



Final Report Coastal Flood Mapping Project

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Submitted by:



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Executive Summary

The Comox Valley Regional District (CVRD) is taking a proactive approach to plan for and manage flood hazards in the CVRD. The region has a history of flooding in river and coastal areas and the severity of flooding is projected to increase under future climate change conditions.

The Coastal Flood Mapping Project is the first step in the CVRD's multi-year process to understand and prepare for flood hazards. The project involved detailed analysis and modelling of river and coastal flood hazards to create a variety of mapping products that show which areas might be exposed to flooding during extreme future storm conditions.

This project considered both coastal and river storm events to build a more comprehensive understanding of flood hazards across the region. Flood conditions in rivers and coastal areas are interconnected and have been considered in parallel to understand how water levels in coastal areas might influence river flood dynamics.

This report provides an overview of the key concepts and methodology of the mapping project. It also shares a snapshot of mapping results to demonstrate how the flood maps can be used to inform future planning and management.

Flood Mapping Approach

The project involved the following four stages of work:

1. Data Collection (base mapping);
2. Modelling (river & coastal);
3. Mapping (regulatory & digital maps); and
4. Reporting (final report, technical memoranda, model user guide, and communication materials).

The project produced multiple types of flood mapping products and a set of technical memoranda describing modelling and mapping approaches. The mapping products include:

- **Region-wide base mapping**, which provided the platform for modelling and mapping for this project;
- **Regulatory floodplain maps**, showing flood inundation extents for an extreme storm event under future climate change conditions. These maps were produced according to established guidelines, including the BC Provincial Flood Hazard Area Land Use Management Guidelines ("Provincial Guidelines", 2018), the 2018 Federal Flood Mapping Framework including relevant guidelines (NRC, 2018), the 2017 Engineers and Geoscientists BC Flood Mapping Guidelines (EGBC, 2011) and the 2004 Fraser Basin Council Floodplain Mapping Guidelines and Specifications (FBC, 2004); and
- **Digital mapping data**, which includes a set of mapping layers that CVRD staff can use to support management of land use in flood hazard areas, future flood management planning, and engagement with the community. The mapping layers include maximum water levels, maximum water depths, maximum flow velocity, flood hazard rating, maximum wave heights in the coastal floodplain, sea level rise planning areas, and setbacks.



Flood Mapping Results

The Coastal Flood Mapping Project produced maps showing flood inundation extents along the entire CVRD shoreline, the lower reaches of the Oyster River and the Puntledge, Tsolum and Courtenay Rivers (Courtenay River system). Mapping results show that properties and infrastructure in low-lying areas along the waterfront may be exposed to flooding during an extreme storm event in the future.

The report highlights flood inundation results across the entire study area and in four specific coastal and river areas. Case study locations were selected because they represent important, low-lying community areas with diverse landscapes that face flood hazards under current and future climate change conditions. The case study reviews are intended to demonstrate mapping features, results, and potential applications for how the mapping can be used for flood management planning. The four case study areas profiled in the report include:

1. **Little River area**, which is located on the alluvial fan at the mouth of the Little River;
2. **Ships Point area** and waterfront park in Electoral Area A east of Fanny Bay;
3. **Goose Spit**, east of Comox including Goose Spit Provincial Park, Canadian Forces Base, and K'ómoks First Nation IR#3; and,
4. The **area upstream of Oyster River Bridge**, from Catherwood Road (south), Regent Road (east), and just north of Glenmore Road (north).

Key findings from analysis of flood mapping results are summarized in the sections below. It is important to note that the majority of these findings do not include consideration of freeboard, as this was only included for 0.5% AEP events for use in the regulatory floodplain maps and defining climate change planning areas (as per the Provincial Guidelines, 2018). Findings that include freeboard are marked with an () icon throughout the report and show flood results that are more extreme to account for flood level uncertainties.

Coastal Flood Mapping Highlights

- **Coastal flooding is expected to inundate only a small portion of land in the CVRD overall.** An extreme 0.5% AEP coastal storm event is expected to inundate over 1,900 ha (1.1%) of land in the CVRD under current conditions and over 2,200 ha (1.3%) of land with 1 m of sea level rise (year 2100).
- **There are a number of communities and agricultural areas in low-lying coastal areas that have been developed and are exposed to coastal flooding from an extreme storm under current and future conditions.** In particular, flooding under a 0.5% AEP coastal storm event under current conditions could inundate a significant portion of lands in Electoral Area B and K'ómoks First Nation reserve lands (IR#1, IR#2, IR#3).
-  **Sea level rise (SLR) is expected to increase flood extents and the total area of land inundated across the CVRD; however, this increase is expected to be modest relative to the significant flooding expected in low-lying areas under current conditions.** "Climate Change Planning Areas" have been developed based on regulatory flood mapping results and represent the additional area of land that would be inundated in the CVRD during a 0.5% AEP storm event with 1 m and 2 m of sea level rise and 15% and 30% increases in river flow. The year 2100 planning area is 276 ha and the year 2200 area includes an additional 343 ha. However, these are on top of over 2,300 ha (just over 1%) of land inundated across the CVRD during the same AEP event under current conditions (0 m SLR and current river flows).
- **Maximum water levels will rise under future climate change scenarios, with levels from a 0.5% AEP coastal storm event today being similar to those expected from a 10% AEP event with 0.5 m of sea**



level rise. This means that, as sea levels rise, smaller storm events will cause more severe flooding reaching higher elevations and further inland.

Oyster River Flood Mapping Highlights

- + Low-lying properties within the confined river valley in the upper reaches of the river are exposed to flooding from a 0.5% AEP river storm event under current and future climate change conditions.** However, properties on the plateau above the valley are above flood levels from even the most extreme storm events considered as part of this project (0.2% AEP). In comparison, the same storm events without freeboard cause significantly less flooding in low-lying areas.
- + Land on the southern side of the river in the lower portion of the river has low exposure, with model results indicating limited inundation of buildings even under an extreme (0.2% AEP) flood with climate change allowance given that most buildings there are location on top of a higher bank.**
- + The Oyster River Community (in the Strathcona Regional District) is protected by the Glenmore Dike and the Glenmore Road Embankment.** The modelling indicates that the crest of the Glenmore Dike is high enough to protect properties north of the dike up to a 0.2% AEP river storm event with a 30% climate change allowance. The Glenmore Road Embankment has a lot of spots that would be overtopped in the 0.5% AEP river storm event with a 15% climate change allowance.
- + Although the dike (and the Glenmore Road Embankment) provides a level of protection from flooding, the Oyster River Community is still exposed to flooding in the event of a dike breach during a storm event.** Modelling results simulating a dike breach at the upstream end of the Glenmore Dike indicate that the 0.5% AEP and 0.2% AEP storm events would cause extensive flooding across the community north of Glenmore Road.
- + For the non dike breach scenarios, different AEP storm events result in minimal change to flood extents in the downstream section of the Oyster River near the mouth.** The channel is well confined on both the north and south banks, with some flow into old flood channels. Climate change, including increased streamflow and sea level rise is expected to increase the flood extents, depth, and velocity in the land north of Glenmore Road during a breach scenario. Furthermore, some of this area is exposed to impacts from coastal storm events, as described in the Oyster River mapping case study (Section 5.4).

Courtenay River System Flood Mapping Highlights

- Flooding extents and water depths on the lower section of the Courtenay River system floodplain, southeast of Highway 19A, are mostly influenced by the coastal water levels.** Most of this area is primarily agricultural fields. Other areas vulnerable to flooding include Lewis Park and the low-lying area surrounding the confluence of the Tsolum River, Puntledge River, and the Old Tsolum Channel.
- High water velocities were observed in the river channel especially at locations like road crossings and river bends.** Near the harbour, the river channel also has high velocities generated during low tide conditions. On the floodplain, velocities are mostly low except for areas around locations where roads overtop during extreme events.
- Most areas on the floodplain have a hazard rating between 0.6 to 4 m²/s,** which (for 1 m water depth) include three different categories (0.6 – 1.0 m²/s: unsafe for people and vehicles, 1.0 – 4.0 m²/s: unsafe for vehicles and people with all buildings vulnerable to structural damage, and above 4.0 m²/s: unsafe for vehicles and people with all buildings vulnerable to failure).



Next Steps for Adaptation

Successful adaptation will involve finding a balance between setting policies in place to avoid future development in flood-prone areas and protecting or moving existing structures, while still preserving the ability of the coastal shoreline and river corridors to adapt to changes in a natural way. The CVRD already administers a number of flood management policy and planning tools. Managing flood risk will likely involve a combination of policy, planning, and site-specific measures that build on the CVRD's existing framework to reduce impacts in high-risk areas.

Communities across BC draw on a range of approaches for flood management and resilience, including:

- giving nature the space to adapt gradually over time in natural and undeveloped areas;
- developing robust emergency preparedness, response, and recovery plans for those areas at risk of flooding to limit loss of life and help in rapid recovery after flooding events;
- establishing policy and planning tools such as Flood Construction Levels (FCLs) and setbacks that guide future development to avoid building in flood-prone areas;
- moving high-risk structures out of flood-prone areas in select and extreme cases; property-level initiatives to floodproof or protect existing structures from flooding and erosion; and,
- using nature-based approaches such as constructed wetlands and beaches to manage erosion and wave effects.

For the CVRD, building resilience to flooding will likely involve a combination of approaches including local, site specific initiatives that property owners can take to reduce flood risks on their properties and broader planning and policy approaches to manage future development in floodplain areas.

Future Considerations

The Coastal Flood Mapping Project is the first step in a multi-year process to understand and develop strategies to build resilience to flooding along the CVRD shoreline and Oyster and Courtenay River systems.

Recommendations for future steps for flood mapping, risk assessment, and adaptation planning include:

1. Use the flood hazard mapping from this project to complete a comprehensive risk assessment to identify priorities as the next stage in the flood management planning process;
2. Use the flood hazard mapping to support the development of regulatory and policy tools for land use management in flood hazard areas;
3. Extend the Tsolum River modelling completed by the City of Courtenay (2013) upstream to the limit of the 1990 Province of BC floodplain mapping;
4. Consider developing updated flood mapping for other rivers in the CVRD including the Trent River and Tsable River;
5. Complete a migration corridor analysis for all CVRD rivers, specifically the Tsolum River;
6. Complete an assessment of potential erosion and intertidal area change linked with estimated flood levels;
7. Improve the reliability of the coastal geomorphologic assessment by conducting field work potentially supplemented with data collected by drone (video);



8. Establish a program for water level monitoring along the rivers within the CVRD for flood warning purposes and future hydraulic model verification;
9. Install dike crest gauges adjacent to the Glenmore Dike and along the Courtenay River as tools to measure and monitor the remaining freeboard during high water level events;
10. Consider preparing model “Green Shores” shore protection designs for different areas (e.g., by shoreline type or wave exposure) in the CVRD that property owners can refer to when designing property-level measures;
11. Hold a webinar to present findings from the Coastal Flood Mapping Project to member municipalities; and
12. Develop educational materials to communicate findings from the project with the CVRD public and build awareness of flood hazards, risks, and potential adaptation approaches.



Key Terms

Annual Exceedance Probability (AEP)	= Annual exceedance probability is the probability that a storm event (e.g., a coastal flood water level) will occur or be exceeded in any given year. For example, a 10% AEP event has a 10% probability in any given year that it or a larger event will occur. AEP is calculated as a 1 divided by the return period.
Bathymetric	= Survey to establish elevations of underwater river channel bed or ocean bed surfaces.
Climate Change	= A change in global or regional climate patterns, in particular a change apparent from the mid to late 20 th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.
Digital Elevation Model (DEM)	= A generic term for a map that represents the topographic elevation of the earth's surface.
Extreme Static Water Levels	= The calculated peak water surface elevation for a given AEP combination of astronomical tides, storm surge, and other long-term components of water level derived by analysis of historical data or using hydraulic modelling software. Extreme static water levels do not include wave runoff. The extreme static water level does not include wave effects and is referred to as the "still water level" when combined with sea level rise.
Flood Hazard Maps	= Engineering maps that display the results of hydrologic and hydraulic investigations (including water level, water depth, and velocity) and show areas that could be flooded under different scenarios. These maps are used for planning purposes related to land use planning, emergency management, and flood mitigation. Note that this is the working definition for this project and other projects or organizations may have a different definition.
Flood Level	= The maximum elevation of the water surface in a given flood scenario. Flood levels that include freeboard are used in the regulatory floodplain mapping and can inform the development of Flood Construction Levels (FCLs) in future phases of flood planning and implementation.
Floodplain	= A lowland area, whether diked, flood proofed, or not which, by reasons of land elevation, is susceptible to flooding from an adjoining watercourse, ocean, lake, or other body of water. In coastal and estuarine areas, the floodplain is the land shoreward of the existing normal high tide line and includes the area of land that may be subject to future flooding due to sea level rise.
Freeboard	= A vertical distance added to a flood level. The freeboard accounts for uncertainties inherent in the estimation of the flood level including uncertainties in storm intensities, river flows, water levels, wave effects, and climate change impacts on these parameters.
LiDAR	= A surveying method that measures distance to a target by illuminating the target with laser light and measuring the reflected light with a sensor. LiDAR stands for Light Detection and Ranging.
Maximum Water Level	= The total maximum elevation that water is expected to reach during a storm event. In coastal areas, the maximum water level occurs at high tide (extreme static water level) and with wind-generated waves.



Regulatory Floodplain Mapping	= Maps used for regulatory purposes, such as developing floodplain bylaws and informing area plans and official community plans. For the Coastal Flood Mapping Project, the regulatory mapping is based on inundation mapping for 0.5% AEP storm events plus a freeboard allowance to establish the flood levels and floodplain limits.
Return Period	= Return period is a way of describing the probability of a storm event. Return period is calculated as 1 divided by the annual exceedance probability (AEP). For example, for a 10-year return period storm event, there is a $1/10=0.1=10\%$ probability in any given year that the event or a larger event will occur. Return period is <u>not</u> the strict frequency of an event, i.e., if a 10-year return period event occurs this year, there is still a 10% probability that will occur next year as well.
Risk	= The chance of injury or loss as defined as a measure of the probability and severity of consequences from a hazard such as flooding. Consequences can range broadly and include adverse effects to health, property, the environment, or other things of value.
Sea Level Rise (SLR)	= The gradual rise in the base sea level due to various processes including thermal expansion of the oceans and loss of glaciers/land ice caused primarily by anthropogenic global warming.
Climate Change Planning Areas	= The area of land expected to be inundated under future climate conditions considering sea level rise and increases in river flow. The year 2100 climate change planning area is calculated as the difference between total inundated area under a 0.5% AEP storm event with 1 m of sea level rise and a 15% increase in river flows compared with the total area inundated under the same event under current conditions (0 m SLR and no increase in river flows). The year 2200 climate change planning area is calculated as the difference between a 0.5% AEP storm event with 2 m of sea level rise and a 30% increase in river flows compared with the year 2100 climate change planning area.
Setback	= Withdrawal of a building or siting of a building or landfill from the natural boundary or other reference line to maintain a floodway (room for flooding to occur without damaging structures) and to allow for potential land erosion.
Still Water Level	= The still water level is the extreme static water level plus sea level rise.
Storm Surge	= The temporary rise in water level, measured above the astronomical tide water level, due to offshore or near-shore storm processes including pressure changes and wind. Storm surge does not include wave effects (wave setup and wave runoff).
Topographic	= The shape and features of a land surface. In the context of this study, topographic features are those above the water level (as opposed to bathymetric which refer to features below the water level).
Wave Runup	= Wave runup is the maximum vertical extent of wave uprush on a beach or structure above the still water level. The wave runup includes the wave setup and may be referred to as “wave effects” in this document.
Wave Setup	= Local increase in mean water level in the breaking wave or “surf” zone as a result of the momentum in the waves being converted into a local increase in the water level as they break and lose energy.



Acronyms

AEP	=	Annual exceedance probability (refer to Key Terms)
DEM	=	Digital elevation model (refer to Key Terms)
CHS	=	Canadian Hydrographic Service
CVRD	=	Comox Valley Regional District
CGVD2013	=	Canadian Geodetic Vertical Datum 2013
EGBC	=	Engineers and Geoscientists BC
HEC-RAS	=	Hydraulic Engineering Centre's River Analysis System (river modelling software)
IPCC	=	Intergovernmental Panel on Climate Change
LiDAR	=	Light Detection and Ranging (refer to Key Terms)
PCIC	=	Pacific Climate Impacts Consortium (University of Victoria)
SHORLAX	=	SHOReLine Analysis by Xsection (KWL wave analysis software)
SLR	=	Sea level rise (refer to Key Terms)
SRD	=	Strathcona Regional District
SWAN	=	Simulating WAVes Nearshore (wave modelling software)

1. Introduction

The Comox Valley Regional District (CVRD) is exposed to flooding from coastal and river storm events. The region has experienced major floods in recent years, which have caused significant damage to property and infrastructure in low-lying coastal areas. These storm events are expected to become more severe as sea levels continue to rise due to climate change.

The CVRD is taking a proactive approach to understand and build resilience to current and future flood risk due to climate change. Flood management planning will involve the multi-year process outlined in Figure 1. This planning process has been adapted from the process outlined in the Province of BC Sea Level Rise Adaptation Primer (2013).



Figure 1: CVRD Flood Management Planning Process

The Coastal Flood Mapping Project represents the first step in the CVRD's planning process. **This report describes the key considerations, methodologies, and outcomes from the project.** It is intended to serve as the foundation for risk assessment and flood management planning.

1.1 Coastal Flood Mapping Project

The Coastal Flood Mapping Project was led by the CVRD between October 2019 and April 2021 with funding provided by the Union of BC Municipalities' Community Emergency Preparedness Fund and the National Disaster Mitigation Program. Technical work was completed by engineering consulting firm Kerr Wood Leidal Associates Ltd. (KWL) with support from Cascadia Coast Research Ltd.



Through this project, the CVRD is taking a proactive approach to update its floodplain maps to consider the anticipated effects of sea level rise according to the guidelines set out in the BC Provincial Flood Hazard Area Land Use Management Guidelines (“Provincial Guidelines”, FLNR 2018). This project puts the CVRD within a cohort of coastal communities who have been early adopters of the updated provincial guidelines. Other communities who have updated their flood mapping to meet the updated guidelines include the Regional District of Nanaimo, Capital Regional District, City of Campbell River, District of Tofino, and District of Ucluelet.

Project Approach

The Coastal Flood Mapping Project represents the first step in the CVRD flood management planning process (Figure 1). The objective of the project is to map flood levels and other hazards for a variety of sea level rise and storm scenarios to inform flood mitigation planning along the entire CVRD shoreline as well as the Courtenay River system and Oyster River.

The project study area includes:

1. The entire CVRD shoreline, from the Oyster River south to Cook Creek including Denman and Hornby Islands;
2. The Oyster River downstream of Highway 19 to its mouth at the Strait of Georgia; and
3. The lower reaches of the Courtenay River, including the Puntledge River (downstream of the BC Hydro Powerhouse) and Tsolum River (downstream of the Piercy Road Bridge/North Courtenay Connector).

The project involved the following four stages of work:

1. Data Collection (base mapping);
2. Modelling (river & coastal);
3. Mapping (regulatory floodplain maps & digital mapping); and
4. Reporting (final report, technical memoranda (appendices), model user guide, and communication materials).

A series of technical memoranda were developed to describe the methodology and key outcomes from each stage in the flood mapping process. Further detail on the methods and outcomes from each stage of work is described in Section 4 and 5 of this report with the supporting technical memoranda included as appendices.

Project Outcomes

The Coastal Flood Mapping Project created a series of regulatory floodplain maps which cover the entire CVRD shoreline, Oyster River, and Courtenay River system. A series of digital mapping products showing different flooding scenarios and parameters such as maximum water level, maximum water depth, maximum flow velocity, flood hazard rating, and maximum wave heights in the coastal floodplain were also created to inform flood management, risk assessment, and emergency planning by CVRD staff. Digital mapping of climate change planning areas and setbacks was also prepared. The regulatory floodplain maps, climate change planning areas, and setback mapping will support future land use planning across the region.



Project Team

The Coastal Flood Mapping Project was led by the CVRD's planning team within the Planning and Development Services department. The CVRD's lead staff member on the project was Robyn Holme, RPP, MCIP (Long Range Planner); the CVRD was supported by Tamsin Lyle, M.Eng., MRM, P.Eng. (Ebbwater Consulting).

The reporting and mapping were produced by the following consulting firms and key individuals:

- Kerr Wood Leidal Associates Ltd. (KWL) – River and Coastal Engineering
 - Eric Morris, M.A.Sc., P.Eng. – Project Manager & Lead Coastal Engineer
 - Craig Sutherland, M.Sc., P.Eng. – Water Resources Engineer (Courtenay River System)
 - David Zabil, M.Sc., P.Eng. – Water Resources Engineer (Oyster River)
 - Chad Davey, M.Sc., R.P. Bio. – Fluvial Geomorphologist and Aquatic Biologist
 - Max Scruton, P.Eng. – Coastal Engineer (Nearshore Wave Modelling)
 - Ryan Taylor, GISP – Lead GIS Analyst
 - Tiffany Soh, B.Sc. – GIS Analyst
 - Mike Currie, M.Eng., P.Eng., FEC – Senior Technical Reviewer
- Cascadia Coast Research (Cascadia) – Coastal Modelling
 - Clayton Hiles, M.Sc., P.Eng. – Coastal Engineer (Deep Water Wave Modelling)
- Bazett Land Surveying (Bazett) – Surveying
 - Dave Bazett, BCLS, CLS – Surveyor (Oyster River Bathymetric Survey)



2. About the CVRD

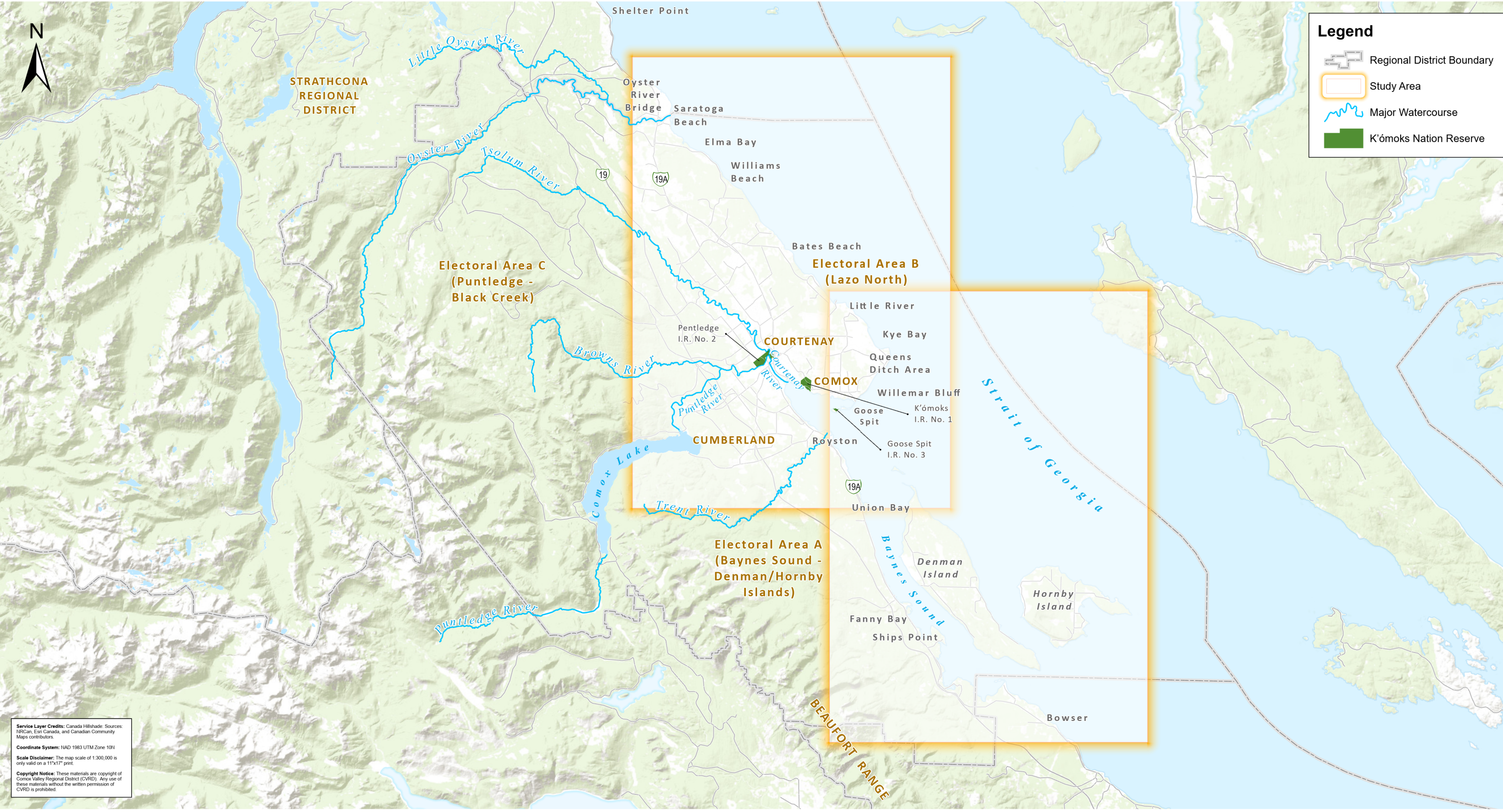
The CVRD is located on the eastern coast of Vancouver Island in the traditional territory of the K'ómoks First Nation. In 2008, the Comox Strathcona Regional District (CSRD) was restructured into two separate regional districts – the Comox Valley Regional District (CVRD) and the Strathcona Regional District. A map of the CVRD is shown in Figure 2, including key CVRD landmarks referred to in this report.

2.1 Community Context

The CVRD is home to over 66,500 people (2016 Census) living in the region's three member municipalities (City of Courtenay, Town of Comox, and the Village of Cumberland) and three electoral areas (Electoral Area A - Baynes Sound including Denman and Hornby Islands, Electoral Area B - Lazo North, and Electoral Area C - Puntledge – Black Creek). The CVRD has experienced consistent growth over the last century with 65% of the population living in core settlement areas of its three municipalities. This growth is expected to continue with the population estimated to reach over 88,000 people by 2030 (Regional Growth Strategy, 2010).

Apart from the density in core settlement areas, land uses across the region are primarily rural with a growing population in the rural electoral areas. There is a significant portion of agricultural land and resource areas (privately managed forests) across the CVRD, including lands along the Oyster and Courtenay Rivers. Single-family homes, parks, and recreation properties (e.g., vacation homes and campsites) line the coast, with views and access to the beaches in the region. Small higher-density areas with commercial, multi-family, and industrial land uses are found in Courtenay, Comox, and the Village of Cumberland (Rural Comox Valley Official Community Plan, 2014).

Retaining local agricultural lands, maintaining a more rural quality of life, and protecting the environment are important community values reflected in the Rural Comox Valley Official Community Plan (2014). These values, as well as protecting public safety and private property, will influence flood management approaches across region. The CVRD has a government-to-government relationship with the K'ómoks First Nation, working together under a shared understanding for living on and caring for the lands in the Comox Valley. The CVRD and K'ómoks First Nation are working in partnership under the K'ómoks Estuary Management Plan to harmonize roles and responsibilities for environmental management in the region (Rural Comox Valley Official Community Plan, 2014).



2.2 Geographic Context

The CVRD covers a diverse landscape including an expansive shoreline, rich agricultural lands, and vibrant forests, rivers, and mountains.

Watersheds and Rivers

The CVRD is located on the east coast of Vancouver Island and spans from the Beaufort Range, across the coastal lowlands to the Strait of Georgia. There are many rivers that flow across the region with the major watersheds being the Oyster River Watershed, the Courtenay River Watershed and the Comox Lake Watershed.

The Oyster River Watershed extends from its' headwaters near the top of Forbidden Plateau coast. Most of the watershed is within the CVRD but some parts of the watershed lie within neighbouring Strathcona Regional District (SRD). In the upper portion of the study area, the channel is locally constrained by bedrock outcrops and is underlain by valley alluvium. Further downstream, there is a decreasing occurrence of bedrock outcrops, the valley widens, and the river encounters a mix of fluvial, deltaic, and shore deposits. At the river mouth, an alluvial fan is evident, having been formed from fluvial processes as a result of river flooding as well as coastal sediment transport processes.

to the
the
river



Figure 3: Comox Lake, Courtenay River Headwaters

The watershed of the Courtenay River includes both the Puntledge River, which extends from its headwaters at Comox Lake, and the Tsolum River which collects runoff from the north and east-facing slopes of Mt. Washington and then flows eastward towards its' confluence with the Puntledge River upstream of the City of Courtenay. Comox Lake is shown in Figure 3.

Coastal Areas

The CVRD is located on a relatively open stretch of shoreline extending 124 km along the east coast of Vancouver Island, with an additional 82 km of shoreline on Denman and Hornby Islands. The shoreline offers extensive recreation amenities and abundant habitat for a range of bird and intertidal species and potential spawning grounds for forage fish. Shoreline types range from low-lying marsh areas in the K'ómoks Estuary (Figure 4) to steep bedrock cliffs on south Denman and Hornby Islands. The northern shoreline on Vancouver Island from Saratoga Beach to Comox consists primarily of

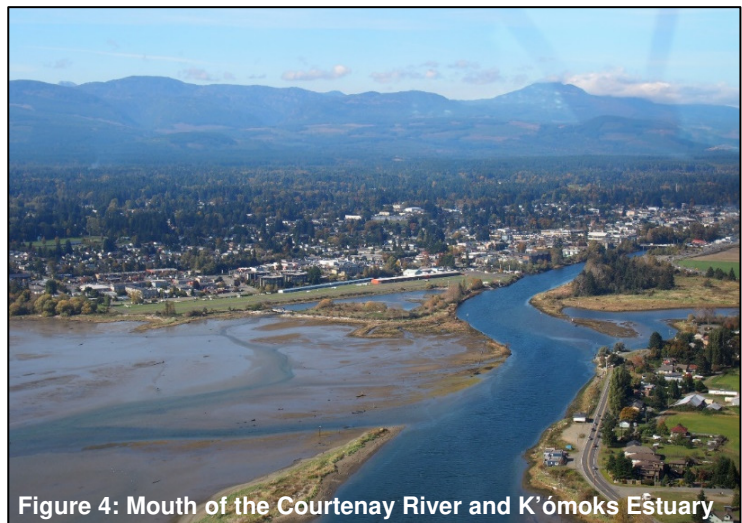


Figure 4: Mouth of the Courtenay River and K'ómoks Estuary

glacial sand/gravel deposits (Figure 5). In some locations, these deposits have been eroded by coastal processes to expose high (up to 50 m) sea bluffs, notably Willemar Bluff (Figure 6), which consist of erodible sand/gravel. This portion of the shoreline fronts the Strait of Georgia and is exposed to relatively high wave energy from the northwest and southeast.

The shoreline from Comox to Royston is in the protected confines of Comox Harbour and has been predominantly formed by the transport of fluvial deposits from the Courtenay River. The shoreline consists typically of sand/gravel/cobble beaches with some low coastal banks. South of Royston, the shoreline consists of a variation of cobble, gravel, and sand beaches, which have been deposited as a result of coastal transport of eroding coastal sediments and from fluvial deposits from the Trent and Tsable Rivers and several creeks. The wave energy along this stretch of shoreline is lower than the northern section because it fronts Baynes Sound that is protected by Denman Island. The most southern portion of the shoreline, near Mud Bay, consists of fine sediment mudflats.

The shoreline of Denman Island is typically composed of low bluffs fronted by bedrock shelves or sand and gravel beaches. The southern Denman Island shoreline has higher bedrock cliffs, while the northeastern portion of Denman Island has similar geology to that of the northern shoreline of CVRD, with glacial deposits which have eroded to form high coastal bluffs in some locations, especially along the exposed north eastern shoreline (Komas Bluffs). Eroded sediments from these coastal bluffs have been transported north by coastal processes to form a sand spit at the northern end of Denman Island and a series of small islands (e.g., Sandy Island).



Figure 5: Northern Shoreline of the CVRD and Little River

The Hornby Island shoreline is similar to that for Denman Island, with low bluffs fronted by bedrock shelves or sand and gravel beaches. The exceptions being the higher bedrock cliffs at western Helliwell Park and the longer stretches of sandy beach at Tribune Bay, Little Tribune Bay, and Whaling Station Bay.

The CVRD shoreline provides habitat for a range of endangered and at-risk bird and animal species. In particular, the Oyster River Estuary and the 3.5 km stretch of shoreline between Elma Bay and Williams Beach is identified in the sensitive habitat inventory mapping database administered by the Coastal Mapping Network group. The K'ómoks Important Bird Area (IBA) extends 14 km along the shore from Bates Beach to Mud Bay, with intertidal and salt marsh habitat that provide important staging and wintering areas for migratory and resident birds (Current Environmental, 2018).



Figure 6: Willemar Bluff

The coast is also a known spawning ground for forage fish including Pacific sand lance and surf smelt, which rely on sediment from natural erosion processes to produce the appropriate mix of sand and gravels for spawning. Fish spawning is not only important for fish populations and ecology, but also provides an essential food source for other fish, birds, and marine mammals (Current Environmental, 2018).

2.3 Flood Management Context

The CVRD has a history of flooding, with major floods recorded as recently as 2014 and 2016 along the Oyster and Courtenay Rivers. Historic storm events have caused significant damage to community infrastructure and property, including washout of roads and bridges, damage to drinking water wells, erosion along trails and roadways, and localized flooding and damage to private property and buildings. Figure 7 outlines the river and coastal storm events recorded in the Oyster River and Courtenay River system over the past 100 years.

These historic and recent storm events have prompted the CVRD to better understand flood hazards in the region and lead flood management planning.

Flood Management Works and Jurisdiction

As a regional district, the CVRD plays a unique role in flood management in collaboration with member municipalities and neighbouring First Nations. Regional districts have broad land management powers that focus on providing services that reach across multiple jurisdictions, such as watershed management and emergency response. While flood management fits within this purview, regional districts have little to no authority to implement flood management initiatives within municipal or First Nation boundaries. For this reason, collaboration with member municipalities and neighbouring First Nations is particularly important for effective flood management in the CVRD.

In particular, the Courtenay River flows through the City of Courtenay and has a long history of flooding. While this Coastal Flood Mapping Project will provide a resource for the City to refer to, ultimately flood planning, decision-making, and implementation will be led by the City. In contrast, the CVRD holds authority to implement flood management works in unincorporated areas and can work to support private landowners to build their own resilience to flood risks on their property.



Currently the CVRD does not have any major flood management structures, such as dikes, within its jurisdiction. There is a dike on the Oyster River (Glenmore Dike) within the neighbouring SRD, which can affect river conditions downstream. The City of Courtenay installs temporary flood control barriers as needed along the Courtenay River to protect low-lying properties from flooding. BC Hydro also owns and operates a dam at Comox Lake in the CVRD in accordance with operating rules, which affect downstream river flows and river water levels.

There are also a number of existing small-scale flood and erosion protection works in the CVRD, many of which were constructed prior to the incorporation of the CVRD in 2008. Flooding and erosion within the Oyster River/Saratoga Beach and Macaulay Road communities prompted the construction of erosion protection at several locations along the length of the Oyster River.

Individual property owners have also constructed flood and erosion protection works in river and coastal areas. A study conducted in 2018 found that over 60% of the shoreline between Saratoga Beach and Kin Beach has been visibly altered for this purpose, predominantly with hard structures such as rip rap or groyne installation (Current Environmental, 2018).

The CVRD continues to collaborate with external and neighbouring groups to support a coordinated approach to flood and erosion management.

Flood Management Framework

Existing policies and plans support flood management across the CVRD today. These documents outline strategies for emergency response during storm events, reducing flood impacts on existing properties in floodplain areas, and incorporating climate change considerations in infrastructure and development planning. Plans and policies considering flood hazards and climate change include:

- **Floodplain Management Bylaw**, No. 600 (2020) – regulates flood construction levels, setbacks, and construction requirements for properties in unincorporated areas within the floodplain;
- **Rural Comox Valley Zoning Bylaw**, No. 520 (2019) – regulates development siting through setbacks and flood construction levels in the Floodplain Management Bylaw;
- **Regional District Building Bylaw**, No. 142 (2011) – requires building permits to adhere to setbacks, flood construction levels, and other siting requirements for flood management;
- **Rural Comox Valley Official Community Plan**, No. 337 (2014) – includes Development Permit Area (DPA) guidelines on shoreline and aquatic and riparian habitat protection measures for waterfront properties;
- **Comox Valley Regional Growth Strategy**, No. 120 (2010) – includes policies for incorporating climate change into strategic decision-making;
- **Comox Valley Emergency Plan** (2018) – provides a high-level risk assessment for emergency events and preparedness, response, and recovery protocols to mitigate impacts;
- **Comox Valley Sustainability Strategy** (2010) – sets objectives for protecting and enhancing natural systems to support environmental services and health; and
- **CVRD 2019 – 2022 Strategic and Financial Plan** (2019) – adopts climate change as a strategic driver for decision-making and requires climate change to be considered in every project.

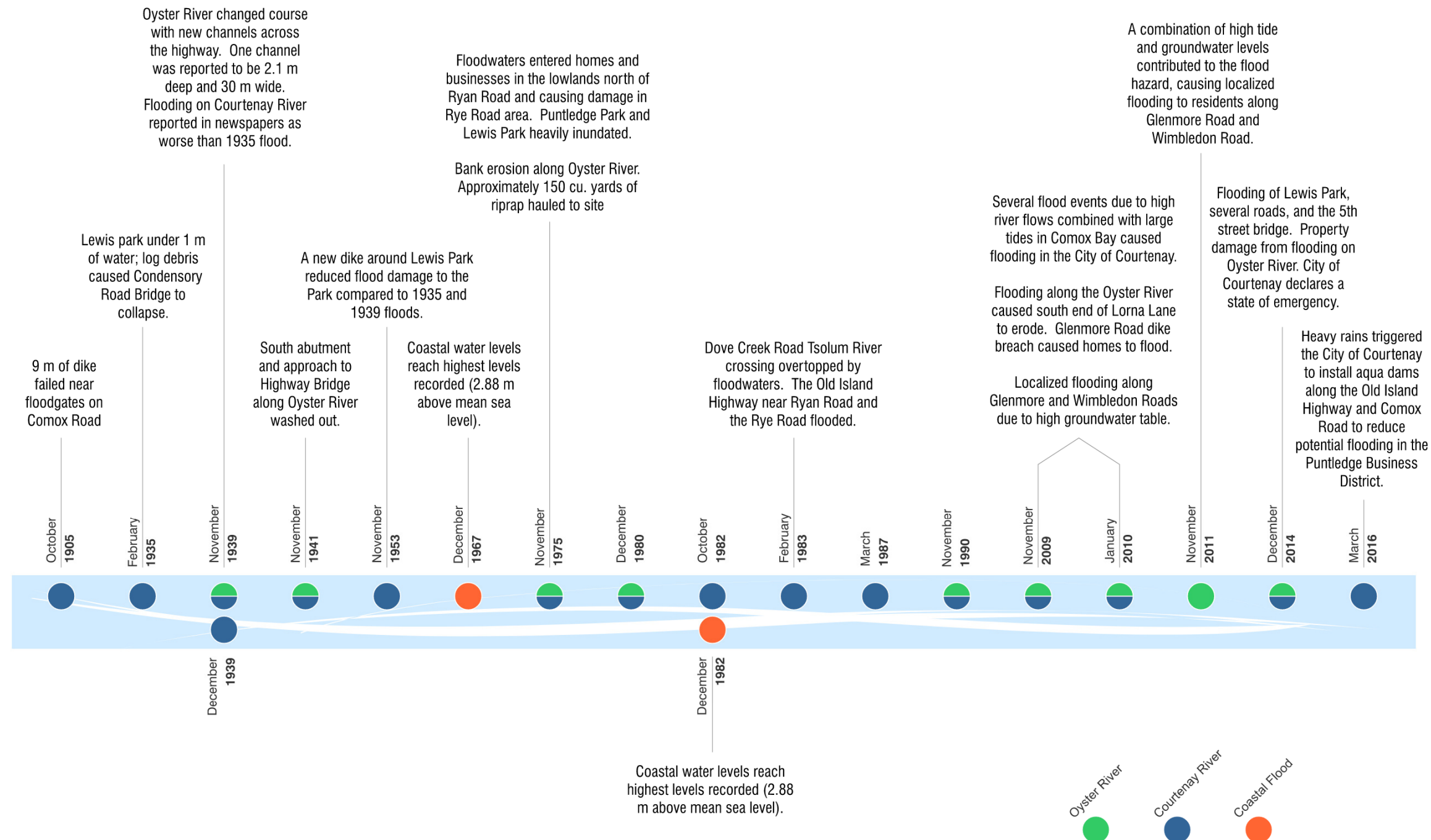


Figure 7: Flood History in the CVRD

3. Flood Hazards in the CVRD

Lands in the CVRD are exposed to flooding from a wide range of interconnected factors including rainfall and snowmelt, extreme high tides and coastal storm events, and shallow groundwater tables. Climate change has the potential to make flooding more severe in the future as precipitation patterns change and sea levels rise.

Section 3 describes the factors that affect coastal and river flooding in the CVRD and how climate change could influence future flooding.

3.1 Coastal Flooding

Coastal flooding happens when ocean levels rise above the elevation of shorelines or waterfront infrastructure and cause inundation on land. Coastal flooding most often occurs when a temporary “storm surge” event coincides with extraordinarily high tides (e.g., spring tides) and windstorms. Coastal flooding events are episodic, with flooding occurring during high tide and receding during low tide, coastal flooding can also be accompanied by wind-generated waves if a windstorm occurs at the same time as a storm surge event.

Figure 8 shows the different water level components that contribute to coastal flooding; these components will shift up and reach higher elevations as sea levels rise gradually over the next several decades.

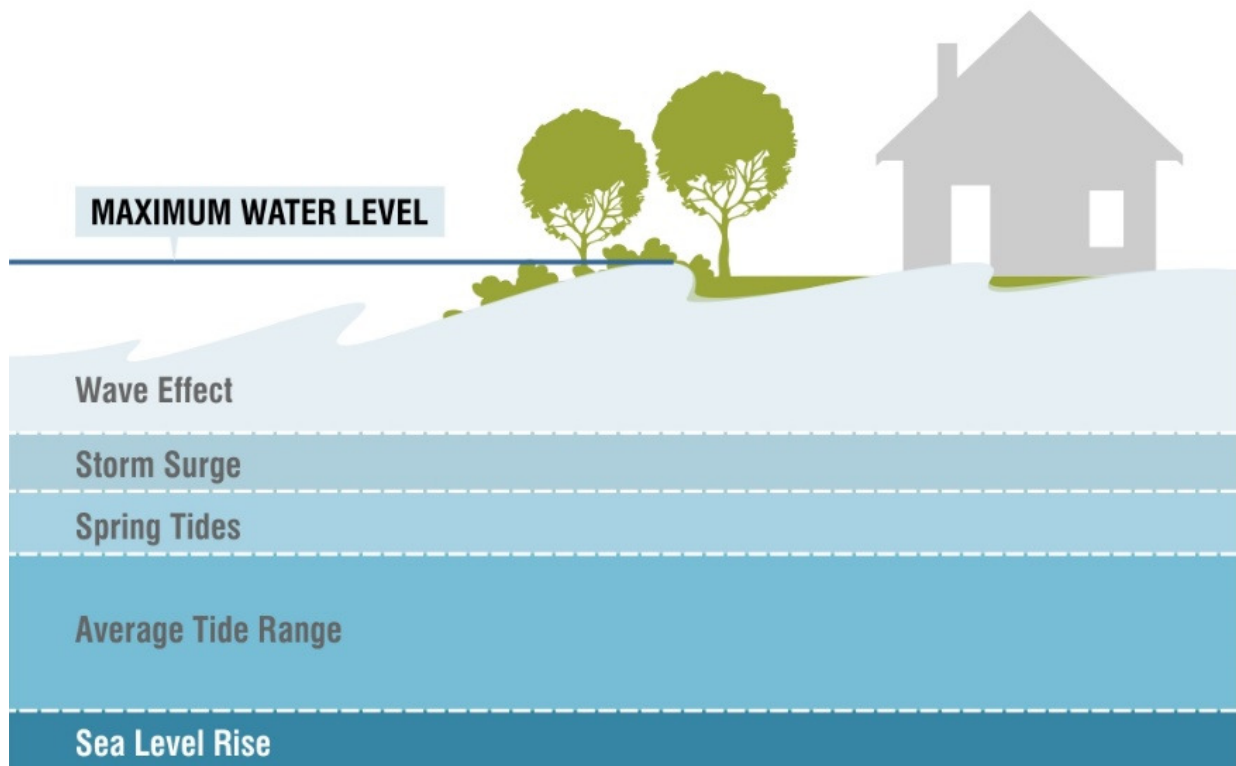


Figure 8: Components of Coastal Flooding



Further detail on the key components of coastal flooding shown in Figure 8 is described below.

Astronomical tides (commonly called “tides”) are variations in sea level due to the gravitational interaction of the earth, the moon, and the sun. Astronomical tide levels vary throughout the world due to variations in gravitational effects and large-scale ocean currents. Astronomical tide levels also vary throughout coastal BC due to local hydraulic effects caused by the flow of water between islands and into bays and inlets.

Larger “**spring tides**” occur when the gravitational forces of the sun and moon are synchronized and the earth, moon, and sun are closer to each other in their elliptical orbits. This causes high tide levels to be higher than the average. Despite their name, spring tide events do not only occur in spring; they can occur any time during the year. “Spring tide” is a historic term that refers to tides “springing forth”.

Storm surges are temporary increases and decreases in ocean water level caused by storm-generated atmospheric pressure fluctuations and wind. Storm surge events are often (but not always) accompanied by strong winds that cause waves to form and break on shore, pushing flooding higher and further inland. These storm events can cause significant damage to coastal areas, particularly when they occur at the same time as a major windstorm, intense rainfall, or river flooding.

Wind-generated **wave effects** (also called “wave runup”) are an important component of coastal flooding. The magnitude of the wave effect at a given location is influenced by the characteristics of the shoreline and its’ exposure. As shown in Figure 9, longer, gentle slopes are more effective at dissipating wave energy and lower the extent of wave runup, overtopping or splashing. In contrast, steeper slopes, or vertical features (e.g., a rocky bluff or steep cliff) cause relatively higher wave runup.

In developed areas, erosion protection measures such as rip rap slopes and seawalls can influence flooding and wave effects and can lead to increased beach erosion and bank destabilization over time.

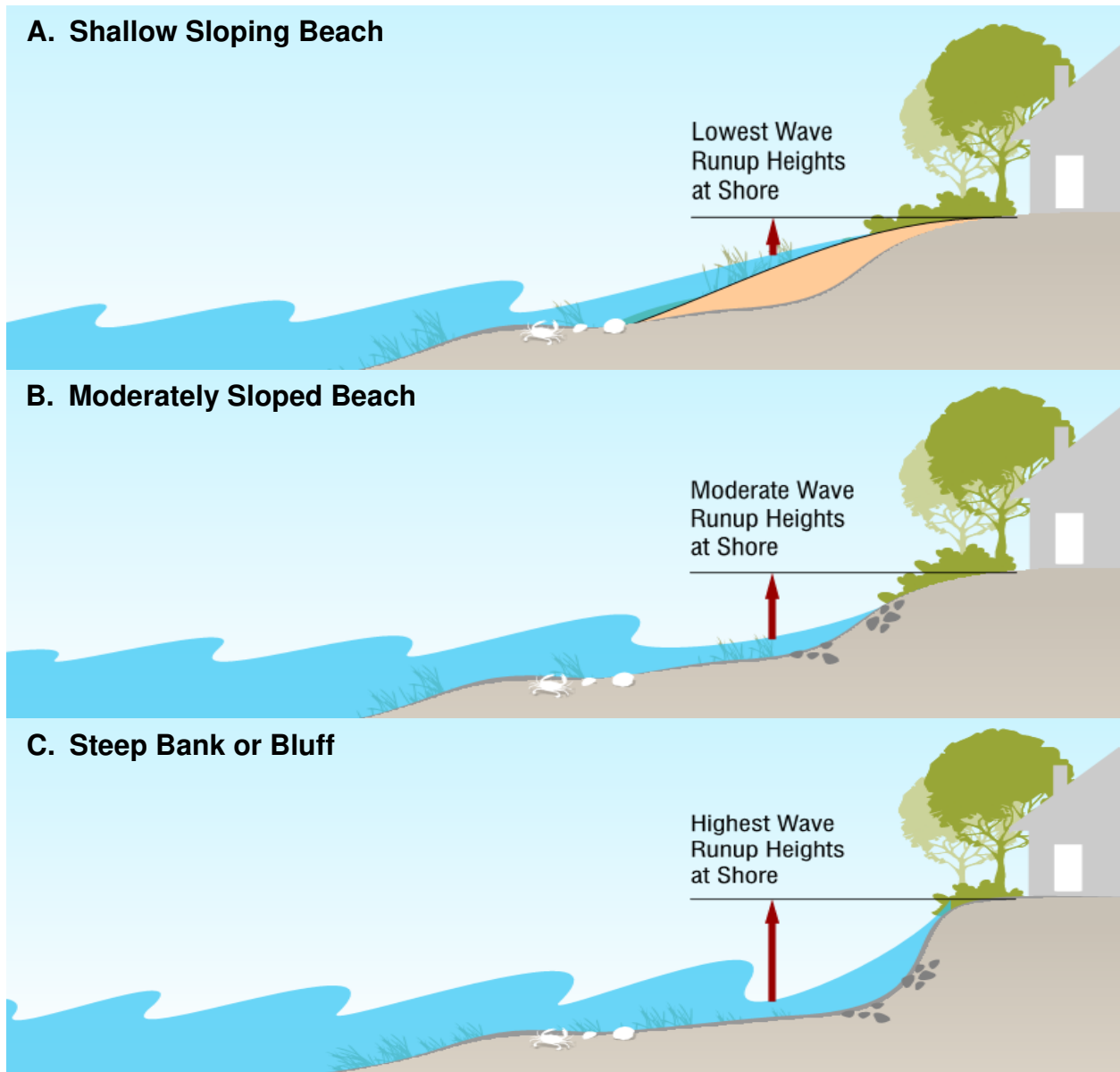


Figure 9: Effect of Different Shoreline Slopes on Wave Runup

Sea Level Rise

Sea level rise is happening and is expected to cause rising water levels along the CVRD shoreline over the coming decades, exacerbating existing coastal and river flood hazards.

Sea level rise refers to rising ocean water levels due to climate change. As global air temperatures rise, glaciers and other ice on land is melting at an increasing rate, causing more freshwater to flow into the ocean. Rising air temperatures are also causing ocean temperatures to rise, ocean water to physically expand (“thermal expansion”), and temperature-driven ocean circulation patterns to change.

While global sea levels rose by an average rate of 1.7 mm per year during the 20th century, since 1993 this rate has increased to over 3 mm per year. While the degree to which sea levels will continue to increase is uncertain, and will vary from place to place, the most recent assessment report by the Intergovernmental Panel on Climate Change (IPCC) estimates that the rate of sea level rise will continue to increase.

The provincial guidelines direct BC local governments to plan for 1 m of sea level rise by the year 2100, and 2 m by year 2200 (Figure 10) compared to a year 2000 baseline. This sea level rise projection was developed in 2011 and may not reflect the most recent sea level rise projections from the IPCC and others; however, it provides a consistent standard for planning across BC.

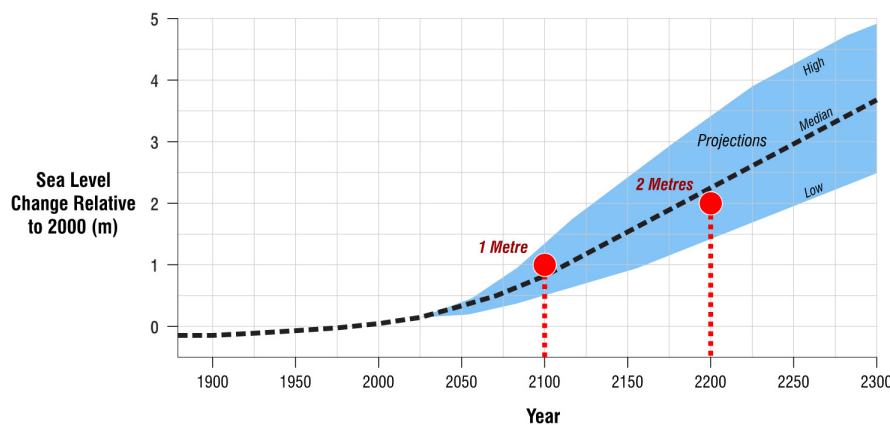


Figure 10: Province of BC Guidelines for Sea Level Rise Planning

On a local scale, the apparent sea level rise will vary from place to place depending on whether land in that area is sinking (“subsidence”) or rising (“rebounding”), which can occur when land previously depressed by ice sheets during the last glacial period gradually rises again or due to uplift of the earth’s crust due to the movement of tectonic plates. These geological conditions are part of the reason the reason that average relative sea level has risen at a rate of 13.3 cm per century in Prince Rupert but only 6.6 cm in Victoria¹.

Regional geological monitoring by Natural Resources Canada shows that the east coast of Vancouver Island (including the CVRD) is, on average, rising by 1.1 mm/year to 5.1 mm/year due to tectonic plate movement at the nearby Cascadia Subduction Zone. However, some areas, such as

¹ BC Ministry of the Environment. 2016. Indicators of Climate Change for British Columbia. Accessed at https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/reporting/envreportbc/archived-reports/climate-change/climatechangeindicators-13sept2016_final.pdf.

lands near the K'ómoks Estuary which are composed of river deposits are likely not rising at this rate or may even be subsiding.

3.2 River Flooding

River flooding happens when river water levels rise above the elevation of banks and flow into neighbouring lands, inundating areas that are normally dry. This can happen when snow accumulates in the mountains and is followed by an intense rainfall event that causes rapid snowmelt and river flows to increase quickly beyond the river channel's bankfull capacity. Though river floods can have a longer duration than coastal floods because they are less influenced by periodic tides, they typically do not include the damaging wave effects that often accompany coastal flooding. River floods can also occur with less warning than coastal floods because rainfall patterns and intensity are more difficult to forecast than storm surges and windstorms.

Floods on the Oyster River and Courtenay River typically occur in the late fall or early winter (November to February) as a result of storms carrying moisture from the Pacific Ocean eastward across Vancouver Island resulting in high intensity rainfall and snow accumulation. Often these scenarios cause extreme flood conditions on both the Courtenay River and Oyster River simultaneously.

River flooding is exacerbated by high coastal water levels due to high tides and storm surge. As ocean waters rise they cause water to "back up" into river systems, increasing water levels above those associated with river flooding alone and can increase the risk of flooding in areas close to where ocean and river waters meet. Areas near the mouths of rivers and creeks are particularly exposed to flooding as they are low-lying and can experience flooding during separate or combined river and coastal storm events. Figure 11 shows a river storm event with influence from different coastal tide and storm events.

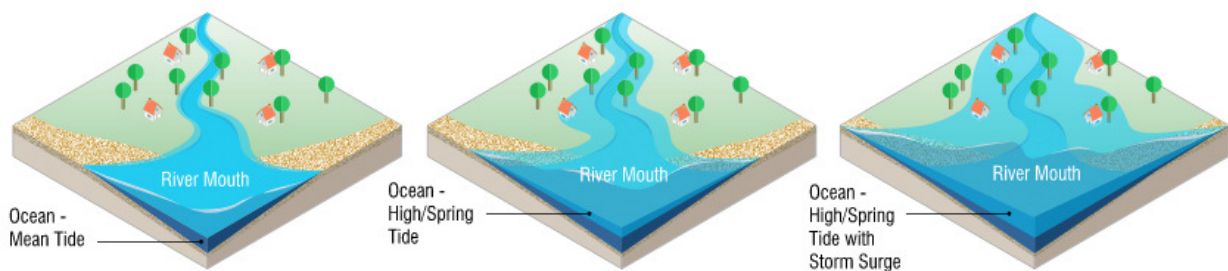


Figure 11: River Storm Event with Influence from Coastal Conditions

Heavy rainfall and rain-on-snow events in the Oyster River Watershed, Comox Lake/Puntledge River Watershed, and the Tsolum River Watershed, combined with high tide/storm surge events at Saratoga Beach and Comox Harbour, have led to damaging floods within the CVRD and the City of Courtenay.

Increased groundwater levels can also exacerbate extreme flooding. In 2011, river flooding in the Glenmore area was exacerbated by high groundwater tables, which reduced the infiltration capacity of the soil and caused more overland flooding.²

² BC Ministry of Environment, "Flooding and Landslide Events of Southern British Columbia 1808-2006", 2007. Accessed at http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/floods_landslides_south1.pdf.



Climate Change Impacts

Climate change has the potential to impact river flood dynamics, causing future peak flows to differ from historical records. Changing precipitation patterns are expected to cause more intense rain events in spring, fall, and winter months. As air temperatures rise, more precipitation is expected to fall as rain than snow. The increase in rainfall during wetter months is expected to cause higher river peak flows than historical records, causing an increased chance of flooding and higher flood levels. In addition, increased variation in temperatures could increase the likelihood and magnitude of rain-on-snow and snowmelt driven floods.

The Pacific Climate Impacts Consortium (PCIC) at the University of Victoria projects that the intensity of precipitation in the CVRD will increase over the next 100 years, with the maximum daily 2% AEP precipitation event increasing by 18% by mid-century and by 30% by the end of the century.³

Based on these projections, future design peak flows under climate change for this project have been increased by a factor of 15% and 30% in modelling and mapping. For example, while a 0.5% AEP river storm event at the mouth of the Oyster River would have a 493 m³/s design peak flow if it occurred today, this is expected to increase by 15% to 567 m³/s by mid-21st century, and 30% to 641 m³/s by the end of the century. Further detail on future AEP design peak flows under climate conditions are provided in **Technical Memoranda #3A** (Appendix C) and **#3B** (Appendix D).

³ Pacific Climate Impacts Consortium, "PCIC Climate Explorer", Accessed March 2020 at <https://pacificclimate.org/analysis-tools/pcic-climate-explorer>.

4. Flood Mapping Approach

The Coastal Flood Mapping Project involved mapping flood levels, water depths, and wave heights along the CVRD shoreline, Oyster River and Courtenay River system. The project assessed flood hazards under a series of extreme flooding scenarios and climate change conditions.

Figure 12 provides an overview of the four stages of work to complete this project, along with the list of technical memoranda associated with each stage. This project represents an early step in the overall flood management planning framework shown in Figure 1.

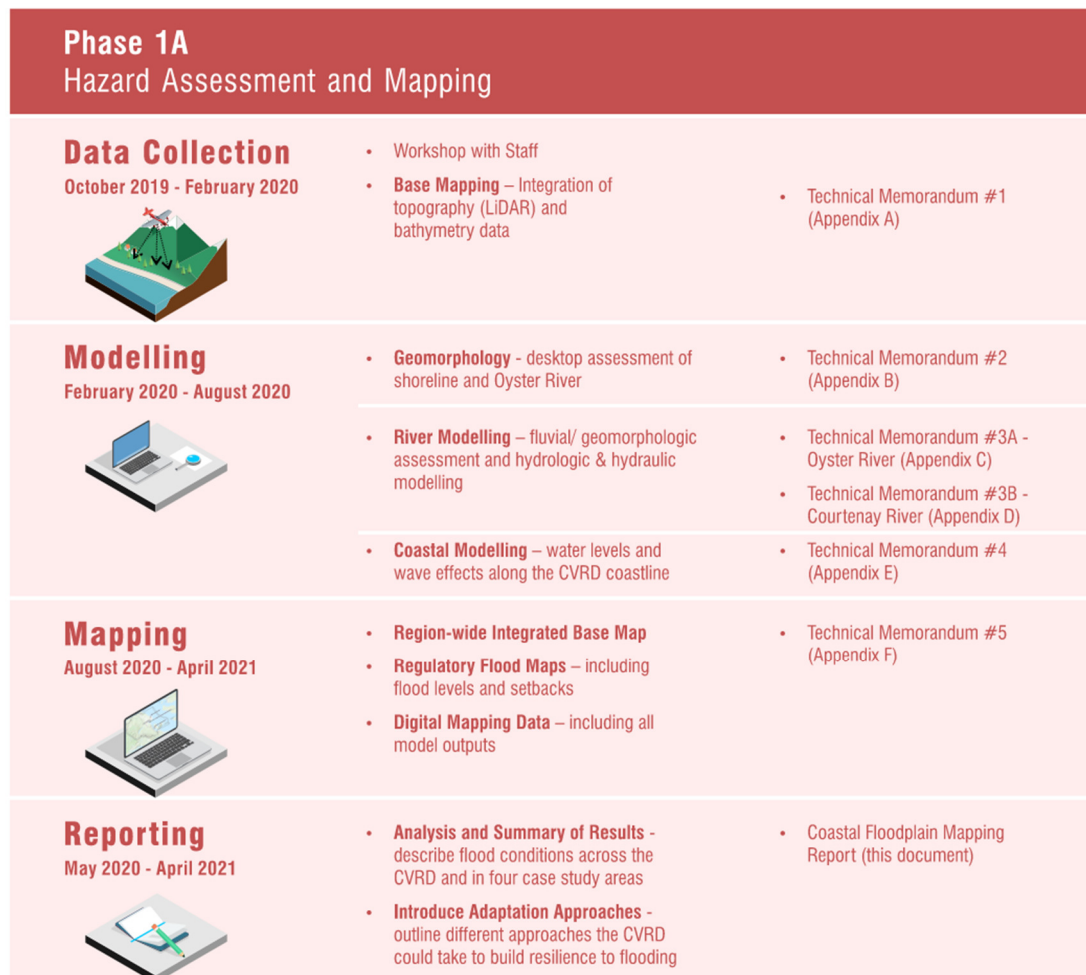


Figure 12: Phase 1A – Coastal Flood Mapping Project Stages

Section 4 describes the key considerations and approaches used in the first three stages of work for this project. Additional detail on methodologies and assumptions are provided in the technical memoranda appendices.



4.1 Data Collection & Base Map Development

The first stage of the project involved collecting and integrating topographic and bathymetric mapping of the CVRD from a variety of sources. This data was consolidated into a set of base maps for use during the modelling and mapping stages of the project. Further details on data collection are provided in **Technical Memorandum #1 – Coastal and River Base Map Development** (Appendix A).

Data Collection

Primary data sources used to develop the project base maps include:

1. **Topographic Mapping** – Base mapping made extensive use of data collected through Light Detection and Ranging (LiDAR) to map topography of upland and intertidal areas. This data was sourced through GeoBC (2018 - 2019) and Strathcona Regional District (SRD, 2016).
2. **Bathymetric Mapping (Deep Water)** – Deep water bathymetry data was used to map the seabed along coastal areas of the CVRD and the Strait of Georgia. The bathymetric data was sourced from the Canadian Hydrographic Service (CHS).
3. **Bathymetric Mapping (Ground Survey)** – Riverbed bathymetry was collected via ground survey (by boat and on foot) for the lower Oyster River as part of the project scope (2019).
4. **Orthophotos** – Aerial photos from two different sources were used to assess geomorphic conditions of the Oyster River (e.g., erosion, habitats) and trace building footprints (CVRD, 2018, SRD, 2017).
5. **Additional Data** – GIS shapefiles included administrative area boundaries, landmarks, parcels, roads, hydrology (watercourse and waterbody), natural areas (parks, ecological reserves, protected areas), and building footprints.

Base Map Development

Base mapping was developed as follows:

- Base mapping for the Oyster River was prepared by integrating the GeoBC and Strathcona Regional District LiDAR topographic datasets with the bathymetric mapping obtained through ground survey. This mapping was used for modelling of the Oyster River;
- A bathymetric Digital Elevation Model (DEM) was prepared by integrating the various CHS bathymetric data sets. This base mapping was used for deep water wave modelling; and
- Cross sections through the shoreline at various locations (transects) were prepared by integrating the GeoBC LiDAR and the bathymetric DEM. These transects were used for the nearshore wave modelling.

Further details on base map development are provided in **Technical Memorandum #1 – Coastal and River Base Map Development** (Appendix A).

The mapping used to develop the model of the Courtenay River system was prepared under a separate project; reference should be made to the KWL memorandum *City of Courtenay, Integrated Flood Management Study, Hydrodynamic Model Development and Flood Management Options Evaluation, November 29, 2013* prepared for McElhanney Engineering for further details on the base mapping used for model development (KWL, 2013).



4.2 Geomorphic Assessment

A **desktop geomorphologic assessment** of the Oyster River was conducted to understand the historic position of the river and where the channel could be positioned in the future. Historic aerial photos were geo-rectified in ArcGIS and reviewed to identify the bank edges and determine historic limits of the river location, its' "migration corridor" and the extents of its' alluvial fan. Geomorphic assessment of the Courtenay River, Puntledge River, and Tsolum River was completed as part of the earlier Courtenay Integrated Flood Management Study (KWL, 2013) and was not a part of the current project.

A desktop geomorphologic assessment of the shoreline was also performed to classify the erodibility of the shoreline. This information was developed as part of the coastal mapping to provide supplemental information when determining building setbacks.

Further information on methods, assumptions, and results from the river and coastal geomorphological assessments is provided in **Technical Memorandum #2 – Fluvial and Coastal Geomorphology** (Appendix B).

4.3 Modelling

Technical analysis of coastal and river flood levels in the CVRD involved a combination of hydrologic and hydraulic modelling. Modelling was completed separately for coastal and river areas, while considering the interrelationship between water levels in both systems and their influence on flooding.

Flood Scenarios

The analysis considered flood levels and depths for a wide range of storm events, ranging from 0.2% AEP (500-year return period storm event) to 10% AEP (10-year return period storm event), with allowances for climate change included in sea levels and river flows. A "dike breach" scenario was also evaluated in the flood modelling for the Oyster River and scenarios with existing and proposed flood protection works in place were modelled for the Courtenay River system. Overall, 32 river flooding scenarios were considered for the Oyster River, 21 river flooding scenarios were considered for the Courtenay River system and 20 coastal flood scenarios were considered as shown in Table 1 and Table 2.

Having mapping available for multiple scenarios will provide the CVRD with the data needed to complete a rigorous risk assessment to inform future flood mitigation planning. While the 0.5% AEP storm event with 1 m of sea level rise is the regulatory standard for planning for this project, considering *more* likely but *less* severe events (e.g., 10% AEP) allows the CVRD and property owners to identify and manage areas that are already at risk of flooding today. Considering *less* likely but *more* severe events (e.g., 0.2% AEP) makes it possible to begin putting plans in place now to manage more severe flooding in the future. Likewise, the mapping for the different sea level rise scenarios will provide the CVRD with information to conduct long term planning and develop phased sea level rise adaptation plans considering more near-term impacts.



Table 1: River Flooding Scenarios

Floodplain	Flood Protection Works	River Flow and Extreme Ocean Water Level (AEP)	Sea Level Rise and River Flow Climate Allowance
Oyster River System	Glenmore Dike – Unbreached	5% (50-year) and 5% (50-year) 10% (10-year) and 10% (10-year) 0.2% (500-year) and 0.2% (500-year) 0.5% (200-year) and 0.5% (200-year) 1% (100-year) and 1% (100-year)	0 m and 0% (current) 0.5 m and 15% (yr. 2050) 1 m and 15% (yr. 2100) 2 m and 30% (yr. 2200)
	Glenmore Dike – Breached	0.2% (500-year) and 0.2% (500-year) 0.5% (200-year) and 0.5% (200-year) 1% (100-year) and 1% (100-year)	
Courtenay River System	Existing	0.2% (500-year) and 0.2% (500-year) 0.5% (200-year) and 0.5% (200-year) 1% (100-year) and 1% (100-year) 5% (50-year) and 5% (50-year) 10% (10-year) and 10% (10-year)	0 m and 0% (current) 0.5 m and 15% (yr. 2050) 1 m and 15% (yr. 2100) 2 m and 30% (yr. 2200)
	Proposed Works In place ¹	0.5% (200-year) and 0.5% (200-year)	
Notes: 1. As per Kerr Wood Leidal Associates Ltd. (2013). <i>City of Courtenay, Integrated Flood Management Study, Hydrodynamic Model Development and Flood Management Options Evaluation.</i>			

Table 2: Coastal Flooding Scenarios

Floodplain	Windstorm and Extreme Ocean Water Level (AEP)	Sea Level Rise
Shoreline	0.2% (500-year) and 0.2% (500-year) 0.5% (200-year) and 0.5% (200-year) 1% (100-year) and 1% (100-year) 5% (50-year) and 5% (50-year) 10% (10-year) and 10% (10-year)	0 m (current) 0.5 m (yr. 2050) 1 m (yr. 2100) 2 m (yr. 2200)

River Modelling

Hydrologic and hydraulic modelling was completed for the Oyster River and Courtenay River system. Modelling used one- and two-dimensional modelling techniques to estimate flood elevations, depths, and flow velocities along the river channel and over the floodplain under a range of river storm events from 10% AEP to 0.2% AEP with climate change considerations. For the Oyster River, a one-dimensional hydraulic model was created for the Upper Oyster River and a two-dimensional hydraulic model was created for the Lower Oyster River, both using HEC-RAS software which was developed by the US Army Corps of Engineers. For the Courtenay River system, flood modelling was derived from

the one-dimensional/two-dimensional model created for the 2013 Courtenay Integrated Flood Management Study using MIKE Flood software developed by the Danish Hydraulic Institute.

Two flood scenarios were simulated using the modelling software in order to account for the influence of the existing Glenmore Dike along the Oyster River:

1. A “no dike breach” scenario, in which the Glenmore Dike was not overtopped or breached and the Glenmore Road Embankment, which acts as a dike in lower flood events, was raised to prevent overtopping, even in the most extreme modelled flood event (0.2% AEP with 30% climate change flow increase) which resulted in confinement of flood flows within the river channel corridor;
2. A “dike breach” scenario, in which a hypothetical dike breach of the Glenmore Dike was simulated to model depth and extent of flooding across the floodplain protected by the dike. In this way, the flood hazards associated with a potential breach of the flood protection infrastructure could be better understood.

Analysis of these two scenarios ensures that the maximum flood levels are depicted on the floodplain maps and the consequence of flooding in the event of a dike breach can be determined. Figure 13 illustrates the river modelling process used in this project.

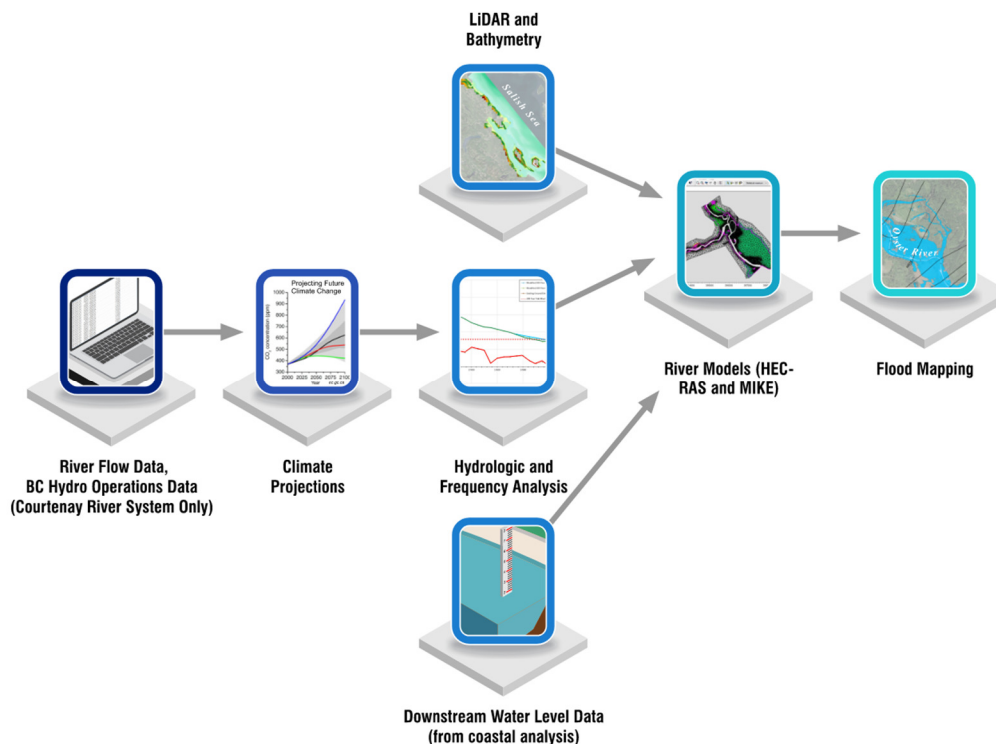


Figure 13: River Modelling Process

The design flood hydrology for the Oyster River modelling was based on flood frequency analysis of using annual extreme flow data recorded at the Oyster River below Woodhus Creek hydrometric station. Design peak flows of between 324 m³/s (10% AEP) and 444 m³/s (0.2% AEP) were used based on historic records between 1973 and 2017.



The design flood hydrology for the Courtenay River modelling was drawn from the regional flood frequency analyses carried out by KWL in 2013 as part of the Courtenay River Integrated Flood Management Study (KWL, 2013), including simulation of the influence of the BC Hydro operations at Comox Lake on peak flows.

Ocean water level boundary conditions for the Oyster River and Courtenay River system models were based on the results of the coastal water level analysis described in the following section. Ocean level and river flood discharges with matching probabilities of occurrence were combined for each design flood case (e.g., the 0.5% AEP river discharge is combined with the 0.5% AEP ocean water level). In order to calculate maximum flow velocities during design storm events, a dynamic ocean water level boundary condition across the full tidal range was simulated. Design peak flows of between 375 m³/s (10% AEP) and 553 m³/s (0.2% AEP) for the Tsolum River and 459 m³/s (10% AEP) and 716 m³/s (0.2% AEP) for the Puntledge River were derived from the data developed during the Courtenay River Integrated Flood Management Study (KWL, 2013).

Details on river flood modelling methods and assumptions are available in **Technical Memorandum #3A – Oyster River Hydrology and Model Assumptions** (Appendix C) and **Technical Memorandum #3B – Courtenay River Hydrology and Model Assumptions** (Appendix D).

Coastal Modelling

Modelling was used to estimate coastal flood levels for a series of sea level rise scenarios and storm events of different probabilities. Scenarios considered in the coastal modelling analysis ranged from 10% AEP to 0.2% AEP extreme ocean water levels and windstorm events along with sea levels ranging from current conditions to conditions with 0.5 m, 1 m, and 2 m of sea level rise. Figure 14 illustrates the coastal modelling process used in this project.

Coastal flood levels and setbacks were estimated using the “probabilistic method” from the provincial guidelines. The probabilistic method was used because there is sufficient data available to perform the analysis and it is generally considered to provide a less conservative (i.e., lower) coastal flood level than the alternative “combined method”. In the probabilistic method, the extreme static ocean water levels are determined through probabilistic analysis of tides and storm surge and are combined with allowances for wave effects, local land uplift or subsidence sea level rise, and freeboard to estimate the flood level and setbacks.

Extreme static ocean water levels, including tides and storm surge, were determined through analysis of historical water level data collected in the Strait of Georgia and CVRD area in particular.

Deep water wave conditions were estimated at a high resolution using the two-dimensional spectral wave model SWAN. The deep-water wave model uses a DEM of the bathymetry as a foundation for the analysis. Windstorm events from each cardinal direction were modelled using spatially and temporally varying wind fields generated from data collected during historical storm events. Wind speeds for each storm event were scaled to extreme values determined through analysis of data collected at Comox Airport.

Nearshore wave modelling was performed based on a one-dimensional “transect” based approach using custom software developed by KWL for high-resolution regional wave effect analysis (SHORLAX). The entire shoreline of the CVRD was divided into 233 transects, selected to be representative of the surrounding coastal “zone” in terms of both topography/bathymetry and wave exposure. The flood levels estimated at the transects were then converted into two-dimensional mapping based on the assumption that the flood level is constant within a given coastal zone. The transects and flooding extents were derived from the LiDAR topography.

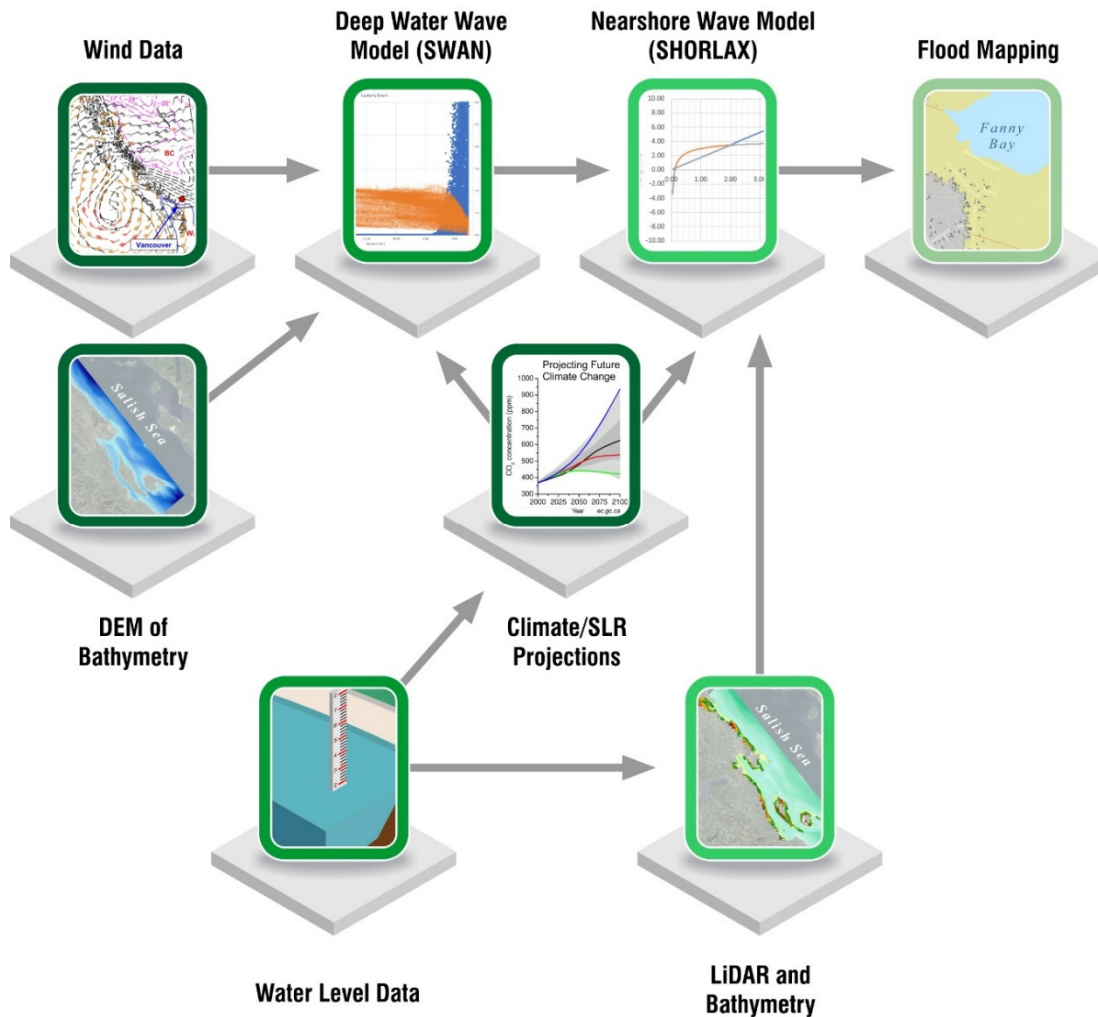


Figure 14: Coastal Modelling Process

More information on coastal modelling methods, assumptions, and results is available in **Technical Memorandum #4 – Coastal Modelling** (Appendix E).

Setbacks

Modelling and assessment results were used to inform the development of setbacks for the CVRD shoreline.

A setback refers to an offset distance of a building or landfill from the natural boundary or other reference line to maintain a floodway and to allow for potential land erosion. Setbacks were developed for the 0.5% AEP event with 1 m of sea level rise using the methods outlined in the provincial guidelines.

Further details on the methods used to determine setback locations are described in **Technical Memorandum #5 – Coastal and Fluvial Mapping Products** (Appendix F).

4.4 Mapping Products

A series of flood mapping products have been developed as part of the Coastal Flood Mapping Project to communicate flood hazards to a range of users including CVRD staff, elected officials, and the public.

The mapping products that were produced as part of this project include over 160 regulatory floodplain maps to 1:4000 scale and digital mapping including flood levels, water depths, velocities, hazard ratings, and wave heights. The mapping products are summarized in Table 3. These mapping products will serve as a platform for future flood management planning and decision-making by the CVRD.

Table 3: Digital Mapping Products

Product	Description
Base Mapping	Base mapping prepared for the project including the processed 2018/2019 GeoBC LiDAR, base mapping prepared for the modelling of the Oyster River, the bathymetric Digital Elevation Model (DEM) used for deep water wave modelling, cross sections through the shoreline at various locations (transects) used for the nearshore wave modelling, cross sections of the upper Oyster River collected during the bathymetric survey and the Oyster River Alluvial Fan boundary.
Regulatory Floodplain Maps	1:4000 scale regulatory floodplain maps that show flood inundation extents for a 0.5% AEP event with 1 m of sea level rise, 15% climate allowance for river flows, plus freeboard. These maps include floodplain limits, labelled flood level elevation contours for river flooding, and labelled coastal flood levels for each coastal zone along the entire shoreline.
Digital Mapping Data (GIS Data)	GIS mapping data has been packaged to allow the CVRD to perform custom mapping and facilitate assessment of hazards and risks as part of the flood management planning process. The digital GIS mapping data includes the following layers¹: • Base mapping; • Maximum water levels; • Maximum water depths; • Maximum flow velocity (river only); • Flood hazard rating (river only); • Maximum wave heights in the coastal floodplain (coastal only); • Year 2100 climate change planning areas (area between 0.5% AEP current conditions and 1 m SLR + 15% river flows, with freeboard) and Year 2200 climate change planning areas (area between 0.5% AEP 1 m SLR + 15% river flows and 2 m SLR + 30% river flows, with freeboard); and • Setbacks (0.5% AEP with 1 m SLR)
Notes: 1. Unless otherwise specified, Tables 1 and 2 provide the list of scenarios considered for each type of digital mapping.	

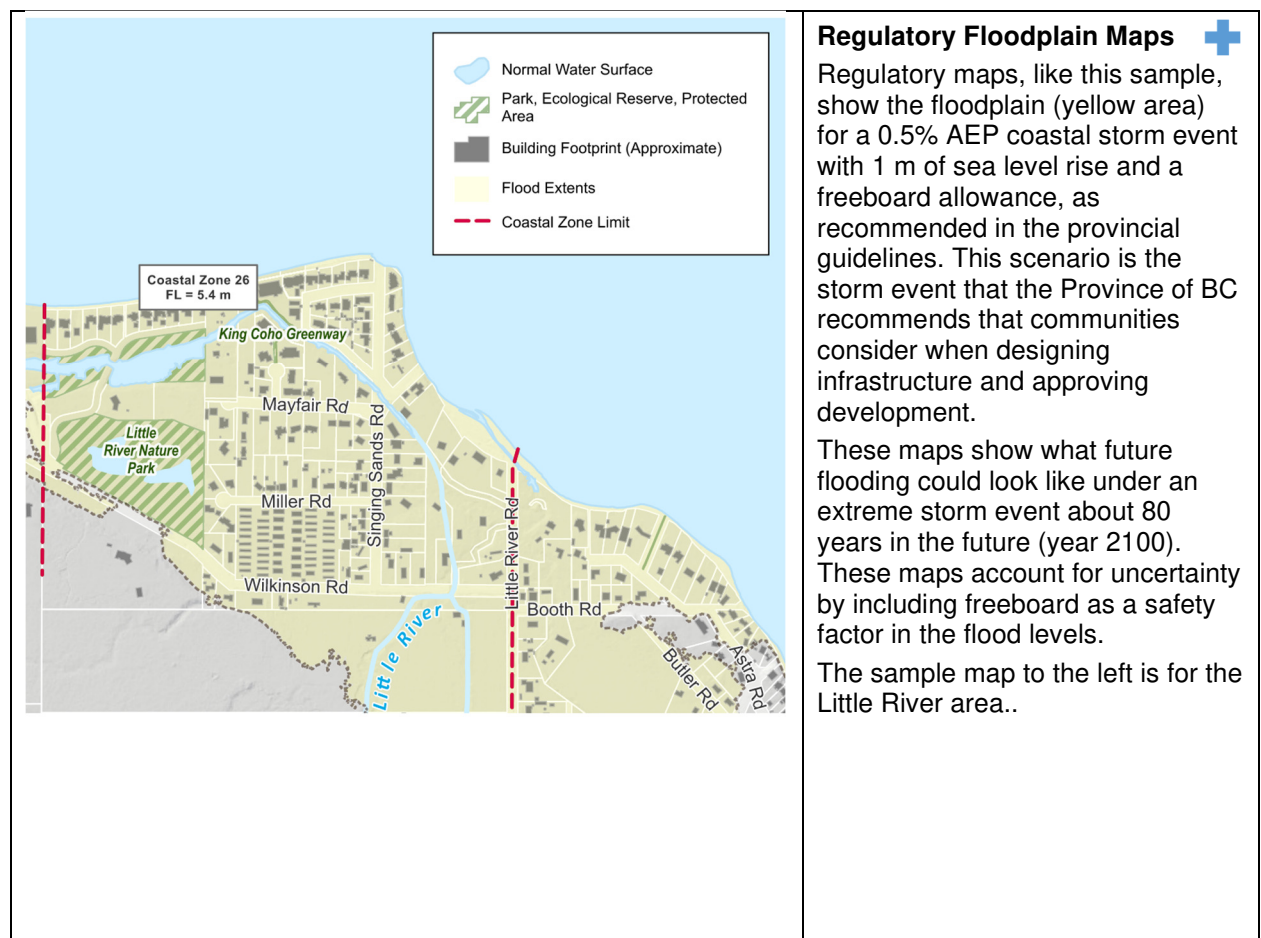
5. Flood Mapping Results

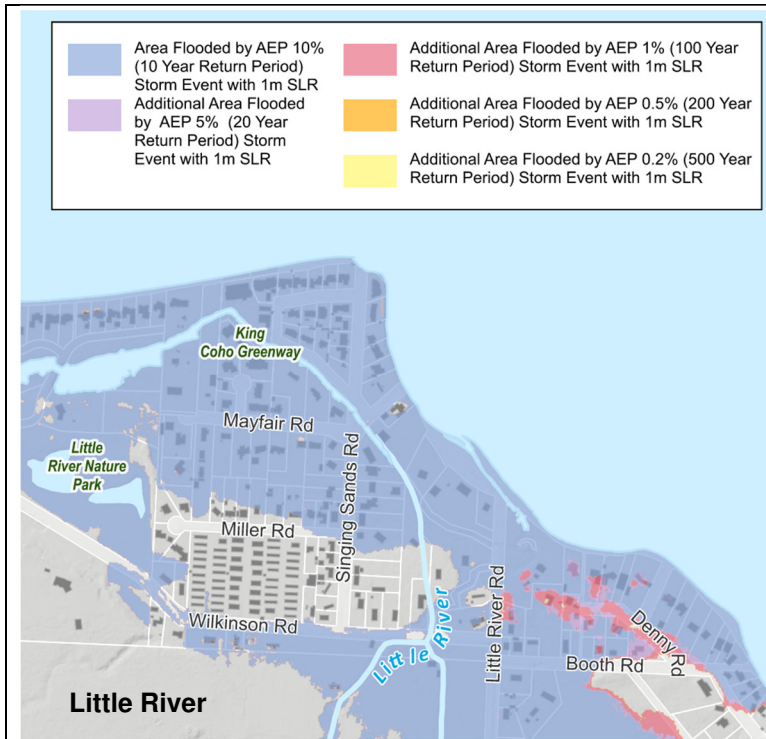
This section provides an overview of the flood maps developed as part of this project, along with an overview of key features included in the regulatory floodplain maps. This section also summarizes key findings about what flood hazards are expected to look like in the CVRD as a whole, and in four case study areas more specifically.

Mapping products reflect a combination of scenarios, with some maps including freeboard to account for uncertainty. Maps and mapping results that reflect scenarios with freeboard are indicated with a (+) icon.

5.1 Flood Map Samples

The project created an array of mapping products to communicate flood hazards broadly and support future flood management planning. Examples of the eight major mapping products listed in Table 3 are shown below to illustrate the range of mapping products created as part of this project and how they can be viewed.





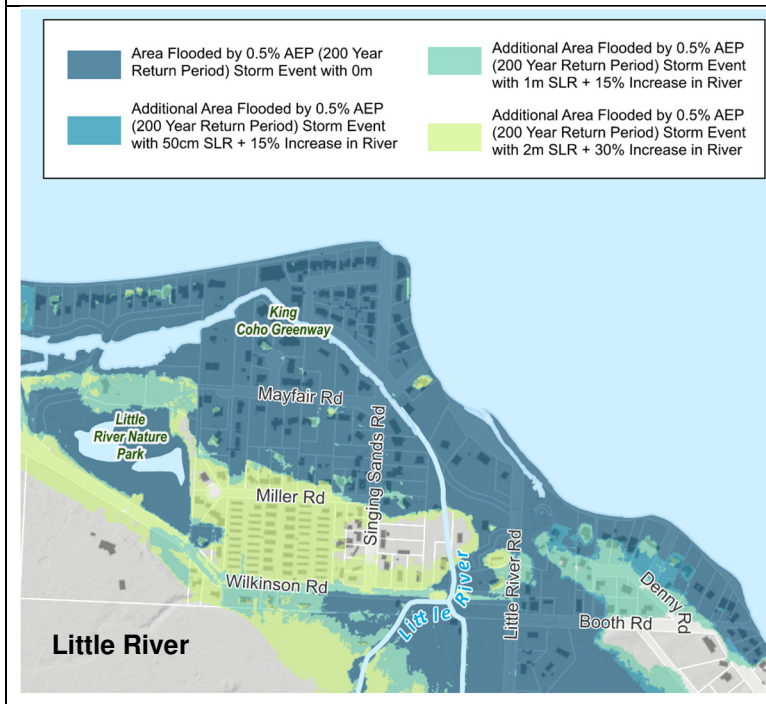
Digital Maps – Maximum Water Levels for Different AEP Storm Events

Coastal and river floodplain limits were mapped for a range of flood probabilities (AEP).

Less likely events (e.g., lower AEP %) correspond with a more severe storm event. For example, out of the five AEP scenarios mapped, a 0.2% AEP is the least likely but most severe.

This sample map shows flooding with extreme static water levels and windstorm (wave runup) with AEPs of 0.2%, 0.5%, 1%, 5%, 10% for 1 m of sea level rise (year 2100). No freeboard allowance is included.

The sample map to the left is for the Little River area.

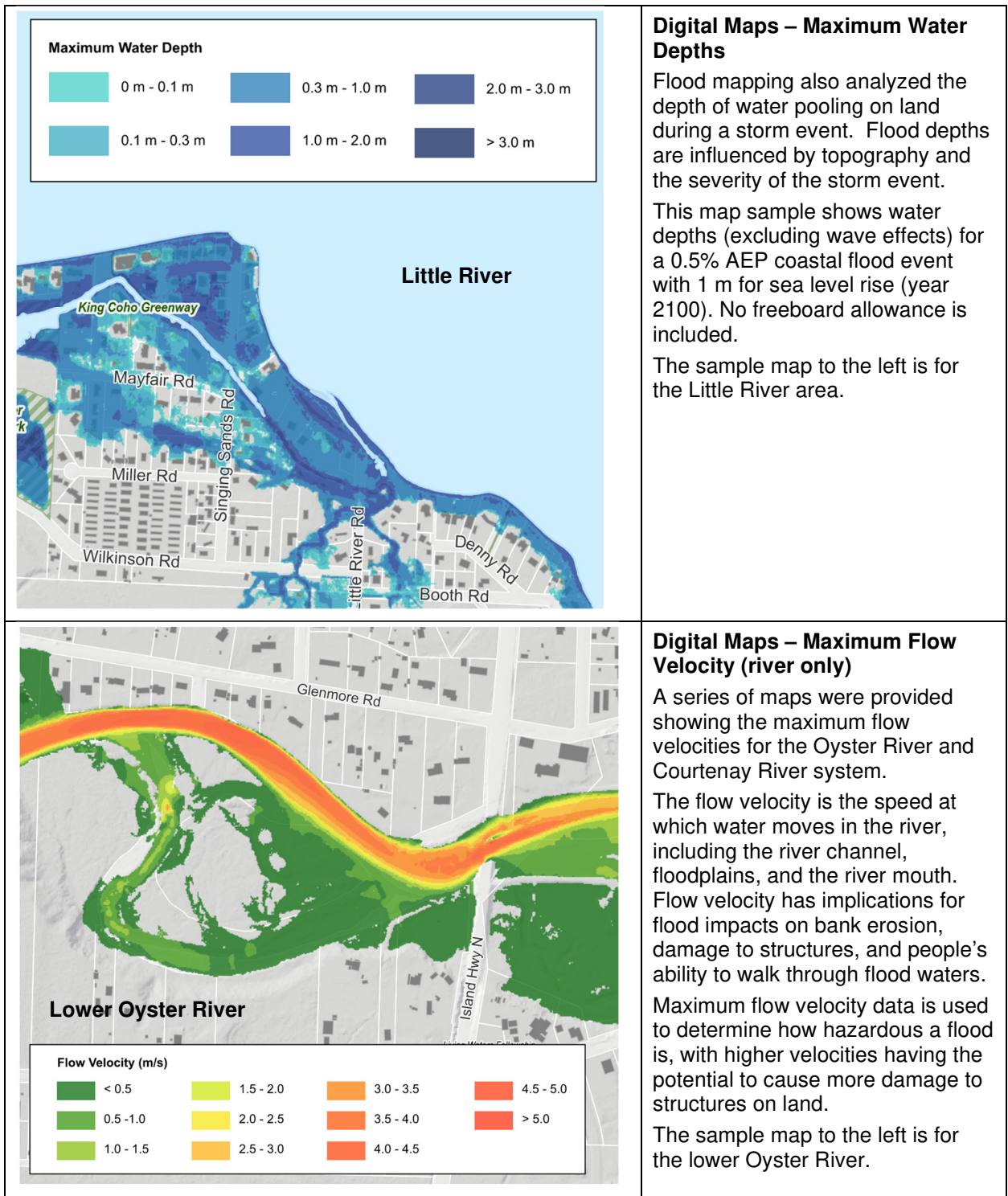


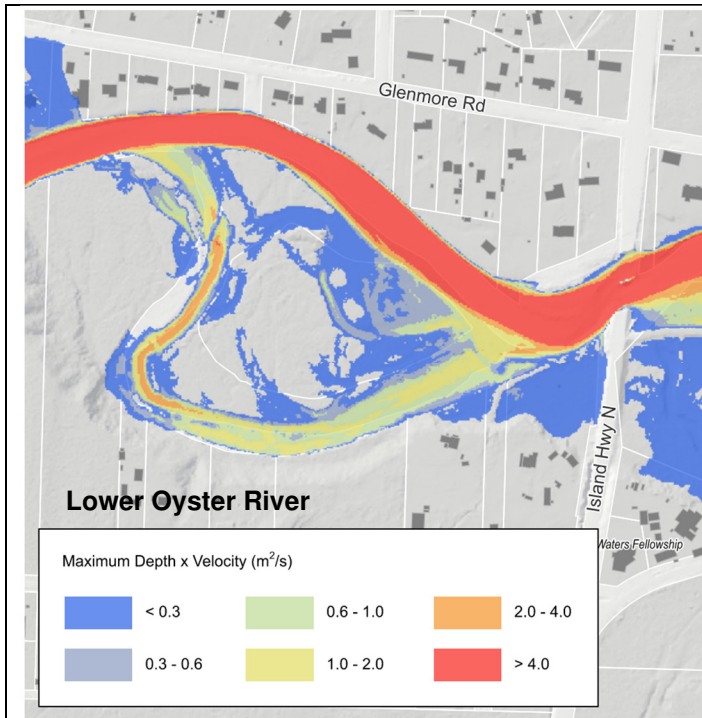
Digital Maps – Maximum Water Levels for Different Sea Level Rise Scenarios

Coastal and river flood levels were mapped for a range of sea level rise scenarios, including current day (0 m), year 2050 (0.5 m), year 2100 (1 m), and year 2200 (2 m) for extreme static water levels and windstorms with an AEP of 0.5%.

These maps tell a story of how flood hazards could become more severe in the future as sea levels rise over time). No freeboard allowance is included.

The sample map to the left is for the Little River area.



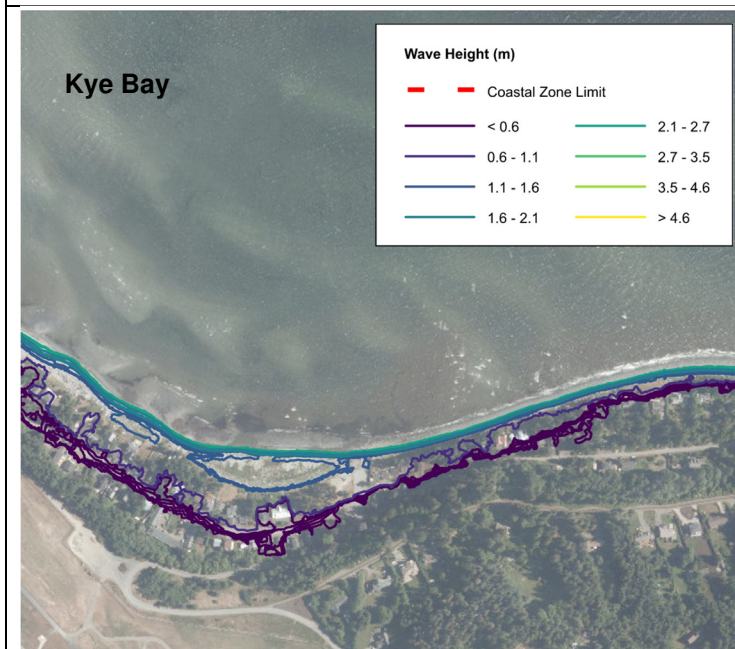


Digital Maps – Flood Hazard Rating (river only)

Flood hazard rating maps show how dangerous a flood could be to people and structures. Hazard ratings are based on how deep flood waters are and how fast the water is flowing (velocity) for a given location at a specific point in time.

Flood hazard ratings are important for understanding the possible consequences flooding could have on structures and communities. This information is a key input into flood risk assessments and future flood management planning.

The sample map to the left is for the lower Oyster River.



Digital Maps – Maximum Wave Heights (coastal only)

The digital mapping also includes wave heights in nearshore areas of the ocean (shoreward of normal high tide) as they propagate inland and run up against the shore. This information can be used in a risk assessment to assign variable levels of risk within the coastal floodplain based on wave height. The map sample shows wave heights in the coastal floodplain for a 0.5% AEP extreme static water level and windstorm with 1 m of sea level rise.

The sample map to the left is for Kye Bay.



Digital Maps – Climate Change Planning Areas +

Climate change planning areas are areas of land that would not be inundated during a major flood today but could be flooded if that same flood happened under future sea level rise and river flow conditions.

The maps include areas exposed to coastal flood hazards, diked areas, and inland floodplains that may be influenced by coastal and river water levels. A freeboard allowance is included.

These maps identify future flood hazard areas so the CVRD and property owners can start planning adaptation approaches.

The sample map to the left is for Ships Point.



Digital Maps – Setbacks

Setback maps show the area of land where development may be regulated in order to maintain a floodway and to allow for potential land erosion.

These maps provide guidance for development to ensure structures are not built in high-risk areas.

The sample map to the left is at Cape Lazo.

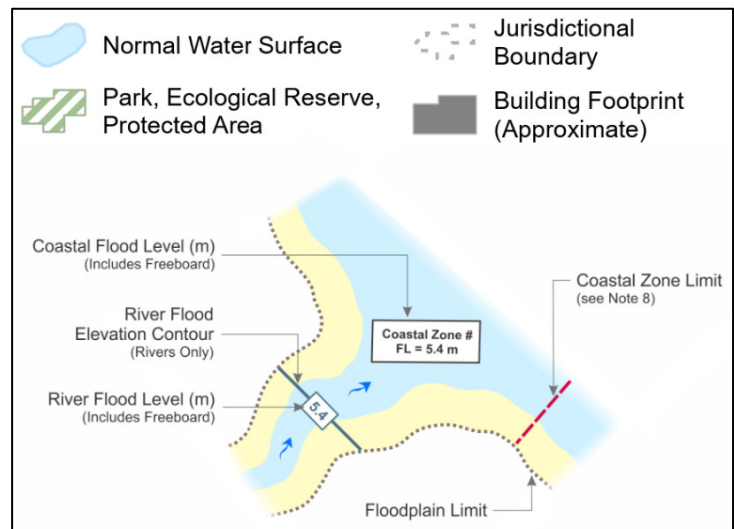
Further detail on each of the mapping products, including notes and limitations is provided in **Technical Memorandum #5 – Coastal and Fluvial Mapping Products** (Appendix F).

5.2 Regulatory Floodplain Mapping Features

The regulatory floodplain maps (first sample shown in Section 5.1, above) have been prepared in accordance with the provincial guidelines. The provincial guidelines are intended to help local governments develop and implement land-use management plans and make subdivision approval decisions for flood hazard areas. The goal is to reduce or prevent injury, human trauma, and loss of life, and to minimize property damage during flooding events. Experience has shown that regulating land development to keep people out of harm's way is the most practical and cost-effective way of achieving these goals.

The provincial guidelines recommend that local governments prepare regulatory floodplain maps that depict the river and coastal flood level for a 0.5% AEP storm event under future climate change conditions (year 2100). They also specify what information should be included in the flood mapping.

The regulatory floodplain maps prepared for this project have been designed to have a simplified appearance that conveys the necessary information as clearly as possible. A description of how to interpret key features of the mapping is outlined below.



Legend

The legend defines the different items shown on the maps. The key items are:

Normal Water Surface: depicts where water can typically be found. On the shoreline it is located at approximately 2 m above the mean water level.

Floodplain: the yellow shading shows the area on land that is inundated during the storm event.

Parks, Ecological Reserve, Protected Area: these areas are shown in a green striped hatch, along with labels for places of interest.

Building Footprints: these show the outlines of existing larger structures as a point of reference.

Floodplain Limit: this line delineates areas that are expected to be wet and dry during a flood.

River Flood Elevation Contour: these are lines of equal elevation in the water surface of the river relative approximately to mean sea level (CGVD2013 datum). The water surface of the river generally falls as it flows to the sea.

Coastal Flood Level: these labels provide the local elevation of the Floodplain Limit in each Coastal Zone (see next page) relative approximately to mean sea level (CGVD2013 datum).

Coastal Zone Limit: these red lines delineate the limits of the coastal zones, which are segments of the shoreline which have similar topography and wave exposure and therefore have similar wave effects. The Coastal Flood Level is constant within a Coastal Zone. Further information of Coastal Zones is provided in **Technical Memorandum #4 – Coastal Modelling and Technical Memorandum #5 – Coastal and Fluvial Mapping Products** (Appendix E and F).

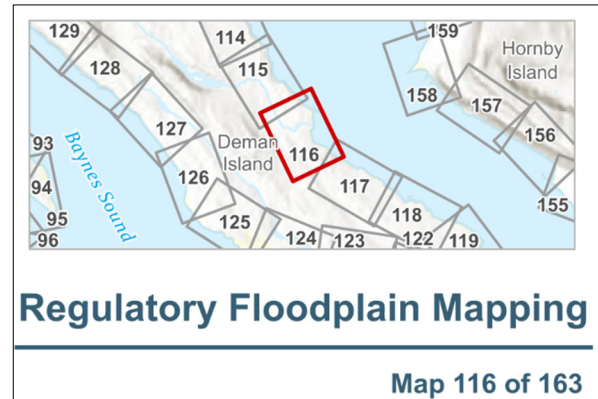
The maps also include a “hillshade” background that gives an idea of the local topography and road and parcel boundaries.

Key Plan: this feature on each map tells you what map you are looking at relative to adjacent maps to help you navigate between maps.

Notes and Limitations

The notes and limitations are the “fine print” on the regulatory maps that describe, in detail, how the regulatory mapping was produced, what information has been provided and what information could not be provided due to the limitations in the way the mapping was produced. Some of the key notes and limitations are:

1. Regulatory floodplain maps are administrative tools which depict the estimated flood levels and floodplain limits for a designated storm and flood events within the map area. Flooding may occur to levels above the estimated flood levels and outside the estimated floodplain limits. The local government does not assume any liability for the accuracy of the estimated flood levels and floodplain limits shown on this map. A site-specific analysis should be conducted to assess the potential for flooding in areas outside/near the mapped floodplain limits.
2. The flood levels and floodplain limits depicted on the maps have been developed using a methodology which is consistent with the BC Flood Hazard Area Land Use Management Guides (FLNR, 2018 – the “provincial guidelines”) for the development of flood construction levels, the Federal Flood Mapping Framework (NRC, 2018) including relevant guidelines, the Engineers and Geoscientists BC Flood Mapping Guidelines (EGBC, 2017) and the Fraser Basin Council Floodplain Mapping Guidelines and Specifications (FBC, 2004).
3. The flood levels and floodplain limits correspond to the peak calculated values of the flood event and may not be contemporaneous across the mapping (i.e., maximum flood levels may occur in different areas at different times).
4. River flood levels are calculated using industry standard hydraulic modelling practices/software assuming open water flow conditions. The river flooding events depicted on the maps have a statistical annual exceedance probability of 0.5% (the flood which is estimated to be equalled or exceeded on average once every 200 years) and occur at an ocean still water level with an annual exceedance probability of 0.5%. River flows have been increased by 15% over current (2020) extreme values to account for projected climate change impacts and ocean extreme static water





levels have been increased by 1.0 m over current extreme values to account for the effects of sea level rise. River flood levels and floodplain limits include a freeboard allowance of 0.6 m.

5. The accuracy of the location of the floodplain limit as shown on the maps is limited by the accuracy of the base topography and the scale at which the maps are produced. The floodplain limits are not established on the ground by legal survey. Existing ground elevations, building and floodproofing elevations should be based on field survey using established benchmarks. The legal boundaries shown on this map are based on cadastral information and are for illustration only. A site-specific legal survey is required to reconcile property locations.
6. The flood maps do not provide information on the potential for site-specific flood-related hazards such as bank erosion, aggradation, debris accumulation or sudden shifts in river channel alignment. The maps do not include all possible flood hazards which may include localized increases in flood levels due to groundwater, tributary streams, storm sewer systems or other phenomena and must be considered together with complementary studies including but not limited to Master Drainage Plans. Flood levels and floodplain limits are not delineated for side streams or tributaries. Flood levels and floodplain limits due to tsunami are not depicted on the maps.

Users should note the dates of base mapping and ground and bathymetric surveys as well as the date of map publication. Subsequent developments or geomorphic changes may render map information obsolete.

Refer to **Technical Memorandum #1 – Coastal and River Base Map Development** (Appendix A) for further information on the base mapping used for this project including dates of collection.



5.3 Region-wide Summary

The Coastal Flood Mapping Project provides important information to build an understanding of what flood hazards look like in the CVRD under current conditions today and with future climate change. Findings show there are key areas in the CVRD that are already exposed to flooding today and are expected to become more exposed as sea levels rise.

This information provides a foundation for the next phase of work to understand the consequence this flooding could have on communities, including impacts to homes, infrastructure, cultural and recreational spaces, and natural habitats. Understanding flood risk and consequences is an important next step for setting priorities for where and how to adapt and build resilience.

This section provides a high-level overview of some of the key findings from the mapping about coastal and river flood hazards across the region. The majority of the findings that are presented do not include freeboard, since freeboard was only added to 0.5% AEP events for use in the regulatory floodplain maps and determining climate change planning areas (as per the provincial guidelines). Findings that include freeboard are marked with an (+) icon and show flood results that are more extreme to account for flood level uncertainty.

Disclaimers for Interpreting the Flood Mapping

It is important to note that flood mapping shows what flooding could look like **without any change or adaptation**. Furthermore, many of the flood scenarios mapped represent extreme flooding events that have a **very low likelihood of occurring** in a given year.

Climate change scenarios show what these extreme events could look like **80 years in the future (year 2100)**. Looking this far into the future will allow the CVRD and property owners to begin planning to manage future flooding in a proactive way.

Coastal Flood Hazard Findings

Coastal flood hazard varies widely across the region. A large portion of the CVRD shoreline is characterized by steep bluffs that protect against coastal flooding. However, there are a number of developed and agricultural lands in low-lying coastal areas that are exposed to flooding today.

Some of the developed areas in the CVRD that are vulnerable to flooding include Little River, Ships Point, Goose Spit, City of Courtenay (near the Courtenay River mouth), areas near the Oyster River mouth (e.g., Saratoga Beach), K'ómoks First Nation, and Whaling Station Bay. Agricultural land in coastal areas is also exposed to impacts from coastal flooding, with the potential for salt water to impact crop yields, drainage, and infrastructure. Some of the agricultural areas that may be exposed to coastal flooding include the Queen's Ditch area, and farms near the mouth of the Oyster River and Courtenay River.

As sea levels rise, flood waters are expected to reach higher elevations and further inland, causing more land to be inundated. Flood hazard findings described in this section have been summarized according to the area of land expected to be inundated, climate change planning areas, and maximum water levels along the shore.

Key findings from coastal flood mapping are summarized here and described in more detail in the following sub-sections.



- **Coastal flooding is expected to inundate only a small portion of land in the CVRD overall.** An extreme 0.5% AEP coastal storm event is expected to inundate over 1,900 ha (1.1%) of land in the CVRD under current conditions and over 2,200 ha (1.3%) of land with 1 m of sea level rise (year 2100).
- **There are a number of communities and agricultural areas in low-lying coastal areas that have been developed and are exposed to coastal flooding from an extreme storm surge under current and future conditions.** In particular, flooding under a 0.5% AEP coastal storm event under current conditions could inundate a significant portion of lands in Electoral Area B and K'ómoks First Nation reserve lands (IR#1, IR#2 and IR#3).
- + **Sea level rise is expected to increase flood extents and the total area of land inundated across the CVRD; however, this increase is expected to be modest relative to the significant flooding expected in low-lying areas under current conditions.** "Climate Change Planning Areas" have been developed based on regulatory flood mapping results and represent the additional area of land that would be inundated in the CVRD during a 0.5% AEP storm event with 1 m and 2 m of sea level rise and 15% and 30% increases in river flows.
- **Maximum water levels are expected to rise under future climate change scenarios, with levels from a 0.5% AEP today being similar to those expected from a 10% AEP coastal storm event with 0.5 m of sea level rise in the future.** This means that, as sea levels rise, smaller storm events will cause more severe flooding reaching higher elevations and further inland.

5.3.1 Total Area of Land Inundated

Maximum water level maps show the total area of land that is expected to be flooded to some degree during the event. The flooded areas presented in this section do not include freeboard and therefore the flooding is more moderate than that shown in the regulatory floodplain maps. The flooded areas also do not consider water depth, which means that some areas that are recorded as flooded could experience very shallow water depths on land compared with others.

Mapping and analysis completed as part of this project suggests that over 1,900 ha, or 1.1% of land across the CVRD, would be inundated during an extreme 0.5% AEP coastal storm event under current conditions (0 m SLR). This increases to over 2,200 ha (1.3% total area) if the same magnitude storm event occurred with 1 m of sea level rise (approximately year 2100), and to over 2,600 ha (1.6%) with 2 m of sea level rise (approximately year 2200). While the lands flooded during these storm events represent a relatively small portion of land in the CVRD, there are a number of developed areas that fall within these floodplains that could be impacted.

A summary of the total area of land inundated under these three scenarios for each local government/ electoral area in the CVRD is shown in Table 4. Of the CVRD Electoral Areas, Electoral Area B is expected to experience the largest total area of land inundated under all three scenarios with the inundated area, accounting for around 10% of land within that sub-region. In comparison, Electoral Areas A (Vancouver Island) and C are expected to have the second and third largest total area inundated (respectively), however this flooding will affect a much smaller proportion of their total land areas. It is expected that flooding on K'ómoks First Nation IR#1 and IR#2 reserve lands could cover over 49% of the combined reserve area.



Table 4: Total Inundated Land Area by Local Government/Electoral Area in the CVRD, (no freeboard)

	Total Area Inundated during a 0.5% AEP event ¹					
	Current Conditions (0 m SLR)		Year 2100 (1 m SLR)		Year 2200 (2 m SLR)	
Local Government/Electoral Area	ha	% of sub-region	ha	% of sub-region	ha	% of sub-region
City of Courtenay	252	8%	277	8%	309	9%
Town of Comox	94	5%	103	5%	119	6%
K'ómoks First Nation (IR#1 & IR#2)	61	41%	68	46%	73	49%
Electoral Area A – Vancouver Island ²	360	1%	473	1%	586	1%
Electoral Area A – Denman/Hornby Islands ²	260	3%	333	4%	414	5%
Electoral Area B – Lazo North	553	10%	594	11%	680	13%
Electoral Area C – Puntledge Black Creek	363	0%	441	0%	503	0%
All Areas	1,944	1.1%	2,289	1.3%	2,684	1.6%
Notes: 1. All "Total Area Inundated" scenarios calculated with the 0.5% AEP (200 Year Return Period) storm event without freeboard. 2. Electoral Area A (Baynes Sound - Denman/Hornby Islands) is broken up into two components for improved resolution.						

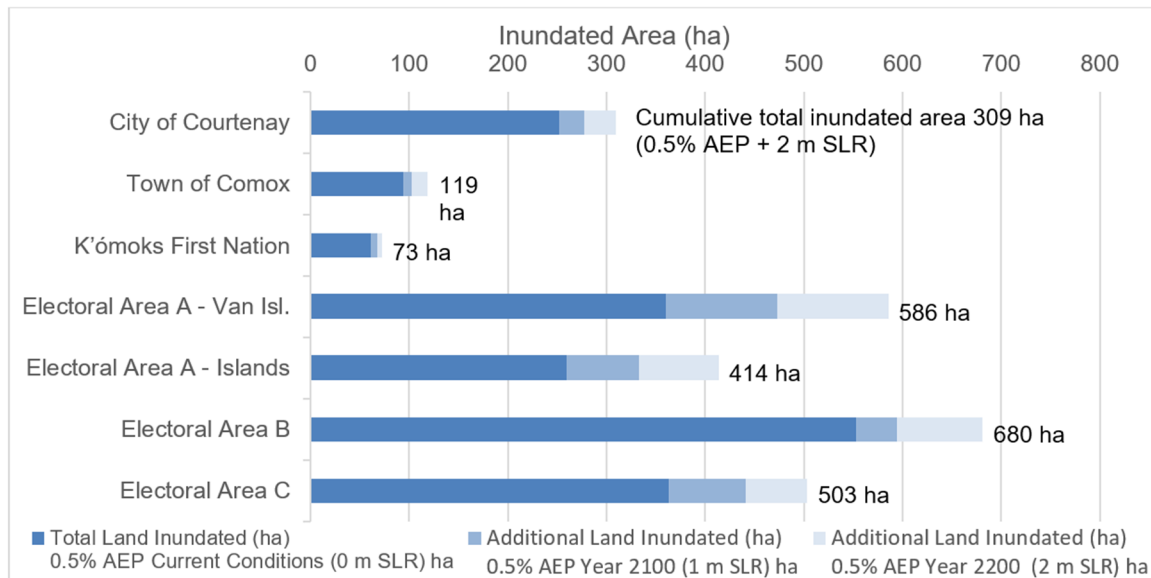


Figure 15: Cumulative Total Area Inundated (0.5% AEP storm event for 0 m, 1 m, 2 m SLR)

Figure 15 shows a cumulative total of land inundated under a 0.5% AEP storm event with 0 m, 1 m, and 2 m of sea level rise. The graph shows that a significant proportion of flooding is expected if this extreme event were to happen under current conditions, with sea level rise adding a relatively moderate increase in additional area of land flooded in most areas. This finding is largely due to the fact that the shoreline of the CVRD largely consists of lower-lying benches backed by steeper bluffs. The lower-lying benches are vulnerable to flooding in an extreme storm event under current conditions, and the incremental increase in flood levels due to sea level rise does not inundate a substantially larger land area because the topography is steeper (on average) in areas flooded by sea level rise.

+ 5.3.2 Climate Change Planning Areas

Climate change planning areas are areas of land that would not be inundated during a major flood today but could be flooded if that same flood happened under future climate conditions considering sea level rise and increases in river flows. For the Coastal Flood Mapping Project, planning areas have been calculated for a 0.5% AEP storm events with a freeboard allowance. Freeboard has been included in these areas to align with the CVRD regulatory floodplain maps, which also include freeboard. This is different from the total inundation areas shown in Table 4 above, which do not include freeboard. More information and a sample climate change planning area map is provided in Section 5.1.

The climate change planning area for the year 2100 is 276 ha, meaning this is the total area of additional land that would be flooded during a 0.5% AEP storm event if it happened 80 years in the future (year 2100) compared with current conditions. The climate change planning area for the year 2200 is 343 ha, which is the *additional* area of land inundated relative to the year 2100 climate change planning area. In these areas, the CVRD and property owners may want to consider flood management strategies to account for increasing flood hazards under future climate conditions.



Table 5: Climate Change Planning Areas, with Freeboard

Local Government/Electoral Area	Climate Change Planning Areas ¹ (ha) <i>additional total area of land inundated</i>	
	Year 2100	Year 2200
City of Courtenay	28	16
Town of Comox	7	13
K'ómoks First Nation	2	1
Electoral Area A – Vancouver Island ²	93	103
Electoral Area A – Denman/Hornby Islands ²	75	80
Electoral Area B – Lazo North	20	82
Electoral Area C – Puntledge Black Creek	52	48
All Areas	276	343
Notes: 1. Both climate change planning area scenarios are calculated with the 0.5% AEP (200 Year Return Period) storm event with freeboard added. 2. Electoral Area A (Baynes Sound - Denman/Hornby Islands) is broken up into two components for improved resolution.		

5.3.3 Maximum Water Levels

As sea levels rise, smaller storm events can cause more severe flooding that reaches higher elevations and further inland. Maximum water levels refer to the total elevation that water is expected to reach during a storm event that occurs at a high ocean water level and with wind-generated waves (refer to Figure 8). **It is important to note that higher maximum water levels do not necessarily mean more flood inundation.** In many cases, areas with steep bluffs have higher maximum water levels due to wave effects that are larger than they are for areas where waves break along more gradual slopes (e.g., a beach). However, the area of land inundated by flooding is generally lower in areas with steeper shorelines relative to areas with flatter, low-lying shorelines.

Average maximum water levels for a range of AEP and sea level rise scenarios for each area in the CVRD are provided in Table 6; no freeboard allowance is included. The maximum water levels are averages weighted by length of shoreline and are useful for comparing maximum water levels in different areas at a high level and determining broad trends in changes in maximum water level with increasing storm severity and with sea level rise. One interesting finding is that the maximum water levels associated with a 10% AEP coastal storm event in the year 2050 (0.5 m SLR) is similar to the levels expected from a much rarer 0.5% AEP event under current conditions (0 m SLR); these scenarios are highlighted (orange) in Table 6.

Table 6: Coastal Maximum Water Levels (Weighted Average¹) for the CVRD (no freeboard)

AEP Scenario	SLR Scenario	Local Government/Electoral Area						
		City of Courtenay	Town of Comox	K'ómoks First Nation	Electoral Area A - Vancouver Island ²	Electoral Area A – Denman and Hornby ²	Electoral Area B	Electoral Area C
10% (10 Year)	0 m	3.7	4.7	4.0	3.7	5.7	4.7	4.5
	0.5 m	4.2	5.3	4.3	4.1	6.4	5.3	5.1
	1 m	4.6	6.0	4.7	4.5	7.1	5.9	5.8
	2 m	5.6	7.3	5.3	5.6	8.2	7.2	6.8
5% (20 Year)	0 m	3.8	4.8	4.0	3.7	6.0	4.9	4.7
	0.5 m	4.2	5.5	4.4	4.2	6.7	5.4	5.3
	1 m	4.7	6.2	4.8	4.6	7.5	6.1	5.9
	2 m	5.6	7.5	5.3	5.7	8.5	7.3	7.2
1% (100 Year)	0 m	4.0	5.1	4.2	4.0	6.7	5.1	4.9
	0.5 m	4.4	5.8	4.6	4.4	7.5	5.8	5.6
	1 m	4.9	6.5	4.9	4.8	8.1	6.4	6.2
	2 m	5.7	8.0	5.5	5.9	9.3	7.7	7.5
0.5% (200 Year)	0 m	4.1	5.2	4.3	4.0	7.1	5.2	5.0
	0.5 m	4.5	5.9	4.7	4.5	7.8	5.8	5.8
	1 m	5.0	6.6	5.0	4.9	8.4	6.5	6.3
	2 m	5.7	8.1	5.5	6.0	9.5	7.7	7.6
0.2% (500 Year)	0 m	4.2	5.4	4.3	4.1	7.6	5.3	5.2
	0.5 m	4.6	6.1	4.8	4.6	8.3	6.0	5.8
	1 m	5.1	6.7	5.1	5.1	9.0	6.6	6.4
	2 m	5.8	8.4	5.6	6.3	10.1	7.9	7.7

Notes:

1. Maximum water level values weighted by representative length of shoreline, without freeboard allowance to CGVD2013 datum. The table should not be used for land use planning or engineering analysis due to the averaging of maximum water levels over large stretches of shoreline.
2. Electoral Area A (Baynes Sound – Denman/Hornby Islands) is broken up into two components for improved maximum water level representation.

River Flood Hazard Findings

Areas in the CVRD that are particularly exposed to combined river and coastal water level effects include communities close to the mouths of the Oyster River, Courtenay River, Trent River, Tsable River, Glen Urquhart Creek/Courtenay Flats Area, and the Queens Ditch area. These areas are labelled on the map in Figure 2.

Key project findings from the river analysis and mapping are summarized in the sections below for the Oyster River and Courtenay River system.

5.3.4 Oyster River

Flood modelling along the Oyster River considered all five AEP river storm events, with a range of coastal water levels and current and climate change conditions. The analysis also considered the

influence of the existing dike (Glenmore Dike) along on the north bank of the river (in the SRD) could have on flooding, including a “no breach” scenario where the dike remains intact during the event, and a “dike breach” scenario to consider what might happen if a portion of the dike were to fail. The influence of a coastal storm surge event on properties at the mouth of the Oyster River was considered as part of the “Coastal Flood Hazard Findings” section; this section focuses on the portion of the river upstream of the Highway 19A Oyster River Bridge.

Key findings from this analysis of flood hazards upstream of the Highway 19A Oyster River Bridge are highlighted below.

Oyster River Flood Mapping Highlights

- +** **Low-lying properties within the confined river valley in the upper reaches of the river are exposed to flooding from a 0.5% AEP river storm event under current and future climate change conditions.** However, properties on the plateau above the valley are above flood levels from even the most extreme storm events considered as part of this project (0.2% AEP). In comparison, the same storm events without freeboard cause significantly less flooding in low-lying areas.
- +** **Land on the southern side of the river in the lower portion of the river has low exposure, with model results indicating limited inundation of buildings even under an extreme (0.2% AEP) flood with climate change allowance given that most buildings there are location on top of a higher bank.**
- +** **The Oyster River Community (in the Strathcona Regional District) is protected by the Glenmore Dike and the Glenmore Road Embankment.** The modelling indicates that the crest of the Glenmore Dike is high enough to protect properties north of the dike up to a 0.2% AEP river storm event with a 30% climate change allowance. The Glenmore Road Embankment has a lot that would be overtopped in the 0.5% AEP river storm event with a 15% climate change allowance.
- +** **Although the dike (and the Glenmore Road Embankment) provides a level of protection from flooding, the Oyster River Community is still exposed to flooding in the event of a dike breach during a storm event.** Modelling results simulating a dike breach at the upstream end of the Glenmore Dike indicate that the 0.5% AEP and 0.2% AEP storm events would cause extensive flooding across the community north of Glenmore Road.
- +** **For the non dike breach scenarios, different AEP storm events result in minimal change to flood extents in the downstream section of the Oyster River near the mouth.** The channel is well confined on both the north and south banks, with some flow into old flood channels. Climate change, including increased streamflow and sea level rise is expected to increase the flood extents, depth, and velocity in the land north of Glenmore Road during a breach scenario. Furthermore, some of this area is exposed to impacts from coastal storm events, as described in the Oyster River mapping case study (Section 5.4).

5.3.5 Courtenay River System

Flood modelling of the Courtenay River system considered all five AEP storm events, with a range of coastal water levels and current and climate change conditions. A scenario including future flood protection was included in the flood modelling (0.5% AEP scenario with 1 m of SLR). The flood protection configuration used for the analysis included flood protection at key locations along Highway 19A and a proposed ring dike in the Old Tsolum Channel area. The flood modelling for the Coastal



Flood Mapping Project built on mapping and modelling completed as part of the Courtenay River Integrated Flood Management Study (KWL, 2013).

Key findings from the analysis of flood hazards for the Courtenay River system are as follows:

- **Flooding extents and water depths on the lower section of the Courtenay River floodplain, southeast of Highway 19A, are mostly influenced by coastal water levels.** Most of this area is primarily agricultural fields. Other areas vulnerable to flooding include Lewis Park and the low-lying area surrounding the confluence of the Tsolum River, Puntledge River, and the Old Tsolum Channel.
- **High water velocities were observed in the river channel, especially at locations like road crossings and river bends.** Near the harbour, the river channel also has high velocities generated during low tide conditions. On the floodplain, velocities are mostly low except for areas around locations where roads overtop during extreme events.
- **Most areas on the floodplain have a hazard rating between 0.6 to 4 m²/s**, which (for 1 m water depth) include three different categories (0.6 – 1.0 m²/s: unsafe for people and vehicles, 1.0 – 4.0 m²/s: unsafe for vehicles and people with all buildings vulnerable to structural damage, and above 4.0 m²/s: unsafe for vehicles and people with all buildings vulnerable to failure). For a sample of a flood hazard rating map, refer to Section 5.1.

5.4 Flood Map Case Studies

The flood maps in the following section show what flooding could look like in key areas during different AEP storm events under current and future conditions. Note that the map excerpts shown in this section **are not regulatory maps, as they do not include a freeboard allowance.**

Maps have been shown for four case study areas within the CVRD to highlight some of the most important findings from the Coastal Flood Mapping Project. Case study communities described in this section include:

- Little River area (coastal flooding);
- Ships Point area (coastal flooding);
- Goose Spit (coastal flooding); and,
- Oyster River mouth and upstream of bridge (river flooding).

These case study locations were selected because they represent important, low-lying community areas with diverse landscapes that face flood hazards under current and future climate change conditions. The maps shown in the following sections represent only a small sample of the hundreds of maps and spatial data generated as part of this project.



Disclaimer for Interpreting these Flood Maps

It is important to reiterate that these flood maps show what flooding could look like **without any change or adaptation**. These maps show flooding under a range of scenarios, including a **higher-likelihood** 10% AEP high ocean water level event (stillwater flooding, no waves), a **lower-likelihood scenario** 10% AEP high ocean water level event *with* waves from a 10% windstorm event, and a **very rare** 0.5% AEP high ocean water level event *with* waves from a rare 0.5% AEP windstorm event). These three scenarios are shown for current sea levels today and 80 years in the future (year 2100) when sea levels are expected to rise by 1 m. Looking this far into the future can help the CVRD and property owners begin planning to manage future flooding in a proactive way.

Little River

The Little River area is located near the Town of Comox in Electoral Area B at the mouth of the Little River, just west of the BC Ferries Terminal. Land use in the area is primarily single family residential. Much of the area was constructed on the alluvial fan⁴ of the river and is low lying and relatively flat. As a result, a significant portion of the Little River area is already vulnerable to shallow flooding during a higher-likelihood storm surge event (10% AEP) with current sea levels.

Figure 17 **Error! Reference source not found.** shows what flooding could look like in the Little River area during different storm events under current sea levels and with 1 m of sea level rise (80 years in the future: year 2100). Each of the maps show flooding expected during a **higher-likelihood high ocean water level event** ("10% AEP without waves"), a **lower-likelihood 10% AEP high ocean water level event with a 10% windstorm event and associated wave effects** ("10% AEP with waves"), and a **very rare 0.5% AEP high ocean water level event with a 0.5% windstorm event and associated wave effects** ("0.5% AEP with waves").

The maps show that Little River area is already vulnerable to flooding at current sea levels, particularly due to wind-generated waves. While a 10% AEP high ocean water level event at current sea levels is expected to cause only a small degree of flooding confined to some backyards in waterfront areas, if a 10% AEP windstorm were to occur at the same time causing waves, flood extents are expected to reach across a large portion of the community. This is because in some areas, stillwater flood levels reach just to the bank during the 10% AEP storm surge event and spill over the bank with wave effects.

With 1 m of sea level rise 80 years in the future, a 10% AEP high ocean water level event (without waves) could cause stillwater flooding to waterfront areas that had been exposed to only shallow flooding under current sea levels. This is expected to cause flooding up to 1 to 2 m depths across residential properties, primary access roadways, and the BC Ferries Terminal. Adding wind and waves to this scenario would cause shallow flooding of an area only slightly larger than that expected during a 10% AEP coastal storm event (with waves) at current sea levels. That said, in all flood scenarios shown here there is a large portion of the area that remains above the flood extents for the current and future high ocean water level and windstorm events.

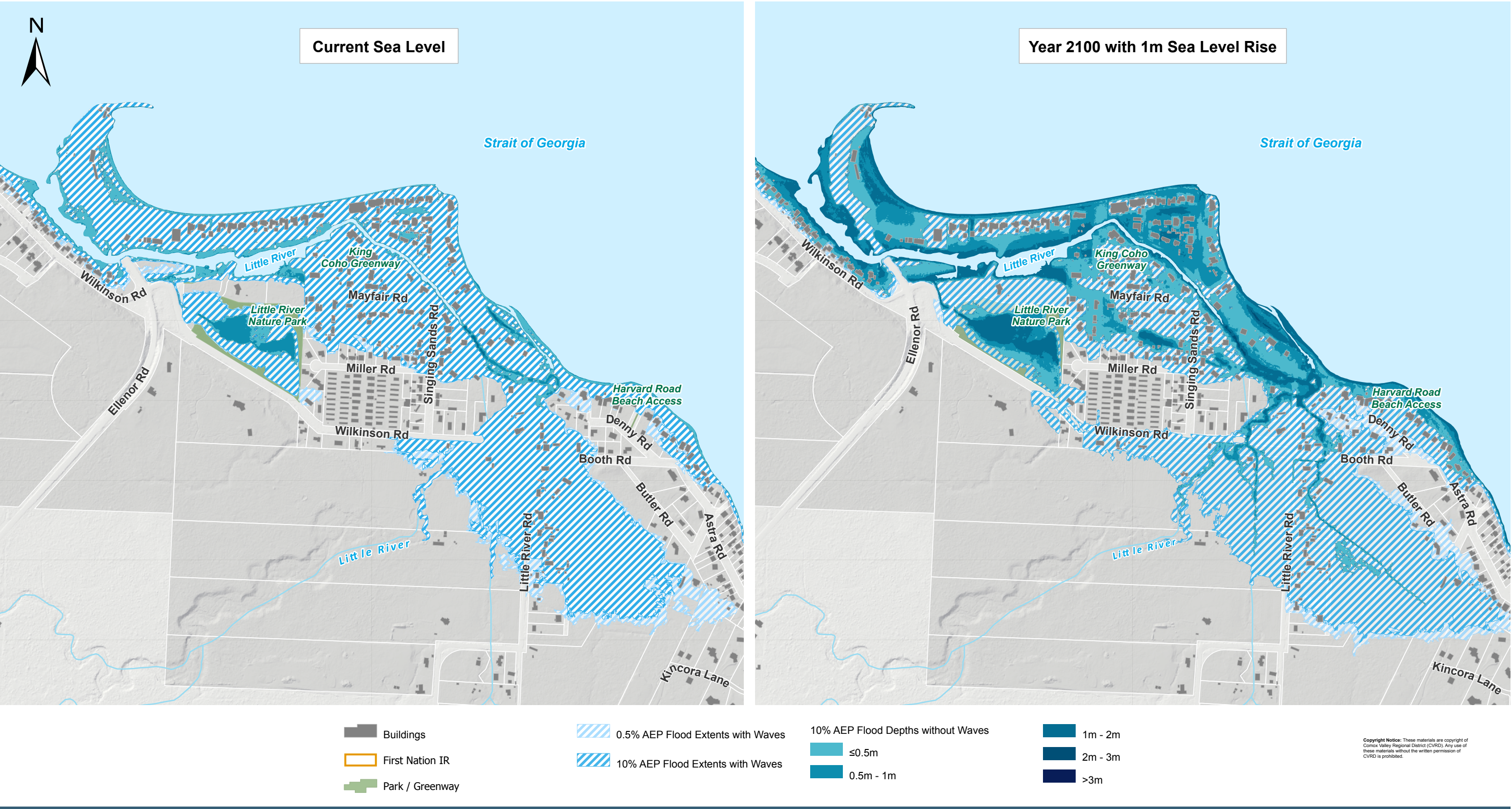
In both current and future sea level scenarios, a rare 0.5% AEP coastal storm event with waves is expected to cause only a small incremental increase in the shallow flooding expected to occur under a 10% AEP event with waves. Together, these findings suggest that the Little River area is already

⁴ Alluvial fans are composed of sediments that were carried there by the river and deposited as the velocities in the river decrease at its' mouth. Alluvial fans, by their nature, tend to be flat, low elevation features which makes them exposed to flooding, particularly as sea levels rise.

exposed to shallow flooding today if a high ocean water level event is accompanied by wind-generated waves. Sea level rise is expected to cause deeper flooding in areas already exposed to flooding from storms under current sea levels, but only cause a marginal increase in the total area of land that gets wet.



Figure 16: Little River Area





Ships Point

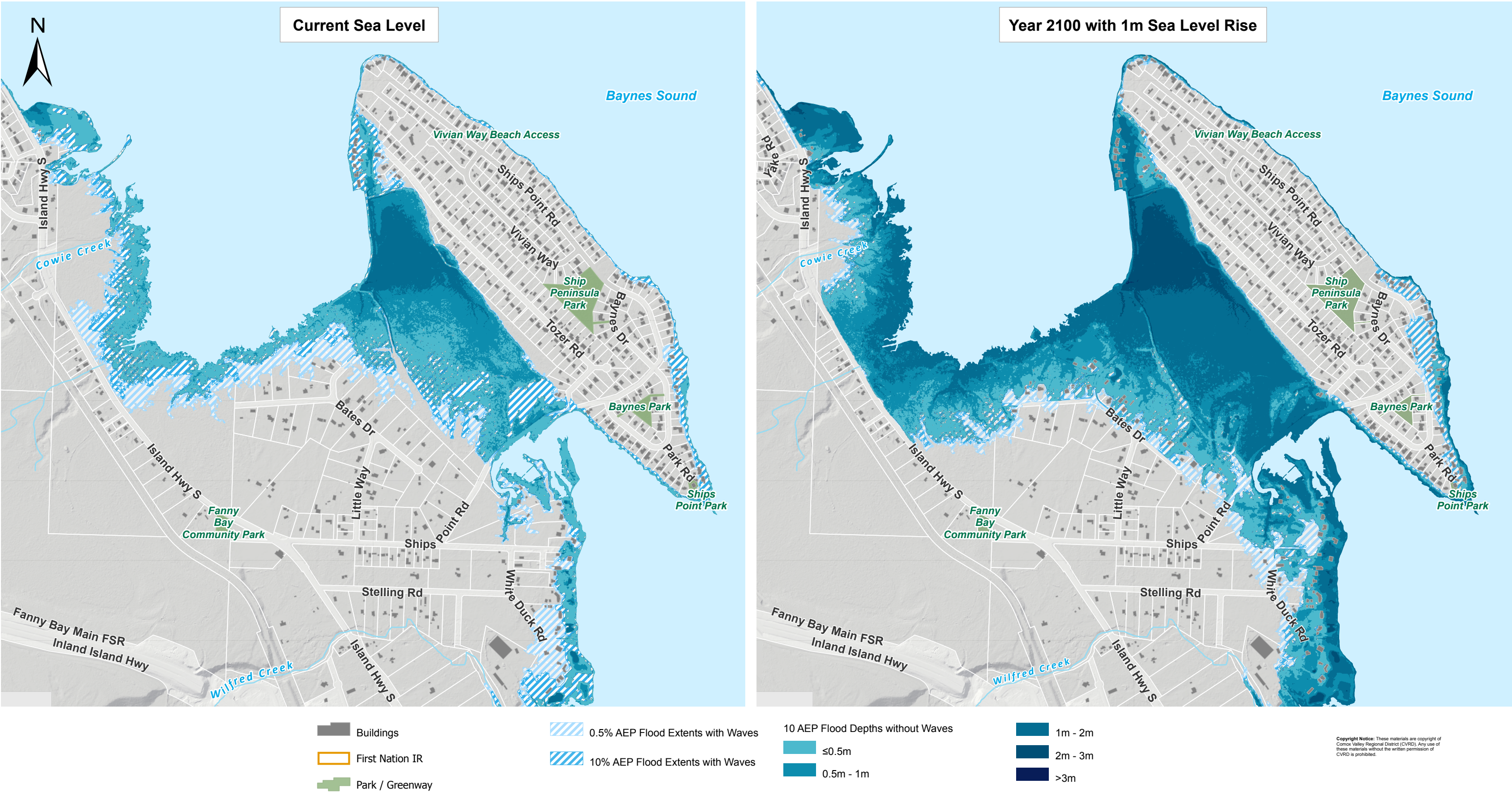
Ships Point is a high ridge peninsula located near Fanny Bay in Electoral Area A, south of the BC Ferries Terminal at Buckley Bay. The peninsula includes homes and businesses in the Ships Point Improvement District and Ships Point Park is located at the eastern tip of the peninsula.

Figure 18 shows what flooding could look like in the Ships Point area during different storm events under current sea levels and with 1 m of sea level rise (80 years in the future: year 2100). Each of the maps show flooding expected during a **higher-likelihood high ocean water level event** ("10% AEP without waves"), a **lower-likelihood 10% AEP high ocean water level event with a 10% windstorm event and associated wave effects** ("10% AEP with waves"), and a **very rare 0.5% AEP high ocean water level event with a 0.5% windstorm event and associated wave effects** ("0.5% AEP with waves").

Flood mapping suggests that, while the majority of buildings in the Improvement District are located above the flood extents shown here, the only access road into the community is exposed to flooding under a relatively higher-likelihood event at current sea levels. This means that a major storm event could block access in and out of the community and have implications for emergency response.

In the Ships Point Improvement District, flooding during a 10% AEP high ocean water level event at current sea levels is expected to cause a small portion of properties at the northwest end of the peninsula to experience less than a 1 m depth of flooding. Furthermore, waterfront properties along the southeast edge of the peninsula could experience shallow backyard flooding in a 10% AEP coastal storm event with waves. With 1 m of sea level rise, areas flooded during the 10% AEP event could experience flooding at greater depths and a small number of additional properties along Ships Point Road may experience shallow flooding from wind-generated waves.

Most of the flooding in this area is expected to occur in the wetland south of the Ships Point Improvement District. Under current sea levels, shallow flooding could extend into the backyards of waterfront properties southeast of the peninsula during a 10% AEP event with waves, and for a small number of properties at the southwest edge of the wetland during a rare 0.5% AEP coastal storm event. In the future, 1 m of sea level rise is expected to cause flood extents and depths to increase around properties in these two areas.



Project No. 2623.014
Date April 2021
Scale 1:13,000
0 50 100 200 Metres

Ships Point 10% AEP and 0.5% AEP Flood Extents for Current Sea Level and with 1 m Sea Level Rise

Figure 18



Goose Spit

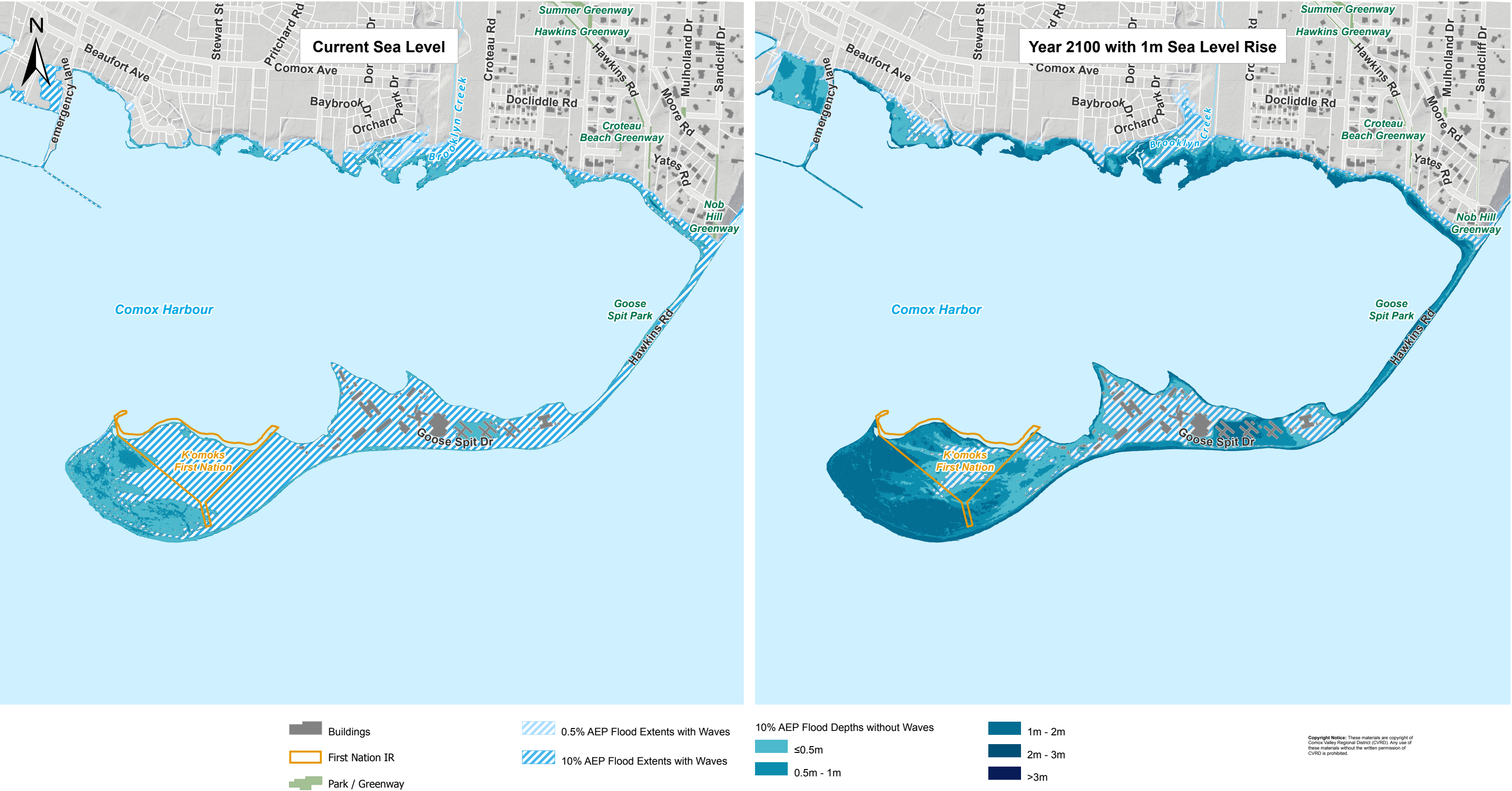
Goose Spit is located east of the Town of Comox in Electoral Area B. It is a low-lying sand spit that, together with Garley Point, creates the Comox Harbour and shelters downtown Comox from flooding and waves. Goose Spit includes the Goose Spit Provincial Park, the HMCS Quadra Canadian Forces Base, and K'ómoks First Nation IR#3.

Figure 19 shows what flooding could look like along Goose Spit during different storm events under current sea levels and with 1 m of sea level rise (80 years in the future: year 2100). Each of the maps shows flooding expected during a **higher-likelihood high ocean water level event** ("10% AEP without waves"), a **lower-likelihood 10% AEP high ocean water level event with a 10% windstorm event and associated wave effects** ("10% AEP with waves"), and a **very rare 0.5% AEP high ocean water level event with a 0.5% windstorm event and associated wave effects** ("0.5% AEP with waves").

The map shows that the tip of Goose Spit and a portion of the military base are exposed to up to 1 m of stillwater flooding from a 10% AEP coastal storm event (without waves) at current sea levels. However, if this event were to be accompanied by a windstorm, shallow flooding could extend across a large portion of the spit including Goose Spit Park and the two primary roads (Hawkins Drive and Goose Spit Drive), with the potential to temporarily block access to K'ómoks Nation IR #3 and the military base.

By year 2100 with 1 m of sea level rise, a large portion of the spit, including the Goose Spit Park and Hawkins Drive is expected to be inundated by flooding up to 2 m depth during a higher-likelihood 10% AEP high ocean water level event without waves. If the 10% AEP event were to occur during a windstorm, shallow flooding could extend across most of the military base.

In contrast, the waterfront in Comox Harbour is relatively protected from flooding and wave effects at current sea levels, with only a narrow strip along the waterfront expecting shallow flooding during a 10% AEP coastal storm event with waves. As sea levels rise, the areas previously only inundated during a 10% storm surge and wave event becomes inundated even without waves, including Marina Park. Even with future sea level rise, the majority of the waterfront buildings in Comox Harbour are above flood extents even during a 0.5% AEP coastal storm event with waves. However, as sea levels continue to rise up to 2 m in the distant future, 180 years from now, the spit is expected to become completely inundated and may provide much less protection against wind-generated waves to Comox Harbour.



Goose Spit 10% AEP and 0.5% AEP Flood Extents for Current Sea Level and with 1 m Sea Level Rise

Figure 19

Oyster River Mouth and Upstream of Bridge

The Oyster River Bridge is located on the Old Island Highway (19A) near the mouth of the Oyster River. It is located at the northern edge of the CVRD boundary and is the primary access road to the Oyster River Community in the SRD. In this area, the Oyster River runs along the boundary between the CVRD and SRD, meaning that flooding should be managed in a coordinated way. The northern riverbank in the SRD is lined with single family homes while the southern bank in the CVRD is forested and largely undeveloped.

The upstream reaches of the Oyster River are within a well-defined valley that keep flows relatively confined within the channel. The downstream reaches of the river open into an alluvial fan where the river flows into the Strait of Georgia. This area along the Oyster River is low-lying and has experienced flooding in the past.



Figure 20: Oyster River Bridge

Figure 21 shows what flooding could look like upstream of the Oyster River Bridge during a **higher-likelihood 10% AEP river storm event** under current and future climate change conditions, compared with a **rare 0.5% AEP river storm event**. These maps also show what flooding could look like if a coastal storm event (with high ocean water levels and waves) were to occur *during* a river storm event. Though a combined river and coastal storm event is very unlikely, the scenarios illustrate how coastal and river flooding can compound and exacerbate flooding around the mouth of the river.

Flood mapping results for the Oyster River show that even a relatively higher-likelihood 10% AEP river storm event could cause up to 2 m of flooding to properties and the forested area along the southern bank of the river, immediately upstream and downstream of the Oyster River Bridge. This same event could also cause inundation of farmland along the north bank, close to the river mouth. Higher river flows under climate change 80 years in the future (year 2100) are expected to cause a small increase in floodplain inundation and depths in the Oyster River Bridge and mouth area.

A much rarer 0.5% AEP river storm event is expected to cause a similarly marginal increase in flooding beyond the higher likelihood 10% AEP event. The 0.5% AEP event does not cause a large increase in flood extents, but it does cause flood depths to increase in all areas relative to the 10% AEP event. This suggests that flood waters will be relatively confined with the existing floodplain and alluvial fan.

Summary

In summary, Figure 17, Figure 18, Figure 19, and Figure 21 show that a 0.5% AEP event without climate change is similar to the flood extents and depths expected under a 10% AEP event *with* climate change. This suggest that flooding that is currently associated with an extremely rare event today will be more likely and occur more frequently under future climate change conditions.



6. Possible Adaptation Approaches

Successful adaptation will involve finding a balance between setting policies in place to move existing structures and avoid future development in flood-prone areas, while still preserving the ability of the coastal shoreline and river corridors to adapt to changes in a natural way.

If left alone, many shorelines will erode, and the local ecosystems will gradually and naturally adapt to look much like they do today. However, in developed waterfront areas, the CVRD may need to explore flood and erosion management policies and structural solutions to reduce the exposure and impact of flooding.

The Province of BC Sea Level Rise Adaptation Primer (2013) outlined four high level approaches for flood management:

1. **Protect** – measures that aim to prevent flooding from occurring;
2. **Accommodate** – measures that allow flooding to happen but reduce its impact on infrastructure or property;
3. **Retreat** – measures that involve moving existing structures out of flood risk areas; and
4. **Avoid** – land use planning measures that aim to manage or reduce the amount of development that happens in high-risk areas.

Communities across BC draw on a range of strategies for flood management and resilience under the broader approaches described above. Key strategies include:

- giving nature the space to adapt gradually over time in natural and undeveloped areas (*accommodate*);
- moving high-risk structures out of flood-prone areas in select and extreme cases (*retreat*);
- establishing policy and planning tools such as Flood Construction Levels (FCLs) and setbacks that guide future development to avoid building in flood-prone areas (*avoid*);
- enabling property-level initiatives to floodproof or protect existing structures from flooding and erosion (*protect*);
- using nature-based approaches such as constructed wetlands and beaches to manage erosion and wave effects (*accommodate, protect*); and
- developing robust emergency preparedness, response, and recovery plans for flood hazard areas to limit loss of life and support recovery after flooding events (*accommodate*).

This Coastal Flood Mapping Project has provided information to support the CVRD's next steps for flood management planning. Though more work still needs to be done to set priorities, future flood management in the CVRD will take a regional approach and involve a combination of strategies tailored to the unique needs and priorities in different areas and communities across the CVRD.

This section describes a broad range of different approaches the CVRD may consider as it moves forward with flood management planning.



6.1 Regional Planning Strategies

One of the most effective ways to manage flood risk is to *avoid* building new development in floodplain areas. These approaches represent land use planning and policy tools that the CVRD could implement to guide land use decisions over the long term.

The CVRD already administers a number of flood management policy and planning tools. The Coastal Flood Mapping Project has produced flood levels and setback areas to inform future land use planning and development in floodplain areas. Flood management initiatives that could build on and integrate with these existing policy tools include:

- updating the CVRD Floodplain Management and Zoning Bylaws to reflect outcomes from this coastal mapping project;
- updating the Shoreline and Aquatic Development Permit Areas (DPAs) in the Rural Comox Valley Official Community Plan (2014) to reflect outcomes from this coastal mapping project;
- requiring climate change risk assessments as part of the development permitting process, such as requiring new developments to complete assessments and management plans for climate-related hazards; and
- integrating consideration of climate change and flood risks into long-range asset management planning and decision-making by, for example, considering flood hazards as part of levels of service targets and annual renewal, replacement, and capital planning processes.

In many cases, policy and planning tools support the gradual, managed, and strategic *retreat* of development out of areas that are at a high risk of flooding. This approach provides an opportunity to repurpose waterfront areas for more compatible uses such as parkland and natural areas. However, managed retreat is not appropriate in all cases, such as areas with high-density development (e.g., downtown centres), critical infrastructure (e.g., water or wastewater treatment plans), or significant cultural sites (e.g., cemeteries or archaeological sites).

6.2 Reach-Scale Approaches

There is a large toolbox of structural measures that communities can draw from to *protect* or *accommodate* developed areas, or “reaches”, from future flooding. These approaches typically use engineered structures to manage flood water levels, wave effects, and erosion. At a high-level, these approaches can be categorized as “hard infrastructure” or “nature-based” strategies, as described in the sub-sections below.

Hard Infrastructure Approaches

Hard infrastructure typically refers to coastal and structural engineering works built to protect developed areas from flood waters, wave runoff, and erosion. These approaches can include, among others:

- berms;
- rock armouring;
- river and sea dikes;
- flood and sea walls;
- offshore reefs/breakwaters; and
- groynes.

Other approaches use structural works to retrofit or adapt existing structures so that they can *accommodate* future flooding while minimizing flood damage on the retrofitted structures. These approaches can include, among others:

- raising structures (e.g., on piles or fill);
- appropriately restricting building use below the flood level; and
- floodproofing structures (wet or dry approaches).

Further detail on these approaches is available in the Province of BC's Sea Level Rise Adaptation Primer (2013).

Most flood management designs use a combination of measures to meet the unique needs of each coastal site and the priorities of the community. The type of measures selected will also depend on the scale of application: whether the measure is being implemented to address flooding at a regional level, municipal level, or for an individual property.

Wherever possible, flood management structures should be designed to be “adaptive”, or flexible and able to be adjusted to future conditions. An example of an adaptive approach is designing a dike that can be raised in the future as sea levels continue to rise.

Nature-Based Approaches

Finding natural approaches to manage flooding and erosion can have many benefits apart from flood protection including enhancing ecological habitats and spaces for recreation along rivers and shorelines.

Natural shorelines are resilient and will shift to accommodate coastal flooding associated with climate change on their own. In areas without development in the floodplain, taking no action may be the best approach to allow ecological systems to adapt naturally over time.

Areas with existing structures within the floodplain may be suitable for taking a more active “nature-based approach” to managing flooding, waves, and erosion. Nature-based approaches mimic natural systems (e.g., beaches, dunes, and wetlands) to protect waterfront properties from flooding and erosion while also restoring and enhancing natural shoreline habitats.

Examples of nature-based approaches in BC include, among others:

- establishing constructed wetlands or salt marshes;
- installing clam gardens;
- using vegetation planting to increase shoreline or riverbank stability;
- combining vegetation plantings with traditional rip rap; and
- constructing engineered beaches by enhancing beaches with plantings, anchored logs, and beach nourishment.

“Green Shores” is a shoreline design framework developed by the Stewardship Centre of British Columbia that is compatible with many of the nature-based approaches described above. The Green Shores approach aims to manage coastal flooding and erosion while maintaining or enhancing shoreline ecological habitats (Stewardship Centre of British Columbia, 2020). It is a well-known model for nature-based coastal management that has been applied by communities across BC. Green Shores approaches typically involve “naturalizing” shoreline areas using materials such as logs, shoreline

vegetation, gravel, and boulders to better withstand wave effects and erosion. While these strategies may be effective for reducing wave effects, managing coastal erosion, temporary flooding, and debris during storm events, they do not entirely mitigate the impacts of sea level rise. Green Shores measures can be effective on their own or may need to be implemented in combination with other, more traditional structural approaches such as sea walls and rip rap.

The Green Shores approach is already being applied in the region, with examples in Campbell River and Qualicum Beach. An example of erosion protection and naturalization using the Green Shores approach is shown in Figure 22.



Figure 22: Green Shores Example in the Community of Bowser

The flood mapping produced as part of this project is intended to provide property owners with the information, they need to make informed decisions about flood levels, setbacks, wave effects, and potential flood protection measures on their lands. When all things are considered, the best long-term flood protection measures in some areas may involve constructing nature-based measures to reduce wave effects and erosion in combination with managed retreat that moves structures inland as they age and require reconstruction or are threatened by flooding as sea levels rise.

6.3 Property-Level Protection

Private property owners may wish to implement flood or erosion management approaches to manage flooding on their property. Typically, these site-specific approaches involve *protect* measures such as nature-based measures for erosion protection or *accommodate* measures to raise or floodproof existing structures. Property-level measures can effectively build a resilience when used on their own or can be used in combination with reach-scale approaches to refine and focus protection within a given property.

Different flood protection measures will have different impacts on managing wave effects (wave runup). As described in Section 3 of this report, long gradual slopes dissipate energy more effectively than steeper slopes. This means that the wave runup along flatter slopes (e.g., engineered beaches) will be lower, while steeper slopes (e.g., a seawall) can be more likely to cause waves to runup higher and overtop structures. Erosion and scour (with associated beach deflation and loss of habitat) often occur when hard erosion protection measures with steeper slopes are built. The relationship between different property-level protection measures, wave runup, and erosion is shown in Figure 23.



Managing Impacts to Adjacent Environments

Property-level measures should be designed to meet the needs of a specific site, while keeping in mind the impact the measures can have on neighbouring properties and sensitive ecosystems. For example, in some cases, installing flood protection measures in one area can increase erosion locally and in neighbouring areas as natural cross-shore and longshore sediment transport systems are disrupted.

The Rural Comox Valley Official Community Plan (2014) includes a DPA for shoreline protection devices. The DPA outlines guidelines to “promote sound shoreline protection device design to protect the natural environmental values and prevent erosion and destabilization of the shoreline”. The DPA states that these devices need to be carefully managed in order to avoid potential negative impacts to the ecological or physical integrity of the shoreline, including uses on adjacent or upland properties. The installation or repair of shoreline protection devices must receive CVRD, provincial and federal approval and meet the guidelines set out in the Rural Comox Valley Official Community Plan (2014).

The Rural Comox Valley Official Community Plan (2014) also includes a DPA for managing development in aquatic and riparian habitat areas to protect natural ecosystems while also protecting development from hazardous conditions. This DPA outlines guidelines for minimizing environmental impacts from development and protection devices, including a requirement for bio-physical assessments prepared by a qualified professional biologist outlining strategies to mitigate impacts on neighbouring habitats during and after construction.

While property-level protection can present an important approach to build flood resilience, it can also lead to fragmented solutions that can diminish the effectiveness of works on adjacent properties. This fragmentation can be managed through strong overarching policy and encouraging neighbouring properties to coordinate measures to promote continuity, consistency, and hazard mitigation effectiveness.

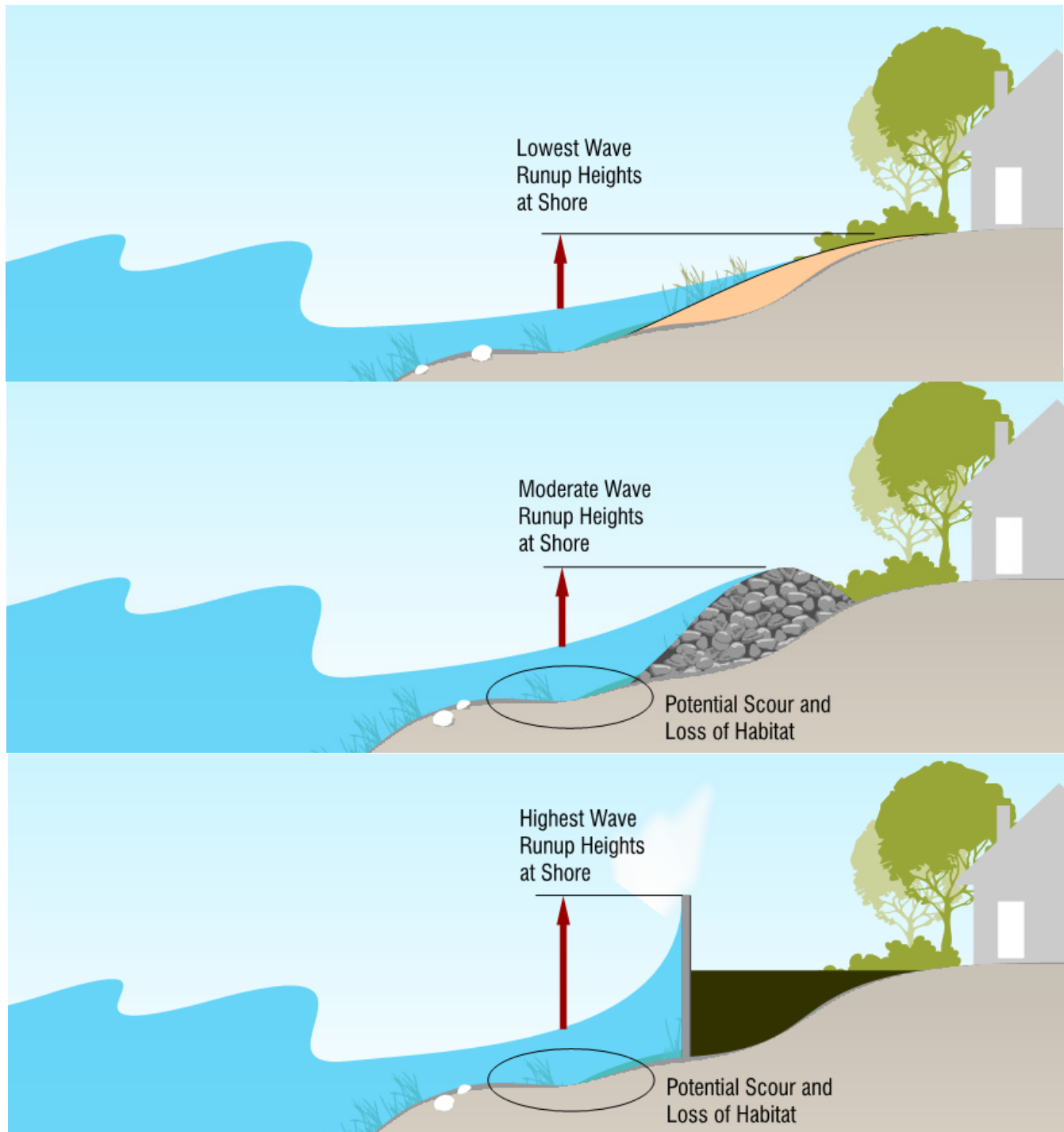


Figure 23: Impacts of Shore Protection on Wave Runup and Erosion



6.4 Regional Collaboration

Flooding does not stop at jurisdictional boundaries. The jurisdictional complexity in the CVRD means that ongoing collaboration with communities and actors across the region will be very important for effective flood management. It will be important that all groups with authority over lands in the CVRD work together toward a regional approach to ensure that flood management measures in one jurisdiction complement the measures being used in adjacent jurisdictions.

There are a number of examples of regional approaches for flood and watershed management on Vancouver Island and across BC, including the:

- Cowichan Valley Regional District Watershed Board⁵;
- Regional District of Nanaimo Drinking Water & Watershed Protection Technical Advisory Committee⁶; and
- North Shore Sea Level Risk Steering Committee⁷.

While each of these regions has developed their own unique approach to collaborative flood management, all three cases have involved the development of a formal partnership with a signed agreement and a committee of representatives from member jurisdictions. These partnerships work together to develop plans and strategy documents for watershed management across their region.

The CVRD could consider opportunities to establish its' own version of a flood management partnership that honours and builds on the existing frameworks communities in the region are already using for managing flood hazards. A regional flood management partnership in the CVRD could include representatives from the following groups:

- | | |
|---|--|
| • Comox Valley Regional District | • Ministry of Environment and Climate Change Strategy |
| • City of Courtenay | • BC Inspector of Dikes |
| • K'ómoks First Nation | • Department of Fisheries and Oceans |
| • Town of Comox | • Department of Defence, or representative from CFB Comox |
| • Village of Cumberland | • Industry and utility representatives |
| • Islands Trust | • Environmental stewardship, stream keepers, agricultural, or business development organizations |
| • Denman Island | • Public representatives |
| • Hornby Island | |
| • Ministry of Forests, Lands, Natural Resource Operations and Rural Development | |

⁵ Cowichan Watershed Board. Accessed September 2020 at <https://cowichanwatershedboard.ca/the-cowichan-watershed-board-2/>.

⁶ More information available on the RDN drinking water and watershed protection action plan website at <https://rdn.bc.ca/dwwwp-action-plan>.

⁷ More information available on the North Shore Sea Level Rise Strategy website at <https://www.dnv.org/sea-level-rise-strategy>.



7. Future Considerations

The Coastal Flood Mapping Project is the first step in a multi-year process to build resilience to flooding along the CVRD shoreline, the Oyster River and Courtenay River system. The comprehensive mapping data provided by this project will support the CVRD in future stages of flood management planning (Figure 1), including risk assessment, adaptation planning, implementation, and ongoing monitoring.

Community engagement across the region will be critical throughout the process to develop strategies that reflect community priorities for coastal development and resilience.

Recommendations for next steps for flood mapping, risk assessment, and adaptation planning include:

1. Use the flood hazard mapping from this project to complete a comprehensive risk assessment to identify priorities as the next stage in the flood management planning process.
2. Use the flood hazard mapping to support the development of regulatory and policy tools for land use management in flood hazard areas.
3. Extend the Tsolum River modelling completed by the City of Courtenay (2013) upstream to the limit of the 1990 Province of BC floodplain mapping.
4. Consider developing updated flood mapping for other rivers in the CVRD including the Trent River and Tsable River.
5. Complete a migration corridor analysis for all CVRD rivers, specifically the Tsolum River.
6. Complete an assessment of potential erosion and intertidal area change linked with estimated flood levels. The mapping has been prepared based on the assumption that the morphology (topography) of the shoreline will not change as sea levels rise. However, erosion and reshaping of the shoreline can be expected to occur in some areas as sea levels rise. The extent to which this occurs will depend on the composition of the shoreline (e.g., sand, gravel, rock) and its' wave exposure. Investigations into morphological changes could be performed in areas of interest to determine potential erosion impacts and associated affects on flood levels.
7. Improve the reliability of the coastal geomorphologic assessment by conducting field work potentially supplemented with data collected by drone (video).
8. Establish a program for water level monitoring along the rivers within the CVRD for flood warning purposes and future hydraulic model verification.
9. Install dike crest gauges adjacent to the Glenmore Dike and along the Courtenay River as tools to measure and monitor the remaining freeboard during high water level events.
10. Consider preparing model "Green Shores" shore protection designs for different areas (e.g., by shoreline type or wave exposure) in the CVRD that property owners can refer to when designing property-level measures.
11. Hold a webinar to present findings from the Coastal Flood Mapping Project to member municipalities.
12. Develop educational materials to communicate findings from the project with the CVRD public and build awareness of flood hazards, risks, and potential adaptation approaches.



8. References

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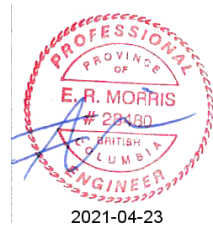


9. Report Submission

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Revision History

Revision #	Date	Status	Revision	Author
0	April 23, 2021	Final		RNH/EM





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Appendix A

Technical Memorandum #1 Coastal and River Base Map Development (included separately)



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Appendix B

Technical Memorandum #2 Fluvial and Coastal Geomorphology (included separately)



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Appendix C

Technical Memorandum #3A Fluvial Modelling – Oyster River Hydrology and Hydraulic Assumptions (included separately)



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Appendix D

Technical Memorandum #3B Courtenay River Modelling – Hydrology and Hydraulic Model Assumptions (included separately)



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Appendix E

Technical Memorandum #4 Coastal Modelling

(included separately)



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Appendix F

Technical Memorandum #5 Coastal and Fluvial Mapping Products (included separately)