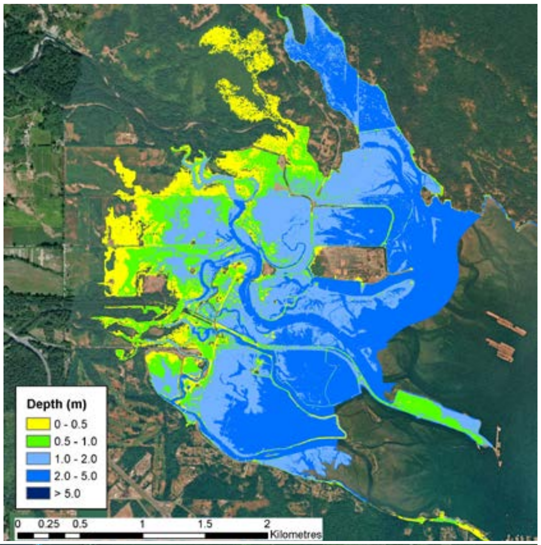

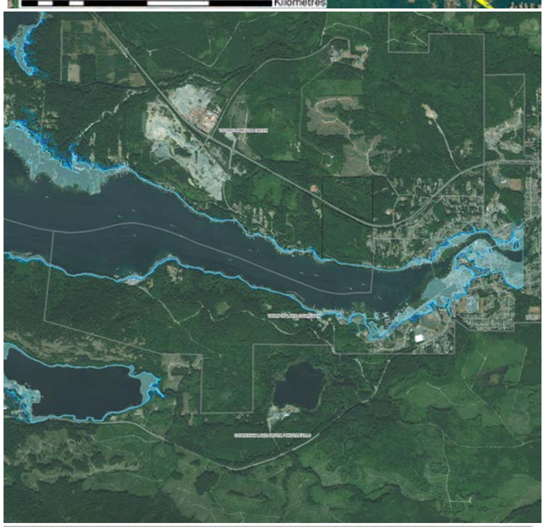

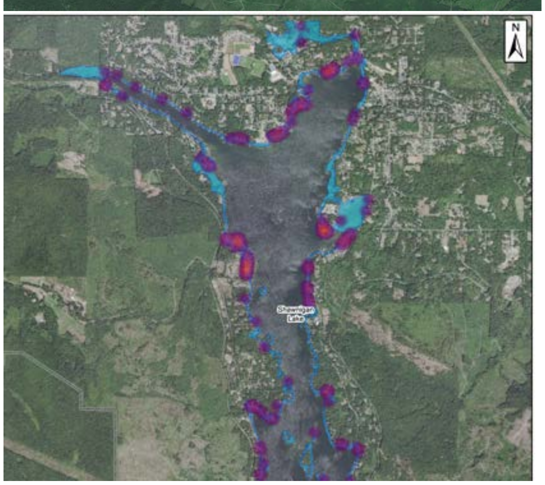

RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE: STRATEGIC CLIMATE RISK ASSESSMENT FOR THE COWICHAN VALLEY REGIONAL DISTRICT

FINAL REPORT
REVISION 1

Prepared for:

CVRD

Cowichan Valley Regional District

8 May 2019

nhc
northwest hydraulic consultants
water resource specialists

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FINAL REPORT
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Prepared for:

Cowichan Valley Regional District
Duncan, BC

Prepared by:

Northwest Hydraulic Consultants Ltd.
Nanaimo, BC

8 May 2019

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DISCLAIMER

CREDITS AND ACKNOWLEDGEMENTS

We wish to acknowledge the guidance provided by Jeff Moore and Kate Miller of the Cowichan Valley Regional District.

The following staff from NHC participated in this study:

Dave McLean: Senior engineer – riverine, lake, and coastal flood hazard analysis

Wil Hilsen: Project manager, geomorphology and risk analysis

Laura Ramsden: Risk analysis and coastal engineering

Kathleen Horita: Hydrology and Quality Checking

Ben Humphreys: GIS analysis

Sarah North: GIS review and support

Monica Mannerström: Risk analysis support

Julie Van de Valk: Risk analysis support

Jasmine Kang: Hydrology

The following staff from EcoPlan supported the stakeholder engagement process and participated in the flood forum:

John Ingram: Principal and Senior Planner

Kathleen Heggie: Planning Associate

EXECUTIVE SUMMARY

This study provides an overview level flood exposure assessment of present-day and three potential future flood hazard scenarios for four study regions within the Cowichan Valley Regional District (CVRD): Cowichan Lake, Shawnigan Lake, Cowichan River (near Riverbottom Road), and the coastline (excluding Electoral Area F).

The results of this assessment are intended to provide a preliminary understanding of the present-day and future flood risks to inform the CVRD, First Nations, and the CVRD's member municipalities and other partners of the flood risks, help prioritize and focus future studies, identify information gaps, and to support future funding applications. A digital database has been developed as a project deliverable to provide the CVRD with a baseline dataset that can be updated and refined over time as new information becomes available.

Objectives

Key objectives of the study are as follows:

- Quantify the exposure of community elements in the region, under both present conditions and under three future climate change scenarios. The assessment is based on the existing information provided by CVRD, background review of available documents, and other desk-top based analysis. No new field investigations or surveys were conducted, and the results presented herein are preliminary.
- Identify areas and elements within the CVRD that have the highest exposure flooding and areas where the exposure is most sensitive to future climate change.
- Provide mapping information and data in a Geographic Information System (GIS) to allow for further analysis of the areas that are considered high risk for flooding presently or in the future.
- Identify data gaps and where existing floodplain mapping should be updated; and,
- Present overview level mitigation approaches that should be evaluated in more detail later.

Methodology

In this study, the potential impact of climate change at some future date is defined as the difference between the future condition and the present-day (historical observed) condition. Therefore, three components have been examined in order to assess these impacts:

1) Present-day flood hazards and flood exposure;

2) Projected change in climatic and hydrological input variables: temperature, precipitation, global ocean level;

3) Projected change to flood levels and flood exposure that will result from the changing climatic and hydrological input variables.

The flood hazard analysis was carried out for several future climate change scenarios using results of past studies and a review of the scientific literature. It was beyond the scope of this study to conduct new climate modelling. The nominal time frame for the assessment extends to the year 2100; however, projected changes in climate and hydrological input variables are highly uncertain due to uncertainties in socio-economic and climate models. Flood impacts associated with climate change will increase incrementally and future projections will need to be refined over time as new information becomes available. Therefore, it must be emphasized that the projected changes to flood levels could occur potentially either sooner, or later than the stated year 2100.

The flood hazards and associated risks are quantified for the 200-year flood event which is defined as an event having a 0.5% annual exceedance probability (AEP) or a 0.5% chance of occurring in any given year. In context of a defined planning horizon, a 200-year flood event has a 10%, 30%, and 39% chance of occurring at least once over an interval of 20, 70, and 100 years, respectively (NHC 2014).

For each flood scenario the Flood Construction Reference Plane (FCRP) has been computed and used for the risk analysis. For lakes and coastal areas, this includes both the "still-water" level due to tides, storm surge, and transient effects due to wave runup. Flood Construction Levels (FCLs) have not been computed for this project.

For this study, vulnerability is assessed based on the number of elements within the FCRP for each flood hazard scenario. These elements are grouped by impact to people, the environment, the economy, infrastructure, and public sensitivity. This methodology is intended to meet the requirements defined by the National Disaster Mitigation Program (NDMP) for assessing risk due to climate change and to support the objectives of this study. All available element information was categorized into the five flood impact categories and to define a method for quantifying the exposure of each element. Elements located within the given FCRP were selected using GIS and counted using a custom Python script. Elements located within each flood scenario boundary were classified by jurisdiction.

Study Limitations

There are several important limitations in the risk assessment. These are grouped into three main categories: 1) general limitations associated with the uncertainty surrounding climate change scenarios, 2) limitations associated with the available data, and 3) limitations associated with the defined study regions. Limitations are discussed in more detail in **Section 3.5**.

Risk Assessment

Flood levels for the Cowichan Lake, Shawnigan Lake, and Cowichan River (near Riverbottom Road) study regions were calculated assuming present-day conditions and increases in flow rates of 10%, 20%, and 40%. Coastal flooding was calculated assuming present-day conditions and future sea level rise (SLR) scenarios of 1.0 m (intermediate), 1.5 m (intermediate-high), and 2.5 m (extreme).

The risk assessment is categorized into two components:

- Floodplain risk assessment and mitigation strategies for the Cowichan Lake, Shawnigan Lake and Cowichan River near Riverbottom Road study regions (**Section 4** to **Section 8**); and,
- Sea Level Rise risk assessment and mitigation strategies (**Section 9** to **Section 11**).

Key recommendations are presented below:

1) Develop a long-term work plan that positions future flood management work (following the general NDMP approach) alongside the ongoing flood hazard and vulnerability projects that the CVRD is presently undertaking;

2) Integrate the results of this study into policy documents to support the administration of land development regulations, flood control bylaws, emergency preparedness, and long term planning and budgeting;

3) Update and expand the CVRD's Integrated Flood Management Plan to account for climate change, addressing the uncertainty in future predictions using a dynamic decision based approach or some other similar approach;

4) Replace the existing obsolete flood hazard maps on Cowichan Lake, Shawnigan Lake, Riverbottom Road and Chemainus River/ Bonsall Creek:

    - Apply modern hydraulic modelling and GIS-based mapping tools.
    - Incorporate the lower reaches of the Cowichan River – Koksilah River floodplain and the Chemainus River – Bonsall Creek floodplain into refined coastal flood assessments to assess complex interactions between the riverine and coastal flood processes.
    - Review the available topographic information and strive to develop a more complete and consistent high resolution digital elevation model (DEM) for all regions. This should include an expansion of the study regions to include areas affected by riverine and coastal processes.
    - Re-survey the Cowichan River (near Riverbottom Road) and use the information to update the flood hazard analysis. Carry out a more detailed assessment of the riverbank

morphology, erosion vulnerability, and channel avulsion potential to update the development restriction zones originally developed by Hardy (1989).

5) Communicate with stakeholders and data providers to refine and expand the flood risk geodatabase:

    - Seek more detailed information from stakeholders to assess the vulnerability of key infrastructure and other exposed elements within the FCRP boundaries.

    - Identify service areas for key elements to determine the affected service area relative to the affected flood area, which may be different.

    - Review the database to standardize the regional datasets, infill data gaps, and audit the database with site assessments, field verifications, and through outreach and engagement.

    - Seek stakeholder input to identify economic, environmental, and societal values for flood exposed elements (which will vary depending on the stakeholder) and determine an appropriate approach for weighting each of the five impact categories.

    - Audit Census data and collect supplemental information where appropriate to address potential misrepresentation of population information in rural areas.

    - Audit Property Assessment data and collect supplemental information where appropriate to address potential inaccuracies in property values associated with the approach applied for this overview level study, and to infill possible data gaps.

6) Expand the engagement process to include other stakeholders in the region:

    - Produce communications materials for educating the public on flood risks and climate change impacts in the region.

    - Engage stakeholders on conceptual flood mitigation and adaptation strategies.

7) Extend the simplified risk analysis carried out in this preliminary study:

    - Carry out more detailed flood intensity analyses for select sub-regions, to consider parameters such as water depth, velocity, sediment concentration, etc.

    - Carry out a more detailed inventory of buildings within flood exposed areas (or select sub-regions) using available up to date ortho-imagery and manually digitizing features. Follow up site assessments or surveys may be warranted to document the elevation of specific features.

    - Prepare flood inundation, flood depth, or hazard rating maps.

- Develop appropriate depth-damage, velocity-damage or other hazard intensity to damage relationships to quantify flood consequence.

8) Run the Cowichan Lake and coastal study region numerical models for other combined wind generated wave events and lake or ocean levels to assess the shoreline erosion vulnerability under different plausible water level and wind conditions. For the coastal study region this could include an analysis of potential for saline intrusion and effects on groundwater.

9) Carry out a more detailed statistical analysis of observed Cowichan Lake wind events to incorporate impacts associated with storm duration. It is recommended the shoreline classification be refined based on a follow up site assessment at key areas that are identified from the results of the numerical modelling. CVRD's coastal flood sensitivity database should be reviewed and incorporated into future assessments of shoreline erosion potential

10) No environmentally sensitive areas (ESA) were identified for the Cowichan Lake study region, based on the available data. An update of ESA assessment and mapping should be carried out for the Cowichan Lake study region. Other study regions should be reviewed to determine the accuracy of ESA mapping to assess whether updates are warranted.

11) Install flood warning systems at key locations in the lake and riverine study regions to provide real time alerts when water levels exceed or rise at a rate beyond a predetermined threshold.

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PART A OVERVIEW

1 INTRODUCTION

The Cowichan Valley Regional District (CVRD) retained Northwest Hydraulic Consultants Ltd. (NHC) and EcoPlan International (EcoPlan) to conduct a preliminary flood hazard and risk assessment, including an assessment of historical flood maps, for four study areas (coastal, riverine and lake) within the Cowichan Valley Regional District (CVRD). The Federal and Provincial government provided generous funding to support the program under the Stream 1 assessment component of the Natural Disaster Mitigation Program (NDMP). This work is nested under the CVRD's New Normal Cowichan Climate Change implementation work and is intended to build a robust understanding of the regions natural hazards and changing climatic conditions affecting its communities so that effective mitigation can be developed.

The CVRD's climate program - New Normal Cowichan involves the following four key phases towards resiliency and adaptation.

- Phase 1: Climate Projections and Impacts Analysis- complete
- Phase 2: Vulnerability and Risk Assessments - ongoing
- Phase 3: Adaptation and Mitigation Strategy - ongoing
- Phase 4: Implementation of the Strategy - ongoing

This work supports both Phase 2 and Phase 3 of that strategy and informs a wide range of current and future planning programs.

Additionally, the Board approved recommendations from the projections and impacts analysis phase provides the following additional guidance going forward in utilizing this work.

- Take a "no-regrets" approach -time for action is now
- Utilize existing projections in all master planning processes
- Establish stretch goals and visions in Cowichan 2050 planning process to ensure that *adaptation is not an automatic fallback position*
- Incorporate projections and impacts into all engineering and water security planning.
- Conduct additional analysis of drought-related indicators to more fully understand specific impacts
- Develop water security plans and watershed strategies to address future conflicts over water use
- Develop an integrated hydrological monitoring and climate network

- Identify and map areas affected by increased climate sensitivity (flooding, erosion, landslides) to assist in identifying specific risks
- Conduct a regional, engineering-based analysis of infrastructure risks to inform asset management
- Develop IDF curves that reflect climate projections for engineering decision making related to infrastructure

1.1 Overview and Purpose

The CVRD has made a long term commitment to develop meaningful climate adaptation plans which are science based and provide both strategic recommendations regarding the impacts on current and future communities. This work is intended to inform current and future risk reduction and resiliency planning policy, identification of potential infrastructure upgrade strategies and protect the individual and aggregated investments in our communities. More importantly its purpose is to help keep people safe from flooding.

The purpose of the climate risk assessment is to identify the potential present-day and future flood exposures to support identification of needed investments in upgrades to analytical tools such as formal mapping or regulatory frameworks such as upgraded standards, and engagement with, key stakeholders within the region exposed to flood related climate change impacts. This will provide the CVRD with information that can be used to develop a decision-making framework for risk tolerance, making strategic investments and taking mitigative and adaptive actions to reduce risk and liability from lake, riverine, and coastal flooding within the study areas and through out the region as a whole.

Present-day and three future potential flood hazard scenarios were examined for each study area to recognize the uncertainties in future magnitude and rate of changes in peak flows and sea levels associated with climate change. This is a "no-regrets" approach based on the precautionary principle, described by Von Schomberg (2004) as follows:

> *Where, following an assessment of available scientific information, there is reasonable concern for the possibility of adverse effects but scientific uncertainty persists, provisional risk management measures based on a broad cost/benefit analysis whereby priority will be given to human health and the environment, necessary to ensure the chosen high level of protection in the Community and proportionate to this level of protection, may be adopted, pending further scientific information for a more comprehensive risk assessment, without having to wait until the reality and seriousness of those adverse effects become fully apparent.*

1.2 Study Objectives

Key objectives of the study are as follows:

- Quantify the exposure of community elements in the region, under both present conditions and under three future climate change scenarios. The assessment is based on the existing information provided by CVRD, background review of available documents, and other desk-top based analysis. No new field investigations or surveys were conducted, and the results presented herein are preliminary.
- Identify areas and elements within the CVRD that have the highest exposure flooding and areas where the exposure is most sensitive to future climate change.
- Provide mapping information and data in a Geographic Information System (GIS) to allow for further analysis of the areas that are considered high risk for flooding presently or in the future.
- Identify data gaps and where existing floodplain mapping should be updated; and,
- Present overview level mitigation approaches that should be evaluated in more detail later.

1.3 Study Regions

The scope of the project includes floodplain risk assessments for three study regions and a SLR risk assessment for the coastal study region (Figure **1**-**1)**:

- Cowichan Lake
- Shawnigan Lake
- A portion of the Cowichan River along Riverbottom Road
- Coastal marine areas of the eastern portion of the CVRD (i.e. excluding Area F) that will be impacted by SLR

The study does not include the riverine flooding or influences of sea levels on riverine flooding on the lower Cowichan-Koksilah River system or Chemainus River, which we understand will be addressed in other future studies.

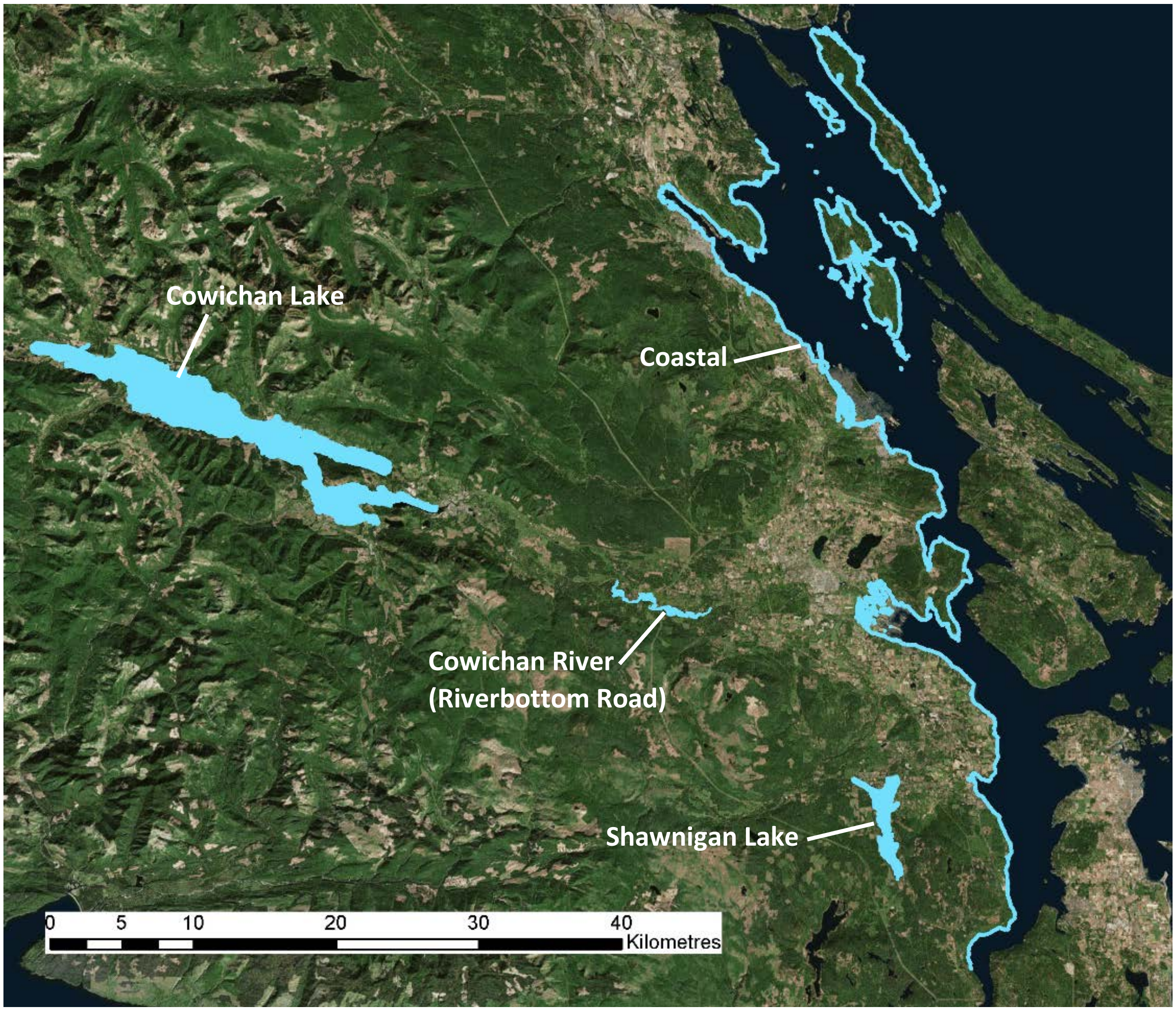


Figure 1-1: CVRD study regions.

2 REGIONAL SETTING

The Cowichan Valley Regional District spans the width of Vancouver Island between the Capital Regional District and the Regional District of Nanaimo, with Cowichan Lake located in its central region. It also includes a portion of the Gulf Islands off the east coast of Vancouver Island (e.g. Thetis Island, Penelakut Island and Valdes Island). The total land area is 3,473 km².

The valley is the traditional home of the Coast Salish First Nations - the Cowichan, or Quw'utsun', whose name has been translated as "back warmed by the sun" or "the warm land".

2.1 Overview

The CVRD has a population of about 83,739 (2016 census). Forest related industries, agriculture and tourism are the main economic drivers of the area. The majority of the population lives along the eastern edge of the region and it is in this developed portion of the region that local government plays the greatest role in activities such as land use planning and risk management. The risk assessments that form the basis for this report deal with study regions within the developed east coast of the region and much of the discussion that follows is most relevant to this portion of the region.

The region includes the following municipalities:

- City of Duncan
- Municipality of North Cowichan
- Town of Lake Cowichan
- Town of Ladysmith

First Nations with land that is potentially located within one or more of the flood scenario boundaries include the following (FN jurisdictions were categorized into seven groups for the coastal study region):

- Cowichan Tribes - Cowichan 1, Cowichan 9, Theik 2, Kil-Pah-Las 3,
- Halalt – Halalt 1, Halalt 2
- Malahat – Malahat 11
- Pauquachin - Hatch Point 12
- Penelakut - Tsussie 6, Tent Island 8, Penelakut Island 7
- Stz'uminus - Squaw-Hay-One 11, Say-la-quas 10, Chemainus 13, Oyster Bay 12
- Lyackson – Lyackson 3, Porlier Pass 5, Shingle Point 4
- Lake Cowichan First Nation
- Kakalatza 6
- Tzart-Lam 5

2.2 Physical Setting

2.2.1 Physiography

The CVRD is located in two principle physiographic regions (**Figure 2-1**):

- Nanaimo Lowlands
- Southern Vancouver Island Ranges

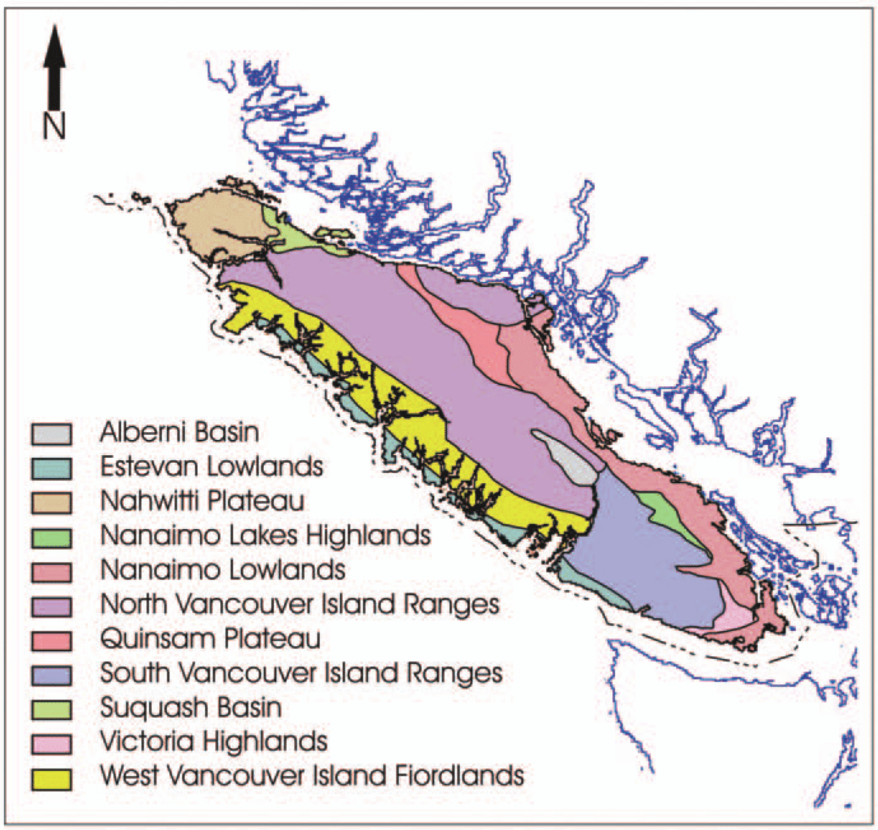


Figure 2-1: Physiographic regions of Vancouver Island (Yorath and Nasmith, 1995).

The landforms and soils in the region have been greatly influenced by the last major glaciation which ended approximately 10,000 years before present. The ice sheet occupied the Strait of Georgia and the eastern coastal lowland of Vancouver Island. Cowichan valley and Chemainus valley were also occupied by valley glaciers at this time. Most of the unconsolidated deposits in the region were deposited during the wasting of the last ice sheet. The surficial deposits are commonly found below an elevation of 160 m. At higher elevations, bedrock is exposed or is covered by a thin mantle of glacial drift.

During glaciation and immediately following the end of the last glaciation, sea level varied dramatically, as a result of both eustatic effects (changes to the level of the ocean) as well as iso-static effects (changes to the land surface due to deformation of the earth's crust from the ice sheet). Following the retreat at the end of the Sumas Stade, the land became emergent and during the period 9,000 to 6,000 years ago, sea level stood approximately 10 m below the present shoreline in some parts of the region (Mathews et al., 1970). Sea level stabilized near its present level approximately 5,500 years ago, although iso-static adjustments persist, causing the land to slowly rise at a rate of 1 to 2 mm/year. Since then, rivers such as the Cowichan-Koksilah River and Chemainus River have built large alluvial deltas of gravel, sand and silt into the Strait of Georgia (**Figure 2-2**).

Figure 2-2: Chemainus River delta and Cowichan-Koksilah River delta.

2.2.2 Principle Watersheds

The principle east-flowing river systems draining the CVRD region include:

- Cowichan River
- Koksilah River
- Somenos Creek
- Shawnigan Creek
- Chemainus River
- Bonsall Creek

Cowichan River is a Heritage River, recognized for its highly valuable and productive fish habitat. The river supports seven species of salmon and trout including important stocks of chinook, coho and chum salmon, as well as steelhead, brown, rainbow and cutthroat trout. The Cowichan River has its headwaters at Hooper Mountain (el. 1,490 m) near the western end of Cowichan Lake. From Cowichan Lake to just upstream of Duncan, the river flows in a narrow valley, then opens onto a wide floodplain until reaching Cowichan Bay. The drainage area near Duncan is 826 km^2. Downstream of Duncan, Somenos Creek drains into the Cowichan River from the north. Several smaller tributaries enter the Somenos system (Bings, Averill, Richards, Quamichan and Tzouhalem creeks).

The Koksilah River has its headwaters at Waterloo Mountain (el. 1,072 m). The drainage area of the Koksilah River at Cowichan Station is 209 km^2. The Koksilah River joins the south branch of the Cowichan River approximately 1.5 km upstream of Cowichan Bay.

The Chemainus River drains 355 km^2 of mainly forested uplands and mountains. The highest point in the basin is on the peak of Mount Whymper at an elevation of 1,540 m. Near Mount Sicker the valley turns northwards and the stream flows through the Nanaimo Lowlands. Downstream of Westholme, the river flows over a broad alluvial plain until entering the Strait of Georgia.

Bonsall Creek drains 36 km^2 and originates as a steep channel in the headwaters of Mount Sicker and Mount Prevost. The channel quickly becomes low gradient and flows into the southern portion of the Chemainus River floodplain. A substantial length of the creek flows through privately owned farmland, Halalt First Nations land, eventually flowing through the Penelakut Reserve at the mouth of the creek.

2.3 Climate and Hydrology

The Cowichan region is located in Canada's only Maritime Mediterranean climatic zone, resulting in the warmest mean year round temperature anywhere in Canada (https://www.cvrd.bc.ca/650/Climate). Mean annual precipitation and temperature varies within the region, depending on the location's elevation and proximity to the ocean.

Figure 2-3 shows monthly temperature and precipitation Cowichan Lake (at the Town of Lake Cowichan) and at Shawnigan Lake. Both stations are at relatively low elevations (177 m at Cowichan Lake and 157 m at Shawnigan Lake). Average temperatures at the two stations were very similar. The annual precipitation averaged 2,207 mm at Cowichan Lake and 1,250 mm at Shawnigan Lake. Approximately 80% of the annual precipitation falls between October and March at both stations.

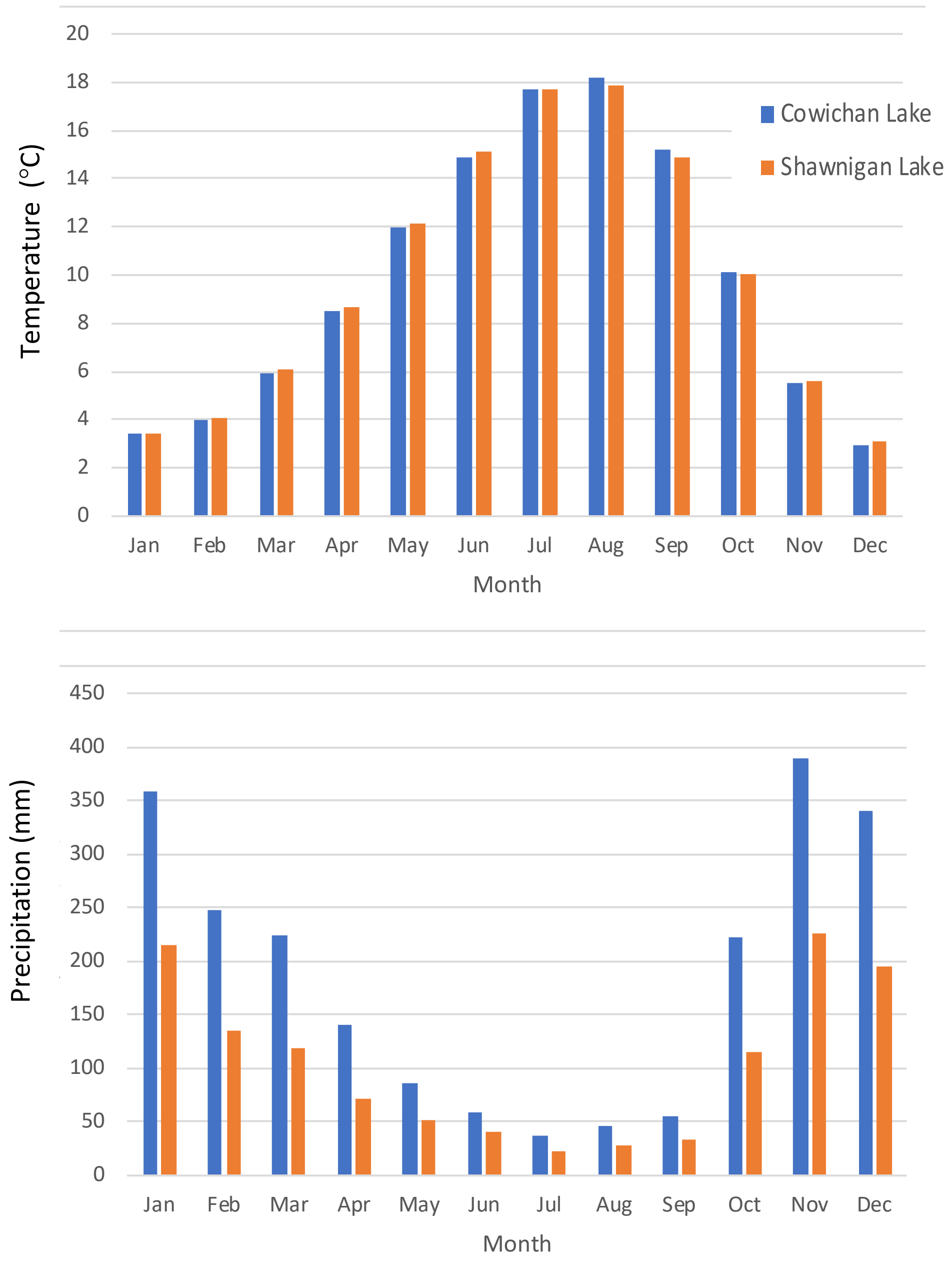


Figure 2-3: Monthly climate normals (1981 to 2010) for Cowichan Lake and Shawnigan Lake.

The total snowfall at Shawnigan Lake averages only 70 mm and 100 mm at Cowichan Lake, corresponding to less than 5% of the total (all snowfall amounts are reported as "water equivalent" values).

Figure 2-4 shows the maximum recorded daily precipitation at the two stations for the period 1981 to 2010. The highest value at Cowichan Lake was 150 mm/day (in January) versus 117 mm/day at Shawnigan Lake (in October). Furthermore, daily precipitation amounts exceeded 120 mm/day in four months (January, March, November and December) at Cowichan Lake. This demonstrates that the southeast part of the region experiences a rain shadow effect compared to the central area.

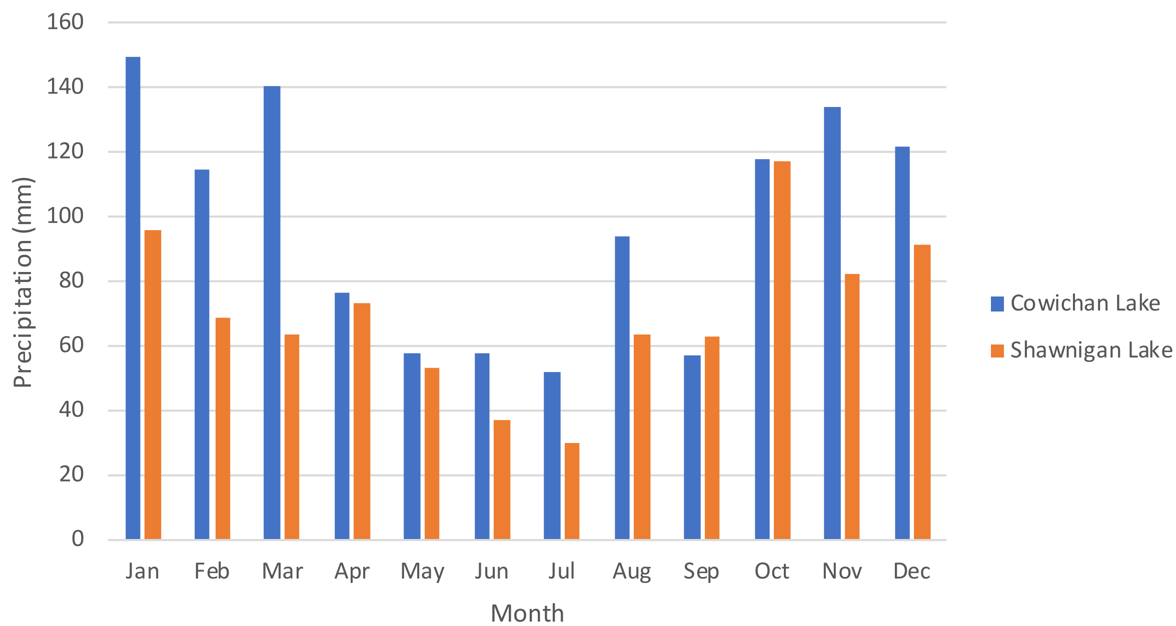


Figure 2-4: Extreme daily precipitation (1981 to 2010) at Cowichan Lake and Shawnigan Lake.

This spatial variation in precipitation is also evident in the climate modelling studies (CVRD 2017; OSU, 2002). In addition, these studies also showed that annual and extreme precipitation amounts increase rapidly with elevation due to orographic effects. In the OSU (2002) study, the estimated mean annual maximum daily precipitation ranged from 120 to 160 mm/day in the Nanaimo Lowlands up to 205 to 250 mm/day further inland along the steeper mountainous slopes. The CVRD 2017 study utilized Global Climate Model data that was statistically downscaled to 10 km resolution and corrected for elevation (provided by the Pacific Climate Impacts Consortium, PCIC), and reports autumn rainfall amounts in the order of 200 to 400 mm over a single season in the lowland areas increasing to 1,200 to 1,400 mm for headwaters regions of the Cowichan River basin.

The most severe floods typically occur from November to March when warm Pacific cyclonic depressions that pass over the Strait of Georgia and generate high rates of precipitation when they are forced to rise over the mountains on Vancouver Island. Riverine and lake floods are often generated as a result of rain-on-snow events (high precipitation combined with snow melt). Flooding and bank erosion can be aggravated by debris jams and sediment deposition, so that the most severe flood damages may not necessarily correspond to the most severe hydro-meteorological events.

Coastal flooding can occur along low-lying areas of the shoreline and occur when high astronomical tides coincide with relatively short-duration storm surges that are generated from low pressure cyclonic depressions passing over the Strait of Georgia. The most severe flooding in the region occurs in low-lying deltaic regions (**Figure 2-2**), where riverine flood levels are increased due to backwater effects from extreme high tides.

2.4 Oceanographic Setting

The east coast of the CVRD is bounded by the southern Strait of Georgia, which forms part of the Salish Sea. The tides in the region are classified as mixed, mainly semi-diurnal, meaning that two highs and lows are experienced each day, but of unequal height. The Canadian Hydrographic Service (CHS) predicts tide level in the region using Fulford Harbour as a reference station. Tide levels have also been measured from 1977 to the present at Patricia Bay in Saanich.

Table 2-1 summarizes published tide statistics at Cowichan Bay provided by the CHS. The tidal range at this location is approximately 3.8 m. The Higher High Water Large Tide (HHWLT) value is the average of the higher high waters from each year over 19 years of tide predictions. It represents the highest astronomical tide that typically occurs in any given year (the colloquial, non-technical term “king tide” is roughly comparable to HHWLT). The observed tide levels at Patricia Bay provide information on the highest recorded still-water ocean levels at the site. These values include storm surge and set-up. In the period of record from 1977 to present, the highest recorded water level was 2.24 m in 1982 (approximately 0.5 m above HHWLT).

Table 2-1: Tide levels referenced to Chart Datum and to Geodetic Datum.

Tide	Chart Datum (m CD)	Geodetic Datum (m CGVD 2013)
Higher High Water Large Tide (HHWLT)	3.9	1.77
Higher High Water Mean Tide (HHWMT)	3.2	0.91
Mean Sea Level (MSL)	2.4	0.17
Lower Low Water Mean Tide (LLWMT)	0.8	-1.33
Lower Low Water Large Tide (LLWLT)	0.1	-2.20

Note: Based on CHS Chart 3478.

Winds are predominantly from the southeast in winter and from the northwest through southwest in summer (Thompson, 1985). Most of the region is not exposed to severe wind-generated waves due to the presence of Saanich Inlet and the Gulf Islands, which shelter the region from the larger waves generated in the Strait. Fetch lengths (the distance that the wind can blow over the open ocean) typically vary from 10 to 20 km.

3 METHODOLOGY AND STUDY LIMITATIONS

3.1 General Approach

In this study, the potential impact of climate change at some future date is defined as the difference between the future condition and the present-day (historical observed) condition.

$$\text{Impact} = \text{future condition} - \text{present-day condition} \quad \text{(Eq. 1)}$$

Therefore, three components have been evaluated in order to assess these impacts:

1) Present-day flood hazards and flood exposure;

2) Projected change in climatic and hydrological input variables: temperature, precipitation, global ocean level;

3) Projected change to flood levels and flood exposure that will result from the changing climatic and hydrological input variables.

3.2 Flood Hazards

The flood hazard analysis was carried out for several future climate change scenarios using results of past studies and a review of the scientific literature. It was beyond the scope of this study to conduct new climate modelling. ***It should be emphasized that scenarios do not predict future changes, but describe future potential conditions in a manner that supports decision-making under conditions of uncertainty (Parris et al., 2012). Scenarios are used to develop and test decisions under a variety of plausible futures. This approach strengthens an organization's ability to recognize, adapt to, and take advantage of changes over time (Parris et al., 2012).***

The nominal time frame for the assessment extends to the year 2100; however, projected changes in climate and hydrological input variables are highly uncertain due to uncertainties in socio-economic and climate models. Flood impacts associated with climate change will increase incrementally and future projections will need to be refined over time as new information becomes available. Therefore, it must be emphasized that the projected changes to flood levels could occur potentially either sooner, or later than the stated year 2100.

Three climate change scenarios are assessed for each study region. Flood levels for the Shawnigan Lake, Cowichan Lake, and Cowichan River (near Riverbottom Road) study regions were calculated assuming increases in flow rates of 10%, 20%, and 40%. Coastal flooding was calculated assuming present-day conditions and future SLR scenarios of 1.0, 1.5, and 2.5 m. The basis for these adopted scenarios is described in **PART B** and **PART C** for the floodplain and sea level rise risk assessments, respectively.

The flood hazards and associated risks are quantified for the 200-year flood event which is defined as an event having a 0.5% annual exceedance probability (AEP) or a 0.5% chance of occurring in any given year. For each flood scenario the **Flood Construction Reference Plane** (FCRP) has been computed and used for the risk analysis. For lakes and coastal areas, the FCRP includes both the “still-water” level due to tides, storm surge, and transient effects due to wave runup. The FCRP is used for assessing flood depths and resulting flood damage to infrastructure and assessing flood risk. This is not the same as the Designated Flood Level (DFL), which includes the tide and storm surge components but does not account for wave effects (FCRP = DFL + wave effects). Elevation data presented in this report are relative to Canadian Vertical Geodetic Datum 2013, unless specified otherwise. All historical floodplain maps, coastal flood studies and data published by Water Survey of Canada (WSC) for this study reference CGVD 1928 and have been converted for this project using mapping software available through Natural Resources Canada.

The Flood Construction Level (FCL) is defined as:

$$FCL = FCRP + FB \qquad \text{(Eq. 2)}$$

where FB is an adopted freeboard value

The FCL is appropriate for preparing floodplain maps and for establishing land-use by-laws to manage land use and is established by local governments by adding an allowance above the FCRP taking into account the, “potential for debris floods, debris flows, ice jams, debris jams, sedimentation, and other phenomena that are harder to predict” (APEGBC 2017). FCL’s have not been computed for this project.

3.3 Risk Assessment

3.3.1 Risk Definitions

For this study, vulnerability is assessed based on the number of elements within the FCRP for each flood hazard scenario. These elements are grouped by impact to people, the environment, the economy, infrastructure, and public sensitivity. This methodology is intended to meet the requirements defined by the NDMP for assessing risk due to climate change and to support the objectives of this study. The NDMP[1] defines a risk assessment as:

> *“the identification of the potential hazards that are present within a defined geographical area, and an assessment of their likelihoods of occurrence, potential impact(s) to people, economy, structures and networks, the natural environment, etc., and the community’s vulnerability with respect to the aforementioned elements.”*

The NDMP methodology differs from a standard risk assessment, which is defined by EGBC (2018) as “the combination of a probability of a flood event and the potential adverse consequences to human health, the environment, and economic activity associated with a flood event”. In some cases, risk is

[1] https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/ndmp/

defined by the expected annual damages (EAD), or the "average damage which can be expected to result from many years of [flood] experiences with conditions remaining unchanged" (US Army Corps of Engineers, 1991). Undertaking a risk assessment using the EAD approach would require a detailed assessment for a large geographic area, which is outside the scope of this study.

3.3.2 Risk Categories

The NDMP structures the risk assessment information template into the following five categories:

- **People and Societal Impacts**
  People and societal impacts are assessed based on the number of people impacted by a disaster or flood event. The framework specifically identifies the number of fatalities or injuries caused by the flood event, the number of people and the duration of displacement, and the ability of local health care resources to treat those injured in the flood.
- **Environmental Impacts**
  Environmental impacts are assessed based on the amount of damage caused to ecosystems and the scale of restoration efforts required after the flood event; damage is assessed based on air quality and water quality. The number of key ecosystems impacted, depth and degree of flooding, and impacts to soil quality are also considered indicators of environmental impact.
- **Local Economic Impacts**
  Economic impacts are assessed based on both direct and indirect losses within a community. Direct economic impacts include damages to homes, businesses, industrial structures, and infrastructure. Indirect losses could include lost income due to closure of business, impacts to transportation routes due to flooding, or productivity losses. Economic impacts are assessed based on the percentage of losses compared to the total economic output of the community.
- **Local Infrastructure Impacts**
  Infrastructure impacts are assessed based on the impact of closure of a service or system to the community. For example, road closures in rural areas may have a much smaller impact on a community compared to closure of a major roadway or highway. The duration of the closure or loss of the system is a crucial component for determining impact; examples of infrastructure included in risk assessments include transportation, energy and utilities, information and communications, health, food and water, and safety and security.
- **Public Sensitivity Impacts**
  Public sensitivity impacts are an indirect impact of flooding that manifest through lost confidence in the government and public officials after significant impacts on the community through the other four categories included in the risk assessment. Flood mitigation and effective land use planning are essential in reducing impacts to the community and maintaining trust in local government officials.

The flood risk assessment methodology used in this study is presented in **Section 3.3.3**.

3.3.3 Risk Analysis Methodology

The approach for this study was to categorize all available element information (described in **Section 3.4**) into the five NDMP flood impact categories described in **Section 3.4.1**, and to define a method for quantifying the exposure of each element. **Table 3-1** summarizes the elements included in the assessment and the method applied to quantify the flood exposure. Elements located within the given FCRP were selected using GIS and counted using a custom Python script. All features located within the present-day or future flood scenarios have been stored in a geodatabase that is included as a deliverable to the CVRD. Elements located within each flood scenario boundary were classified by jurisdiction.

This geodatabase provides a baseline dataset that should be updated over time as new information becomes available for the features included in the database, and as new features or previously unidentified features are identified within the flood scenario boundaries.

Future phases of work should be carried out to categorize other features by flood depth, and to examine other flood scenarios. It is assumed this phase of work would incorporate more detailed information about the potential vulnerability of exposed features to flooding to determine the impacts associated with different flood depth categories. Preliminary analyses were carried out for the present-day scenario to consider flood depth related impacts for properties, using the Cowichan Lake study region as an example to demonstrate how flood depth information could be integrated into more detailed flood hazard and flood risk studies. Flood depths and flood hazard intensity are discussed in more detail for the Cowichan Lake study region in **Section 5.5.**

Table 3-1: Summary of data sources analyzed in risk assessment and the method used to quantify exposure.

Impact Category	Elements Exposed	Method for Quantifying Exposure
People and Societal	Population	Number of people [1]
	Hospitals, long-term care facilities, elder care facilities	Number of health care facilities
	Emergency Centres	Number of fire, ambulance, police, coast guard, and community centres
	Residential, commercial, industrial buildings	Number of structures
	Schools, child care facilities	Number of schools
Environmental	Terrestrial ecosystem boundaries	Area of terrestrial ecosystems
	Sensitive ecosystems	Area of sensitive ecosystems
	Freshwater Atlas (FWA) Stream Atlas	Length of FWA streams
	Gas stations	Number of gas stations
Local Economic	Direct economic exposure	Dollar value ($CAD 2018) of property assessment values (building only using address data) [2, 3]
Local Infrastructure	Roads	Length of roads
	Bridges	Number of bridges with both causeways located in FCRP [4]
	Railway	Length of rail
	Utilities including BC Hydro, Fortis, Shaw, and Telus structures	Number of facilities for each stakeholder
	CVRD sewer structures	Number of sewer structures
	CVRD reservoirs	Number of reservoirs
	CVRD water structures	Number of water structures
	Culverts	Number of culverts
Public Sensitivity	Sensitivity of each jurisdiction	Total area exposed

Note:

1. The population per square meter was calculated for each census dissemination block. The area of the census block within the FCRP was calculated and converted to a population. Therefore, this method may be over-conservative for estimating the population exposed in rural regions.
2. Assessment values were provided by the CVRD for each lot; these assessment values were applied to the feature attributes of the building point feature class in order to calculate the value of structures exposed, compared to the total value of the land and structure.
3. Assumes the home is exposed and vulnerable to flooding if it is within the FCRP boundary; reduction of impacts to structures through implementation of flood-proofing is not considered as part of this study.
4. The bridge low chord elevation was not included as part of this study. The bridge is assumed to be exposed if one bridge approach is located within the FCRP.

3.4 Available Data

Spatial data used in the risk assessment was obtained from several sources including the CVRD, DataBC, Statistics Canada (Census 2016), and in several cases digitized by NHC using GIS and aerial photographs.

3.4.1 Topographic Data

A Digital Elevation Model (DEM) was developed for each study region using available LiDAR datasets provided by CVRD. For the Riverbottom Road study region, part of the DEM was created using contours digitized from the provincial floodplain maps (MoE 1997). The DEM data was used to delineate the boundary for each flood scenario, and each boundary was used for the flood exposure analysis.

3.4.2 Cadastral

Relevant cadastral data used in the risk assessment includes:

- CVRD electoral area and municipal boundaries and First Nations administrative boundaries – used to delineate jurisdictions;
- Address points for all the buildings in the CVRD, including land use classification (i.e. residential, commercial, industrial); and,
- Cadastral parcels and zoning bylaw areas in the CVRD.

GIS analysis approach was to assume buildings were represented by the location of each property address point provided by CVRD. A buffer around the points was not applied because in many cases the address point for a given property did not closely match the centroid of the building and there was a potential this approach would substantially overestimate the number of buildings within each flood scenario boundary.

The total number of points and total value of properties within each flood scenario boundary was selected, and classified by zoning type (residential, commercial, industrial). Where a given property parcel within the coastal region is located adjacent to a parcel zoned as industrial but has no zoning classification, it is assigned industrial zoning.

3.4.3 Property Assessment data

BC Assessment 2018 data was provided by CVRD in GIS (polygon feature class) format and assigned to property address points using an overlay analysis using gross property values. In some cases, more than one address is associated with a given property assessment polygon in which case the property value was split evenly amongst the property points. In other cases, the address points did not overlap with property assessment polygons.

Some property assessment values, particularly for some First Nations lands were inconsistent, with some address points having unique values and others showing the total land value for multiple address points.

For the latter case, each address point was assigned an equal portion of the total value. In other cases, data gaps exist in the property value database which results in some addresses being unassigned a property value and therefore underestimates the total value of land within the flood scenario boundaries.

3.4.4 Census

The population and census boundaries from 2016 were obtained from Statistics Canada (2016). Data was downloaded for the smallest available geographic area: dissemination blocks. Dissemination blocks are defined as areas "bounded on all sides by roads and/ or boundaries of standard geographic areas" (Statistics Canada, 2016). Statistics Canada rounds population counts to a base of 5 for any dissemination blocks having a population less than 15. The GIS analysis approach for this study was to multiply the 2016 census population count for each census block by the percentage of overlap within each flood scenario boundary to compute the total corrected population number for each flood scenario.

3.4.5 Infrastructure

Infrastructure and other physical items that are a component of the long term operation of service systems such as water, sewer, power, communications etc. are sometimes referred to as capital assets. These features were counted either as point, line, or polygon features by counting the number of each point or polygon, or total length of line within each flood scenario boundary. Relevant infrastructure or asset data available for the region and used in the risk assessment includes:

- Point features
  - Emergency centres – hospitals, fire, ambulance, police, coast guard, community centres, long term care, elder care facilities
  - Schools, child care facilities
  - Culverts
  - Utilities including BC Hydro, Fortis, Shaw, and Telus
- Line features:
  - Roads
  - Rail
  - Bridges (assumed to be flooded if either end of the bridge is located within the flood boundary)
- Polygon features:
  - CVRD sewer structures
  - CVRD water supply structures, including reservoirs

3.4.6 Environmental

Relevant environmental data was counted as either point, line, or polygon features by counting the number of each point or polygon, or total length of line within each flood scenario boundary. Available data for the region used in the risk assessment includes:

- Point features:
  - Gas stations were included under the environmental category and were interpreted as described in **Section 3.4.7**
- Line features:
  - Freshwater atlas streams
- Polygon features:
  - Terrestrial ecosystem boundaries
  - Sensitive ecosystems
- Raster features:
  - Land use classification obtained from the Annual Crop Inventory from GeoBC including urban and developed, agricultural, grasslands, shrubs, and forests, wetlands, and exposed and barren land.

3.4.7 Interpreted Spatial Data

The following spatial data was interpreted and digitized by NHC using available ortho-imagery, Google Maps, and Google Earth:

- Gas stations based on Google Earth and Google Maps search results
- Coastal and lake marinas in the CVRD
- Industrial buildings, such as ferry terminals and forestry assets including mills, ports, and warehouses, from ESRI World Imagery

3.4.8 Interpreted flood scenario boundaries

Analysis for each study region required a set of flood scenario polygons to be defined using flood extents computed for each scenario as the 'exterior' boundary and a defined shoreline or bankline as the 'interior' boundary. For mapping purposes, the 'interior' boundary is unnecessary to visually represent the flood boundary; therefore, the 'exterior' boundary was converted to a polyline that was smoothed and simplified to remove discontinuities, isolated areas that were less than 50 m^2. For the analysis component of this study, a different 'interior' boundary was used for each study region as follows:

- Cowichan Lake – Water elevation of 163 m, as derived from LiDAR.

- Shawnigan Lake – FWA lake shapefile.
- Coastline – FWA coastline shapefile was applied for most of the coastline; however, the boundary was shifted farther offshore in several areas in order to include islands, intertidal zones and industrial facilities that would otherwise be excluded. A contour elevation of -0.25 m, as derived from LiDAR, was used to delineate the three largest islands in the coastal study region.

3.4.9 Quality Assurance and Quality Control

A two-fold process was carried out for quality assurance and quality control components of this assessment. Quality assurance (QA) was integrated into all phases of the study, from the design of the analytical approach to the implementation of the analysis processes. Quality control (QC) focused on the quality of the results of each stage of the processing, and included the following primary checks:

- Visual check of flood scenario boundary lines for intersections, data gaps or other irregularities in GIS at a scale of 1:1,000
- Review of property address points and property values for those assessment polygons with multiple address points to ensure the total property value was split between the address points rather than assigning the total value to each. A manual check of the attribute table was carried out to confirm whether it matched the results of the processed data.
- Comparison of property address points that were not assigned an assessment value to the property assessment polygons and available ortho-imagery. In Cowichan Bay, 39 address points along Cowichan Bay Road, near Cowichan Bay marina, were not associated with a property assessment polygon and were manually adjusted to be incorporated into the adjacent assessment polygons located on the waterside of the road. Other areas, such as a substantial portion of Cowichan Tribes land west of Tzouhalem Road, are assumed to be gaps in the assessment database and were not assigned values. In Town of Lake Cowichan, gaps were manually infilled using data obtained from the BC Assessment website.
- Review of results of data analysis to ensure the total quantities of each ESRI File Geodatabase feature class produced for the project for each flood scenario matches those that were processed using spreadsheets and presented in the report tables.

During the checking process, a discrepancy between the GIS output data totals and spreadsheet results indicated whether an error was made in one of the two methods of processing. All identified errors were reviewed and corrected during the QC process. For risk categories measured by area or length, small discrepancies remain between the GIS output data and spreadsheet results due to the different methodology used for each calculated total quantity. Areas and lengths were calculated over the whole geographic region for the GIS output data; whereas, the spreadsheet results calculated the totals by summing the computed values for each electoral district. Small rounding errors are compounded when summing the totals for each electoral district, particularly where there are several electoral districts within the study region. Values between the two approaches were within 0% to 1% of one another, typically amounting to a few hectares or a few meters difference.

All calculated areas for raster features are derived from the area of raster cells that intersect the flooded area, and as such are multiples of the raster cell area. Raster datasets were checked by comparing computed areas to a manual check of the counted number of rasters in a given jurisdiction and factoring in the grid cell resolution (30 m by 30 m). This approach yielded few discrepancies, with the largest less than 1% (or <0.01 ha) difference in total computed area of terrestrial ecosystem for the extreme scenario. Most results had either no discrepancy between the two computational approaches or the discrepancy was less than 0.1%.

3.5 Study Limitations

There are several important limitations in the risk assessment. These are grouped into three main categories: 1) general limitations associated with the uncertainty surrounding climate change scenarios, 2) limitations associated with the available data, and 3) limitations associated with the defined study regions.

3.5.1 Limitations of Climate Change Projections

Although there is a general consensus about the direction of future average climatic conditions (PCIC, 2009), the level of uncertainty increases appreciably when inferring future changes to extreme weather events and changes to peak river discharges in large, complex watersheds (Kundzewicz et al., 2013). Similarly, estimates of future SLR are highly uncertain, extending over a range of approximately 2 m (NOAA, 2017, Parris et al., 2012). Therefore, the scenarios used in this analysis do not represent accurate predictions of future changes, but describe future plausible conditions based on the available level of understanding today.

3.5.2 Limitations of Available Data

A key limitation to the risk assessment component of this study is the focus on element inventory information provided by CVRD or identified from desk-top based analysis and background data review. Future phases of work should include concentrated efforts to work with member municipalities, First Nations, other key stakeholders, and community members to identify elements that may not yet be incorporated into database and to identify economic, environmental, and societal values for flood exposed elements.

Another limitation to the risk assessment component is the level of detail for some of the stakeholder utilities exposed to flooding. Stakeholders will have a more thorough understanding of the flood risk pertaining to individual structures and should be involved in further discussion of mitigation and exposure to flooding. For instance, elements exposed to flooding may be vulnerable only beyond a certain water depth or velocity threshold, and others may not be vulnerable at all.

Furthermore, impacts associated with damaged infrastructure may extend beyond the flood affected area or may be limited to part of the flood affected area. For instance, a flooded sewer lift station or BC Hydro underground vault that becomes damaged will impact a service area that may be outside areas directly affected by flooding. Other limitations are associated with data gaps or resolution:

- The available LiDAR data is incomplete at the eastern end of Cowichan Lake and along portions of Riverbottom Road. Therefore, the present analysis underestimates the risks in these regions.
- The assessment is based on multiple LiDAR datasets, with acquisition dates ranging from 2008 to 2016. Variable approaches have been used for data collection, verification, and processing; therefore, the quality of the data and preliminary mapping of flood scenarios is inconsistent.
- The population count methodology may misrepresent population in rural areas because the tally is based on percent of area of census block within the FCRP; a portion of the census block may be flooded but no people may live in that area. However, along Cowichan Lake, the census blocks often align with the shoreline where most people live.
- It is assumed a building exists for each address point in the property database. However, the address data points frequently do not accurately represent the location of the primary building. Furthermore, there are many cases where more than one building is located on a given property. For instance, a commercial property designated for mobile home living would have many buildings located on the lot, but only one address. Another example includes industrial properties with many buildings used for a variety of specific purposes. It is also possible that an address point may exist in locations where a building does not exist.

  A cursory review of all four study regions was carried out using available imagery to interpret additional buildings to include in the assessment; however, site verification and detailed mapping of additional buildings was outside of the scope of this overview level study and any adjustments made to account for multiple buildings on a given property should not be considered exhaustive. Furthermore, many residential properties appear to have boat houses or accessory buildings in addition to the main building. It is unclear whether these buildings are livable or of significant value therefore they were not included in this assessment. For cases where more than one building was mapped for a given property, the value of the property was split between the points.
- Property assessment data is sometimes inconsistent, incomplete, and difficult to interpret with certainty, particularly along Cowichan Bay Road near Cowichan Bay Marina, in Town of Cowichan Lake, and for First Nations lands. The approach applied for evaluating the value of exposed properties is described in **Section 3.4.3**. <u>There is a strong possibility that property exposures are under represented for First Nations land</u>, and manual adjustments to infill gaps in assessment data and assign property values to ‘null value’ address points were not exhaustive. A more accurate assessment for these lands would require input from First Nations Land Administrators.
- The exposure assessment assumes the location of the point features derived from the address feature class represents the location of the primary building on the land parcel. This approach is

considered appropriate for this overview level assessment; however, more accurate representation of buildings may require manual digitizing of building locations using available ortho-imagery and application of an appropriate point buffer or alternately each building could be delineated as a polygon feature.

- Municipal assets for Town of Lake Cowichan were not included in the datasets provided for the Cowichan Lake study region. Some assets may be exposed yet not identified in this study.
- Annual Crop Inventory raster data was analysed in GIS using an 'extract by mask' processing tool that clipped a given raster to each flood scenario boundary polygon only if the centre of that raster cell falls within the polygon. As such, areas computed using the raster data are slightly smaller than areas computed using other polygon features.
- Bridge locations were defined using information from DataBC. Spot checking this data with ortho-imagery identified some cases where bridges did not align with the physical location identified in the imagery; offset by as much as 50 m. Some bridges located within a flood scenario boundary using the digital dataset may actually be outside the flood scenario boundary or vice-versa. More accurate mapping of bridges would require a more detailed review of the database; editing or digitizing bridge locations using available ortho-imagery; and supplemented as appropriate with field confirmations.
- Spot checking the 'interior' boundary with available ortho-imagery identified some cases where the boundary excluded discrete areas along the waterfront:
  - Cowichan Lake study region: occasional small areas (mostly <1 ha), and one larger area (~ 6 ha) along the southeast of the lake. These excluded areas appear to be mostly wetlands. In three instances, property address points within the Cowichan Lake study region were located outside of the flood scenario polygons (i.e. located lakeward of the 'interior' boundary), and these were manually adjusted to lie landward of this boundary.
  - Shawnigan Lake study region: occasional small areas (< 0.5 ha) that appear to be forested or narrow slivers along lake frontages.
  - Coastal study region: narrow strips (≤10 m wide) of mostly forested, undeveloped land, or bare land within industrial zones. In addition, GIS interpolation of a 500 m long strip within the DEM, resulted in the exclusion of a 30 m to 60 m wide swath of bare land, north of Cowichan Estuary and south of Mount Tzouhalem.

    In one instance a property address point in the Cowichan Bay electoral area was located outside the 'interior' boundary and it was manually adjusted to lie within the flood scenario boundaries. The property associated with this address point is at the Cowichan Bay boat launch. The value of the lot was included in the assessment; however, based on a review of Google Street View it is assumed this address point is not associated with a building (this property includes a sewer lift station, which is already accounted for in the public utility category).

The discrepancies are considered negligible for the purpose of this study. More accurate mapping of the shoreline or bankline would require a detailed review of the database; editing or digitizing the defined 'interior' boundary using available ortho-imagery; and supplemented as appropriate with field confirmations.

3.5.3 Limitations of Defined Study Regions

Riverine floodplains in the lower reaches of the Cowichan River – Koksilah River floodplain and the Chemainus River – Bonsall Creek floodplain are not part of this study. Exclusion of these areas considerably under-represents regional flood exposures. Future studies should incorporate more complex interactions between the riverine and coastal flood processes. The boundaries of the riverine floodplains may not be substantially affected by backwatering effects associated with SLR; however, noticeable changes in flood depths are expected.

PART B FLOODPLAIN RISK ASSESSMENT

4 CLIMATE CHANGE SCENARIOS

Downscaled climate projections were developed by the CVRD with the support of the Pacific Climate Impacts Consortium (PCIC) in 2017 to provide strategic planning guidance for the CVRD (CVRD 2017). The analysis was conducted for three Green House Gas (GHG) emission scenarios, RCP[2]2.6, RCP4.5 and RCP 8.5. Results of the "business as usual" scenario (RCP8.5) are reported in detail in that report, while results for the other scenarios are available as a download. An ensemble of 12 climate models were chosen for that study to represent the range of projected change in each climate parameter. For each parameter, both the mean and the 10th to 90th percentile range are reported. Due to the uncertainties associated with climate projections, a conservative approach to risk management adopted by the CVRD is to plan for the 10th or 90th percentile value, rather than for the mean.

4.1 Temperature and Precipitation

At a broad, regional level, the climate in the region is expected to experience the following changes described below and in **Table 4-1**:

- More precipitation in the fall, winter and spring
- A decrease in snowpack
- More intense extreme events (including precipitation)

Table 4-1: Projected climate change in region (CVRD 2017).

Climate Variable	Change by 2050s	Change by 2080s
Higher winter temperature	+2.4 °C (1.3 °C to 3.3 °C)	+4.4 °C (2.6 °C to 6.4 °C)
April 1st snowpack	-84.7% (-74.6% to -91.5%)	-99.1% (-96.9% to -99.7%)

Note: Mean changes from present-day values are shown. 10th and 90th percentile values are included in parenthesis.

A sub-regional analysis was also carried out to characterize more localized changes within the region. The drainage into Cowichan Lake was identified as part of the "Water Supply Watersheds", while Shawnigan Lake was identified as part of the "Developed Area Watersheds" (**Figure 4-1**) . Projected impacts to wet-season precipitation (autumn/winter) are summarized in **Table 4-2**. No projections were made on how these meteorological changes would affect runoff and peak discharges in the watersheds.

[2] RCP refers to Representation Concentration Pathway, which is a greenhouse gas concentration trajectory adopted by the International Panel on Climate Change.

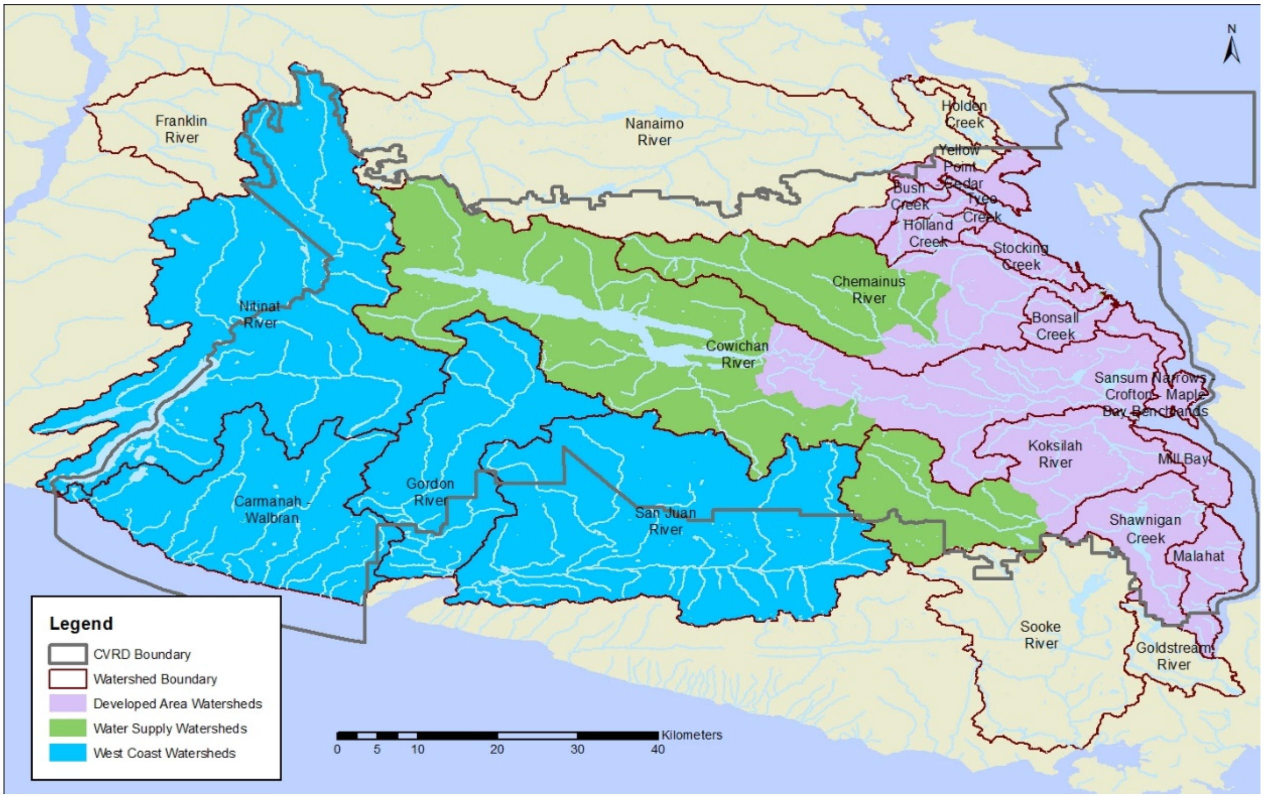


Figure 4-1: Watershed sub-regions for Climate Projections.

Table 4-2: Projections of extreme rainfall in the sub-region (CVRD 2017).

Precipitation Parameter	Cowichan Lake 2050s	Cowichan Lake 2080s	Shawnigan Lake 2050s	Shawnigan Lake 2080s
5-day Maximum Precipitation	20% (4% - 37%)	43% (14% - 60%)	14% (5% - 29%)	33% (8% - 47%)
1-day Maximum Precipitation	14% (2% - 24%)	24% (8% - 35%)	10% (2% - 19%)	18% (6% - 28%)
1:20 Year wettest day precipitation	38% (11% - 59%)	49% (27% - 70%)	23% (8% - 41%)	34% (13% - 34%)

Note: Mean changes from present-day values are shown. 10th and 90th percentile values are included in parenthesis.

4.2 Hydrology

A previous climate change assessment was described in KWL (2011a) using results of an older climate change assessment carried out by PCIC (2009). The PCIC output consisted of average monthly changes to temperature and precipitation that were intended to be representative of conditions in the 2050s. KWL (2011a) input these monthly climate variables input into a simplified hydrological model to estimate corresponding changes to monthly average discharges at the Cowichan River at Lake Cowichan WSC gauge location. Wet-season monthly discharges increased by between 11% (January) and 49%

(December), and average increases over the five-month period from October to February amounted to 20%. These values are indicative of potential changes to runoff but are not necessarily representative of impacts to peak flow conditions. Additionally, the PCIC results are lower than more recent projections that show higher rates of change which suggests the results from this assessment are outdated. Additional climate and hydrological modelling would be required to improve these projections, and are not included in the scope of work for this study.

APEGBC (2017) and EGBC (2018) discuss accounting for climate change in flood predictions and describe in a general way some of the changes that are expected. The guidance includes incrementing the design floods by 10% in the absence of more detailed information. Other, indirect climate change effects such as wildfire or beetle infestation could substantially alter the forest canopy coverage, which could substantially increase run-off rates. While there is a clear need to provide quantitative information for flood management and planning, the underlying projections of climate change are subject to large and unquantifiable uncertainty. Main sources of uncertainty include:

- Unknown future emissions of greenhouse gases
- Uncertain response of the global climate system to increases in greenhouse gas concentrations
- Incomplete understanding of regional manifestations that will result from global changes

The analysis by Kundzewicz et al. (2013), which is based on a vast body of literature including the IPCC SREX[3] report on climate extremes, concluded:

"presently we have only low confidence in numerical projections of changes in flood magnitude or frequency resulting from climate change".

Given these limitations and the limited hydrological analysis that has been carried out to link climate and runoff, three plausible future scenarios have been adopted for this study:

- 200-year flood discharge + 10%
- 200-year flood discharge + 20%
- 200-year flood discharge + 40%

In 2008 an Integrated Flood Management Plan was prepared for the lower Cowichan-Koksilah River (NHC, 2009) and include Year 2100 climate change scenarios based on an assumed 15% increase in flood discharge on the Cowichan River and 20% on the Koksilah River. The analysis presented herein covers a wider range of conditions, but is generally consistent with, these earlier assumptions.

[3] IPCC SREX refers to the Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.

4.3 Flood Construction Reference Plane Computation

As described in **Section 3.2**, the FCRP is a function of the DFL and wave run-up. For the Cowichan Lake and Shawnigan Lake study regions, the FCRP was computed by combining the estimated lake level for a 200-year lake inflow event with the computed wave run-up effects for a coinciding designated wind event (described in **Section 5.3.5** and **Section 6.3.4** for Cowichan Lake and Shawnigan Lake study regions, respectively). For Cowichan Lake study region, wave run-up was computed by dividing the shoreline into segments and assigning the midpoint slope value of each segment for wave run-up computations. Each segment was then assigned a wave run-up category and summed to the DFL to compute the FCRP. A single value was applied for Shawnigan Lake, which has a limited fetch and wind generated wave potential compared to Cowichan Lake.

5 COWICHAN LAKE STUDY REGION

This study region includes the entire floodplain around Cowichan Lake.

5.1 Overview

The watershed of Cowichan Lake consists of mountainous forest and has a total area of 589.5 km^2. Cowichan Lake has a surface area of 61.7 km^2. The largest community is Town of Lake Cowichan, which is located at the east end of the lake. Other communities include Youbou, Caycuse, and Honeymoon Bay. The highest inflows and lake levels generally occur in November, December, and January as a result of heavy rainfall or rain on snow processes.

The Cowichan Lake weir was licensed in 1956 to BC Forest Products, in order to allow water to be drawn out of the river near Duncan and piped to the Crofton pulp mill. The weir only begins to store water once the lake drops below the crest of the weir in the spring. During the rest of the year, water flows freely over the weir and water levels on Cowichan Lake are controlled naturally. **Figure 5-1** shows the weir and flood gates. **Figure 5-2** illustrates how the hydraulic control is situated downstream of the weir in the narrow constriction at the old trestle bridge during the flood season.

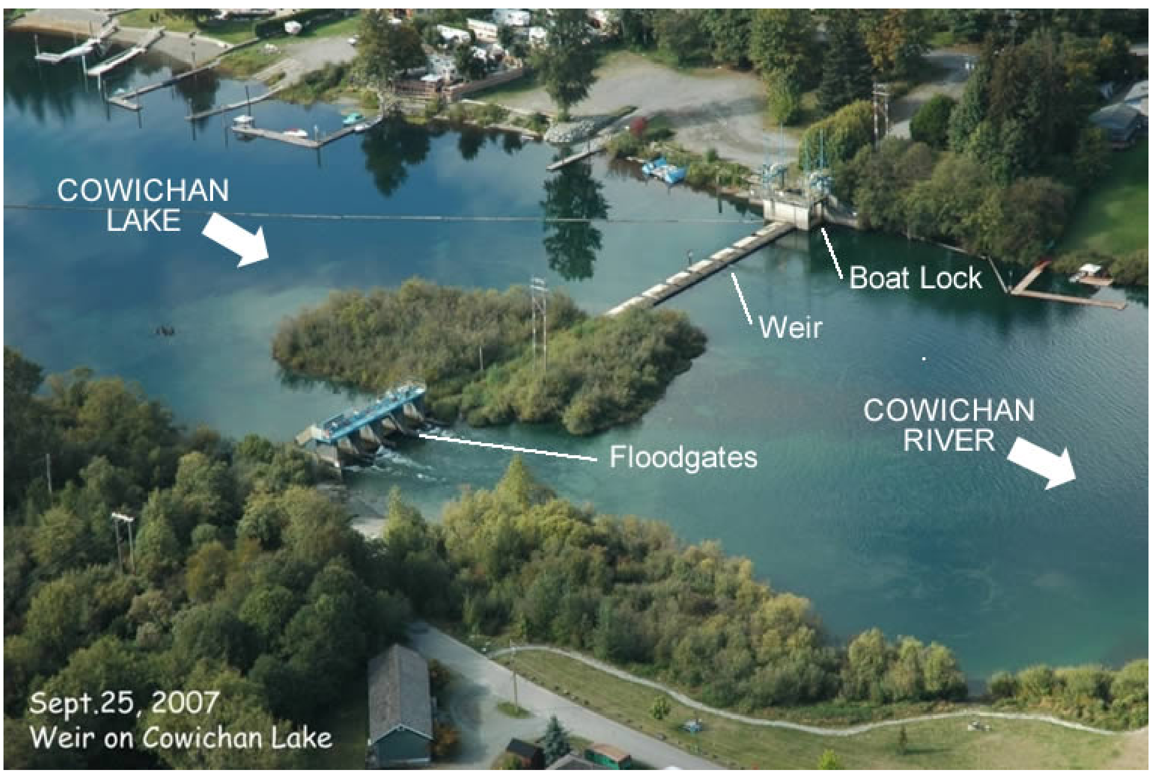


Figure 5-1: Cowichan weir, from Cowichan Watershed Board. (http://www.cowichanwatershedboard.ca)

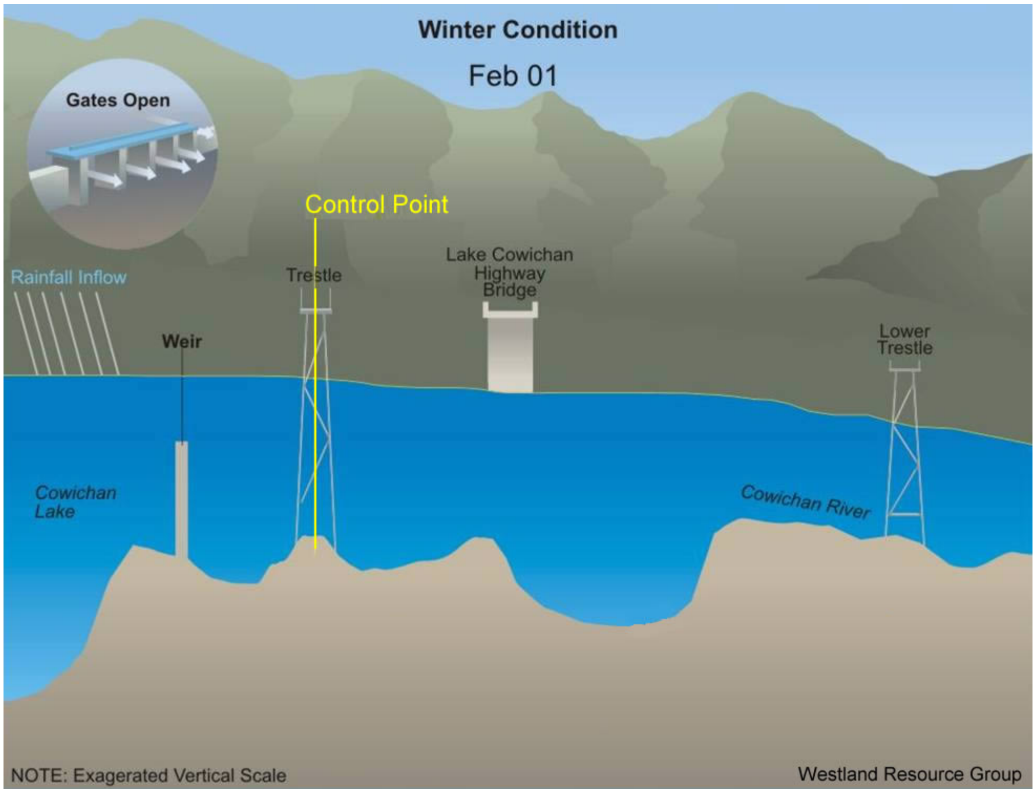


Figure 5-2: Flow control in the vicinity of Cowichan weir during the flood season (November-February), from Cowichan Basin Water Management Plan (Westland 2007). (http://www.cowichanwatershedboard.ca/content/cowichan-lake-weir)

5.2 Previous Studies

The BC Ministry of Environment (MoE) published floodplain maps for Cowichan Lake and a portion of the Cowichan River below the lake outlet in 1984. **Figure 5-3** shows the extent of the six floodplain map sheets. The published FCL on Cowichan Lake is 167.53 m, which includes an undetermined amount of freeboard. Assuming a 0.6 m freeboard, the corresponding FCRP is 166.93 m. FCRP values at the river downstream of Cowichan Lake weir through the town were 0.3 m to 1.4 m lower than at the lake.

MoE reported that there have been requests to revise the flood maps because they show an FCL that is considerably higher than that of historical observations and experience (MoE, 1993). For example, the highest recorded lake level in 1968 was 165.59 m, which is 1.4 m lower than the adopted FCRP. MoE indicated that details for the basis of the original estimate were not available. This issue was never resolved, and it was decided to retain the original floodplain maps without revision until better information came available.

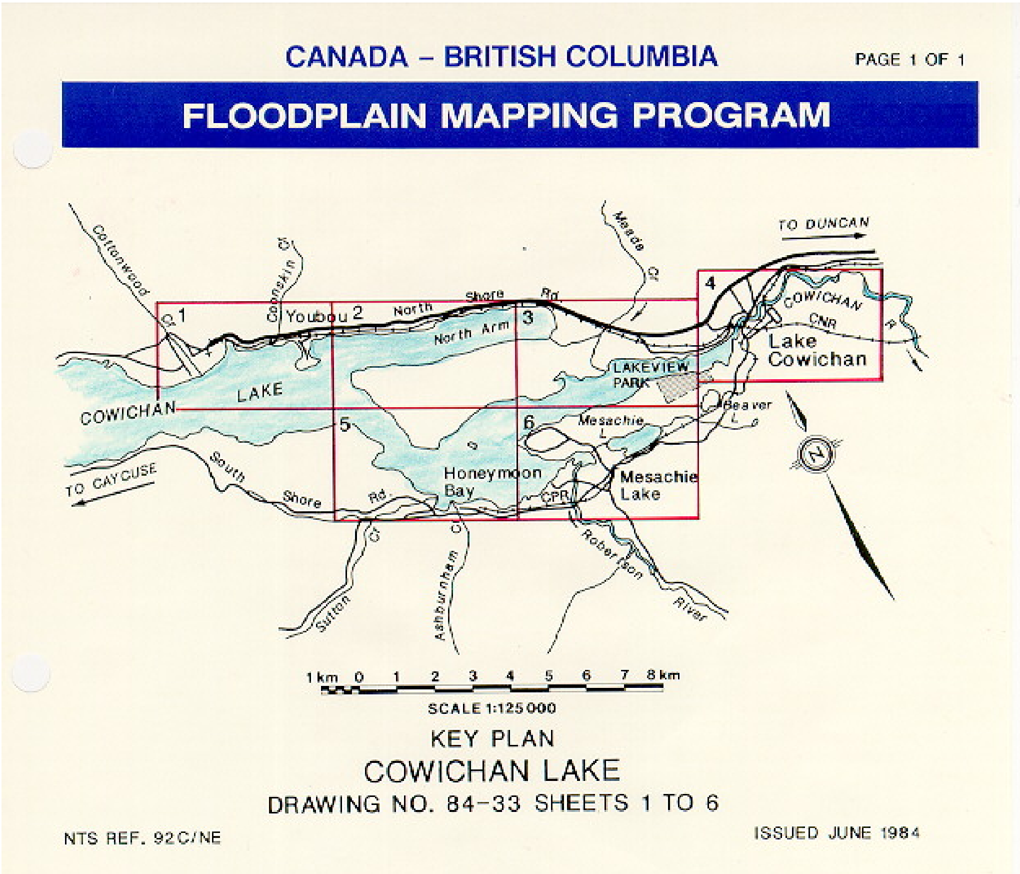


Figure 5-3: Floodplain map sheets on Cowichan Lake and a portion of Cowichan River.

5.3 Flood Hazard Assessment

5.3.1 Review of Available Data

Table 5-1 lists the hydrometric information available for assessing flood levels on Cowichan Lake. Only water levels are published from the gauge on the lake (08HA009). Discharges and water levels are available from the gauge on the river below the lake outlet (08HA002).

Table 5-1: Available hydrometric data on Cowichan Lake.

Gauge	Name	Period of Operation
08HA009	Cowichan Lake near (Town of) Lake Cowichan	1913-1921, 1952-2018
08HA002	Cowichan River at (Town of) Lake Cowichan	1913-1921, 1940-2018

There are 62 years of relatively complete records available for assessing flood conditions on the lake. The main limitation of the data is that prior to 2009 the lake levels were measured manually once per day. Since 2009, water levels have been recorded continuously.

A review of the hydrometric data showed that most extreme flood events have occurred before 1980. For example, the historical flood of record on Cowichan Lake is believed to have occurred in 1935, although none of the gauges were operating at that time (MoE, 1993). Furthermore, four of the five highest recorded levels on Cowichan Lake and discharges to the Cowichan River all occurred before 1980. The last moderately high flood event occurred in 1992. A trend analysis of annual maximum values showed there are strong cyclical variations over periods of decades (commonly referred to as the Pacific Decadal Oscillation), but no systematic trend for increasing peak discharges or water levels could be discerned.

A flood frequency analysis was conducted on the long-term lake level gauges (08HA009) and on the river gauges below the lake outlets (08HA002). This analysis is summarized in **Figure 5-4** and **Figure 5-5**. **Table 5-2** summarizes these results. The estimated 200-year lake level is similar to previous estimates made by MoE (1993) and KWL (2010), but substantially lower than the 1984 floodplain mapping FCRP.

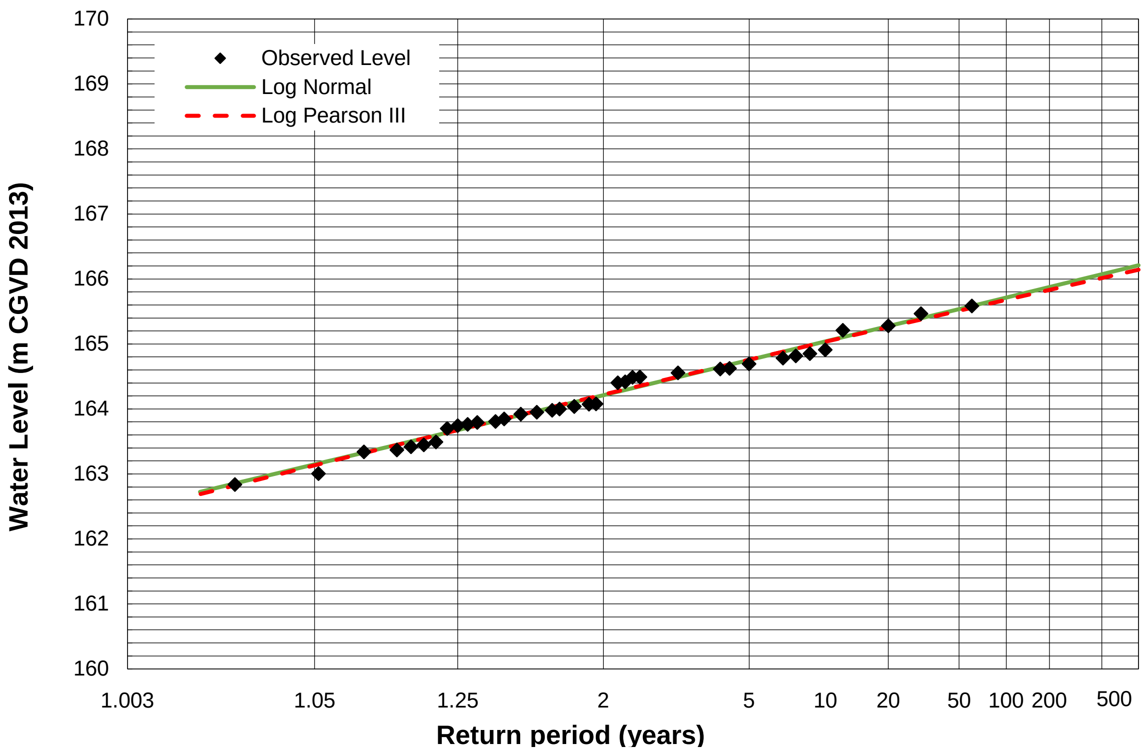


Figure 5-4: Frequency analysis of annual maximum water levels on Cowichan Lake (Gauge 08HA009).

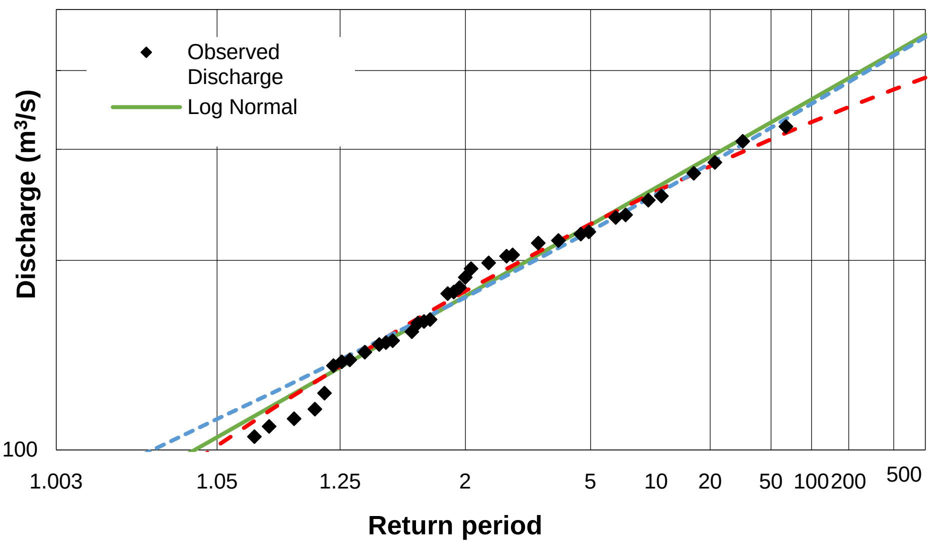


Figure 5-5: Frequency analysis of annual maximum discharges at outlet of Cowichan Lake (Gauge 08HA002).

Table 5-2: Estimated peak lake levels and Cowichan River outflows (historical conditions) based on WSC measurements.

Return Period (Years)	Lake Level (m) 08HA009	Outflow from Lake (m^3/s) 08HA002
200	165.9	365
100	165.7	350
50	165.5	320
20	165.3	285
10	165.0	260
2	164.2	180

5.3.2 Methodology For Assessing Climate Change Effects

Peak lake levels during a flood event are governed by three factors:

- The inflow hydrograph to the lake
- The elevation of the lake at the start of the flood event
- The hydraulic characteristics at the outlet of the lake which controls the relation between lake level and outflow discharge

The available WSC hydrometric data record only lake levels and discharges at the outlet of the lake, not inflows to the lake. Therefore, a flood routing analysis was carried out using the recorded outflows, lake levels and lake storage characteristics to generate a time series of synthetic inflow hydrographs.

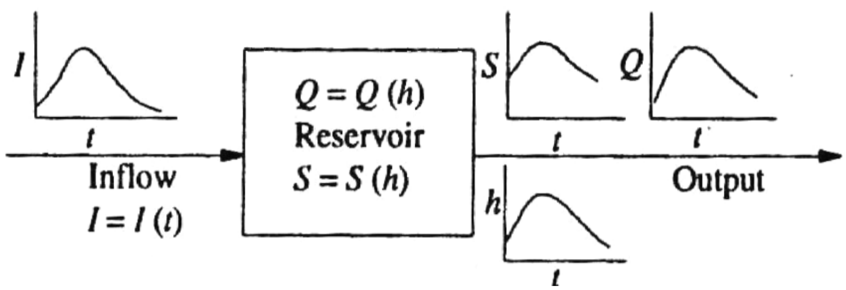
Daily lake inflows during each year of historical record were estimated as follows:

$$I - O = \frac{\Delta S}{\Delta t} \quad \text{or } I = O + \frac{\Delta S}{\Delta t} \qquad \text{(Eq. 3)}$$

where I is the inflow discharge to the lake, O is the outflow discharging from the lake and ΔS is the change in lake storage volume in time interval Δt.

A flood frequency analysis was carried out using the synthetic record to estimate the magnitude and frequency of maximum daily inflows (I) for a range of return periods (2-year to 500-year). The adopted 200-year daily inflow was used as an input parameter to the lake routing analysis to compute the 200-year lake level and outflow discharge. This involves re-arranging Equation 3, using the adopted 200-year inflow hydrograph as the known variable to solve for the corresponding outflow and lake level, illustrated conceptually in **Figure 5-6**.

$$O = I - \frac{\Delta S}{\Delta t} \qquad \text{(Eq. 4)}$$



For reservoir routing, the following data must be known:

1. Storage volume *vs* elevation for the reservoir;
2. Water-surface elevation *vs* outflow and hence storage *vs* outflow discharge;
3. Inflow hydrograph, I – I(t); and
4. Initial values of S, I, and Q at time t=0.

Figure 5-6: Schematic reservoir routing analysis.

The estimated present-day 200-year inflow value (I_h) was adjusted to account for the future climate change effects as follows:

$$I_f = KI_h \qquad \text{(Eq. 5)}$$

where I_f is the future 200-year inflow discharge and K is the projected increase in discharge due to climate change.

The value of K applied for the analysis of future scenarios ranged from 1.1 to 1.4 (corresponding to an increase of between 10% and 40%), and the lake routing analysis was repeated for each climate change scenario to compute the resulting outflow discharge and corresponding lake level.

5.3.3 Hydrological Analysis – Present Conditions

Lake inflow hydrographs were estimated for 62 years of coincident observed daily lake levels and river outflows. The annual maximum daily inflow was then determined and used in a frequency analysis. Log Pearson Type III, Log Normal and Gumbel distributions were fitted to the data. **Figure 5-7** summarizes the results of this analysis. A visual best-fit was used to select the final adopted values. The estimated 200-year inflow (900 m^3/s) is 2.5 times larger than the corresponding outflow. This illustrates the large effect of the lake in attenuating peak flows on the lower Cowichan River.

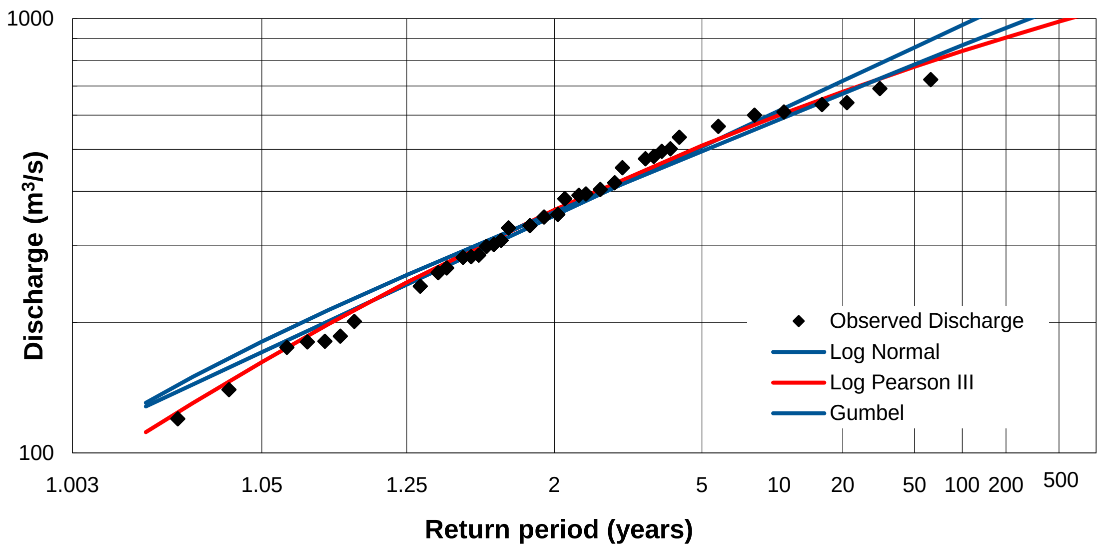


Figure 5-7: Frequency analysis of computed daily inflows to Cowichan Lake.

5.3.4 Hydrological Analysis – Climate Change Scenarios

Figure 5-8 and **Figure 5-9** show simulated hydrographs for the estimated present-day 200-year flood and a future scenario with flows increased by 10%. **Table 5-3** summarizes the results of this analysis for the historical flood of record in 1968, the estimated present-day 200-year flood and the three future scenarios. This table illustrates two points. First, the estimated present-day 200-year flood level is 0.35 m higher than the flood of record which was experienced in 1968. Secondly, the future 200-year flood scenarios range from +0.33 m to +1.27 m higher than the estimated present-day 200-year flood level.

Table 5-3: Estimated peak lake levels and Cowichan River outflows based on available hydrometric records.

Simulated Inflow Condition	Inflow (m^3/s)	Outflow (m^3/s)	Lake Level (m)	Increase due to Climate Change (m)
1968 flood of record	690	317	165.55	---
200-year present-day	900	358	165.90	0.00
200-year + 10%	990	398	166.23	+0.33
200-year + 20%	1,080	439	166.55	+0.66
200-year + 40%	1,260	521	167.17	+1.27

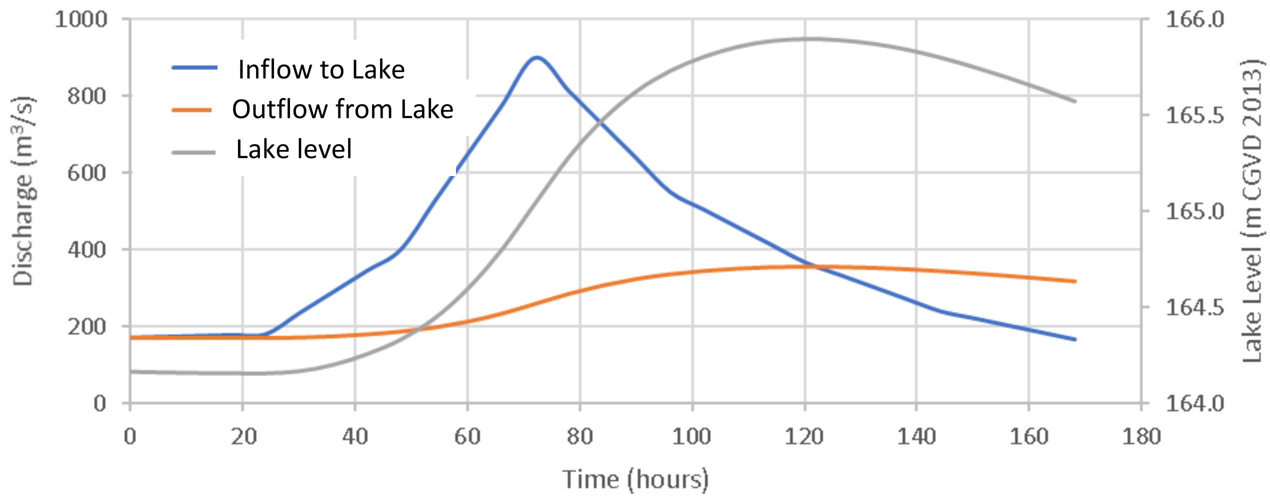


Figure 5-8: Computed lake level and river outflows during the projected 200-year flood event.

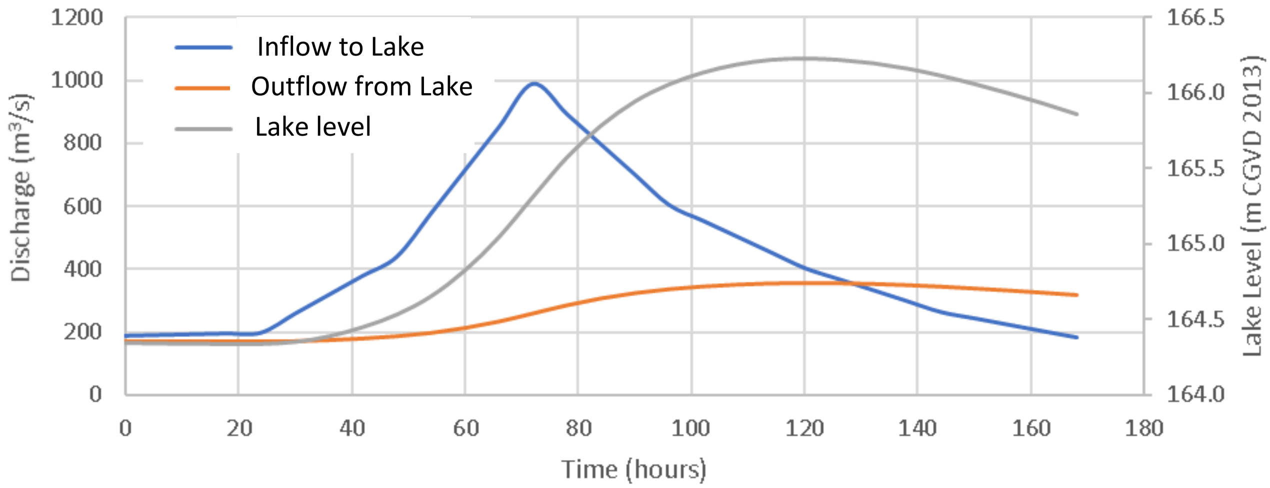


Figure 5-9: Computed lake level and river outflows during the projected 200-year flood event. The estimated 200-year lake inflow hydrograph was increased by 10% to account for a moderate increase due to climate change.

5.3.5 Wave Effects

Wind-generated waves on Cowichan Lake can generate wave runup effects when they break, which increases the water level above the computed still-water level presented in **Table 5-3**. Wind-generated waves in the lakes depend mainly on the maximum wind speed and fetch distance that the winds can blow across. Based on a review of historical water level and wind data, it was concluded there is a low likelihood of a coinciding 200-year lake level and 200-year wind event; therefore, wave hindcasting was carried out to estimate the significant wave height (H_s) and wave period (T_p) during a 1:10 year wind event. Wave heights were calculated for the two dominant wind directions (westerly and easterly) to represent the maximum potential wave height along the shoreline for the design event.

The FCRP was defined spatially along the shoreline for each of the four scenarios (present-day and three future) as:

$$FCRP = WL + R \qquad \text{(Eq. 6)}$$

where WL is the estimated 200-year lake level and R is the estimated local wave runup during a coinciding 1:10-year wind event.

The Simulating Waves Nearshore (SWAN) model was used to calculate significant wave height, and wave run-up was calculated using empirical equations developed by Stockdon et al. for a beach (Equations 7, 8, and 9). It is a phased-average model that uses the action balance equation to predict the evolution of the wave action density spectrum in space and time. An example of the significant wave height for a 10-year north-westerly and south-easterly wind events are shown in **Figure 5-10** and **Figure 5-11**, respectively. The significant wave heights vary substantially along the shoreline for the north-westerly and south-easterly wind scenarios, ranging from 0.1 m to 1.0 m with an average wave height of 0.5 m.

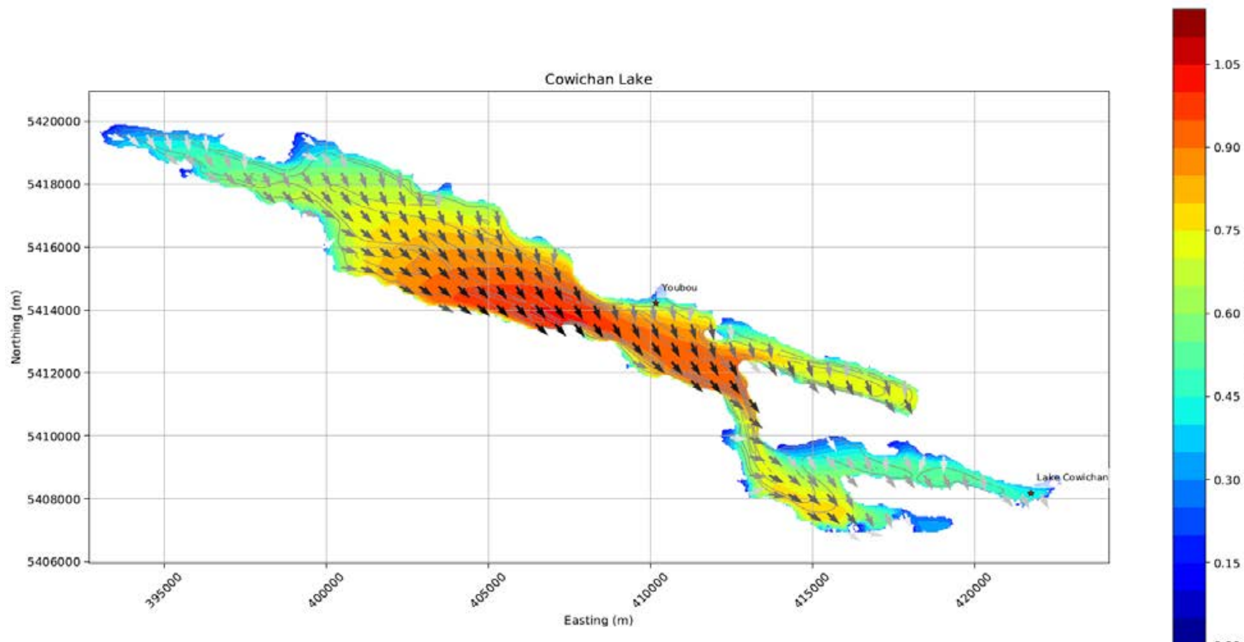
$$\varepsilon_0 = tan\beta * \left(\frac{H_0}{L_0}\right)^{-\frac{1}{2}} \quad \text{(Eq. 7)}$$

$$R_{2\%} = 0.043(H_0L_0)^{0.5} \text{ for ε0 < 0.3} \quad \text{(Eq. 8)}$$

$$R_{2\%} = 1.1\left[0.35tan\beta_f(H_0L_0)^{0.5} + \frac{\left[H_0L_0\left(0.563tan\beta_f^2+0.004\right)\right]^{0.5}}{2}\right] \text{ for ε0 >= 0.3} \quad \text{(Eq. 9)}$$

Where,

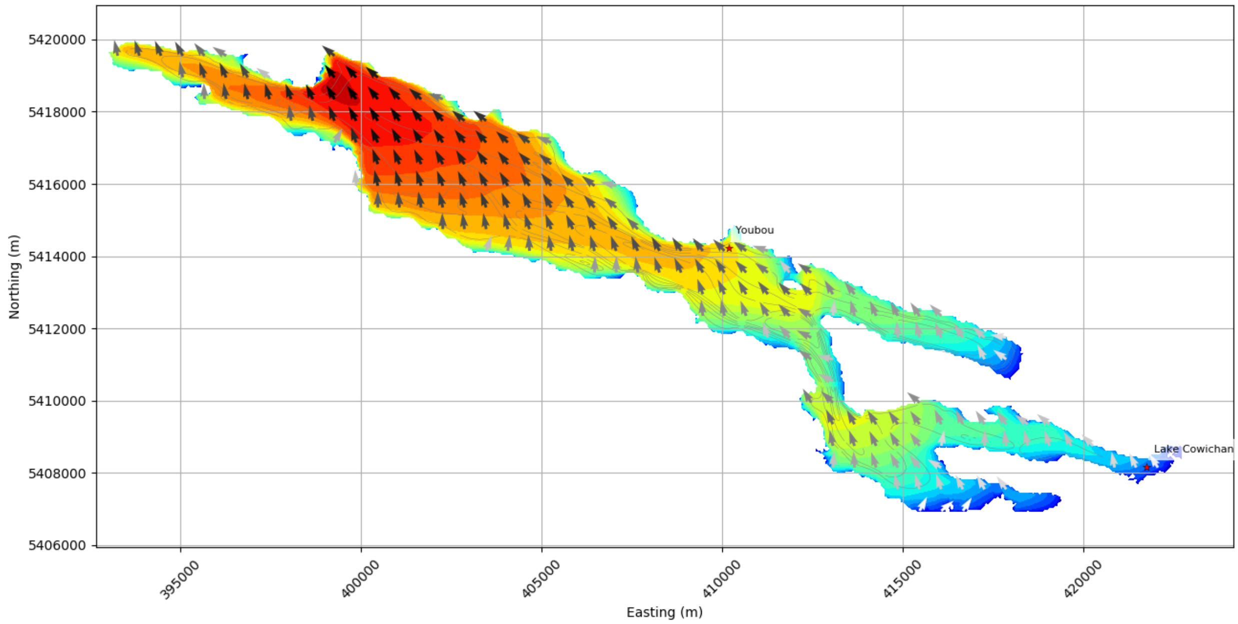
- β is the beach slope
- H0 is the significant wave height (m)
- L0 is the deep-water wave length (m)
- R2% is the wave run-up exceeded 2% of the time



Note:

1. Directional vectors are the mean wave direction
2. Vectors are shown for every 12 grid cells

Figure 5-10: Significant wave heights calculated for Cowichan Lake for a north-westerly 10-year wind event.



Note:

1. Directional vectors are the mean wave direction
2. Vectors are shown for every 12 grid cells

Figure 5-11: Significant wave heights calculated for Cowichan Lake for a south-easterly 10-year wind event.

Local wave runup was calculated for 1 km reaches along the shoreline of Cowichan Lake and converted to three classes of wave effects as shown in **Table 5-4** and the maximum computed run-up for the two simulated wind events are presented in **Figure 5-12.**

Table 5-4: Range of wave effects for shoreline reaches along Cowichan Lake.

Class	Wave Effects (m)
1	0.23
2	0.64
3	1.29

The Cowichan Lake FCRP boundary was calculated along the shoreline using GIS. The base case FCRP for Cowichan Lake used in the risk assessment was the present-day 200-year still water lake level plus wave effects (based on location) as shown in **Table 5-3** and **Table 5-4**, respectively. This is lower than the FCRP derived from the 1984 floodplain mapping (using the assumption described in **Section 5.2**); however, it is similar to previous estimates made by MoE (1993) and KWL (2010) and is considered to be a more appropriate representation of the present-day Cowichan Lake flood hazard. **Photo 5-1** illustrates the computed FCRP's for this study, and shows the MoE (1984) FCRP for context.

Photo 5-1: Illustrative example of Cowichan Lake study region FCRP's for present-day and future scenarios and 1984 (MoE) FCL at Central Park, Honeymoon Bay. The 1984 reported 200-year FCRP is shown for context.

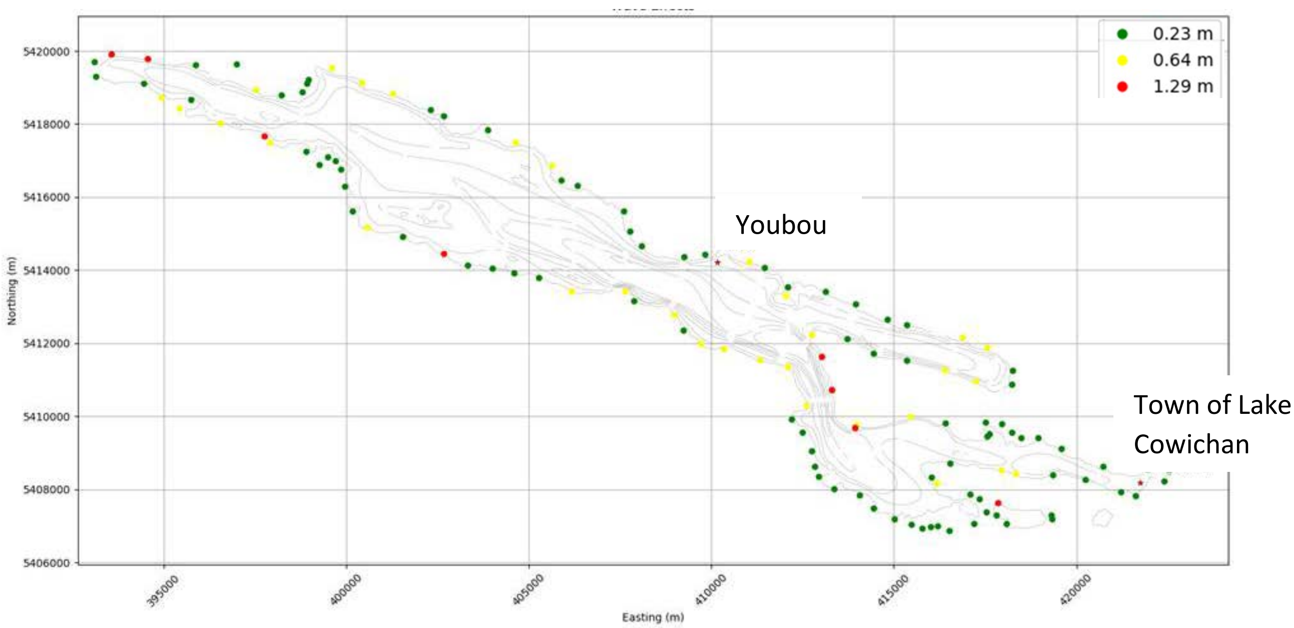


Figure 5-12: Computed maximum run-up for the north-westerly and south-easterly 10-year wind events.

5.3.6 Shoreline Erosion

Wind generated wave effects are considerable on Cowichan Lake and could impact the shoreline through erosional and depositional processes. The vulnerability of the shoreline to erosion will depend on the underlying geology and surficial sediments on the shoreline, vegetation type and density growing within the run-up zone, presence of hardened shorelines, groynes, or other features that can attenuate or accentuate wave effects, shoreline gradient, shoreline orientation, wind fetch, and water level during a given wind event. Waves generated by boats can also contribute to shoreline erosion. Longer term effects associated with long-shore sediment transport processes can alter the shorelines vulnerability to erosion. **Photo 5-2** shows an eroding shoreline at an old mill site near Youbou.

Shoreline erosion processes are more often likely to be active during lower lake level conditions than considered for this study and could include more severe wind events. Future phases of work could include an analysis of numerical model run scenarios of several combined wind generated wave events and lake levels to assess the shoreline erosion vulnerability under different plausible water level and wind conditions. A statistical analysis of observed wind events could be assessed in more detail to incorporate impacts associated with storm duration. KWL (2014) classified the shoreline substrate, geology, and gradient based on a visual assessment by boat. It is recommended the shoreline classification be refined based on a follow up site assessment at key areas that are identified from the results of the numerical modelling.

Photo 5-2: Example of shoreline erosion on Cowichan Lake, at former mill site near Youbou.

5.4 Risk Analysis

5.4.1 Jurisdictional Boundaries

Figure 5-13 shows the delineation of jurisdictions used in the Cowichan Lake risk assessment. The jurisdictions in the Cowichan Lake area include Area I – Youbou/ Meade Creek, Lake Cowichan First Nation, Area F - Cowichan Lake South / Skutz Falls, and Town of Lake Cowichan. The largest population centres and urban development include the Town of Lake Cowichan and Youbou, although people have settled around the large areas of the perimeter of the northwestern and southwestern shoreline.

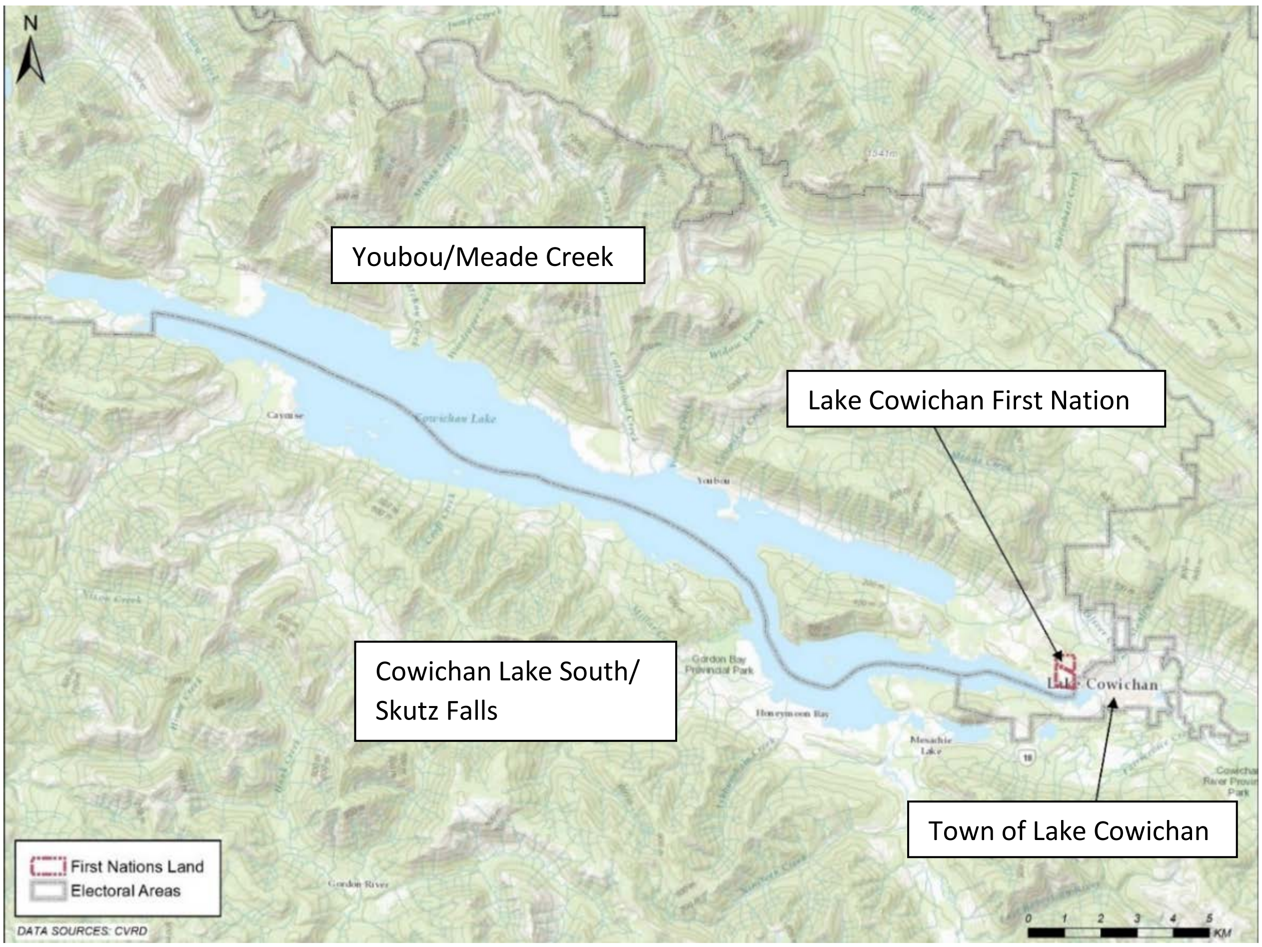


Figure 5-13: Delineation of jurisdictions used for Cowichan Lake study region risk assessment.

5.4.2 Results

The flood risk assessment was completed for Cowichan Lake using the methodology discussed in **Section 3.3**. **Table 5-5** summarizes the percentage of land flooded in the Cowichan Lake study region, categorized by jurisdiction. For all scenarios, the total flooded land area is a relatively small percentage of the total land area for each jurisdiction. The largest total land area affected lies within the Cowichan

Lake/ Skutz Falls jurisdiction although a substantially larger percentage of land area is affected for the Town of Lake Cowichan compared to other jurisdictions, particularly because the town's jurisdictional boundary is much smaller.

Table 5-5: Summary of percentage of land flooded in the Cowichan Lake study region, categorized by jurisdiction.

Jurisdiction	Total Land Area (ha)	Percentage of Land Flooded			
		200-Yr	200-Yr +10%	200-Yr +20%	200-Yr +40%
Cowichan Lake South/ Skutz Falls	194,607	0.1%	0.2%	0.2%	0.2%
Town of Lake Cowichan	955	4.6%	5.1%	5.5%	6.5%
Youbou/ Meade Creek	54,566	0.3%	0.4%	0.4%	0.5%
Lake Cowichan First Nation	42	1.6%	1.7%	1.8%	1.9%
Total	250,169	0.2%	0.2%	0.2%	0.3%

The following section presents the results of the analysis in a series of bar charts and a summary table that shows the total value of the given element exposed for each jurisdiction. These figures and table demonstrate the relative impacts and the change in exposure with increasing climate change impacts. A detailed summary of the elements exposed are provided in tabular format in **Appendix A** and a series of visualization tools are presented in **Appendix B** including heat maps showing the relative density of properties affected by flooding for each scenario, and plan maps showing examples of element exposures for select sites.

People and Societal Impacts

Figure 5-14 presents the population, number of residential buildings, hospitals, emergency centres, schools, and childcare facilities exposed in the FCRP. There are 347 people exposed to flooding in the 200-year flood event under present conditions, increasing to 539 people for the +40% climate change scenario; representing a 18%, 31%, and 55% increase over the present-day scenario for the +10%, +20%, and +40% future scenarios, respectively. Between 65% and 70% of the exposed population live in the Town of Lake Cowichan for all scenarios. There are 200 residential buildings located within the present-day flood scenario, increasing by 27%, 54%, and 103% over the present-day scenario for the +10%, +20%, and +40% future scenarios, respectively. One and two emergency centres in Town of Lake Cowichan are in the 200-year FCRP for the +20% and +40% climate change scenarios, respectively. No hospitals, schools, or childcare facilities are exposed for either the +40% or present-day scenarios.

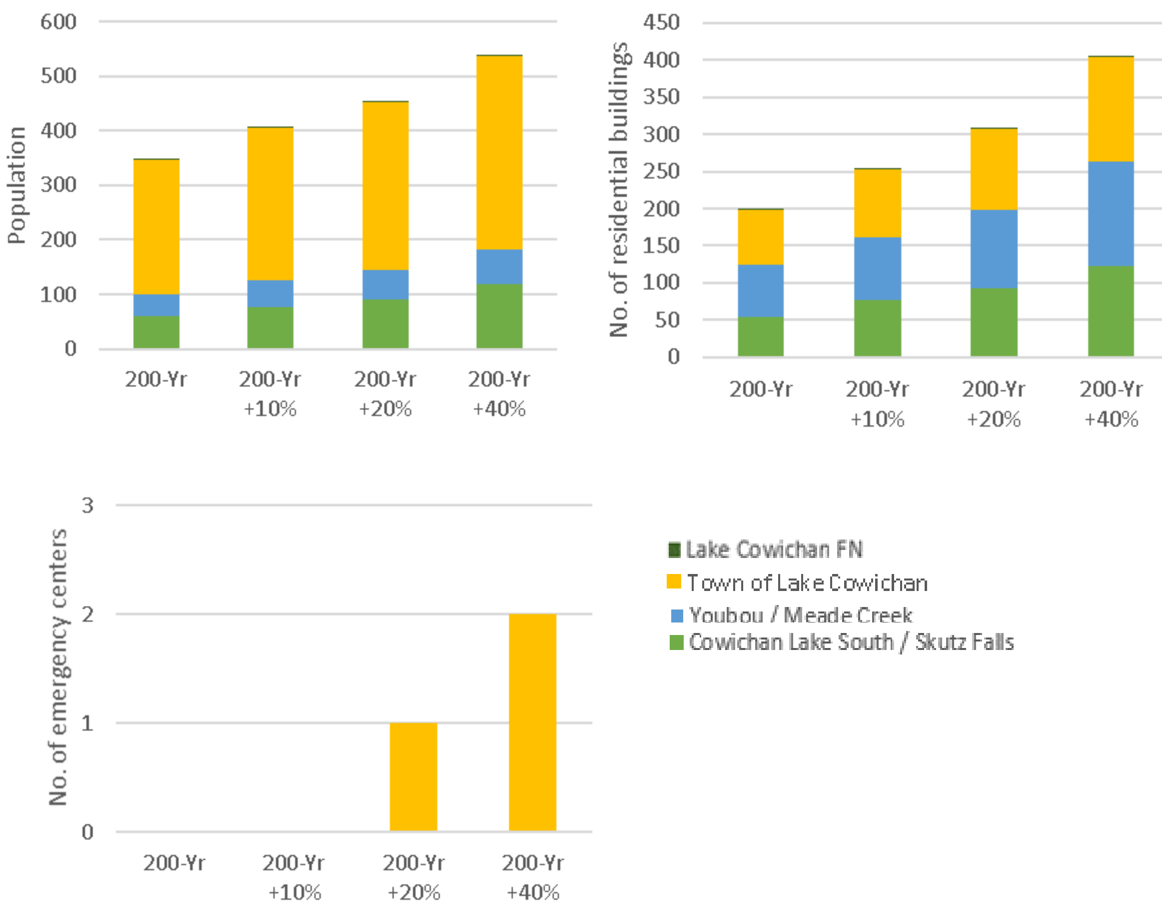


Figure 5-14: People and societal impacts – quantified flood exposures.

Environmental Impacts

Environmental impacts are assessed based on the area of terrestrial ecosystems and sensitive ecosystems, the length of FWA streams, and the number of gas stations located in the FCRP. The counts of elements within the FCRP for each flood scenario are shown in **Figure 5-15**. There are almost 10 km of streams in the FCRP for the 200-year scenario under present-day conditions, and almost 14 km for the +40% climate change scenario; representing a 7%, 19%, and 39% increase over the present-day scenario for the 10%, 20%, and 40% future scenarios, respectively. There are no sensitive or terrestrial ecosystems or gas stations mapped in the FCRP for any flood scenario (approximately 0.01 ha of terrestrial ecosystems were identified for the +40% scenario; however, this is considered negligible for the purposes of this study).

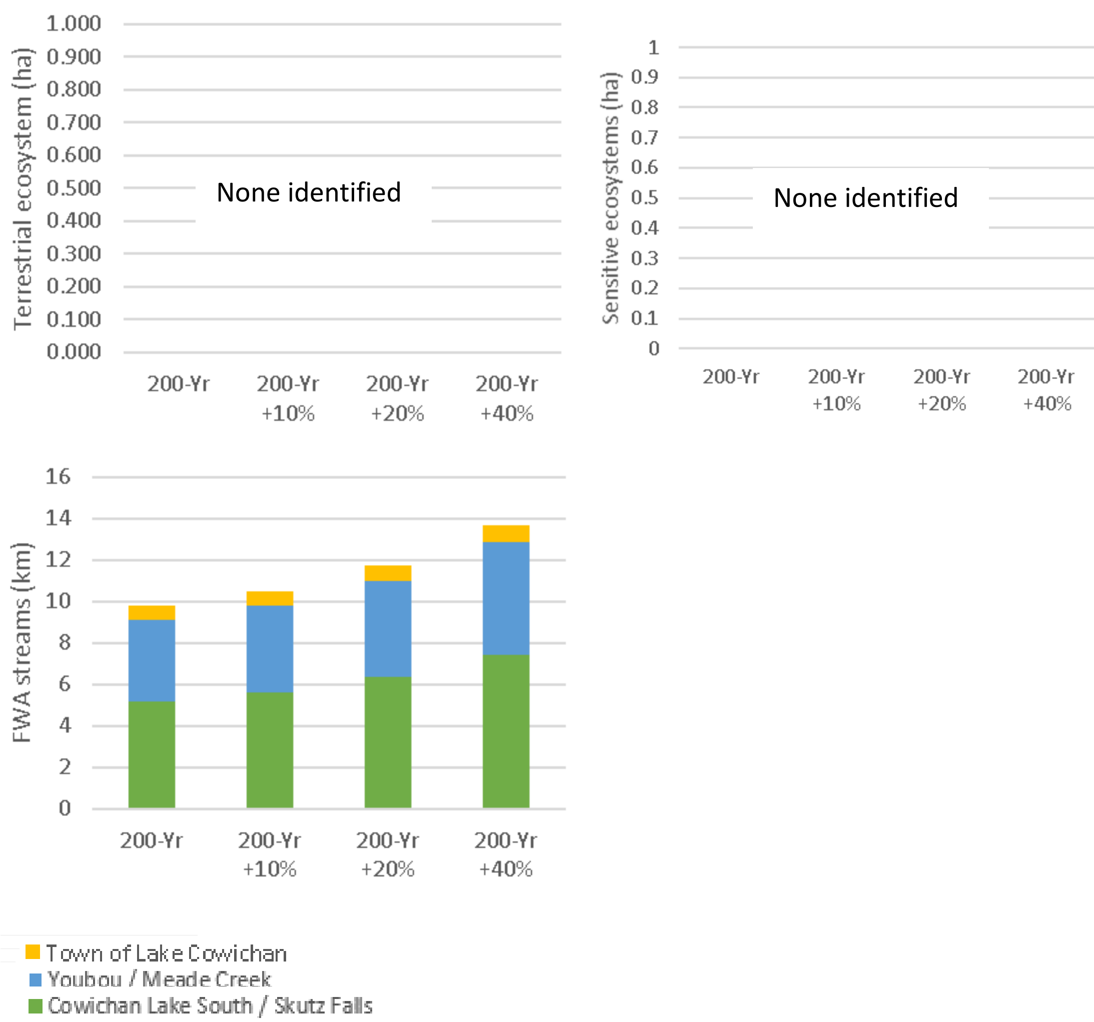


Figure 5-15: Environmental impacts – quantified flood exposures.

Local Economic Impacts

Local economic impacts are evaluated based on the assessed value of properties exposed in the FCRP. The value of properties for each flood scenario is shown in **Figure 5-16**. The greatest value of properties in the FCRP for both scenarios are in Area I – Youbou/ Meade Creek, corresponding to the greatest number of properties exposed in this jurisdiction. The value of residential and commercial properties exposed increases from $90.9 M to $194.8 M and $23.4 M to $40.2 M between the present-day and +40% climate change scenario, respectively. This represents a 29%, 61%, and 116%; and 20%, 31%, and 72% increase over the present-day scenario for the 10%, 20%, and 40% future scenarios, respectively. Total property value includes commercial, industrial, and residential properties in addition to other properties that are either zoned differently have no assigned zoning value. Industrial property value exposed remains at $0.2 M for all scenarios except for the +40% future scenario which increases to $1M.

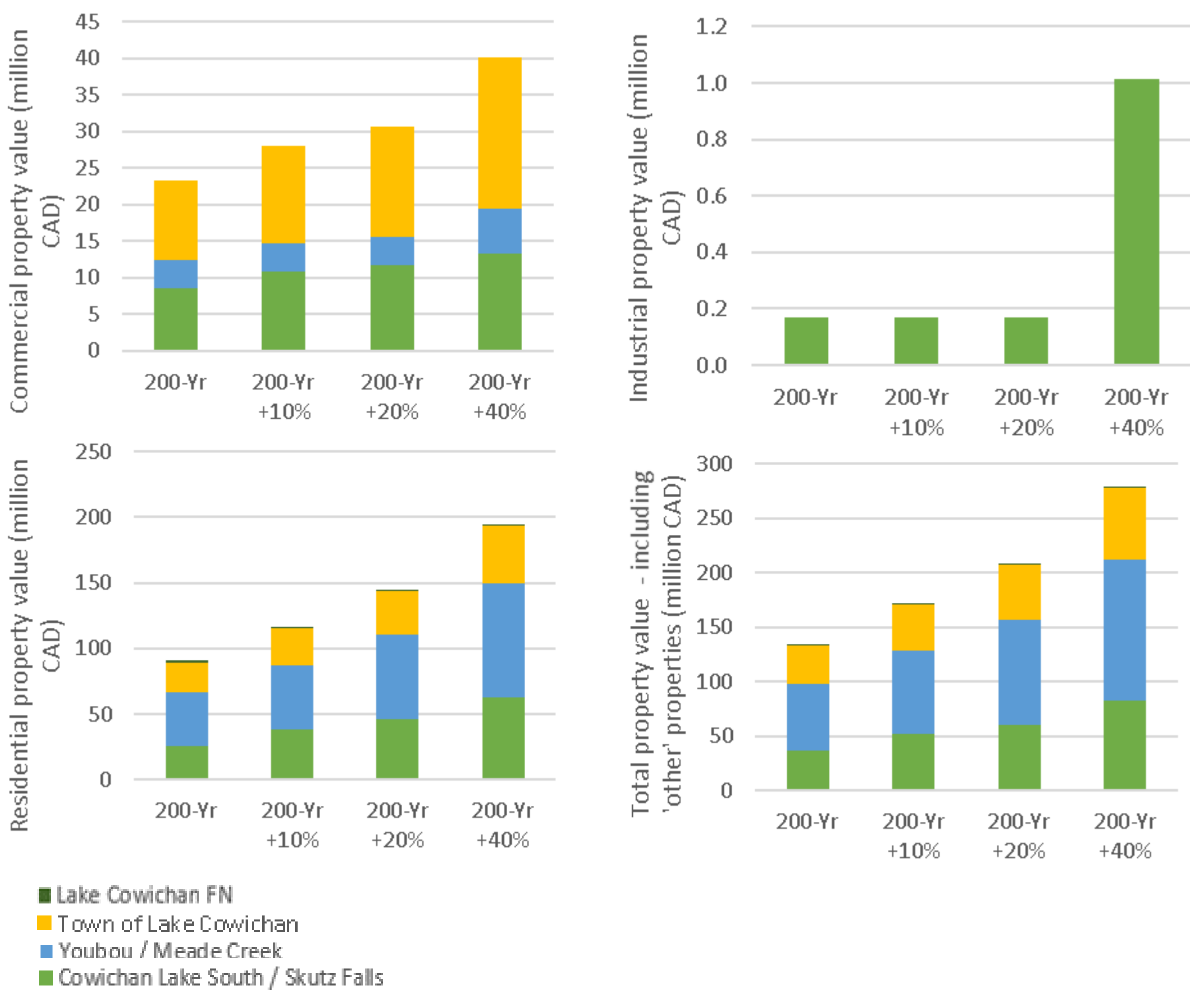


Figure 5-16: Local economic impacts – quantified flood exposures (property values).

Local Infrastructure Impacts

Local infrastructure impacts are assessed based on the number of industrial and commercial buildings, utilities, CVRD water supply and sewer structures, and length of transportation networks exposed in the FCRP. As noted in **Section 3.5.2** this assessment focusses on direct impacts. Damaged or unusable infrastructure can have indirect impacts where the affected service area extends beyond flood extents. The count of elements within the FCRP for each flood scenario are shown in **Figure 5-17** to **Figure 5-20**.

Figure 5-17 shows one industrial building located in the FCRP, within Area F - Cowichan Lake South/ Skutz Falls for the present-day condition and increasing to two buildings under the +40% climate change scenario. There are 83 commercial buildings exposed under the present-day scenario, mainly in the Town of Lake Cowichan. Commercial building exposure increases by 37%, 55%, and 90% over the present-day scenario for the 10%, 20%, and 40% future scenarios, respectively. **Figure 5-18** shows the impact to private stakeholder utility structures including BC Hydro, Fortis BC, Shaw, and Telus. The largest number of utilities structures in the FCRP belong to Shaw, with 26 exposed assets under the present-day scenario; increasing by 23%, 54%, and 100% over the present-day scenario for the 10%, 20%, and 40% future scenarios, respectively. Eight BC Hydro structures are in the present-day FCRP; increasing by 62%, 88%, and 125% over the present-day scenario for the 10%, 20%, and 40% future scenarios, respectively. Four Telus assets are exposed in the present-day scenario increasing to 6 between the +20% and +40% scenarios. Two and four CVRD water and sewer utilities are exposed under all scenarios, respectively as shown in **Figure 5-19**. Water and sewer infrastructure for Town of Lake Cowichan are not included in the database provided by CVRD for this study; however, the Town of Lake Cowichan website identifies they are responsible for water and sewer utilities and some municipal water or sewer assets may be exposed under certain flood scenarios.

Figure 5-20 shows 7 km of roads currently in the FCRP, with most roads located in Town of Lake Cowichan. The exposure increases by 36%, 57%, and 113% over the present-day scenario for the +10%, +20%, and +40% future scenarios, respectively. The location of exposed roads is more evenly distributed between Area F - Cowichan Lake South/ Skutz Falls, Area I – Youbou/ Meade Creek, and Town of Lake Cowichan for the +40% scenario, although relatively more culverts appear to be affected in Area I – Youbou/ Meade Creek electoral area for all scenarios. In total, 48 culverts are exposed in the present-day scenario; increasing by 52%, 71%, and 133% over the present-day scenario for the 10%, 20%, and 40% future scenarios, respectively. Two bridges are exposed in the present-day scenario increasing to four between the +20% and +40% scenario. There are no railways in the FCRP for any scenario.

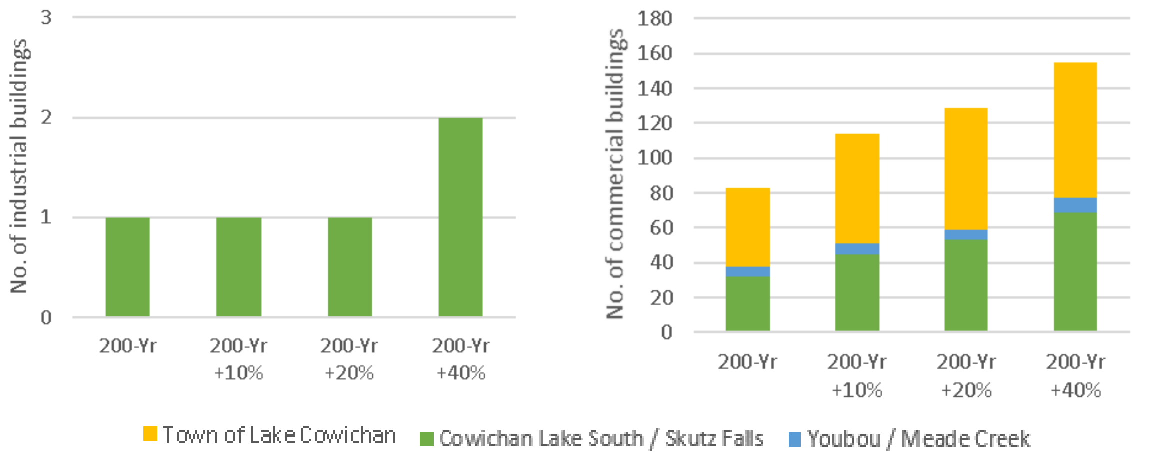


Figure 5-17: Local infrastructure impacts – quantified flood exposures (industrial and commercial buildings).

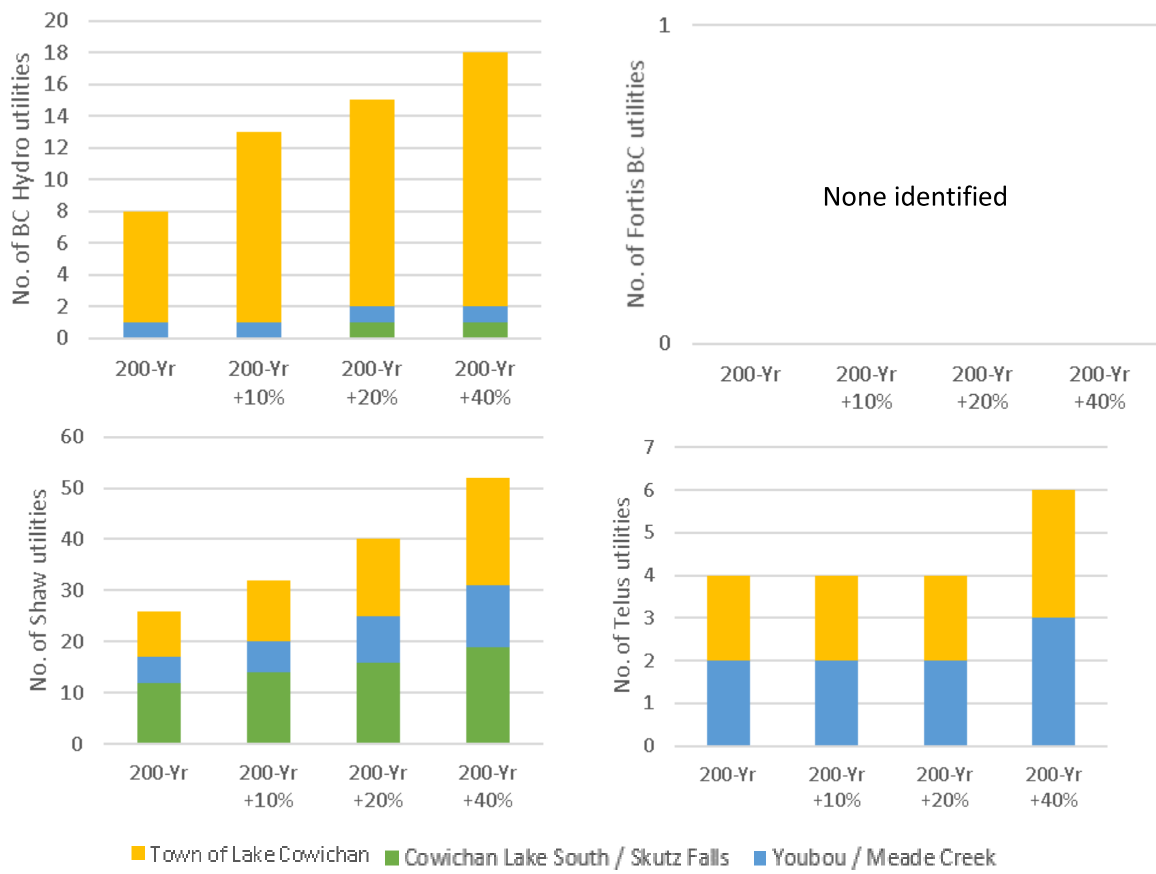


Figure 5-18: Local infrastructure impacts – quantified flood exposures (Shaw, Hydro, Telus).

Figure 5-19: Local infrastructure impacts – quantified flood exposures (water and sewer).

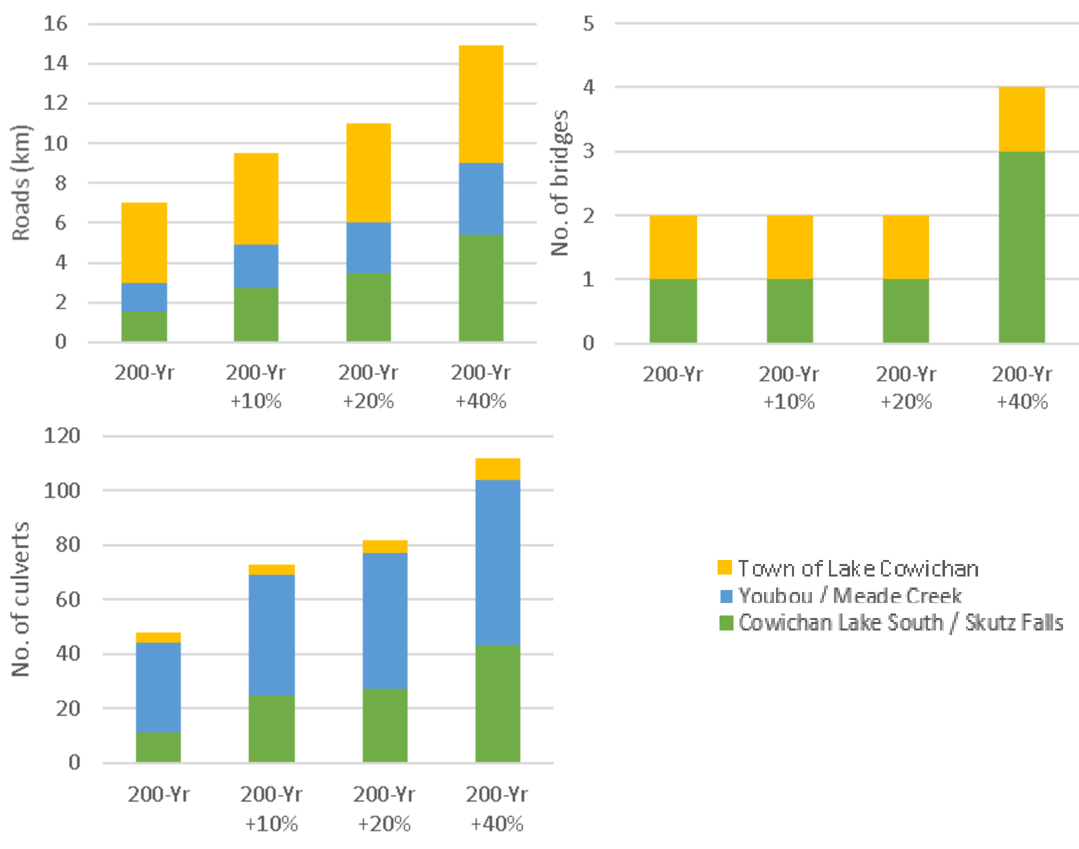


Figure 5-20: Local infrastructure impacts – quantified flood exposures (transportation infrastructure).

Public Sensitivity Impacts

Public sensitivity impacts are assessed based on land area exposed, categorized by land use: urban and developed, agricultural, grasslands, shrublands and forests, wetlands, and barren and exposed land. The total land area of each category for each flood scenario is shown in **Figure 5-21**. Predominantly grasslands, shrublands and forests areas are exposed from lake flooding with the second largest exposure being urban and developed areas. There are 367 ha and 91 ha exposed under the present-day scenario for these two land areas, respectively. Exposure increases for these land areas by 11%, 22%, and 43%; and 16%, 30%, and 63% over the present-day scenario for the 10%, 20%, and 40% future scenarios, respectively. Wetlands exposure ranges from 23 ha and 26 ha for the present-day and +40% future scenario. Exposed barren areas represent 7 ha increasing to 8 ha between the +10% and +20% future scenario. No agricultural areas are exposed for any scenario.

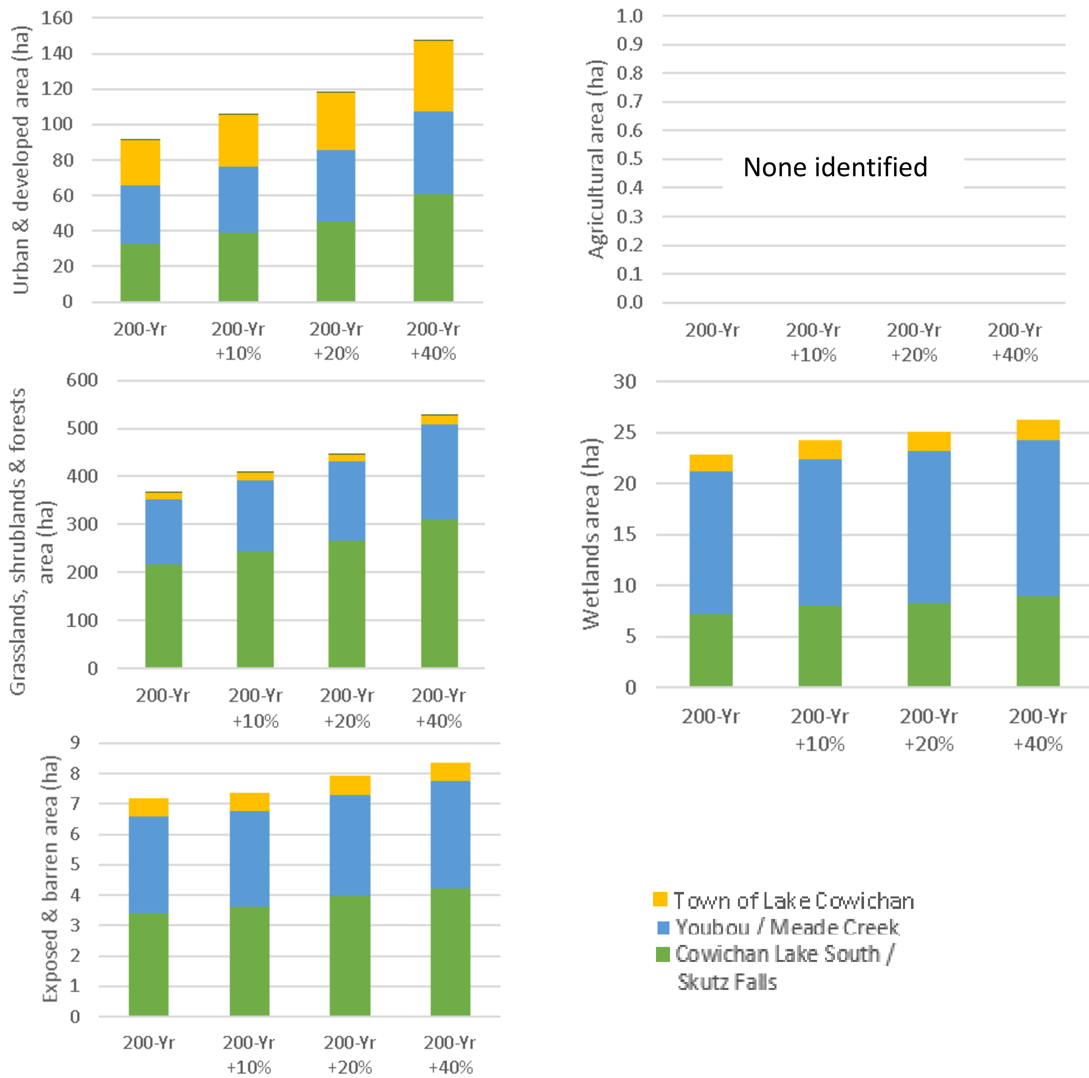


Figure 5-21: Public sensitivity impacts – quantified flood exposures.

5.4.3 Discussion

The total elements exposed for Cowichan Lake for the present-day and three future scenarios are shown in **Table 5-6**. Based on the census data 347 people are exposed under the present-day flood scenario with approximately 70% of people located within the Town of Lake Cowichan, 17% in Area F – Cowichan Lake South/ Skutz Falls, 12% within Area I – Youbou/ Meade Creek and the remainder within Lake Cowichan FN. Population exposure is sensitive to future climate change impacts, increasing by 18%, 31%, and 55% for the +10%, +20%, and +40% climate change scenarios, respectively. One emergency center is exposed under +20% future scenario increasing to two under the +40% future scenario. Both emergency centers are located within the Town of Lake Cowichan.

Most exposed property value is residential, with $90.9 M compared to $23.4 M for commercial properties, representing 200 and 83 buildings, respectively, for the present-day scenario. The number of residential buildings is relatively evenly distributed between Town of Lake Cowichan, Area F and Area I with 37%, 27%, and 36% for the present-day scenario, respectively; whereas affected commercial buildings are primarily located in Town of Lake Cowichan with lesser amounts in Area F and Area I, representing 54%, 39%, and 7%, for the present-day scenario respectively. Residential buildings are relatively more sensitive to climate change than commercial buildings. One Lake Cowichan FN residential building is exposed for all scenarios.

Some property is zoned industrial, located within Area F. Exposure remains steady at $0.2 M for present-day and +20% future scenarios, increasing to $1 M under +40% future scenario, which corresponds to the increase from one to two industrial buildings affected.

Identified environmental impacts include almost 10 km of streams under the present-day scenario, remaining relatively steady under the +10% future scenario and increasing relatively more under the +20% and +40% scenarios, respectively. Most (53%) identified streams are within Area F and Area I (40%).

Private stakeholder utility assets exposed under the present-day scenario include Shaw (26), BC Hydro (8), and Telus (4). Exposures of Shaw assets increases most substantially between the +20% and +40% future scenarios and for BC Hydro assets has substantial incremental increases for all future scenarios, and includes s a substation that could have indirect effects on other areas served by this facility. Two and four CVRD water and sewer utilities are exposed under all scenarios, respectively; however, this analysis may under-represent exposed infrastructure for Town of Lake Cowichan because data for this municipality was not included in the database provided by CVRD for this study.

Most exposed roads are in Town of Lake Cowichan (58%) with 19% and 22% within Area I and Area F for the present-day scenario, respectively. The exposure increases by 36%, 57%, and 113% over the present-day scenario for the +10%, +20%, and +40% future scenarios, respectively. Exposure of culverts is relatively larger in Area I for all scenarios and is sensitive to climate change scenarios. Two bridges are exposed in the present-day scenario; one in Town of Lake Cowichan and one in Area F. This increases to four between the +20% and +40% scenario with an increase in exposed structures in Area F. There are no railways in the FCRP for any scenario.

Most exposed land is grasslands, shrublands and forests areas (367 ha under present-day scenario) with the second largest exposure being urban and developed areas (91 ha under present-day scenario). Urban and developed areas are sensitive to climate change scenarios, with the largest increase between the +20% and +40% scenario. This land area predominantly Area F and Area I, with substantial coverage within Town of Lake Cowichan and the remainder with Lake Cowichan FN. Wetlands and exposed barren areas represent between 23 ha and 26 ha and between 7 ha and 8 ha for the present-day and +40% future scenario, respectively. No agricultural areas are exposed for any scenario.

Table 5-6: Summary of total elements exposed for the Cowichan Lake study region.

Category	Exposed Elements	Unit	Total			
			200-year	200-year +10%	200-year +20%	200-year +40%
People & Societal	Population	number	347	408	454	539
	Residential Buildings		200	254	308	405
	Hospitals		0	0	0	0
	Emergency Centers		0	0	1	2
	Schools & Childcare facilities		0	0	0	0
Environmental	Terrestrial Ecosystem	ha	0	0	0	0
	Sensitive Ecosystem	ha	0	0	0	0
	FWA Streams	km	9.8	10.5	11.7	13.6
	Gas Stations	number	0	0	0	0
Local Economic	Commercial property value	million $CAD	23.4	28.0	30.7	40.2
	Industrial property value		0.2	0.2	0.2	1.0
	Residential property value		90.9	116.4	145.1	194.8
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)		134.3	172.2	208.3	278.8
Local Infrastructure	Industrial Buildings	number	1	1	1	2
	Commercial Buildings		83	114	129	155
	BC Hydro Assets		8	13	15	18
	Fortis BC Assets		0	0	0	0
	Shaw Assets		26	32	40	52
	Telus Assets		4	4	4	6
	CVRD Sanitary Sewer Assets		4	4	4	4

Category	Exposed Elements	Unit	Total			
			200-year	200-year +10%	200-year +20%	200-year +40%
	CVRD Reservoirs		0	0	0	0
	CVRD Water System Assets		2	2	2	2
	Road Length	km	7.0	9.5	11.0	14.9
	Bridges	number	2	2	2	4
	Culverts	number	48	73	82	112
	Rail	km	0	0	0	0
	Urban & Developed Area	ha	91	106	118	148
	Agricultural Area		0	0	0	0
	Grasslands, Shrublands & Forests Area		367	407	446	526
	Wetlands Area		23	24	25	26
	Exposed & Barren Area		7	7	8	8

5.5 Flood Hazard Intensity Analysis

As described in **Section 3.3.1**, risk is defined as the combined effects of the probability and magnitude of flood event and the resulting consequences should the hazard occur. EGBC (2018) defines consequence, exposure, and vulnerability as follows:

- Consequence: "the outcomes or potential outcomes arising from the occurrence of a flood, expressed qualitatively or quantitatively in terms of loss, disadvantage or gain, damage, injury, or loss of life". In this context, the outcome from a flood event depends on (a) the degree of exposure to the flood event and (b) the vulnerability.
- Exposure: "the degree of loss to a given element or set of elements within the area affected by the flood hazard".
- "Vulnerability is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of damage relative to the value of the property; for persons it will be the probability that a particular life will be lost".

Figure 5-22 presents a theoretical relationship between property flood damage and the intensity of the flood hazard. The flood hazard intensity is a function of water depth and velocity, duration of the flood event, and presence of contaminants and sediment that can create negatively impacts.

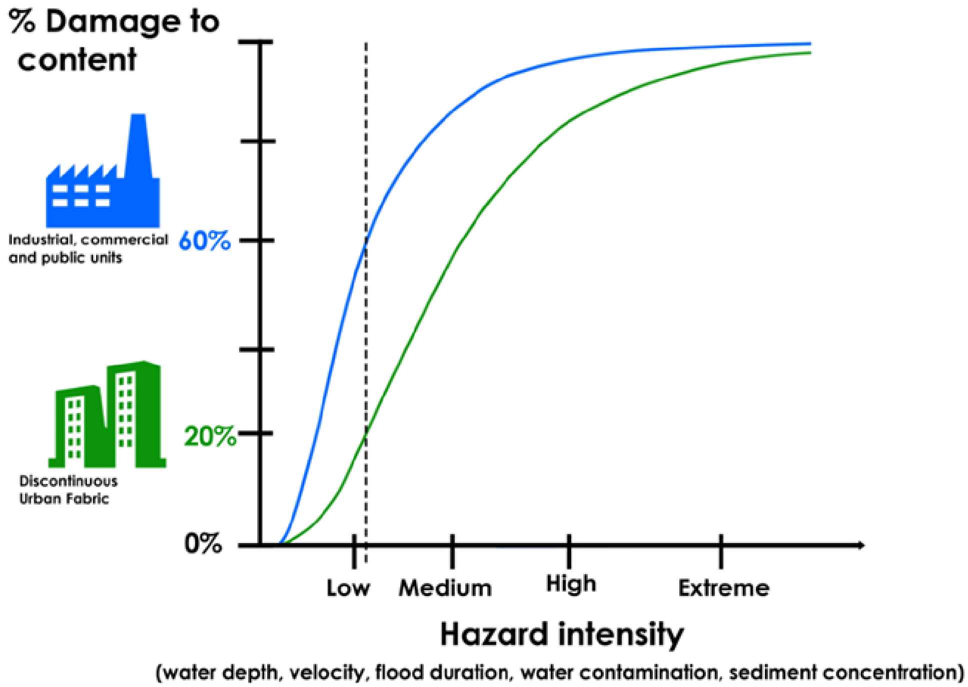


Figure 5-22: Theoretical relationship between Hazard Intensity and Damage (after *Albano et. al., 2015).*

For this overview level study, flood risk is based on the exposure of an element to flooding. More detailed analysis, along with element specific vulnerability information would be required to carry out a hazard intensity analysis. For the Cowichan Lake study region, a flood depth analysis was carried out for exposed buildings, using address point feature class as a proxy for building locations for each parcel. The purpose of this preliminary analysis is to present sample results to demonstrate an approach for evaluating potential impacts based on flood depth, whereby the study region is mapped according to five water depth classes that can be related to the potential threat to property and livelihood.

Table 5-7 presents an approach for mapping flood depth based on EXCIMAP (2007) and Japan Ministry of Land, Infrastructure and Transport (MLIT 2005). **Figure 5-23** presents an example flood depth map for Town of Lake Cowichan and **Table 5-8** categorizes exposed buildings by depth class for the present-day FCRP for the entire Cowichan Lake study region for all zones (including those other than residential, commercial, and industrial).

Table 5-7: Summary of depth classes for flood hazard mapping.

Depth (m)	Description
0 - 0.5	▪ most houses are dry; ▪ walking in moving water or driving is potentially dangerous; ▪ basements and underground parking may be flooded, potentially causing evacuation
0.5 - 1.0	▪ water on ground floor; ▪ basements and underground parking may be flooded, potentially causing evacuation; ▪ electricity failed; ▪ vehicles are commonly carried off roadways
1.0 - 2.0	▪ ground floor flooded; ▪ residents evacuate
2.0 - 5.0	▪ first floor and often roof covered by water; ▪ residents evacuate
> 5.0	▪ first floor and often roof covered by water; ▪ residents evacuate

Table 5-8: Summary of proportion of total number of buildings within the present-day FCRP boundary within each depth class (using address points as a proxy) for all zones (also includes zones other than residential, industrial, commercial).

Depth Class (m)	Count	Percentage of total number of exposed elements in FCRP
<0.5	127	40%
0.5 – 1	102	32%
1 – 2	75	24%
2 – 5	13	4%
> 5	0	0%
Total no. properties in FCRP boundary	317	100%

Note:

1. Assumes one exposed element per parcel (based on geographic location of address feature point class).

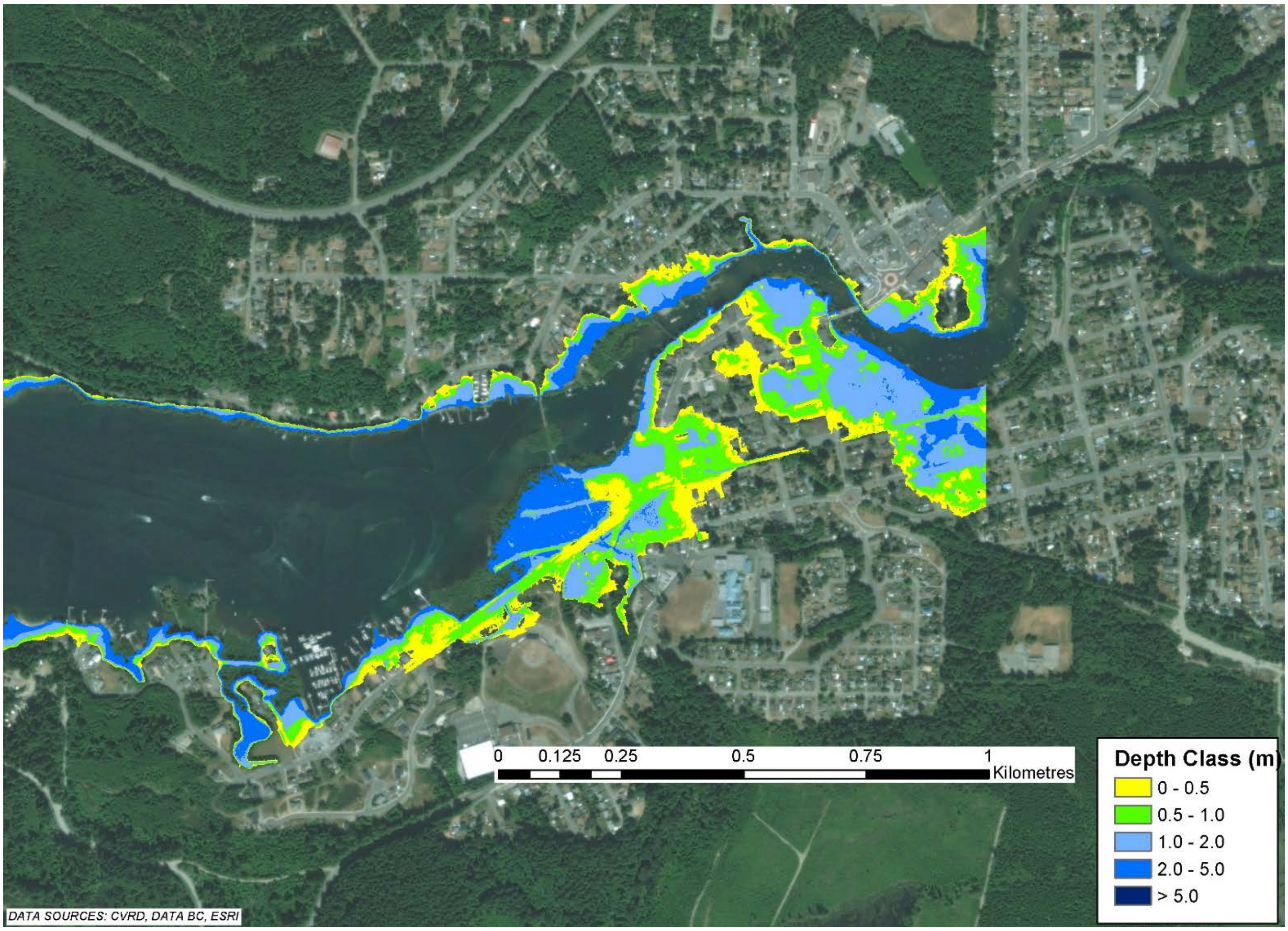


Figure 5-23: Example flood depth map for Town of Lake Cowichan, for present-day FCRP.

6 SHAWNIGAN LAKE STUDY REGION

6.1 Overview

Shawnigan Lake watershed drains approximately 71 km^2 of relatively low-gradient forest land, ranging in elevation from 380 m to 117 m at its outlet. The surface area of the lake is 5.4 km^2 which accounts for approximately 8% of the watershed area. The village of Shawnigan Lake is located on the eastern shore. The southern end of the lake is largely undeveloped. Shawnigan Creek forms the outlet at the north end of the lake and flows east into Mill Bay. Floods are generated in the autumn and winter months during periods of high rainfall. Due to the low elevation of the watershed, the contribution from snowmelt is believed to be relatively minor.

Prior to the 1960s, water levels in Shawnigan Lake were controlled by a natural constriction in Shawnigan Creek. In 1964, a weir was constructed 450 m downstream of the outlet – a simple stop log structure with concrete headwalls. In 1983 the dam was modified and in 1984 a rule curve was developed to control summer lake levels. A new dam was constructed in 2006, 5 m downstream of the old structure. The new dam is a gated structure with a fish ladder and a by-pass channel (**Photo 6-1**).

Photo 6-1: Shawnigan Lake weir constructed in 2006.

6.2 Previous Studies

Three floodplain map sheets were prepared by MoE for Shawnigan Lake and were published in 1979. The FCL was 119.2 m CGVD 1928, which corresponds to approximately 119.4 m CGVD 2013. No information is available on how the level was determined or the freeboard that was adopted. Based on other similar studies, we have assumed a freeboard of between 0.3 m and 0.6 m was added to account for local wave effects such as runup. Based on this assumption, the corresponding FCRP is somewhere between 118.6 to 118.9 m. By comparison, the highest observed lake levels reached elevation 118.39 m in 1972 and 118.3 m in 1979 (Talbot, 1985).

6.3 Flood Hazard Assessment

6.3.1 Review of Available Data

Table 6-1 lists the hydrometric information available for assessing flood levels on Shawnigan Lake. The lake gauge records daily observed water levels. Unfortunately, the gauges on the rivers are missing significant periods of flow data and could not be used for a flood frequency analysis. The exception was the year of 1979, coinciding with the MoE floodplain mapping study, which was used as an independent check in the final analysis relating lake levels to discharge.

Lake level data used for Shawnigan Lake was daily data provided by the CVRD (1999-2017) and annual maximum and minimum observations for 1970-1982 as reported in a water level study by the Water Management branch (Talbot, 1985).

Table 6-1: Available hydrometric data on Shawnigan Lake.

WSC Gauge	Name	Period of Record
08HA004	Shawnigan Creek below Shawnigan Lake	1914-1917, 1976-1979, 1984-1989
08HA033	Shawnigan Creek near Mill Bay	1974-2009
08HA032	Shawnigan Lake opposite Memory Island	1970-1994
	CVRD observed lake levels	1999-2017
	Water Management Branch Report (Talbot, 1985)	1970-1982 (annual minimum and maximum only, extracted from daily manual measurements)

The recorded peak or annual maximum lake level data at Shawnigan Lake is quite limited with 12 years of data from 1970-1982(Talbot, 1985) and an additional 17 years from 2000-2017 provided by the CVRD. The quality of the historical data is unknown. A flood frequency analysis was conducted on the data and this analysis is summarized in **Figure 6-1**. **Table 6-2** summarizes these results. The predicted 200-year lake level is within 0.15 m of previous estimates made by the 1979 floodplain mapping FCRP and by Talbot (1985).

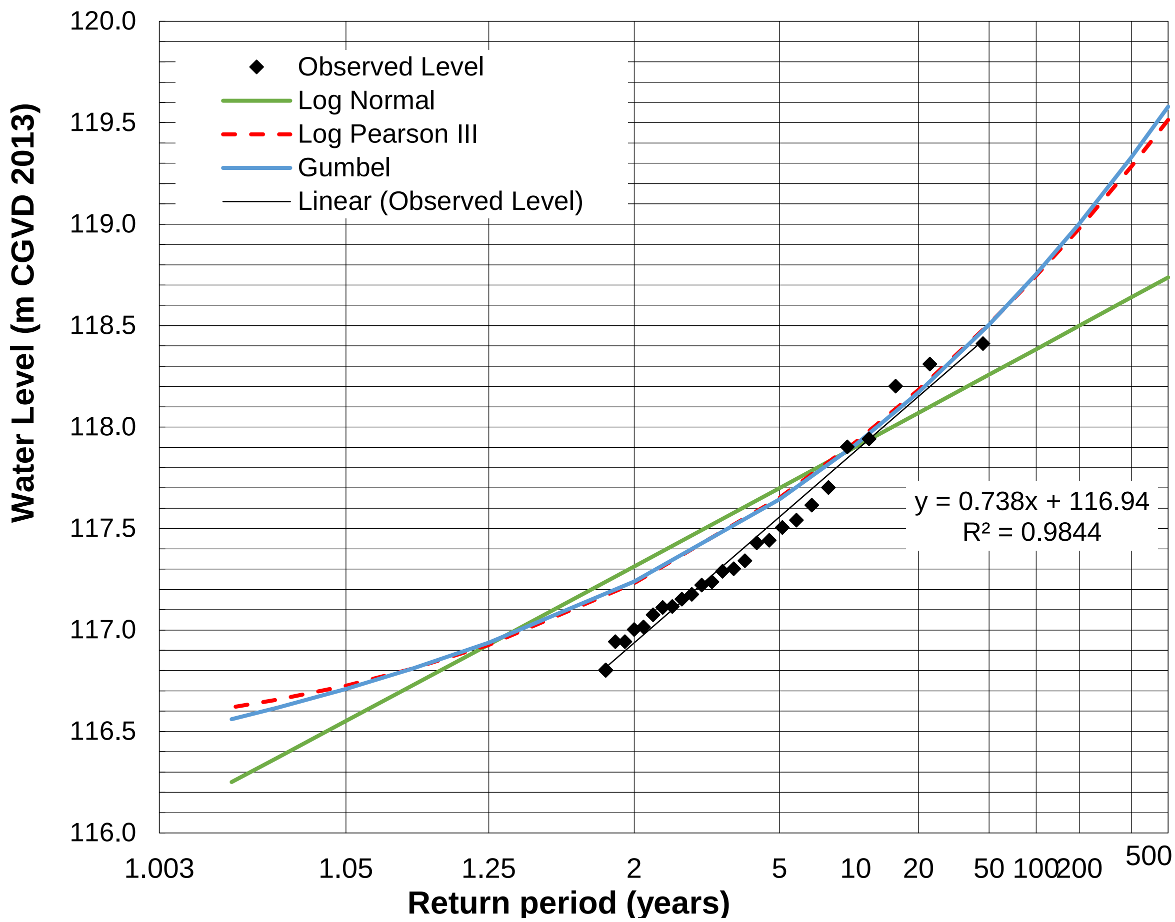


Figure 6-1: Frequency analysis of annual maximum water levels on Shawnigan Lake.

Table 6-2: Estimated peak lake levels (historical conditions) based on manual gauge measurements.

Return Period (Years)	Lake Level (m) (Talbot 1985) and CVRD
200	118.84
100	118.66
50	118.46
20	118.15
10	117.89
2	116.94

During a site visit on 5 February 2019, a Shawnigan Lake contractor identified the high water mark on the Galley Grill docks from the 2018/2019 winter. From discussion with Shawnigan Lake residents, this past winter corresponded to approximately a 1 in 10 year lake level. The high water mark was surveyed with an RTK GPS at El.117.8 m, 0.10m lower than the 10 year flood level estimated in **Table 6-2**.

The weir at Shawnigan Lake was first built in 1964 and then modified using sandbags and flashboards to increase the invert elevation in 1983. The outlet of Shawnigan Lake and the weir was surveyed in 1979 by the Ministry of Environment with the data recorded in Drawing No. 4984-8B (Ministry of Environment, 1980). In 2006, the existing weir was decommissioned and replaced with a new one approx. 5 m downstream. The design drawings were completed by John Braybrooks Engineering (2005). There was no design report available. Relevant weir design parameters for past and present conditions are listed in **Table 6-3**.

Table 6-3: Shawnigan Weir Design Parameters.

Design Parameter	1964 to 1983[1]	1983 to 2006[2]	2006 to Present[3]
Sill Invert Elevation (m CGVD 2013)	115.34	116.2	115.68
Width of Stop Log Opening (m)	3.05	Unknown	6.1
Crest Elevation (m CVD 2013)	115.95	Unknown	117.18

Note:

1. Ministry of Environment, 1980.
2. Talbot, 1985.
3. John Braybrooks Engineering, 2005.

6.3.2 Methodology

The peak lake levels during a flood are governed by three main factors:

- The inflow hydrograph to the lake
- The elevation of the lake at the start of the flood event
- The hydraulic characteristics at the outlet of the lake which controls the relation between lake level and outflow discharge

A lake routing analysis was carried out using a similar approach as for the Cowichan Lake study region (**Section 5.3.2**). However, given that there is only a short record of lake levels and discharges below the lake, a simpler approach was adopted. The outflow at the lake was determined through a regional analysis and the flows were then related to the lake level through a broad-crested weir equation and a discharge elevation rating curve developed in the water management branch study by Talbot (1985). A check on this relationship and the coefficients used was done using recorded WSC gauge data for a relatively high flow event in December of 1979.

6.3.3 Hydrological Analysis-Present Conditions

The Shawnigan Lake watershed is relatively large (71 km^2) with very little gauged flow data available. A regional analysis of flood frequencies was conducted to determine peak flows at the outlet of the lake. The Cowichan Lake watershed was chosen as the candidate for a regional analysis of the Shawnigan Lake watershed for the following reasons:

- Sixty-six years of recorded lake level and lake outflow data suitable for flood frequency analysis and development of relationship to lake levels, outflows, and suitable for a flow routing analysis to estimate flow inflows
- The lake encompasses 10% of the total watershed area which is similar to Shawnigan Lake (8%)
- Proximity to the Shawnigan Lake watershed
- Similarities in watershed characteristics.

The Modified Index Flood (MIF) method with an exponent of 1 was used to relate flood frequency analysis and flood routing results from Cowichan River at the outlet of Cowichan Lake to the Shawnigan Creek discharges at the outlet of Shawnigan Lake. The MIF can be estimated from the equation:

$$Q_2 = Q_1 \left(\frac{A_1}{A_2}\right)^n \qquad \text{(Eq. 10)}$$

where Q_1 is the known peak discharge, Q_2 is the unknown peak discharge, A_1 is the known basin area, and A_2 is the basin area for the unknown discharge. The areas of each watershed and lake is listed in **Table 6-4**. The results of the regional analysis on peak outflows from the lake are shown in **Table 6-5**.

Table 6-4: Watershed and Lake Areas for Cowichan Lake and Shawnigan Lake.

	Cowichan Lake	Shawnigan Lake
Watershed Area at the Lake outlet (km^2)	594	71
Lake Area (km^2)	61.7	5.4
Percentage of Lake to Watershed Area	10%	8%

Table 6-5: Modified Index Flood Results for outflow flood frequencies at the outlet of Shawnigan Lake.

Simulated Inflow Condition	Cowichan Lake Outlet (m^3/s)	Shawnigan Lake Outlet (m^3/s)
100-year historical	350	42
200-year historical	358	43

The discharge at the outlet of Shawnigan Lake was related to the lake elevation in the water level study completed by the Water Management Branch of the Province of BC in 1985. This relationship is currently the best estimate available for relating the lake level at Shawnigan to the outflow discharge. **Figure 6-2** shows the relationship extracted directly from (Talbot, 1985) with a rating curve fitted to the line. The rating curve relationship adjusted to CGVD 2013 is:

$$Q = 3.1(WSE - 115.338)^{2.05} \qquad \text{(Eq. 11)}$$

where WSE is the water surface elevation of the lake and Q is the discharge at the outlet. The 1979 flood event was captured by WSC gauge 08HA004 and was used to check the validity of the discharge elevation relationship at greater outflow discharges (**Figure 6-2**).

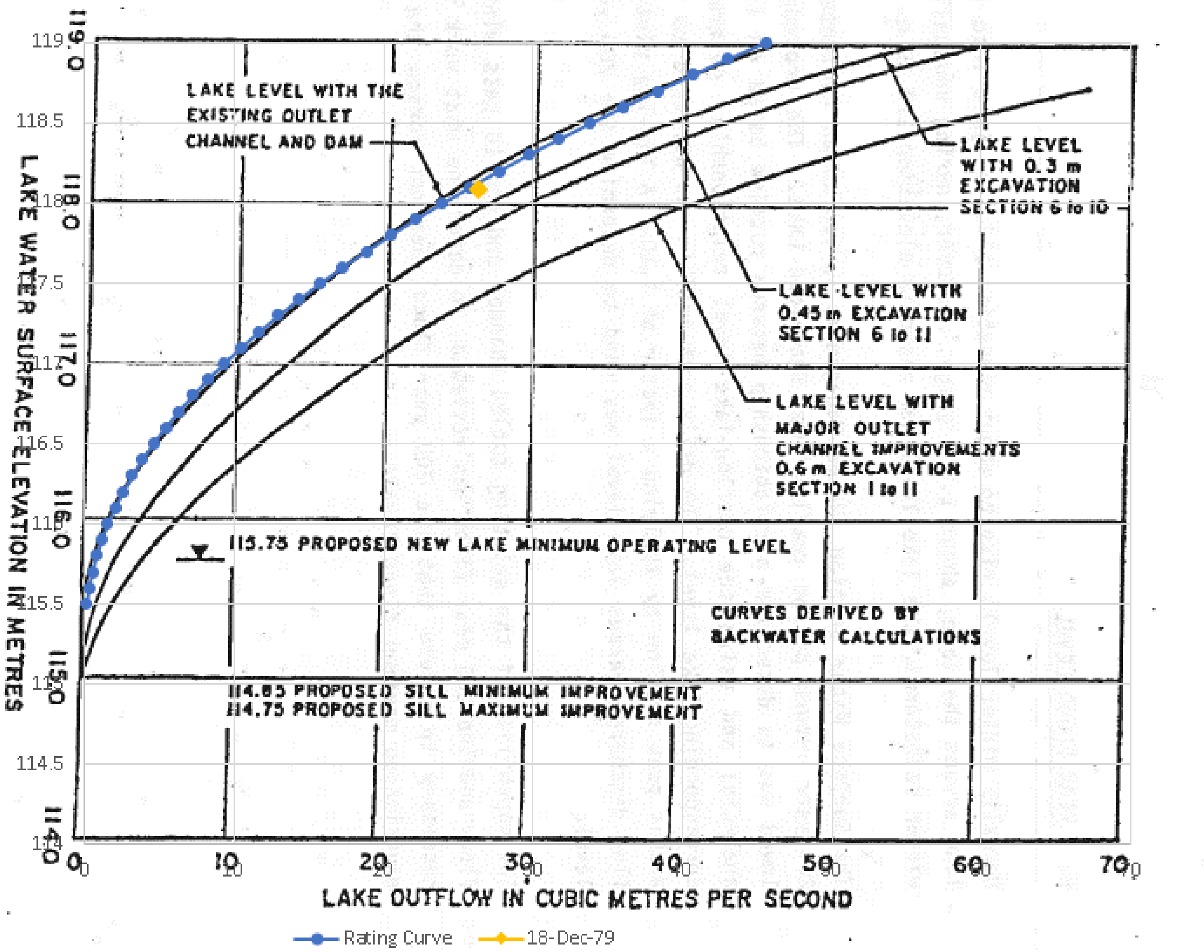


Figure 6-2: Discharge Elevation relationship developed by Talbot (1985) with fitted rating curve developed by NHC and WSC (08HA004) gauge measurement from the flood in December 1979. Elevations are in CGVD1928 HT97.

A weir relationship was also developed to relate the river water level at the weir to the discharge. The purpose of developing the weir relationship was to gain an understanding how the new weir affects the water level (both on the river and at the lake) and discharge relationship. The weir relationship was compared against the discharge elevation relationship developed by the Water Management Branch in 1985. The shape of the curves should be the same, but the weir equation should produce slightly lower (0.1 to 0.5 m) water surface elevations for the same discharge value given that the weir is located approximately 350 m downstream of the lake outlet.

The discharge over a weir is described by the broad-crested weir equation shown below relating the upstream water level and the weir configuration to the discharge over the weir.

$$Q = CH^{3/2} \quad \text{(Eq. 12)}$$

Where H is the height of the upstream water level above the weir crest and C is an empirical coefficient.

A discharge elevation relationship was developed for the old weir (before 2006) and the more recently constructed weir (2006 to present). **Figure 6-3** shows the two weir curves and how they relate to the discharge elevation relationship by Talbot (1985). Since the weir was reconstructed, it allows for a greater outflow discharge from Shawnigan Creek once the lake reaches higher lake levels (> 118 m) conducive to flooding.

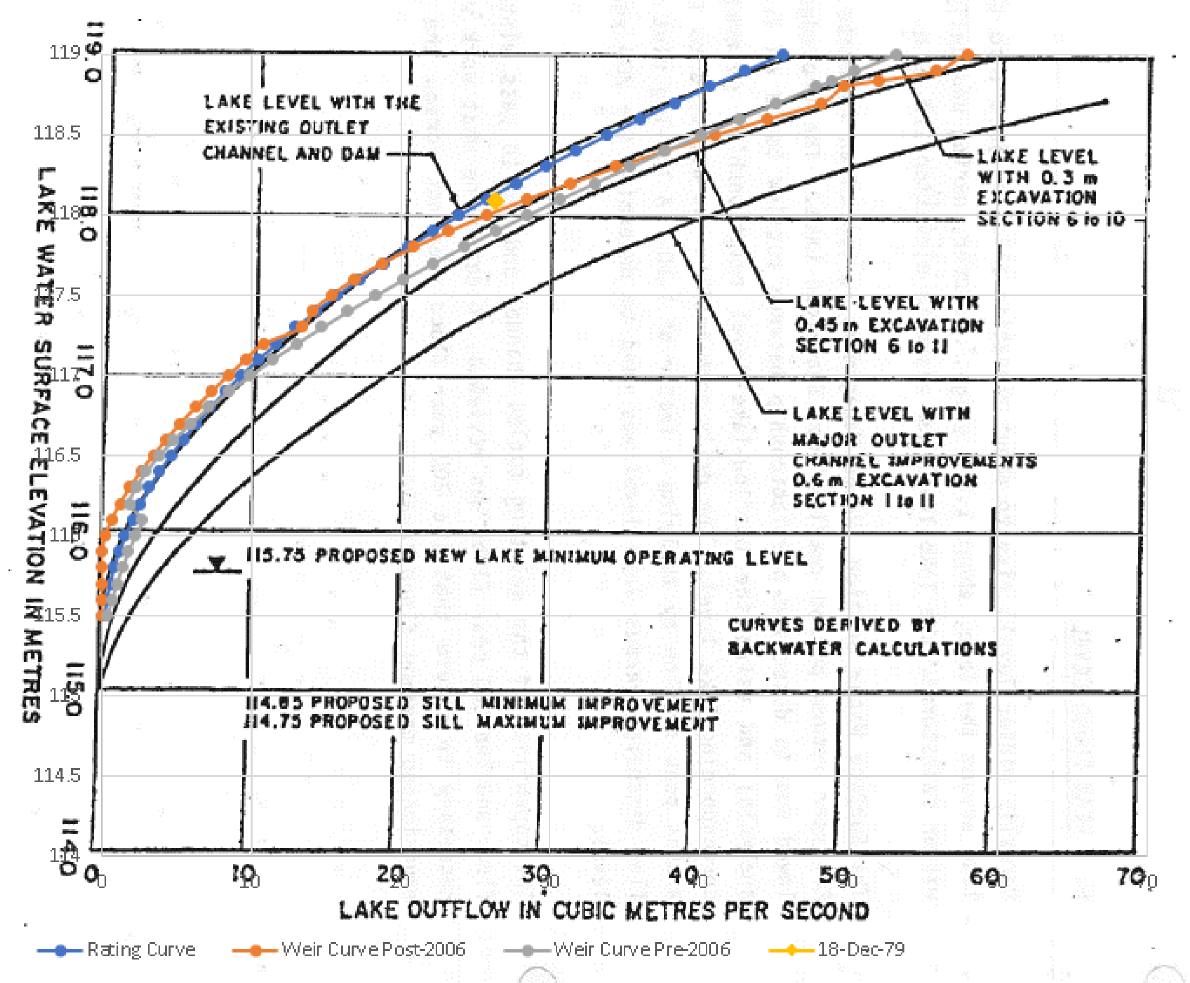


Figure 6-3: Discharge elevation curve by Talbot (1985) fitted with a rating curve and overlain with Weir equations for Pre- and Post-2006. Figure elevations shown in CGVD1928 HT97.

A frequency analysis of annual maximum lake levels was carried out to provide direct estimates of the present-day 200-year lake elevations. These values provided an independent check on the regionalization assumption and the rating curve developed above.

6.3.4 Flood Hazard Analysis-Future Climate Change Scenarios

Assumptions

The estimated 200-year lake outflow value (O_h) was adjusted to account for the future climate change effects as follows:

$$O_f = KO_h \qquad \text{(Eq. 13)}$$

where O_f is the future 200-year outflow discharge as determined through regional analysis and K is the projected increase in discharge due to climate change.

The value of K ranged from 1.1 to 1.4 (corresponding to an increase of between 10% and 40%) as described above. The discharge elevation relationship was then used in order to compute the corresponding lake level.

The estimated wave runup was then added to the still water lake levels to estimate the future FCRP.

Wave Effects

The wave run-up at Shawnigan Lake was calculated using a wind hindcast analysis. Maximum computed wave run-up value of 0.2 m was applied to the lake to account for wave effects.

Flood Construction Reference Plane

The FCRP is calculated by adding the wave-runup to the peak lake level. The estimated peak lake levels and FCRP for Shawnigan Lake for the base case and climate change scenarios are shown in **Table 6-6**. **Photo 6-2** illustrates the computed FCRP's for this study.

Table 6-6: Estimated peak lake levels and Shawnigan Weir outflows.

Simulated Flow Scenario	Outflow [1] (m^3/s)	Lake Level (m)	Increase due to Climate Change (m)	FCRP (m)
1979 flood of record	26.3	118.3	---	118.5
200-year present-day	43.0	118.8	0.0	119.0
200 year + 10%	48.0	119.1	0.3	119.3
200-year + 20%	52.0	119.3	0.5	119.5
200-year + 40%	57.0	119.4	0.7	119.6

Note:

1. These discharges were related to the lake levels with the weir as constructed prior to 2005. The new weir (post-2005) geometry allows for greater creek flows for the same water level. Peak discharges for Shawnigan Creek were not in the scope of this study.

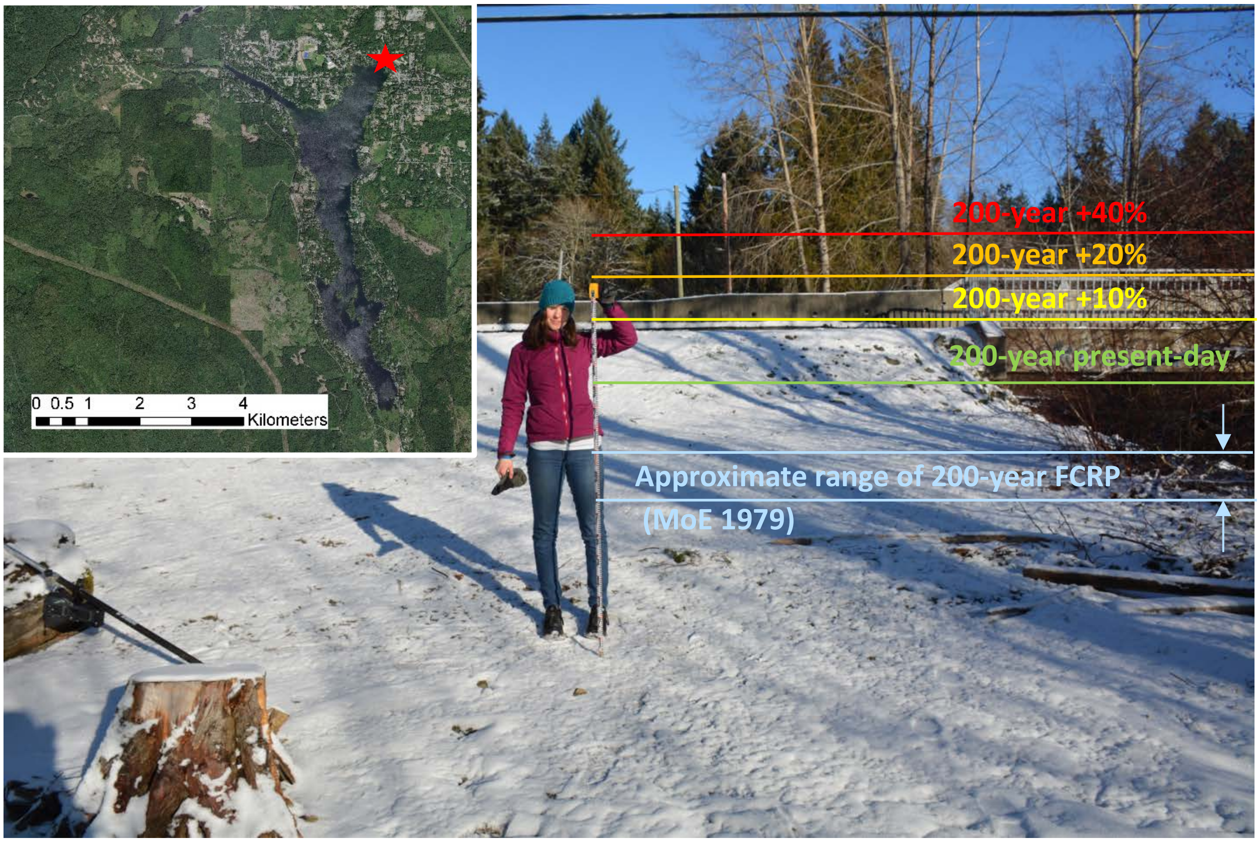


Photo 6-2: Illustrative example of Shawnigan Lake study region FCRP's for present-day and three future scenarios, and an approximate range of the 200-year FCRP based on the FCL adopted by MoE (1979).

6.4 Risk Analysis

6.4.1 Results

The flood risk assessment was completed for Shawnigan Lake using the methodology discussed in **Section 3.3**. **Table 6-7** summarizes the percentage of land flooded in the Shawnigan Lake study region. The table indicates the study region area impacted is relatively insensitive to lake flooding associated with a +10% change in hydrologic inflow to the lake with increasing sensitivity to lake level changes associated with increased lake inflows of between +20% and +40%.

Table 6-7: Summary of percentage of land flooded in the Shawnigan Lake study region.

Jurisdiction	Total Land Area (ha)	Percentage of Land Flooded			
		200-Yr	200-Yr +10%	200-Yr +20%	200-Yr +40%
Shawnigan Lake	30,343	0.4%	0.4%	0.5%	0.5%

The following section presents the results of the analysis in a series of bar charts and a summary table that shows the total value of the given element exposed for each jurisdiction. These figures and table demonstrate the relative impacts and the change in exposure with increasing climate change impacts. A detailed summary of the elements exposed are provided in tabular format in **Appendix A** and a series of visualization tools are presented in **Appendix B** including heat maps showing the relative density of properties affected by flooding for each scenario.

People and Societal Impacts

Figure 6-4 presents the population, number of residential buildings, hospitals, emergency centres, schools, and childcare facilities exposed in the FCRP. Based on the available census data there are 182 people exposed to flooding in the 200-year flood event under present conditions; increasing by 12%, 22%, and 29% over the present-day scenario for the +10%, +20%, and +40% scenarios, respectively. The number of residential buildings exposed increases from 131 for the present-day scenario to 162, 184, and 199, which represents a 24%, 40%, and 52% increase for the +10%, +20%, and +40% scenarios, respectively. No emergency centres, hospitals, schools, or childcare facilities are exposed for any flood scenarios in the Shawnigan Lake study region.

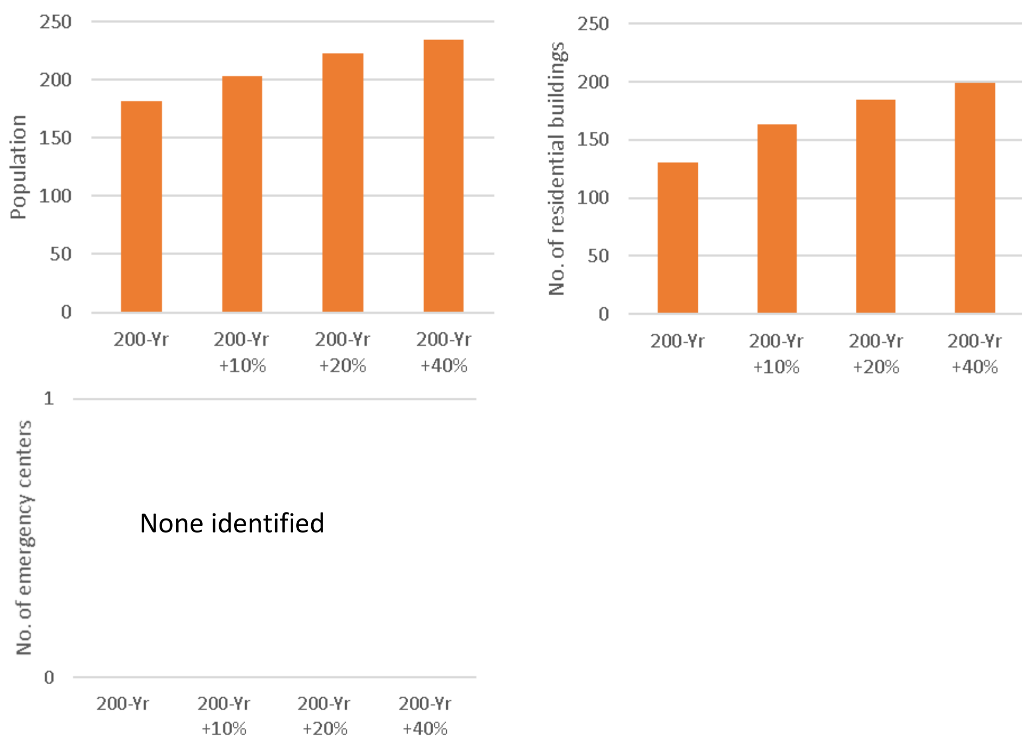


Figure 6-4: People and societal impacts – quantified flood exposures.

Environmental Impacts

Environmental impacts are assessed based on the area of terrestrial ecosystems and sensitive ecosystems, the length of FWA streams, and the number of gas stations located in the FCRP. The counts of elements within the FCRP for each flood scenario are shown in **Figure 6-5**. There is approximately 1 ha of terrestrial ecosystem exposed during the present-day scenario, increasing by a factor of two for the +10% and +20% climate change scenarios and increasing by a factor of three for the +40% scenario. Between 33 Ha and 36 ha of sensitive ecosystem are exposed during the present-day and +40% climate change scenario, respectively. Most of the increase occurs between the present-day and +10% scenario (6% increase) compared to the +20% and +40% scenarios (9% increase over the present-day scenario). Approximately 3 to 4 km of streams are in the FCRP for all scenarios with a relatively linear increase in exposure with increasing FCRP. There are no gas stations in the FCRP for either the +40% or present-day scenarios.

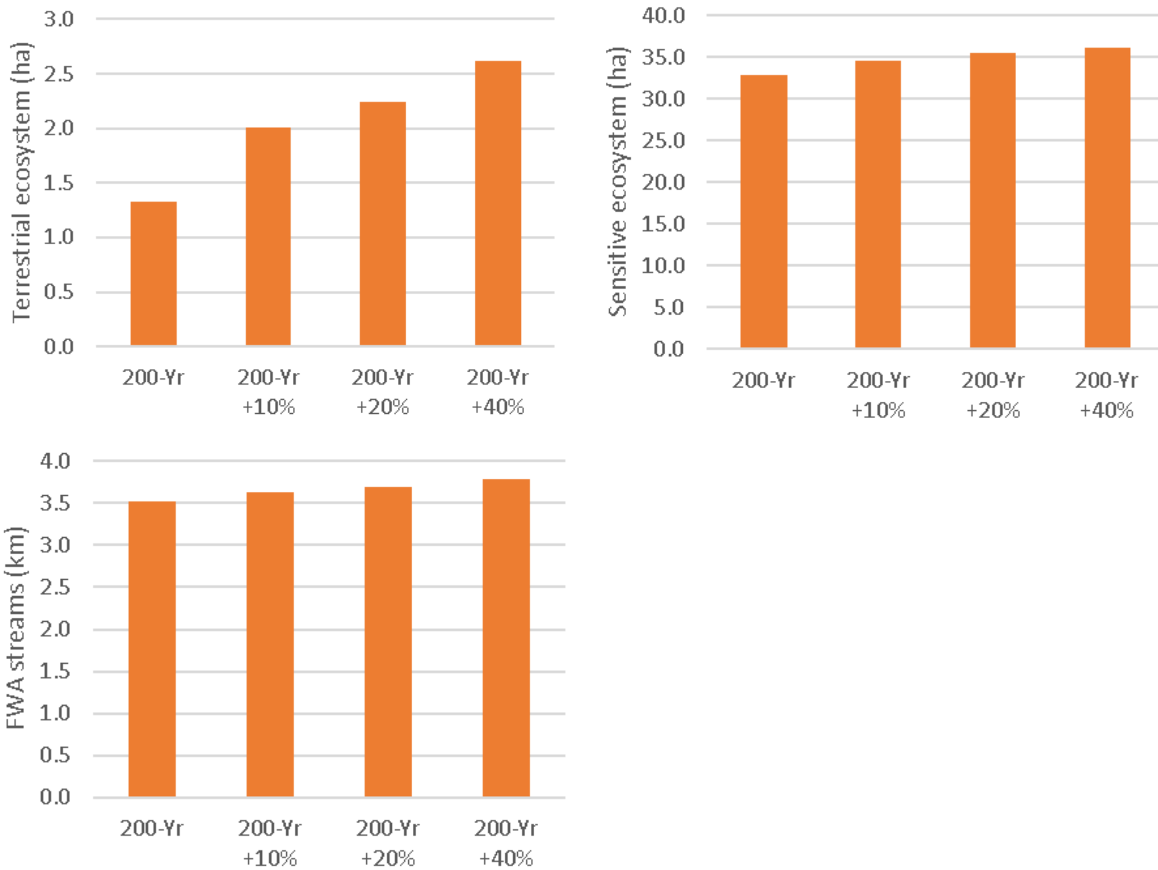


Figure 6-5: Environmental impacts – quantified flood exposures.

Local Economic Impacts

Local economic impacts are assessed based on the assessed value of properties exposed in the FCRP. The value of properties for each flood scenario is shown in **Figure 6-6**. Approximately $1.7 M dollars of commercial property value is exposed during all scenarios. Residential properties exposed increase from about $91 M to $133 M between the present-day and +40% climate change scenario representing a 20%, 33%, and 46% increase over present-day for the +10%, +20%, and +40% scenarios, respectively.

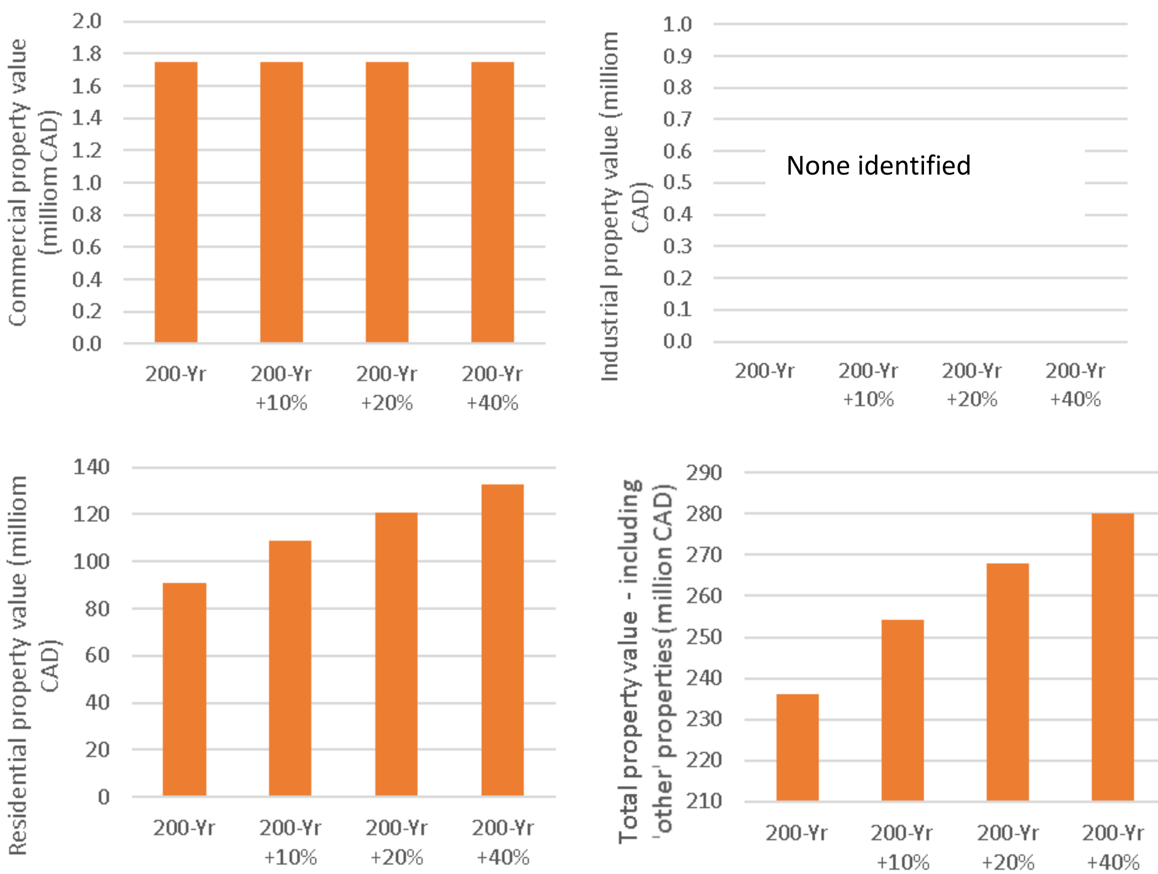


Figure 6-6: Local economic impacts – quantified flood exposures (property values).

Local Infrastructure Impacts

Local infrastructure impacts are assessed based on the number of industrial and commercial buildings, utilities, CVRD water supply and sewer structures, and length of transportation networks exposed in the FCRP. The count of elements within the FCRP for each flood scenario are shown in **Figure 6-7** to **Figure 6-10**.

Figure 6-7 shows no industrial buildings and three commercial buildings exposed for all scenarios. **Figure 6-8** shows the impact to private stakeholder utility structures including BC Hydro, Fortis BC, Shaw, and Telus. Only one BC Hydro structure is affected and no Fortis BC Gas utilities for all scenarios. The largest number of utilities structures in the FCRP belong to Shaw, increasing from 15 to 19 assets exposed between the present-day and +40% climate change scenario; representing a 6%, 20%, and 27% increase over the present-day scenario for the +10%, +20%, and +40% scenarios, respectively. No CVRD sewer utilities and two CVRD water utility assets exist for all scenarios as shown in **Figure 6-9**.

Figure 6-10 shows about 1.5 km of roads in the present-day FCRP, increasing to over 3 km for the +40% climate change scenario; representing a 40%, 87%, and 127% increase over the present-day scenario for the +10%, +20%, and +40% scenarios, respectively. Two bridges are exposed in the present-day scenario, increasing to 3 for the +20% and +40% climate change scenarios. The number of exposed culverts increases from 15 to 35 between the present-day and +40% scenario; representing a 33%, 93%, and 133% over the present-day scenario for the +10%, +20%, and +40% scenarios, respectively. From 1 km to 1.8 km of railway line is exposed between the present-day and +40% climate change scenario; representing a 30%, 70% and 80% increase over present-day scenario for the +10%, +20%, and +40% scenarios, respectively.

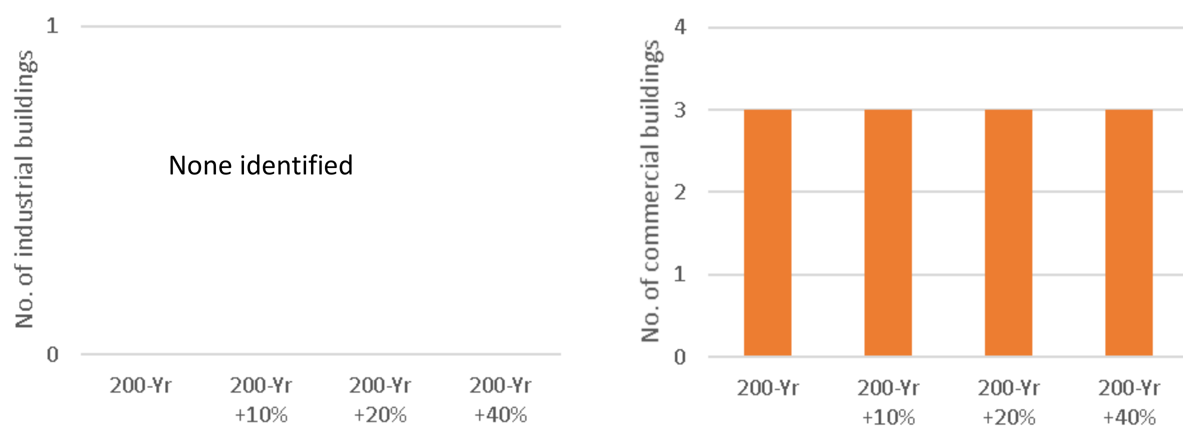


Figure 6-7: Local infrastructure impacts – quantified flood exposures (industrial and commercial buildings).

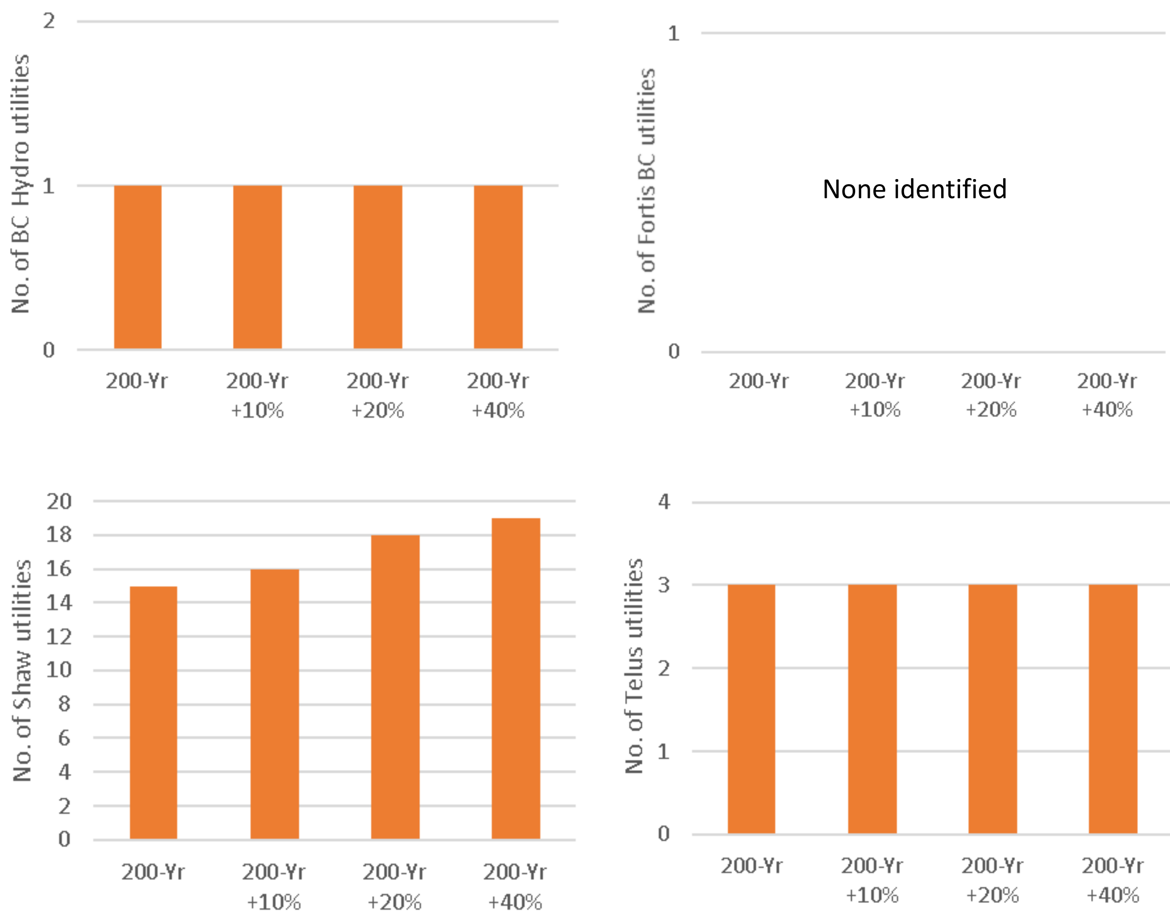


Figure 6-8: Local infrastructure impacts – quantified flood exposures (Shaw, Hydro, Telus).

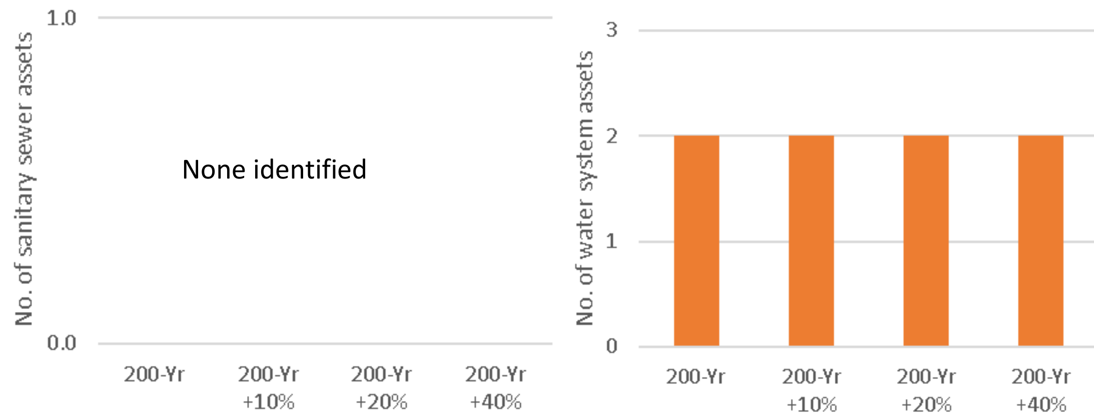


Figure 6-9: Local infrastructure impacts – quantified flood exposures (water and sewer).

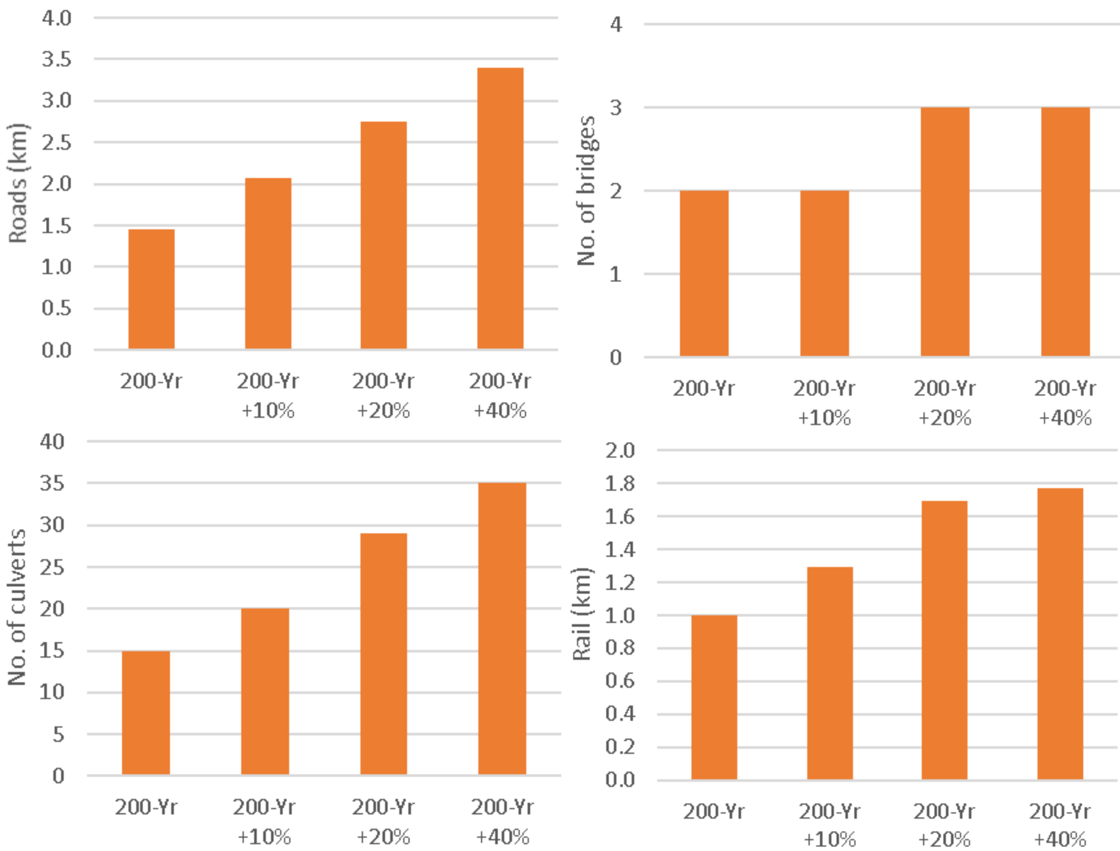


Figure 6-10: Local infrastructure impacts – quantified flood exposures (transportation infrastructure).

Public Sensitivity Impacts

Public sensitivity impacts are assessed based on land area exposed, categorized by land use: urban and developed, agricultural, grasslands, shrublands and forests, wetlands, and barren and exposed land. The total land area of each category for each flood scenario is shown in **Figure 6-11**.

The FCRP covers over 47 ha of urban and developed areas; 64 ha of grasslands, shrublands and forest areas; 9 ha of wetlands; and less than 1 ha of exposed and barren area. Urban and developed areas increase by 15%, 26%, and 34% for the +10%, +20%, and +40% scenarios, respectively. Grasslands, shrublands, and forests areas increase by 11%, 16%, and 22% for the +10%, +20%, and +40% scenarios, respectively. Wetlands and exposed and barren areas are insensitive to increased FCRP for all future flood scenarios.

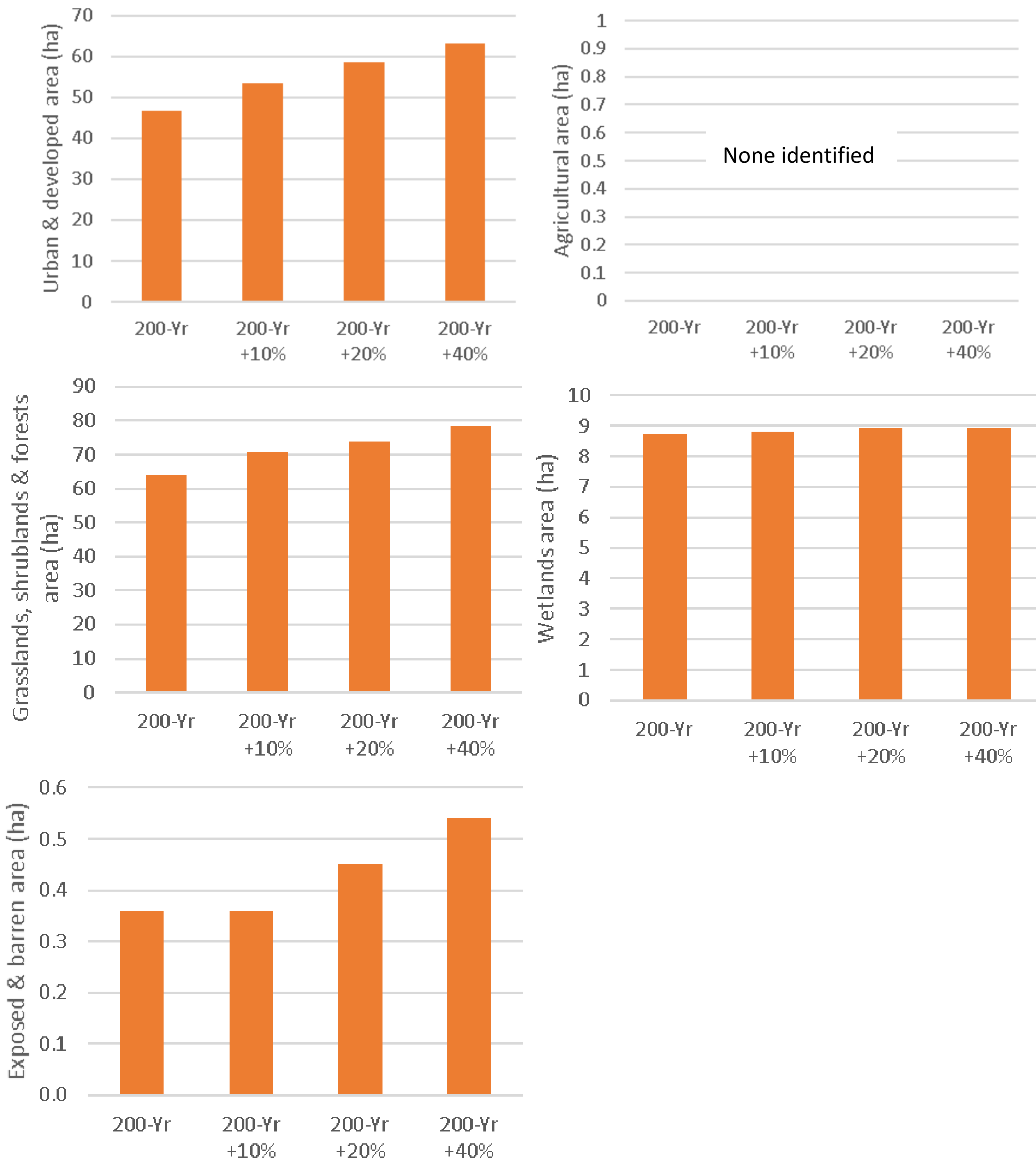


Figure 6-11: Public sensitivity impacts – quantified flood exposures.

6.4.2 Discussion

The results of the risk assessment for Shawnigan Lake show a significant number of people, properties, and transportation structures located in the 200-year FCRP. The total elements exposed for Shawnigan Lake for the present-day, +10%, +20%, and +40% 200-year FCRP scenarios are shown in **Table 6-8**.

The land area exposed under present-day scenario is relatively extreme and the study region is moderately sensitive to increased FCRP associated with future lake flood scenario. Based on the available census data there are 182 people exposed to flooding in the 200-year flood event under present conditions, and this increases relatively linearly for the future scenarios. Under present-day scenario there are 131 residential buildings exposed, increasing by 24%, 40%, and 50% above present-day exposure for the +10%, +20%, and +40% scenarios. No emergency centres, hospitals, schools, or childcare facilities are exposed for any flood scenarios.

Approximately 1 ha of terrestrial ecosystem is exposed during the present-day scenario, and although this element is relatively sensitive to future scenarios the total area of land impacted is relatively small. Between 33 Ha and 36 ha of sensitive ecosystem are exposed during the present-day and +40% climate change scenario, respectively with the area being most sensitive to the +10% future scenario. Approximately 3 to 4 km of streams are in the FCRP for all scenarios and this element is relatively insensitive to future scenarios. No gas stations are exposed for any flood scenarios.

Three commercial buildings, representing approximately $1.7M dollars of value, are exposed for all scenarios, indicating an exposure under the present-day scenario and insensitivity to future increases in flood magnitude. Residential property exposure under present-day is valued at $90.7 M and is relatively sensitive to all climate change scenarios, increasing by 20%, 33%, and 46% for the +10%, +20%, and +40% scenarios. No industrial buildings are exposed for any scenarios.

For all scenarios only one BC Hydro structure and two CVRD water utility assets are affected; and no Fortis BC Gas utilities, CVRD sewer utilities. There are 15 Shaw facilities exposed under present-day scenario, increasing by 6%, 20%, and 27% over the present-day scenario for the +10%, +20%, and +40% scenarios, respectively.

Between 1.5 km to 3.4 km of roads and 15 to 35 culverts are exposed in the present-day and +40% scenarios, respectively, and the pattern of exposure under climate change scenarios indicates these elements are sensitive to increased flood levels. Inundated roads and culverts could impact access and egress to some areas within the study region, and inundated culverts may potentially impact areas farther upstream of the culvert crossing that may otherwise be outside of the area directly inundated by lake flooding. Two bridges are exposed in the present-day, increasing to 3 for the +20% and +40% climate change scenarios. Most of the study region is comprised of grasslands, shrublands and forest areas (~53%) or urban and developed areas (~39%). These areas are relatively sensitive to future changes in flood magnitude. Wetlands and exposed and barren areas cover a much smaller area and are insensitive to climate change scenarios.

Table 6-8: Summary of total elements exposed for Shawnigan Lake study region.

Category	Exposed Elements	Unit	Total			
			200-year	200-year +10%	200-year +20%	200-year +40%
People & Societal	Population	number	182	203	223	235
	Residential Buildings		131	162	184	199
	Hospitals		0	0	0	0
	Emergency Centers		0	0	0	0
	Schools & Childcare facilities		0	0	0	0
Environmental	Terrestrial Ecosystem	ha	1	2	2	3
	Sensitive Ecosystem	ha	33	35	35	36
	FWA Streams	km	3.5	3.6	3.7	3.8
	Gas Stations	number	0	0	0	0
Local Economic	Commercial property value	million $CAD	1.7	1.7	1.7	1.7
	Industrial property value		-	-	-	-
	Residential property value		90.7	108.8	120.7	132.8
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)		236.6	254.2	268.1	280.1
Local Infrastructure	Industrial Buildings	number	0	0	0	0
	Commercial Buildings		3	3	3	3
	BC Hydro Assets		1	1	1	1
	Fortis BC Assets		0	0	0	0
	Shaw Assets		15	16	18	19
	Telus Assets		3	3	3	3
	CVRD Sanitary Sewer Assets		0	0	0	0
	CVRD Reservoirs		0	0	0	0
	CVRD Water System Assets		2	2	2	2
	Road Length	km	1.5	2.1	2.8	3.4
	Bridges	number	2	2	3	3
	Culverts	number	15	20	29	35
	Rail	km	1.0	1.3	1.7	1.8
	Urban & Developed Area	ha	47	53	59	63
	Agricultural Area		0	0	0	0
	Grasslands, Shrublands & Forests Area		64	71	74	78

Category	Exposed Elements	Unit	Total			
			200-year	200-year +10%	200-year +20%	200-year +40%
	Wetlands Area		9	9	9	9
	Exposed & Barren Area		<1	<1	<1	<1

7 RIVERBOTTOM ROAD STUDY REGION

7.1 Overview

Cowichan Lake near Riverbottom Road is an approximately 14 km river reach located downstream of Cowichan Lake and upstream of Duncan, BC. Through this reach, the river meanders across a broad low lying alluvial floodplain. The channel has an irregular meandering pattern with frequent irregular bar formations. The channel is often confined on one or both sides by steep slopes, and the channel typically has a top width of between 40 m and 60 m. Occasionally, the channel migration zone is wider where vegetation patterns, topographic irregularities, and other features visible from the available imagery demarcate the position of historical channel pathways and abandoned meander loops.

7.2 Previous Studies

Hardy BBT Ltd. (Hardy) conducted a channel stability assessment of the Cowichan River in the Riverbottom Road reach in 1989 (Hardy 1989). The purpose of the study was to assist the CVRD in regulating development by assessing the risk of erosion and flooding on this section of the Cowichan River. The study established a hazard map showing areas where river erosion (and associated flooding) are likely to occur. This involved preparing channel shift maps from historical air photography (1958, 1972, and 1986) and 1:5000 scale cadastral mapping to delineate channel changes with time. The analysis showed the upper 10.9 km reach was characterized by significant lateral erosion and channel shifting. A hazard map was prepared delineating zone having varying flood and erosion potential:

- Zone A: represents land that was unconditionally unsuitable for development based on the estimated potential for lateral erosion within a 50-year planning horizon. The zone was delineated assuming future river movement could fall within a band 30 m each side of the Zone A boundary.
- Zone B: represents land that was conditionally suitable for development based on an assessment of erosion and flooding hazards. Within this zone, land was reportedly beyond the probably limits of erosion within the 50-year planning horizon but may still be subject to flooding.
- Zone C: represents land that was determined to be unconditionally suitable for development as these areas were identified to lie beyond the interpreted zone of lateral erosion and flooding.

The BC Ministry of Environment subsequently published floodplain maps on the Riverbottom Road reach in 1997 (MoE 1997). The surveys of the river channel were carried out in 1991. Flood discharges for the analysis were based on the WSC gauge Cowichan River at Duncan (08HA002), with discharges as follows:

- 20-year instantaneous maximum discharge: 523 m^3/s
- 200-year instantaneous maximum discharge: 700 m^3/s

These values were identical to the flows used for the lower river at Duncan, which is a conservative assumption since the drainage area for the Riverbottom Road area is substantially smaller than at Duncan.

7.3 Flood and Erosion Hazard Assessment

7.3.1 Hydrology

Figure 7-1 presents annual maximum daily flows for WSC gauge 08HA011 (Cowichan River near Duncan) between 1960 and 2017. The 2-year, 5-year, 10-year, and 20-year return period annual maximum daily flows are plotted for reference. The largest annual maximum daily flow for the period of record occurred in 1961 (558 m^3/s) and is one of only three events that matched or exceeded the 20-year flow (425 m^3/s); all of which occurred before 1973. Since 1973, only three events have matched or exceeded the 10-year flow (385 m^3/s): 1980, 1986, and 2009.

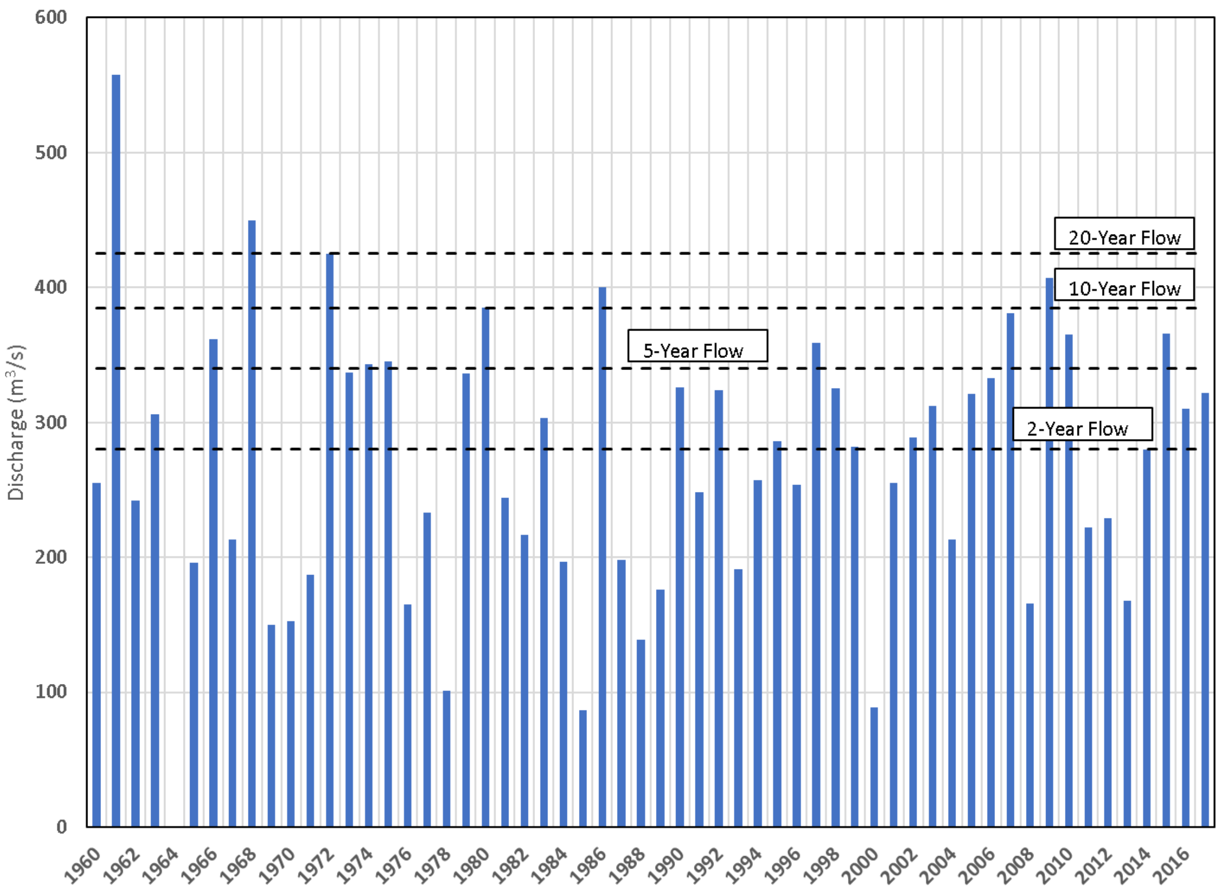


Figure 7-1: Annual maximum daily flows for WSC Gauge 08HA001 (Cowichan River near Duncan). Return periods for the 2-year, 5-year, 10-year, and 20-year daily flows are shown for reference.

7.3.2 Flood Hazard Analysis

Water surface elevations (WSE) for Riverbottom Road were calculated for the estimated present-day and future climate change scenarios for the 20-year and 200-year floods using the flood model that was developed (by others) for the 1997 floodplain mapping (MoE 1997). The floodway is defined as the limits of the 20-year flood and the flood fringe is defined as the limits of the 200-year flood. Development should not be allowed within the floodway, but may be allowed within the flood fringe as long as flood-proofing strategies are used. Cowichan River discharge and the modelled upstream and downstream WSE for Riverbottom Road are provided in **Table 7-1**.

The flood hazard assessment for this study region includes the identification of areas that could potentially be affected, recommendations for follow up assessments, investigations, and data collection to more comprehensively define flood hazard zones for this study region. It is outside of the present scope of work to derive a future bankline position; however, an approach to this is described in **Section 7.3.3**.

Table 7-1: Estimated Cowichan River Discharge and modelled upstream and downstream water surface elevations (WSE) for Riverbottom Road for the floodway and flood fringe.

200-Year Flow Scenario	Floodway - 20 Year			Flood Fringe - 200 Year		
	Discharge (m^3/s)	Model Upstream WSE (m)	Model Downstream WSE (m)	Discharge (m^3/s)	Model Upstream WSE (m)	Model Downstream WSE (m)
Present-day (base case)	422	80.5	41.2	565	80.7	41.8
Base case + 10%	464	80.5	41.4	621	80.8	42.0
Base case + 20%	506	80.6	41.6	678	80.9	42.2
Base case + 40%	591	80.8	41.9	790	81.1	42.6

7.3.3 Channel Stability Under Past and Present-day Conditions

Historical bankline maps were prepared from available air photos (1946, 1958, 1962, 1979, 1986, 1993, 1998, and 2007). Google Earth imagery from 2017 was also used. **Figure 7-2** to **Figure 7-4** present the mapped channel position over time. Some visible features in the imagery appear to be remnants of channels that were active sometime before 1946; however, it is difficult to interpret how extensively this occurred in the floodplain.

Historical channel shift patterns are characterized by lateral erosion, meander migration at the outside of meander bends, and occasional channel avulsion that is triggered by accumulation of sediment and wood debris in the channel and results in the sudden change in channel pattern as the river finds a new flow path. Avulsions can result in the formation of new channels or re-activation of former channels that partially or completely cut off flow from the former main channel.

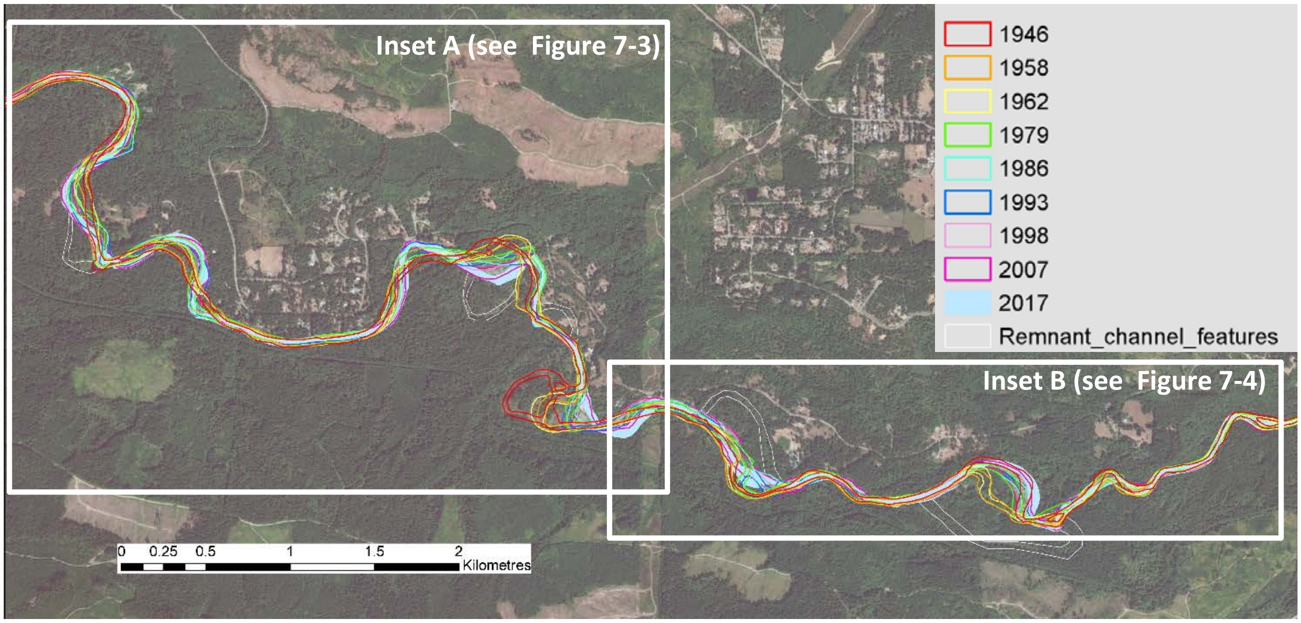


Figure 7-2: Cowichan River historical bankline position (based on images from 1946 to 2007).

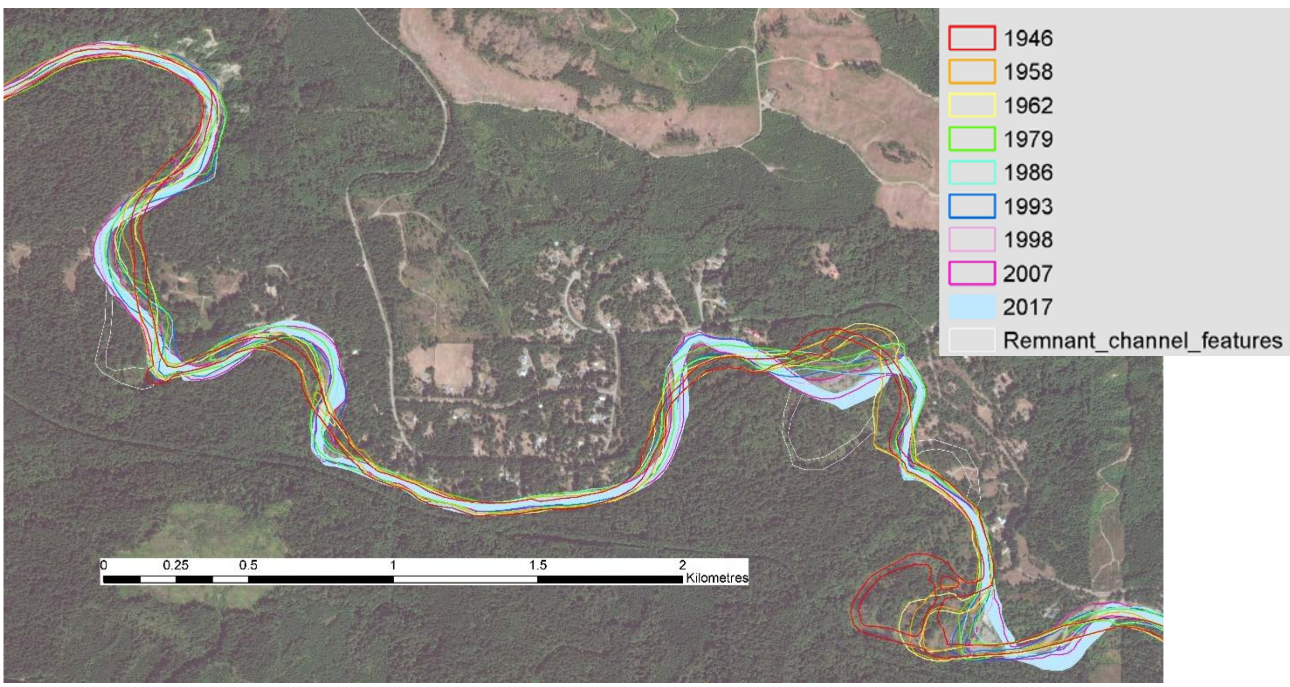


Figure 7-3: Cowichan River historical bankline position – Inset A (based on images from 1946 to 2007).

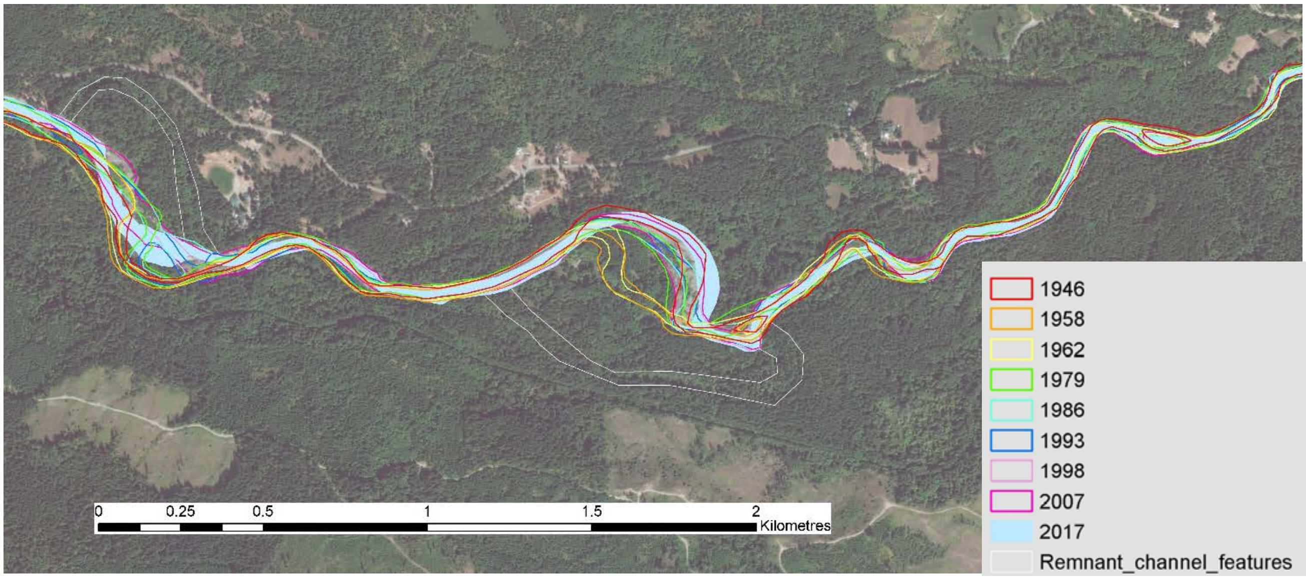


Figure 7-4: Cowichan River historical bankline position – Inset B (based on images from 1946 to 2007).

Historical channel positions were analysed in GIS and presented in **Figure 7-5** to **Figure 7-7** to map channel occupancy over the 61 years of record, remnant channel features visible in the available imagery, and to compare the mapping to a historical assessment of flooding and erosion potential in the study region based on Hazard Zone A (Hardy 1989) and the present-day 20-year flow (floodway) boundary (MoE 1997) and a future floodway boundary scenario (with a 40% in river flow rates).

Lateral migration rates vary along the reach and over time. No obvious trends between the rate of channel migration or channel shifting and annual maximum daily flows were identified, indicating the strong influence of channel configuration, bank lithology, and presence of sediment and wood debris accumulation on bank erosion rates. Historical channel avulsions are apparent at five distinct locations over the period of record; two occurred in the period between 1946 and 1958, two occurred in the period between 1962 and 1979, and one occurred between 1979 and 1986.

The mapped historical channel occupancy and remnant channel features lie within Hardy Zone A for most locations in the study region, except for a few discrete locations where channel erosion has extended beyond the zone boundary, and where former channels have been abandoned through channel avulsion and meander cut-off processes. As described in **Section 7.3.2**, the computed 20-year flood boundary represents the floodway zone where flows generally are deeper and higher velocity relative to flood fringe areas and can be subject to greater erosive forces and more active channel processes. The floodway boundary extends beyond the boundary of Hardy Zone A in several locations for both the present-day and future scenario and indicates a need to update the erosion hazard zone mapping for this study region.

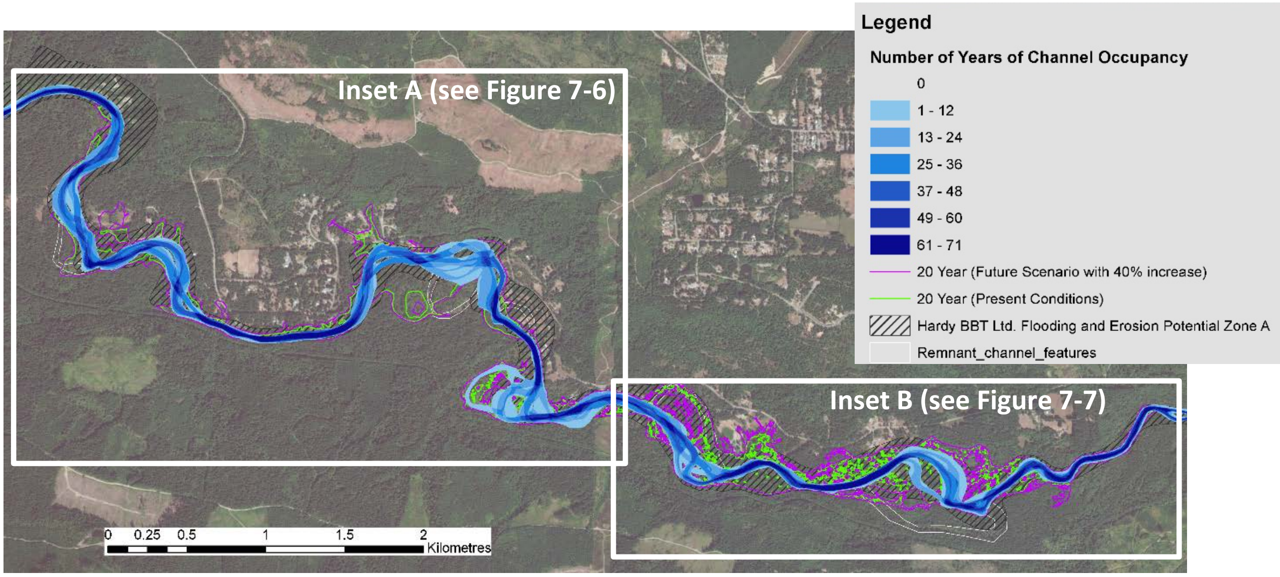


Figure 7-5: Cowichan River historical channel occupancy and 20-year flood scenarios.

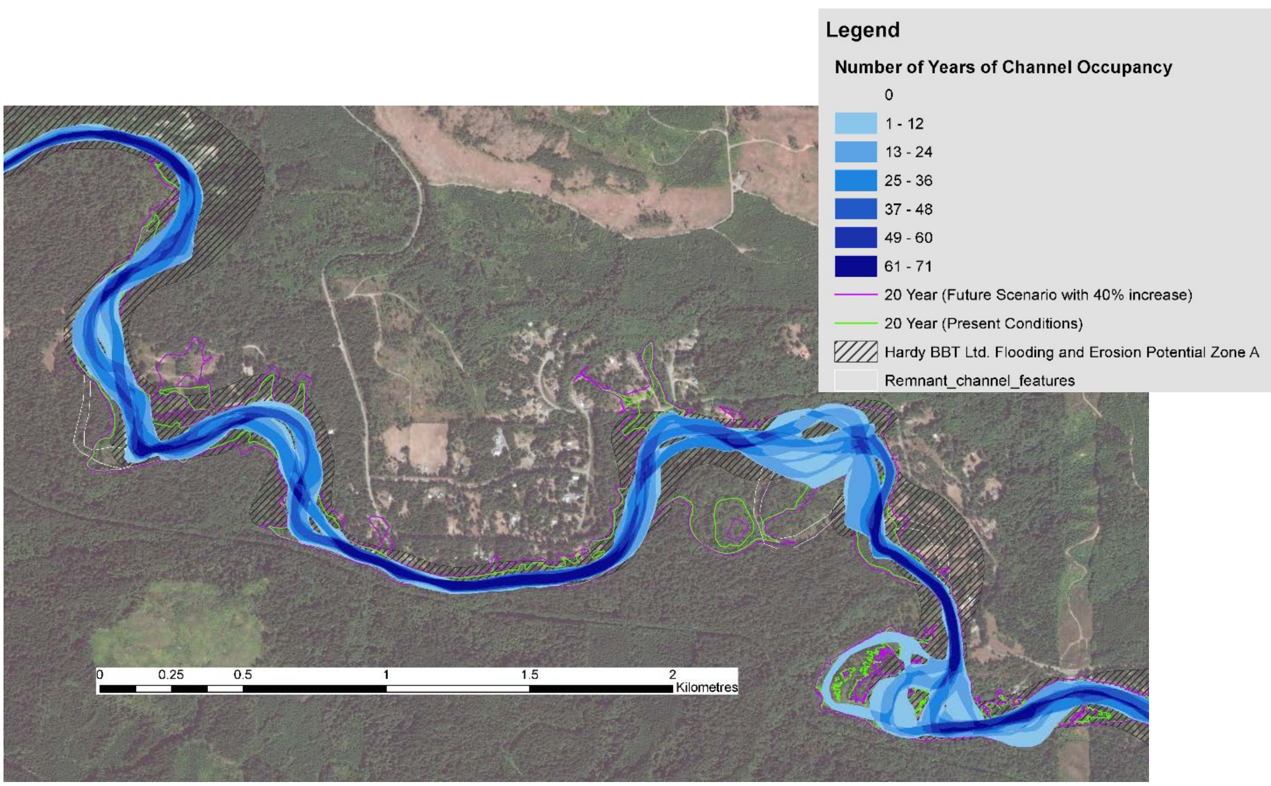


Figure 7-6: Cowichan River historical channel occupancy and 20-year flood scenarios (Inset A).

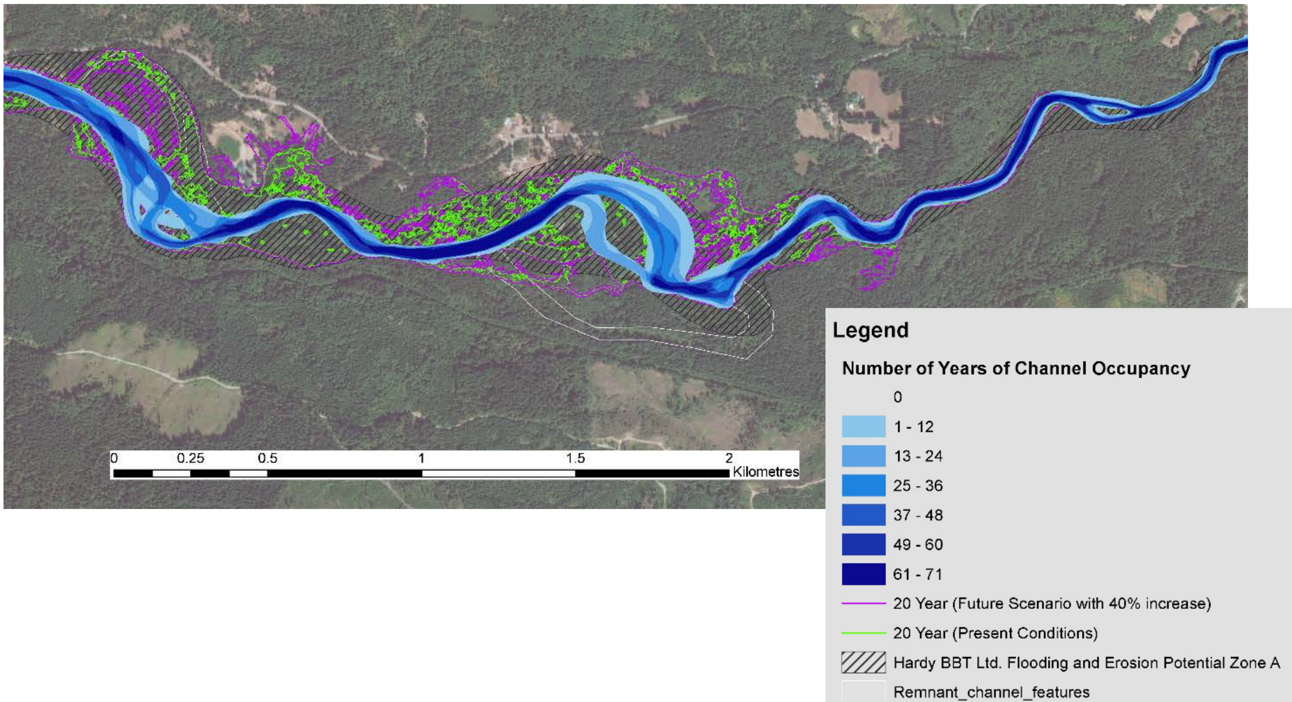


Figure 7-7: Cowichan River historical channel occupancy and 20-year flood scenarios (Inset B).

7.3.4 Future Potential Erosion Hazard Zones

Channel changes are expected to occur in the future as flood discharges increase due to climate change. Channel dimensions such as top width and depth are controlled by a river's "channel-forming" discharge, which usually corresponds to a relatively frequently occurring flood (typically having a return period of between 2 years and 5 years). Stable channel relations developed on gravel-bed rivers in western Canada show that a 30% increase in the channel-forming discharge would result in an increase in channel top width by approximately 15%. With the present channel having a top width of 40 to 60 m, this means the river would widen by at least 6 to 8 m.

It is outside of the present scope of work to derive a potential future bankline position; however, it is expected that increased flood discharges due to climate change would affect the magnitude and frequency of channel instability and flooding due to several factors:

- Experience on the Cowichan River has demonstrated that bank erosion is usually triggered by high flows (typically when floods exceed a 5-year to 10-year recurrence interval) in response to local sediment accumulation on bars and log jams which alter flow paths and trigger local bank failures. Consequently, an increase in the magnitude and frequency of high flows will produce a similar increase to the frequency and magnitude of bank failure and channel shifting.

- More frequent occurrences of flows that exceed bankfull stage will reactivate former side channels and silted-in distributary channels, leading to new avulsion paths and further channel shifting.

Increased precipitation and stream discharges will promote more frequent landslide activity and slumping along valley walls and fluvial terraces upstream of the Riverbottom Road reach. This will increase the overall supply of sediment to the river, which will contribute to additional channel instability and bank erosion problems in reaches downstream of these failures.

Assuming future bankline erosion rates are in the order of past rates and a future regime channel width is approximately 10 m wider than present, an updated Hazard Zone A for a 50-year planning timeframe can be approximated. Hazard Zone A, as presented by Hardy (1989), should be updated based on more recent information that shows the alignment of the active channel extending beyond the limits of Zone A, to accommodate anticipated changes to the regime channel geometry due to effects from climate change, and using professional judgement of likely future channel migration scenarios given the present channel condition.

7.4 Risk Analysis

7.4.1 Results

The flood risk assessment was completed for Cowichan River Riverbottom Road study region using the methodology discussed in **Section 3.3**. **Table 7-2** summarizes the percentage of land flooded in the Cowichan River (Riverbottom Road) study region, categorized by jurisdiction. The Area F – Cowichan Lake South/ Skutz Falls (RBR) jurisdiction has the largest total land area and the largest flooded area relative to other jurisdictions. Both FN jurisdictions are much smaller in area; however, proportionally this represents much more flooded land, each with about 40% of total land area impacted.

Table 7-2: Summary of percentage of land flooded in the Cowichan River (Riverbottom Road) study region, categorized by jurisdiction.

Jurisdiction	Total Land Area (ha)	Percentage of Land Flooded	
		200-Yr	200-Yr +40%
Cowichan Lake South/ Skutz Falls (RBR)	194,607	<0.1%	0.1%
Cowichan Station/ Sahtlam/ Glenora RBR	13,573	0.7%	0.9%
Kakalatza 6	8	40.2%	47.1%
Tzart-Lam 5	9	37.0%	39.6%
Total	208,197	0.1%	0.1%

The following section presents the results of the analysis in a series of bar charts and a summary table that shows the total value of the given element exposed for each jurisdiction. These figures and table demonstrate the relative impacts and the change in exposure with increasing climate change impacts. For this study, the analysis for Cowichan River (Riverbottom Road) study region was limited to present-day condition and +40% future flow scenario with climate change. A detailed summary of the elements exposed are provided in tabular format in **Appendix A** and a series of visualization tools are presented in **Appendix B** including heat maps showing the relative density of properties affected by flooding for each scenario.

People and Societal Impacts

Figure 7-8 presents the population, number of residential buildings, hospitals, emergency centres, schools, and childcare facilities exposed in the FCRP. Based on the Census data there are 61 people exposed to flooding in the 200-year flood event under present conditions, increasing to 90 for the +40% climate change scenario; a 48% increase in exposure. For these scenarios the number of residential buildings exposed doubles from 5 to 20 (300% increase), and all lie within the Area F – Cowichan Lake South/Skutz Falls electoral area. No emergency centres, hospitals, schools, or childcare facilities are exposed.

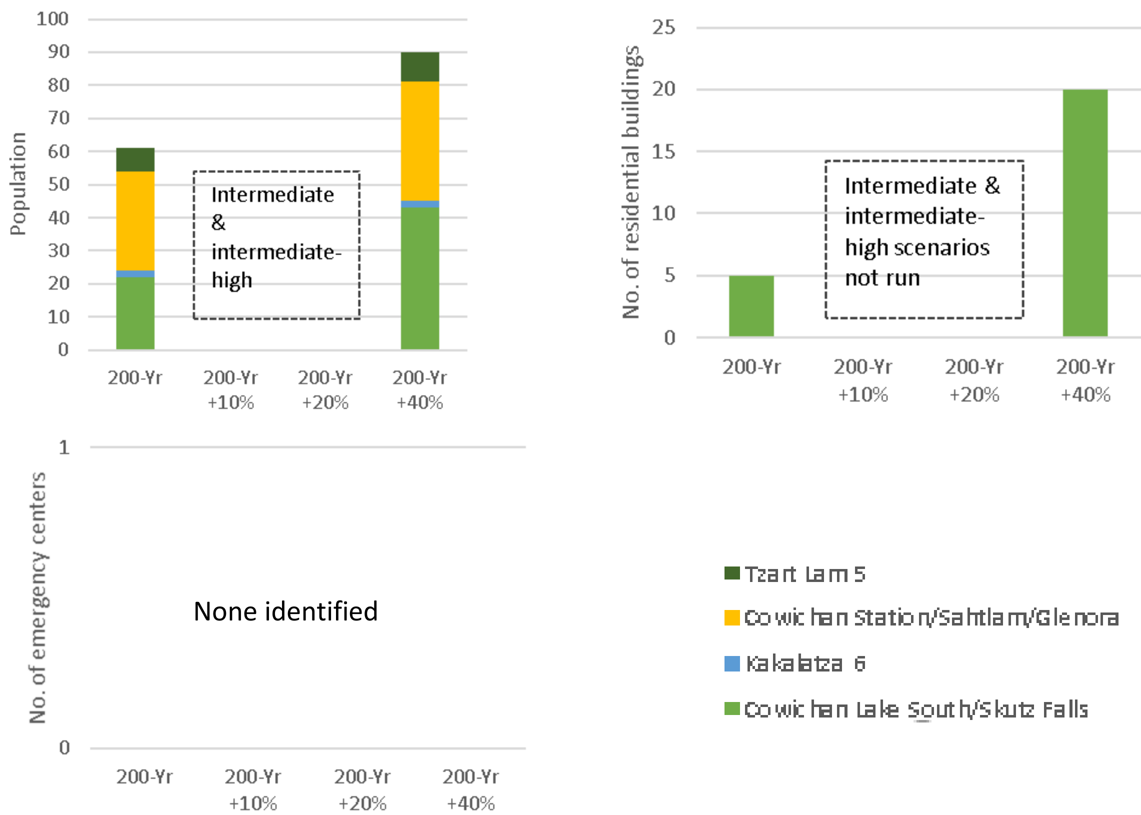


Figure 7-8: People and societal impacts – quantified flood exposures.

Environmental Impacts

Environmental impacts are assessed based on the area of terrestrial ecosystems and sensitive ecosystems, the length of FWA streams, and the number of gas stations located in the FCRP. The counts of elements within the FCRP are shown in **Figure 7-9**. There is 29 ha of terrestrial ecosystem and approximately 134 ha of sensitive ecosystem exposed during the present-day scenario, increasing to 36 ha and 149 ha, respectively for the +40% climate change scenario; an increase of 23% and 12%, respectively. Almost 15 km of streams are in the FCRP for both the 200-year present-day and +40% climate change scenario. There are no gas stations in the FCRP for either the +40% or present-day scenarios.

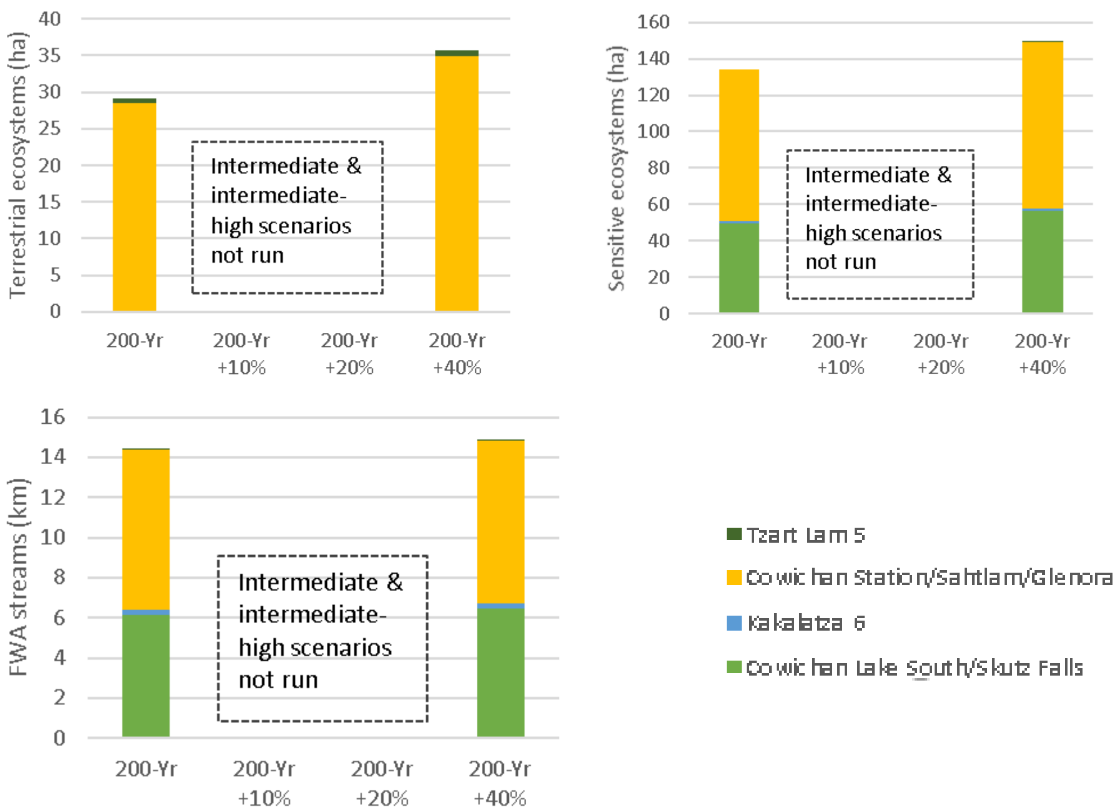


Figure 7-9: Environmental impacts – quantified flood exposures.

Local Economic Impacts

Local economic impacts are assessed based on the assessed value of properties exposed in the FCRP. The value of properties for each flood scenario is shown in **Figure 7-10**. No commercial or industrial property is within the FCRP boundary for this study region. Approximately $3.3M of residential property value is exposed during the present-day, increasing to almost $11.2M under the +40% climate change scenario, an 236% increase.

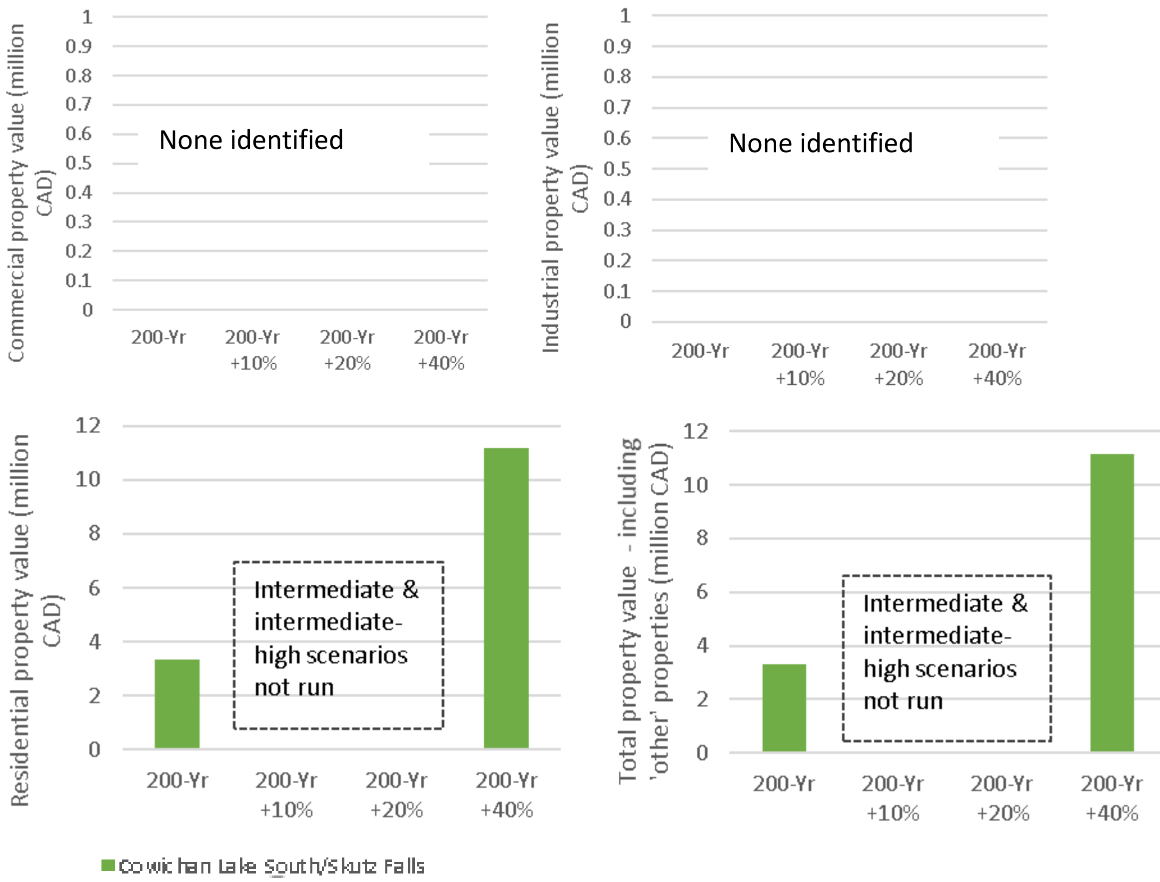


Figure 7-10: Local economic impacts – quantified flood exposures (property values).

Local Infrastructure Impacts

Local infrastructure impacts are assessed based on the number of industrial and commercial buildings, utilities, CVRD water supply and sewer structures, and transportation assets exposed in the FCRP, of which there are none within the Riverbottom Road study region aside from transportation assets presented in **Figure 7-11**.

Approximately 0.2 km of roads are located within the present-day FCRP, increasing to about 1 km for the +40% climate change scenario, a 570% increase. Two culverts are exposed in the present-day scenario, increasing to 10 in the +40% climate change scenario (a 400% increase), and no bridges are exposed in either scenario.

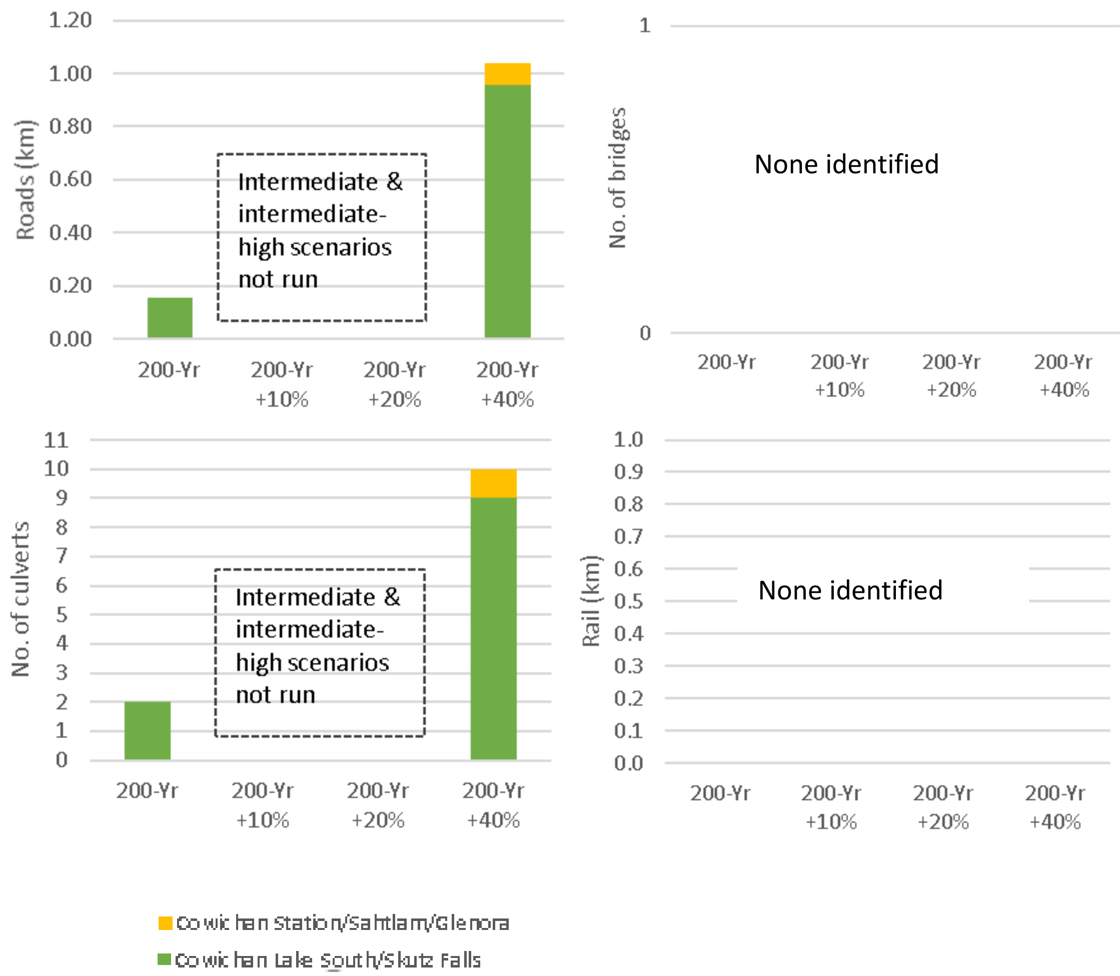


Figure 7-11: Local infrastructure impacts – quantified flood exposures (transportation infrastructure).

Public Sensitivity Impacts

Public sensitivity impacts are assessed based on land area exposed, categorized by land use: urban and developed, agricultural, grasslands, shrublands and forests, wetlands, and barren and exposed land. The total land area of each category for each flood scenario is shown in **Figure 7-12**. The FCRP covers over 25 ha of urban and developed land; 133 ha of grasslands, shrubland, and forest area; and 13 ha of wetland for the present-day scenario. Under the +40% climate change scenario these land areas increase to 33 ha, 179 ha, and 14 ha, respectively; an increase of 31%, 34%, and 5%, respectively. No agricultural land exists within either flood scenario boundary.

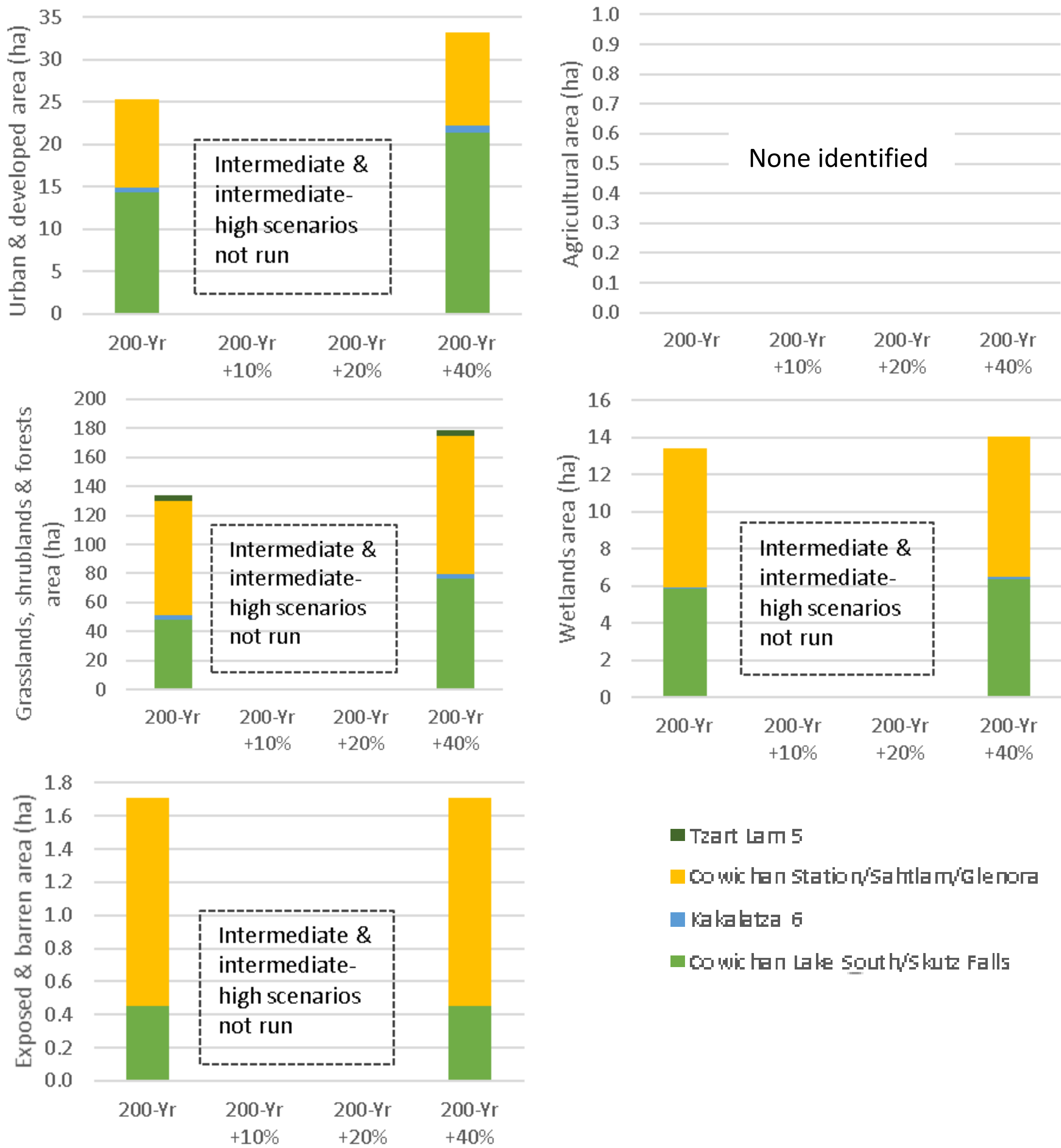


Figure 7-12: Public sensitivity impacts – quantified flood exposures.

7.4.2 Discussion

The total elements exposed for Riverbottom Road for the present-day 200-year FCRP and the +40% scenario, are shown in **Table 7-3.**

Based on the Census data, there are 61 people exposed to flooding under present conditions, increasing to 90 for the +40% scenario, between 40% and 50% within the Cowichan Station/ Sahtlam/ Glenora jurisdiction, depending on the flood scenario. Fewer population numbers are in the Cowichan Lake South/ Skutz Falls jurisdiction with between 12% and 15% within the two FN jurisdictions, depending on the flood scenario.

In general, exposures within this study region primarily comprise of either residential buildings within Area F – Cowichan Lake South/ Skutz Falls electoral area, or grasslands, shrublands, and forest areas. A more detailed review of population exposure is warranted considering no residential buildings are included in the inventory for other jurisdictions. Five residential buildings are exposed under present-day scenario increasing to twenty under the +40% climate change scenario. Impacts on property values increases from $3.3M to $11.2M between the present-day and +40% climate change scenario.

A minor amount of transportation infrastructure appears to be exposed; however, the road network in this area are generally limited to single routes; therefore, an impassible section of road could result in loss of access or egress to residential homes. No bridges and ten culverts are inundated under both scenarios; a minor length of road is inundated under present-day scenario (0.2 km), increasing fivefold to 1.0 km for the +40% scenario.

Table 7-3: Summary of total elements exposed for the (Cowichan River) Riverbottom Road study region.

Category	Exposed Elements	Unit	Total	
			200-year	200-year +40%
People & Societal	Population	number	61	90
	Residential Buildings	number	5	20
	Hospitals	number	0	0
	Emergency Centers	number	0	0
	Schools & Childcare facilities	number	0	0
Environmental	Terrestrial Ecosystem	ha	29	36
	Sensitive Ecosystem	ha	134	149
	FWA Streams	km	14.4	14.8
	Gas Stations	number	0	0
Local Economic	Commercial property value	million $CAD	-	-
	Industrial property value	million $CAD	-	-

Category	Exposed Elements	Unit	Total	
			200-year	200-year +40%
	Residential property value		3.3	11.2
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)		3.3	11.2
Local Infrastructure	Industrial Buildings	number	0	0
	Commercial Buildings	number	0	0
	BC Hydro Assets	number	0	0
	Fortis BC Assets	number	0	0
	Shaw Assets	number	0	0
	Telus Assets	number	0	0
	CVRD Sanitary Sewer Assets	number	0	0
	CVRD Reservoirs	number	0	0
	CVRD Water System Assets	number	0	0
	Road Length	km	0.2	1.0
	Bridges	number	0	0
	Culverts	number	2	10
	Rail	km	0	0
	Urban & Developed Area	ha	25	33
	Agricultural Area	ha	0	0
	Grasslands, Shrublands & Forests Area	ha	133	179
	Wetlands Area	ha	13	14
	Exposed & Barren Area	ha	2	2

8 LAKE AND RIVERINE FLOODPLAIN MITIGATION STRATEGIES

8.1 Beginning of Modern Flood Management

River and coastal diking were carried out along portions of the Cowichan River in the 1950s and 1960s. Coastal dikes such as the Dinsdale Farm Dike, Rodenbush Dike and Blackley Farm Dike were originally constructed as "ring dikes" to create polders for farm land. Major river dikes were constructed along the banks of the Cowichan River downstream of Highway 1 in the 1980s. These dikes were constructed relatively close to the river in most locations, reducing floodplain conveyance and making them susceptible to impacts from sedimentation and erosion.

Floodplain mapping was carried out on several areas under the Canada-Provincial Floodplain Mapping Program that ran between 1974 and 2003. This work included:

- Shawnigan Lake (1979)
- Cowichan Lake (1984)
- Chemainus River (1990)
- Lower Cowichan-Koksilah River, and
- Cowichan River at Riverbottom Road (1997)

These studies focused primarily on riverine flooding, with relatively less attention given to coastal flooding issues. The floodplain maps were utilized by communities for regulating future developments on floodplains and for land-use planning. However, floodplain maps need to be periodically updated and revised to account for hydrological changes, developments on the floodplains and topographical changes to the rivers due to erosion and sedimentation. All of these maps are obsolete and need to be updated. In 2004, responsibility for floodplain mapping was downloaded by the provincial government to local government.

8.2 Future Flood Planning and Flood Mitigation

Many planners describe three different ways communities can respond to flood risks (**Figure 8-1**):

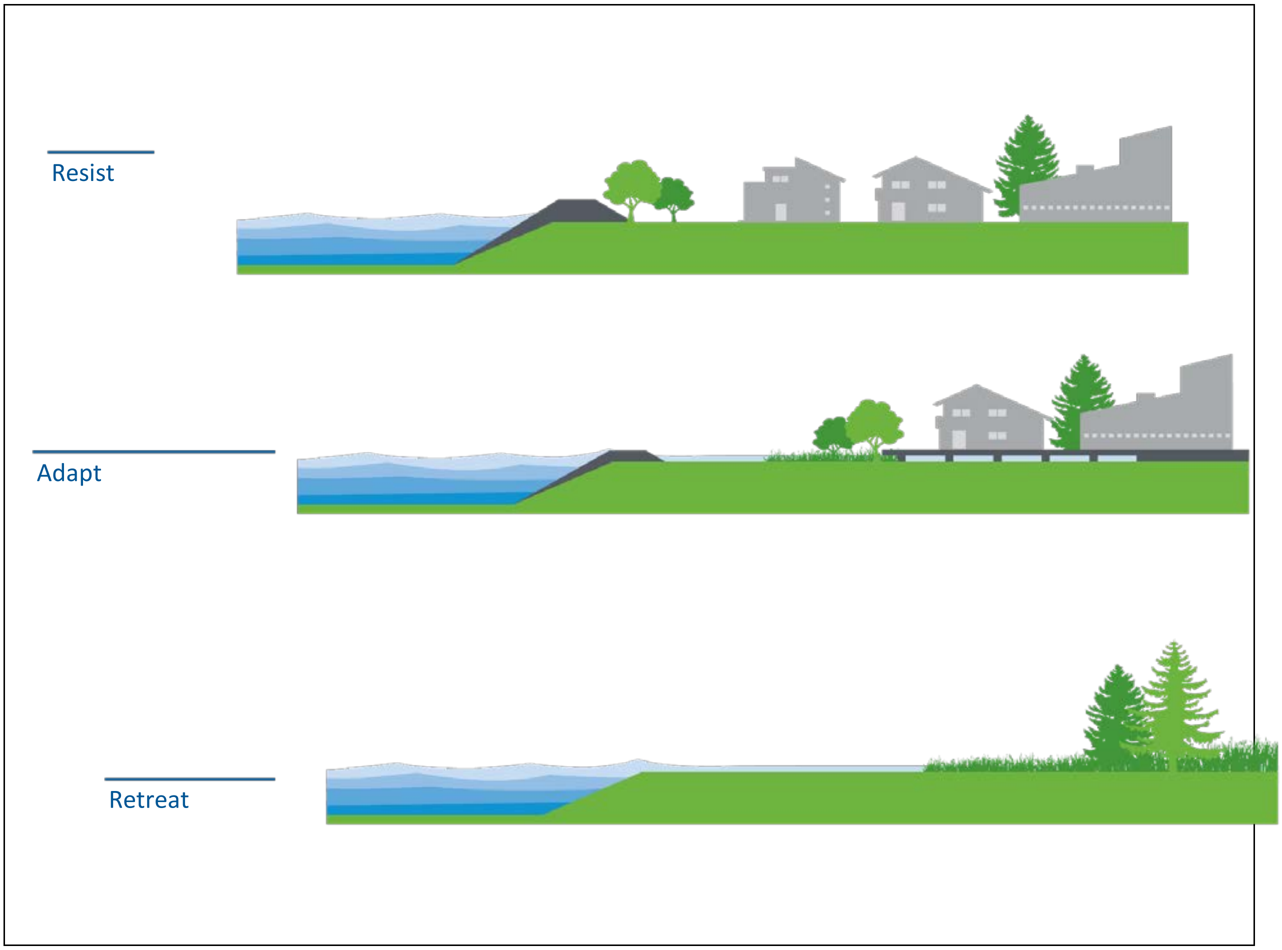


Figure 8-1: Adaptation approaches to flood risks.

- "Resist" is the traditional engineering approach and involves relying predominantly on structural defences such as dikes or dams to hold the water back. All structural defences require maintenance and upgrades, and are vulnerable to failure. Therefore, they should not be the only defence.
- "Adapt" allows existing infrastructure to be exposed to the flood hazard, but ensures it is sufficiently protected to limit structural damage and ensure no injury or loss of life. This involves identification of the flood hazards, flood proofing of existing structures, flood warning systems, changing land-use practices, policy implementation, and others. Exposure to the flood hazard is still present but the vulnerability of the exposed element is reduced, thus lowering the overall hazard.

- "Retreat" is generally the last resort reserved for areas where the hazard is too high. To retreat is to allow the water to take its natural course, and elements are moved sufficiently far away that it is no longer exposed to the hazard.

In practice, these approaches all involve some combination of structural and non-structural mitigation measures. The difference is mainly in terms of which measures are relied on most for mitigating the hazard. For example, even when a flood control dike is constructed to resist flooding, a range of adaptive, non-structural measures are usually implemented behind the dike. These could include land-use planning measures requiring flood proofing of residence, and limiting the types of infrastructure behind the dike (restricting construction of new hospitals or emergency centres to areas outside the flood fringe).

Also, many adaptation approaches still rely on structural flood control measures as an important aspect of mitigating against flooding. For example, the widespread and highly successful program of levee set-back projects that has been underway throughout the United States over the last 20 years involves a combination of resisting and adapting to the flood hazard. In this case, the focus is on how to resist against flooding in a manner that reduces the risk of levee failure and enhances a community's resilience to withstand future climate change.

The approach of relying solely on structural flood control measures ("resist") is widely recognized as a costly endeavour that will not be sustainable over the long term and can potentially increase the flood risk over time by encouraging higher degrees of development within flood protection zones than otherwise may occur.

Section 8.2.1 describes potential mitigation and adaptation concepts that could be carried out at Shawnigan Lake or Cowichan Lake study regions and **Section 8.2.5** describes the same for Riverbottom Road study region.

8.2.1 Mitigation and Adaptation Concepts for Shawnigan Lake and Cowichan Lake

The flood hazard analysis in **Sections 5.3** and **6.3** showed flood levels could be raised by up to 1.3 m on Cowichan Lake and up to 0.6 m on Shawnigan Lake. The following sections describe potential flood mitigation concepts and strategies that could be considered to address these impacts.

Modify Lake Outlet ("Resist" Approach)

There are only a limited number of structural flood mitigation measures that could be considered for resisting flooding. Lake levels are controlled by the inflow hydrograph, the lake storage and the hydraulic characteristics of the outlet. One alternative could include lake outlet modification to increase its capacity, by lowering the outlet's control or by enlarging the outlet (widening) in order to increase its conveyance. This type of change may cause some degree of localized increases in flow velocities and depth; however, more detailed assessment would be required to assess for potential impacts to properties near the lake outlet or upper river. However, downstream effects in the river downstream of the lake are more likely to be related to future effects associated with climate change than changes to the weir outlet. The environmental and social impacts of modifying the structures would need to be assessed to determine the feasibility of this type of intervention.

A weir has been constructed at the outlet of both Cowichan Lake and Shawnigan Lake, and these structures are intended primarily for retaining water during the dry season. The flow control gates are open in the winter months and the weir eventually is overtopped as inflows to the lake exceeds outflows and water levels increase; the weir structure is not the main control of lake levels during the months when the lakes are at their highest. For Cowichan Lake, the control in the winter months is a natural bedrock constriction downstream of the weir (**Figure 5-2**).

In order to lower the lake level at Cowichan Lake, this feature would have to be removed and the upper channel of the Cowichan River would have to be lowered to allow for the lake to drain to lower levels. Further channel excavation would be required downstream of this feature in order to significantly lower the outlet water levels. At present, there is only a 0.5 m water level drop between the lake and the river at the WSC gauge on the Cowichan River on the Cowichan Lake Road bridge. In order to lower the lake level by approximately 1 m, channel excavation would need to be carried out over a distance of at least 1 km downstream from the weir. Lowering the winter time natural control at Cowichan Lake could have severe water storage implications if the lake level is drawn down farther than it is able to replenish during late winter or early spring; any modifications to Cowichan Lake outlet control must carefully consider and integrate both flood mitigation and water storage objectives. Other considerations should include potential impacts associated with altered groundwater levels.

A similar approach as described above could be considered to lower the level of Shawnigan Lake to reduce the potential for flooding. Similarly, the potential impacts to water storage and groundwater conditions should be considered when evaluating the feasibility of a lowered winter time lake level.

8.2.2 Flood Warning System (“Adapt” approach)

Flood warning systems are a valuable component of an emergency management program to reduce vulnerability to flooding by providing advance notice of potentially hazardous flood conditions. Real time water level sensors installed at key locations could be programmed to send an alert via a cellular or satellite communications system when water levels rise above a threshold level. This type of system requires a capital investment, and ongoing monitoring and maintenance to support its proper functioning.

8.2.3 Road Improvements (“Adapt” approach)

Several kilometers of roads will be inundated in the present and future design flood scenarios. For evacuation routes and other routes to emergency centers or other important facilities, consideration should be made to raise the road and install relief culverts or change its alignment out of the floodplain area. For other roads, temporary inundation may not be a concern depending on the frequency and duration of flooding, volume of traffic on the road, and presence of alternate routes.

Floodproofing ("Adapt" approach)

Buildings within the floodplain can undergo floodproofing which can involve any combination of the following:

- Raising the foundation elevation to above the flood construction level.
- Basements can remain but must allow the flow of water to equalize pressures if there is a high flow of water. All utilities must be moved to upper floors above the FCL.
- Installing a backwater valve on the sewer outlet to prevent the backwater of sewage back into the building.
- Scour protection around the foundations ranging from riprap to bioengineering solutions depending on the expected waves and velocities expected.
- Landscaping on the properties to allow for and direct the flow of water away from the building or to store water. Examples are swales and detention ponds.

8.2.4 Retreat

In floodplain areas that are still undeveloped, these areas should be kept in a natural state and the land should remain undeveloped. Undeveloped land can be rehabilitated as riparian and aquatic habitat. Future urban development should be promoted in areas with low flood risk and a lower habitat sensitivity. Tools that help with the long-term planning are Flood Hazard Maps and Habitat Sensitivity Maps.

In some developed areas that will be subject to deep flooding or high wave attack, it may not be practical to protect or adapt. This study provides key information on the present-day and future flood potential and exposures, and the recommendations and conclusions presented in **Section 13** are intended to inform long term planning such that development in potential flood zones does not create an unacceptable level of risk, as determined by the governing jurisdiction.

8.2.5 Riverbottom Road

8.2.6 Structural Flood Control Measures ("Resist" approach)

Future development on the floodplain may eventually require consideration of flood control measures. For instance, the Cowichan IFMP (NHC 2009) recommended setting back flood dikes to retain floodplain conveyance and to reduce the risk of failure from channel shifting and erosion (Strategy 1 through 4). Since the IFMP was adopted by the CVRD, the benefits of setting back dikes have been validated through several projects, particularly the major initiatives being implemented in Washington State (**Figure 8-2**, USACE 2017). These benefits include reduced risk of dike failures under varying flood flows and improving ecosystem health. This approach makes structural measures far more robust to future flood conditions, since flood levels are relatively insensitive to discharge when the floodplain can convey a large fraction of the total flow.

If dike construction is determined by the CVRD to be an appropriate mitigation measure, it is important to recognize other non-structural flood management measures would still be required for areas in the floodplain behind the set-back dikes (discussed below).

8.2.7 Non-structural Flood Control Measures ("Resist" approach)

The Cowichan River has a relative abundance of sediment and large woody debris (LWD). Ongoing channel maintenance activities in the lower Cowichan River have been recurring since 2013 to remove accumulating sediment and wood and improve the hydraulic capacity of the channel. Strategic management of sediment and LWD in the Cowichan River near Riverbottom Road could reduce the bank erosion and channel avulsion potential in key areas. Access to key areas may be challenging, and a cost-benefit analysis of future sediment and LWD management is warranted as part of the evaluation of mitigation options for this study region.

Flood By-Laws and Land Use Controls ("Adapt" approach)

Updated floodplain mapping and land-use controls would be effective for limiting exposure on the floodplain. Both flood and erosion hazards would need to be addressed. This would require updating the 1997 floodplain maps that are currently in-use and updating the erosion hazard zones that were established by BBT Hardy in the 1980s.

Future floodplain mapping would need to map both the "floodway" and "flood fringe" zones (NHC, 2009) in order to define areas where development could still occur on the floodplain. Updated erosion hazard maps would identify the channel migration zone, where developments would experience both flooding and erosion hazards. These areas would also be excluded from future development.

Flood warning ("Adapt" approach)

Flood warning systems can be used to assist in flood proofing and evacuation planning in critical flood prone areas. The existing gauge on the Cowichan River at the outlet of Cowichan Lake can provide useful information on future flows and expected levels at this site. Real-time gauges in the Riverbottom Road reach could also provide information on rapid increases in water levels due to log jams and debris accumulation in the channel. However, given the relatively short response times of the river, it may be difficult to respond quickly enough to prevent damage from occurring.

ERDC/CHL CHETN-VII-17
July 2017

US Army Corps of Engineers®

Overview of Levee Setback Projects and Benefits

by Travis A. Dahl, Charles H. Theiling, and Waleska Echevarria

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) provides an overview of levee setback projects and their potential benefits. Levee setbacks relocate a traditional river levee farther away from the channel to provide additional floodplain storage, thereby reducing flood heights, slowing flood peaks, and in some cases, providing ecosystem and recreational benefits.

INTRODUCTION: Levee setbacks are generally defined in relation to existing, traditional levees. Typical levees constrain the overbank flow of a river to a defined channel to restrict the area of potential flooding. Levee setbacks relocate the levee farther away from the river channel to provide additional floodplain storage, reducing flood heights. This area between the levees and the main river is sometimes referred to as the batture. Figure 1 illustrates how a levee setback can be used to create additional floodplain and allow more room for the river to adjust.

Figure 1. Levee setback on the Puyallup River in Washington State with flow from left to right. The red line indicates the historical right-descending bank levee alignment. The yellow line approximates the present setback levee, which has more than doubled the room for the river in some areas.

Approved for public release; distribution is unlimited.

Figure 8-2: Example of a levee setback project on the Puyallup River in Washington State (USACE, CHETN, VII-17, July 2017).

PART C SEA LEVEL RISE RISK ASSESSMENT

9 SEA LEVEL RISE SCENARIOS

9.1 Global Sea Level Rise

As with all climate projections, there is a significant amount of uncertainty regarding rates and magnitude of SLR. In 2011, the provincial government issued guidelines for coastal flood hazards (MoE, 2011). These guidelines recommend that local governments plan for a 1 m rise in global mean sea level between the year 2000 and 2100 and a 2 m rise between the year 2000 and 2200, as shown in **Figure 9-1**. This figure also illustrates a range of uncertainty in these projections, with the range in the rise varying from about 0.5 m to 1.3 m by the year 2100 and between 1.4 m and 3.4 m by the year 2200. In recognition of the evolving state of climate science, the intent was for these recommendations to be reviewed every 10 years or sooner to incorporate new information.

Research on SLR has been ongoing since the provincial guidelines were issued. The most recent comprehensive study relevant to this project was published by the National Oceanographic and Atmospheric Administration in 2017 (NOAA, 2017). The report includes recent observations and modelling literature related to potential rapid ice melt in Greenland and Antarctica. The projections, and results presented in several peer-reviewed publications, support a plausible global mean SLR in the range of 2.0 to 2.7 m and recent observations regarding Antarctic ice-sheet instability indicate that such outcomes may be more likely than previously thought. As a result, NOAA (2017) recommended a revised "extreme" upper bound scenario of 2.5 m by the year 2100 (0.5 m higher than the upper bound estimate published in Parris et al., 2012), which was adopted previously in the third US National Climate Assessment.

Figure 9-1 plots the range of the NOAA (2017) projections in the lower set of curves. The RCP 8.5 5% (lower bound) and RCP 8.5 95% (upper bound) confidence levels that were used in the MoE (2011) guidelines are shown for reference. The two lines used in the 2011 document follow closely to the "Low" and "Intermediate" NOAA (2017) curves.

Table 9-1 (from Kopp et al., 2014) assigns probability of exceedance estimates to the various scenarios, in order to help interpret the meanings of the designations. A global SLR of 2.5 m by the year 2100 was considered approaching an upper limit estimate at that time.

Table 9-1. Probability of exceeding median global SLR scenarios in 2100 based on Kopp et al. (2014).

GMSL Rise Scenario	SLR (m)	Probability
Low	0.3	100%
Intermediate-Low	0.5	96%
Intermediate	1.0	17%
Intermediate-High	1.5	1.3%
High	2.0	0.3%
Extreme	2.5	0.1%

Note: probability values are for RCP8.5.

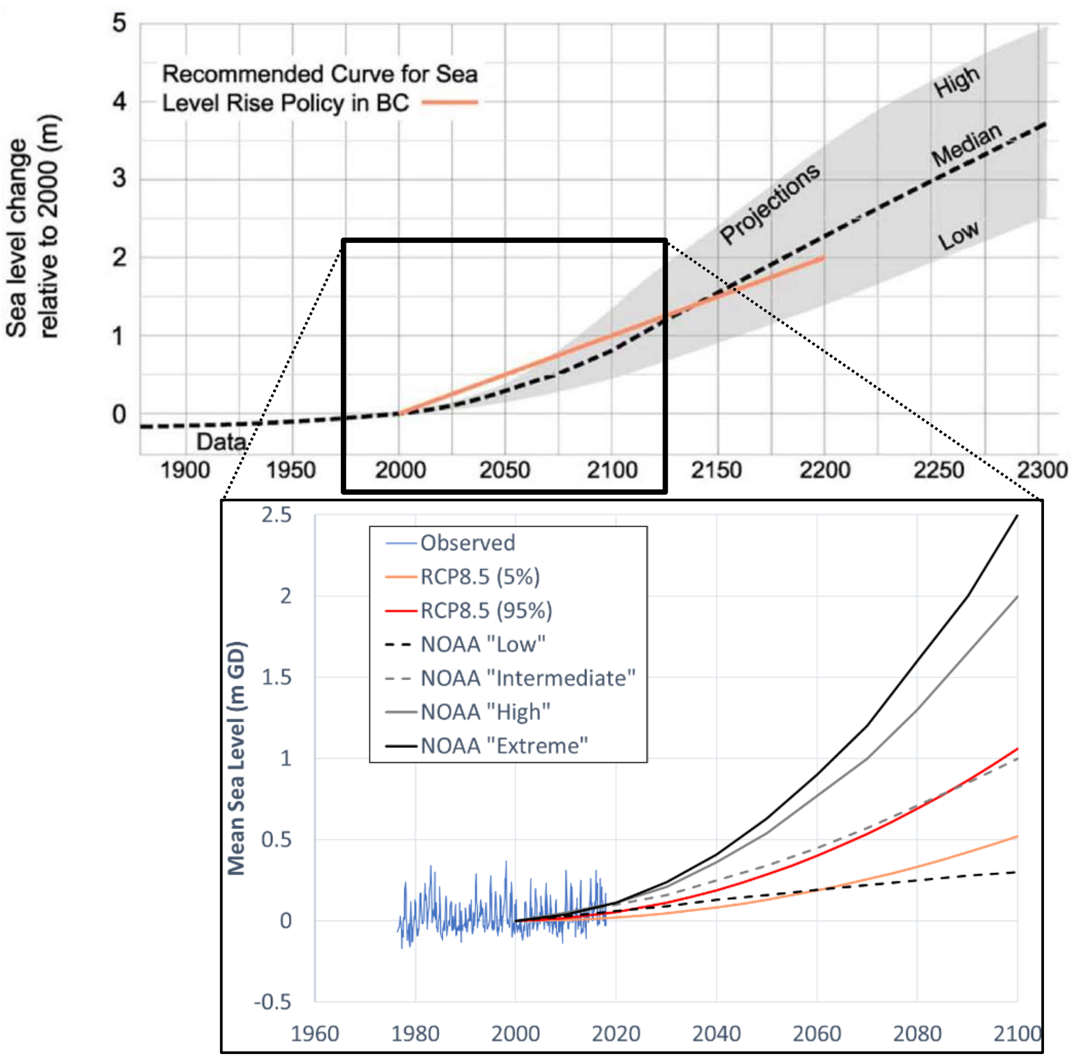


Figure 9-1: Global SLR from MoE (2011) (top plot) and updated predicted global SLR scenarios and observed ocean levels at Patricia Bay (NOAA, 2017) (bottom plot).

Recently Le Bars et al. (2017) provided an updated projection of global SLR accounting for increased potential for rapid break-up of Antarctic ice shelves. The projections were intended to provide a "high-end" estimate of sea-level rise for the year 2100. For the RCP8.5 emission scenario, the median estimate was 1.84 m, and the 95% quantile estimate was 2.92 m.

For the purpose of this study three plausible global SLR scenarios have been selected using the results in NOAA (2017) as a guide:

- Intermediate: 1.0 m
- Intermediate-High: 1.5 m
- Extreme: 2.5 m

9.2 Regional Sea Level Rise

Regional SLR is computed by adjusting global SLR values for regional ground movements such as uplift (land rising relative to the sea) or subsidence (land lowering relative to the sea). For this study regional effects were assumed to be negligible. This section describes the rationale for applying this assumption.

Global SLR projections represent global average eustatic changes only, and need to be adjusted to account for local isostatic effects that can cause the land to become higher or lower relative to sea levels. Previous estimates of isostatic effects were summarized in MoE (2011) using results compiled from other geological studies. A representative estimate of the isostatic adjustment to the year 2100 along the CVRD's eastern shoreline is -0.17 m (MoE 2011), which accounts for the slow progressive uplift of the land since the end of the last glaciation.

In addition to isostatic effects, other regional factors can affect local SLR, including:

- Ocean and atmospheric dynamics
- Local contributions from glacier and ice-sheet melt

The results of a NOAA (2017) study suggests SLR on the west coast of North America near Vancouver Island is expected to exceed the global average rate by at least 0.2 m, which will offset the isostatic adjustment due to vertical land changes. To summarize, with a -0.17 m isostatic adjustment and +0.2 m adjustment for 'other' regional factors, the difference between the global SLR and regional SLR is 0.03 m, which is considered negligible for the context of this study.

9.3 Flood Construction Reference Plane Computation

As described in **Section 3.2**, the FCRP is a function of the DFL and wave run-up. The Flood Hazard Area Land Use Management Guidelines – Sea Level Rise Amendment (MFLNRORD 2018) identifies two methods for computing the DFL:

- Combined: based on simultaneous occurrence of Higher High Water Large Tide[4] (HHWLT) elevation, the estimated storm surge for a 1:200 year AEP event.
- Probabilistic: 1:200 year AEP event as determined by a probabilistic analysis of tides and storm surge.

For this study, the simplistic and more conservative 'combined approach' was applied for computing the DFL for the coastal and lake study regions. A described in **Section 9.2** SLR computations apply global SLR values. For wave run-up effects, preliminary year 2100 coastal flood estimates for the BC coastal floodplain mapping guidelines list a standard value of 0.65 m for a natural pebble or gravel beach (KWL, 2011b). For this study a more comprehensive approach for computing wave run-up was applied, by dividing the shoreline into segments and assigning the midpoint slope value of each segment for wave run-up computations. Each segment was then assigned a wave run-up category and summed to the DFL to compute the FCRP.

[4] HHWLT values are defined in Canadian Hydrographic Services (CHS) tide tables.

10 COASTAL STUDY REGION

10.1 Setting

CVRD's eastern coastline is over 36 km long, including several gulf islands (Valdes, Thetis, Penelakut, etc.). The southern extent of CVRD's eastern coastline is located in Finlayson Arm, approximately 4.7 km south-west of McCardy Point and it extends to Mermaid Cove, north of Ladysmith and Chemainus 13. The coastline is predominantly steep, rocky bluff with a narrow marine shelf with a sandy gravel shoreline. There are two prominent estuaries, formed where the alluvial gravel, sand, and silt has been deposited at the mouths of the Cowichan-Koksilah and Chemainus river systems. The lower reaches of these river systems have formed broad, gentle gradient floodplains that are susceptible to complex interactions between the riverine and coastal systems. A substantial portion of the shoreline is used for industrial and commercial activities to support fishing and other marine harvesting, logging activities, port facilities, and marinas and ferry terminals.

10.2 Previous Studies

The BC Ministry of Environment (MoE) floodplain mapping study estimated a coastal flood level of 3.4 m in 1997. The coastal flood level included Higher High Water Large Tide (HHWLT), a 1:200 year storm surge allowance based on observed data, and an allowance for uncertainty to account for local wave effects. NHC (2009) conducted an updated analysis using observed tides at Patricia Bay since 1977. The adopted coastal flood level in NHC (2008) was similar to the value published in MoE (1997). Both values represent "still water levels" and do not include wave runup. NHC estimated flood levels in the estuary and lower Cowichan – Koksilah River system using an unsteady hydrodynamic model (MikeFlood). These simulations included a future scenario assuming a 1 m rise in the ocean level. CVRD (2013) generated Year 2100 FCL mapping following the methodologies described in Coastal Floodplain Mapping – Guidelines and Specifications (KWL 2011b).

MoE (2011) published preliminary guidelines assessing coastal flood levels along the entire coastline of BC. Given the very large spatial extent of the study a very simplistic approach was developed for estimating the future coastal FCRP:

$$FCRP_{2100} = HHWLT + SS_{200} + R + GSLR + RSL \qquad \text{(Eq. 14)}$$

Where,

- HHWLT[5] is the published Higher High Water Large Tide
- SS_{200} is the 200-year instantaneous maximum storm surge determined from an analysis of observed tide levels
- R is the wave runup
- GSLR is the global SLR for the future condition, assuming GSLR would rise 0.5 m by the year 2050 and 1 m by 2100
- RSL is the regional sea level adjustment to account for isostatic and tectonic effects

Other, more detailed, investigations have shown this approach is very conservative since it assumes coincident occurrence of the highest astronomical tide of the year with a 200-year storm surge and wave runup. The simplified method typically overpredicts by 0.5 m to 0.8 m. A summary of the calculation is given in **Table 10-1**.

Table 10-1: Preliminary flood construction levels previously reported for east Vancouver Island, based on MoE (2011) guidelines.

FCL Component	Elevation (m CGVD 1928)	Elevation (m CGVD 2013)
HHWLT	1.5	1.64
Storm Surge	1.3	1.44
Wave Runup Effect	0.65	0.65
Present FCRP	3.45	3.63
Global SLR (m)	1.00	1.00
Regional Adjustment	-0.17	-0.17
2100 FCRP	4.28	4.46
Freeboard	0.6	0.6
2100 FCL	4.88	5.06

Note:

1. Source: MoE (2011) and CVRD (2017).

10.3 Coastal Flood Hazards

A regional wave model was developed for the Strait of Georgia in order to calculate wave heights for the CVRD's eastern shoreline. Wave run-up estimates follow the same approach applied for the Cowichan Lake study region; based on equations developed by Stockdon et al. (2006) summarized in Equations 7 to 9 in **Section 5.3.5**.

[5] HHWLT is the average of the highest predicted tides in each year, determined over a 19-year period.

Due to the large spatial extents of the CVRD coastline included in the study, the MoE (2011) methodology for calculating FCRP was adopted for this study to calculate present-day and future flood risk. NHC developed a numerical model of the coastline to assess how local wave effects and runup varies along the shoreline. The FCRP for future scenarios including SLR is defined in Equation 15:

$$FCRPL_{2100} = HHWLT + SS_{200} + R + GSLR + RSL \qquad \text{(Eq. 15)}$$

Where,

- **HHWLT** is the published Higher High Water Large Tide
- **SS_{200}** is the 200-year instantaneous maximum storm surge determined from an analysis of observed tide levels
- **R** is the wave runup
- **GSLR** is the global SLR for the future condition
- **RSL** is the regional sea level adjustment to account for isostatic and tectonic effects

10.3.1 Sea Level Rise Scenarios

The three adopted SLR scenarios in this study are as follows:

- 1.0 m (intermediate)
- 1.5 m (Intermediate-High)
- 2.5 m (Extreme)

The basis for these scenarios is described in **Section 4.** The computed FCRPs adopted for the coastal study region are presented in **Table 10-2.**

Table 10-2: Designated coastal flood level (FCRP) projections for present (Year 2000), and three future SLR scenarios for Year 2100.

FCRP Component	Elevation (m)			
	Present Condition	Intermediate	Intermediate-High	Extreme
HHWLT	1.6	1.6	1.6	1.64
Storm Surge	1.3	1.3	1.3	1.3
Wave Runup Effect [1]	Site-specific			
Present FCRP	3.73	3.73	3.73	3.73
Global SLR (m)	---	1.0	1.5	2.5
Regional Adjustment	---	---	---	---
2100 FCRP	Site specific			

Note:

1. Wave runup effects will be calculated in more detail for the study region because the magnitude is site specific and depends on shoreline variability such as beach slopes and fetch length; for details see NHC (2018).

10.3.2 Wave Effects

Wind-generated waves on the coast can generate wave runup effects when they break, which increases the water level above the computed still-water level presented in **Table 10-2**. Wind-generated waves depend mainly on the maximum wind speed and fetch distance that the winds can blow across; therefore, wave hindcasting was carried out to estimate the significant wave height (H_s) and wave period (T_p) during a 1:10 year wind event. Based on a review of historical water level and wind data, it was concluded there is a low likelihood of a coinciding HHWLT, design storm surge, and 200-year wind event. The FCRP was defined spatially along the shoreline for each of the four scenarios (present-day and three future) by computing wave heights for the two dominant wind directions (westerly and easterly) and adopting the maximum value.

SWAN was used to develop a coarse grid model of Georgia Strait, and two nested models were developed: one for the northern sub-region and one for the southern sub-region. Significant wave height was computed using the nested grid SWAN model and empirical equations as a function of maximum offshore wave height, wave period, and shoreline gradient. An example of the significant wave height for a 10-year south-easterly and north-westerly wind events are shown in **Figure 10-1** and **Figure 10-2**, respectively for the coarse grid**. Figure 10-3** and **Figure 10-4** present the northern sub-region nested grid for the 10-year south-easterly and north-westerly wind events, respectively.

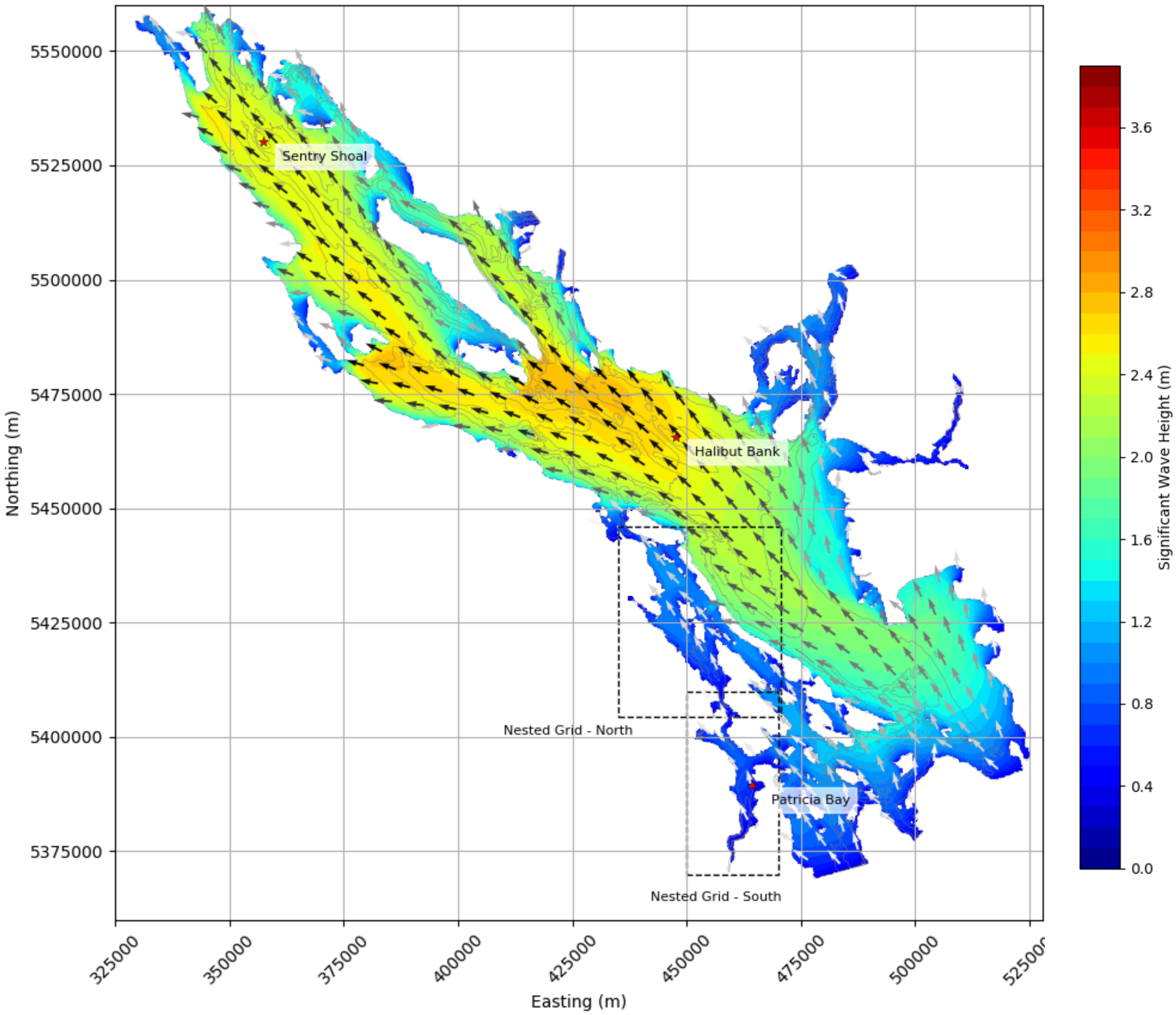


Figure 10-1: Significant wave heights calculated for Georgia Strait (SWAN model coarse grid) for a south-easterly 10-year wind event.

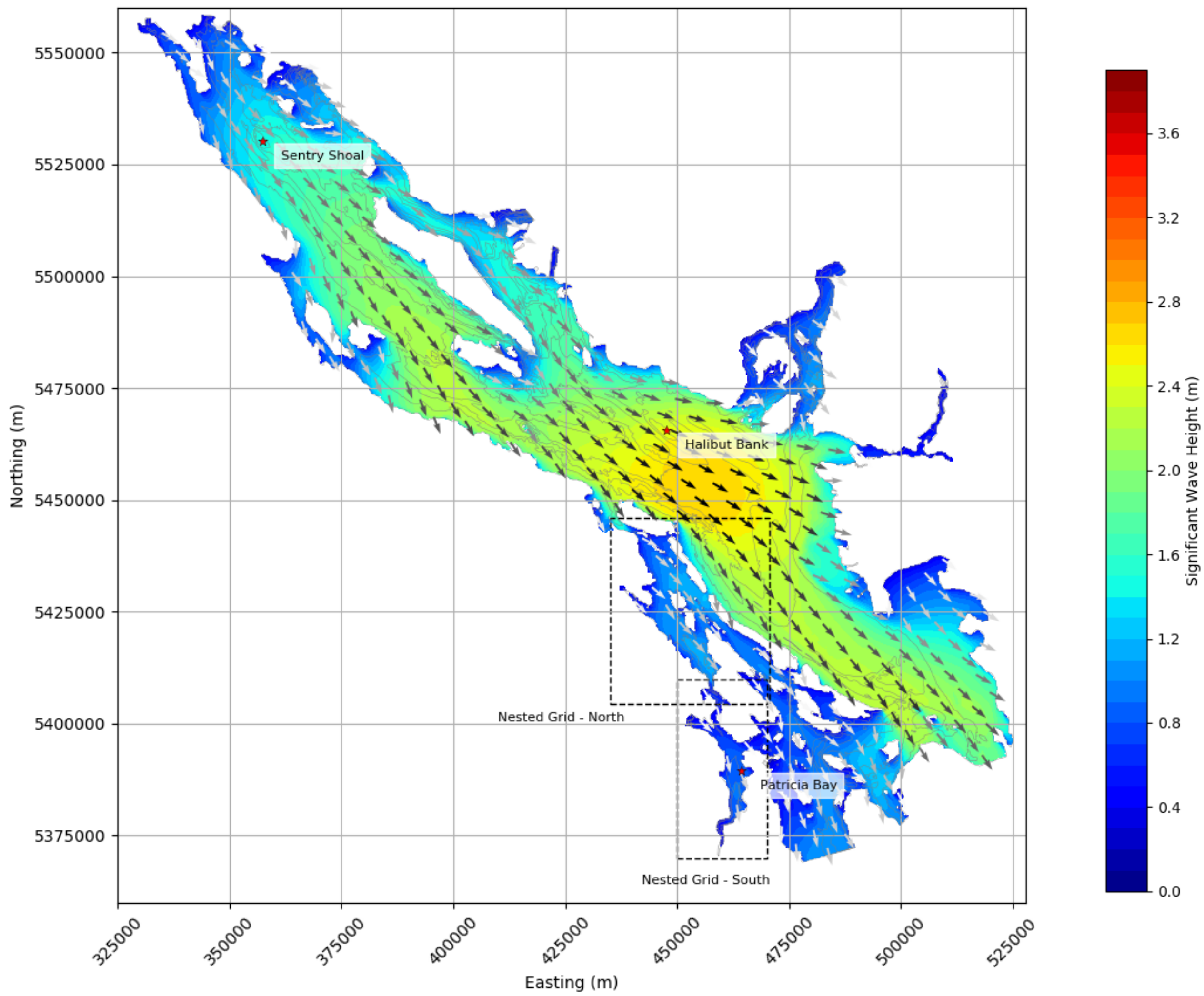


Figure 10-2: Significant wave heights calculated for Georgia Strait (SWAN model coarse grid) for a north-westerly 10-year wind event.

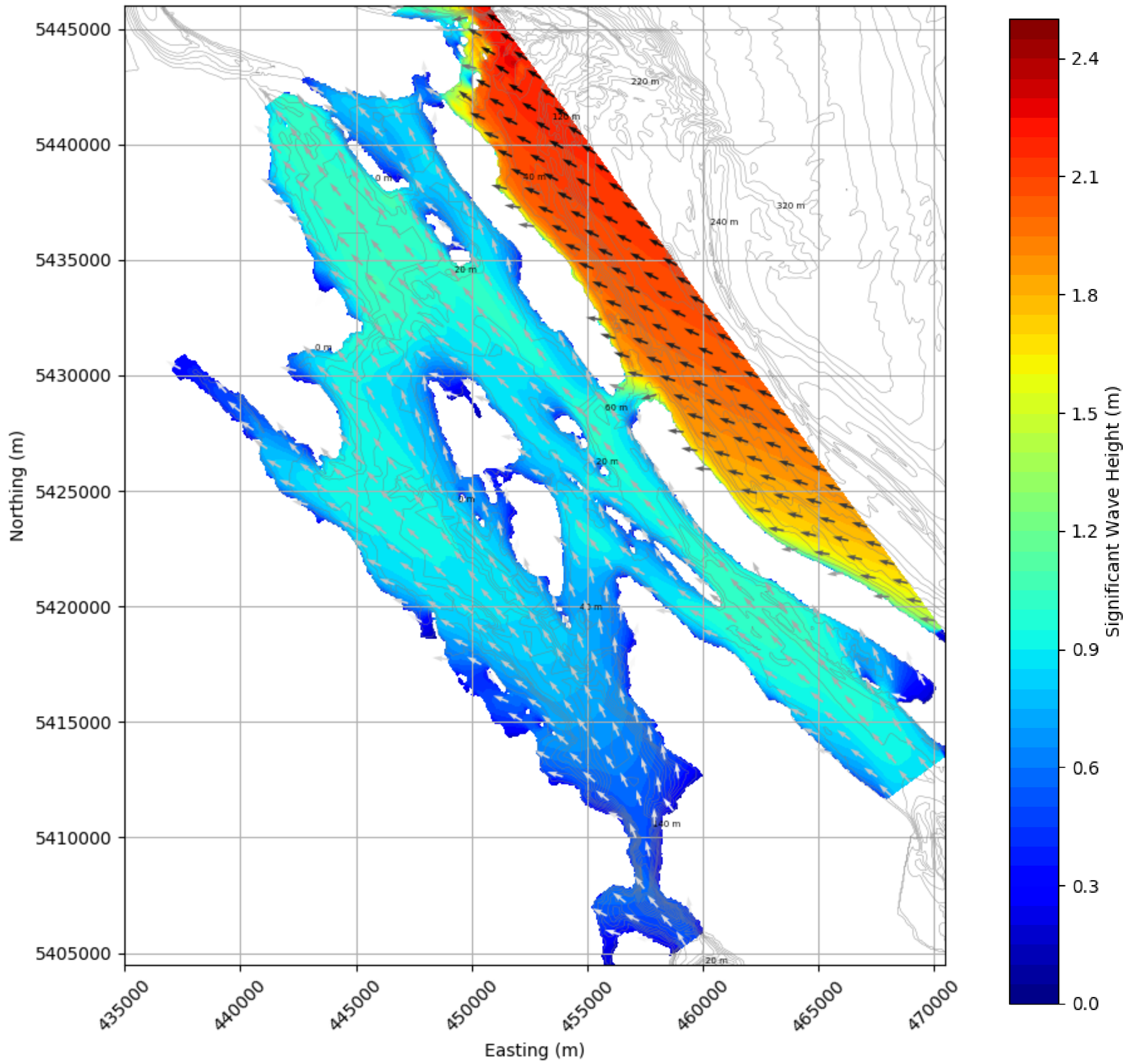


Figure 10-3: Significant wave heights calculated for Georgia Strait (SWAN model nested grid) for a south-easterly 10-year wind event.

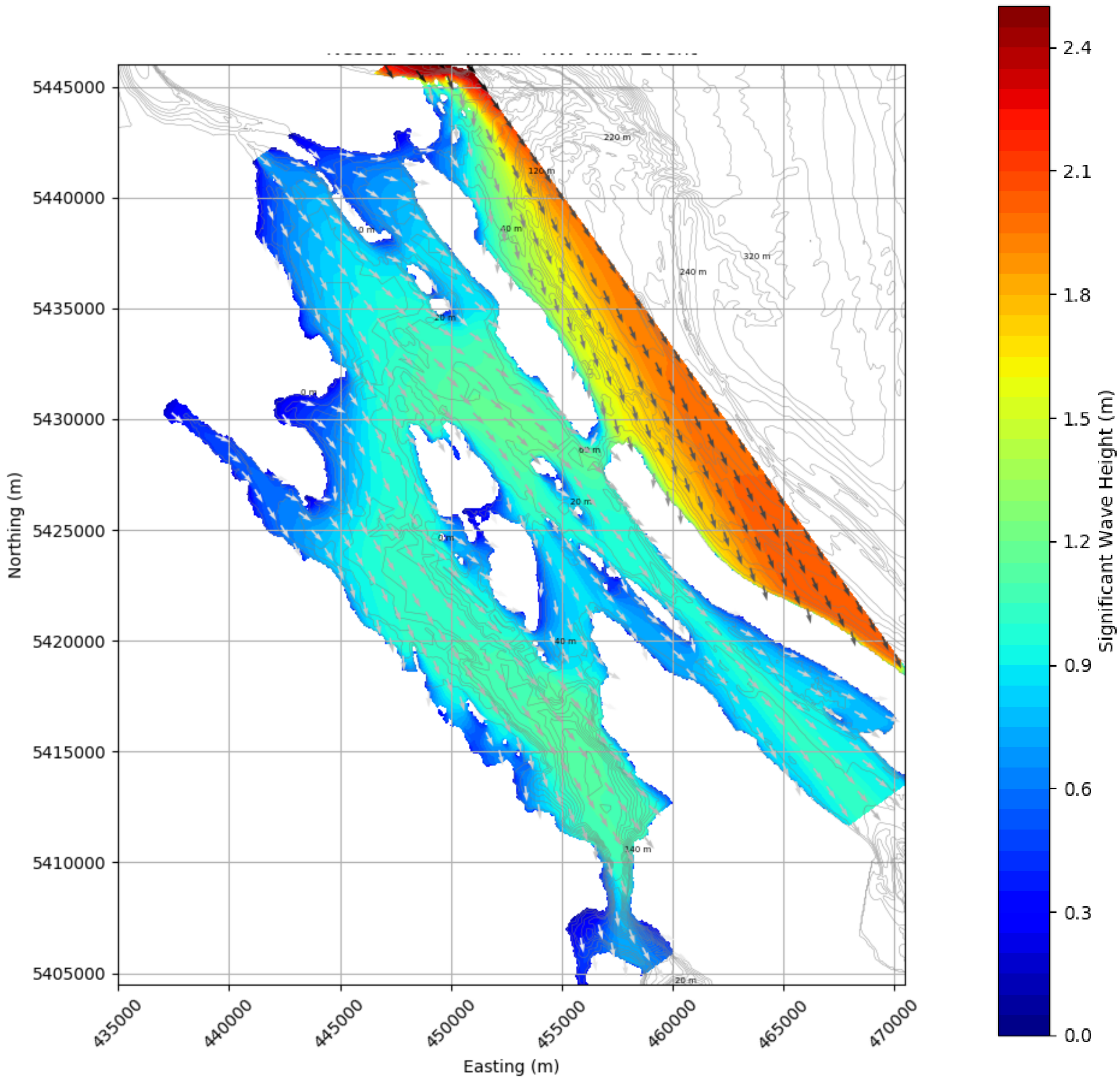


Figure 10-4: Significant wave heights calculated for the northern portion of the CVRD coastal study region (SWAN model nested grid) for a north-westerly 10-year wind event.

Local wave runup was calculated for 500 m reaches along the coastline and converted to three classes of wave effects as shown in **Table 10-3** and **Figure 10-5** presents the maximum computed run-up value for the two simulated wind events**.**

Table 10-3: Range of wave effects for coastline reaches.

Class	Wave Effects (m)
1	0.3
2	0.65
3	1.0

The coastal FCRP was calculated using GIS. The base case FCRP used in the risk assessment was the present-day sea level plus wave effects (based on location) as shown in **Table 10-2** and **Table 10-3**, respectively. **Photo 10-1** illustrates the computed FCRP's for this study at a location in Cowichan Estuary.

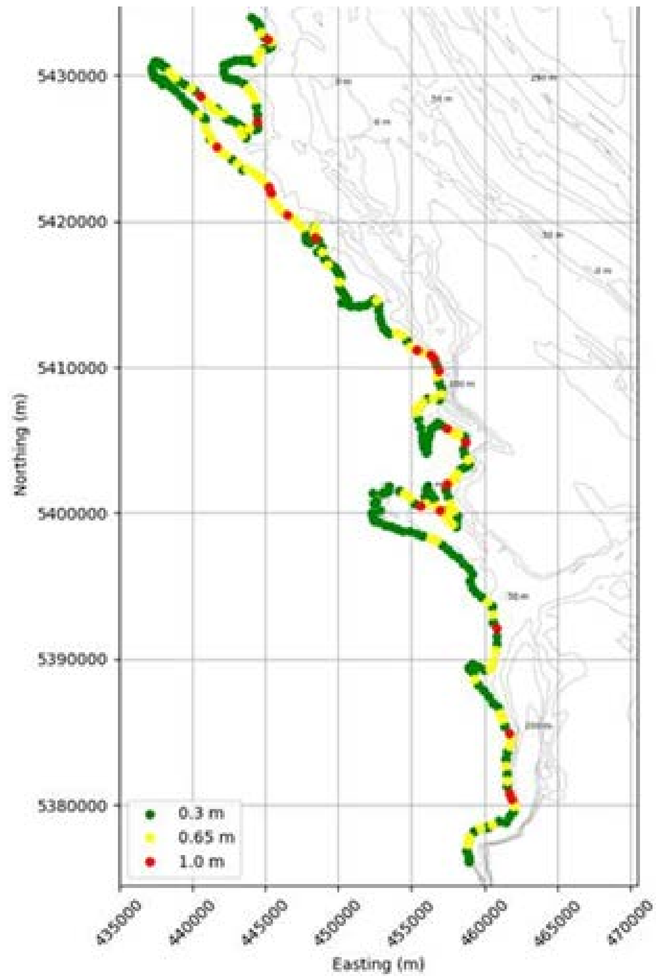


Figure 10-5: Computed maximum run-up for the north-westerly and south-easterly 10-year wind events.

Photo 10-1: Illustrative example of coastal study region FCRP's for present-day and three future scenarios at Cowichan Estuary.

10.3.3 Coastal Erosion

Tides, storm surge, and waves are the main driving forces affecting coastal processes (erosion, longshore transport, and deposition). Longer term changes that can impact shoreline processes include altered sediment supply rates, shoreline hardening, and SLR. Over time, the probability of a storm event occurring at higher water elevations that present-day will increase over time due to SLR. The vulnerability of the shoreline to erosion will depend on the underlying geology and surficial sediments on the shoreline; vegetation type and density growing within the run-up zone; presence of hardened shorelines, groynes, or other features that can attenuate or accentuate wave effects; shoreline gradient; shoreline orientation; wind fetch; and water level during a given wind event. Waves generated by boats can also contribute to shoreline erosion.

CVRD's coastal flood sensitivity database already includes shoreline erosion rank, coastal flood sensitivity, and anthropogenic risk rank based on a 1 m SLR scenario. The database should be reviewed and incorporated into future assessments of shoreline erosion potential and to evaluate potential 'down shore' impacts associated with future shoreline protection project proposals.

10.4 Coastal Flood Risks

10.4.1 Regional Boundaries

The CVRD's eastern coastal region is expansive and is comprised of several different local jurisdictions. **Figure 10-6** shows the electoral area and First Nations land boundaries and location of municipalities within the CVRD's eastern coastal region.

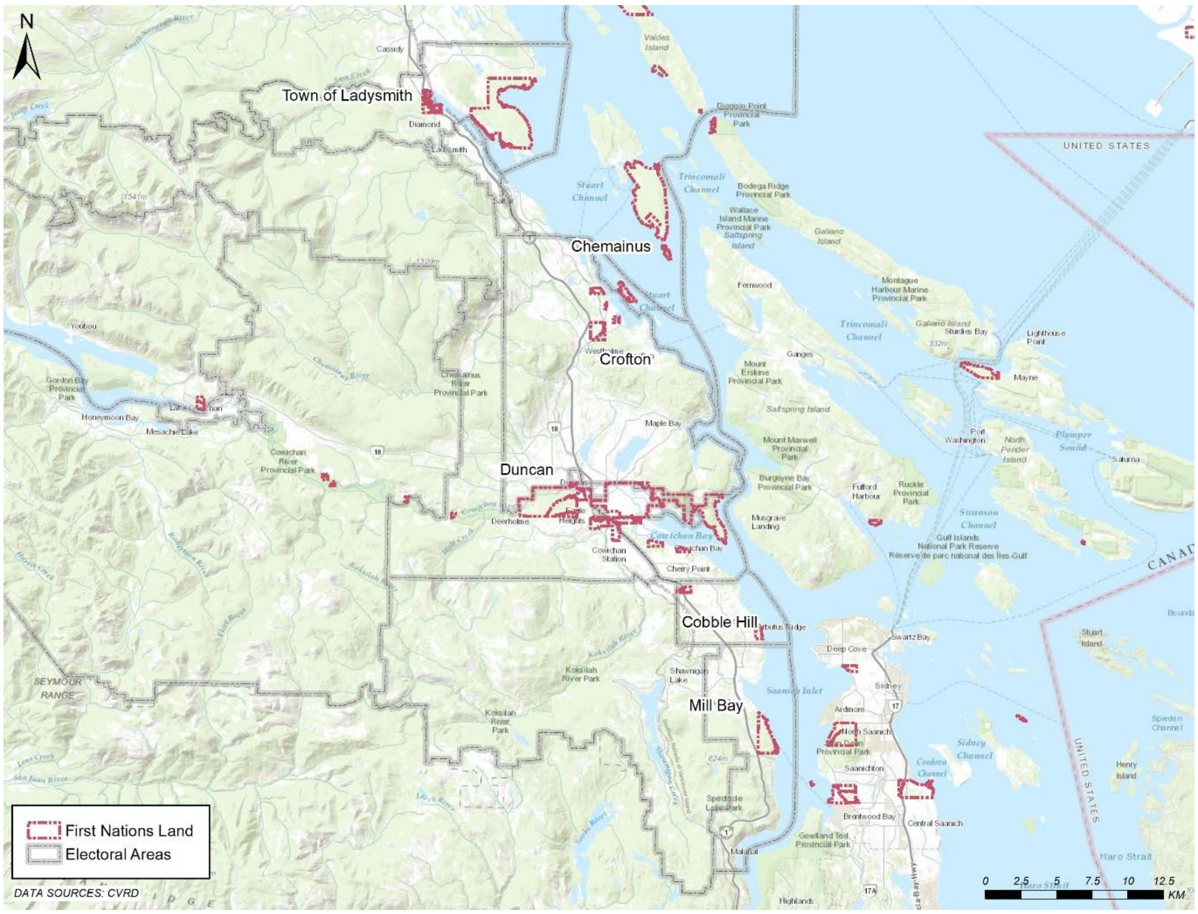


Figure 10-6: Coastal Study Region.

10.4.2 Risk Analysis Results

The flood risk assessment was completed for the coastal study region using the methodology discussed in **Section 3.3**.**Table 10-4** summarizes the percentage of land flooded in the coastal study region, categorized by jurisdiction. Cowichan Tribes jurisdiction has a substantial proportional and total area of land exposed and is also is the most sensitive to future increases in flood magnitude as represented by the future flood scenarios. Municipality of North Cowichan and Cowichan Bay jurisdictions have the first and second largest areas exposed, respectively, although the area exposed is relatively insensitive to future increases in flood magnitude. Halalt FN group is the largest proportional land area affected; however, this jurisdiction has a total land area of only 176 ha.

Table 10-4: Summary of percentage of land flooded in the coastal study region, categorized by jurisdiction.

Jurisdiction	Total Land Area (ha)	Percentage of Land Flooded			
		0 m SLR	1 m SLR	1.5 m SLR	2.5 m SLR
Cowichan Tribes	2,627	11.4%	16.4%	18.5%	21.6%
Halalt	176	33.8%	35.1%	35.7%	38.5%
Malahat	260	1.3%	1.4%	1.5%	1.7%
Pauquachin	55	5.4%	6.4%	6.8%	7.5%
Penelakut	946	3.1%	3.9%	4.3%	5.1%
Stz'uminus	1,838	3.6%	4.3%	4.7%	5.4%
Lyackson	780	2.9%	3.3%	3.6%	4.0%
Cobble Hill	3,194	0.4%	0.4%	0.4%	0.5%
Cowichan Bay	5,155	10.0%	10.6%	10.8%	11.2%
Mill Bay/ Malahat	7,647	0.5%	0.6%	0.6%	0.7%
Municipality of North Cowichan	21,271	3.0%	3.5%	3.6%	3.9%
North Oyster/ Diamond	10,394	0.6%	0.8%	0.9%	1.2%
Saltair/ Gulf Islands	53,719	0.5%	0.5%	0.6%	0.6%
Town of Ladysmith	1,478	3.4%	4.5%	4.8%	5.0%
Cowichan Station/ Sahtlam/ Glenora	13,573	0%	0%	<0.1%	0.1%
Total	123,115	1.7%	2.0%	2.1%	2.3%

The following section presents the results of the analysis in a series of bar charts and a summary table that shows the total value of the given element exposed for each jurisdiction. These figures and table demonstrate the relative impacts and the change in exposure with increasing climate change impacts. A detailed summary of the elements exposed are provided in tabular format in **Appendix A** and a series of visualization tools are presented in **Appendix B** including heat maps showing the relative density of properties affected by flooding for each scenario, and plan maps showing examples of element exposures for select sites.

People and Societal Impacts

Figure 10-7 presents the population, number of residential buildings, and emergency centres exposed in the FCRP. There are 757 people exposed to flooding under present conditions, increasing to 1,347 people for the 2.5 m SLR scenario; representing a 33%, 47%, and 78% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. The number of residential buildings exposed increases from 43 for the present-day scenario to 178 under the 2.5 m SLR scenario; representing a 93%, 156%, and 314% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. Property assessment data, particularly for First Nations lands appear inconsistent with occasional data gaps, therefore, it is possible that property exposures are under-represented (described in **Section 3.5**).

No emergency centres are exposed under present-day conditions increasing to one under a 1 m SLR scenario and two for the 1.5 m and 2.5 m scenarios. No hospitals, schools, or childcare facilities are exposed for all assessed scenarios.

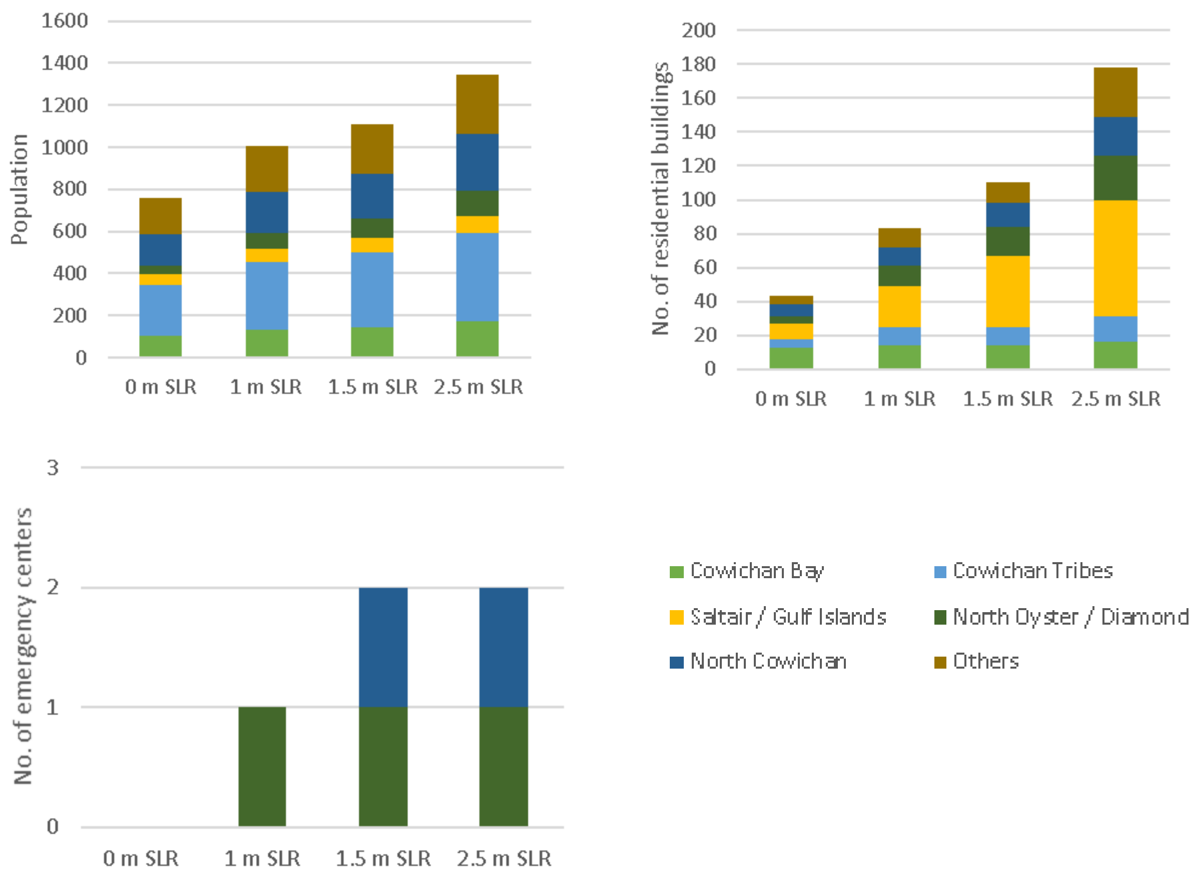


Figure 10-7: People and societal impacts – quantified flood exposures.

Environmental Impacts

Environmental impacts are assessed based on the area of terrestrial ecosystems and sensitive ecosystems, the length of FWA streams, and the number of gas stations located in the FCRP. The counts of elements identified within the FCRP for each flood scenario are shown in **Figure 10-8**. There is 1,311 ha of terrestrial ecosystem exposed during the present-day scenario, increasing to 2,063 ha for the 2.5 m SLR scenario; representing a 26%, 37%, and 57% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. There is 545 ha of sensitive ecosystem exposed during the present-day scenario, increasing to 741 ha for the 2.5 m SLR scenario; representing a 17%, 25%, and 36% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. There are about 48 km of streams exposed under present-day scenario and about 60 km under the 2.5 m SLR scenario; representing a 11%, 16%, and 23% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. There are no gas stations in the FCRP for any assessed scenarios.

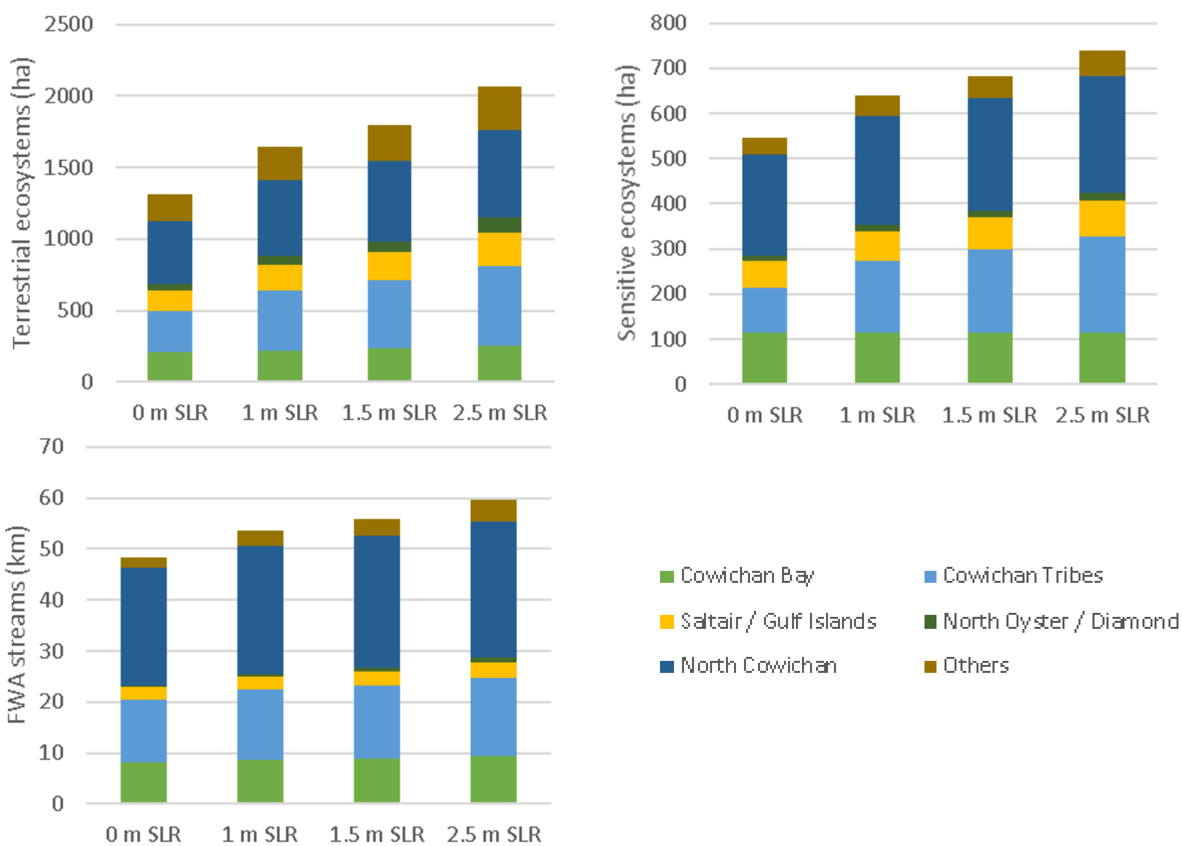


Figure 10-8: Environmental impacts – quantified flood exposures.

Local Economic Impacts

Local economic impacts are assessed based on the assessed value of properties exposed in the FCRP. The value of properties for each flood scenario is shown in **Figure 10-9**. There is $17.2 M worth of residential property affected under the present-day scenario, increasing to $98.0 M under the 2.5 m SLR scenario; representing an 130%, 250%, and 470% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. As described in **Section 3.5**, inconsistent property assessment data, particularly for First Nations lands, may under-represent flood exposures and a more thorough audit of the property assessment database assessment is recommended. For instance, residential property values for Chemainus 13 were computed by dividing the total value for that land parcel (~$52M) by the total number of properties points in the address geodatabase.

There is $7.6 M worth of industrial property and $11.5 M worth of commercial properties exposed during the present-day scenario, increasing to $33.6 M and $19.3 M under the 2.5 m SLR scenario, respectively. This represents a 222%, 305% and 343% increase for industrial and 21%, 27%, and 68% increase for commercial properties over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively.

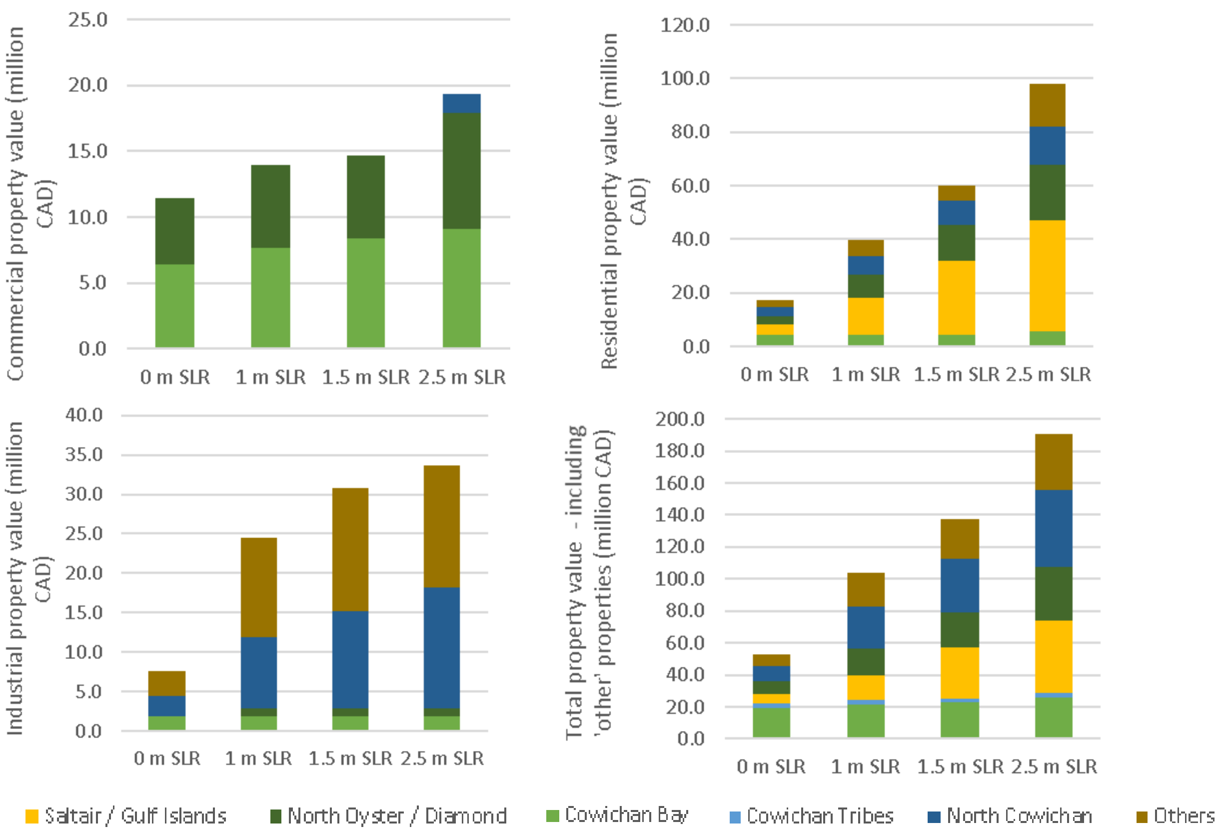


Figure 10-9: Local economic impacts – quantified flood exposures (property values).

Local Infrastructure Impacts

Local infrastructure impacts are assessed based on the number of industrial and commercial buildings, utilities, CVRD water supply and sewer structures, and transportation assets exposed in the FCRP. The count of elements within the FCRP for each flood scenario are shown in **Figure 10-10** to **Figure 10-13**.

Figure 10-10 shows 14 industrial buildings located in the present-day FCRP and 36 in the 2.5 m SLR scenario; representing a 107%, 143%, and 157% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. Twenty one commercial buildings are exposed under present-day conditions, increasing to thirty six under 2.5 m SLR, representing a 33%, 43%, and 71% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. **Figure 10-11** shows the impact to private stakeholder utility structures including BC Hydro, Fortis BC, Shaw, and Telus. No BC Hydro structures are affected under present-day conditions, increasing to one under 1 m SLR, two under 1.5 m SLR, and to nine under 2.5 m SLR. No Fortis BC Gas utilities are in the FCRP. The largest number of utilities structures in the FCRP belong to Shaw, increasing from 124 to 140 between the present-day and 2.5 m SLR scenario, representing a 4%, 8%, and 13% increase over present-day conditions for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. Five Telus facilities are affected under present-day scenario increasing to 8 under 1 m SLR and to 9 under 1.5 m SLR. One CVRD sewer utility is exposed under present-day conditions, increasing to two with 1.5 m SLR. No CVRD water utility assets exist in the FCRP for any scenarios as shown in **Figure 10-12**.

Figure 10-13 shows 11.5 km of roads and 31 culverts exposed under the present-day scenario, increasing to 26.8 km and 81 culverts for the 2.5 m SLR scenario, respectively. This represents a 52%, 80%, and 133%; and 52%, 110%, and 161% increase over the present-day scenario for the 1 m, 1.5 m, and 2.5 m SLR scenarios, respectively. Nine bridges are exposed under the present-day scenario increasing to 11 under the 1.5 m SLR scenario. Railway lines are not exposed under present-day scenario and only marginally under future SLR scenarios. Three BC ferries terminals (Chemainus, Crofton, and Mill Bay) and eight wood processing facilities are exposed for all scenarios. Eleven marinas are within the present-day FCRP boundary and twelve in all future scenario boundaries.

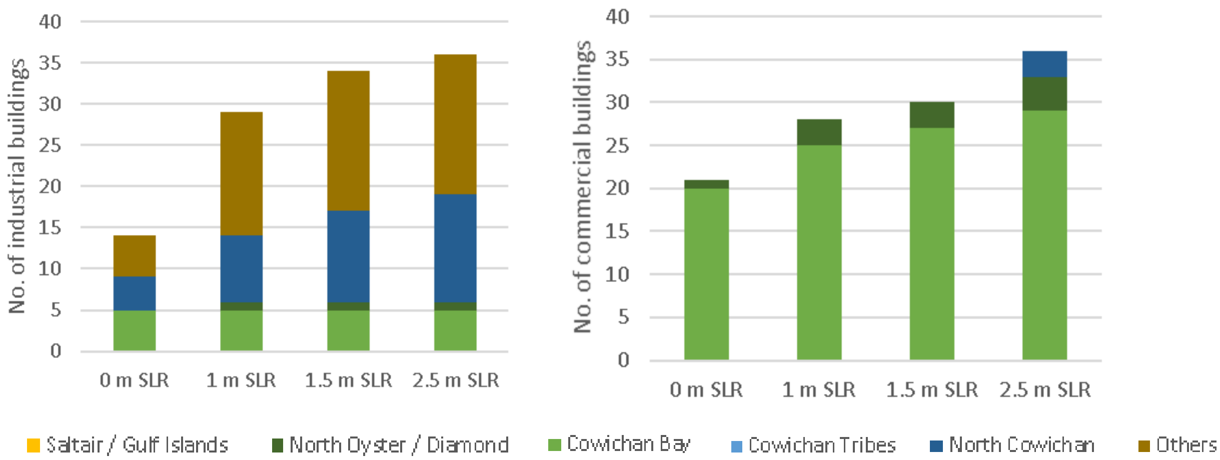


Figure 10-10: Local infrastructure impacts – quantified flood exposures (industrial and commercial buildings).

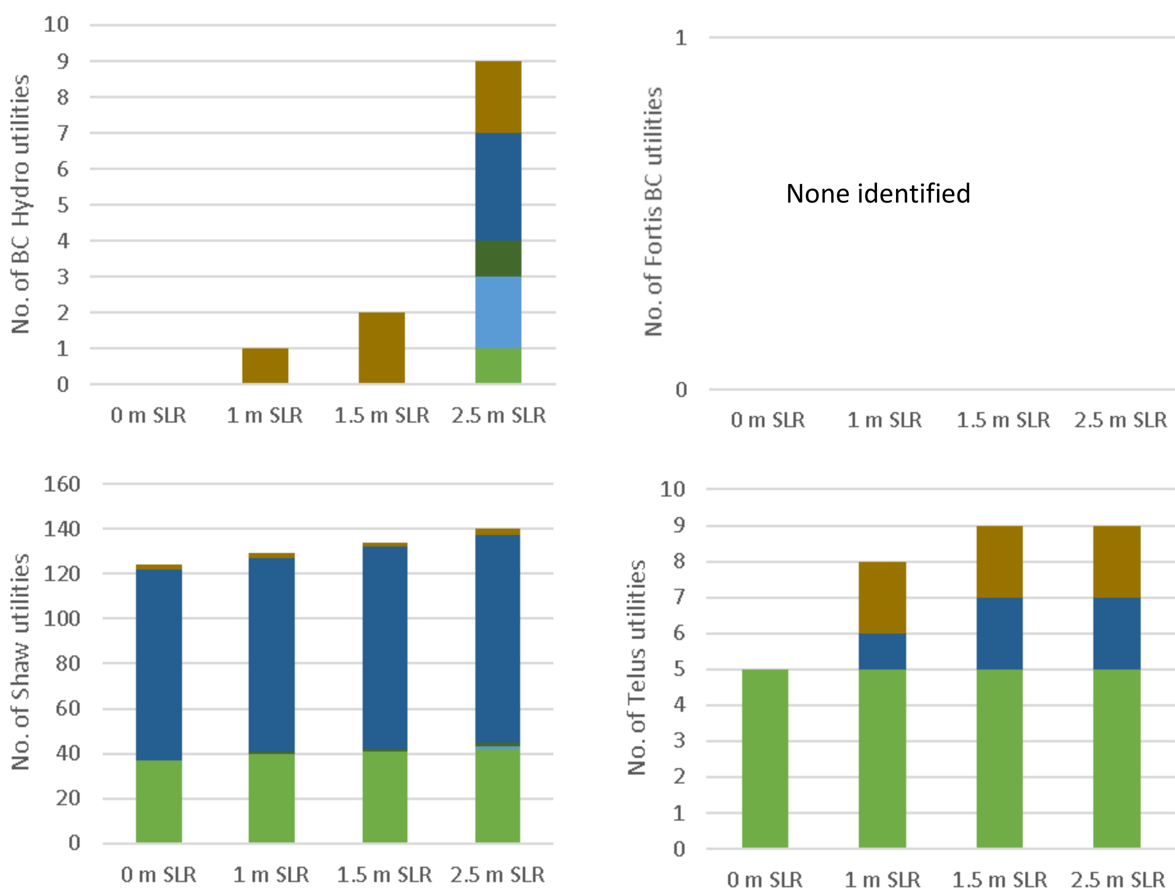


Figure 10-11: Local infrastructure impacts – quantified flood exposures (Shaw, Hydro, Telus).

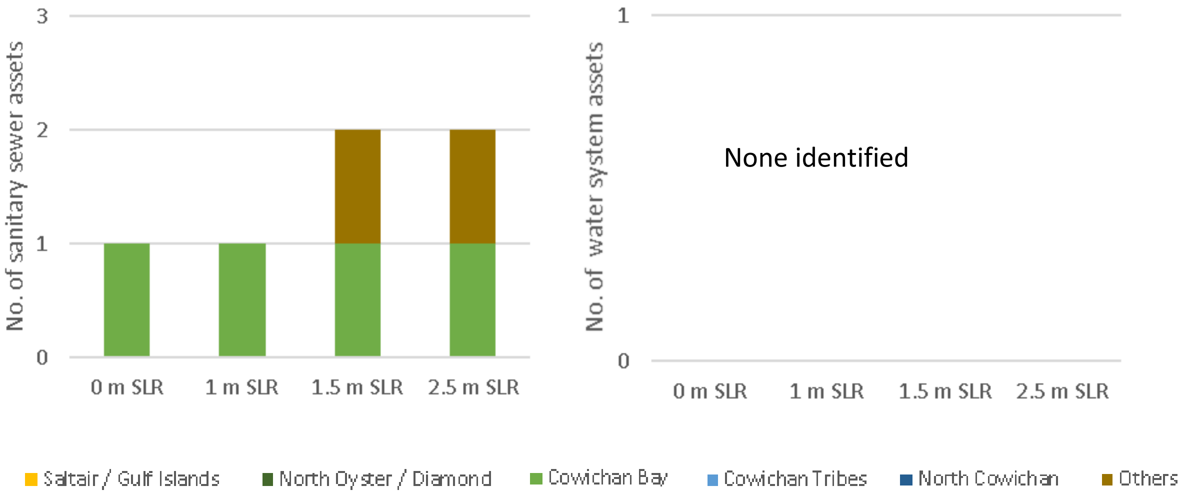


Figure 10-12: Local infrastructure impacts – quantified flood exposures (water and sewer).

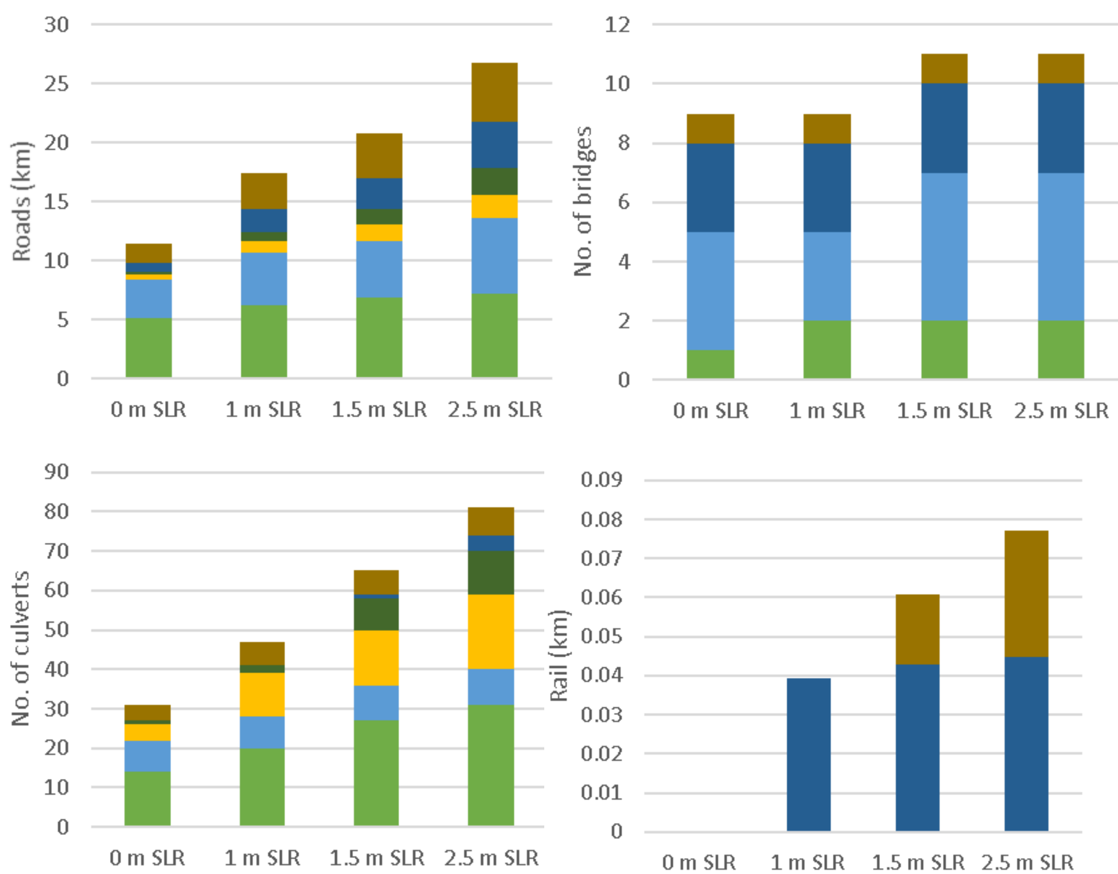


Figure 10-13: Local infrastructure impacts – quantified flood exposures (transportation infrastructure).

Public Sensitivity Impacts

Public sensitivity impacts are assessed based on land area exposed, categorized by land use: urban and developed, agricultural, grasslands, shrublands and forests, wetlands, and barren and exposed land. The total land area of each category for each flood scenario is shown in **Figure 10-14**. There is 662 ha of exposed and barren land; 430 ha of urban and developed area; 343 ha of grasslands, shrublands, and forests; 179 ha of wetlands; and 139 ha of agricultural land for the present-day scenario. Grasslands, shrublands, and forests areas have the largest proportional increase (133% for 2.5 m SLR scenario relative to present-day), followed by agricultural land (74% for 2.5 m SLR scenario).

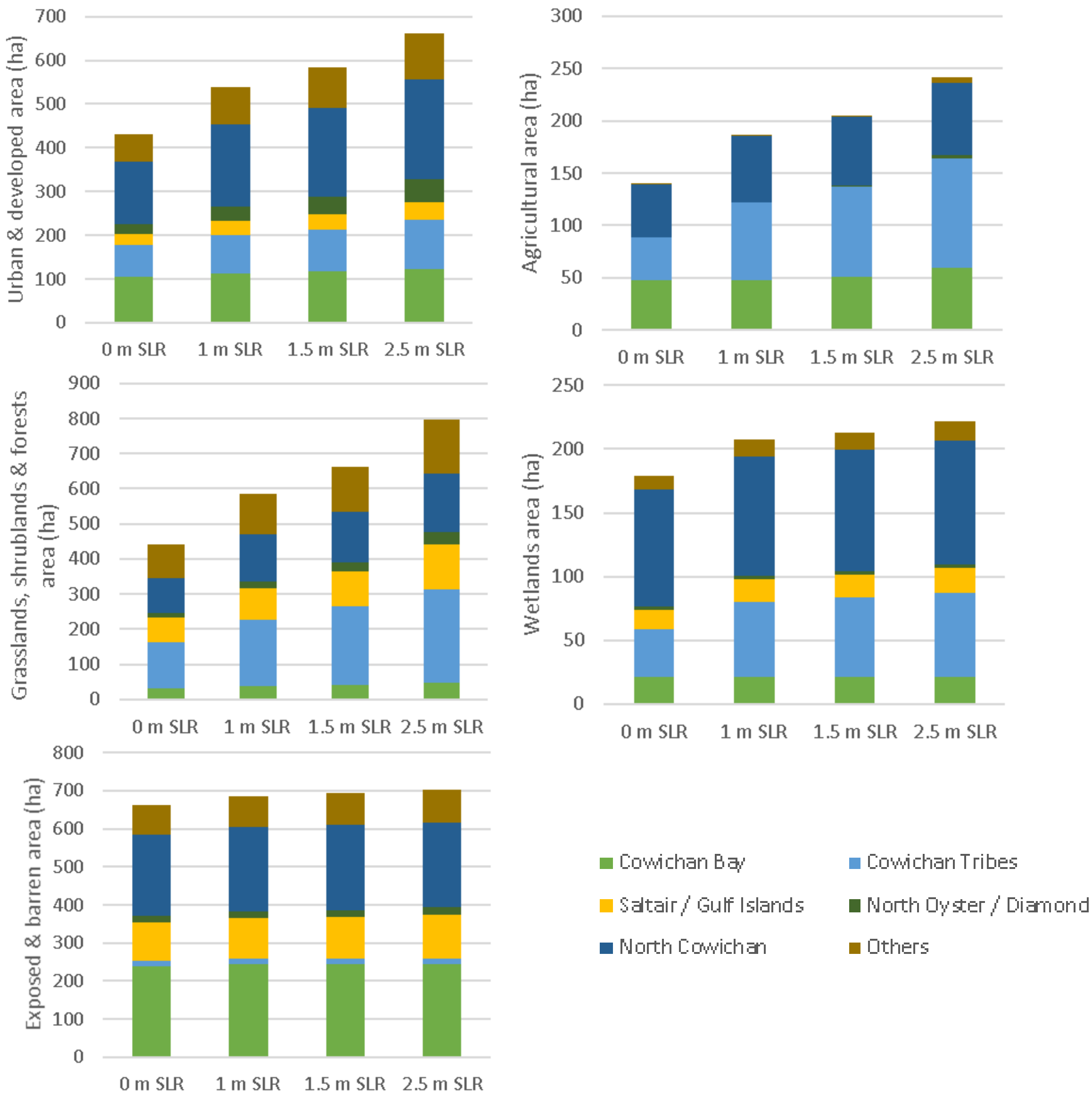


Figure 10-14: Public sensitivity impacts – quantified flood exposures.

10.4.3 Discussion of Results

The total elements exposed for coastal study region for the present-day FCRP and three future scenarios are shown in **Table 10-5**.

There is a substantial population exposed under the present-day scenario, predominantly within the Cowichan Tribes jurisdiction followed by North Cowichan and Cowichan Bay. Relatively steady increases in exposure are apparent with increasing SLR condition, demonstrating the coastal study region is sensitive to future changes.

The number of exposed residential buildings nearly doubles with 1 m SLR from 43 (representing $17.2 M) under present-day to 83 ($39.6 M), with the number of buildings exposed increasing by 156% and 314% relative to the present-day scenario for the 1.5 m and 2.5 m SLR scenarios. Property assessment data, particularly for First Nations lands, appear inconsistent. It is possible that property exposures are under-represented, and a more thorough audit of the property assessment database assessment is recommended. Affected residential buildings and property values predominantly lie within the Saltair/ Gulf Islands jurisdiction followed by North Oyster/ Diamond, North Cowichan, Cowichan Bay, and Cowichan Tribes jurisdictions. No emergency centers are exposed under present-day scenario to two for all future scenarios; one located in North Oyster/ Diamond jurisdiction and one in North Cowichan jurisdiction. No hospitals, schools, or childcare facilities are exposed for all scenarios.

Exposure of industrial properties increases by almost fourfold with 1 m SLR with substantially smaller incremental increases with larger SLR scenarios. Most affected areas (and property values) are within the North Cowichan and Cowichan Bay jurisdiction for the present-day scenario with Ladysmith, North Oyster/ Diamond and Mill Bay/ Malahat also becoming exposed under the 1 m SLR scenario. Commercial property values increase by 21% and 27% for 1 m and 1.5 m SLR scenarios; however, they are highly sensitive to increases between 1.5 m and 2.5 m SLR (68% increase over present-day scenario). Most commercial properties lie within the Cowichan Bay jurisdiction with some in the North Oyster/ Diamond jurisdiction, and includes North Cowichan jurisdiction for the 2.5 m SLR scenario.

For all scenarios most changes to exposed watercourses and terrestrial and sensitive ecosystems occur within the North Cowichan, Cowichan Bay, Cowichan Tribes and Ladysmith jurisdictions. These areas are moderately sensitive to future effects from SLR.

Shaw assets are exposed under all scenarios but are relatively insensitive to future changes with SLR. Most of these assets are in North Cowichan with a substantial number in Cowichan Bay jurisdiction. Relatively few numbers of Telus assets are exposed, and are relatively insensitive to future changes with SLR. Most lie within Cowichan Bay, with a substantial number in North Cowichan, and some in Mill Bay/ Malahat and Ladysmith jurisdictions. One CVRD sewer asset located within Cowichan Bay jurisdiction is exposed for all flood scenarios with one in Mill Bay/ Malahat jurisdiction becoming exposed under the 1.5 m SLR scenarios.

A substantial length of roads and number of culverts are exposed under the present-day flood scenario and this element is relatively sensitive to increase flood levels with SLR. A substantial proportion of exposed roads lie within Cowichan Bay and Cowichan Tribes jurisdiction with the remainder falling within several other jurisdictions. Roads in North Cowichan become proportionally more exposed with future SLR scenarios. The number of bridges exposed to flooding increases from 9 under present-day to 11 under the 1.5 m SLR scenario, mostly within Cowichan Tribes and North Cowichan jurisdictions.

Affected agricultural areas and urban and developed areas are predominantly in the Cowichan Tribes, Cowichan Bay and North Cowichan jurisdictions and are moderately sensitive to SLR. Affected grasslands, shrublands and forests areas are more sensitive to change, and predominantly lie within Cowichan Tribes, North Cowichan and Saltair/ Gulf islands regions.

Table 10-5: Summary of total elements exposed for the coastal study region.

Category	Exposed Elements	Unit	Total			
			Present-day	1 m SLR	1.5 m SLR	2.5 m SLR
People & Societal	Population	number	757	1,006	1,110	1,347
	Residential Buildings	number	43	83	110	178
	Hospitals	number	0	0	0	0
	Emergency Centers	number	0	1	2	2
	Schools & Childcare facilities	number	0	0	0	0
Environmental	Terrestrial Ecosystem	ha	1,311	1,647	1,799	2,063
	Sensitive Ecosystem	ha	545	640	682	741
	FWA Streams	km	48.4	53.5	55.9	59.6
	Gas Stations	number	0	0	0	0
Local Economic	Commercial property value	*million $CAD*	*11.5*	14.0	14.6	19.3
	Industrial property value	*million $CAD*	7.6	24.4	30.7	33.6
	Residential property value	*million $CAD*	17.2	39.6	60.2	98.0
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	*million $CAD*	52.9	103.9	137.2	190.3
Local Infrastructure	Industrial Buildings	number	14	29	34	36
	Commercial Buildings	number	21	28	30	36
	BC Hydro Assets	number	0	1	2	9
	Fortis BC Assets	number	0	0	0	0
	Shaw Assets	number	124	129	134	140
	Telus Assets	number	5	8	9	9

Category	Exposed Elements	Unit	Total			
			Present-day	1 m SLR	1.5 m SLR	2.5 m SLR
	CVRD Sanitary Sewer Assets		1	1	2	2
	CVRD Reservoirs		0	0	0	0
	CVRD Water System Assets		0	0	0	0
	Road Length	km	11.5	17.5	20.7	26.8
	Bridges	number	9	9	11	11
	Culverts	number	31	47	65	81
	Rail	km	0	0	0.1	0.1
	Urban & Developed Area	ha	430	538	583	662
	Agricultural Area		139	186	204	241
	Grasslands, Shrublands & Forests Area		443	586	663	798
	Wetlands Area		179	207	213	222
	Exposed & Barren Area		662	686	692	702

11 COASTAL FLOOD MITIGATION STRATEGIES

Today, communities in the region face an uncertain change in the hydrological regime due to future climate change. The new challenge facing the region is to develop strategies and planning tools to cope with these future changes, even though the magnitude and timing of the changes is highly uncertain.

11.1 Coastal Study Region

Increased ocean levels and coastal flooding will have the greatest physical impact to the low lying deltas of the Chemainus River and Cowichan-Koksilah River systems (**Figure 2-2**). These impacts will be experienced both at the tidal flats and shoreline as well as far upstream in the rivers due to increased backwater flooding. The increased backwater will lead to increased sedimentation and an upstream shift in the main zone of active sedimentation. In addition to flooding, these impacts will include physical changes to the shoreline and estuary (erosion and sedimentation), as well as changes to habitat and eco systems, and changes to land-use practices (for example, some farmland may become unusable due to increased salinization). Other areas along the coast will be subject to increased ocean levels and wave runup causing increased severity of beach erosion and shoreline retreat.

11.1.1 Resist Using Structural Flood Control Measures

Sea Dikes and Sea Dams

Sea dikes are commonly used to protect low lying deltas and coastal plains from high tides. For example, extensive sea dikes have been constructed around portions of Lulu Island in Richmond, portions of Delta and in Surrey near the mouth of the Serpentine and Nicomekl Rivers.

The Dinsdale Dike at the mouth of the Koksilah River and Blackey Farms Dike near the mouth of the Cowichan River are examples of older sea dikes that were used to protect farm land from riverine-ocean floods.

Sea dikes require special provisions freshwater inflows from coastal rivers and drainage channels. This normally require constructing a sea dams at the river mouth, with provision to prevent ocean inflows during rising tides and drainage structures to discharge freshwater outflows during falling tides. Drainage can be accomplished either by gravity or by pumping. In a gravity drainage system, fresh water backs up behind the dam when the sea dams are closed, creating deep ponding and upstream inundation from backwater. Therefore, this type of structure does not eliminate flooding, but it does limit its severity. It also protects agricultural land against salt water intrusion from surface flows.

Large sea dams have operated at the mouth of the Serpentine River and Nicomekl River in Surrey for nearly a century. These structures use gravity drainage to provide drainage control. However, the daily flood flows on the Nicomekl and Serpentine Rivers are approximately one fifth of the peak flood flows on the Cowichan River.

Set Back Dikes on Coastal Rivers

Existing flood dikes along the lower portions of the main rivers will need to be upgraded to accommodate the higher ocean levels and backwater effects. It was outside the scope of this present study to assess the upstream extent and increase in dike crest elevation that would be required. The problem is compounded by the problem that both the freshwater river discharge and the ocean level are expected to increase as a result of climate change.

The most effective method will be to utilize set back dike concepts as described previously in **Section 8** and in **Figure 8-2**).

Shoreline Protection

Areas along the coast outside of the river deltas will be exposed to more severe coastal erosion and wave runup during winter storms. Common methods of shoreline protection involve constructing riprap revetments and sea walls, beach restoration (beach nourishment) or Green Shores-style bio-engineering protection.

11.1.2 Adaptation

Flood Proofing

Raising homes or commercial facilities on fill, piles or pontoons have all been used in other jurisdictions to reduce flood damage to homes and commercial buildings. Raising roads and bridges to ensure safe evacuation is another component of flood proofing.

Land Use and Land use Planning

Providing updated floodplain maps and regulating future developments will be a required component to future flood management in the coastal areas, regardless of other initiatives.

11.1.3 Retreat

Land Use Changes

Some areas on the floodplain may become unsuitable or unsustainable for current land use practices. For example, it may be impractical or un-economic to provide structural flood mitigation measures to some areas due to the very high depth of flooding or high severity of erosion.

Some agricultural practices along low lying areas near the coast may also become less productive due to increased salinity.

PART D FUTURE WORK, CONCLUSIONS, AND RECOMMENDATIONS

12 FUTURE WORK

12.1 Data Gaps and Deficiencies

In order to refine these preliminary assessments and complete a rigorous flood risk analysis, additional data collection, analytical computations, modelling and GIS analysis and analytical computations and modelling will be required. Data gaps for the exposure assessment are described in **Section 3.5**. The following basic data is required to prepare updated flood hazard maps that meet current EGBC standards:

- Update and replace the BC Ministry of Environment's existing floodplain maps of Cowichan Lake, Shawnigan Lake, Riverbottom Road, Chemainus River and Bonsall Creek as soon as possible. These maps are between 20 to 40 years old and are no longer representative of current or future flooding conditions.
- Acquire additional Lidar data for portions of Cowichan Lake (downstream of weir) and portions of Cowichan River at Riverbottom Road and review the Lidar coverage for other critical floodplain areas such as along the Chemainus River.
- Collect additional bathymetric surveys on the Cowichan River at Riverbottom Road and at the outlet and weir on Shawnigan Lake.
- Install a continuously recording water level gauge on Shawnigan Lake.

12.2 Priorities Areas for Future Studies

This present study did not assess two of the most critical areas within the region: Chemainus River/ Bonsall Creek and Lower Cowichan-Koksilah River. These areas should have a very high priority for further assessment.

12.3 Flood Management Planning and Climate Change

12.3.1 Need to Update Flood Management Planning Strategies

The 2009 Integrated Flood Management Plan (IFMP) for the Cowichan-Koksilah River assessed climate change and SLR scenarios, but did not explicitly incorporate future climate change into the strategy and planning process. For example, although future sea level rise scenarios were modelled they were not considered in the estimated coastal flood construction level. However, subsequent EMBC-funded dike upgrades incorporated a change in future flood discharges (10% increase in 200-year discharge). The general principles of the IFMP remain valid and are appropriate for mitigating flooding under a changing climate. However, it should be updated to reflect the sensitivity analysis completed herein.

Section 12.3.2 provides a brief overview of a potential model for planning for uncertainty. This type of approach should be reviewed and assessed in terms of its applicability and utility for the Cowichan region.

12.3.2 Dynamic Adaptive Policy Pathways

Deep uncertainty is defined by Hallegate et al (2012) as "a situation in which analysts do not know or cannot agree on (1) models that relate key forces that shape the future, (2) probability distributions of key variables and parameters in these models, and/or (3) the value of alternative outcomes." Flooding impacted by climate change (including SLR and precipitation increases) demonstrate very "deep uncertainty" as shown by the broad range in SLR and precipitation estimates as discussed in detail in Section PART B and the potential impacts caused by flooding demonstrated in the risk analysis. An additional uncertainty related to quantifying flood risk is socio-economic growth (i.e. population and value of properties or infrastructure in the floodplain) and technological developments in the future.

The deep uncertainty inherent to climate change and flood risk presents a new challenge for decision-making and design of communities and infrastructure within the current or future floodplain. Previously, engineering and urban planning was dependent on historical observations and infrastructure was designed by extrapolating the observed trends into the future (Hallegate, 2012). Examples of flood mitigation strategies are discussed in detail in **Section 8** and **Section 11**. Historically, a "static 'optimal' plan using a single 'most likely' future … or static 'robust' plan that will produce acceptable outcomes in most plausible future worlds" (Haasnoot, 2013) was implemented in flood management strategies. An example of this type of approach is the Integrated Flood Management Plan developed for the Cowichan River (NHC 2009).

Due to climate change impacts, extrapolation of historical data into the future is no longer a reliable methodology. Traditional adaptation strategies may reach the limits to their effectiveness (technical, economical, socio-political) under extreme climate change scenarios (Nicholls et al, 2017) (i.e., 2.5 m SLR for the coast or +40% increase to precipitation for the lakes and rivers). The key question becomes, how to efficiently design a community to be resilient against many possible design floods in the future? For example, the 200-year design flood today **may** become the 1-year design flood by the year 2100 due to climate change. Using the example of a dyke design, it is not necessarily feasible or required to design a sea dyke for SLR of 2.5 m today, but it may be necessary in the future. However, implementing adaptation strategies such as dyke designs typically take decades to complete from conceptual design to construction. It is crucial to begin planning infrastructure and communities to adapt to future extreme flooding scenarios in the present.

Dynamic Adaptive Policy Pathways (DAPP) implements a planning strategy that recognizes the deep uncertainty inherent to climate change impacts. DAPP is presented in **Figure 12-1** and is defined by Haasnoot (2013) as an integrated approach that includes:

- "*transient scenarios* representing a variety of relevant uncertainties and their development over time" such as SLR or increases to precipitation

- "different types of *actions* to handle vulnerabilities and opportunities" such as a variety of flood mitigation strategies
- "*Adaptation Pathways* describing sequences of promising actions" or combining flood mitigation strategies to achieve variable objectives
- "a *monitoring system* with related *contingency actions* to keep the plan on the track of preferred pathway" such as monitoring observed SLR and comparing observations to predictions and adjusting the plan as necessary

Figure 12-1: Dynamic Adaptive Policy pathways from Haasnoot et al (2013).

Examples from around the world that have begun to plan infrastructure using a DAPP approach include the Thames River TE2100 Plan as shown in **Figure 12-2** (Environment Agency, 2012); water management for New York (Rosenzweigh et al., 2011; Yohe and Leichenko, 2010) and New Zealand (Lawrence and Manning, 2012); and the Rhine Delta (Delta Programme, 2011, 2012; Jeuken and Reeder, 2011; Roosjen et al., 2012). The TE2100 Plan shows several mitigation strategies beginning with the existing system, and progressing to raising the current defenses, to constructing a new barrage which could potentially protect against 4 m of SLR. The flood mitigation strategies progress from relatively simple solutions to complex from technical, economical, and socio-political perspectives. Simple solutions that can be implemented now are adopted for the present-day, and plans for complex solutions are begun, with the recognition that it could take decades to implement complex flood mitigation strategies.

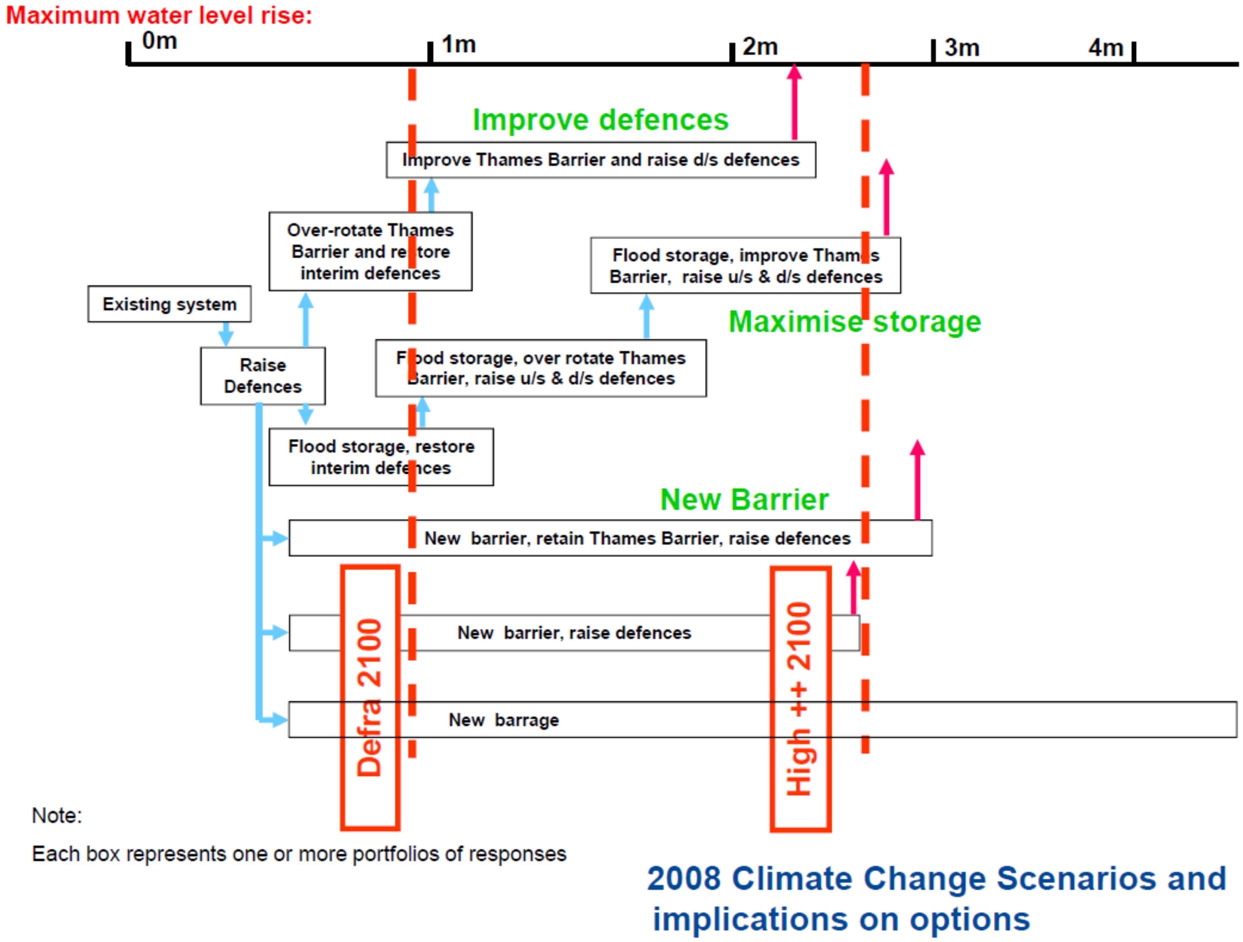


Figure 12-2: Example of a dynamic adaptive policy pathway from TE2100 (Environment Agency UK, 2012) for the Thames River.

13 CONCLUSIONS AND RECOMMENDATIONS

This study provides an overview level flood exposure assessment of present-day and three potential future flood hazard scenarios for four study regions with CVRD: Cowichan Lake, Shawnigan Lake, Cowichan River (near Riverbottom Road), and the coastline (excluding Electoral Area F)

The results of this assessment are intended to provide a preliminary understanding of the present-day and future flood risks to inform the CVRD, First Nations, and the CVRD's member municipalities and other partners of the flood risks, help prioritize and focus future studies, identify information gaps, and to support future funding applications. A digital database has been developed as a project deliverable to provide the CVRD with a baseline dataset that can be updated and refined over time as new information becomes available.

Key recommendations are presented below:

1) Develop a long-term work plan that positions future flood management work (following the general NDMP approach) alongside the ongoing flood hazard and vulnerability projects that the CVRD is presently undertaking;

2) Integrate the results of this study into policy documents to support the administration of land development regulations, flood control bylaws, emergency preparedness, and long term planning and budgeting;

3) Update and expand the CVRD's Integrated Flood Management Plan to account for climate change, addressing the uncertainty in future predictions using a dynamic decision based approach or some other similar approach;

4) Replace the existing obsolete flood hazard maps on Cowichan Lake, Shawnigan Lake, Riverbottom Road and Chemainus River/ Bonsall Creek:

    - Apply modern hydraulic modelling and GIS-based mapping tools.
    - Incorporate the lower reaches of the Cowichan River – Koksilah River floodplain and the Chemainus River – Bonsall Creek floodplain into refined coastal flood assessments to assess complex interactions between the riverine and coastal flood processes.
    - Review the available topographic information and strive to develop a more complete and consistent high resolution DEM for all regions. This should include an expansion of the study regions to include areas affected by riverine and coastal processes.
    - Re-survey the Cowichan River (near Riverbottom Road) and use the information to update the flood hazard analysis. Carry out a more detailed assessment of the riverbank morphology, erosion vulnerability, and channel avulsion potential to update the development restriction zones originally developed by Hardy (1989).

5) Communicate with stakeholders and data providers to refine and expand the flood risk geodatabase:

    - Seek more detailed information from stakeholders to assess the vulnerability of key infrastructure and other exposed elements within the FCRP boundaries.

    - Identify service areas for key elements to determine the affected service area relative to the affected flood area, which may be different.

    - Review the database to standardize the regional datasets, infill data gaps, and audit the database with site assessments, field verifications, and through outreach and engagement.

    - Seek stakeholder input to identify economic, environmental, and societal values for flood exposed elements (which will vary depending on the stakeholder) and determine an appropriate approach for weighting each of the five impact categories.

    - Audit Census data and collect supplemental information where appropriate to address potential misrepresentation of population information in rural areas.

    - Audit Property Assessment data and collect supplemental information where appropriate to address potential inaccuracies in property values associated with the approach applied for this overview level study, and to infill possible data gaps.

6) Expand the engagement process to include other stakeholders in the region:

    - Produce communications materials for educating the public on flood risks and climate change impacts in the region.

    - Engage stakeholders on conceptual flood mitigation and adaptation strategies.

7) Extend the simplified risk analysis carried out in this preliminary study:

    - Carry out more detailed flood intensity analyses for select sub-regions, to consider parameters such as water depth, velocity, sediment concentration, etc.

    - Carry out a more detailed inventory of buildings within flood exposed areas (or select sub-regions) using available up-to-date ortho-imagery and manually digitizing features. Follow up site assessments or surveys may be warranted to document the elevation of specific features.

    - Prepare flood inundation, flood depth, or hazard rating maps.

    - Develop appropriate depth-damage, velocity-damage or other hazard intensity to damage relationships to quantify flood consequence.

8) Run the Cowichan Lake and coastal study region numerical models for other combined wind generated wave events and lake or ocean levels to assess the shoreline erosion vulnerability under different plausible water level and wind conditions. For the coastal study region this could include an analysis of potential for saline intrusion and effects on groundwater.

9) Carry out a more detailed statistical analysis of observed wind events for the Cowichan Lake and Coastal study regions to incorporate impacts associated with storm duration. KWL (2014) classified the Cowichan Lake shoreline substrate, geology, and gradient based on a visual assessment by boat. It is recommended the shoreline classification be refined based on a follow up site assessment at key areas that are identified from the results of the numerical modelling. CVRD's coastal flood sensitivity database should be reviewed and incorporated into future assessments of shoreline erosion potential.

10) No environmentally sensitive areas (ESA) were identified for the Cowichan Lake study region, based on the available data. An update of ESA assessment and mapping should be carried out for the Cowichan Lake study region. Other study regions should be reviewed to determine the accuracy of ESA mapping to assess whether updates are warranted.

11) Install flood warning systems at key locations in the lake and riverine study regions to provide real time alerts when water levels exceed or rise at a rate beyond a predetermined threshold.

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Appendix A: Risk Assessment Result Tables

Table A-1 Present Scenario (Floodplains) Detailed Results

Category	Element	Quantity	SHAWNIGAN LAKE	COWICHAN LAKE						RIVERBOTTOM ROAD				
				First Nation	Electoral Area		Municipality		First Nation		Electoral Area		
				Lake Cowichan FN	Cowichan Lake South / Skutz Falls	Youbou / Meade Creek	Town of Lake Cowichan	Total	Tzart Lam 5	Kakalatza 6	Cowichan Lake South/Skutz Falls	Cowichan Station/ Sahtlam/ Glenora	Total
1. People and Societal Impacts	Population	Number	182	1	60	41	245	347	7	2	22	30	61
	Residential buildings	Number	131	1	54	71	74	200	0	0	5	0	5
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	0	0	0
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	1	0	0	0	0	0	1	0	0	28	29
	Sensitive ecosystem	Area (ha)	33	0	0	0	0	0	0	1	50	83	134
	FWA Stream impacts	Length (km)	3.5	0.0	5.2	3.9	0.7	9.8	0.0	0.2	6.1	8.0	14.4
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ 1.7	$ -	$ 8.5	$ 3.9	$ 11.0	$ 23.4	$ -	$ -	$ -	$ -	$ -
	Industrial property value	Millions CAD	$ -	$ -	$ 0.2	$ -	$ -	$ 0.2	$ -	$ -	$ -	$ -	$ -
	Residential property value	Millions CAD	$ 90.7	$ 1.4	$ 26.0	$ 40.9	$ 22.6	$ 90.9	$ -	$ -	$ 3.3	$ -	$ 3.3
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ 236.1	$ 1.4	$ 37.0	$ 61.3	$ 34.6	$ 134.3	$ -	$ -	$ 3.3	$ -	$ 3.3
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	1	0	0	1	0	0	0	0	0
	Commercial buildings	Number	3	0	32	6	45	83	0	0	0	0	0
	BC Hydro utilities	Number	1	0	0	1	7	8	0	0	0	0	0
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	15	0	12	5	9	26	0	0	0	0	0
	Telus utilities	Number	3	0	0	2	2	4	0	0	0	0	0
	Sanitary sewer assets	Number	0	0	4	0	0	4	0	0	0	0	0
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	2	0	2	0	0	2	0	0	0	0	0
	Roads	Length (km)	1.5	0.0	1.6	1.4	4.1	7.0	0.0	0.0	0.2	0.0	0.2
	Bridges	Number	2	0	1	0	1	2	0	0	0	0	0
	Culverts	Number	15	0	11	33	4	48	0	0	2	0	2
	Rail	Length (km)	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	47	0	33	33	25	91	0	1	14	10	25
	Agricultural	Area (ha)	0	0	0	0	0	0	0	0	0	0	0
	Grasslands, shrublands & forests	Area (ha)	64	0	218	135	14	367	3	3	49	79	133
	Wetlands	Area (ha)	9	0	7	14	2	23	0	0	6	7	13
	Exposed and barren land	Area (ha)	0	0	3	3	1	7	0	0	0	1	2

Table A-2 +10% Scenario (Floodplains) Detailed Results

Category	Element	Quantity	SHAWNIGAN LAKE	COWICHAN LAKE				
				First Nation	Electoral Area		Municipality	
				Lake Cowichan FN	Cowichan Lake South / Skutz Falls	Youbou / Meade Creek	Town of Lake Cowichan	Total
1. People and Societal Impacts	Population	Number	203	2	76	51	279	408
	Residential buildings	Number	162	1	77	84	92	254
	Hospitals	Number	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0
	Schools and childcare facilities	Number	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	2	0	0	0	0	0
	Sensitive ecosystem	Area (ha)	35	0	0	0	0	0
	FWA Stream impacts	Length (km)	3.6	0.0	5.6	4.2	0.7	10.5
	Gas stations	Number	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ 1.7	$ -	$ 10.9	$ 3.9	$ 13.2	$ 28.0
	Industrial property value	Millions CAD	$ -	$ -	$ 0.2	$ -	$ -	$ 0.2
	Residential property value	Millions CAD	$ 108.8	$ 1.4	$ 38.0	$ 49.1	$ 27.9	$ 116.4
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ 254.2	$ 1.4	$ 51.4	$ 76.6	$ 42.7	$ 172.2
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	1	0	0	1
	Commercial buildings	Number	3	0	45	6	63	114
	BC Hydro utilities	Number	1	0	0	1	12	13
	Fortis BC utilities	Number	0	0	0	0	0	0
	Shaw utilities	Number	16	0	14	6	12	32
	Telus utilities	Number	3	0	0	2	2	4
	Sanitary sewer assets	Number	0	0	4	0	0	4
	Reservoirs	Number	0	0	0	0	0	0
	Potable water assets	Number	2	0	2	0	0	2
	Roads	Length (km)	2.1	0.0	2.7	2.2	4.6	9.5
	Bridges	Number	2	0	1	0	1	2
	Culverts	Number	20	0	25	44	4	73
	Rail	Length (km)	1.3	0.0	0.0	0.0	0.0	0.0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	53	0	39	37	29	106
	Agricultural	Area (ha)	0	0	0	0	0	0
	Grasslands, shrublands & forests	Area (ha)	71	0	243	150	14	407
	Wetlands	Area (ha)	9	0	8	14	2	24
	Exposed and barren land	Area (ha)	0	0	4	3	1	7

Table A-3 +20% Scenario (Floodplains) Detailed Results

Category	Element	Quantity	SHAWNIGAN LAKE	COWICHAN LAKE				
				First Nation	Electoral Area		Municipality	
				Lake Cowichan FN	Cowichan Lake South / Skutz Falls	Youbou / Meade Creek	Town of Lake Cowichan	Total
1. People and Societal Impacts	Population	Number	223	2	90	54	308	454
	Residential buildings	Number	184	1	92	106	109	308
	Hospitals	Number	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	1	1
	Schools and childcare facilities	Number	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	2	0	0	0	0	0
	Sensitive ecosystem	Area (ha)	35	0	0	0	0	0
	FWA Stream impacts	Length (km)	3.7	0.0	6.4	4.6	0.7	11.7
	Gas stations	Number	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ 1.7	$ -	$ 11.7	$ 3.9	$ 15.2	$ 30.7
	Industrial property value	Millions CAD	$ -	$ -	$ 0.2	$ -	$ -	$ 0.2
	Residential property value	Millions CAD	$ 120.7	$ 1.4	$ 45.9	$ 64.3	$ 33.5	$ 145.1
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ 268.1	$ 1.4	$ 60.1	$ 96.2	$ 50.6	$ 208.3
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	1	0	0	1
	Commercial buildings	Number	3	0	53	6	70	129
	BC Hydro utilities	Number	1	0	1	1	13	15
	Fortis BC utilities	Number	0	0	0	0	0	0
	Shaw utilities	Number	18	0	16	9	15	40
	Telus utilities	Number	3	0	0	2	2	4
	Sanitary sewer assets	Number	0	0	4	0	0	4
	Reservoirs	Number	0	0	0	0	0	0
	Potable water assets	Number	2	0	2	0	0	2
	Roads	Length (km)	2.8	0.0	3.5	2.5	5.0	11.0
	Bridges	Number	3	0	1	0	1	2
	Culverts	Number	29	0	27	50	5	82
	Rail	Length (km)	1.7	0.0	0.0	0.0	0.0	0.0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	59	0	45	41	32	118
	Agricultural	Area (ha)	0	0	0	0	0	0
	Grasslands, shrublands & forests	Area (ha)	74	0	266	165	15	446
	Wetlands	Area (ha)	9	0	8	15	2	25
	Exposed and barren land	Area (ha)	0	0	4	3	1	8

Table A-4 +40% Scenario (Floodplains) Detailed Results

Category	Element	Quantity	SHAWNIGAN LAKE	COWICHAN LAKE						RIVERBOTTOM ROAD				
				First Nation	First Nation		Municipality			First Nation		Electoral Area		
				Lake Cowichan FN	Cowichan Lake South / Skutz Falls	Youbou / Meade Creek	Town of Lake Cowichan	Total		Tzart Lam 5	Kakalatza 6	Cowichan Lake South/Skutz Falls	Cowichan Station/ Sahtlam/ Glenora	Total
1. People and Societal Impacts	Population	Number	235	2	118	64	355	539		9	2	43	36	90
	Residential buildings	Number	199	1	122	141	141	405		0	0	20	0	20
	Hospitals	Number	0	0	0	0	0	0		0	0	0	0	0
	Emergency centers	Number	0	0	0	0	2	2		0	0	0	0	0
	Schools and childcare facilities	Number	0	0	0	0	0	0		0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	3	0	0	0	0	0		1	0	0	35	36
	Sensitive ecosystem	Area (ha)	36	0	0	0	0	0		0	1	56	92	149
	FWA Stream impacts	Length (km)	3.8	0.0	7.4	5.4	0.8	13.6		0.0	0.2	6.5	8.1	14.8
	Gas stations	Number	0	0	0	0	0	0		0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ 1.7	$ -	$ 13.2	$ 6.2	$ 20.7	$ 40.2		$ -	$ -	$ -	$ -	$ -
	Industrial property value	Millions CAD	$ -	$ -	$ 1.0	$ -	$ -	$ 1.0		$ -	$ -	$ -	$ -	$ -
	Residential property value	Millions CAD	$ 132.8	$ 1.4	$ 62.3	$ 87.5	$ 43.5	$ 194.8		$ -	$ -	$ 11.2	$ -	$ 11.2
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ 280.1	$ 1.4	$ 82.4	$ 128.9	$ 66.1	$ 278.8		$ -	$ -	$ 11.2	$ -	$ 11.2
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	2	0	0	2		0	0	0	0	0
	Commercial buildings	Number	3	0	69	8	78	155		0	0	0	0	0
	BC Hydro utilities	Number	1	0	1	1	16	18		0	0	0	0	0
	Fortis BC utilities	Number	0	0	0	0	0	0		0	0	0	0	0
	Shaw utilities	Number	19	0	19	12	21	52		0	0	0	0	0
	Telus utilities	Number	3	0	0	3	3	6		0	0	0	0	0
	Sanitary sewer assets	Number	0	0	4	0	0	4		0	0	0	0	0
	Reservoirs	Number	0	0	0	0	0	0		0	0	0	0	0
	Potable water assets	Number	2	0	2	0	0	2		0	0	0	0	0
	Roads	Length (km)	3.4	0.0	5.4	3.7	5.9	14.9		0.0	0.0	1.0	0.1	1.0
	Bridges	Number	3	0	3	0	1	4		0	0	0	0	0
	Culverts	Number	35	0	43	61	8	112		0	0	9	1	10
	Rail	Length (km)	1.8	0	0	0	0	0		0	0	0	0	0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	63	0	61	47	40	148		0	1	21	11	33
	Agricultural	Area (ha)	0	0	0	0	0	0		0	0	0	0	0
	Grasslands, shrublands & forests	Area (ha)	78	0	310	198	18	526		4	3	76	96	179
	Wetlands	Area (ha)	9	0	9	15	2	26		0	0	6	8	14
	Exposed and barren land	Area (ha)	1	0	4	4	1	8		0	0	0	1	2

Table A-5 Present Scenario (Coastal) Detailed Results

Category	Element	Quantity	COASTAL														
			Cowichan Tribes				Halalt		Malahat	Pauquachin	Penelakut			Stz'uminus			
			Cowichan 1	Cowichan 9	Theik 2	Kil-Pah-Las 3	Halalt 1	Halalt 2	Malahat 11	Hatch Point 12	Tsussie 6	Tent Island 8	Penelakut Island 7	Squaw-Hay-One 11	Say-La-Quas 10	Chemainus 13	Oyster Bay 12
1. People and Societal Impacts	Population	Number	215	17	3	5	0	0	0	0	79	0	4	0	0	31	3
	Residential buildings	Number	2	3	0	0	0	0	0	0	0	0	0	0	0	3	0
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	268	16	2	2	54	0	2	1	13	3	9	0	2	30	13
	Sensitive ecosystem	Area (ha)	100	0	0	0	3	0	0	0	3	2	2	0	2	1	6
	FWA Stream impacts	Length (km)	10.9	1.6	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.4	0.0
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Industrial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2.3	$ -
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ -	$ -	$ -	$ 2.9	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2.3	$ -
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Commercial buildings	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	BC Hydro utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Telus utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sanitary sewer assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	Length (km)	2.7	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.7	0.0
	Bridges	Number	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Culverts	Number	3	0	5	0	0	0	0	0	0	0	0	0	0	0	0
	Rail	Length (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	62	7	1	1	0	0	2	1	9	0	3	0	0	7	6
	Agricultural	Area (ha)	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grasslands, shrublands & forests	Area (ha)	122	9	0	1	52	0	0	1	2	1	4	0	2	9	3
	Wetlands	Area (ha)	37	1	0	0	2	0	0	0	1	0	1	0	0	3	1
	Exposed and barren land	Area (ha)	4	0	9	0	3	0	1	1	0	1	4	0	0	23	7

Table A-5 Present Scenario (Coastal) Detailed Results

Category	Element	Quantity	COASTAL (continued)												
			Lyackson			Electoral Area						Municipality			
			Lyackson 3	Porlier Pass 5	Shingle Point 4	Mill Bay / Malahat	Cobble Hill	Cowichan Bay	Cowichan Station / Sahtlam / Glenora	Saltair / Gulf Islands	North Oyster / Diamond	North Cowichan	Ladysmith	Duncan	Total
1. People and Societal Impacts	Population	Number	0	0	0	19	10	107	0	49	41	149	25	0	757
	Residential buildings	Number	0	0	2	0	0	13	0	9	4	7	0	0	43
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	16	0	4	21	5	210	0	144	42	443	10	0	1,311
	Sensitive ecosystem	Area (ha)	6	0	0	8	1	114	0	59	11	223	3	0	545
	FWA Stream impacts	Length (km)	0.4	0.0	0.0	0.5	0.2	8.0	0.0	2.4	0.4	23.1	0.2	0.0	48.4
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ 6.4	$ -	$ -	$ 5.1	$ -	$ -	$ -	$ 11.5
	Industrial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ 1.9	$ -	$ -	$ -	$ 2.5	$ 3.2	$ -	$ 7.6
	Residential property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ 4.2	$ -	$ 4.2	$ 3.1	$ 3.5	$ -	$ -	$ 17.2
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ -	$ -	$ -	$ 2.2	$ -	$ 19.4	$ -	$ 5.9	$ 8.2	$ 9.0	$ 3.2	$ -	$ 52.9
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	0	0	0	5	0	0	0	4	5	0	14
	Commercial buildings	Number	0	0	0	0	0	20	0	0	1	0	0	0	21
	BC Hydro utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	0	0	0	0	0	37	0	0	0	85	2	0	124
	Telus utilities	Number	0	0	0	0	0	5	0	0	0	0	0	0	5
	Sanitary sewer assets	Number	0	0	0	0	0	1	0	0	0	0	0	0	1
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	Length (km)	0.0	0.0	0.0	0.3	0.1	5.1	0.0	0.5	0.2	0.8	0.2	0.0	11.5
	Bridges	Number	0	0	0	0	1	1	0	0	0	3	0	0	9
	Culverts	Number	0	0	0	2	2	14	0	4	1	0	0	0	31
	Rail	Length (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	0	0	0	13	5	106	0	26	22	145	15	0	430
	Agricultural	Area (ha)	0	0	0	0	0	48	0	0	0	51	0	0	139
	Grasslands, shrublands & forests	Area (ha)	12	0	3	5	1	33	0	69	12	101	2	0	443
	Wetlands	Area (ha)	1	0	0	1	0	22	0	15	2	92	1	0	179
	Exposed and barren land	Area (ha)	4	0	1	10	4	240	0	102	16	215	17	0	662

Table A-6 Intermediate Scenario (Coastal) Detailed Results

			COASTAL														
			Cowichan Tribes				Halalt		Malahat	Pauquachin	Penelakut			Stz'uminus			
Category	Element	Quantity	Cowichan 1	Cowichan 9	Theik 2	Kil-Pah-Las 3	Halalt 1	Halalt 2	Malahat 11	Hatch Point 12	Tsussie 6	Tent Island 8	Penelakut Island 7	Squaw-Hay-One 11	Say-La-Quas 10	Chemainus 13	Oyster Bay 12
1. People and Societal Impacts	Population	Number	297	18	4	6	0	1	1	1	89	0	6	0	0	0	46
	Residential buildings	Number	5	6	0	0	0	0	0	0	0	0	0	0	0	2	4
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	398	17	2	2	54	2	2	2	14	4	14	0	3	4	38
	Sensitive ecosystem	Area (ha)	158	0	0	0	3	1	0	0	3	3	2	0	3	0	2
	FWA Stream impacts	Length (km)	12.2	1.6	0.0	0.0	0.0	0.4	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.4
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Industrial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3.1
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ -	$ -	$ -	$ 2.9	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3.1
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Commercial buildings	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	BC Hydro utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Telus utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sanitary sewer assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	Length (km)	3.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.3	0.0	0.0	0.0	1.1
	Bridges	Number	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Culverts	Number	3	0	5	0	0	0	0	0	0	0	0	0	0	0	0
	Rail	Length (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	78	8	2	1	0	1	2	1	10	0	5	0	0	0	9
	Agricultural	Area (ha)	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grasslands, shrublands & forests	Area (ha)	179	9	0	1	52	1	0	1	3	2	8	0	3	3	13
	Wetlands	Area (ha)	58	1	0	0	2	0	0	0	1	0	1	0	0	0	3
	Exposed and barren land	Area (ha)	4	0	9	0	3	0	1	1	0	1	5	0	0	1	24

Table A-6 Intermediate Scenario (Coastal) Detailed Results

Category	Element	Quantity	COASTAL (continued)												
			Lyackson			Electoral Area						Municipality			
			Lyackson 3	Porlier Pass 5	Shingle Point 4	Mill Bay / Malahat	Cobble Hill	Cowichan Bay	Cowichan Station / Sahtlam / Glenora	Saltair / Gulf Islands	North Oyster / Diamond	North Cowichan	Ladysmith	Duncan	Total
1. People and Societal Impacts	Population	Number	6	0	0	26	12	131	0	62	77	190	33	0	1,006
	Residential buildings	Number	2	0	0	3	0	14	0	24	12	11	0	0	83
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	1	0	0	0	1
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	16	19	0	28	7	223	0	178	61	533	24	0	1,647
	Sensitive ecosystem	Area (ha)	6	7	0	9	1	115	0	67	14	243	4	0	640
	FWA Stream impacts	Length (km)	0.0	0.4	0.0	0.7	0.3	8.6	0.0	2.6	0.5	25.0	0.3	0.0	53.5
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ 7.7	$ -	$ -	$ 6.3	$ -	$ -	$ -	$ 14.0
	Industrial property value	Millions CAD	$ -	$ -	$ -	$ 0.5	$ -	$ 1.9	$ -	$ -	$ 1.0	$ 9.1	$ 12.0	$ -	$ 24.4
	Residential property value	Millions CAD	$ -	$ -	$ -	$ 2.6	$ -	$ 4.4	$ -	$ 13.8	$ 8.8	$ 6.9	$ -	$ -	$ 39.6
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ -	$ -	$ -	$ 6.4	$ -	$ 21.4	$ -	$ 15.5	$ 17.0	$ 25.7	$ 12.0	$ -	$ 103.9
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	0	3	0	5	0	0	1	8	12	0	29
	Commercial buildings	Number	0	0	0	0	0	25	0	0	3	0	0	0	28
	BC Hydro utilities	Number	0	0	0	0	0	0	0	0	0	0	1	0	1
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	0	0	0	0	0	40	0	0	1	86	2	0	129
	Telus utilities	Number	0	0	0	1	0	5	0	0	0	1	1	0	8
	Sanitary sewer assets	Number	0	0	0	0	0	1	0	0	0	0	0	0	1
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	Length (km)	0.0	0.0	0.0	0.9	0.1	6.2	0.0	1.1	0.8	2.0	0.3	0.0	17.5
	Bridges	Number	0	0	0	0	1	2	0	0	0	3	0	0	9
	Culverts	Number	0	0	0	4	2	20	0	11	2	0	0	0	47
	Rail	Length (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	6	0	0	17	6	113	0	32	32	188	28	0	538
	Agricultural	Area (ha)	0	0	0	0	0	48	0	0	0	63	0	0	186
	Grasslands, shrublands & forests	Area (ha)	5	15	0	6	2	39	0	90	20	133	2	0	586
	Wetlands	Area (ha)	1	2	0	2	0	22	0	17	3	94	1	0	207
	Exposed and barren land	Area (ha)	7	4	0	12	4	245	0	108	17	222	18	0	685

Table A-7 Intermediate-High Scenario (Coastal) Detailed Results

Category	Element	Quantity	COASTAL														
			Cowichan Tribes				Halalt		Malahat	Pauquachin	Penelakut			Stz'uminus			
			Cowichan 1	Cowichan 9	Theik 2	Kil-Pah-Las 3	Halalt 1	Halalt 2	Malahat 11	Hatch Point 12	Tsussie 6	Tent Island 8	Penelakut Island 7	Squaw-Hay-One 11	Say-La-Quas 10	Chemainus 13	Oyster Bay 12
1. People and Societal Impacts	Population	Number	331	18	4	6	0	2	1	1	90	0	7	0	0	51	7
	Residential buildings	Number	5	6	0	0	0	0	0	0	0	0	0	0	0	4	2
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	454	17	2	2	54	3	3	2	14	4	17	1	4	43	18
	Sensitive ecosystem	Area (ha)	184	0	0	0	3	2	0	0	3	3	2	0	4	3	6
	FWA Stream impacts	Length (km)	12.6	1.6	0.0	0.0	0.0	0.6	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.4	0.0
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Industrial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3.1	$ -
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ -	$ -	$ -	$ 2.9	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3.1	$ -
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Commercial buildings	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	BC Hydro utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Telus utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sanitary sewer assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	Length (km)	3.9	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	1.5	0.0
	Bridges	Number	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Culverts	Number	3	0	6	0	0	0	0	0	0	0	0	0	0	0	0
	Rail	Length (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	86	8	2	1	0	1	2	1	10	0	5	1	0	10	7
	Agricultural	Area (ha)	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grasslands, shrublands & forests	Area (ha)	212	9	0	1	52	2	0	1	3	2	9	0	3	16	7
	Wetlands	Area (ha)	61	1	0	0	2	0	0	0	1	0	2	0	0	3	1
	Exposed and barren land	Area (ha)	4	0	9	0	3	0	1	1	0	1	5	0	0	25	7

Table A-7 Intermediate-High Scenario (Coastal) Detailed Res

Category	Element	Quantity	COASTAL (continued)												
			Lyackson			Electoral Area						Municipality			
			Lyackson 3	Porlier Pass 5	Shingle Point 4	Mill Bay / Malahat	Cobble Hill	Cowichan Bay	Cowichan Station / Sahtlam / Glenora	Saltair / Gulf Islands	North Oyster / Diamond	North Cowichan	Ladysmith	Duncan	Total
1. People and Societal Impacts	Population	Number	0	0	0	30	12	144	0	67	91	212	36	0	1,110
	Residential buildings	Number	0	0	2	4	0	14	0	42	17	14	0	0	110
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	1	1	0	0	2
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	21	0	4	30	7	234	0	196	76	564	27	0	1,799
	Sensitive ecosystem	Area (ha)	8	0	0	10	1	115	0	71	15	249	4	0	682
	FWA Stream impacts	Length (km)	0.4	0.0	0.0	0.8	0.3	9.0	0.0	2.7	1.0	25.7	0.3	0.0	55.9
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ 8.4	$ -	$ -	$ 6.3	$ -	$ -	$ -	$ 14.6
	Industrial property value	Millions CAD	$ -	$ -	$ -	$ 0.5	$ -	$ 1.9	$ -	$ -	$ 1.0	$ 12.4	$ 15.0	$ -	$ 30.7
	Residential property value	Millions CAD	$ -	$ -	$ -	$ 2.6	$ -	$ 4.4	$ -	$ 27.6	$ 13.1	$ 9.3	$ -	$ -	$ 60.2
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ -	$ -	$ -	$ 6.4	$ -	$ 22.6	$ -	$ 31.8	$ 22.1	$ 33.3	$ 15.0	$ -	$ 137.2
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	0	3	0	5	0	0	1	11	14	0	34
	Commercial buildings	Number	0	0	0	0	0	27	0	0	3	0	0	0	30
	BC Hydro utilities	Number	0	0	0	1	0	0	0	0	0	0	1	0	2
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	0	0	0	0	0	41	0	0	1	90	2	0	134
	Telus utilities	Number	0	0	0	1	0	5	0	0	0	2	1	0	9
	Sanitary sewer assets	Number	0	0	0	1	0	1	0	0	0	0	0	0	2
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	Length (km)	0.0	0.0	0.0	1.0	0.1	6.8	0.0	1.4	1.3	2.7	0.5	0.0	20.7
	Bridges	Number	0	0	0	0	1	2	0	0	0	3	0	0	11
	Culverts	Number	0	0	0	4	2	27	0	14	8	1	0	0	65
	Rail	Length (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	0	0	0	19	6	118	0	35	39	204	30	0	583
	Agricultural	Area (ha)	0	0	0	0	0	51	0	0	1	66	0	0	204
	Grasslands, shrublands & forests	Area (ha)	16	0	3	7	2	42	0	101	25	145	3	0	663
	Wetlands	Area (ha)	2	0	0	2	0	22	0	18	3	95	1	0	213
	Exposed and barren land	Area (ha)	5	0	1	12	4	245	0	110	18	223	19	0	692

Table A-8 Extreme Scenario (Coastal) Detailed Results

Category	Element	Quantity	COASTAL														
			Cowichan Tribes				Halalt		Malahat	Pauquachin	Penelakut			Stz'uminus			
Category	Element	Quantity	Cowichan 1	Cowichan 9	Theik 2	Kil-Pah-Las 3	Halalt 1	Halalt 2	Malahat 11	Hatch Point 12	Tsussie 6	Tent Island 8	Penelakut Island 7	Squaw-Hay-One 11	Say-La-Quas 10	Chemainus 13	Oyster Bay 12
1. People and Societal Impacts	Population	Number	393	18	4	6	0	6	1	1	91	0	10	0	0	61	8
	Residential buildings	Number	9	6	0	0	0	0	0	0	0	0	5	0	0	8	2
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	535	18	3	3	54	8	3	2	15	5	24	1	4	54	20
	Sensitive ecosystem	Area (ha)	212	0	0	0	3	6	0	0	3	4	2	0	4	4	6
	FWA Stream impacts	Length (km)	13.9	1.6	0.0	0.0	0.0	1.0	0.0	0.1	0.4	0.0	0.1	0.0	0.0	0.5	0.0
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Industrial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.5	$ -	$ -	$ 6.2	$ -
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ -	$ -	$ -	$ 2.9	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.5	$ -	$ -	$ 6.2	$ -
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Commercial buildings	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	BC Hydro utilities	Number	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Telus utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sanitary sewer assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	Length (km)	5.4	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.5	0.0	0.0	2.3	0.0
	Bridges	Number	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Culverts	Number	3	0	6	0	0	0	0	0	0	0	0	0	0	0	0
	Rail	Length (km)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	102	8	2	1	0	2	3	1	10	0	6	1	0	12	7
	Agricultural	Area (ha)	105	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grasslands, shrublands & forests	Area (ha)	256	9	0	1	52	6	0	2	3	3	14	0	4	24	9
	Wetlands	Area (ha)	65	1	0	0	2	1	0	0	1	0	2	0	0	3	1
	Exposed and barren land	Area (ha)	4	0	9	0	3	0	1	1	0	1	5	0	0	25	7

Table A-8 Extreme Scenario (Coastal) Detailed Results

			COASTAL (continued)												
			Lyackson			Electoral Area						Municipality			
Category	Element	Quantity	Lyackson 3	Porlier Pass 5	Shingle Point 4	Mill Bay / Malahat	Cobble Hill	Cowichan Bay	Cowichan Station / Sahtlam / Glenora	Saltair / Gulf Islands	North Oyster / Diamond	North Cowichan	Ladysmith	Duncan	Total
1. People and Societal Impacts	Population	Number	0	0	0	40	15	171	6	81	123	269	43	0	1,347
	Residential buildings	Number	0	0	2	12	0	16	0	69	26	23	0	0	178
	Hospitals	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Emergency centers	Number	0	0	0	0	0	0	0	0	1	1	0	0	2
	Schools and childcare facilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Environmental Impacts	Terrestrial ecosystem	Area (ha)	24	0	5	35	8	254	7	234	103	616	30	0	2,063
	Sensitive ecosystem	Area (ha)	9	0	0	11	1	115	0	81	17	259	4	0	741
	FWA Stream impacts	Length (km)	0.4	0.0	0.0	0.9	0.4	9.3	0.0	2.8	1.2	26.6	0.4	0.0	59.6
	Gas stations	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Local Economic Impacts	Commercial property value	Millions CAD	$ -	$ -	$ -	$ -	$ -	$ 9.1	$ -	$ -	$ 8.8	$ 1.4	$ -	$ -	$ 19.3
	Industrial property value	Millions CAD	$ -	$ -	$ -	$ 0.5	$ -	$ 1.9	$ -	$ -	$ 1.0	$ 15.3	$ 15.0	$ -	$ 33.6
	Residential property value	Millions CAD	$ -	$ -	$ -	$ 9.1	$ -	$ 5.5	$ -	$ 41.4	$ 21.0	$ 14.1	$ -	$ -	$ 98.0
	Total property value (also incl. properties zoned other than commercial, industrial, and residential)	Millions CAD	$ -	$ -	$ -	$ 12.9	$ -	$ 25.9	$ -	$ 45.5	$ 33.1	$ 48.4	$ 15.0	$ -	$ 190.3
4. Local Infrastructure Impacts	Industrial buildings	Number	0	0	0	3	0	5	0	0	1	13	14	0	36
	Commercial buildings	Number	0	0	0	0	0	29	0	0	4	3	0	0	36
	BC Hydro utilities	Number	0	0	0	1	0	1	0	0	1	3	1	0	9
	Fortis BC utilities	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shaw utilities	Number	0	0	0	1	0	42	0	0	2	92	2	0	140
	Telus utilities	Number	0	0	0	1	0	5	0	0	0	2	1	0	9
	Sanitary sewer assets	Number	0	0	0	1	0	1	0	0	0	0	0	0	2
	Reservoirs	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potable water assets	Number	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	Length (km)	0.0	0.0	0.0	1.1	0.1	7.2	0.0	1.9	2.4	3.8	0.6	0.0	26.8
	Bridges	Number	0	0	0	0	1	2	0	0	0	3	0	0	11
	Culverts	Number	0	0	0	5	2	31	0	19	11	4	0	0	81
	Rail	Length (km)	0	0	0	0	0	0	0.03	0	0	0.04	0	0	0.1
5. Public Sensitivity Impacts	Urban and developed	Area (ha)	0	0	0	22	7	123	1	40	51	229	33	0	662
	Agricultural	Area (ha)	0	0	0	0	0	59	5	0	3	69	0	0	241
	Grasslands, shrublands & forests	Area (ha)	18	0	4	8	2	48	1	127	36	167	3	0	798
	Wetlands	Area (ha)	2	0	0	2	0	22	0	20	3	96	1	0	222
	Exposed and barren land	Area (ha)	5	0	1	13	4	245	0	115	19	223	19	0	702

Appendix B: Exposure and Vulnerability Visualization Maps

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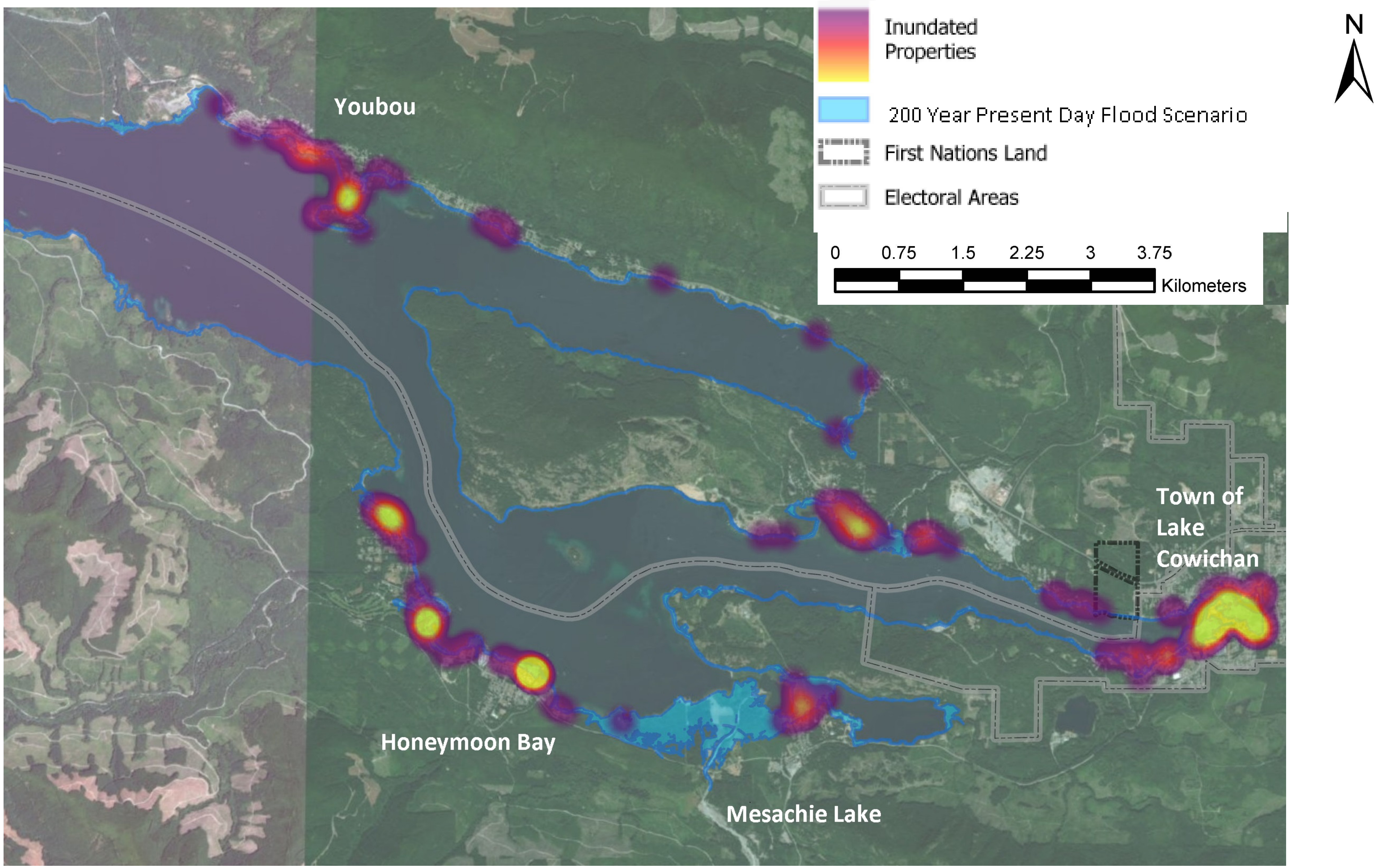

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN LAKE (EAST)
200 YEAR PRESENT DAY
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-101
SHEET NUMBER	1 OF 31
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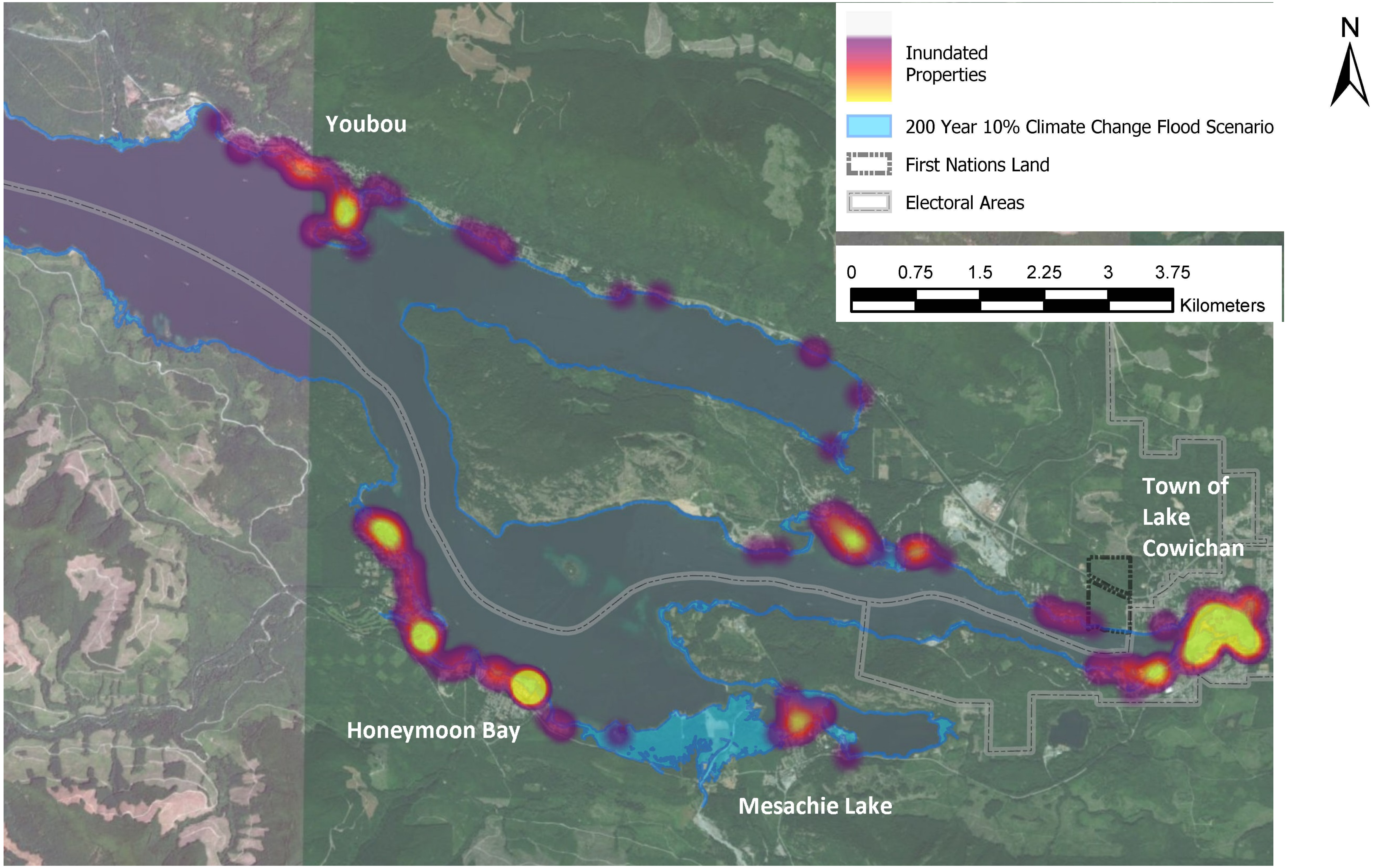

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN LAKE (EAST)
200 YEAR 10%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-102
SHEET NUMBER	2 OF 31
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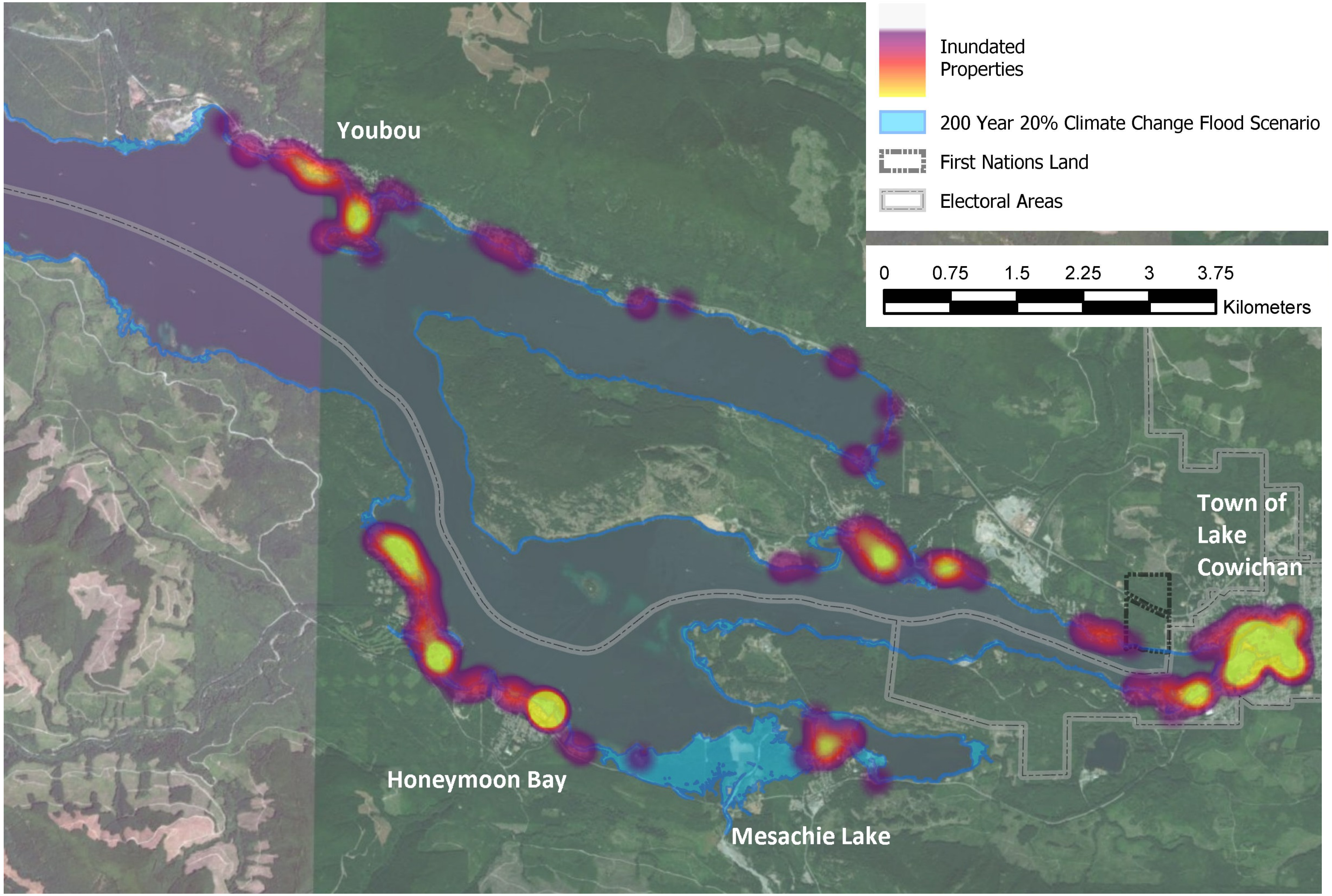

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN LAKE (EAST)
200 YEAR 20%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-103
SHEET NUMBER	3 OF 31
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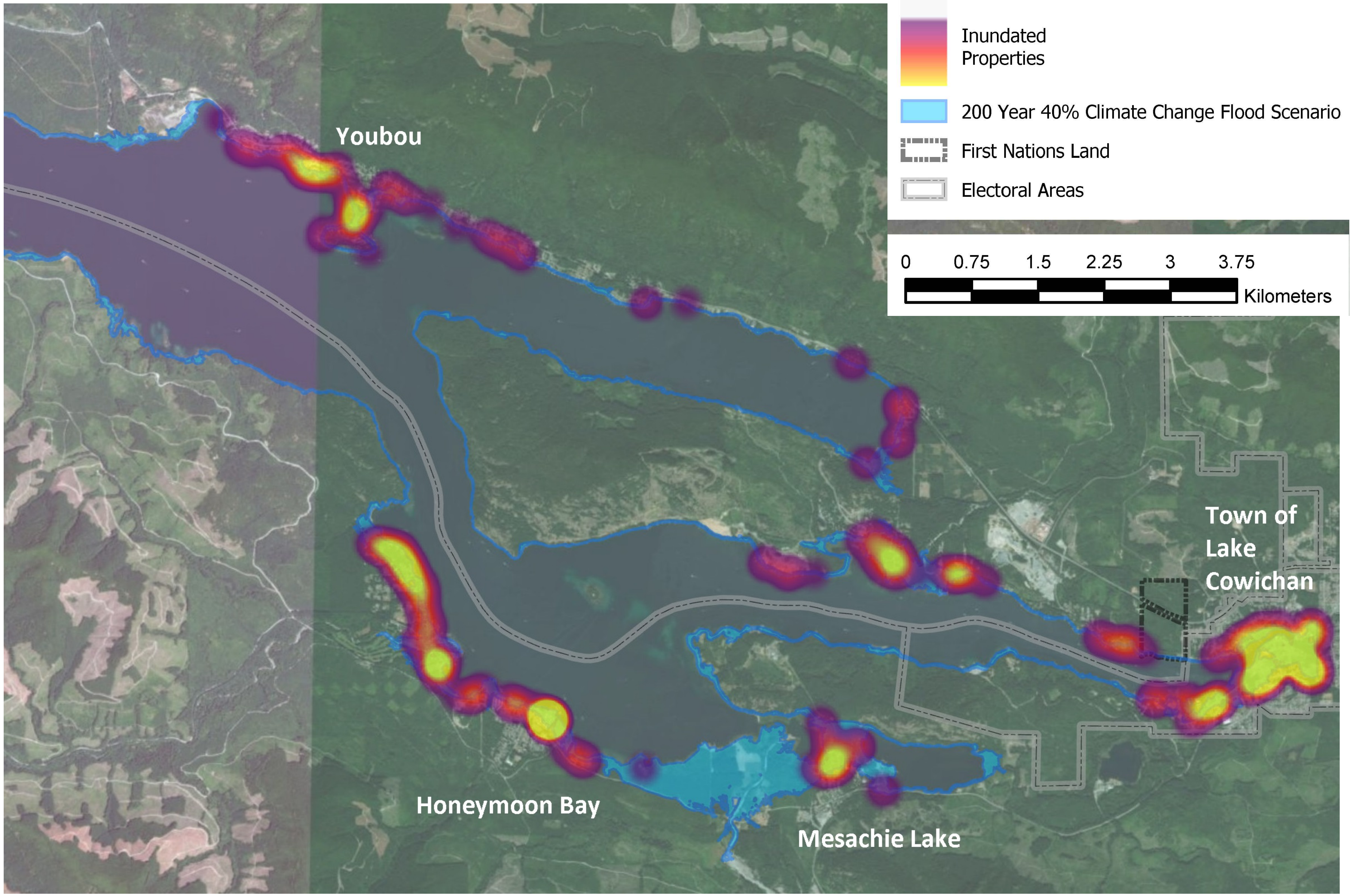

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN LAKE (EAST)
200 YEAR 40%
CLIMATE CHANGE FLOOD SCENARIO

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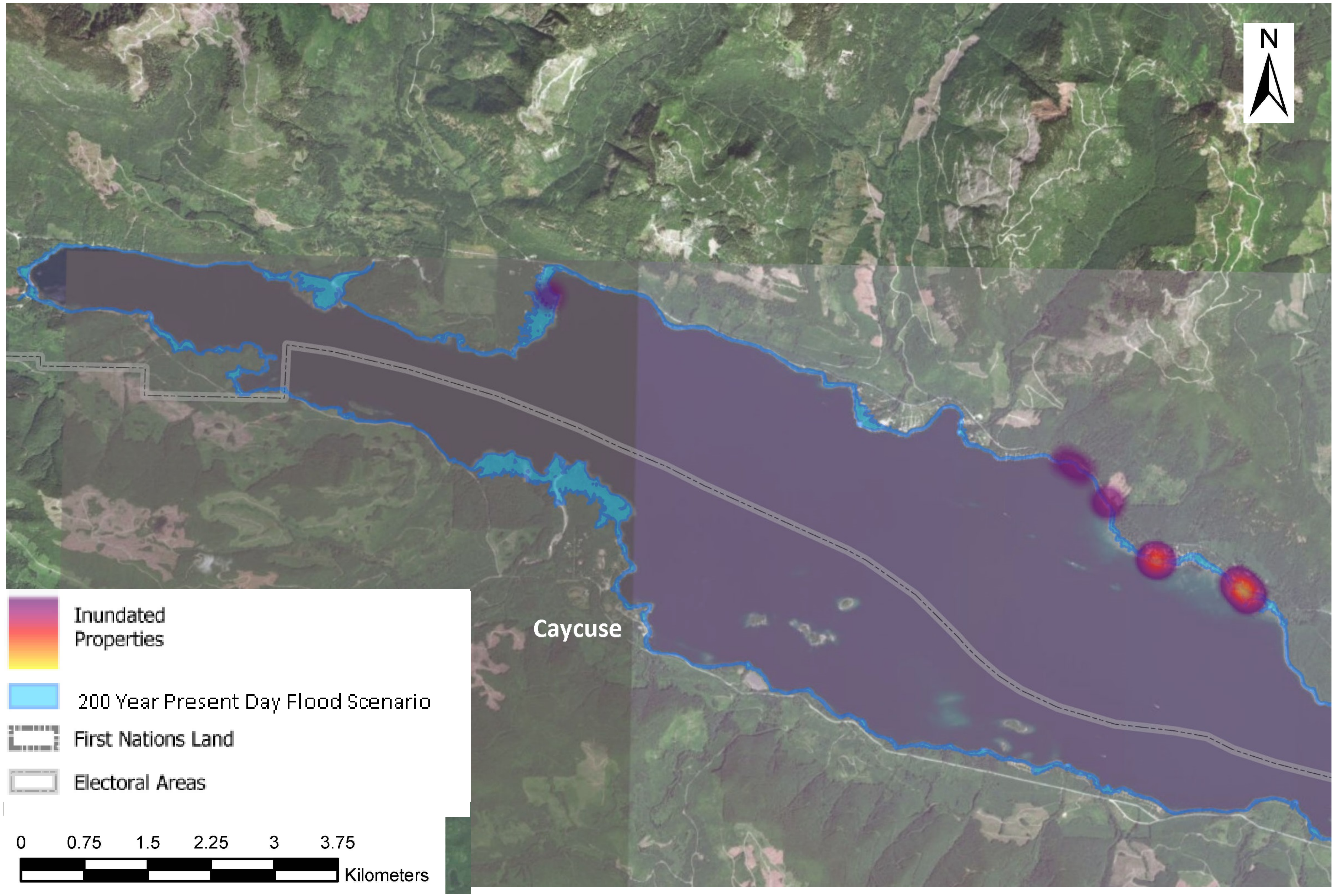

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN LAKE (WEST)
200 YEAR PRESENT DAY
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-105
SHEET NUMBER	5 OF 31
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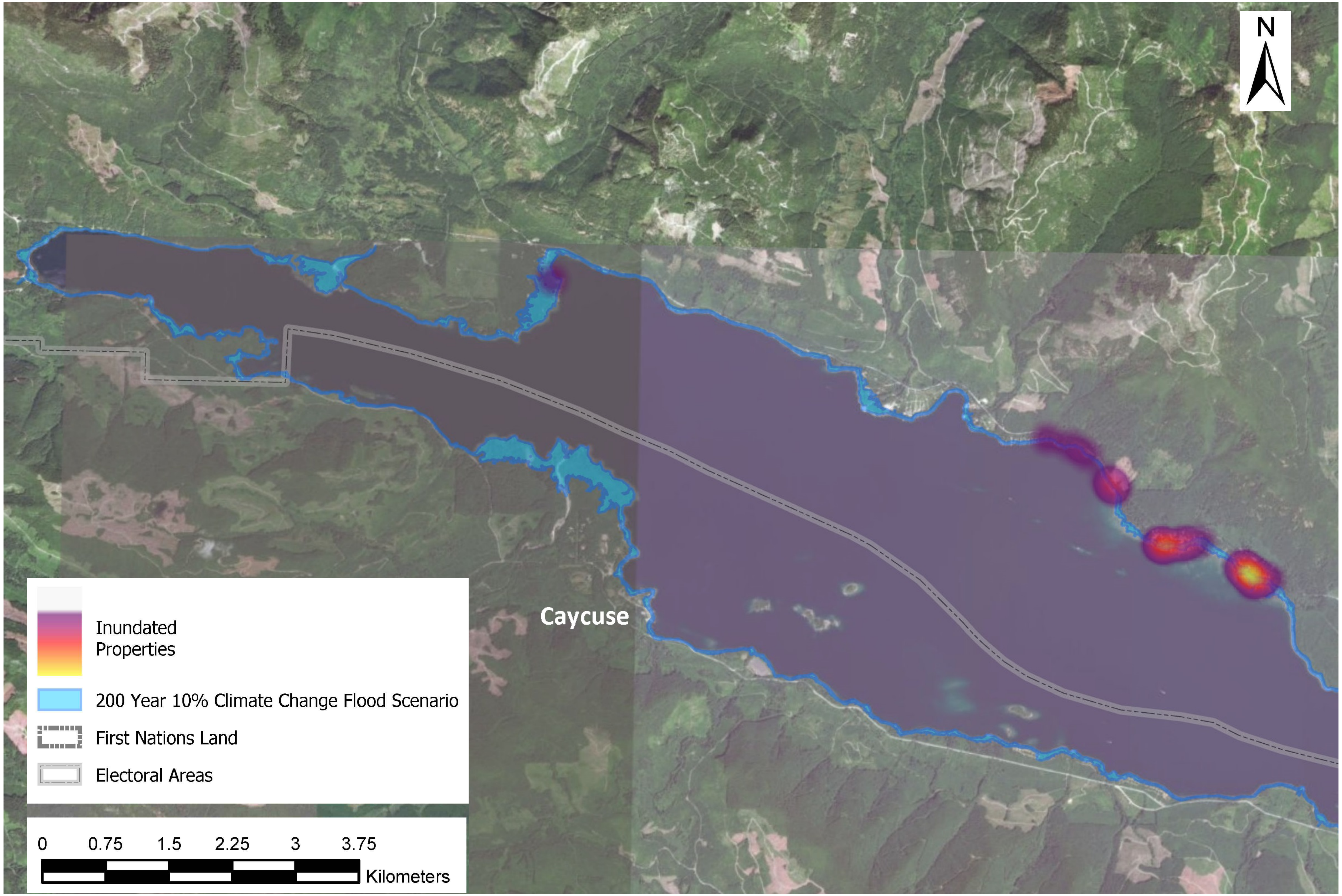

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE
PROPERTY VULNERABILITY
COWICHAN LAKE (WEST)
200 YEAR 10%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-106
SHEET NUMBER	6 OF 31
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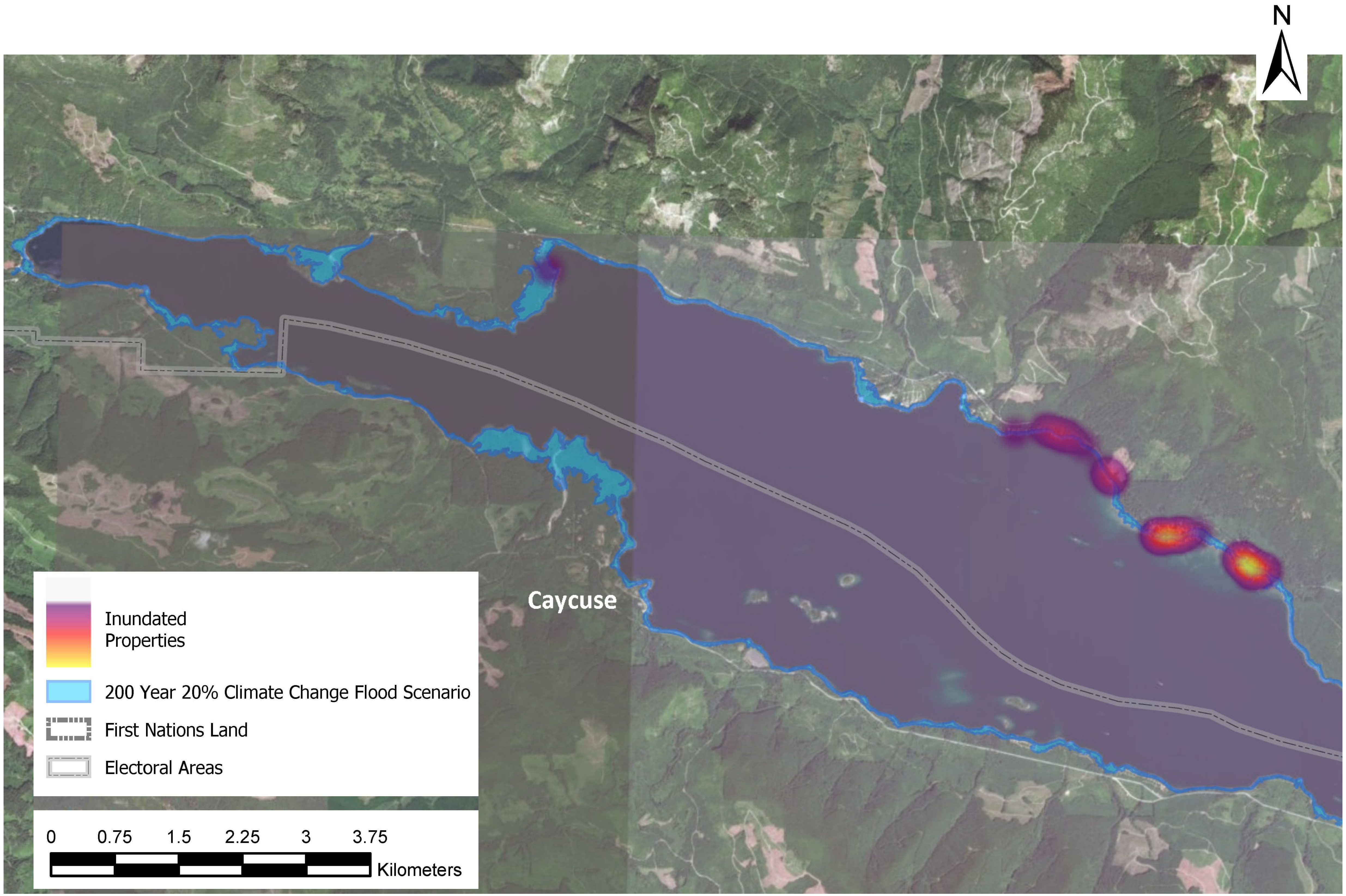

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN LAKE (WEST)
200 YEAR 20%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-107
SHEET NUMBER	7 OF 31
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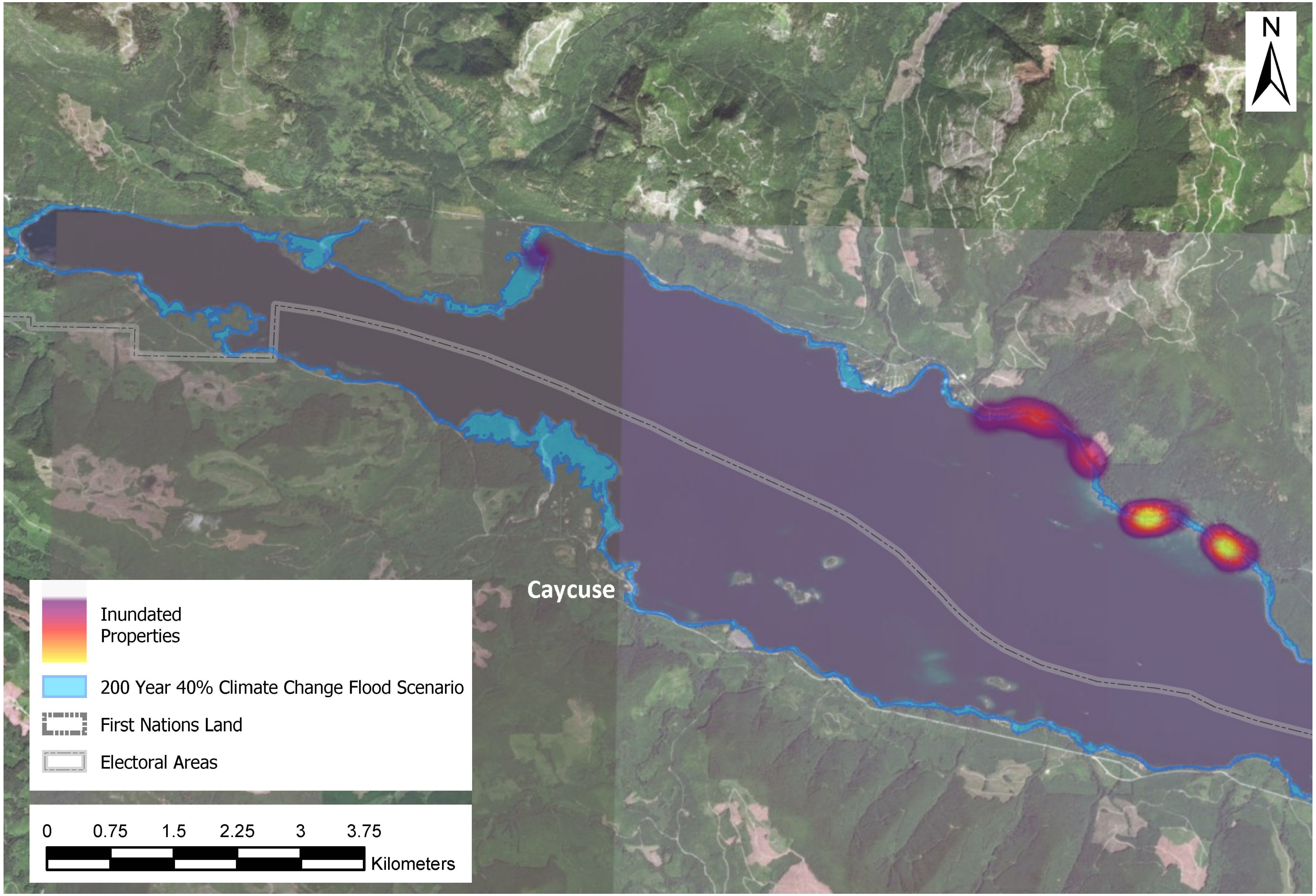

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN LAKE (WEST)
200 YEAR 40%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-108
SHEET NUMBER	8 OF 31
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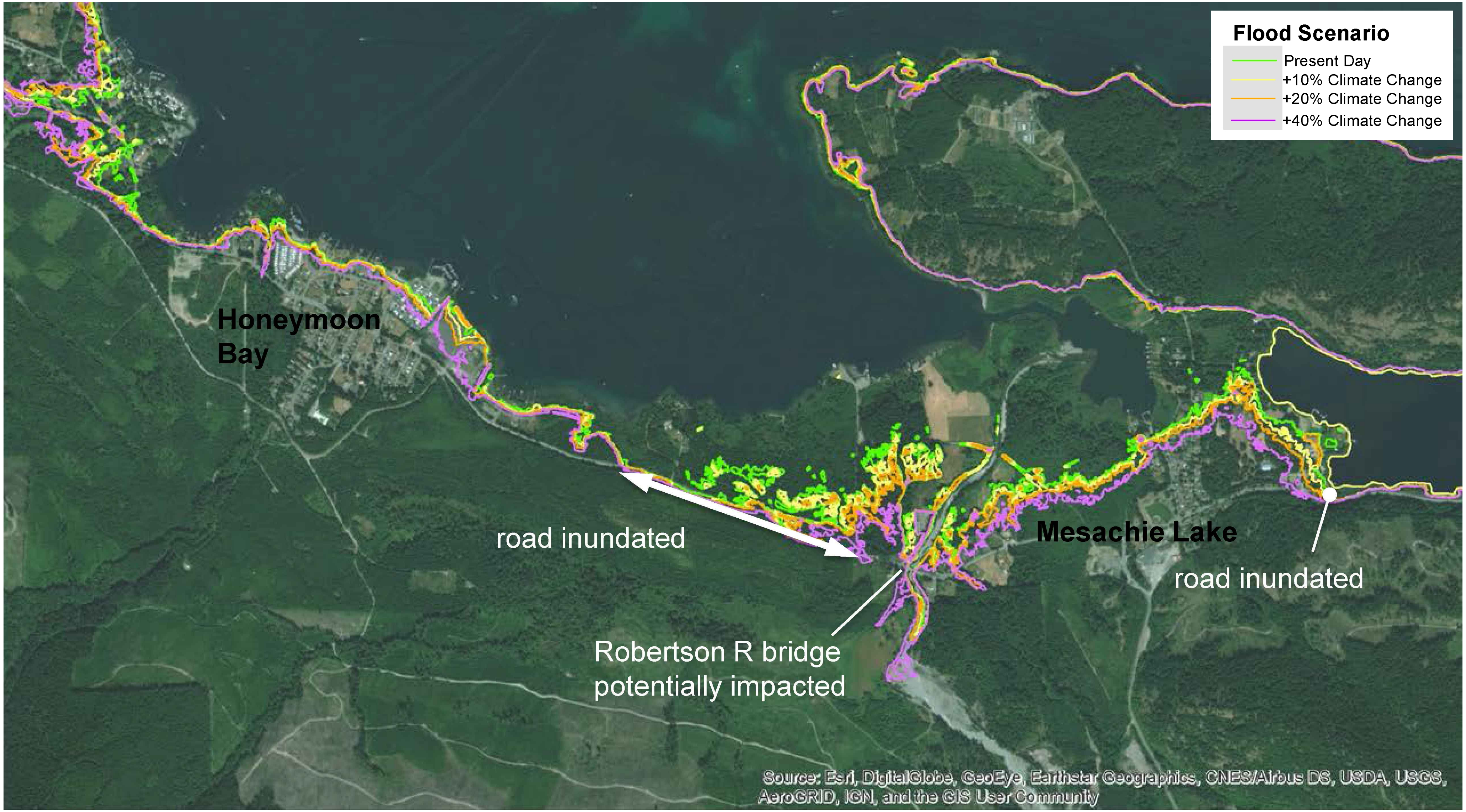

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COWICHAN LAKE NEAR MESACHIE LAKE

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-109
SHEET NUMBER	9 OF 31
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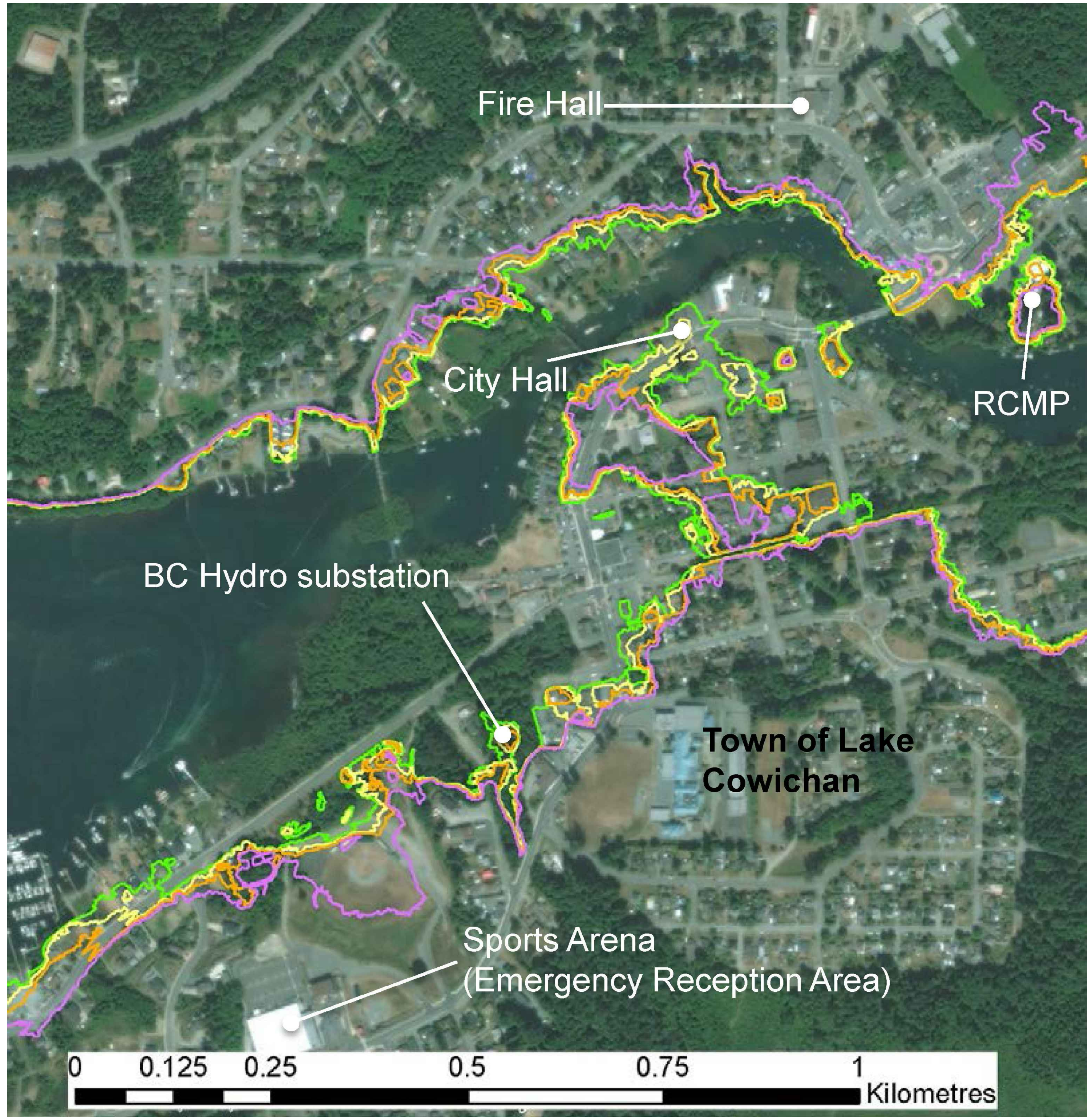

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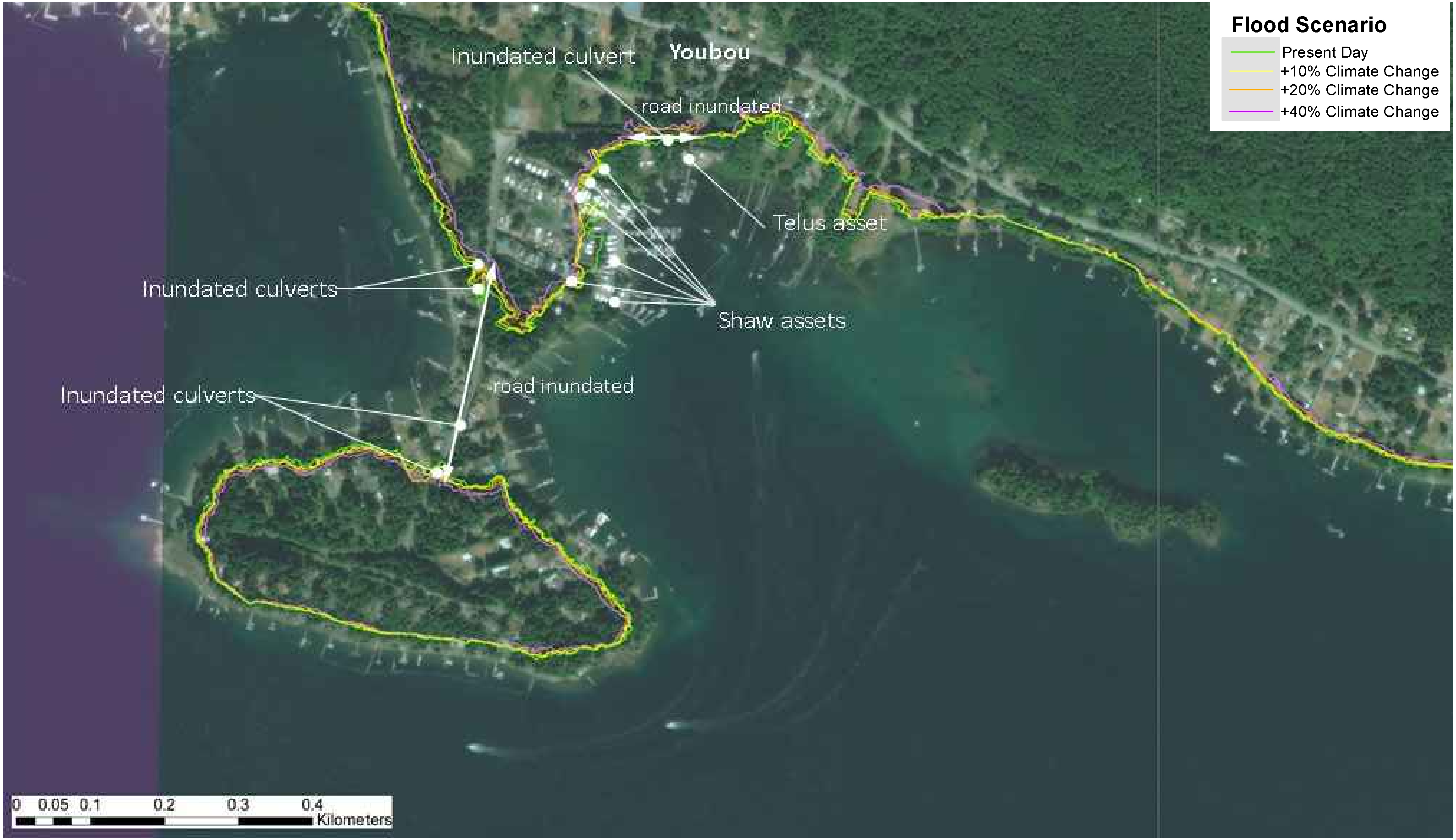
RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COWICHAN LAKE NEAR LAKE COWICHAN

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-110
SHEET NUMBER	10 OF 31
REVISION	



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DRAWING INFORMATION	
DATE	30 APR 2019
DESIGNED BY	WPH
DRAWN BY	CSM
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SHEET SIZE	B (11" x 17")

RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COWICHAN LAKE NEAR YOUBOU

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-111
SHEET NUMBER	11 OF 31
REVISION	

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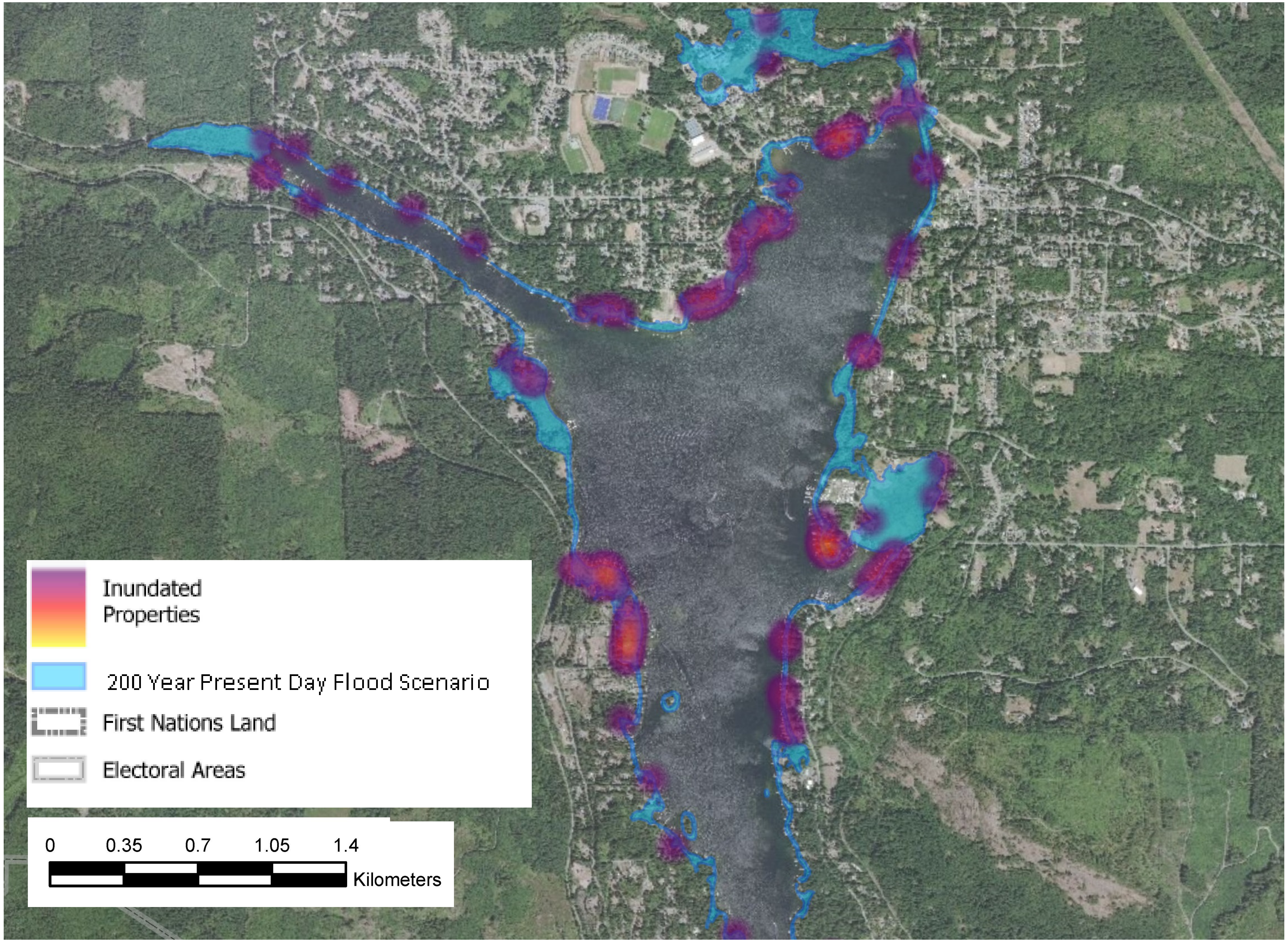

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DATE	8 MAY 2019
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SHEET SIZE	B (11" x 17")

RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
SHAWNIGAN LAKE (NORTH)
200 YEAR PRESENT DAY
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-112
SHEET NUMBER	12 OF 31
REVISION	

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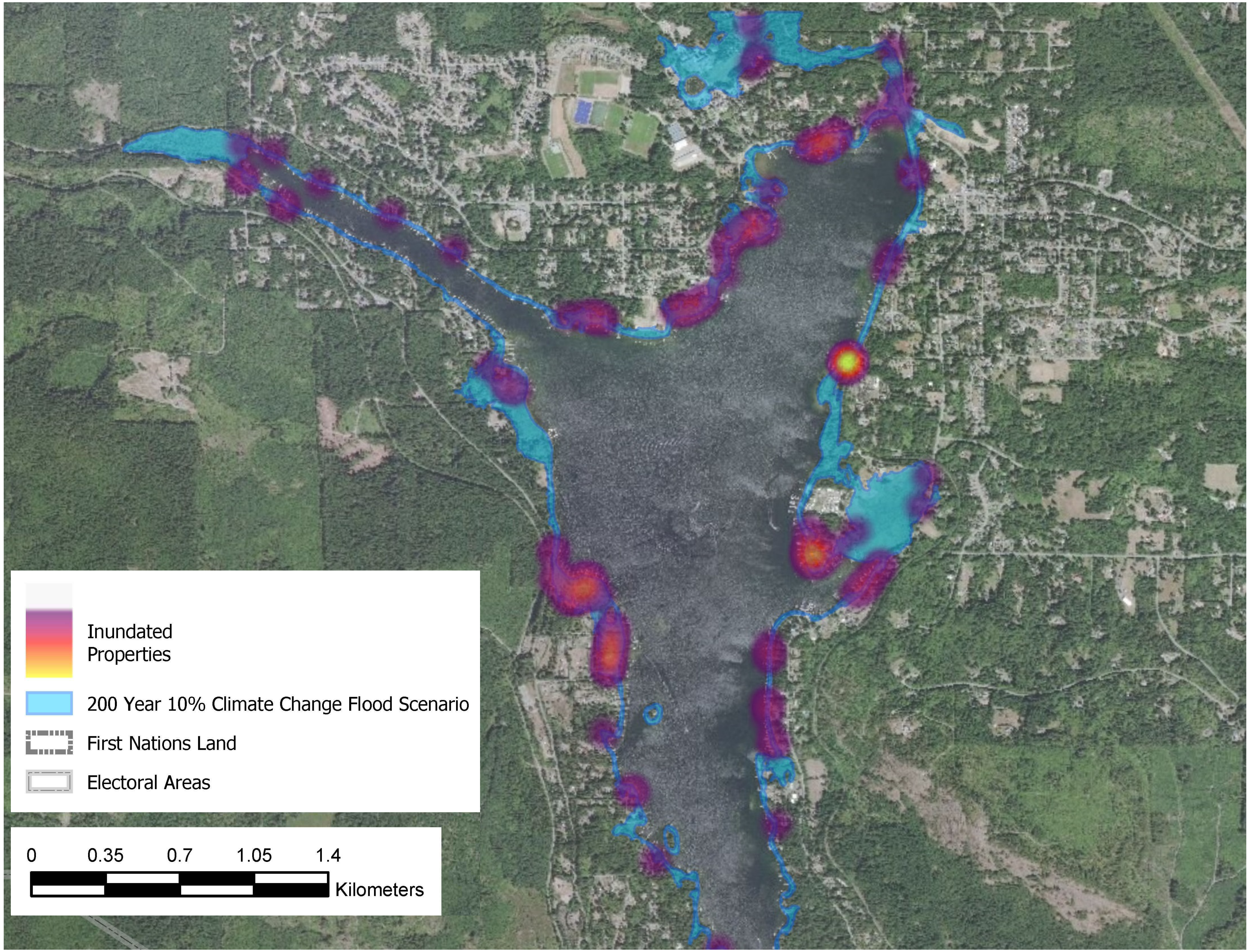

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE
PROPERTY VULNERABILITY
SHAWNIGAN LAKE (NORTH)
200 YEAR 10%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-113
SHEET NUMBER	13 OF 31
REVISION	

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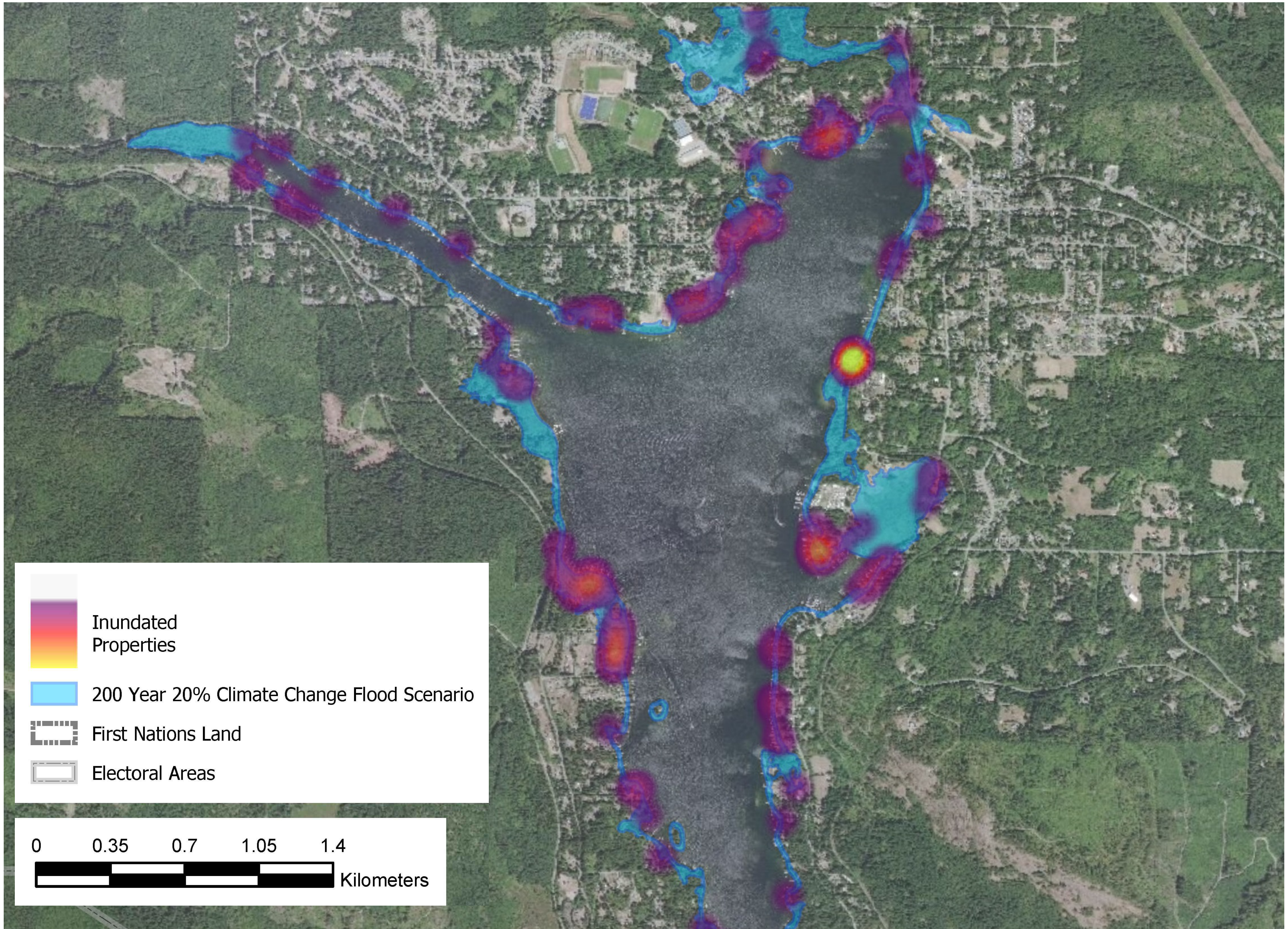

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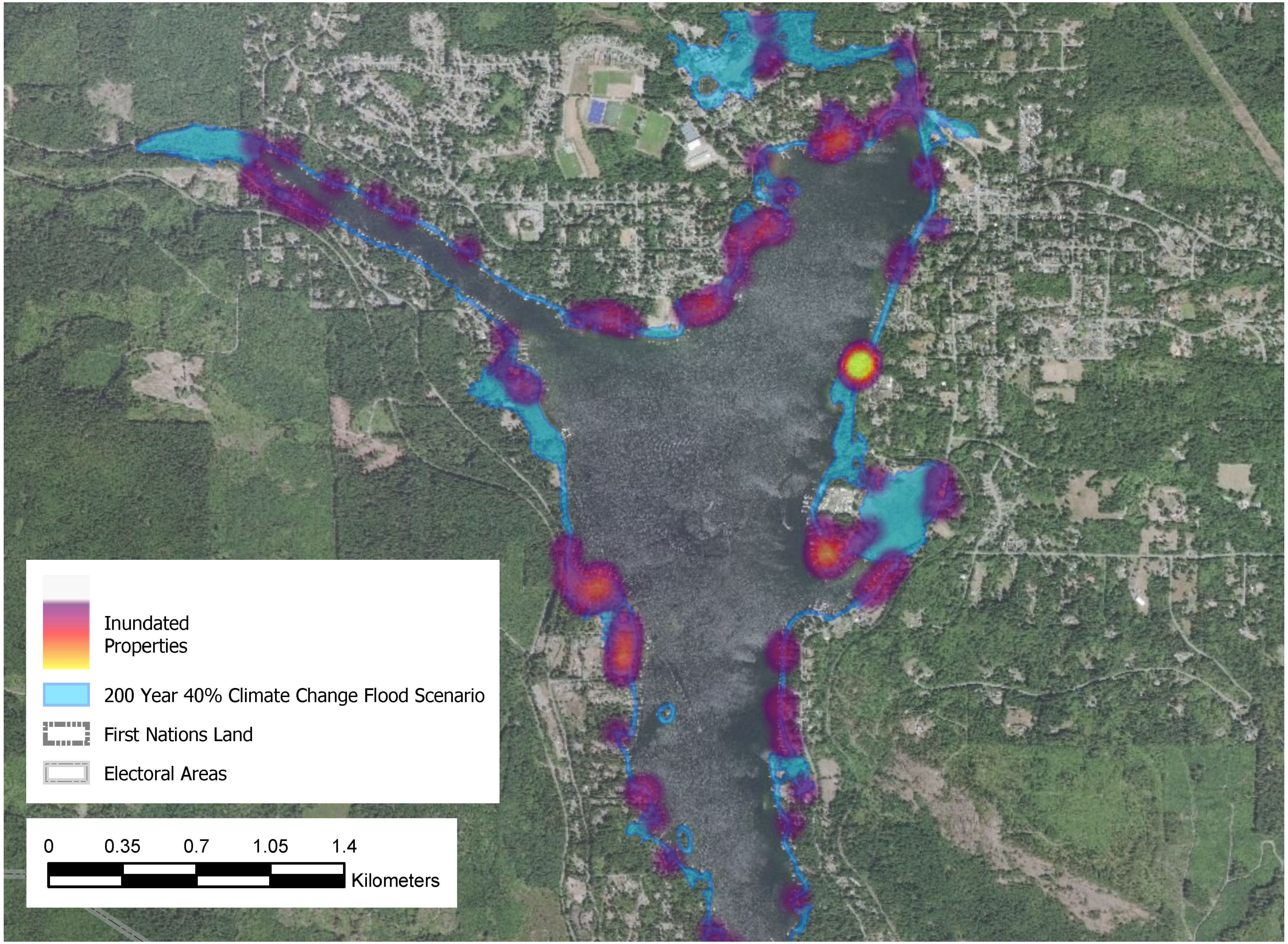
RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
SHAWNIGAN LAKE (NORTH)
200 YEAR 20%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-114
SHEET NUMBER	14 OF 31
REVISION	

Filename: \\mainfile-nan\Projects\Active\3003765 CVRD Risk Assessment\96 CAD\3003765-100_Figures.dwg, 28-Mar-19 3:23:07 PM



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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
SHAWNIGAN LAKE (NORTH)
200 YEAR 40%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-115
SHEET NUMBER	15 OF 31
REVISION	

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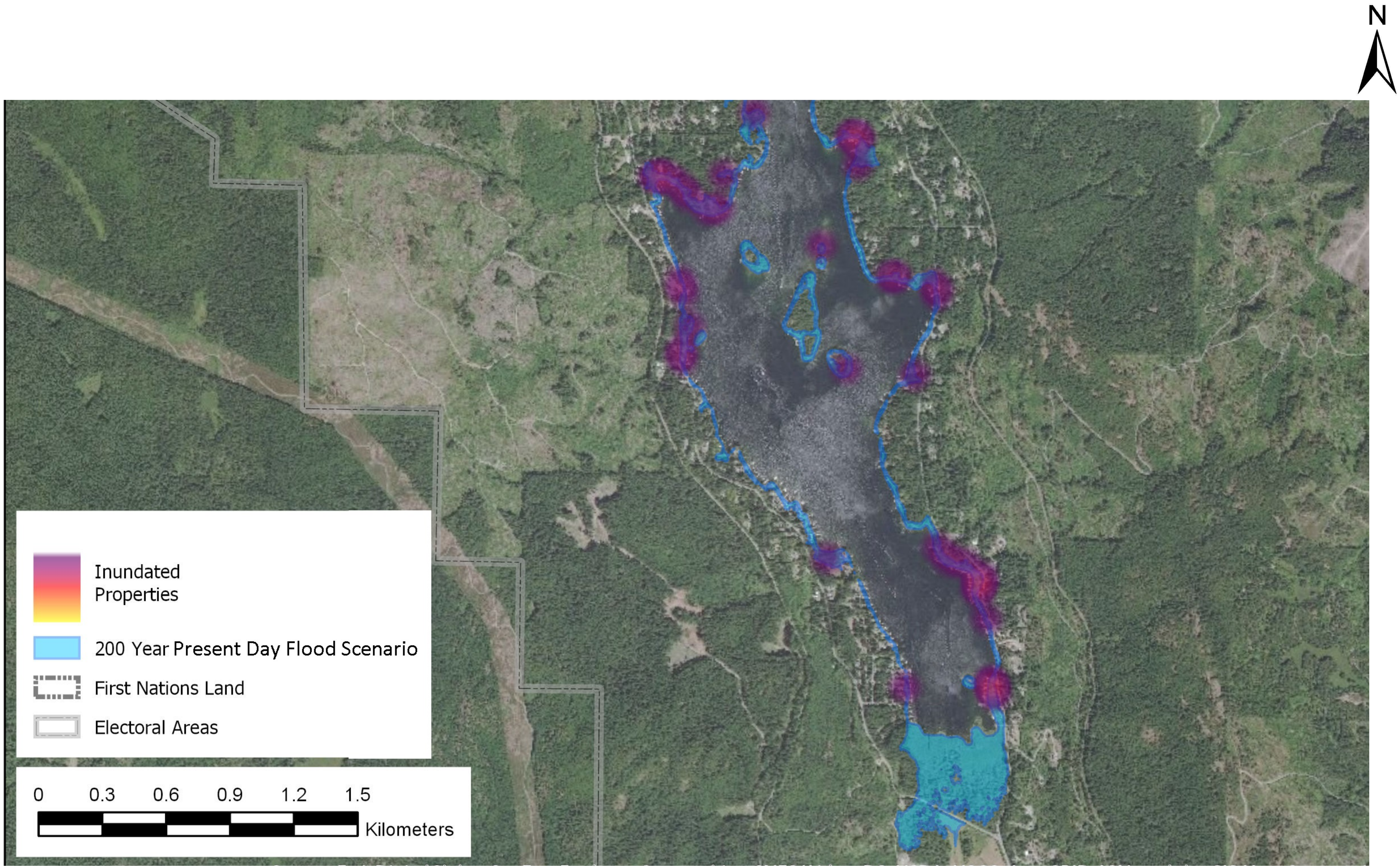

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
SHAWNIGAN LAKE (SOUTH)
200 YEAR PRESENT DAY
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-116
SHEET NUMBER	16 OF 31
REVISION	

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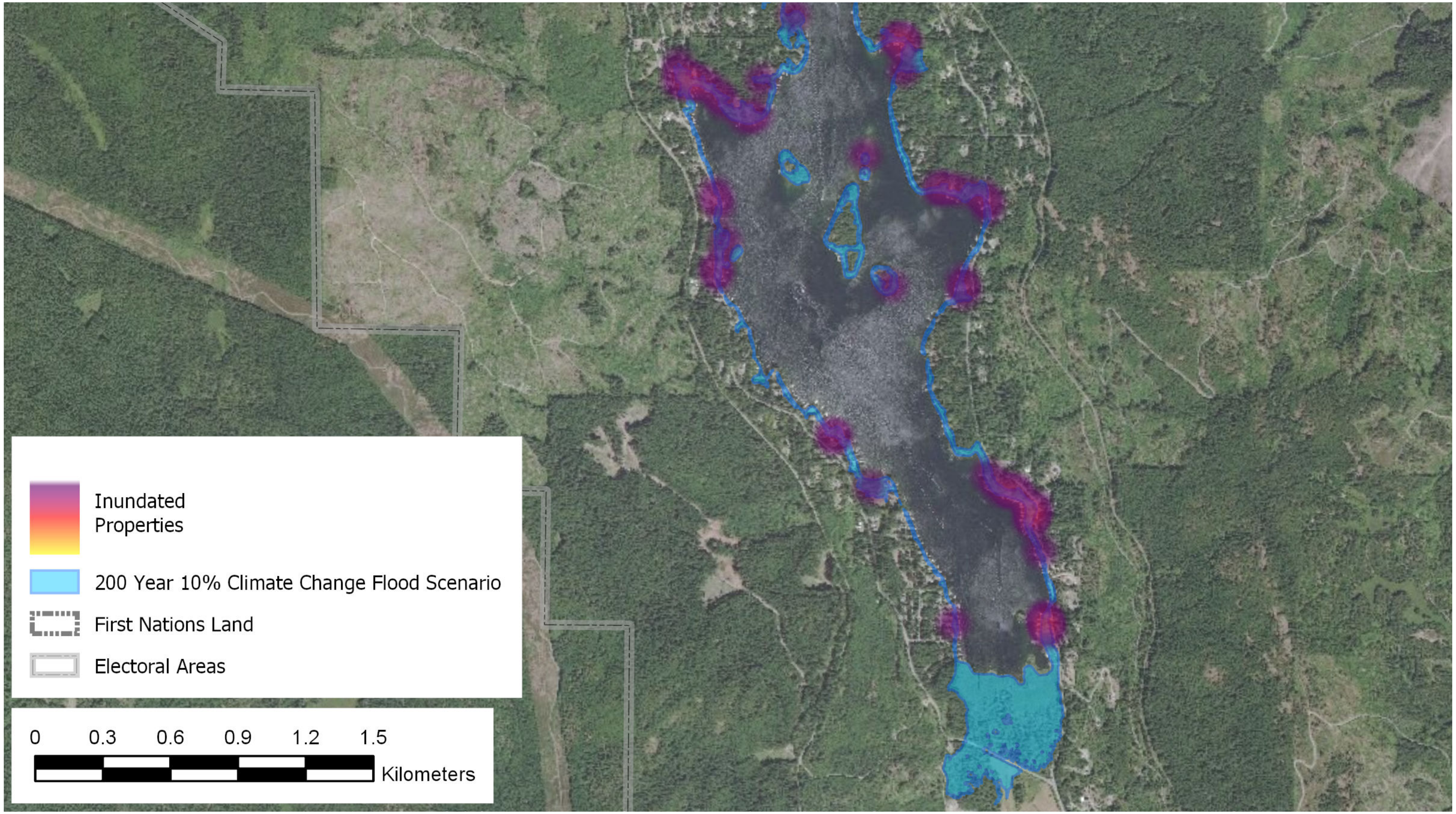

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
SHAWNIGAN LAKE (SOUTH)
200 YEAR 10%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-117
SHEET NUMBER	17 OF 31
REVISION	

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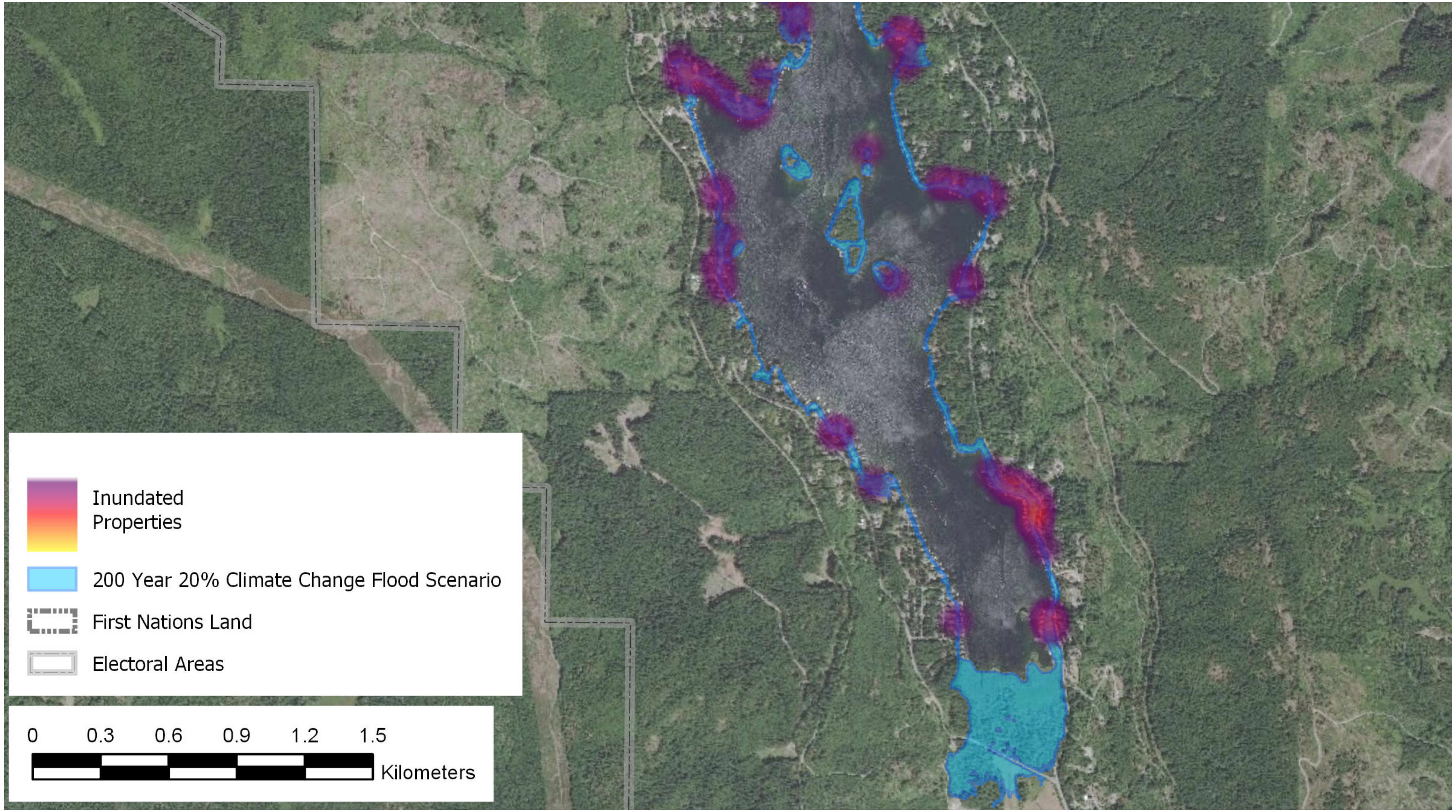

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
SHAWNIGAN LAKE (SOUTH)
200 YEAR 20%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-118
SHEET NUMBER	18 OF 31
REVISION	

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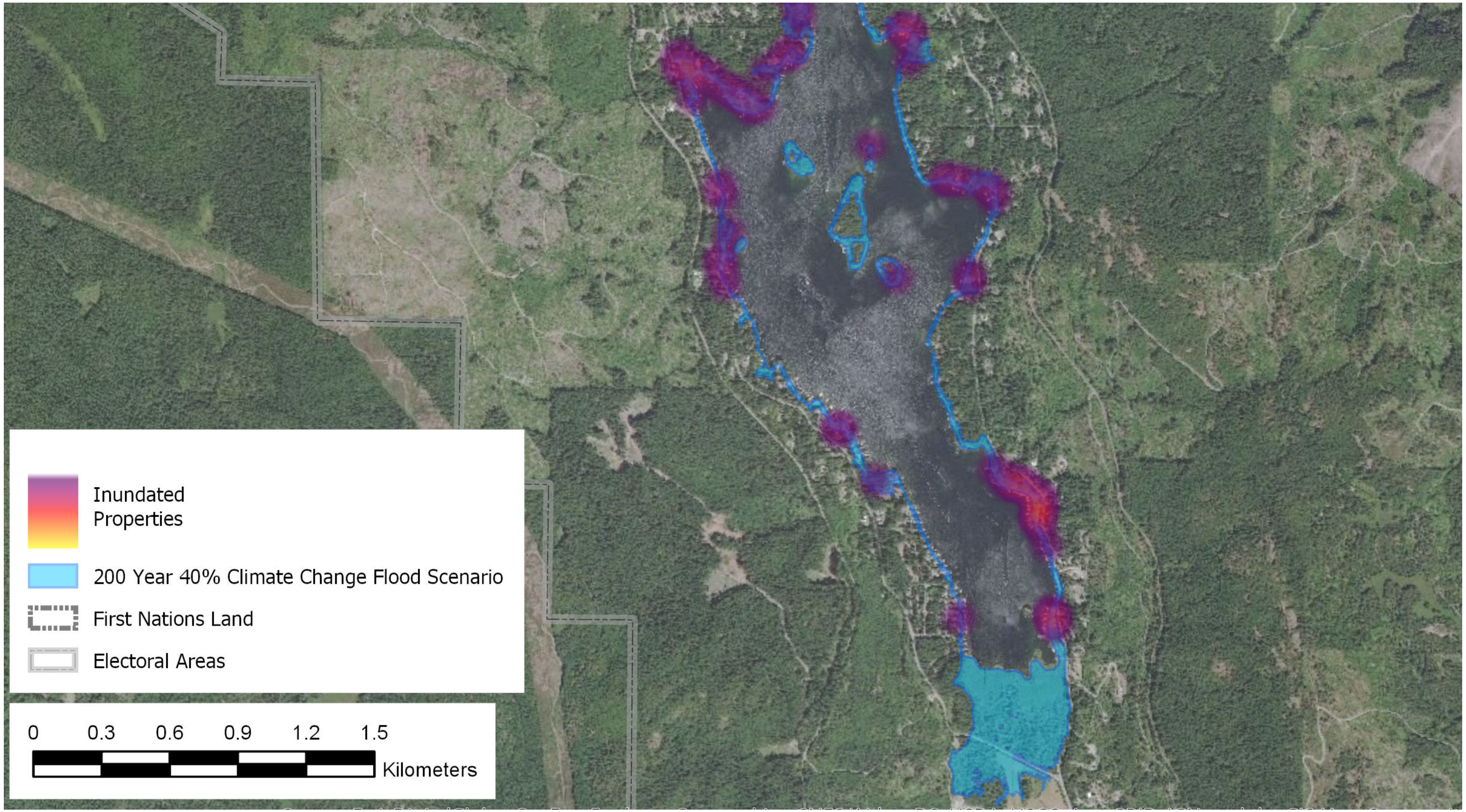

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
SHAWNIGAN LAKE (SOUTH)
200 YEAR 40%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-119
SHEET NUMBER	19 OF 31
REVISION	

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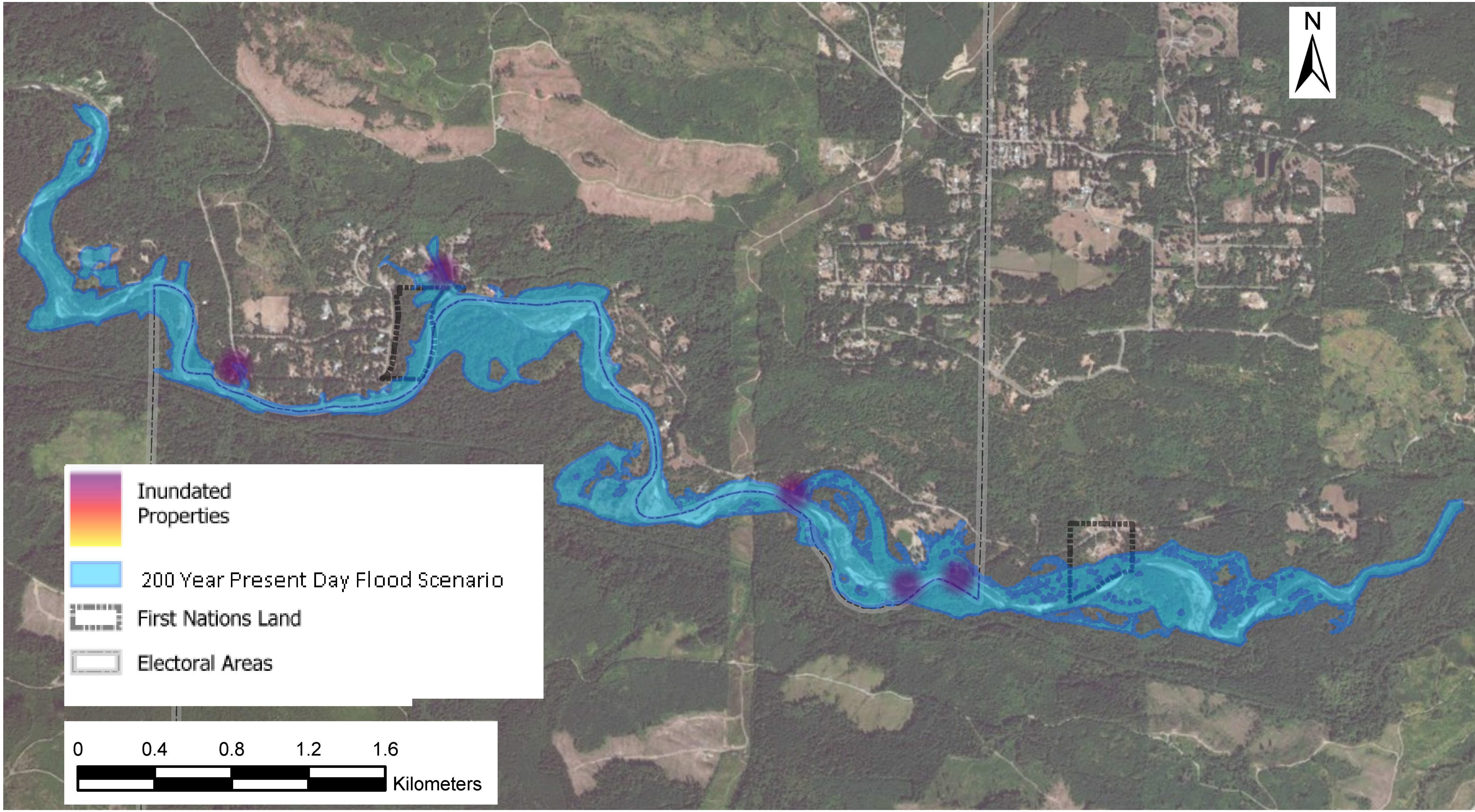

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DATE	7 MAY 2019
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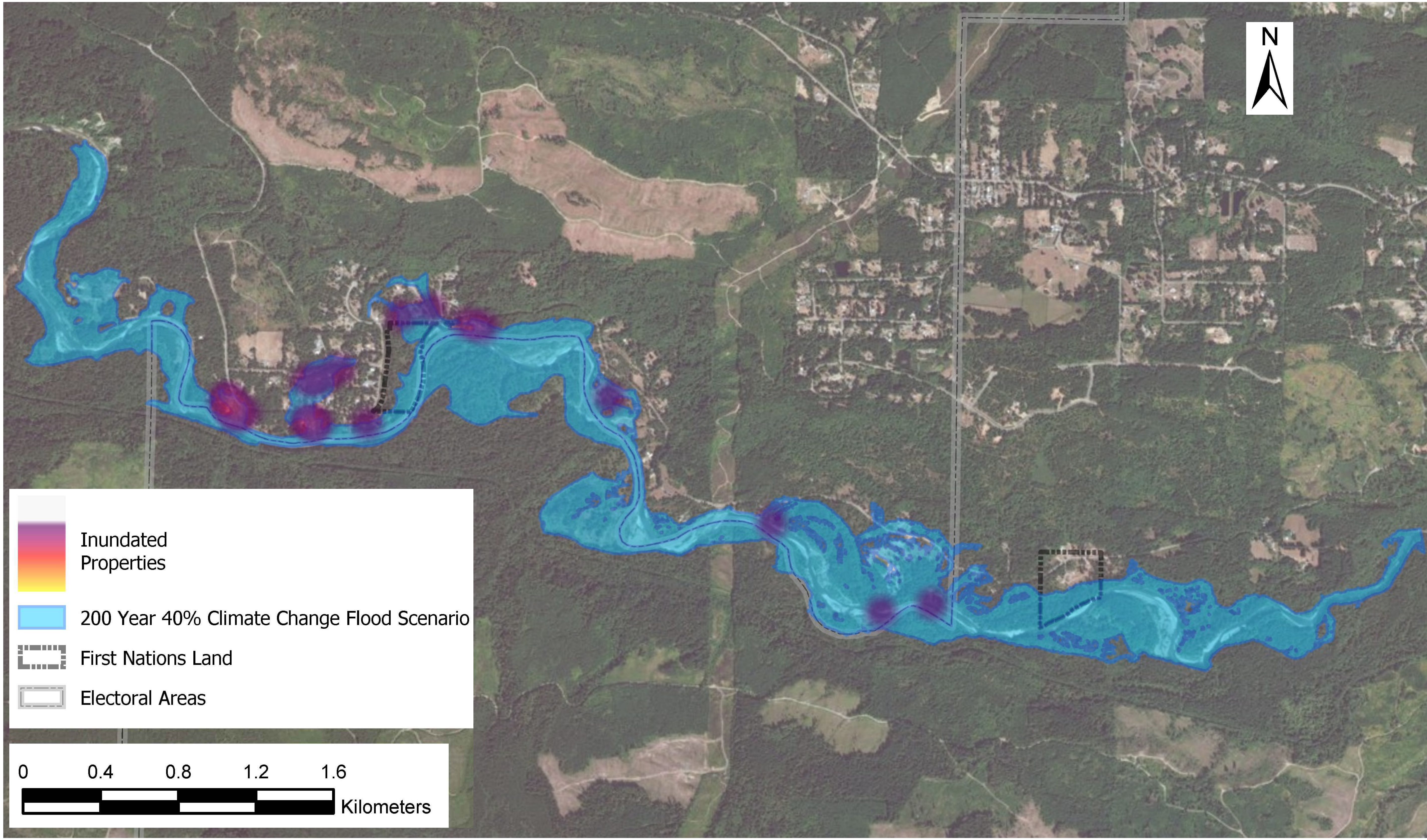
RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN RIVER (RIVERBOTTOM ROAD)
200 YEAR PRESENT DAY
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-120
SHEET NUMBER	20 OF 31
REVISION	



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SHEET SIZE	B (11" x 17")

RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COWICHAN RIVER (RIVERBOTTOM ROAD)
200 YEAR 40%
CLIMATE CHANGE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-121
SHEET NUMBER	21 OF 31
REVISION	

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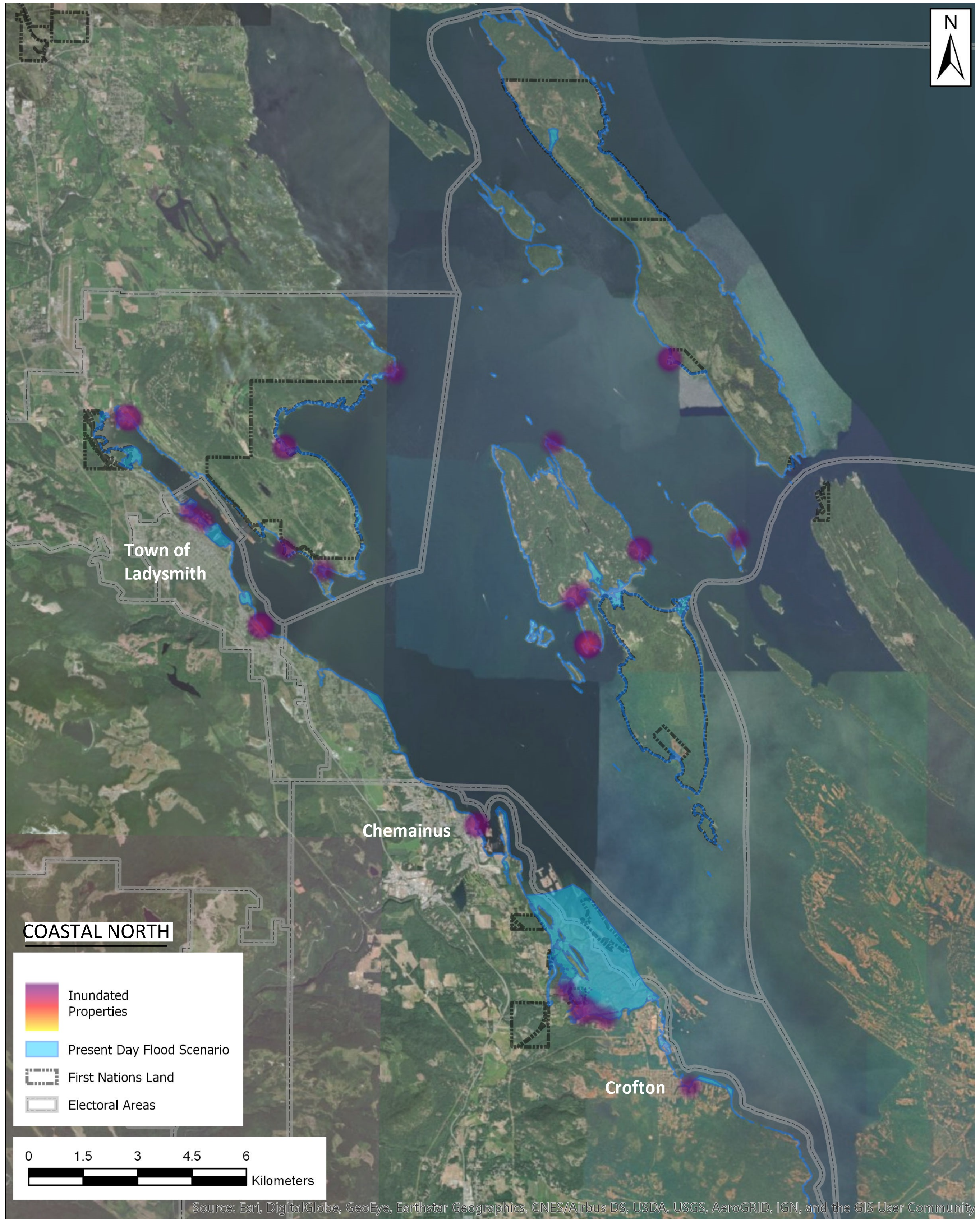

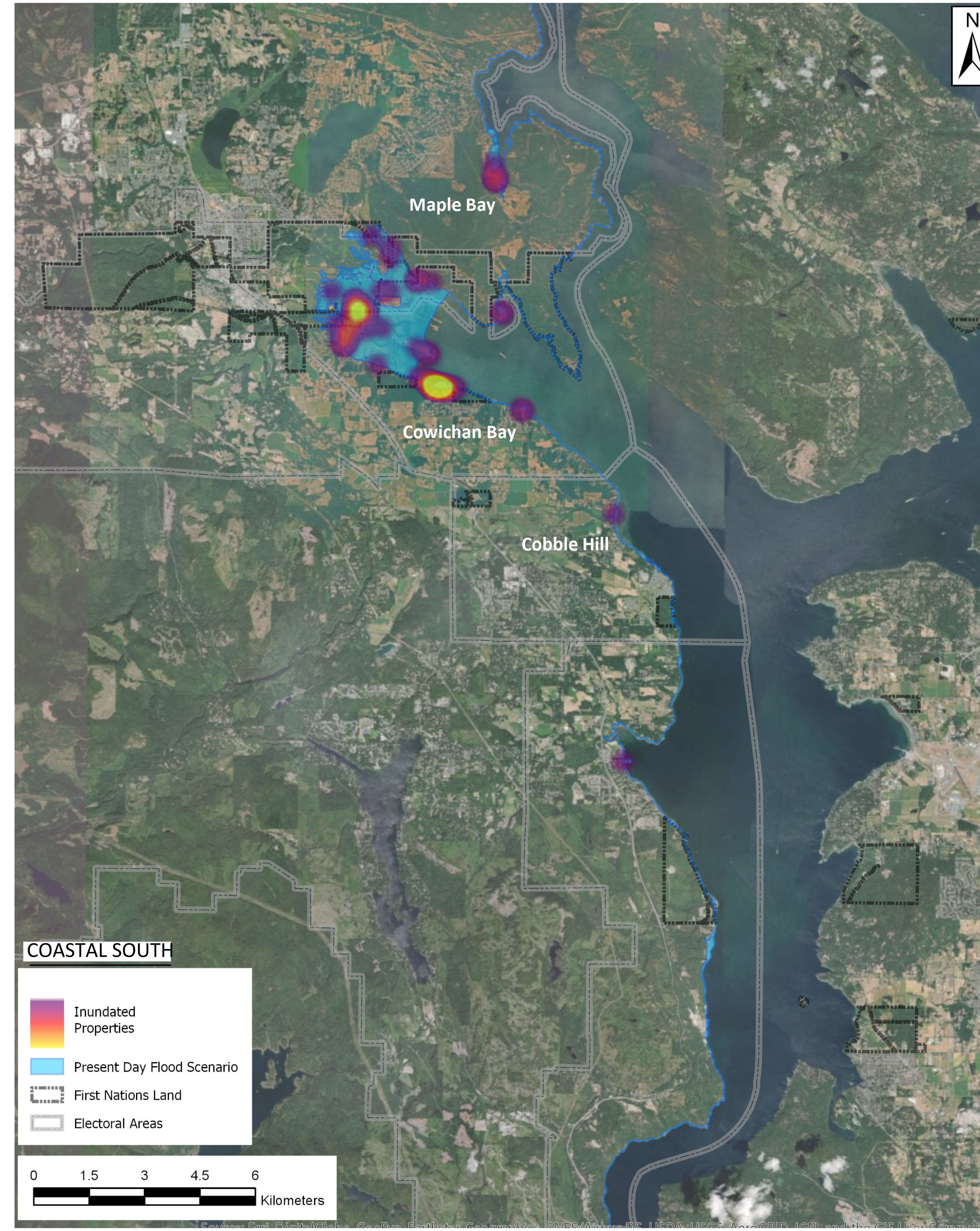

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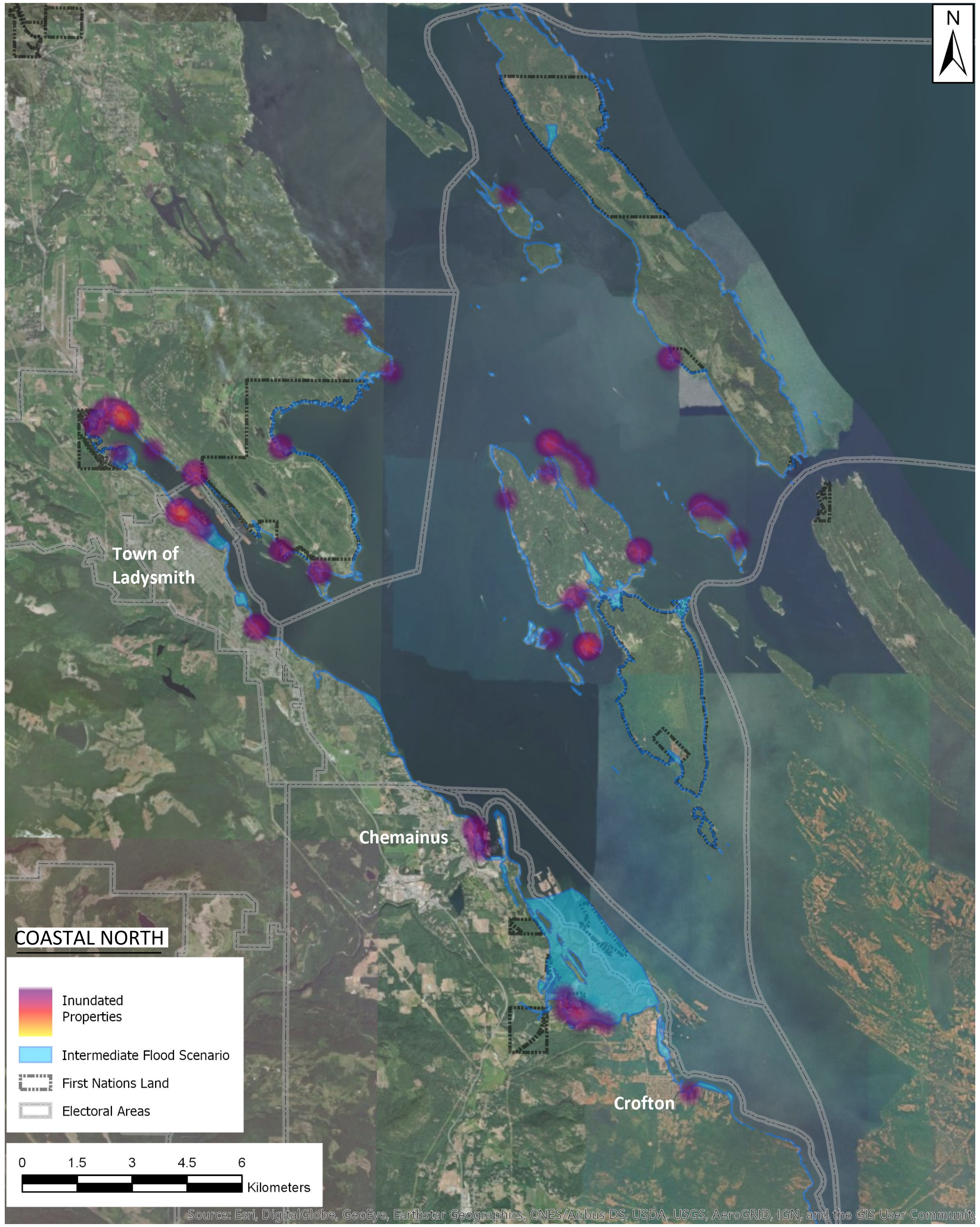
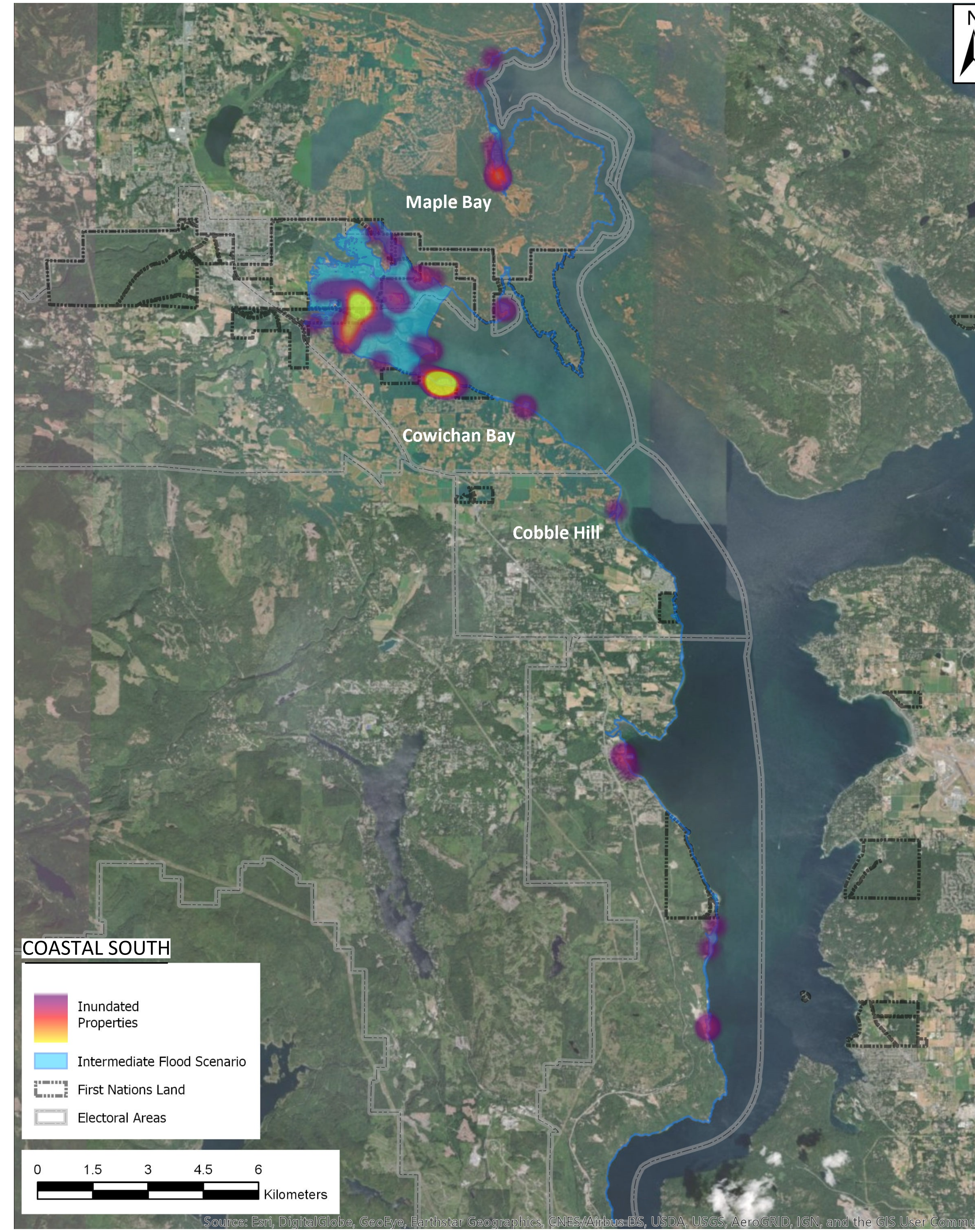
SHEET SIZE	B (11" x 17")

RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COASTAL
PRESENT DAY FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-122
SHEET NUMBER	22 OF 31
REVISION	





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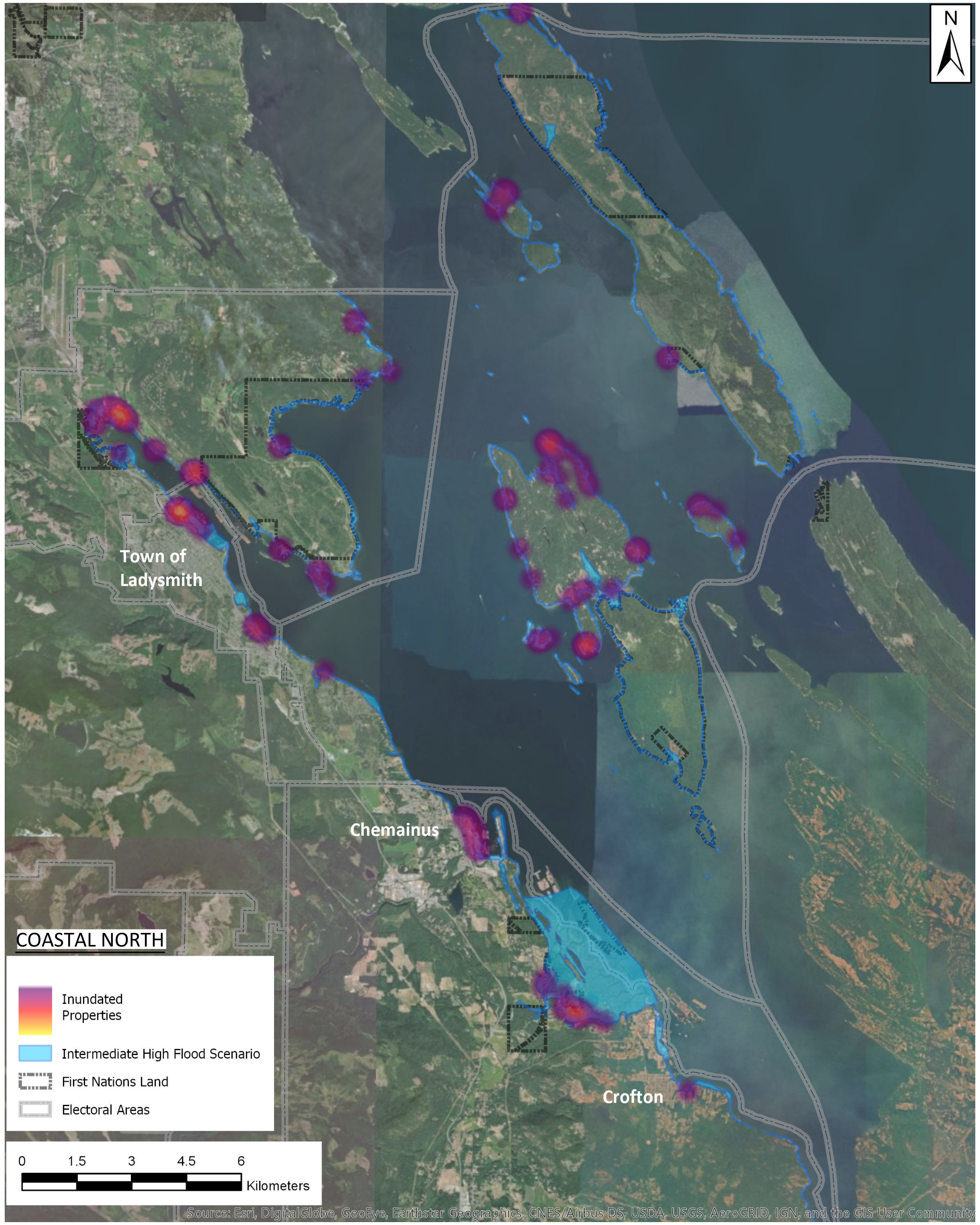
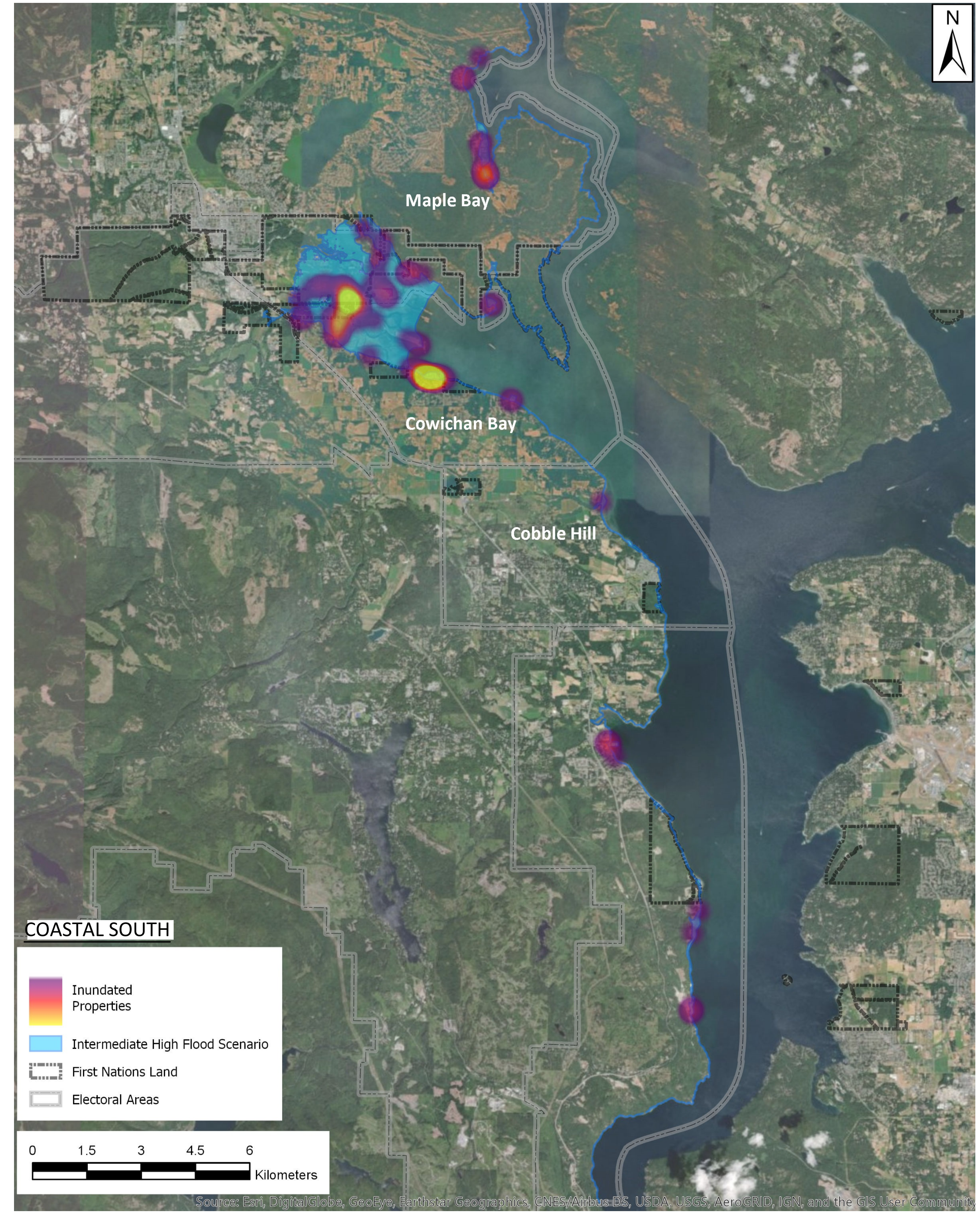
RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COASTAL
INTERMEDIATE FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-123
SHEET NUMBER	23 OF 31
REVISION	

Filename: \\mainfile-nan\Projects\Active\3003765 CVRD Risk Assessment\96 CAD\3003765-100_Figures.dwg, 28-Mar-19 3:23:07 PM





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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COASTAL
INTERMEDIATE HIGH FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-124
SHEET NUMBER	24 OF 31
REVISION	

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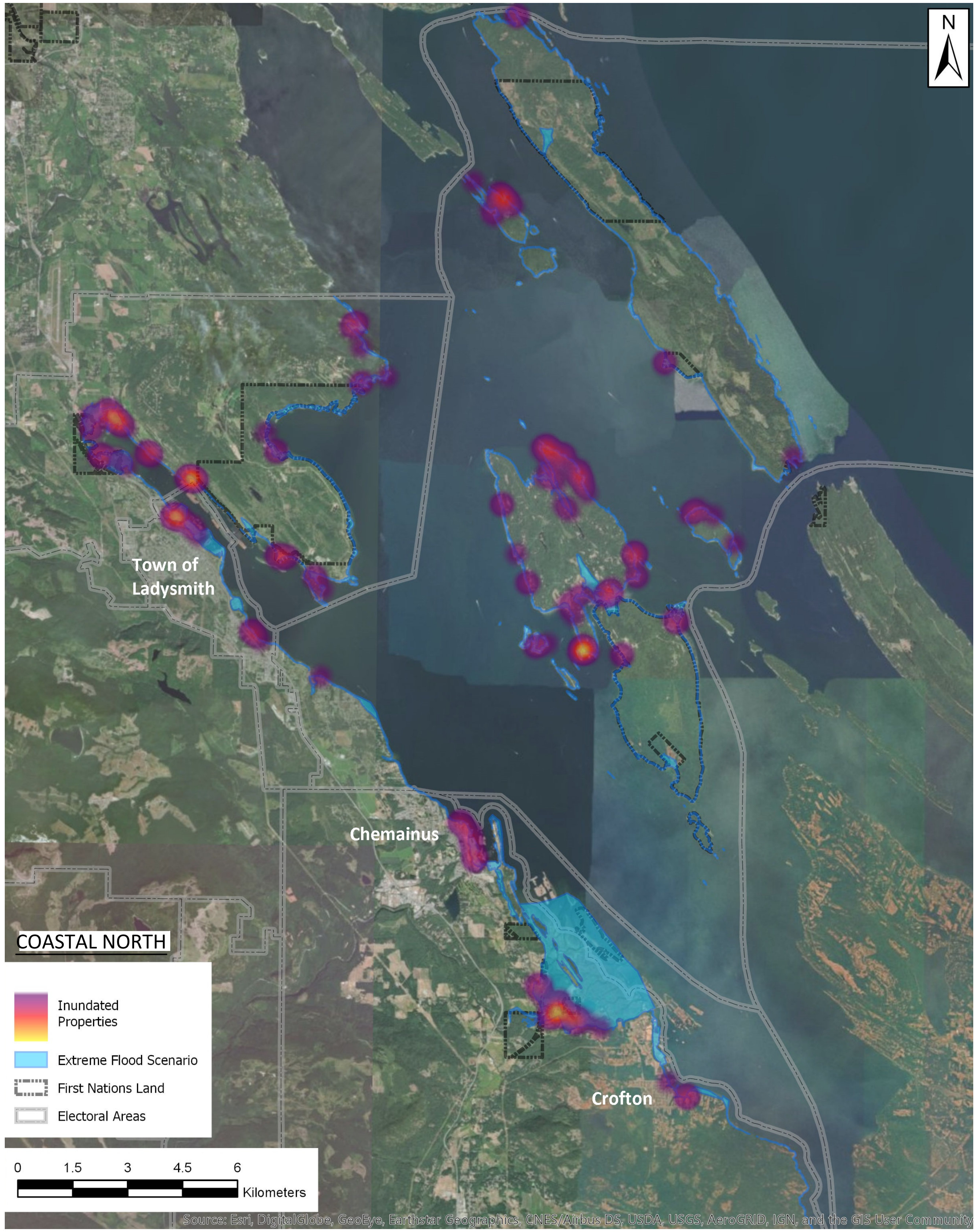

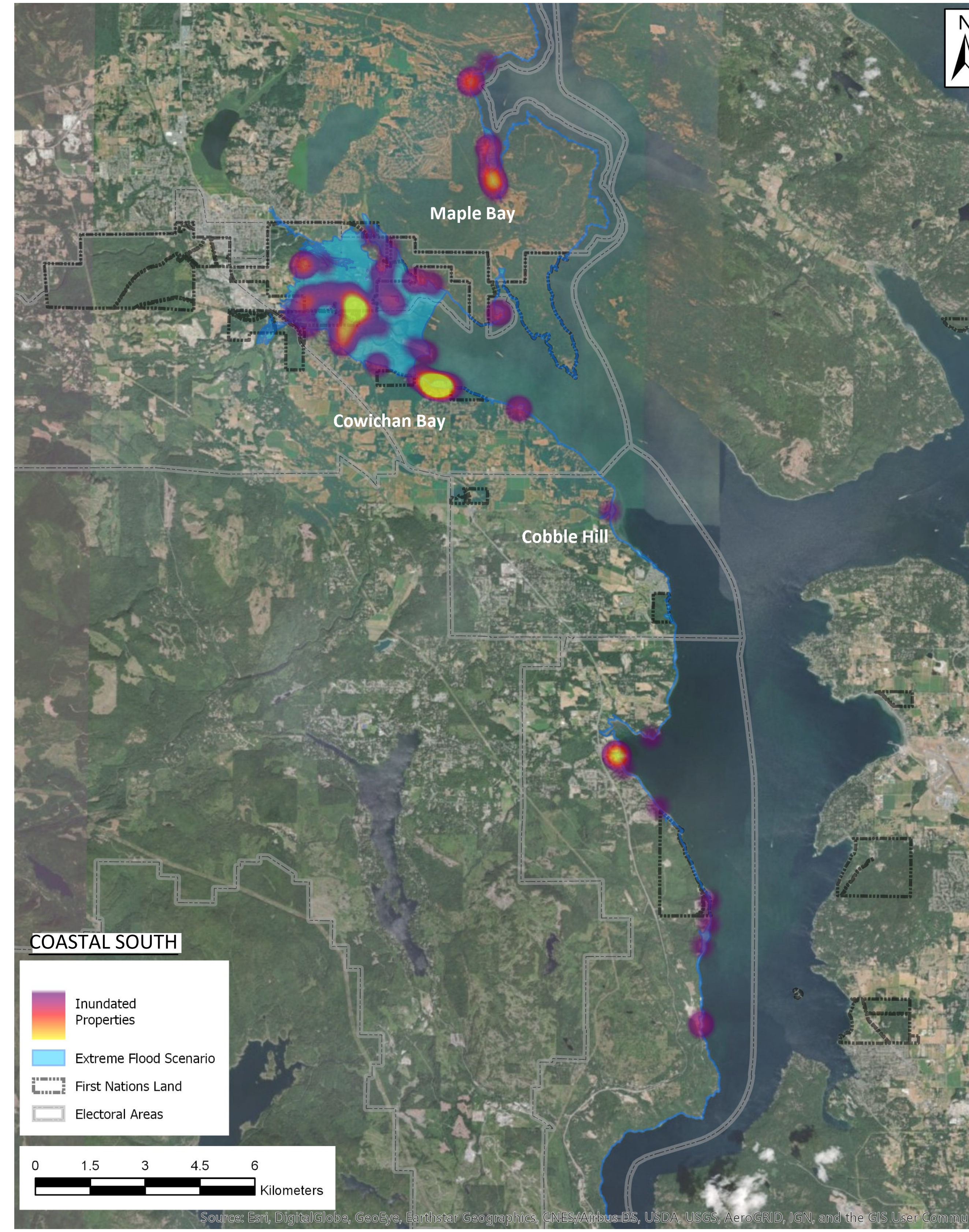

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

PROPERTY VULNERABILITY
COASTAL
EXTREME FLOOD SCENARIO

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-125
SHEET NUMBER	25 OF 31
REVISION	

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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COASTAL NEAR MILL BAY

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-126
SHEET NUMBER	26 OF 31
REVISION	

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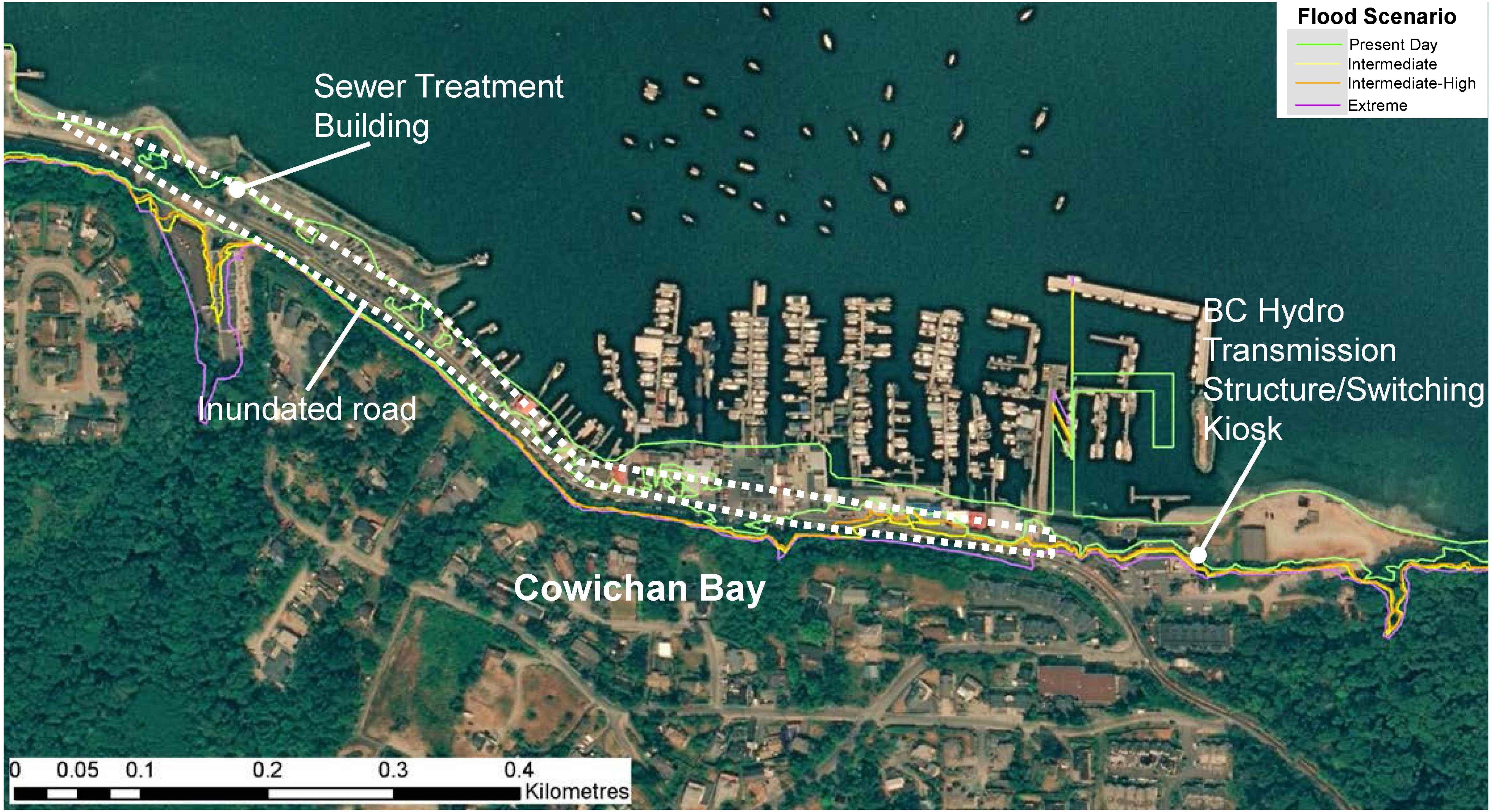

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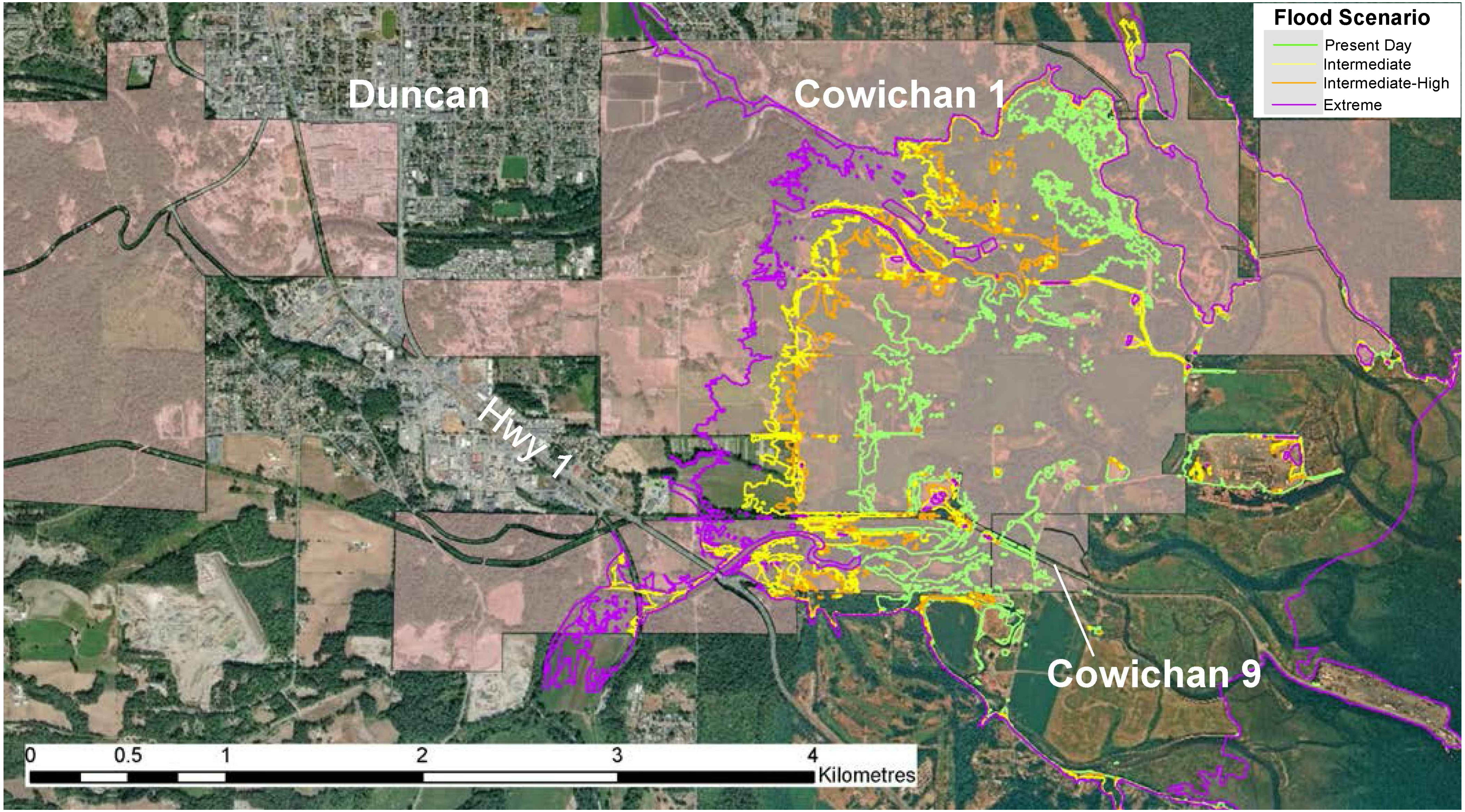
RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COASTAL NEAR COWICHAN BAY

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-127
SHEET NUMBER	27 OF 31
REVISION	

Filename: \\mainfile-nan\Projects\Active\3003765 CVRD Risk Assessment\96 CAD\3003765-100_Figures.dwg, 28-Mar-19 3:23:07 PM



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SHEET SIZE	B (11" x 17")

RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COASTAL NEAR DUNCAN

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-128
SHEET NUMBER	28 OF 31
REVISION	

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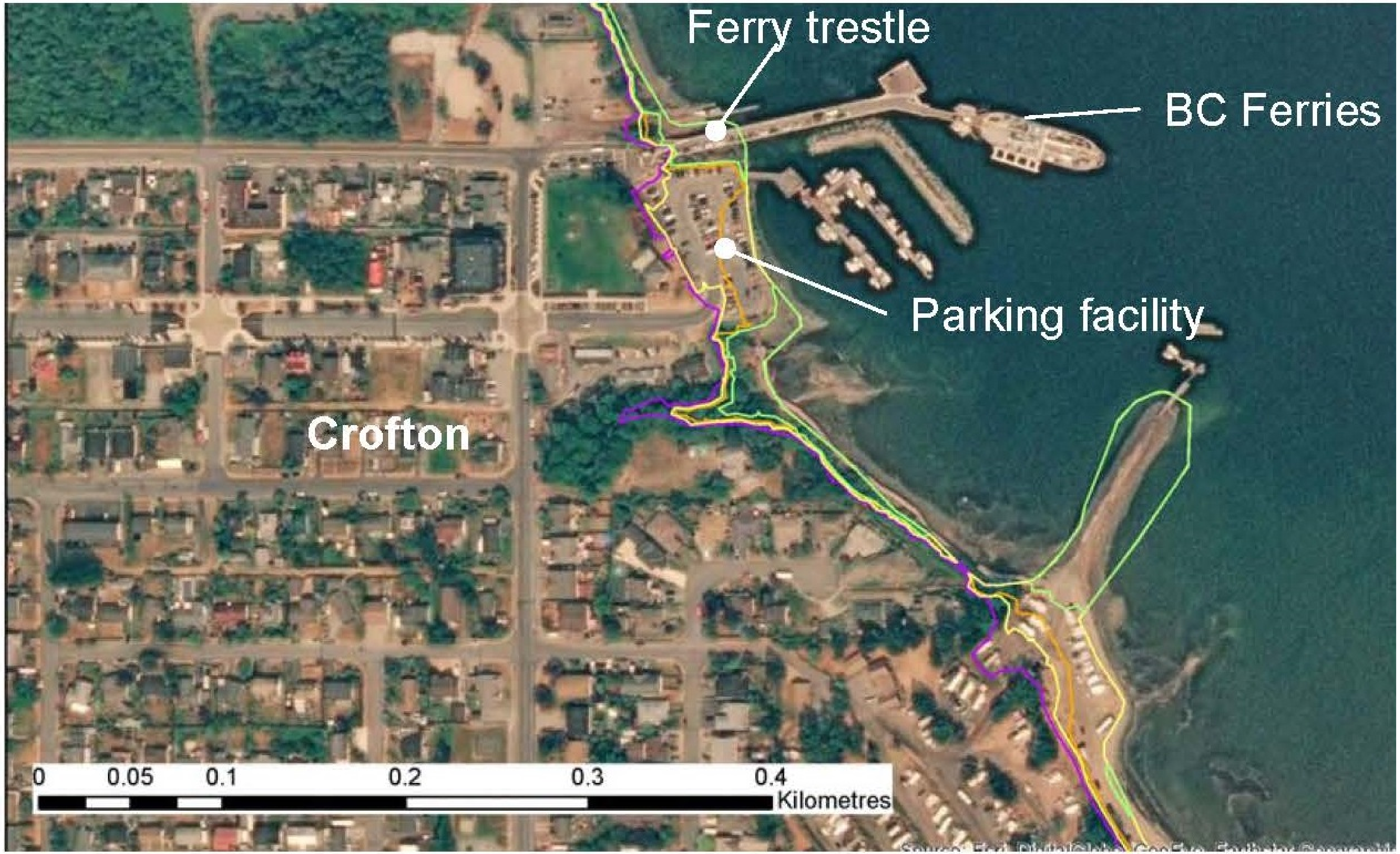

Flood Scenario

- Present Day
- Intermediate
- Intermediate-High
- Extreme

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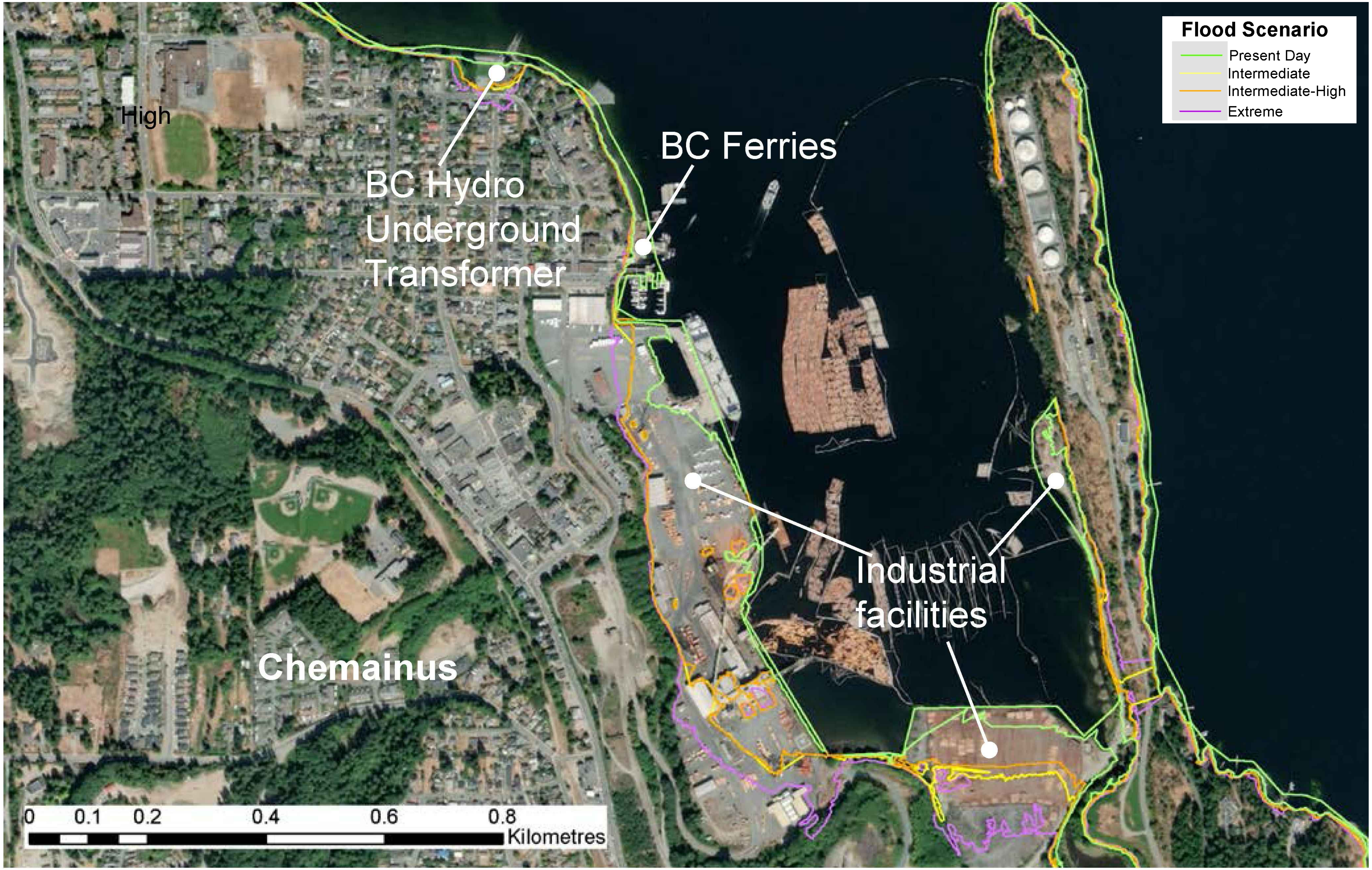
RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COASTAL NEAR CROFTON

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-129
SHEET NUMBER	29 OF 31
REVISION	



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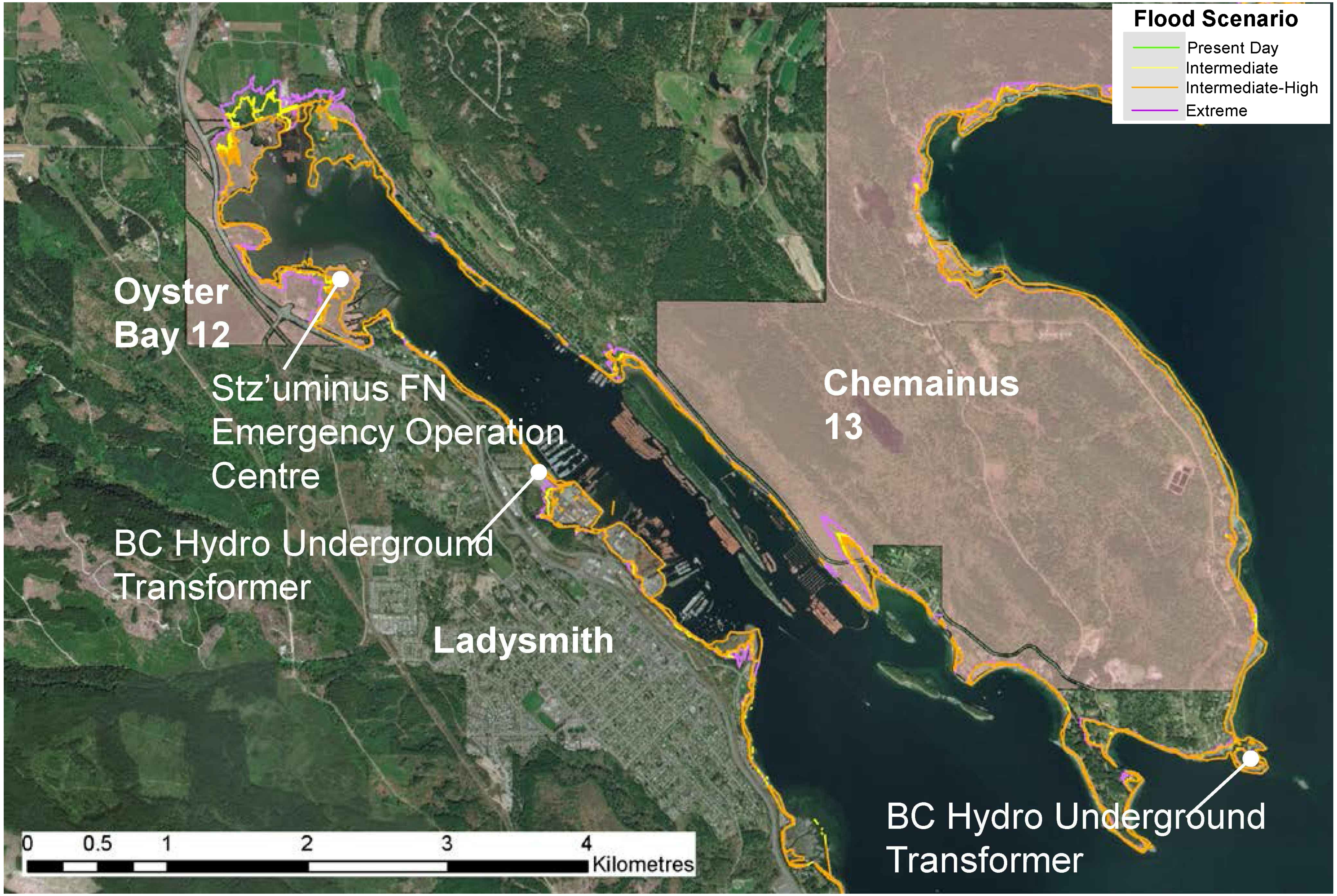
REVISIONS		

DRAWING INFORMATION	
DATE	30 APR 2019
DESIGNED BY	WPH
DRAWN BY	CSM
CHECKED BY	WPH
SHEET SIZE	B (11" x 17")

RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COASTAL NEAR CHEMAINUS

PROJECT NUMBER	3003765
DRAWING NUMBER	3003765-130
SHEET NUMBER	30 OF 31
REVISION	



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RISK ASSESSMENT OF FLOODPLAINS AND COASTAL SEA LEVEL RISE

FLOOD EXPOSURE - COASTAL NEAR LADYSMITH

PROJECT NUMBER	3003765
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SHEET NUMBER	31 OF 31
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