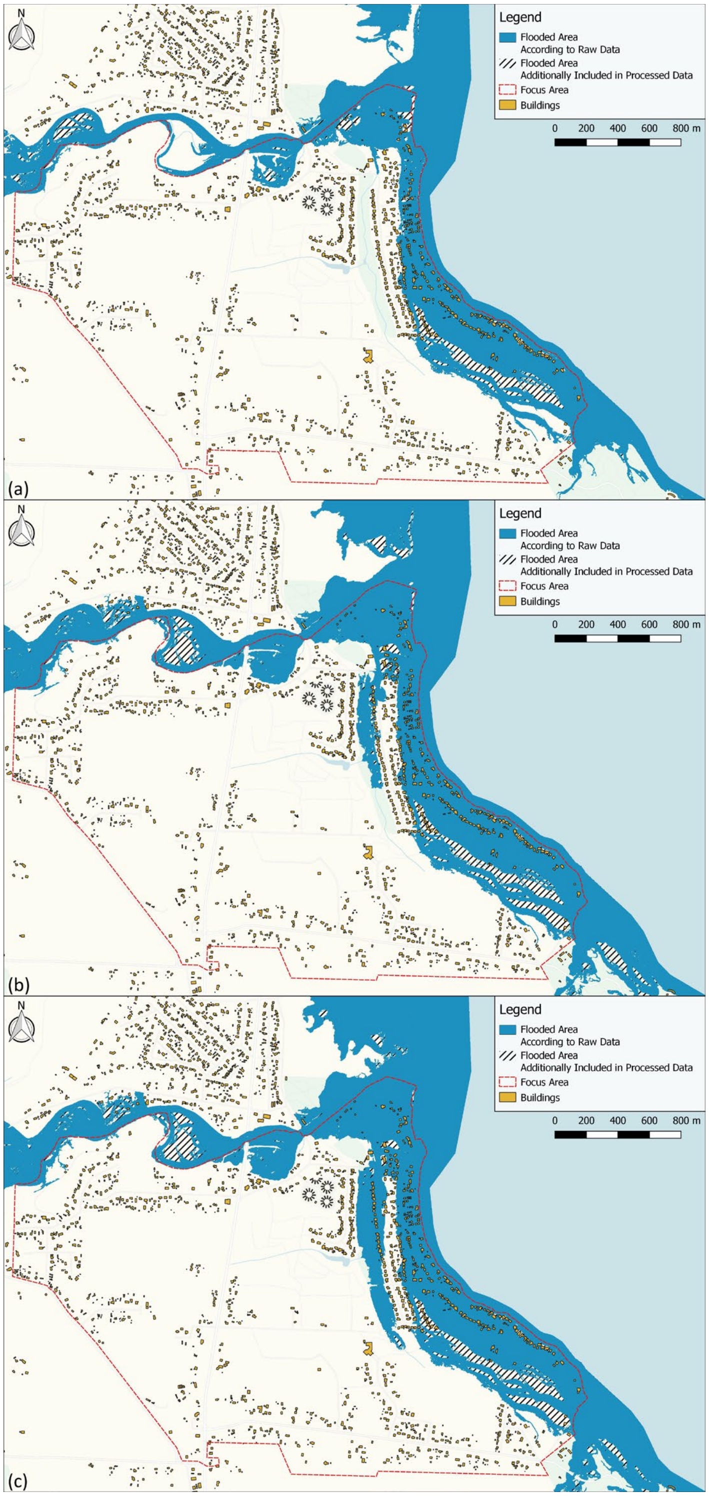


Figure 3-1. Raw and processed flooded areas at Saratoga Beach for the 0.0 m SLR, 10% AEP flood scenario (a), the 0.5 m SLR, 0.5% AEP flood scenario (b), and the 1.0 m SLR, 0.5% AEP flood scenario (c). Areas shown in blue define the flood extents according to the raw data, whereas the black diagonal lines show the additional areas included in the processed data. Detailed analysis is presented in Section 3.2.

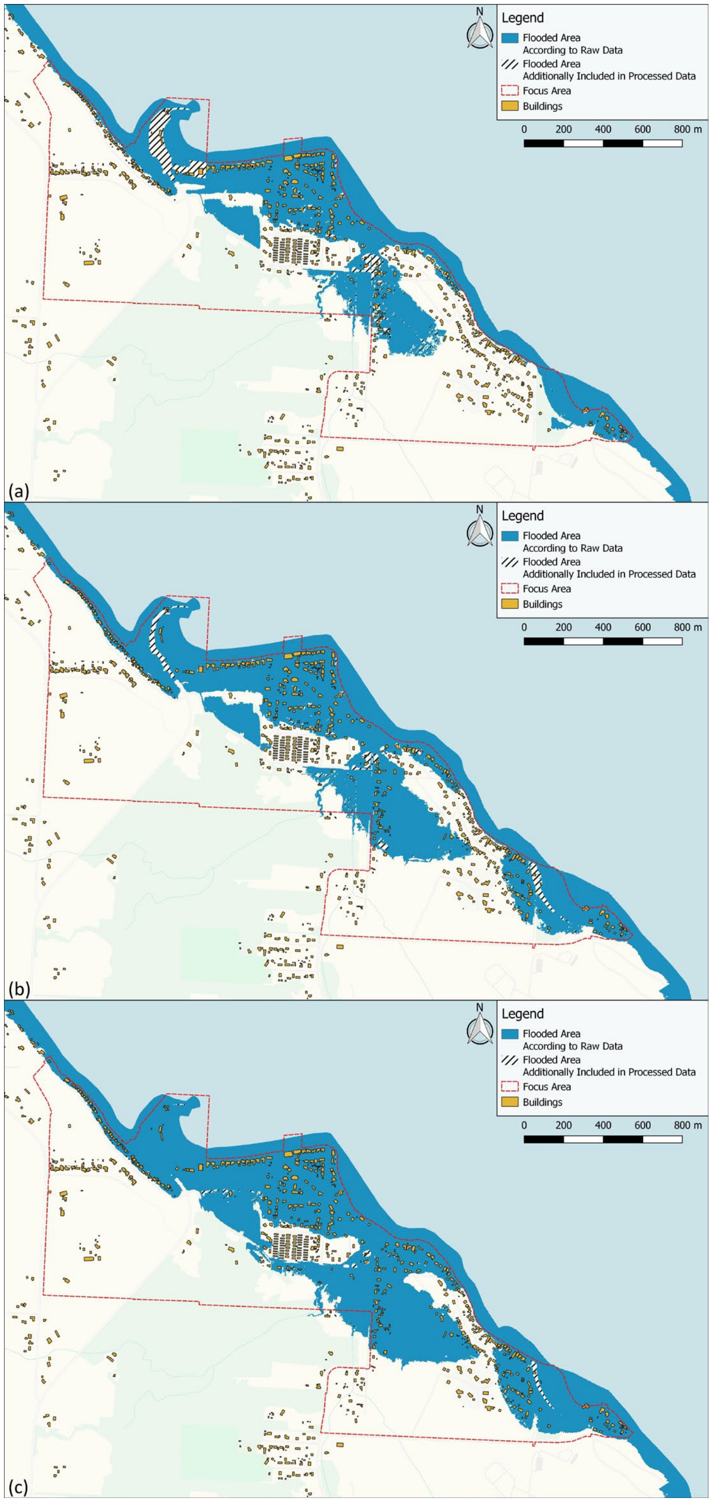


Figure 3-2. Raw and processed flooded areas in Little River in the 0.0 m SLR, 10% AEP scenario (a), in the 0.5 m SLR, 0.5% AEP scenario (b), in the 1.0 m SLR, 0.5% AEP scenario (c). Areas shown in blue define the flood extents according to the raw data, whereas the black diagonal lines show the additional areas included in the processed data. Detailed analysis can be seen in Section 3.2.

Based on the visual inspection, we chose to review the Saratoga Beach and Little River focus areas in more detail through the quantitative investigation.

3.2 Quantitative Investigation

For the Saratoga and Little River focus areas, we compared layers based on two metrics (number of flooded buildings and flooded areas); please see the final report and Appendix A for information on risk assessment and the metrics used for this study. The number of flooded buildings was calculated by overlaying the buildings layer on the flood layers. The results of our quantitative investigation are summarized in Table 3-1 and Table 3-2.

Table 3-1. Comparisons for Saratoga Beach.

Scenario	Flooded Buildings (Raw Data) (#)	Flooded Buildings (Processed Data) (#)	Difference in Flooded Building numbers	Flooded Area (Raw Data) (Ha)	Flooded Area (Processed Data) (Ha)	Difference in Flooded Area
Short-term	374	393	5%	82	93	14%
Mid-term	517	537	4%	100	111	12%
Long-term	570	588	3%	108	119	10%

Table 3-2. Comparisons for Little River.

Scenario	Flooded Buildings (Raw Data) (#)	Flooded Buildings (Processed Data) (#)	Difference in Flooded Building Numbers	Flooded Area (Raw Data) (Ha)	Flooded Area (Processed Data) (Ha)	Difference in Flooded Area
Short-term	316	334	6%	58	64	11%
Mid-term	447	454	2%	77	81	5%
Long-term	514	518	1%	92	94	1%

The estimation of flood impacts based on the processed data is consistently higher for Saratoga Beach (Table 3-1). However, the difference is less substantial in terms of flooded buildings (range of 3 % to 5%) compared to the difference in flooded areas (range of 10% to 14%). The difference also becomes more negligible in the mid-term and long-term planning range scenarios compared to the short-term scenario.

The analysis conducted for Little River (Table 3-2) demonstrates a pattern consistent with Saratoga Beach. The difference becomes smaller in the larger flood scenarios (long-term planning range). For Little River, the difference is reduced to 1% for flooded buildings and flooded areas in the mid-term and long-term scenarios.

Our quantitative results show that there can be up to 6% difference in flooded building numbers and up to 14% difference in flooded areas in the short-term scenario. However, the differences decline significantly in the mid-term and long-term scenarios (higher sea level rise and larger floods), which indicates that raw data and processed data are more similar during the occurrence of larger floods. The difference in flooded buildings is also consistently smaller than the difference in flooded areas, indicating that the areas of difference are likely less populated. The assumption that fewer people reside in the areas of difference is also supported by the maps shown in Figure 3-1 and Figure 3-2). This suggests that the differences will have less effect on the risk assessment indicators whose consequences are more influenced by building footprint data compared to flooded areas

3.3 Discussion

As stated in Section 2.3, we applied a sensitivity analysis to assess the difference between using the raw and processed data because it is not feasible to examine every dry island in the raw data. However, according to the sensitivity analysis, the differences between using the raw and processed data are not profound, especially for the building footprint data. Therefore, using either type of data (raw or processed) for flood risk assessment will yield a similar level of uncertainty.

High level flood risk assessments only take into account the spatial extents of the flood (as opposed to flood depth, velocity, and other characteristics). Despite the uncertainty associated with them, using simplified vector datasets provides technical and practical benefits. Processed data with fewer complex geometries are better suited for planning and can convey information more effectively to the general public. Furthermore, the islands in the raw data can still be prone to indirect and intangible impacts. Direct flood impacts can occur over time if local topography changes. A slightly conservative flood extent, provided that it does not lead to significant overestimation of the risk associated with the different indicators, can therefore provide a robust and consistent assessment. The 1% to 6% relative increase in flood impacts is well within expected tolerances given the compounding uncertainties associated with natural hazard risk assessments.

4 Conclusion and Recommendation

In Phase 1 of the CFAS project, KWL developed two types of flood mapping data (raw and processed data). We developed and conducted a sensitivity analysis, including qualitative and quantitative investigations, of the data to inform Phase 2 risk assessment activities.

We conclude this document by answering the questions proposed in Section 2.3:

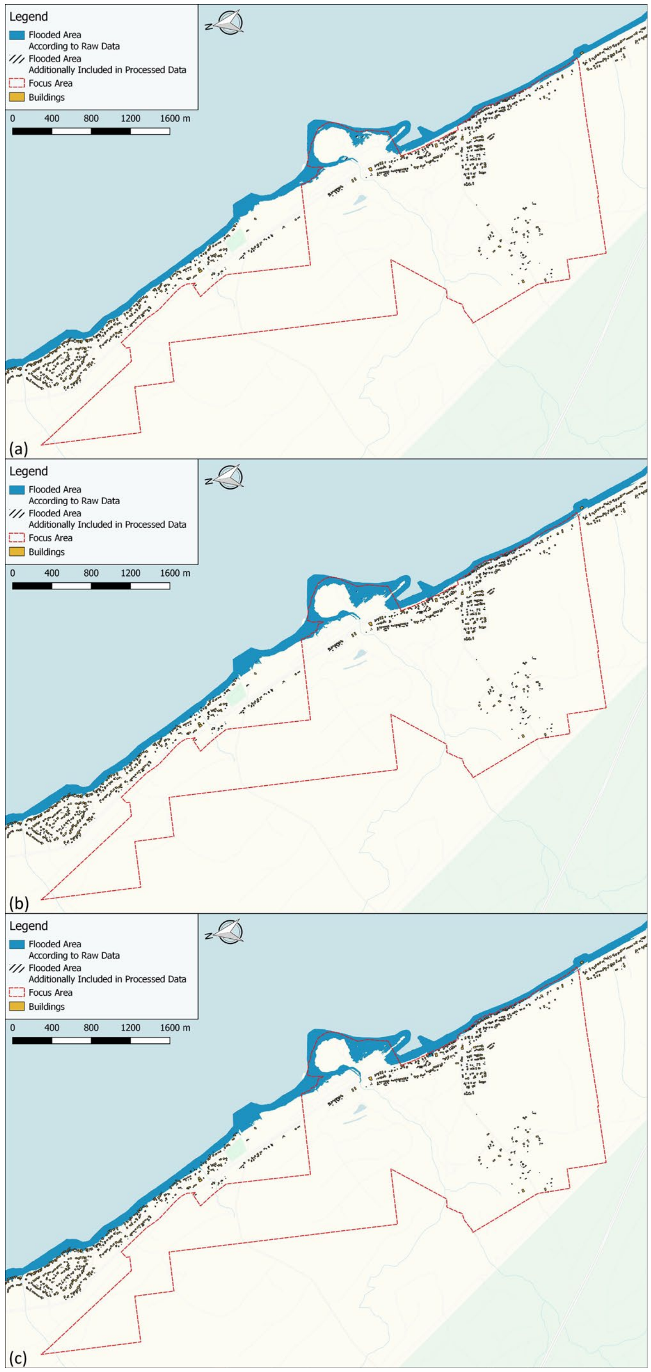
1. There is no simple answer to which layer is more accurate. However, the sensitivity analysis results show that the processed data provide more conservative flood extents and quantitative consequence results. Further, the differences are generally small, especially in the mid-term and long-term planning range scenarios. The uncertainty will be similar regardless of which data is used for flood risk assessment.
2. The processed data can be used to conduct a robust high-level risk assessment. As they are a simplified version of the raster layers, they will be more usable and will produce more easily comprehensible results. This is, provided that the intrinsic uncertainty associated with their development is acknowledged, as detailed in this document.

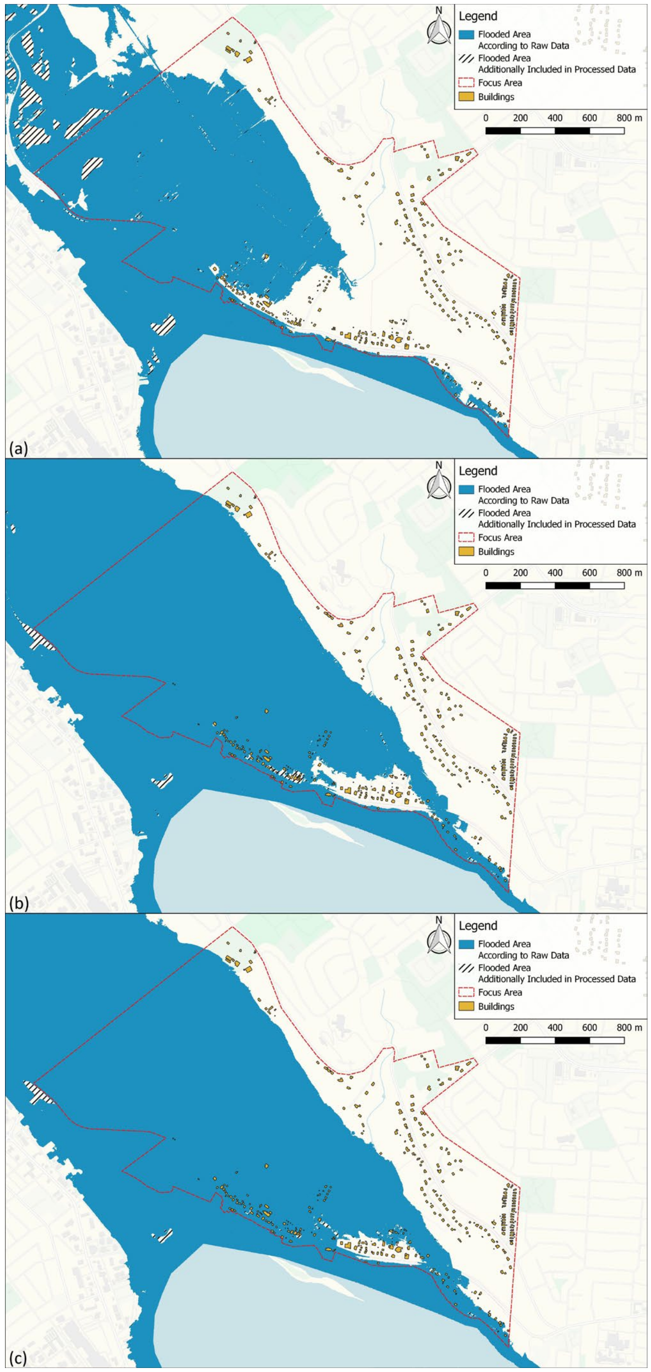
Based on the above we recommended and selected the processed flood hazard data, which was produced in Phase 1 of the CFAS, for use within the Phase 2 risk assessment.

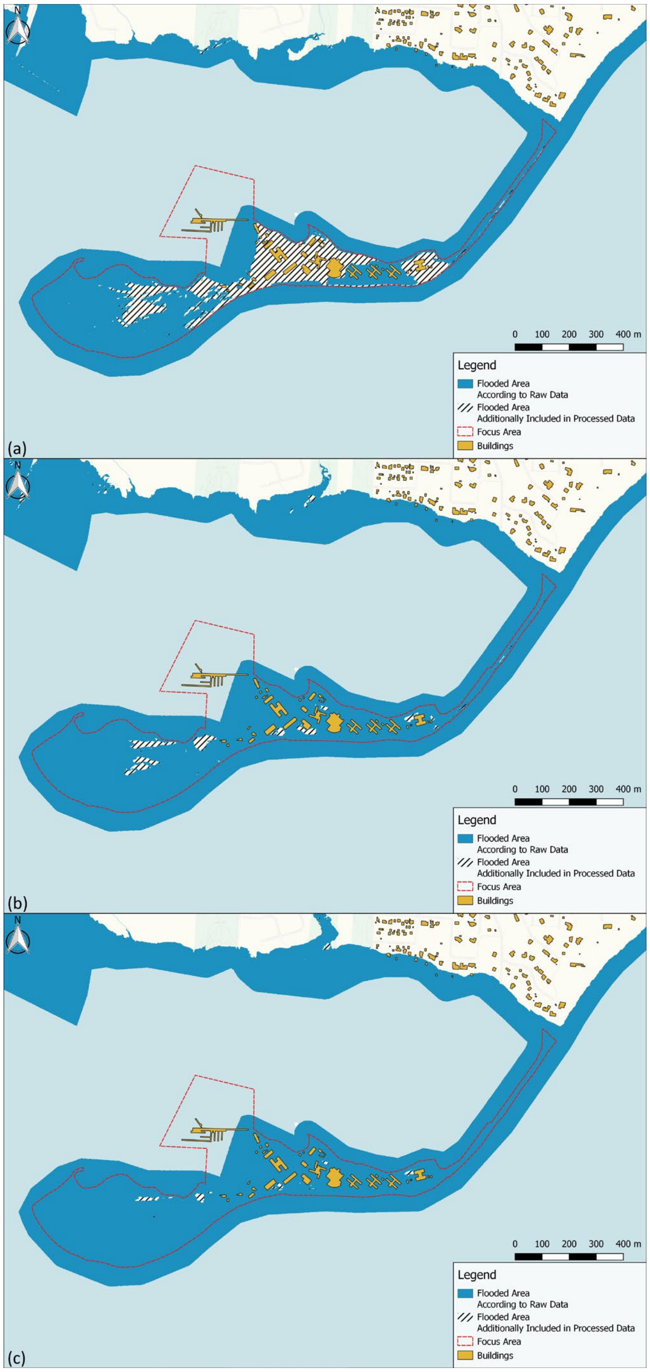
Reference

Kerr Wood Leidal Associates Ltd (KWL). 2021. Coastal Flood Mapping Project. Report Prepared for Comox Valley Regional District.

Attachment 1 – Maps Containing the Raw and Processed Data of Other Focus Areas)




Legend
Flooded Area According to Raw Data
Flooded Area Additionally Included in Processed Data
Focus Area
Buildings
0 200 400 600 800 m
N
(a)
(b)
(c)


0 100 200 300 400 m
Legend
Flooded Area
According to Raw Data
Flooded Area
Additionally Included in Processed Data
Focus Area
Buildings
(a)
(b)
(c)