CITY OF CAMPBELL RIVER

SEA LEVEL RISE – ECOSYSTEMS AND SPECIES AT RISK ASSESSMENT

PREPARED FOR

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Executive Summary

The Ecosystems and Species at Risk Study initiated by the City of Campbell River (the City) builds upon the City's knowledge base regarding the potential impacts of Sea Level Rise (SLR) to the coastal and estuarine shorelines of Campbell River. This study considers ecosystem services, including those associated with potentially ameliorating impacts from SLR. The main purpose of the study was to determine the impacts of SLR on ecosystem services throughout the study area, which extends from Race Point Road to the north and Ocean Grove Road to the south. Inside this study area, there were two focus areas: the Campbell River estuary; and shoreline zones north and south of the estuary. To address the main purpose of the study, the following components were included:

- Compilation of ecosystem services unique to the study area into Provisioning, Regulating, Habitat and Cultural categories, using existing studies as a basis;
- Establishment of indicators and units of measure for each ecosystem service category;
- Determination of SLR elevations, using 0.5 m and 1.0 m SLR scenarios and projected extreme storm event water levels calculated by previous coastal engineering studies;
- Identification of ecosystems established from previous studies throughout the study area and ranking the current value of the ecosystems;
- Mapping projected changes to ecosystem distribution as a result of 0.5 m and 1.0 m SLR scenarios (including extreme storm event water levels) and determining associated impacts to ecosystem services;
- Assessment of current fish and wildlife habitat values;
- Establishment of indicator sites that can be used to measure future changes to fish and wildlife values and connected ecosystem services as a result of SLR;
- Calculation of erosion potential and impacts to ecosystem services from elevated sediment levels, changing water quality and altered physical processes resulting from SLR; and
- Determination of potential impacts from SLR on contaminated sites and assessment of interactions between SLR and contaminated sites.

The existing ecosystem mapping, which focused on the Campbell River estuary, was used to delineate the following ecosystems: River Channel; Mudflat; Marsh; Cobble Shore; Swamp; Riparian; Forest; Terrestrial Herbaceous; and Backshore Riparian. Using the 0.5 m SLR scenario as an example, the following spatial changes to the mapped ecosystems were calculated: River Channel: 59.98 ha inundated (60.01 ha current area); Cobble Shore: complete inundation; Forest: 9.54 ha inundated (10.33 ha current area); Marsh: 35.15 ha inundated (35.21 ha current area); Mudflat: complete inundation; Riparian: 29.21 ha inundated (30.24 ha current area); Swamp: complete inundation; Terrestrial Herbaceous: 8.61 ha inundated (9.91 ha current area).

The apparent almost complete inundation of all ecosystems, even at the 0.5 m SLR scenario, was considered in combination with the fact that the final elevations included extreme weather and tide events (temporary inundation during extreme events). Considering the long-term temporal aspect of SLR, ecosystem migration into candidate areas between the existing edge of the estuary and an elevation of approximately 6 m was determined to be a mechanism that could help maintain some of the values provided by the various ecosystem services, the specifics of which would require further study. The main areas where ecosystem migration could occur include Nunns Creek Park and all other riparian, seepage and agricultural areas adjacent to the estuary. Other locations include abandoned industrial lands close to the Campbell River, parks, playing fields and older residential areas (*e.g.* the Campbellton area).

To help determine potential changes to fish habitat ecosystem services, five forage fish Indicator Sites were established in the study area. Sediment analysis and field assessments revealed that potential spawning habitat for surf smelt and/or Pacific sand lance occurs at all the Indicator Sites. A repeatable assessment methodology established as part of this study will allow for changes to habitat suitability to be monitored over the long term to help determine impacts from SLR and measure impacts to important ecosystem services.

Two index reaches were established in the lower segments of Willow Creek and Simms Creek to measure current fish habitat attributes between tidewater and points 200 m upstream. A repeatable survey methodology can be employed in these index reaches to determine long-term impacts resulting from SLR to key freshwater fish habitat and ecosystem services. Both index reaches were found to provide habitat for native salmonids, but anthropogenic modifications associated with riparian encroachment, historical channelization, bank erosion and invasive plants have decreased the resilience of the habitat.

As part of the wildlife assessment, the study area was confirmed to provide habitat for the following provincially blue-listed wildlife species: great blue heron, barn swallow and purple martin. Habitat for these species would be negatively impacted by any losses to the estuarine ecosystems associated with inundation from SLR. To help measure future changes to key wildlife species in the study area and help determine impacts to ecosystem services, a bald eagle breeding success indicator was established. This indicator uses documented bald eagle breeding behaviour as a measure of ecosystem services mainly included in the "Habitat" category. An apparent recent declining trend in breeding success was noted as part of the study, which is a trend that can be monitored over the long term.

In addition to ecosystems and species at risk, geoscience formed a significant component of this study, which helped to inform potential impacts to ecosystem services from SLR. A GIS-modelling approach was used to determine surface erosion potential for the City of Campbell River under 0.5 and 1.0 m SLR scenarios. Results indicate that the highest erosion potential occurs in the following areas: (1) along the coastline of the estuary, particularly (i) directly north of the estuary and immediately west from the edge of Tyee Spit, (ii) at Duncan Bay, and (iii) the northern tip of the study area to the east of the North Island Highway, (2) along the northern and southern banks of the Campbell River along the stretch that flows directly into Elk Falls Provincial Park and the estuary, and (3) immediately south of the estuary at Nunns Creek Park.

Additionally, mapping of groundwater wells located within the City of Campbell River indicates that approximately 20 wells in Aquifers 852 and 853 are within at-risk areas under the 0.5 m and 1.0 m SLR scenarios.

SLR can affect contaminated sites through inundation by rising marine waters, storm surge and wave 'run-up' to higher elevations, and saltwater intrusion in the subsurface. When contaminated site inventory data for the City of Campbell River was superimposed over results of the geoscience modelling conducted by Madrone, the majority of MoECCS 'SITE' files within City limits are shown inside or proximal to the risk areas under 0.5 m and 1.0 m SLR scenarios. Moreover, there are several suspected and closed Federal Contaminated Sites Inventory files in the risk areas.

Various levels of anthropogenic impacts along the City of Campbell River's shoreline continue to erode ecosystem services that would naturally help to protect against SLR. As a result, future impacts from SLR may be exacerbated in Campbell River in comparison with other coastal communities where functioning ecosystems still occur in the coastal fringe. To help preserve the value of ecosystem services, it will be extremely important not to separate ecological integrity from economic prosperity – the two systems are inextricably linked.

To help reverse the current trend of the deterioration of important ecosystem services, proactive planning mechanisms (including public education) will be required over the long term. There is the potential for local governments to take a leading role in responsible development in coastal areas that address SLR and are sympathetic to the maintenance of ecosystem services. This will help to avoid potential development of human settlements in coastal fringes, which are likely going to become hazardous to inhabit over the longer term.

The successful restoration of industrial areas to functioning ecosystems in the Campbell River estuary was noted throughout the study. Restoration, therefore, will prove to be a viable and valuable tool in helping to reduce impacts from SLR.

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Sea Level Rise – Ecosystems and Species at Risk Assessment

1 Introduction

In 2019, the City of Campbell River initiated the Ecosystems and Species at Risk Study. The purpose of the project was to assess, update and obtain the data and information required for the City of Campbell River (the City) to better identify, reduce harm and make shared decisions around resource stewardship and management along the approximately 15 km of urbanized shoreline within the City boundaries. The information provided by this study will then be used to plan and prepare for predicted Sea Level Rise (SLR) in order to best inform land base investments and urban planning, management of natural resources and risk managing for contaminated sites, and management decision-making. The urgency for this work is emphasized by the recently published report, *Canada's Top Climate Change Risks* (Council of Canadian Academies 2019), where five of the top six areas of climate change risk apply to Campbell River. According to this report the areas of risk can be "meaningfully reduced through adaptation measures that lessen vulnerability or exposure".

The concept of "coastal squeeze" readily applies to the City of Campbell River. Because of the occurrence of hardened structures such as Highway 19, armoured shorelines and the Sea Walk, there is little space available for the migration of unique coastal habitats in the face of SLR (hence the term "coastal squeeze"). There is also minimal buffering between the marine environment and coastal infrastructure (*e.g.* private property, commercial enterprises and/or industrial areas). Campbell River already experiences issues with coastal erosion and flooding, and the City recognizes the concerns associated with SLR, coastal squeeze and the broader issue of global climate change. The City are committed to applying forward-thinking mechanisms to address the challenges. For example, the City is nearing completion of a multi-year planning project: Campbell River – Rising Seas. The project uses a phased approach involving information gathering, technical studies, public input and the development of a strategic action plan.

Other jurisdictions on the east coast of Vancouver Island are also being proactive in addressing the global issue of SLR. For example, the Comox Valley Regional District recently secured funding through the National Disaster Mitigation Program to undertake coastal flood and SLR mapping.

The City has already completed numerous studies associated with SLR, which have (generally) focused on impacts to infrastructure. These existing studies are being used to help guide the City's SLR action plan. The ecosystem and species at risk study differs from these previous assessments in that it focuses on the importance of ecosystem services in providing natural benefits to humans, most importantly with regard to helping to ameliorate expected impacts from SLR.

Management strategies that have been developed by the City that are relevant to SLR and planning for development in the coastal fringe include, but are not limited to, the Foreshore and Campbell River Estuary Development Permit Areas (City of Campbell River Official Community Plan 2017). The City is continuing to build upon options for the protection of sensitive habitat through recent discussions related to the mapping of Environmentally Sensitive Areas (ESAs) and the function of Development Permit Areas.

1.1 Study Area

The City of Campbell River is located midway along the eastern side of Vancouver Island, approximately 265 km north of Victoria, BC. The entire shoreline distance within the City of Campbell River is about 20 km. The study area focuses on two main areas – the Campbell River estuary, and shoreline areas north and south of the estuary (from Race Point Road in the north to Ocean Grove Road south of Willow Point). Highway access along most of this waterfront has encouraged residential and commercial developments, with considerable foreshore hardening and, in many areas, clearing of vegetation to create ocean views. Focus was applied to the main estuary when describing ecosystem services, but other areas were also included in the study to capture the importance of other sensitive habitat (*e.g.* forage fish habitat, creek estuaries and the lower reaches of creeks).

The Campbell River estuary is one of the largest freshwater estuaries on the east coast of Vancouver Island and has a total area of over two square kilometres. The estuary and river together are very important salmon producing areas that also provide important habitat for birds, mammals, aquatic organisms and several rare plants and ecosystems. The estuary is also used for recreation and light industry in the form of marinas and a seaplane base. Past sawmills and other forestry-based industries resulted in significant degradation of the estuary.

The Campbell River is known as a Heritage River. Heritage Rivers are selected based on a system that reflects the diversity of B.C's rivers, with the aim being to: "…encourage community-based stewardship, to provide a model for public participation in river management, to formally recognize outstanding examples of our river heritage and to reflect the vision for each river as we move into the future" (BC Heritage Rivers Program, BC Parks 2019).

Considerable volunteer work, coordinated by Greenways Land Trust in collaboration with other partners including Wei Wai Kum First Nation, has been completed in recent years to restore portions of the estuary. In addition to other restoration work, estuarine islands have been created and planted with native vegetation as part of compensation work for the loss of functioning estuarine habitat from a dry land log sort (Dawe 2015). An on-going project entitled *Restoring Ecological Function in the Campbell River Estuary* (Greenways Land Trust 2019) has been, and continues to be, a valuable aspect of restoration work in the Campbell River estuary. The City has been instrumental in providing funding to stewardship groups for ongoing restoration work. In addition, the City has invested in the enhancement and restoration of the estuary through on-going projects (*e.g.* the Baikie Island Nature Reserve).

When discussing estuarine environments in his book Fisherman's Fall (1964), Roderick Haig-Brown, who was a fly-fisher, conservationist and writer with profound connections to Campbell River, provides a measure of the magnitude of estuarine ecosystems: "*Only when one has walked the flat places and heard the wind in the grasses, explored the sloughs and side-channels, watched the tides and faced the storms, does a river mouth take on character and substance and reveal its dramatic power*." This quote helps to sum up the range of biological, geophysical and ecological inter-connections and unique attributes that occur in estuaries that ultimately drive the provision of estuarine ecosystem services.

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Figure 1:
Study Area Overview

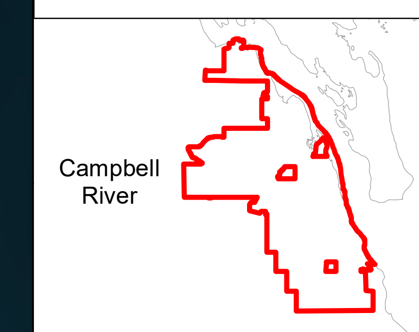
PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE: 1:58,000	**MAPPING DATE:** October 17, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Campbell River City Limit
Northern & Southern Study Area Limits
Watercourse



0 0.5 1 2 Kilometers
1:58,000

N
W E
S

1.2 Climate Change and Sea Level Rise

Numerous studies indicate that sea levels are rising, and will continue to rise for centuries, even if emissions of greenhouse gases cease and concentrations of these gases in the atmosphere stabilize (*e.g.* Church and White 2011). A global estimate of SLR between 1880 and 2009, as calculated in a study by Church and White (2011), is 21 cm. The main contributions to SLR are from melting land ice across the globe and melting ice sheets in Antarctica and Greenland.

SLR appears to have accelerated over recent times, with a rate of rise trend of approximately 1.7 mm per year between 1900 and 2009. In that time period, the rate of rise since 1961 has been estimated to be approximately 1.9 mm per year (Church and White 2011). A very recent special report produced by the United Nation's Intergovernmental Panel on Climate Change (IPCC) in September 2019 established a SLR rate of rise trend of 2.1 mm per year between 1970 and 2015. Between 1993 and 2015, the rate of rise trend increased to 3.2 mm per year and between 2005 and 2015, the trend increased to 3.6 mm per year. It may be difficult to accurately determine specific impacts from SLR based on factors such as isostatic and seismic adjustment, where any immediate impacts from SLR may be decreased, but the trends suggest that SLR will have significant impacts upon most coastal areas around the globe in the near future.

1.3 The Concept of Ecosystem Services

The word "ecosystem" will be frequently used in this report. General definitions and concepts of an ecosystem include:

- A biological community of interacting organisms (such as vegetation or fish) and their physical environment;
- A community of living organisms in conjunction with the non-living components of their environment, interacting as a system. These biotic (living) and abiotic (non-living) components are linked together through nutrient cycles and energy flows; and
- Areas with similar vegetation, soils, and landform can be mapped as ecosystems.

With the current estimates of SLR, we can expect there to be changes to how coastal and estuarine ecosystems are distributed across the landscape. For example, tidal freshwater and brackish marshes are expected to decline in area and be converted to saltwater marshes. On a per-unit-area basis, tidal freshwater wetlands provide higher levels of ecosystem services (including productivity and waste treatment) than do salt marshes (Craft et. al. 2009). The effects of this conversion may be compounded by altered river flow regimes and increased demand for freshwater.

Based on definitions in the Millennium Ecosystem Assessment (MEA 2005), "*ecosystem services are the benefits people obtain from ecosystems*". In an urban environment, ecosystem services can be provided by urban forests, streams, lakes, and ponds, but also by "green infrastructure" including parks, vacant lots, gardens, and stormwater retention ponds (Elmqvist *et al* 2015). Some of the important services provided by these green spaces include microclimate regulation, water regulation, pollution reduction, health benefits, habitat services and cultural benefits. Green spaces in urban areas can correlate to longevity, reduced stress and improved mental health, which translate into higher well-being (Elmqvist *et al* 2015).

The topic of ecosystem services has been studied and discussed extensively in the recent years, and in an extensive review, Elmqvist *et al* (2015) put an economic value on some of the ecosystem services provided by green infrastructure in urban areas. These values are in addition to the monetary benefits provided, such as from the sale of raw materials and food. They found that the average value in US$ (2013) was:

- $647/ha/yr for pollution and air quality regulation;
- $395/ha/yr for carbon sequestration and $3,125/ha/yr for carbon storage;
- $922/ha/yr for storm water reduction;
- $1,412/ha/yr for energy savings/temperature regulation;
- $6,325/ha/yr for recreation and other amenity services; and
- $18,870/ha/yr for positive health effects.

It is important to put a monetary value on non-monetary benefits of ecosystem services because the failure to consider the value of these services has led to the widespread disappearance of ecosystems (Barbier *et al* 2011). However, it is equally important to recognize that assigning a notional monetary value should not be taken to imply that these services are therefore tradeable or replaceable (Spash 2008). The global decline of coastal and estuarine ecosystems due to human activities is intense and increasing, affecting several of the services provided by these ecosystems. Some of the impacts to the services provided include a reduction in the number of viable fisheries, a decrease in the provision of nursery habitats for juvenile fish, reduced coverage of seagrass beds and wetlands and a reduction in the filtering and detoxification services provided by submerged vegetation, suspension feeders and wetlands. If we consider the economic value provided by these ecosystem services, destruction of ecosystems for economic development can no longer be viewed as "costless" by those responsible for managing and approving such developments (Barbier *et al*. 2011).

1.4 Objectives

The City recognizes that accurate, up-to-date information and data about the current status of shoreline ecosystems and their components provides essential baseline information. The information can be used to inform land use planning processes and help develop management strategies and decision-making processes in the scenario of rising sea levels. To help guide the content of the assessment, a meeting was held with City planning staff on August 9th, 2019. During the meeting, we were able to gain valuable local knowledge and insight into the considerable challenges involved with coastal squeeze while also gaining an understanding of specific ecological resources in the study area.

The overall objectives of this study are to:

- Identify types of ecosystem services, using the "Provisioning, Regulating, Habitat and Cultural" categories (as per Hattam *et al* 2015) and determine the benefits that are currently being provided.
- To determine indicators of ecosystem services (using the four different categories) that can be measured spatially and temporally to determine changes in the provision of ecosystem service benefits (focusing on estuarine and foreshore areas).
- Describe how ecosystem services in the study area will be affected by SLR in combination with high river flow events and hydrological, meteorological, and tidal events.
- Create an inventory of red and blue-listed species and plant communities within the study area.
- Create an inventory of foreshore and marine ecosystems and rank their current condition.

- Identify and describe geophysical and hydrological implications of sea level rise in terms of potential impacts to ecosystem services and changes to physical processes such as erosion and sedimentation. In particular, assessing potential impacts to groundwater, channel morphology, water quality, aquatic habitat and aquatic species in Campbell River.
- Identify actual or potentially contaminated sites along the marine foreshore, and in the estuary area where tidal fluxing and wave-action (with rising levels) could act upon (erode) and re-distribute surficial contaminants. This would be most pertinent along the Campbell River banks and estuary, where a number of historical mills and other industrial operations were located.
- Gain an understanding of the level of current anthropogenic and hydrological conditions and modifications that may be having an impact on ecosystem services and the resilience of ecosystems. These conditions could include drainage systems, development, development patterns/plans, groynes, rip-rap, and other hardened shorelines.
- Support integrated ecological (conservation) mapping, modeling and analyses to improve spatial conservation planning, and formulation of natural resource management strategies.
- Inform prioritization of future data collection and planning to focus on resources, areas or attributes most in need of protection, and/or climate change mitigation strategies.
- Provide recommendations for mitigation strategies to address identified risks.

The report has been separated into the following sections to help meet these objectives:

- Ecosystems and vegetation;
- Fish and wildlife;
- Geoscience and hydrology; and
- Contaminated sites.

The over-arching concept of ecosystem services has been discussed throughout the report.

2 General Methodology

2.1 Background Research

Based on the considerable volume of background data and assessments, research became a primary aspect of the assessment to gain an understanding of the main concerns and help guide the assessment. Of the background reports, the assessment completed in 2017 by Mimulus Biological Consultants provided perhaps the main basis for establishing applicable ecosystems (including spatial coverage) that could be used to establish ecosystem services and ecosystem service categories. Studies related to marine ecosystem services conducted by Hattam *et al* (2015) provided relevant information with regard to the formation of ecosystem categories and applicable indicators.

2.2 Compilation of Ecosystem Service Categories and Indicators

One of the main components of the assessment was to compile a comprehensive list of ecosystem services, ecosystem categories and indicators of changing conditions. A combination of brainstorming and research, using a list of ecosystems first outlined in Hattam *et al* (2015) as a basis, allowed for the establishment of ecosystem services under the “Provisioning”, “Regulating”, “Habitat” and “Cultural” categories. In addition, eight ecosystem types, established by previous mapping completed by Mimulus (2017) were used in the analysis: River Channel, Mudflat, Marsh, Cobble Shore, Swamp, Riparian, Forest, Terrestrial Herbaceous and Backshore Riparian. For each of these ecosystems, a list of ecosystem service examples was provided for each category. For each category, suggested indicators were compiled, along with recommended units/strategies for measurement, to determine changes to the indicators over time.

One of the goals of the project was to identify “Indicator Sites” associated with components that are relatively straightforward to measure and compare over time, that provide important ecosystem services, and would be expected to display measurable changes as a result of SLR. The scope of the project meant that there was limited time available for field surveys and follow-up assessments, which affected the number of specific Indicator Sites that could be identified. As a result, Indicator Sites were chosen where the maximum relevance to the project objectives could be achieved. In each case, established and repeatable assessment methodologies will provide a baseline for collecting and comparing Indicator Site attributes over the long term. One specific indicator, using long-term trends in bald eagle (*Haliaeetus leucocephalus)* nesting success, would need to rely on data collected as part of the on-going Wildlife Tree Stewardship Atlas (WiTS) initiative. This province-wide program aims to support the protection of specific raptor species through the mapping and monitoring of bald eagle and osprey (*Pandion haliaetus*) nests (WiTS 2019). These Indicator Sites are discussed in further detail, where relevant, to each discipline.

2.3 Establishing SLR Elevations

The SLR elevations used for analyses in this report reflect the contents in the report prepared for the City by Northwest Hydraulics Consultants Ltd. (2019), whereby 0.5 m and 1.0 m sea level rise scenarios were used to calculate variable flood construction levels[1] (FCLs) for the entire Campbell River foreshore. Parameters used by Northwest Hydraulics to calculate FCLs include: design water level[2], SLR, vertical land motion (uplift), wave effect and freeboard[3]. For the purposes of our report, we used all the parameters to calculate SLR elevations for foreshore areas minus freeboard. Based on our professional opinion, freeboard has no bearing towards the ecological assessment and erosion assessment (presented in Table 1 below).

[1] Flood construction level is defined by the City of Campbell River in *Introduction to Sea Level Rise, Risks and Adaptation Methods* (November 2018) as "the required minimum elevation for the base of a floor structure for habitable floors or for the storage of valuable goods"

[2] Projected water level during a 1 in 200-year storm event

[3] Freeboard is defined by the City of Campbell River in *Introduction to Sea Level Rise, Risks and Adaptation Methods* (November 2018) as "a vertical distance between the anticipated Wave Effects and the Flood Construction Level"

TABLE 1: FLOOD CONSTRUCTION LEVELS FOR SECTIONS OF THE CAMPBELL RIVER SHORELINE - TAKEN FROM NORTHWEST HYDRAULICS CONSULTANTS LTD. (2019).

Section	Design water level (m)	SLR (m)	Uplift (m)	Wave effect (m)	SLR elevation (m)
1 – Ocean Grove	2.45	0.50	-0.21	2.2	4.9
2a – Willow Point South	2.45	0.50	-0.21	4.1	6.8
2b – Willow Point Central	2.45	0.50	-0.21	2.9	5.6
2c – Willow Point North	2.45	0.50	-0.21	2.1	4.8
3 – Frank James Park to Simms Creek PS	2.45	0.50	-0.21	2.1	4.8
4 – Simms Creek Pump Station to Big Rock	2.45	0.50	-0.21	2.1	4.8
5 – Big Rock to Rotary Beach Park	2.45	0.50	-0.21	2.2	4.9
6 – Rotary Beach Park to Hidden Harbour	2.45	0.50	-0.21	1.7	4.4
7 – Hidden Harbour to Anchor Inn	2.45	0.50	-0.21	1.8	4.5
8 – Anchor Inn to Maritime Heritage Centre	2.45	0.50	-0.21	2.1	4.8
9 – Ostler Park	2.45	0.50	-0.21	1.8	4.5
10a – Downtown Waterfront (Hwy 19A)	2.45	0.50	-0.21	1.9	4.6
10b – Downtown (inshore Breakwaters)	2.45	0.50	-0.21	0.6	3.3
11 – Tyee Point	2.45	0.50	-0.21	0.9	3.6
12 – Campbell River to McDonald Road	2.45	0.50	-0.21	2.4	5.1
13 – McDonald Road to Barclay Road	2.45	0.50	-0.21	3.0	5.7
14 – Duncan Bay	2.45	0.50	-0.21	1.9	4.6

TABLE 1 CONT.

Section	Design water level (m)	SLR (m)	Uplift (m)	Wave effect (m)	SLR elevation (m)
1 – Ocean Grove	2.45	1.00	-0.41	2.3	5.3
2a – Willow Point South	2.45	1.00	-0.41	4.7	7.7
2b – Willow Point Central	2.45	1.00	-0.41	3.0	6.0
2c – Willow Point North	2.45	1.00	-0.41	2.4	5.4
3 – Frank James Park to Simms Creek PS	2.45	1.00	-0.41	2.1	5.1
4 – Simms Creek Pump Station to Big Rock	2.45	1.00	-0.41	2.1	5.1
5 – Big Rock to Rotary Beach Park	2.45	1.00	-0.41	2.3	5.3
6 – Rotary Beach Park to Hidden Harbour	2.45	1.00	-0.41	1.7	4.7
7 – Hidden Harbour to Anchor Inn	2.45	1.00	-0.41	1.8	4.8
8 – Anchor Inn to Maritime Heritage Centre	2.45	1.00	-0.41	2.1	5.1
9 – Ostler Park	2.45	1.00	-0.41	1.8	4.8
10a – Downtown Waterfront (Hwy 19A)	2.45	1.00	-0.41	1.9	4.9
10b – Downtown (inshore Breakwaters)	2.45	1.00	-0.41	0.6	3.6
11 – Tyee Point	2.45	1.00	-0.41	0.9	3.9
12 – Campbell River to McDonald Road	2.45	1.00	-0.41	2.4	5.4
13 – McDonald Road to Barclay Road	2.45	1.00	-0.41	3.0	6.0
14 – Duncan Bay	2.45	1.00	-0.41	1.9	4.9

2.4 Field Assessment

The field component of the assessment was minimal in scope and provided a high-level overview of the study area to help gain an understanding of the various challenges associated with SLR and provide a general picture of the condition of the ecosystem types. The field assessment, which was completed on August 7th and 8th 2019, also allowed for specific areas of interest to be visited. Detailed assessments were conducted, where feasible, to provide relevant information that can be used to monitor changes to important ecosystem services over the long term (*e.g.* forage fish habitat, estuarine ecosystems and freshwater habitat in specific creeks). This included assessing several areas along the foreshore, visits to Nunns Creek Park and the McDonald/Barclay Road area (near the northern extent of the study area) and a focused study of the estuary.

The focus of the field visit was to gain a general understanding of the current ecological condition to help in the ecosystem ranking process and help establish and build upon the various ecosystem services, categories and indicators that had been compiled prior to the fieldwork. Ecosystem mapping and the compilation of vegetation lists had already been completed in previous assessments funded by the City.

Throughout the field assessment, general notes were taken to describe the various ecosystem types, using existing mapping as a base. Particular attention was given to determining areas of anthropogenic disturbance and current resilience of ecosystems that would combine with the ecosystem ranking aspect of the project. Representative photos were taken to indicate current conditions and a species list of wildlife use was also completed (with particular attention given to rare species occurrences). General observations and notes were taken to describe fishery resource attributes.

3 Compiled Ecosystem Service Categories and Indicators

The following sections describe, in general terms, the four ecosystem service categories and associated indicators that were used in this assessment. Table 2 provides a list of these categories and shows examples of associated services. The ecosystem services listed in Table 2 are integral to each component of the assessment: ecosystems and vegetation, fish and wildlife, geoscience and contaminated sites.

3.1 Provisioning Ecosystem Services

This ecosystem category specifically addresses the provision of material products such as food, raw materials, fresh water and medicinal resources. In terms of the Campbell River area, some examples of the provisioning category would be food resources captured from the ocean or river, such as shellfish and salmon.

PHOTO 1: SUCCESSFUL FISHERIES DEPEND UPON PROVISIONING ECOSYSTEM SERVICES
Web-based image

3.2 Regulating Ecosystem Services

Services provided by the regulating category include flood control, protection of coastal areas from erosion, maintenance of air and water quality, soil production and stabilization, carbon sequestration and noise buffering. This category is especially applicable to the Campbell River area in terms of SLR, based on the important services provided by ecosystems in terms of coastal erosion protection.

PHOTO 2: BACKSHORE VEGETATION AT THE 50TH PARALLEL IN CAMPBELL RIVER PROVIDES REGULATING SERVICES IN THE FORM OF EROSION PROTECTION. AUGUST 7TH, 2019.
Photo credit: Trystan Willmott.

3.3 Habitat Ecosystem Services

This ecosystem service category is extremely important in that it ensures the provision of suitable habitat for fish, wildlife, invertebrates and vegetation. All these resources ultimately provide direct and indirect benefits to humans.

PHOTO 3: FUNCTIONING RIPARIAN AREAS ADJACENT TO CAMPBELL RIVER PROVIDES HABITAT SERVICES IN THE FORM OF WATER TEMPERATURE REGULATION, PROVISION OF NUTRIENTS INTO FISH HABITAT, BANK STABILIZATION, WATER PURIFICATION AND THE PROVISION OF UNIQUE VEGETATION AND WILDLIFE HABITAT NICHES. AUGUST 8TH, 2019.
Photo credit: Trystan Willmott

3.4 Cultural Ecosystem Services

While perhaps being the most difficult category to measure, cultural ecosystem services likely provide the most salient benefits to humans. Trends in tourism and usage of certain areas for certain activities (*e.g.* bird watching/hiking) may be measurable, but other cultural aspects such as spiritual experiences, cultural identity, traditional knowledge, inspiration and sense of place are also associated with this category.

PHOTO 4: A BIRDWATCHER'S BLIND LOCATED ON THE WESTERN SIDE OF TYEE SPIT GIVES AN EXAMPLE OF HOW THE ESTUARINE ECOSYSTEM PROVIDES A CULTURAL SERVICE IN THE FORM OF A RECREATIONAL ACTIVITY. AUGUST 7TH, 2019.
Photo credit: Trystan Willmott

3.5 Ecosystem Service Indicators

In order to determine changes to ecosystem services, it is necessary to establish indicators. In order to be effective, indicators must reflect the dynamic nature of ecosystems, while also being measurable. Indicators and suggested measurement units/strategies were chosen for each ecosystem category (refer to Table 2).

Generally, units of measure that relate to human benefits can be readily established for ecosystem services that involve physical processes. It is difficult to determine indicators for certain aspects of the "Cultural" ecosystem service category, as parts of this category deal with spiritual components and human well-being. For example, it is difficult to measure the value of experiencing your daughter catch her first pink salmon (*Oncorhynchus gorbuscha*) on a fly rod, but personal experience has shown that this human benefit, which is ultimately tied to the services provided by ecosystems, is priceless. While there may be no tangible measure of the enjoyment of activities such as recreational fishing, these activities are known to provide significant spiritual benefits that rely entirely upon ecosystem services. For most people, activities such as fishing are not about the provisioning aspect of fishing in terms of obtaining food to eat but are associated with a way of life and/or benefits to mental and physical health.

PHOTO 5: THE HUMAN BENEFITS FROM RECERATIONAL FISHING ARE DIFFICULT TO PHYSICALLY MEASURE BUT ARE READILY APPARENT IN SOME CASES. CAMPBELL RIVER PINK SALMON – AUGUST 2019.
Photo credit: Trystan Willmott

TABLE 2: ECOSYSTEM TYPES, CATEGORY, EXAMPLES, INDICATORS AND UNITS OF MEASURE.

ECOSYSTEM TYPE	ECOSYSTEM SERVICE CATEGORY	ECOSYSTEM SERVICE EXAMPLES	SUGGESTED INDICATOR (specific measurable Indicator Sites already assessed as part of the study for Campbell River are highlighted)	SUGGESTED MEASUREMENT UNITS (specific measurable units already included as part of the study for Campbell River are highlighted) Area-based calculations of Campbell River estuary ecosystems that have been provided in this assessment can be used to predict and monitor long-term changes to the various ecosystem service categories based on varying degrees of SLR - refer to Figures 4 and 5. Not all measurement units reflect local impacts associated with SLR – some include regional and/or global impacts
Summary of Ecosystem Services: Definitions and Examples	Provisioning Services	Providing a food or other product (fish, shellfish etc.) or edible/medicinal plants. The ecosystem generates biological productivity and diversity, which aids the growth of the product	The population size of the given product(s)	Fish escapement data from DFO; number of fisheries openings/closures; clam harvest data; degree of edible/medicinal plant use
	Regulating Services	Regulation and maintenance of natural systems: coastline protection; erosion control; air quality; water purification; flood control; carbon sequestration; nutrient cycling; attenuation and/or dissipations of wave energy; flood reduction; sediment stabilization and soil retention from plant roots; nutrient uptake/cycling; filtering/storing of contaminants; natural deposition of sediments resulting in creation of land at deltas	Trends in coastal erosion and flooding; trends in water quality	Water quality monitoring; observations and measurements of flooding frequency and coastal erosion; shoreline stability measurements
	Habitat Services	Provision of habitats for fish, wildlife, invertebrates, plants and vegetation assemblages. Habitat provides suitable reproductive and nursery grounds and sheltered living space to allow for biological productivity and diversity	Population health; quality/suitability of habitat	Record and compare species sightings, populations and habitat quality over time
	Cultural Services	Use by local First Nations, recreational values, aesthetic values, spiritual enrichment, education opportunities, tourism and research. The ecosystem provides a unique and aesthetic landscape	Trends in public usage and tourism	Measure public use over time with guestbooks, surveys; monitor trends in tourism use of specific areas

TABLE 2: ECOSYSTEM TYPES, CATEGORY, EXAMPLES, INDICATORS AND UNITS OF MEASURE.

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River Channel (RC)	Provisioning Services	Fish production. The mixing of freshwater and saltwater, along with the nutrients transported by both river and ocean currents results in highly productive waters	Diversity and abundance of fish populations	Fish population estimates to determine productivity over time.
	Regulating Services	Flood control; sediment movement and deposition; erosion control; nutrient cycling	Water quality, stream flows, channel stability, sediment loading. **Specific Indicator Sites for Willow and Simms Creek have been set up that are relevant to this category**	Metrics on channel width, depth, and water volumes; water quality; fish population escapements; physical habitat measurements; channel morphology measurements; measurements/observations of disturbance indicators. Measure water quality, presences of contaminants. Use the assessment of potential changes to the Campbell River channel (from anticipated aggradation and erosion) as a basis for determining specific vulnerable areas. **Simms Creek and Willow Creek Index Reaches have been assessed in detail to provide specific habitat attributes that can be monitored over time**
	Habitat Services	Fish staging habitat, fish spawning habitat, migration routes/travel corridors for fish, rearing habitat for fish. Bird habitat; sheltered waters for waterfowl and seabirds; nutrient inputs resulting from spawning salmon, ocean inputs and delta sediments	Productivity/diversity of habitat. **Specific Indicator Sites for Willow and Simms Creek have been set up that are relevant to this category**	Measurements of fish habitat quality - amount of rearing, cover, spawning, staging, migration habitat for fish. **Simms Creek and Willow Creek Index Reaches have been assessed in detail to provide specific habitat attributes that can be monitored over time**
	Cultural Services	Unique and aesthetic landscape provides opportunities for use by FN, recreation/tourism attractions (kayaks, sailing, canoeing, recreational fishing, snorkeling), Tyee Club, marina and heritage focal point for the City and historical use	Trends in public use	Measure degree of public use; monitor success of recreational fishing (e.g. Tyee club membership) and FN traditional use; measure trends in tourism related to recreational fisheries

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Mudflat (MF)	Provisioning Services	Provision of marine food species including shellfish and fish.	Diversity and abundance of fish and shellfish; distribution and range of plant species. **Willow Creek estuary Indicator Site has been established, which is relevant to this category**	Metrics on fish and shellfish populations. **Willow Creek estuary Indicator Site can be used to monitor changes in mudflat coverage over time.**
	Regulating Services	Filtration of water entering the estuary; high diversity of plant species and high plant productivity allow for carbon sequestration; burial of detritus also provides carbon sequestration); water purification via nutrient uptake; erosion control via sediment stabilization from plant roots; nutrient inputs from fresh water and seawater; dissipation of wave energy; sediment stabilization from plant roots and rhizomes.	Water quality; trends in coastal erosion; spatial coverage of mudflats; volume of potential carbon sequestration. **Willow Creek estuary Indicator Site has been established, which is relevant to this category**	Measure water quality, species diversity/abundance; assess sediment profile and monitor over time (sands, silts, clays, gravels). Measure spatial coverage of important habitat such as eelgrass and monitor over time. **Willow Creek estuary Indicator Site can be used to monitor changes in mudflat coverage over time.**
	Habitat Services	Rearing habitat for young salmon, e.g. eelgrass, also provides habitat for many marine species such as shellfish. Sediment deposition provides substrate for aquatic vegetation such as eelgrass. Rich foraging habitat for wading shore birds	Trends in critical habitat coverage - e.g. eelgrass; trends in bird use	Monitor habitat available for features such as eelgrass beds; monitor health, vigour and spatial coverage of critical habitat such as eelgrass. Monitor rate of sedimentation and sediment profile (% silt, clay, sand, gravel). Monitor population trends of wading shorebirds (e.g. using bird counts)
	Cultural Services	Species occur that are important for tourism, recreation, education and research such as shellfish	Degree of public use	Measure available habitat and monitor trends in culturally important species.

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Marsh (MA)	Provisioning Services	Rearing habitat for young salmonids and other species of plants and animals.	Diversity and abundance of species that are culturally important.	Measure available habitat.
	Regulating Services	Dissipation of wave energy (wave speed, height, duration); high water uptake and holding capacity. Slower currents allow sediments to settle out of the water column; marshes have been used for greywater treatments, and as a last stage in sewage treatment.	Spatial coverage of marsh ecosystems; trends in coastal erosion and flooding. **Willow Creek estuary Indicator Site has been established, which is relevant to this category**	Monitor ground water movement and hydrology in marshes; assess and monitor changes to spatial areas of marsh habitat. **Willow Creek estuary Indicator Site can be used to monitor changes in marsh coverage over time.**
	Habitat Services	Important bird and fish habitat, particularly for waterfowl and nesting birds. Rare plant and rare ecosystem habitat. Slow moving water deposits water-borne sediments, brackish water may be preferential habitat for some species	Diversity and abundance of fish, birds and rare plants. Presence of listed dominant marsh plants, number of occurrences of rare plants and rare ecosystems	Measure trends in populations over time - e.g. bird counts, rare plant surveys, fish populations and assessments of available habitat.
	Cultural Services	Recreation, aesthetics, FN use of plants such as cattail and tule. Mosaic of open water and vegetated areas results in unique landscapes, allowing for public use	Degree of public use.	Monitor public use over time. monitor trends in culturally important species.

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Cobble shore (CS)	Provisioning Services	Source of fish and shellfish that are used for human consumption.	Diversity and abundance of species that are culturally important.	Monitor the abundance and distribution of species that are culturally important and monitor harvesting activities.
	Regulating Services	Wave dissipation - beaches attenuate waves and are at the frontier of SLR and changing coastal processes.	Sediment distribution and movement along the foreshore; trends in coastal erosion; trends in impacts from foreshore hardening; trends in foreshore area hardening.	Monitor accumulation/ablation rates of sediment and monitor distribution of beach particle sizes. Monitor the effects of foreshore hardening and trends in spatial coverage of hardened shorelines.
	Habitat Services	Provision of habitat for shorebirds that forage along beaches, wildlife habitat, and forage fish spawning areas. Type of substrate and exposure to wind and waves will influence habitat suitability.	Spatial coverage of available habitat. Substrate composition in terms of preferences for forage fish. **Forage fish Indicator Sites have been established that are relevant to this category.**	Monitor spatial and temporal changes in forage fish habitat availability through sediment sampling and profiling. **Sediment sampling and profiling has been established at 5 forage fish sites to enable changes to forage fish spawning suitability to be monitored over time.**
	Cultural Services	Popular for walkers, provision of scenic viewpoints, launching areas for small watercraft, beachcombing, tourist-related businesses, swimming, scuba diving, beach fishing, archaeological potential. Beach substrate can vary: sandy, gravelly, or cobbly. Substrate type may dictate use.	Degree of public use.	Monitor public use and types of public activity. Monitor/map archaeological evidence of FN historical use

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Swamp (SW)	Provisioning Services	Production of numerous plant and animal species including edible plants and berries and medicinal plants. Rich soils, good nutrient cycling, and areas of open water result in productive growth of herbs, grasses and shrubs	Diversity and abundance of species that are culturally important.	Monitor spatial coverage and abundance of species that are culturally important. Monitor ground water movement, underground aquifers, and other hydrological metrics
	Regulating Services	Flood control (winter flooding), dissipation of wave energy (at high tide only); fine sediments settle out of low energy watercourses (sloughs and backwaters) allowing for water filtration and purification. Groundwater inflow, surface aeration and elevated microsites allow significant plant growth; rich soils result in high species diversity	Water quality; trends in coastal erosion; spatial coverage of swamps	Monitor the hydrology of swamp areas, both from tidal and freshwater influence (including water quality); monitor erosion trends; monitor spatial coverage of swamp ecosystems.
	Habitat Services	Tall shrubs provide good bird nesting and forage habitat for birds, provision of rearing habitat for fish and habitat for aquatic mammals. Tall shrubs provide shelter and security for many animals including ungulates, and grass cover for grazing. Shrubs provide browse for some species	Diversity of plants and animals	Measure trends in populations over time - e.g. bird counts, rare plant surveys, fish population assessments.
	Cultural Services	Provision of berry picking areas and birdwatching. Presence of aesthetic landscapes; trail areas available for recreation	Degree of public use.	Monitor public use over time.

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Riparian (RI)	Provisioning Services	Provision of unique vegetation assemblages that can provide medicinal and forage plants	Abundance and diversity of medicinal and food plants	Monitor trends in plant/vegetation diversity and abundance
	Regulating Services	Bank stabilization along creeks and shorelines, flood control, wave dissipation (along larger channels), improving water quality, ensuring water availability. Annual flooding brings sediments which are deposited in riparian areas (silts, sands, and clays).	Degree of bankside erosion and armouring. Water quality and quantity.	Measure and monitor spatial coverage of riparian areas.
	Habitat Services	High wildlife use especially during salmon spawning season. Insect and litter fall from streamside vegetation provides food for fish and nutrients to the water. Trees provide nesting and perching habitat for raptors adjacent to high quality forage habitat. Riparian vegetation regulates water temperature within optimal range for salmonids.	Abundance and diversity of wildlife and fish. **Specific Indicator Sites for Simms and Willow Creek have been set up that are relevant to this category**	Measure and monitor the distribution and diversity of plants and animals in riparian buffers; measure and monitor abundance and diversity of fish over time. Measure water quality parameters (e.g. temperature). **Simms Creek and Willow Creek Index Reaches have been assessed in detail to provide specific habitat attributes that can be monitored over time**
	Cultural Services	Raised riverbanks and gravel bars provide places for recreational activities such as fishing, bird watching and walking	Good balance of public use, without disturbing wildlife or plant cover	Measure public use with guestbooks and surveys. Assess and monitor numbers of classroom excursions. Monitor use of interpretive trails in riparian areas. Monitor inherent community values/prosperity in terms of time invested in volunteering/contributing to community programs to enhance riparian habitat (such as replanting), volunteer work - e.g. Greenways programs/initiatives.

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Forest (FO)	Provisioning Services	Provision of edible plants and berries; provision of rich soil.	Abundance and diversity of medicinal and food plants	Monitor trends in plant/vegetation diversity and abundance, especially those that are culturally important for medicine and/or food
	Regulating Services	Air quality; provision of soil stabilization from tree roots; erosion control; dissipation of wind energy; buffer effect on winter floods; carbon sequestration; nutrient cycling; noise buffering; sediment and erosion control; nutrient uptake	Shoreline stability, amount of area available for carbon sequestration; local changes in wind damage	Measure forest health and spatial coverage of functioning forest ecosystems. Measure and monitor potential for carbon sequestration over time
	Habitat Services	Significant habitat diversity and provision of unique habitat niches. The rich soils of the estuary provide suitable growing conditions for significant trees	Structural stage, spatial coverage of functioning forest and species diversity	Measure and monitor structural stage over time; conduct forest monitoring to determine range of species and spatial coverage of functioning forest cover
	Cultural Services	Walking trails, attractions associated with mature/old growth trees; FN use of medicinal plants (e.g. cedar bark stripping).	Degree of public use.	Monitor public use over time

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Terrestrial Herbaceous (TH)	Provisioning Services	Area of high plant and animal biodiversity, including unique plants that provide medicinal and food benefits	Abundance and diversity of medicinal and food plants	Monitor trends in plant/vegetation diversity and abundance, especially those that are culturally important for medicine and/or food
	Regulating Services	Plant roots will help stabilize soil and improve soil structure	Spatial coverage of terrestrial herbaceous ecosystems	Conduct plant inventories to measure plant presence and numbers; monitor spatial coverage of terrestrial herbaceous ecosystems
	Habitat Services	Provide unique habitat niches for rare plants; songbird habitat; butterfly and insect habitat.	Distribution and abundance of rare species	Monitor rare element populations and diversity
	Cultural Services	Open areas that are popular with walkers; provision of viewscapes, provision of edible and medicinal plants	Degree of public use	Monitor public use over time

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Backshore Riparian	Provisioning Services	Provision of medicinal and edible plants	Diversity and abundance of species that are culturally important.	Verify and monitor over time the presence / absence of key plant species
	Regulating Services	Slope stabilization; water filtration; wave energy dissipation; sediment and erosion control.	Trends in coastal erosion and foreshore protection requirements; water quality	Measure the width and integrity of the backshore area and monitor over time; measure and monitor trends in coastal erosion processes
	Habitat Services	Provision of shade over the adjacent foreshore that is important for forage fish; provision of shelter from wind (also important for forage fish). Presence of important edge habitat along the interface between the ocean and terrestrial zone. Trees provide important perching and nesting habitat for species such as bald eagles and herons in this zone. Also, unique habitat attributes for salt tolerant rare plants and ecosystems. Detritus from birds and animals adds soil nutrients (bones, shells and excrement).	Diversity and abundance of species use. Spatial coverage of available habitat that provides biological function to forage fish habitat. **Forage fish Indicator Sites have been established that are relevant to this category. Bald eagle nests have also been compiled in terms of nesting success, which is also relevant to this category.**	Measure and monitor occurrence of healthy mature trees suitable for perching and nesting and for provision of benefits to forage fish; assess and monitor biological function of backshore habitat in terms of impacts from anthropogenic disturbance; measure and monitor abundance and diversity of rare elements adapted to backshore zones (e.g. bald eagle nests). **Detailed assessments of the backshore zone have been conducted at 5 forage fish Indicator Sites to enable changes to forage fish spawning suitability (in terms of suitability of the backshore zone) to be monitored over time. Data have been compiled with regard to bald eagle nests, to allow for nesting success to be monitored over time.**
	Cultural Services	Provision of viewscapes, pedestrian and bike trails; potential for traditional FN use; wildlife viewing; kayak launching areas	Degree of public use	Monitor public use over time

4 Vegetation and Ecosystems

The scope of the vegetation and ecosystem component of this project is to describe the current status of ecosystems (including condition ranking) throughout the study area, to gain an appreciation of potential impacts to ecosystem services in the face of slowly rising sea levels. The focus of the assessment was the Campbell River estuary (*i.e.* the wetland ecosystems and plants in the estuary), including rare ecosystems and rare plants. Low lying areas adjacent to the focus areas are also considered in the analysis – the Nunns Creek area for example. The Willow Creek estuary was also included as a focus area, and general observations were conducted of the foreshore along the entirety of the study area. The study area is in the Coastal Western Hemlock very dry maritime biogeoclimatic subzone – CWHxm (Green and Klinka 1994), and within the traditional territory of the Wei Wai Kum First Nation.

4.1 Definitions

4.1.1 Ecosystem

Building on the definition in Section 1.3, according to Green and Klinka (1994), an ecosystem consists of a particular plant community and the associated topography, soil, and climate. An ecosystem is the product of a complex interaction of vegetation, animals, microorganisms, and physical environment. Boundaries between ecosystems in the landscape can be abrupt or gradual. Ecosystem boundaries are generally abrupt in the Campbell River estuary.

A sensitive ecosystem is one that is fragile and/or rare (Ward *et al* 1998). Sensitive ecosystems are valuable in that they provide critical habitat for Species at Risk (species that are Provincially Red listed – extirpated, endangered or threatened or Provincially Blue listed - special concern), have a high level of biodiversity, and can provide wildlife travel corridors.

In British Columbia, the Biogeoclimatic Ecosystem Classification (BEC) groups similar segments of the landscape (ecosystems) into a hierarchical classification system. This system is used by land managers throughout BC.

Climate is generally the most important factor influencing the development of ecosystems. However, in the Campbell River estuary the most important factors are water-related: volume and flow of water currents (fresh or saltwater); exposure to tidal influence; water quality; exposure to high or low energy waves; rates of natural sedimentation; flooding intervals; and periods of inundation. Sea level changes will influence the composition and distribution of future ecosystems.

4.1.2 Disturbance

Disturbances are defined, in the context of this report, as a disruption of the natural environment that can be benign, positive, or negative. Positive disturbances can create opportunities for new plant establishment (*e.g.* a forest gap created by windfall), and negative disturbances can result in plant mortality and can impact ecosystems. Often it is the intensity and scale of a disturbance which is critical. Given that SLR is a result of anthropogenic carbon enrichment of the atmosphere, it is classified as an un-natural disturbance. In general, disturbances often play a critical role in landscape ecology and can play a role in ecosystem renewal and creating conditions for plant colonization.

Natural disturbances include:

- windthrow
- winter freshwater flooding on and adjacent to rivers and streams
- annual deposition of delta-building sediments
- high energy wave action on beaches
- daily tidal fluctuations
- winter storms and wind assisted tidal surges

Un-natural disturbances include:

- land clearing and development
- machine use and motorized recreation
- disruption of soil hydrology (for example water pumping)
- over-use of trails

- sea-level rise
- invasive plants
- over-population of a disruptive species (*e.g.* excessive grazing caused by Canada geese - *Branta canadensis*)
- excessive sedimentation resulting from upstream activities
- excessive movement of beach sediments as a result of adjacent beach hardening
- dumping of excess water or stormwater originating from hardened surfaces
- excessive nutrients (such as phosphorus) resulting from domestic or agricultural use
- introduction of pollutants and "novel entities" such as plastics into the environment

4.2 Methodology

4.2.1 Background Research

One of the objectives of this study was to create an inventory of red and blue-listed plant communities within the study area. To do this, the BC Conservation Data Centre (CDC) BC Species and Ecosystem Explorer tool was accessed to check for known occurrences of rare communities within and adjacent to the study area (CDC 2019). In addition, a list of rare wildlife species on the Provincial Red list (extirpated, endangered, or threatened) or Blue list (special concern) that have potential to occur in the study area (based on habitat-type) was generated. This list has been provided in Appendix 1.

The Sensitive Ecosystem Inventory (SEI) of southeastern Vancouver Island was completed in 1997 (Ward *et al* 1997) and later updated in 2004 to reflect land use changes. The most recent version of the mapping available through the BC Data Catalogue (https://catalogue.data.gov.bc.ca/) was reviewed with the most current imagery in the area to determine the distribution of documented sensitive ecosystems in the Study Area.

4.2.2 Spatial Changes in Ecosystem Coverage

GIS analysis was used to evaluate the current spatial coverage of ecosystems in the main Campbell River estuary (Mimulus 2017). This analysis was conducted to help understand potential losses to the spatial coverage of ecosystems under 0.5 m and 1.0 m SLR scenarios. Elevation overlays (contours) were then applied to the ecosystem map

(Mimulus 2017) to determine areas that would be inundated and affected by 0.5 m and 1m SLR scenarios. The FCL parameters associated with Coastal Section 11 – Tyee Spit (as per Table 1) were used in the analysis for the estuarine ecosystems, as this was considered the most relevant location (see Section 2.3). It should be noted that this FCL includes a wave effect allowance. Because waves are limited in the Campbell River estuary, the estimated impacts are likely to be conservative. The GIS process also provided an analysis and visual representation of areas where ecosystems could potentially relocate in the event of inundation.

The following is a summary of the analyses conducted:

1. Predicted loss of wetland ecosystems: conducted using two scenarios of sea level rise: 0.5 and 1 metre (corresponding to FCLs of 3.6 and 3.9 metres respectively). The analysis was completed using ArcMap software, and using data provided by the City as well as provincially available baseline data such as contours and imagery.
2. Migration of ecosystems: mapping of adjacent areas where estuarine wetland ecosystems and rare plants could potentially move. These areas are those between the current estuary and the 6 m contour (above current sea level). The 6 m contour approximately demarcates the point where the gently sloping lowlands meet steeper slopes. The area below 6 m in elevation includes the Nunn's Creek watershed and other riparian areas adjacent to the estuary and in the Campbellton vicinity.
3. Impacts on the rare plants currently present in the various wetland ecosystems
4. Ecosystem service categories: determining those that are applicable to each of the ecosystem types (Table 2).
5. Ecosystem Condition Ranking: providing a measure of the current resilience of ecosystems
6. Descriptions of the mapped wetlands: including dominant plants, mode of deposition and other information.

The units of measure used in the analyses are the wetland ecosystems mapped in the estuary by Mimulus Biological in 2017 that are presented in both Figure 2 and Table 3. To visualize their geographical position from low to high, the wetlands are presented in order of relative height above sea level (lowest to highest), except the units "Ocean" and "Developed", which are not used in the analysis. Detailed descriptions of the different ecosystem types are presented in Section 4.3. River Channel (RC), technically speaking a marine ecosystem, and was included in the analysis.

TABLE 3: LIST OF CAMPBELL RIVER ESTUARY ECOSYSTEM TYPES USED IN THE ANALYSIS (FROM MIMULUS 2017).

Ecosystem Type	Description (Mimulus 2017)	Area 2019 (ha)	Typical tidal range (Madrone)
River Channel (RC)	Aquatic habitat consisting of river and marine channels	60	Occurs at sea level
Mudflat (MF)	Low areas dominated by muddy substrates	38.9	Low intertidal areas
Marsh (MS)	Wetland ecosystems (freshwater or brackish) dominated by grass-like plants	35.2	Mid-tidal areas
Cobble Shore (CS)	Mid to high intertidal beach areas dominated by cobbles and gravel	7.2	Mid to high intertidal areas
Swamp (SW)	Wetlands dominated by tall shrubs and diverse herbs	2	Upper tidal range
Riparian (RI)	Treed and brushy areas adjacent to rivers, streams and other wetlands, floodplain communities	30.2	Upper tidal range, annual to infrequent winter flooding
Forest (FO)	Treed areas above tidal influence.	10.3	Forest areas in estuary experience one-in-five-year flooding (either above or below ground)
Terrestrial Herbaceous (TH)	Perched beach areas dominated by herbs and shrubs	9.9	Above tidal influence (such as the higher ground on Tyee Spit).
Total Hectares (includes small "Developed" areas)		215.8	

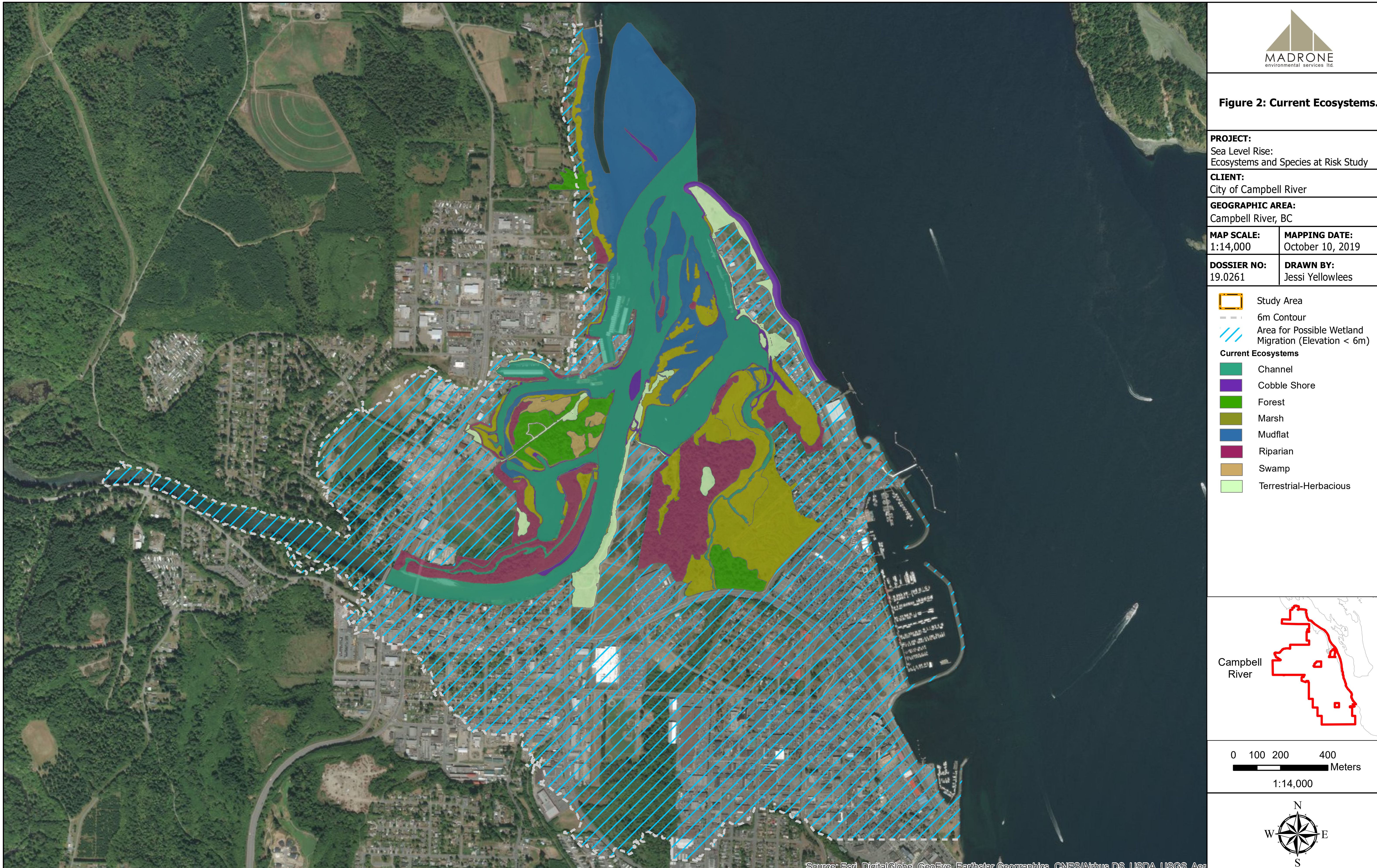

Figure 2: Current Ecosystems.

4.2.3 Willow Creek Estuary Vegetation Community Transect

The functions of estuarine habitats, which occur at the interface between fresh and saltwater, will be impacted by SLR. As such, in addition to the detailed mapping analysis of the ecosystem polygons that occur in the Campbell River estuary, a specific vegetation transect was established at the Willow Creek estuary to provide a baseline of current vegetation communities. The detailed vegetation data collected at the Willow Creek estuary allows the estuary to be used as an Indicator Site to measure long-term changes in vegetation and estuarine processes.

The transect was established in a representative segment of the estuary during a low tide from the edge of the creek channel to the edge of estuarine-influenced vegetation (a length of 34 m). Zones of vegetation along the transect were described and measured, using a fixed tape measure to determine the width of each zone and percentage cover of plant species to indicate the distribution of species in each zone. This mapping of vegetation zones was done at a much finer scale than the Mimulus mapping. Representative photos were taken along the vegetation transect.

4.2.4 Ecosystem Condition and Conservation Ranking

Ecosystem condition and conservation ranking of estuarine wetlands was completed following the criteria described in "Standard for Mapping Ecosystems at Risk in BC" (2006). The population of the table was completed using available information, imagery, field observations, and in some cases professional judgement. The ranked attributes are presented and defined in Table 4.

TABLE 4: ATTRIBUTES USED IN ECOSYSTEM RANKING.

ATTRIBUTE	COMMENTS AND SOURCE
Relative height above sea-level (0-8)	Proximity to sea-level; indicator of level of tidal inundation; rated from sea-level (0) to above tidal influence (8)
Saltwater tolerance	Tolerance of ecosystem to salt or brackish water (related to above); low, medium, high
Disturbance Adaptability	Inherent adaptability of ecosystem to disturbance (low, medium, high), based on professional judgement
Likelihood to increase (I) or decrease (D)	Based on above, the likelihood (or not) that an ecosystem will colonize new areas and increase in area - if suitable sites are available and the member plants can readily propagate – either from seeds or vegetative reproduction (Sculthorpe 1967)
Disturbances currently present	Known adjacent disturbances; based on maps, imagery, and field observations
Known threats	Based on maps, imagery, and field observations
Adjacent land use	Based on maps, imagery, and field observations
Invasive plants present	Based on Mimulus (2017) and field observations
Fragmentation	Fragmentation from roads, houses, or development (0-5%; 5-25%; 25-75%)
Landscape context	Excellent (0-5% fragmentation); Good (up to 25% fragmentation); Fair (>25% fragmented); Poor <25% natural or semi-natural vegetation.
Rare plants present	Based on Mimulus (2017) and field observations
Overall condition rating	Assessment of composition, structure, and ecological function. Excellent (4) typical climax vegetation; Good (3) mature seral vegetation; Fair (2) disturbances and invasive plants present; Poor (1) significant disturbances, structures, and invasive plants
SEI class and subclass	Classification code from Min of Env. (2006)
Provincial wetland code	Classification code from MacKenzie and Moran (2006).

4.3 Results

4.3.1 Documented Rare Vegetation Communities and Sensitive Ecosystems

Table 5 displays the results of the background research to determine the documented occurrence of rare plants and vegetation communities in the study area. The most recent review of the Sensitive Ecosystem Inventory (SEI) mapping (2019) showed that more polygons have been impacted since the mapping was updated in 2004 (see Ministry of Environment 2006 for definitions of Sensitive Ecosystems). Remaining sensitive ecosystems are found around the estuary within the IR#11 lands, Raven Park and Baikie Island, and along Simms Creek. These sensitive ecosystems include Riparian (RI) and Wetland (WN) classes in combination with the marsh (ms), swamp (sp) and shallow water (sw) subclasses (Figure 3).

TABLE 5: CDC SUMMARY OF RARE PLANT SPECIES AND ECOLOGICAL COMMUNITIES DOCUMENTED AS OCCURRING IN THE CAMPBELL RIVER ESTUARY.

CDC occurrence Record #	SPECIES NAME	LATIN NAME	BC STATUS	NOTES	POTENTIAL LOCATION IN STUDY AREA
Plants					
7198	Deltoid balsamroot	*Balsamorhiza deltoidea*	Red	well-drained areas in full sun	CR estuary and exposed shoreline
14437	Henderson's checkermallow	*Sidalcea hendersonii*	Red	wet meadows	CR estuary
41723	Vancouver Island beggarticks	*Bidens amplissima*	Blue	wetland annual	CR estuary
77274	Philadelphia daisy	*Erigeron philadelphieus*	Red	biennial, hairy, ray flowers numerous	CR estuary and exposed shoreline
Ecological Communities					
8950	Tufted hairgrass – Meadow barley	*Deschampsia cespitosa - Hordeum brachyantherum*	Red	estuary type Ed01	CR estuary

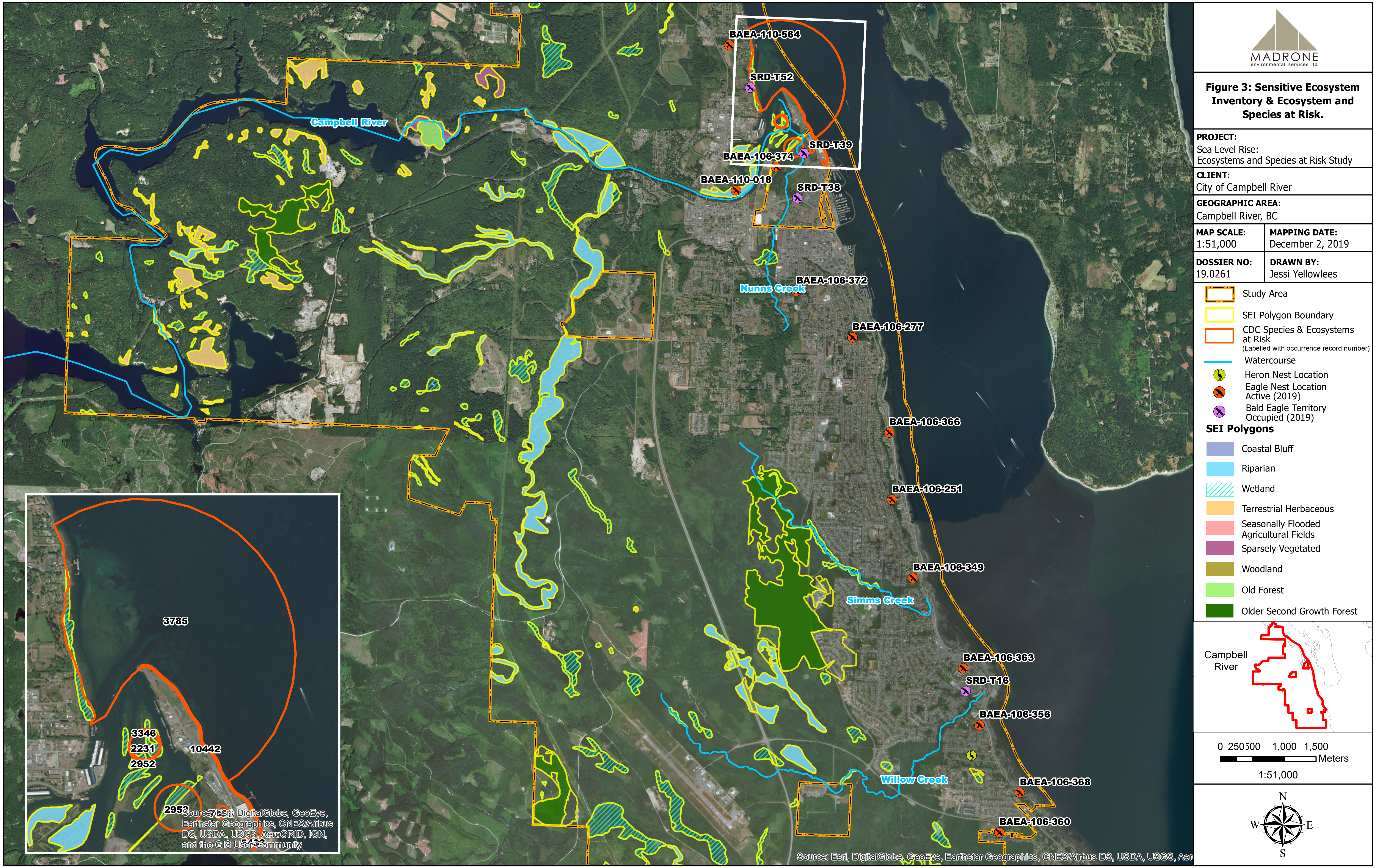

Figure 3: Sensitive Ecosystem Inventory & Ecosystem and Species at Risk.

PROJECT: Sea Level Rise: Ecosystems and Species at Risk Study	
CLIENT: City of Campbell River	
GEOGRAPHIC AREA: Campbell River, BC	
MAP SCALE: 1:51,000	**MAPPING DATE:** December 2, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

4.3.2 Description of Mapped Wetlands in the Campbell River Estuary

The following section presents the attributes of the different wetland ecosystems mapped by Mimulus in 2017 and used in our analysis. Several non-vegetated units mapped by Mimulus are not described in this section, namely "Ocean" and "Developed". Some of the wetland definitions and realms are taken from McKenzie and Moran (2004). Other attributes result from mapping and researching information on wetland formation.

In this section, wetland ecosystems are presented from the lowest to highest relative position above sea level (in the estuarine context). The scale used is 0 – 8, with 0 being at sea level (RC), and 8 being highest (TH). Note that this informal scale was used to help the reader visualize the locations of the ecosystems within the estuary. Some sloping ecosystem types, such as Cobble Shore, will span a range of positions above sea level. The area (hectares-ha) of each unit is based on the Mimulus mapping (2017).

River Channel (RC)
Mode of channel creation and deposition: created by combined river and tidal currents
Relative position above sea level: 0 (at sea level)
Current Area: 60 ha
Plants: In the main-stem river channel most plants occur on the edges, which in this case overlap with other wetland units such as Mudflat (MF). Mid-channel plants are most likely to be aquatic algae, mosses and submerged plants. Areas with gentle currents may have emergent plants, or plants that are grounded to the waterway's bed, but have stems and flowers that extend above the water line.

Mudflat (MF)
Definition: lower intertidal area dominated by muddy substrates
Realm: estuary: tidal flat
Mode of deposition: fine sediments (silts and clays) resulting from settling in areas with slowly moving water (backwaters and protected areas)
Relative position above sea level: 1
Current Area: 38.9 ha
Tree or shrub canopy cover: none
Rare plant habitat: small spike rush

Common plants: typically low plant cover but up to 25% cover of aquatic plants in some areas; plants include common silverweed, common spike rush, small spike rush, arctic rush, green ribbon, eelgrass, sea moss, rockweed, sea lettuce, western lilaeopsis, low clubrush, beaked ditch grass; plant distribution is dictated by the amount of tidal inundation; this wetland type is also impacted by Canada geese (refer to Dawe 2015 and Section 5.6 for more detail).
Other ecotypes present: CS

<u>**Marsh (MS)**</u>
Definition: a marsh is a permanently to seasonally flooded wetland dominated by emergent grass-like vegetation
Realm: estuary: marsh; or wetland: marsh
Mode of deposition: Formed on sediments (silts, sands, and clays) that have settled in areas with slow moving currents (either freshwater or seawater). Water is often brackish.
Relative position above sea level: 2
Current Area: 35.2 ha
Tree or shrub canopy cover: scattered shrubs present
Rare plants: Henderson's checker mallow, western St. John's wort, Philadelphia fleabane, small spike rush
Common plants: Arctic rush, Lyngbye's sedge, common silverweed, soft-stemmed bulrush, Pacific water parsley, Douglas' aster, Sitka willow, common cattail, small-flowered bulrush, skunk cabbage, tufted hairgrass, hardhack, Pacific willow, sweet gale, black twinberry, Pacific crabapple. Plants are often specific to a microsite
Other ecotypes present: RC, SW, MF
Comments: the listed Tufted hairgrass – Meadow barley ecosystem (Ed01) may be present on higher microsites with less frequent inundation; marshes typically have a mosaic of areas with high vegetation cover and areas of open water. Plant cover can range from 25 – 75%, with the remaining area being open water. Marshes have the highest presence of rare plants (4 species) compared to other units. This unit is also impacted by Canada geese.

<u>**Cobble Shore (CS)**</u>
Definition: high intertidal areas dominated by cobbles and gravels
Realm: beach: beach-land
Mode of deposition: created in areas of high energy wave action
Relative position above sea level: 3

Current Area: 7.2 ha
Tree or shrub canopy cover: none, full light
Rare plant habitat: small spike rush
This ecosystem type typically has low plant cover (1 – 25%), but some polygons have as much as 75% plant cover
Common plants: This unit has a range of elevations which is reflected in the plants present that include: green ribbon, arctic rush, common silverweed, low clubrush, Lyngbyes's sedge, sea milkwort, eelgrass (lower areas), and sea moss (distribution varies by amount of tidal inundation)
Other ecotypes present: MS, MF
Comments: the listed (Ed01 Tufted hairgrass – Meadow barley) is also present in areas with less frequent inundation

Swamp (SW)
Definition: a swamp is a nutrient rich wetland ecosystem where significant groundwater inflow, periodic surface aeration, and /or elevated microsites allow growth of trees or tall shrubs under sub-hydric (wet) conditions (McKenzie and Moran 2004)
Realm: wetland: swamp
Mode of deposition: fine sediments (silts and clays) resulting from settling in areas with low energy freshwater systems (former sloughs, high water tables)
Relative position above sea level: 4
Current Area: 2 ha
Tree or shrub cover: high cover of tall shrubs (2- 8 m)
Herb cover: 25-75% cover, often dense
Rare plants: Henderson's checker mallow and western St. John's wort
Common plants: Pacific crabapple, willows, sweet gale, salmonberry, common horsetail, common silverweed, Douglas' aster, field mint, Pacific water-parsley, skunk cabbage, coastal red elderberry, red-osier dogwood, hardhack, common cattail, slough sedge, Pacific ninebark, sedges
Other ecotypes present: MS, RC
Comments: the listed Tufted hairgrass – Meadow barley ecosystem (Ed01) may be present on higher microsites with less frequent inundation.

Riparian (R)

Definition: vegetated areas immediately adjacent to streams or rivers, and often on levees
Realm: floodgroup: low or medium bench floodplain
Mode of deposition: deposition of sediments (gravels, sand, silts and clays) resulting from flowing water (streams, creeks, and rivers)
Relative position above sea level: 5
Current Area: 30.2 ha
Tree and shrub cover: tree and shrub cover are high, and herbs are often dense in any openings
Rare plants: Henderson's checker mallow
Common plants: red-osier dogwood, horsetails, thimbleberry, common snowberry, red alder, Sitka spruce, grasses, Pacific nine-bark, cascara, hardhack. These plants vary in their position according to the amount of overbank flooding as well as substrate type
Other ecotypes present: SW, RC, TH, MS

Forest (FO)

Definition (in estuarine context): tree dominated, growing on stabilized soil, but subject to occasional flooding
Realm: most forests in the estuary occur on high bench floodplains; in the biogeoclimatic classification they would be CWHxm / 08 Sitka spruce – Salmonberry
Mode of deposition: deposition of sediments from infrequent overbank flooding (every 5-10 years)
Relative position above sea level: 6
Current Area: 10.3 ha
Tree, shrub and plant cover: high canopy cover from trees and shrubs; high plant diversity with a good representation of trees, shrubs and herbs
Rare plant habitat: none listed
Common plants:
Trees: red alder, Sitka spruce, Douglas-fir, big-leaf maple, western redcedar.
Shrubs: Pacific crabapple, ocean spray, dull Oregon grape, Himalayan blackberry, trailing blackberry, Nootka rose, salmonberry, snowberry, thimbleberry, red-osier dogwood, Pacific nine-bark, black twinberry, red elderberry, Pacific willow
Herbs and grasses: orchard grass, sword fern, cow-parsnip, lady fern, horsetail fern, slough sedge, skunk cabbage, reed canary grass

Terrestrial herbaceous (TH)

Definition: terrestrial plant communities dominated by herbs

Realm: in the study area, areas mapped as TH are on elevated beach materials: beach: beachland

Mode of deposition: former beach areas now slightly elevated and often dominated by cobbles and gravels

Relative position above sea level: 7

Current Area: 9.9 ha

Tree, shrub and herb cover: by definition, the tree and shrub cover are less than 10%; generally dominated by herbs

Rare plants: Henderson's checker mallow, western St. John's wort (*Deltoid balsamroot*) is found just outside the focus mapping area

Common plants: dune wildrye, slough sedge, Puget Sound gumweed, seashore lupine, Nootka rose, ocean spray, Pacific crabapple, Pacific nine-bark, Pacific willow, red-flowering currant, red-osier dogwood, Sitka willow, tall Oregon grape, thimbleberry, black cottonwood, red alder, Sitka spruce.

4.3.3 Area-Based Indicators of Spatial Changes in Ecosystem Coverage

The GIS analysis found that estuarine and shoreline ecosystems will be impacted under 0.5 m and 1.0 m SLR scenarios. Changes in spatial coverage can be measured over time and are directly linked to the indicators and units of measure listed in Table 2 for the various ecosystem service categories associated with the Campbell River estuary.

Given the long period of time over which rising sea levels are predicted to occur, it is difficult to predict the precise amount of ecosystem loss, given that ecosystem migration will be a factor and that some ecosystems will re-colonize areas better than others. For example, the Mudflat ecosystem unit is predicted to easily colonize suitable areas (Table 6), since aquatic species have propagules that are distributed in water, and often have vegetative reproduction (new plants can form from displaced or fragmented roots or stems) (Sculthorpe 1967).

Ecosystem loss will understandably first impact those ecosystems that are closer to sea level and experience more frequent tidal inundation. These include the Mudflat and Marsh units. However, as mentioned, these are also the units that are predicted to colonize new areas more readily. Regarding impact on rare elements, the Marsh unit provides habitat to four rare plants and one rare ecosystem. For River Channel (RC), being already effectively inundated, the current river channel will become deeper and will cover more area.

The analysis shows that the 0.5 m and 1.0 m SLR scenarios will result in a dramatic loss of the spatial coverage of all ecosystems, with less impact to Terrestrial-Herbaceous ecosystems (Figures 4 and 5). However, for some ecosystems, residual vegetated areas will remain. These areas will be crucial to the contribution of migration into new areas. Even the 0.5 m SLR scenario (FCL of 3.6 m) will result in almost total inundation of all ecosystems in their current locations during intense storms, except Forest and Terrestrial-Herbaceous (Figure 5). However, SLR will take many years, and it is possible that the wetland ecosystems could have largely colonized new areas by the time the 0.5 m and 1.0 m SLR elevations are reached. Figures 6 and 7 summarize the areas affected by the 0.5 m and 1.0 m SLR scenarios respectively.

The Shoreline and Backshore Vegetation ecosystem types were not used in this estuarine-focused analysis. Due to the low-lying location, it is assumed that these ecosystems will be impacted by even a 0.5 m rise in sea level, especially when the FCL is considered.

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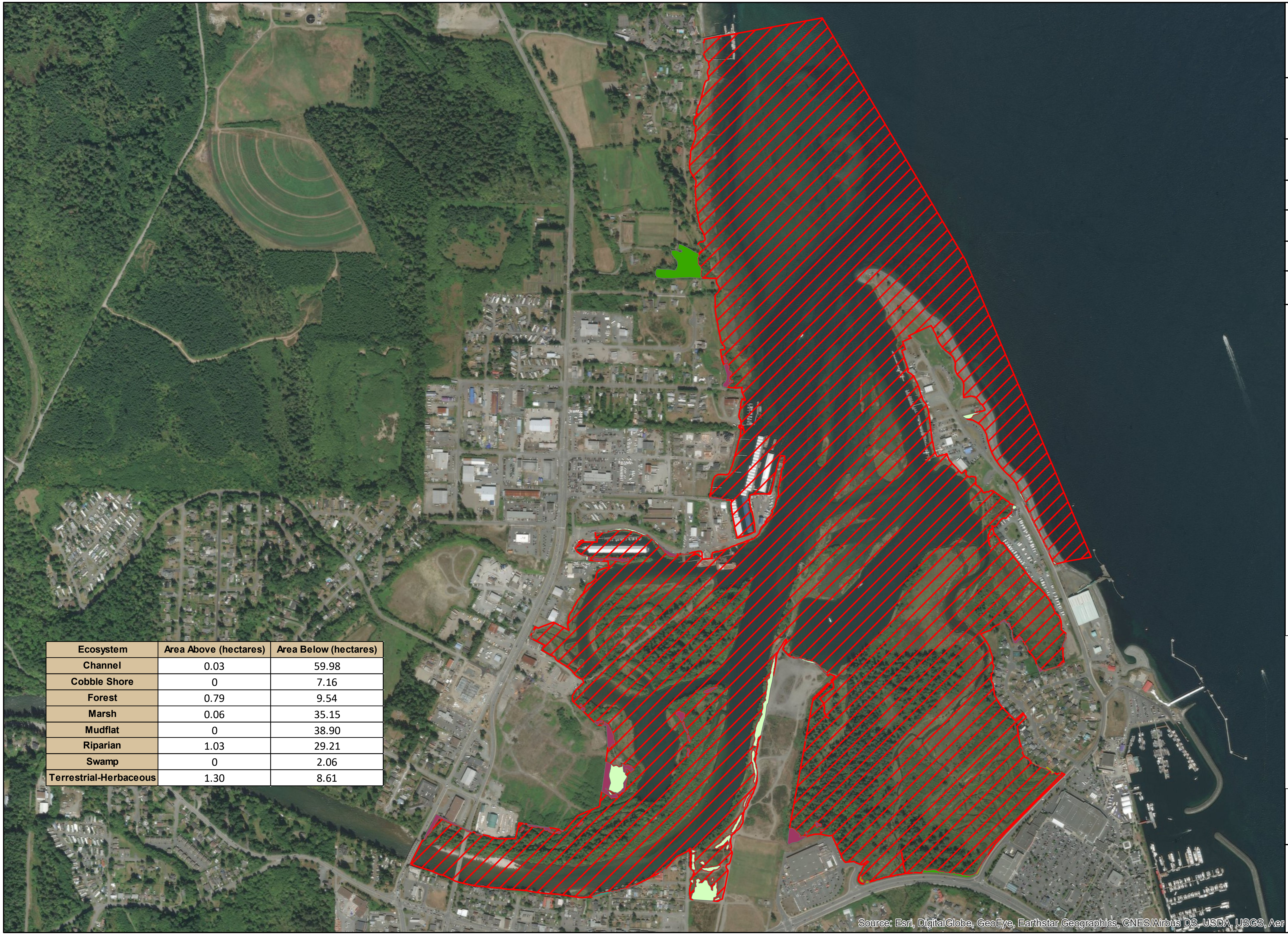
Figure 4: Areas Impacted by 0.5m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

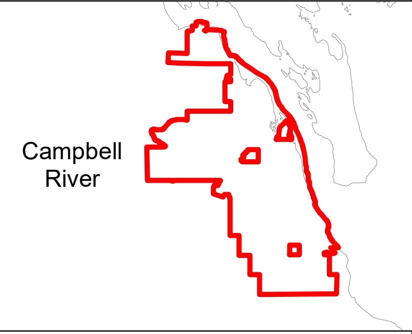
MAP SCALE:	**MAPPING DATE:**
1:10,000	November 20, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees



Ecosystem	Area Above (hectares)	Area Below (hectares)
Channel	0.03	59.98
Cobble Shore	0	7.16
Forest	0.79	9.54
Marsh	0.06	35.15
Mudflat	0	38.90
Riparian	1.03	29.21
Swamp	0	2.06
Terrestrial-Herbaceous	1.30	8.61

Areas Impacted by 0.5m Sea Level Rise

Ecosystems:
- Channel
- Cobble Shore
- Forest
- Marsh
- Mudflat
- Riparian
- Swamp
- Terrestrial-Herbaceous



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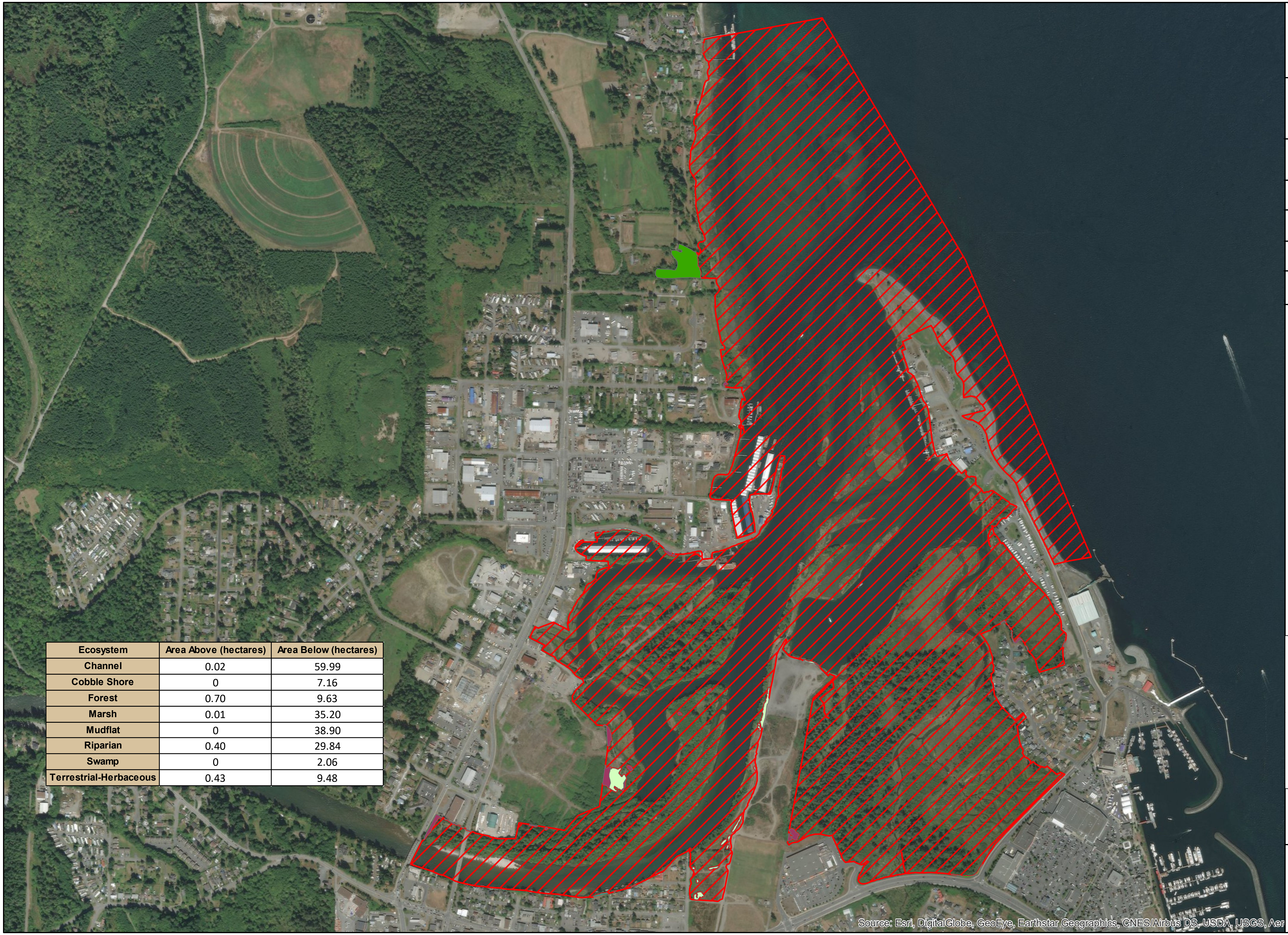

Ecosystem	Area Above (hectares)	Area Below (hectares)
Channel	0.02	59.99
Cobble Shore	0	7.16
Forest	0.70	9.63
Marsh	0.01	35.20
Mudflat	0	38.90
Riparian	0.40	29.84
Swamp	0	2.06
Terrestrial-Herbaceous	0.43	9.48

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Figure 5: Areas Impacted by 1m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

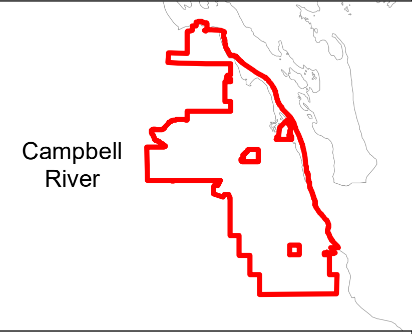
GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	MAPPING DATE:
1:10,000	November 20, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Areas Impacted by 1m Sea Level Rise

Ecosystems:

- Channel
- Cobble Shore
- Forest
- Marsh
- Mudflat
- Riparian
- Swamp
- Terrestrial-Herbaceous



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N W E S

FIGURE 6: IMPACT OF 0.5M RISE IN SEA LEVEL (AREAS IN HECTARES) TO ECOSYSTEM IN CAMPBELL RIVER ESTUARY.

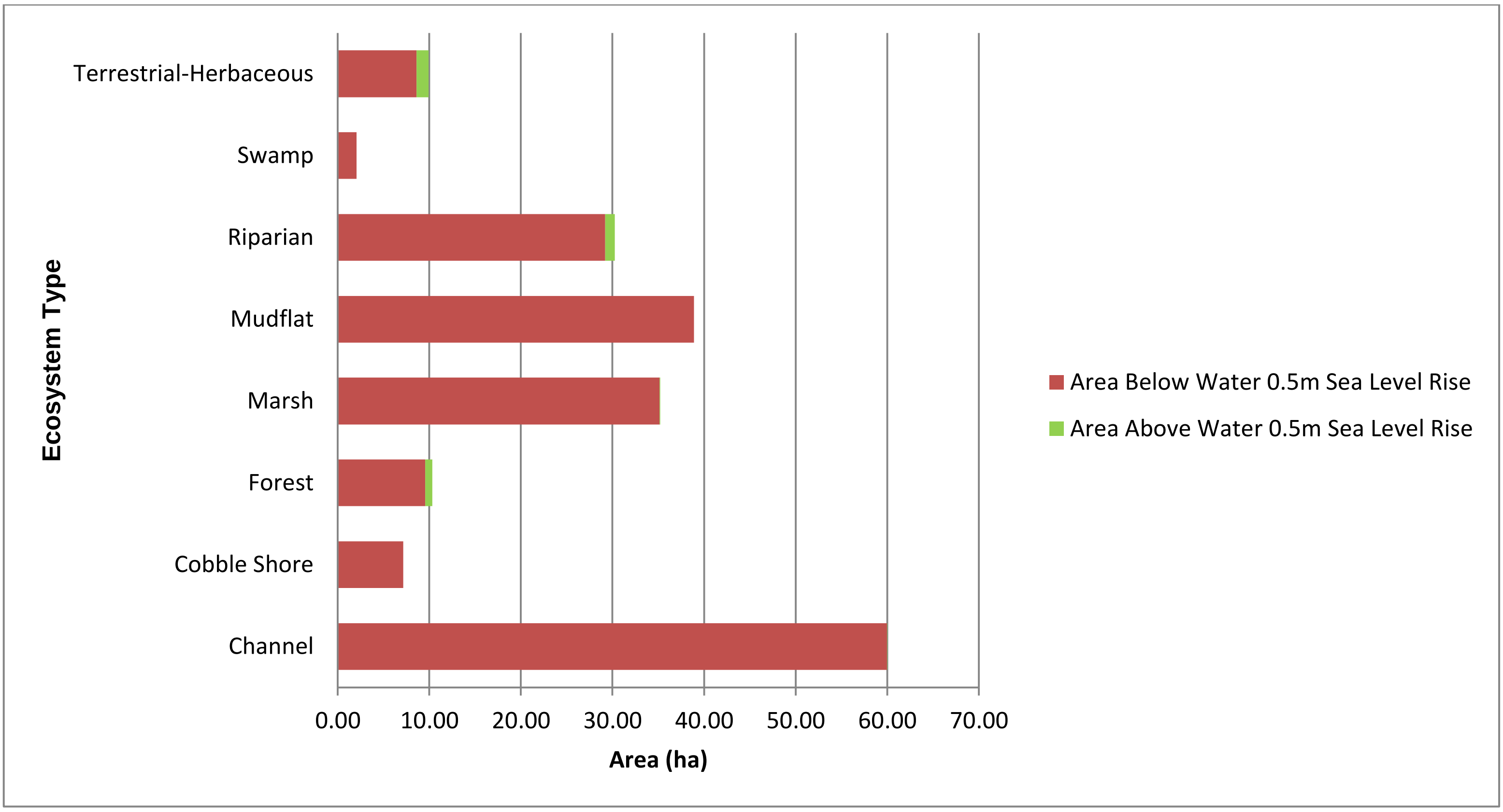
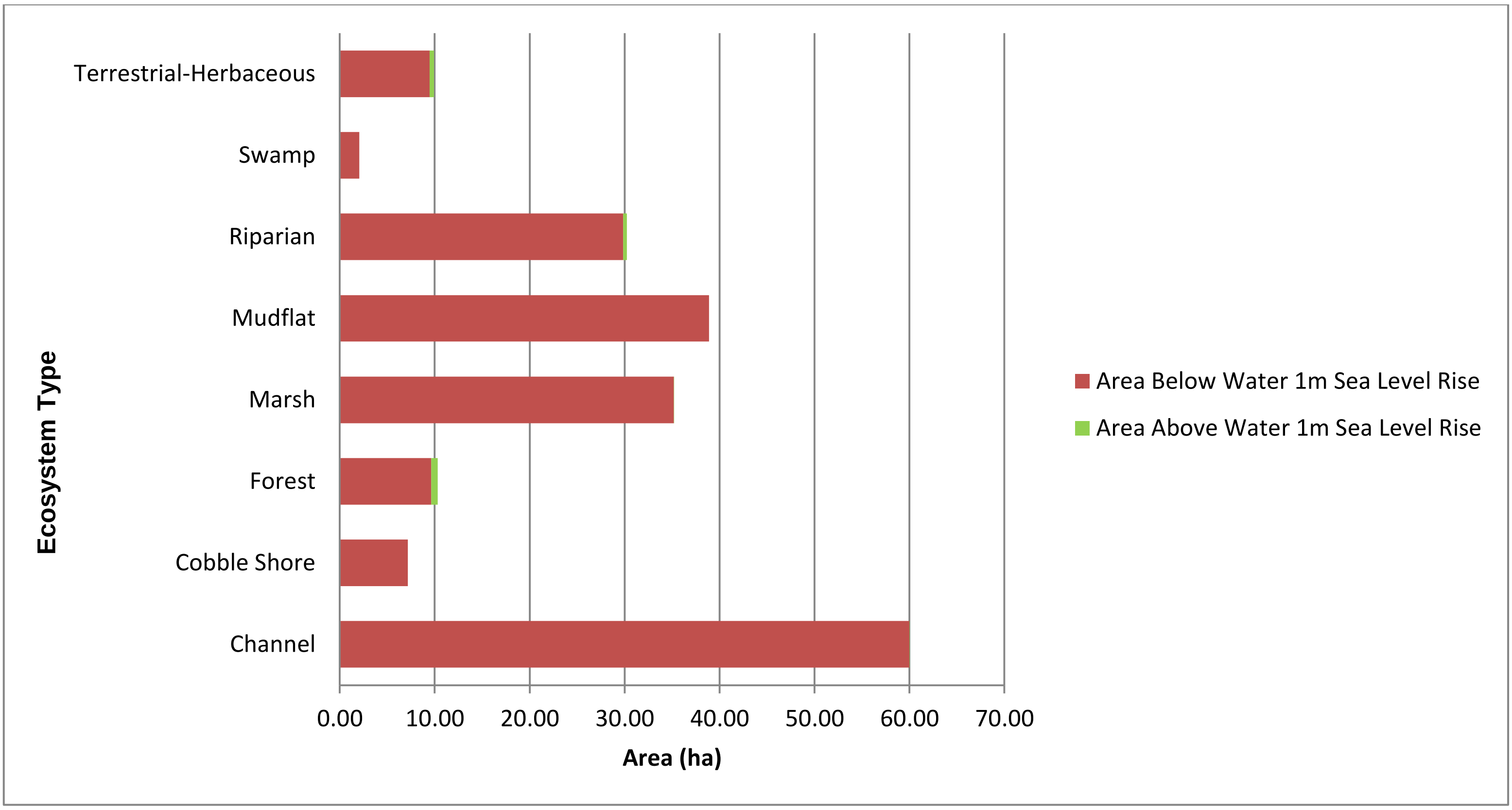


FIGURE 7: IMPACT OF 1.0M RISE IN SEA LEVEL (AREAS IN HECTARES) TO ECOSYSTEM IN CAMPBELL RIVER ESTUARY.



4.3.4 Migration of Ecosystems

This analysis looked at areas adjacent to the estuary where wetland ecosystems could potentially move into. Candidate areas are those between the existing edge of the estuary and the 6 m contour above current sea level (portrayed in Figure 2). Six metres above sea level is the approximate point where the land rises more steeply away from the estuary. Plants will colonize new areas when the ecological conditions are suitable - such as hydrology, appropriate soils, light, connectivity, and appropriate disturbance regime (in this case, for example, annual flooding or natural sedimentation). Refer to Table 6 for information on the intrinsic ability of ecosystem types to re-colonize new areas.

Faced with rising sea-levels, plants and ecosystems will first move into riparian zones that are already connected to the estuary. Specific areas include the Nunns Creek watershed; this area has protected riparian buffer reserves on both sides and leads into Nunns Creek Park, which is only a few metres above sea level. All other riparian, seepage and agricultural areas adjacent to the estuary will be candidate areas for re-location.

Secondary areas include abandoned industrial lands close to the river, where log dumping and log booming formerly took place. Other areas include parks, playing fields, and older residential areas that are close to the estuary and at risk of inundation – such as those in the Campbellton area. The City will need to gradually plan for this inward migration of ecosystems – on a lot by lot basis. Areas with compacted soils close to the river should be lightly trenched and re-planted as soon as is practical, and any pavement or asphalt should be removed.

4.3.5 Impact on Rare Plants and Ecosystems

The impact of SLR on rare plants and ecosystems is closely tied to the wetland types that provide appropriate habitat. For example, the Marsh ecosystem provides habitat for four rare plants and one ecosystem type. Unless migration occurs, the Marsh ecosystem will be almost completely inundated during intense storms matched with a high tide, even with a sea-level rise of 0.5 m.

Management of SLR impacts should include accurate baseline location mapping, monitoring, seed collection for propagation of new plants, and likely plant salvage. Accurate information on populations and coverage will help in planning and monitoring. Being aware of the current geographic distribution of these elements is important for sourcing possible seed sources, or even transplanting programs. Several of the rare plants in the estuary have a limited distribution, while the Tufted Hairgrass – Meadow Barley vegetation assemblage is rare but nevertheless has a wide distribution in coastal BC.

4.3.6 Conservation Criteria – Ecosystem Ranking

Table 6 provides a general summary of ecosystem information and provides the results of the ecosystem ranking analysis. This information is to be used as a general reference for conservation planning, as well as for engaging in restoration, rare and invasive plant management, and to inform on-going development of ecosystem services. The definitions for each of the column headings are presented in Table 4. These are largely based on information found in Section 4 of "Standard for Mapping Ecosystems at Risk in BC" (Ministry of Environment 2006). The ecosystem ranking in columns 5 and 6 refers to the inherent ability of ecosystems in the estuary to adapt to changing conditions associated with SLR (or other disturbances). For example, Mudflats (MF) are expected to increase in area because aquatic plants readily disperse in water. Note that the "increase" and "decrease" in this context is not the same as the actual predicted ecosystem loss discussed in Section 4.3.3.

TABLE 6: SUMMARY OF INFORMATION ON ESTUARINE ECOSYSTEMS, INCLUDING CONSERVATION PLANNING CRITERIA AND RESILIENCE TO SEA LEVEL RISE (OR OTHER DISTURBANCES).

Ecotype	Total current coverage (ha)**	Relative height above sea-level (0-8)	Saltwater tolerance (L/M/H)	Disturbance Adaptability (L/M/H)	Likelihood to increase (I) or decrease (D)*	Disturbances present	Known Threats	Adjacent Land Use	Invasives Present (Y/N)	Fragmentation (0-5%; 5-25%; >25%)	Landscape Context (E/G/F/P)	Condition Rating (1-5) (good to bad)	Rare Plants Present (Y/N)	SEI Class and Subclass	Provincial TEM mapcode
River/Channel (RC)	60	0	H	H	I	potential low water quality, shoreline erosion	high water turbidity	marina, seaplane base	N	n/a	G	2	N	RI:ri	RI; GB; Fa
Mudflat (MF)	38.9	1	H	H (aquatic plants colonize easily)	I	potential low water quality, waves from boats, Canada geese grazing at low tide	high water turbidity	marina, seaplane base, walking trails	N	5-25% (est.)	G	2	Y	IT	Em; Et
Marsh (MS)	35.2	3	M	H (aquatic plants colonize easily)	I	waves, Canada goose forage	high water turbidity, shoreline erosion	marina, seaplane base, walking trails	Y	5-25% (est.)	F	2	Y	IT; WN:ms	Et; Em; Wm
Cobble Shore (CS)	7.2	4	M	M	Same	high energy waves, Canada goose forage	shoreline hardening, development	seaplane base, walking trails, development	Y	5-25% (est.)	F	2	Y	IT	Bb; BE
Swamp (SW)	2	5	M	L	D	Canada goose forage	development, changes in hydrology	development	Y	>25%	F	3	Y	WN:sp	Ws; Em
Riparian (R)	30.2	6	M	M	D	flooding	development, changes in hydrology, garbage	roads, development	Y	>25%	F	3	Y	RI	Fm; Fl

Ecotype	Total current coverage (ha)**	Relative height above sea-level (0-8)	Saltwater tolerance (L/M/H)	Disturbance Adaptability (L/M/H)	Likelihood to increase (I) or decrease (D)*	Disturbances present	Known Threats	Adjacent Land Use	Invasives Present (Y/N)	Fragmentation (0-5%; 5-25%; >25%)	Landscape Context (E/G/F/P)	Condition Rating (1-5) (good to bad)	Rare Plants Present (Y/N)	SEI Class and Subclass	Provincial TEM mapcode
Forest (FO)	10.3	7	L	M	D	changes in hydrology	development, changes in hydrology	roads, development	Y	>25%	F	3	N	RI:fh; MF	numerical site series
Terrestrial Herbaceous (TH)	9.9	8	L	L	D	land clearing	development, changes in hydrology	development, housing	Y	>25%	P	4	Y	HB:cs; SV	BE
Backshore vegetation	12	4	H	M	D	tree cutting, vegetation removal, roads	fragmentation	housing and roads	Y	>25%	P	2	Y	IT	Bb; BE

**Total ecosystem coverage in the estuary is 215.8 ha. Including the backshore vegetation, it is 227.8 ha.

*This column refers to the intrinsic ability of an ecosystem type to readily recolonize new areas.

4.3.7 Shoreline Ecosystems

As noted, the focus of the ecosystem and vegetation assessment was the Campbell River estuary. However, the backshore riparian ecosystem that stretches along most of the area beyond the Campbell River estuary performs valuable ecosystem services. The backshore riparian ecosystem is fragmented and has been considerably impacted by transportation infrastructure and clearing to create ocean views.

Backshore vegetation occurs in areas above the high tide zone at the point where upland vegetation is capable of growing. Undisturbed backshore vegetation, in the Campbell River context, consists of mature deciduous and coniferous trees such as bigleaf maple, red alder, Douglas-fir and Sitka spruce interspersed with native shrubs and herbs. Old logs and pieces of driftwood may be present. Photo 2 provides an example of backshore vegetation in the study area.

Backshore vegetation grows on rocky headlands, but more commonly, in the Campbell River context, it occurs on the beach sediments that occur above the high tide mark, and in the sea-spray and storm surge zone. The sediments are non-consolidated sands and gravels of marine origin – essentially perched beaches that are now inactive. In some areas that have been exposed to wave and wind action in the past, beach materials may have been formed into small dune-like features on which vegetation is now growing. The gravelly soil is inherently nutrient poor; however, there are inputs that increase soil nutrient levels including:

- Salt spray
- Leaf litter from vegetation
- Nitrogen fixation from various plants – such as red alder and red clover
- Windblown seaweeds
- Bones and shell fragments resulting from foraging animals

4.4 Discussion

4.4.1 Management of Estuarine Ecosystems

4.4.1.1 Buffers

Buffers, defined as strips of undisturbed native vegetation at least 10 m wide, help to maintain the function of ecosystem services associated with the buffered ecosystem. Buffers are commonly prescribed for riparian ecosystems under the provincial Riparian Areas Protection Regulation (RAPR). Buffers provide visual screens for wildlife using ecosystems such as wetlands and provide security from predators (including hunters). Buffers may serve to limit access from livestock and improve habitat complexity for species that use multiple habitats. Buffers reduce sedimentation originating from upstream erosion and provide wildlife movement corridors. Buffers will also help maintain shoreline erosion and mitigate wave energy. Culturally modified trees may be present in buffer areas and these and other signs of use are of historical interest to archaeologists and First Nation communities.

In many cases, buffers will grow naturally if an area remains undisturbed. Examples of places where buffers would be important include Campbell River Spit, adjacent to any transportation infrastructure and in association with housing developments.

4.4.1.2 Invasive plants

Invasive plants are non-native species that are likely to cause environmental and economic harm. These plants often lack natural predators and, as a result, populations can spread quickly. Invasive plants often displace native vegetation and are typically of less value to wildlife. In the project study area, invasive plants are commonly found along paths, roads, in areas that are frequently flooded, or areas where garden refuse has been dumped.

After habitat loss, invasive species are the second largest threat to wetland ecosystems. In the Campbell River estuary, plants such as purple loosestrife and yellow flag iris are of concern on wetland edges due to their ability to outcompete native plants and the quantity and persistence of their seed production. In drier areas, Scotch broom can spread quickly but can be controlled with persistent removal. Giant knotweed is also a difficult plant to eradicate since it can reproduce from small root fragments. These invasive plants diminish the ecosystem services otherwise provided by these wetlands.

Invasive plants typically require full light to grow, but several plants can grow in full shade. A common technique to discourage invasive plants is to increase shade by growing tall shrubs or trees. However, this technique will not work for shade tolerant plants such as English ivy or English holly. This adaptation to shade gives these plants the potential to spread into functioning ecosystems.

Considerable volunteer work has been coordinated by Greenways Land Trust to reduce the number of invasive plants in the Campbell River estuary. This work should continue to be supported by the City. Common invasive plants found in the study area are shown in Table 7.

TABLE 7: INVASIVE PLANTS FOUND IN THE CAMPBELL RIVER ESTUARY (MIMULUS 2017). THE PRESENCE OF DAPHNE LAUREL IS NOT CONFIRMED.

Common name	Latin name	Growth requirement
Bull thistle	*Cirsium vulgare*	Full light
Canada thistle	*Cirsium arvense*	Full light
Creeping buttercup	*Ranunculus repens*	Full light, moist areas
Curled dock	*Rumex crispus*	Full light
English holly	*Ilex aquifolium*	Shade tolerant
English ivy	*Hedera helix*	Shade tolerant
Daphne laurel	*Daphne laureola*	Shade tolerant
Giant knotweed	*Fallopia japonica*	Full light
Himalayan blackberry	*Rubus discolor*	Full light
Purple loosestrife	*Lythrum salicaria*	Full light, wetland edges
Scotch broom	*Cytisus scoparius*	Full light
St. John's wort	*Hypericum perforatum*	Full light
Yellow flag iris	*Iris pseudoacorus*	Full light and moist areas

4.4.1.3 Elements of Healthy Wetlands

Elements of healthy wetlands, including those found in the Campbell River estuary, will vary between wetlands, but can include the following measurable factors (from Fletcher *et al* 2019). These factors can be measured to indicate changes to ecosystem service categories shown in Table 2:

- Plant vigour and recruitment (new plants) – in both wetland and buffer areas;
- The variety of microsites that are present within a wetland;
- Presence of coarse woody debris (CWD), in a range of sizes (important for amphibians);

- Dead tree presence around the edges (sources of CWD);
- Hydrological regime - slight changes in water drawdown or inundation can modify the wetland plant association;
- Presence and depth of water, seasonality and duration of water in the rooting zone;
- Water quality (smell, colour, pH, turbidity and temperature); and
- Quality of adjacent upland habitat to allow wildlife movement, foraging and breeding.

4.4.2 Managing Rare Plants and Ecosystems

Programs to ensure the survival and distribution of rare plants and ecosystems (as described in Table 5) will be important in terms of reducing impacts from SLR. These programs may include seed collection, propagation and growing of rare plants in a nursery followed by planting into the appropriate ecosystem type. Accurate mapping of rare element locations will be required to inform monitoring of element populations as well as spatial coverage and geographic distribution. Several of the rare plants in the Campbell River estuary have a very limited local distribution, while the Tufted Hairgrass – Meadow Barley ecosystem, while rare, has a wide distribution in coastal BC. Management documents for each of these rare elements are available on the Conservation Data Centre website (www2.gov.bc.ca/gov/plants-animals-ecosystems/conservation-data-centre).

4.5 Willow Creek Estuary – Indicator Site

A 34 m long vegetation transect was established in the Willow Creek estuary in order to monitor changes to vegetation over time resulting from SLR. The transect will provide an accurate description of the current distribution and range of species that can be monitored over the long term (Table 8). The Willow Creek estuary is easily accessible, and the spatial extent is such that it can be easily inventoried and assessed over subsequent years to determine potential shifts in vegetation types and abundance. Any shifts would help to inform impacts to numerous ecosystem service categories, but mainly the “Regulating” and “Habitat” categories linked with Marsh and Mudflat estuarine ecosystems (*e.g.* attenuation of wave energy, erosion control, pollution control, nutrient cycling, provision of productive fish habitat and provision of habitat niches for wildlife).

Changes noted over time would not only be linked to the function of the Willow Creek estuary but could also help predict or assess the magnitude of potential impacts to larger estuarine ecosystems, such as the Campbell River estuary. The Simms Creek estuary would also be expected to reflect similar changes, based on the fact that Willow Creek and Simms Creek are comparable in terms of magnitude. The spatial extents and characteristics of the estuaries are also very similar.

The Willow Creek estuary has been restored through the construction of a sheltering berm to the south that protects the area from wind and wave energy. Vegetation has also been planted around the margins of the estuary and invasive plants are being actively removed. Stone lines have been placed in the creek channel to encourage the creation of pool habitat units in the estuary.

The estuarine restoration at Willow Creek was conducted due to the fact that the original location of the estuary was eliminated when the creek was diverted directly into the Strait of Georgia. Despite the restoration efforts, the Willow Creek estuary is susceptible to SLR as it is confined, with any potential adaptive shifts currently being constrained by the highway, which passes close to the inland limit of the estuary.

Despite the small size of the Willow Creek estuary, the importance of this type of ecosystem to salmonid fish was demonstrated during the field assessment. The main pool in the estuary was being used by juvenile coho salmon (*Oncorhynchus kisutch*) during the field visit. Several hundred juveniles were observed in the pool actively feeding when the vegetation transect was completed. The use of this pool by salmonids for rearing also demonstrates the value of enhancement activities in helping to return some of the services that were lost when Willow Creek and the original estuary were impacted by construction of the highway.

TABLE 8: SUMMARY OF VEGETATION ZONES IN WILLOW CREEK ESTUARY.

Vegetation Zone	Estimated amount of inundation (% time)	Dominant plants	Latin name	% plant cover	Location on transect (wet to dry)
1	>80%	sea-shore saltgrass	*Distichlis spicata*	5	0-16 m
1		Lyngbye's sedge	*Carex lyngbyei*	75	
1		silverweed	*Potentilla anserina spp. pacifica*	5	
1		meadow barley	*Hordeum brachyantherum*	10	
1		reed canary grass	*Phalaris arundinacea*	5	
2	60-80%	silverweed	*Potentilla anserina spp. pacifica*	90	16-20m
2		meadow barley	*Hordeum brachyantherum*	10	
3	40-60%	gumweed	*Grindelia integrifolia*	75	20-24m
3		silver burweed	*Ambrosia chamissonis*	15	
3		alfalfa	*Medicago sativa*	10	
4	20-40%	gumweed	*Grindelia integrifolia*	100	24-27m
5	0-20%	dune grass	*Elymus mollis*	25	27-34m
5		Nootka rose	*Rosa nutkatensis*	25	
5		gumweed	*Grindelia integrifolia*	20	
5		common yarrow	*Achillea millefolium*	10	
5		beach pea	*Lathyrus japonicus*	10	
5		orchard grass	*Dactylis glomerata*	10	

PHOTO 6: SOUTHWESTERLY VIEW OVER THE WILLOW CREEK ESTUARY. NOTE THE GRADATION OF VEGETATION ZONES, WITH THE AREA OF GREATEST INUNDATION ON THE RIGHT OF PHOTO AND DRIEST ON THE LEFT. AUGUST 7, 2019.
Photo credit: Trystan Willmott

PHOTO 7: SOUTHERLY VIEW OVER THE WILLOW CREEK ESTUARY. THE POOL IN THE FOREGROUND HAS BEEN CREATED BY THE PLACEMENT OF STONE LINES IN THE RIVER CHANNEL. AUGUST 7, 2019.
Photo credit: Trystan Willmott

PHOTO 8: LOOKING SOUTH TOWARDS THE ROCK GROIN THAT WAS CONSTRUCTED IN 1994 TO HELP CREATE SHELTER FROM PREVAILING WINDS AND ENABLE THE CREATION OF AN ESTUARINE HABITAT AT THE MOUTH OF WILLOW CREEK. AUGUST 7, 2019.
Photo credit: Trystan Willmott

PHOTO 9: LOOKING SOUTH EAST OVER THE WILLOW CREEK ESTUARY TOWARDS THE MAIN VEGETATED AREA WHERE THE VEGETATION TRANSECT WAS CONDUCTED. AUGUST 7, 2019.
Photo credit: Trystan Willmott

PHOTO 10: LOOKING SOUTH OVER THE LINE OF THE VEGETATION TRANSECT IN THE WILLOW CREEK ESTUARY. AUGUST 7, 2019.
Photo credit: Trystan Willmott

5 Fish and Wildlife

The scope of the project did not include conducting fish sampling to determine specific species abundance or distribution, nor were detailed habitat assessments or habitat suitability rankings conducted for wildlife. Background research (in addition to local knowledge) was used to determine documented occurrences of fish and wildlife resources throughout the study area. In addition, observations during the field assessment were used to describe the general fish and wildlife attributes of the study area. Where necessary and applicable to the scope of the project, detailed assessments were conducted (*e.g.* in relation to Indicator Sites established for forage fish and freshwater habitat in the lower reaches of Simms and Willow Creeks).

5.1 Background Research – Fisheries Resource Values

To determine the documented range of fish habitat and fish distribution in the study area, the Habitat Wizard database was accessed (Habitat Wizard 2019). This provincial database provides information related to fish distribution but is by no means an exhaustive data set. It can be used to provide a general picture of the distribution of fish throughout a watershed. The local knowledge of Madrone biologists, especially in terms of recreational angling, was also used to help describe the values of fishery resources.

5.2 Background Research – Wildlife

As a main component of the species at risk aspect of the assessment, the BC Conservation Data Centre (CDC), BC Species and Ecosystem Explorer tool was accessed to check for known occurrences of rare wildlife (CDC 2019). The review of CDC data included checking for sensitive rare elements within and adjacent to the study area. In addition, a list of rare wildlife species on the Provincial Red list (extirpated, endangered, or threatened) or Blue list (special concern) that have potential to occur in the study area (based on habitat-type) was generated. This list has been provided in Appendix 1. The Wildlife Tree Stewardship Program web-based map of known raptor nest locations was also accessed (WiTS 2019).

5.3 Forage Fish Habitat – Assessment Methodology

The habitat preferences of Surf Smelt (*Hypomesus pretiosus*) - SS and Pacific Sand Lance (*Ammodytes hexapterus*) - PSL were the main focus of this assessment. These species are a component of the BC coast beach-spawning “forage fish” population, which also includes Pacific herring (*Clupea pallasi*). These fish form a critical part of the marine ecosystem, linking marine zooplankton to the production of predatory fish, birds and mammals in the upper food web (de Graaf 2017). The ocean-phase life period of Pacific salmon (especially chinook salmon – *Oncorhynchus tshawytscha* and coho salmon) depends upon forage fish (including SS and PSL) (de Graaf 2017).

Because it is located in the upper intertidal zone, spawning habitat for forage fish occurs at the frontier of changing conditions induced by SLR, and (under the umbrella of the "Habitat" ecosystem service category) was chosen as an important aspect of the project. In addition to the impacts of SLR, forage fish are susceptible to anthropogenic modifications to both the foreshore and backshore riparian areas.

Considering the current general decline of Pacific salmon stocks throughout the Pacific Northwest, the integrity of forage fish populations is extremely important. In addition, the apparent decline of species such as the Endangered Northeast Pacific southern resident killer whale (*Orcinus orca* pop. 5) that rely significantly upon chinook salmon is also a concern that has links to the general health of the forage fish population.

To help understand the field assessment process and provide some context as to the requirements of forage fish, the following sections provide background information related to the biology of forage fish.

5.3.1 Surf Smelt Spawning Habitat Preferences

One of the most important aspects of SS spawning habitat is the presence of a suitable sediment size mix at an appropriate intertidal level along the shoreline (Penttila 2007). The elevation on the beach that is used by SS for spawning is generally between the upper high tide line and the low high tide line (de Graaf 2017). Confirmed SS spawning has been documented in regions of the beach between 1.5 m and 4.5 m above chart datum, with spawning also documented at the highest level of the maximum high tide (de Graaf 2017).

SS are dependent upon a gravel component in the beach sediment, with the majority of spawning activity having been documented in sediment with particle sizes between 1 mm and 10 mm (Penttila 2001; cited in de Graaf 2017). SS spawning activity occurs in very shallow water during high tides (Penttila 2007). Based on the relative hostility of the SS spawning zone along the upper beach zone, the eggs of SS appear to have adapted to become resilient (at least to a certain extent) to temperature variations, salinity changes and desiccation (Penttila 2007). Throughout their range in the Pacific Northwest, SS are known to spawn year-round, with specific winter and summer spawning aggregations

(Penttila 2007). The incubation period for eggs is approximately 2 weeks over the summer months and 4 to 8 weeks during the winter (Penttila 2007).

5.3.2 Pacific Sand Lance Spawning Habitat Preferences

The spawning habitat used by PSL parallels that of SS spawning habitat, *i.e.* with regard to beach elevation and sediment type, and eggs of both species have been found in the same beach sediment during the winter months (Penttila 2007). PSL spawning activity can occur at lower elevations on the beach in comparison with SS (Penttila 2007). The typical particle size of PSL spawning substrate is generally a finer-grained sand mix compared to SS, with most spawning activity being documented in sand particles between 0.2 mm – 0.4 mm (Penttila 2007). As with SS, PSL eggs are thought to be resilient to extremes in temperature and salinity (Penttila 2007). Throughout their range in the Pacific Northwest, PSL have been shown to spawn in the fall and early winter months, with eggs incubating for approximately 1 month (Penttila 2007).

5.3.3 Importance of Functioning Backshore Vegetation to Forage Fish

Because SS and PSL spawning habitat is in the upper intertidal zone, both species depend upon functioning marine riparian vegetation (Backshore Riparian ecosystem type) to reduce erosion/transportation of sediment, reduce surface run-off of potential pollutants and provide shade to incubating eggs. Shade from marine riparian vegetation helps prevent the desiccation of incubating eggs from sunlight and increased temperatures (Penttila 2007). Vegetation also reduces the drying effect of wind, and SS and/or PSL eggs that occur in beaches adjacent to exposed marine riparian areas generally have a higher potential for desiccation from wind (de Graaf 2017). The provision of shade is not as important to the value of PSL spawning habitat, based on the timing of spawning (fall and early winter), and also not as important to winter-spawning SS (Penttila 2007).

The natural supply/transportation of sediment along a beach and clean water are also extremely important to the integrity of SS and PSL spawning habitat (de Graaf 2017). Modifications such as piping storm drainage can lead to the erosion of suitably sized sediment (both on the beach and in the backshore zone), bank instability and the concentration of pollutants. Larger shoreline modifications may interfere with the along-shore transportation of sediments that create SS and PSL spawning habitat.

5.3.4 Field Data Collection

Areas identified as supporting the best available potential forage fish spawning habitat in the City of Campbell River Marine Foreshore Fish Habitat Assessment (NHC and Current

Environmental 2011) were used to help locate sites for forage fish assessments, as part of the implementation of ecosystem service Indicator Sites to measure specific ecosystem service categories listed in Table 2 (refer to Section 5.7 for more detail). If the intertidal zone contained a suitable sediment mix for forage fish spawning in the areas broadly identified in the 2011 NHC and Current Environmental Report (areas rated as "Moderate" substrate suitability), sediment samples were taken for further analysis. The previous suitability mapping was used as a guide, but on occasion, observations in the field did not match the previous suitability mapping. In such instances, sediment samples were taken to indicate current areas of potential forage fish spawning habitat. In addition, forage fish spawning habitat suitability data was collected at each site.

At each of the five forage fish Indicator Sites (refer to Figure 8 for an overview of locations), transects were set parallel to the high tide line at a beach elevation equivalent to where SS and PSL spawning habitat would commonly occur (*i.e.* between the "high" high water mark and the "low" high water mark – approximately 0.4 m to 4.6 m Chart Datum) (McElhanney *et al* 2016). The location of the transect was adjusted depending on the species most likely to occur, because PSL tend to spawn slightly lower down on the beach face compared to SS. Transects were completed at a representative location within the boundaries of the sampled beach unit in areas that represented typical conditions of the overall habitat type.

Data collected at each of the assessed beach unit transects included information related to: the location of each assessed beach unit; physical beach attributes (*e.g.* slope and width of the beach); qualitative attributes of potential spawning habitat (*e.g.* depth of sediment, coverage of sediment, type of sediment, width of potential spawning habitat, potential species use); function of marine backshore vegetation; foreshore modification; backshore modification; foreshore land use; and backshore land use. Appendix 2 contains the full range of data collected at each forage fish sample site.

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Figure 8: Forage Fish Habitat Indicator Sites - Overview.

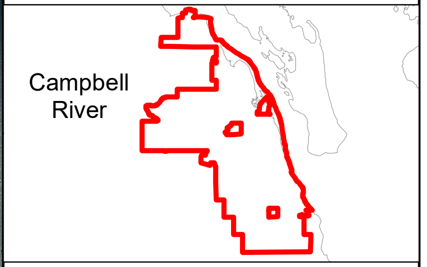
PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	MAPPING DATE:
1:42,500	October 10, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area
Watercourse
Forage Fish Habitat Indicator Sites



0 250 500 1,000 1,500 Meters
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N W E S

5.3.5 Field Data Analysis

Sediment grain size distribution was analyzed to help confirm the presence/absence of potential SS and/or PSL spawning habitat. Sediment samples were collected at each assessed beach unit transect. A representative 1 litre sample (equating to at least 1kg of dry sediment weight) was collected from a random location along each 30 m transect. The samples were scooped, bagged and labeled, making sure to sample at a depth of between 2.5 cm and 5 cm. This depth is consistent with the depth used for collecting samples to assess for SS and/or PSL embryos (as per methodology established by de Graff).

As the main objective of the project was to determine the current suitability of potential forage fish spawning habitat, the proportion of sediment particles in the preferred SS (1 – 10 mm diameter) and PSL (0.2 – 0.4 mm diameter) sediment spawning ranges were isolated from the field samples. This was achieved by air-drying the samples for 7 weeks and then sieving 1 kg of each sample through a stack of four Tyler Canadian Standard Sieves with available mesh sizes that closely matched the spawning diameter ranges: 0.21 mm; 0.42 mm; 1.0 mm and 9.5 mm. The weight of each collected fraction (including material that was either larger than 9.5 mm, less than 0.21 mm or between 0.42 mm and 1 mm) was then measured and expressed as a percentage of the overall sample weight.

PHOTO 11: SEDIMENT SAMPLES AFTER AIR DRYING PRIOR TO THE GRAIN SIZE SIEVING ANALYSIS.
Photo credit: Trystan Willmott

PHOTO 12: STACK OF SIEVES (9.5 MM, 1.0 MM, 0.42 MM AND 0.21 MM) AND SHAKER MACHINE USED FOR THE GRAIN SIZE ANALYSIS.
Photo credit: Trystan Willmott

Bar charts were produced (refer to Section 5.7) to provide a measure of the spawning habitat quality (per species) of each of the assessed indicator sites. These bar charts can be reproduced during subsequent years to help monitor long-term changes in sediment type and assess changes to potential forage fish spawning quality, and, therefore, components of the "Habitat" ecosystem service category, as a result of SLR (Backshore Riparian and Cobble Shore ecosystem types).

5.4 Stream Reach Assessment Methodology

To provide an indication of the current habitat attributes of stream reaches that could potentially be influenced by SLR, detailed reach analyses were completed for two streams: Simms Creek and Willow Creek (Figure 9). The lower 200 m of these streams were assessed in detail using Resource Information Standards Committee (RISC) site cards. Small streams such as Simms Creek and Willow Creek are often overlooked in terms of fish habitat value, but species such as coho salmon and coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) are small stream specialists.

These two index reaches can be used as Indicator Sites (refer to Section 5.8 for more detail), to help identify long-term changes to key freshwater habitat attributes that are part of the "Habitat" Ecosystem Service category (River Channel and Riparian ecosystem types). In particular, impacts to important species such as coho salmon and coastal cutthroat trout, which are able to exploit the habitat that is available in small streams, will be highlighted.

Along each stream reach, physical habitat attributes were collected, focusing on the quality of habitat in terms of providing rearing, spawning, overwintering and migration areas for salmonid fish. Data concerning channel dimensions (width, depth and gradient), channel morphology, disturbance indicators, bank shape/texture, riparian vegetation and type/abundance of cover were collected along each reach (refer to Appendix 3 for a full range of data collected along each index reach). Representative photos were taken during the survey of each reach.

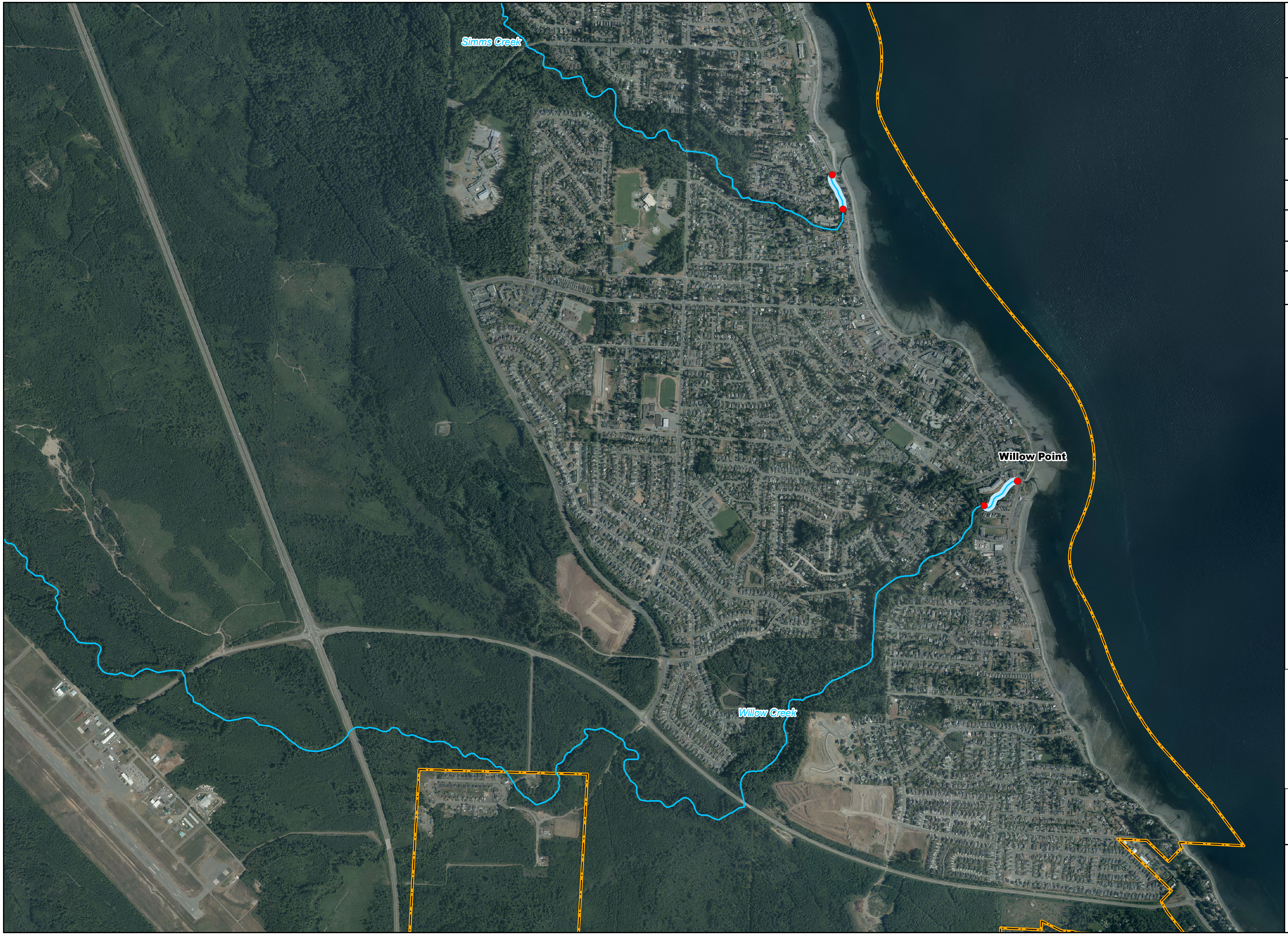

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Figure 9: Index Reaches - Overview.

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE: 1:17,000	**MAPPING DATE:** October 15, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

5.5 Results

5.5.1 Documented Fishery Resources

As per Habitat Wizard (2019), Campbell River provides documented habitat for a range of species. The natural distribution of anadromous fish, which are species that (generally) spend most of their life cycle rearing in the ocean and return to natal streams to spawn, is limited to a relatively short reach. This is due to the occurrence of Elk Falls, which is a definitive barrier to upstream fish movement. Above this barrier, the upper Campbell River system provides habitat for numerous resident fish. Anadromous fish documented as occurring in the Campbell River main stem include chinook salmon, coho salmon, chum salmon (*Oncorhynchus keta*), pink salmon, sockeye salmon (*O. nerka*), steelhead (*O. mykiss*) and anadromous coastal cutthroat trout. Documented resident fish species in the Campbell River main stem include coastal cutthroat trout, rainbow trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*), coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*Cottus asper*), slimy sculpin (*Cottus cognatus*) and threespine stickleback (*Gasterosteus aculeatus*).

Simms Creek, Willow Creek and Nunns Creek are other main systems that occur in the study area. Simms Creek provides documented habitat for chinook salmon, chum salmon, coho salmon, pink salmon, steelhead, coastal cutthroat trout, rainbow trout, sculpin (general) and threespine stickleback. Willow Creek contains documented populations of chinook salmon, chum salmon, coho salmon, pink salmon, steelhead, coastal cutthroat trout, coastrange sculpin and threespine stickleback. Nunns Creek provides known habitat for coho salmon, coastal cutthroat trout and threespine stickleback.

The fishery resource in and around Campbell River is extremely important to the local and extended economy and provides benefits in terms of First Nation resources. Indeed, Campbell River is known as 'The Salmon Capital of the World". Perhaps as an indication of future trends in salmon abundance, the fishery closures for chinook salmon in the early summer of 2019 no doubt had far-reaching impacts to the local community in terms of realized economic impacts. The closure would have had a domino effect on the economy in terms of lost revenue for guiding outfits, decreases in tourism and impacts to local businesses. This is an example of how ecosystem services provide measurable benefits to humans and highlights the inextricable link between functioning ecosystems and a functioning economy. This is because chinook salmon productivity is linked to the health of ecosystems and the services that are provided (*e.g.* forage fish habitat).

In addition to saltwater fishing opportunities, the Campbell River main stem represents an extremely important fishery resource. Generally, fishing opportunities occur year-round, with the annual pink salmon run in the summertime perhaps providing the most popular and busiest fishery. Pink salmon are significantly enhanced on the Campbell River system at the Quinsam River hatchery, with returns over recent years being significant (anecdotal evidence for 2019 suggests in excess of 500 000 pink salmon returned to the Campbell River). Whether the enhancement is having impacts upon other species of fish is not within the scope of this assessment, but an over-abundance of pink salmon may disrupt the natural ocean food chain, leading to lower food availability for species such as chinook and coho salmon.

In what would appear to be more of a positive reflection of at least the local chinook salmon population, the recent (September 20th, 2019) opening for chinook retention on the Campbell River main stem no doubt resulted in a boost for the local economy. Retention of chinook salmon in the main stem itself (beyond the specific regulations associated with the Tyee Pool and the Tyee Club) has not occurred for several years.

The fishery resource in Campbell River is also important on a historical scale. The Tyee Club provides an extremely important tourism benefit for Campbell River. This club was established in 1925 and provides an opportunity for members to fish in rowing boats using specific tackle. Any chinook salmon captured by approved methods that is over 30lb qualifies as a "Tyee". Ultimately, the long-term success of the recreational fishery, including the Tyee Club, relies on ecosystem services.

Another reminder of the importance of Campbell River's fishery resource is the Roderick Haig-Brown Heritage House. Roderick Haig-Brown (1908-1976) was a fly-fisherman, writer and conservationist who developed a deep understanding of the natural world. His former presence in the Campbell River area helps to qualify Campbell River as an important area not only for recreational fishing, but also helps to highlight the significance of sound conservation practices that were established by Haig-Brown.

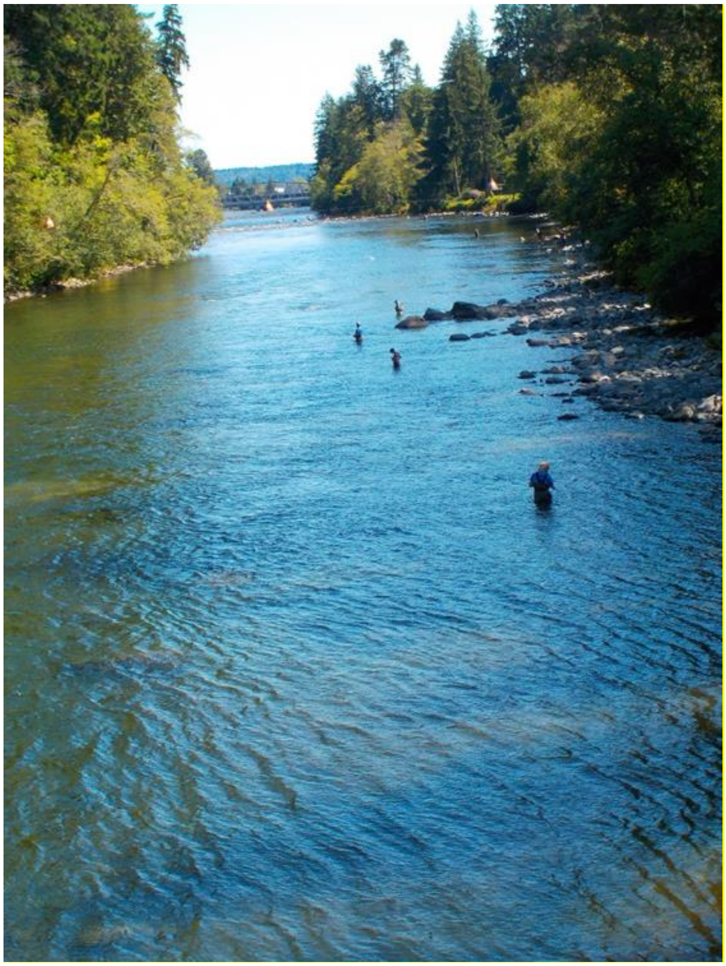

PHOTO 13: THE ANNUAL CAMPBELL RIVER RECREATIONAL PINK SALMON FISHERY ATTARCTS A SIGNIFICANT NUMBER OF LOCAL AND VISITING ANGLERS, PROVIDING INCOME TO THE LOCAL ECONOMY – PHOTO TAKEN IN MID AUGUST 2019.
Photo credit: Trystan Willmott

5.5.2 Documented Rare Wildlife Species and Known Raptor and Heron Nest Locations

The results of the BC CDC search found that only one rare wildlife species, the brant goose (*Branta bernicla*) was documented as occurring in the study area (Occurrence Record No. 7196). This record is from 1973 with the last observation date from 1988. The brant is a blue-listed (threatened) species in BC. The fact that only one listed species was documented as occurring does not accurately portray the current or potential distribution of rare wildlife species in the study area. Additional blue-listed species were observed during the field assessment (refer to Section 5.6) and potentially occurring rare wildlife species are included in Appendix 1.

The WiTS search indicated that there are well over 60 documented bald eagle nests in the City of Campbell River area. The WiTS mapping includes all nests that have ever been located. All of the nests are also shown on the City's online mapping service. However, many of these nests are no longer viable for use ("nest down", "fallen trees" and "cut trees"). For this assessment, we focused on the area within 1km of the shoreline between the former Elk Falls mill site (north) and Jubilee Parkway (south). Based on the status information provided in WiTS as well as additional information gathered through personal communication with Ian Moul, R.P.Bio. of WiTS, only 12 nests were occupied in 2019 within the focal study area. Four known territories were also occupied in 2019 where there was no viable nest (Figure 3). There are no known osprey (*Pandion haliaetus*) nests.

Personal communication with Terri Martin from the City provided information regarding the only verified location of a great blue heron (*Ardea herodias fannini*) nest in the study area. The *fannini* subspecies of great blue heron is blue-listed (threatened) in BC. This nest is located near Twillingate Road and Wayne Road and was active and successful in 2019, though the exact number of chicks raised is unknown. The location of the nest is indicated on Figure 3 along with the previously occupied nest location nearby. Another potential nest site is located near Hidden Harbour Park North, though this location has not been confirmed. We tried to verify the status of this nesting location during the field assessment, but we were unable to access the property.

5.6 General Fish Habitat and Wildlife Observations

During the two-day field assessment, the value of the diverse habitat associated with the Campbell River estuary was witnessed. Restoration and enhancement initiatives were noted throughout, especially in the Baikie Island Nature Reserve. In addition to the benefits associated with the main Campbell River main stem and connected riparian habitat, prime examples of the productivity and function of the estuary were specifically noted in the NCC and Raven side channels, which are part of the Baikie Island Nature Reserve. These channels epitomize what can be achieved when ecosystems are restored, given an appropriate natural setting (*i.e.* estuarine ecosystem). These side channels consist of a diversity of fish and wildlife habitat in the form of functioning riparian habitat, stable LWD, spawning habitat, deep pools, mature trees and cool, clean perennial water availability.

PHOTO 14: HABITAT COMPLEXITY ASSOCIATED WITH THE RAVEN SIDE CHANNEL. AUGUST 7TH, 2019
Photo credit: Trystan Willmott

The mosaic of habitat types and abundance of edge habitat throughout the Campbell River estuary provide significant habitat attributes for wildlife. Despite the time of year, numerous species of birds were heard and/or observed while conducting the field visits:

- belted kingfishers (*Megaceryle alcyon*);
- great blue herons;
- barn swallows (*Hirundo rustica*);
- turkey vultures (*Cathartes aura*);
- bald eagles;
- common mergansers (*Mergus merganser*);
- willow flycatchers (*Empidonax traillii*);
- northern flickers (*Colaptes auratus*);
- common yellowthroats (*Geothlypis trichas*);
- glaucous-winged gulls (*Larus glaucescens*); and
- purple martins (*Progne subis*).

The majority of the species listed above were observed either in or flying over the Campbell River estuary. Great blue herons were also observed sporadically foraging on the foreshore throughout the study area.

The Campbell River estuary provides important habitat for migrating birds as part of the "Pacific Flyway". To provide some context as to the importance of the habitat, a study conducted by the Canadian Wildlife Service that documented bird use in the estuary between 1982 and 1984 indicated that a minimum of 5, 689 birds used the estuary for at least part of their life history during the study period (Dawe et al 1995). The number of species using the estuary over the study period was 125 (Dawe et al 1995).

The barn swallow is considered to be provincially blue-listed, threatened federally and included in Schedule 1 as threatened under the Species at Risk Act (SARA). The purple martin is blue-listed on a provincial basis, and the great blue heron is considered to be provincially blue-listed, a federal species of special concern and is included in Schedule 1 of the SARA as a species of special concern. The apparent success of the purple martin nest box program in the Campbell River estuary was observed during the field visit, where the birds were seen in and around the area of the nest boxes.

Potential impacts to these rare species would be expected to be tied to the loss in spatial coverage of the mosaic of estuarine ecosystems described in Section 4. It is possible that species would move over time, assuming that ecosystems are able to successfully migrate, and specific habitat niches are maintained.

PHOTO 15: PURPLE MARTIN NEST BOXES LOCATED IN THE CAMPBELL RIVER ESTUARY. AUGUST 7TH, 2019
Photo credit: Trystan Willmott

PHOTO 16: GREAT BLUE HERON FORAGING IN THE STUDY AREA. AUGUST 7TH, 2019
Photo credit: Trystan Willmott

Resident Canada geese were also noted in relatively high numbers throughout the Campbell River estuary. These birds were mainly observed on the intertidal islands that were constructed and planted as part of habitat enhancement to compensate for the historical construction of a dry land log sort (as described in Dawe et al 2015). The impacts of Canada geese are not discussed in detail as part of this assessment, but it is known that grazing impacts have negative effects upon primary marsh production, with associated impacts to the detrital food web (Dawe et al 2015). Canada goose grazing impacts will likely reduce the resiliency of estuarine ecosystems to impacts associated with SLR.

A study completed by Dawe et al (2015) seems to support the assumption that Canada goose grazing can have serious implications to the recovery of estuarine ecosystems. In the study, islands constructed in 1981 to compensate for the construction of a dry land log sort were monitored between 1994 and 2012. The main findings of the study showed that restoration of desirable vegetation on the islands was initially very successful, but grazing impacts from Canada geese have resulted in significant impacts to the vegetation assemblages on both the constructed and natural islands.

PHOTO 17: RESIDENT CANADA GEESE FORAGING IN THE CAMPBELL RIVER ESTUARY. AUGUST 7TH, 2019
Photo credit: Trystan Willmott

Specific values of estuarine ecosystems and connected freshwater habitat was also noted in the Simms Creek and Willow Creek estuaries. These areas were subject to more detailed assessments, as described in Section 5.8.

Another location that was noted as providing significant fish and wildlife habitat diversity was the area of habitat restoration near the Discovery Harbour Shopping Centre. A complex of planted estuarine channels was created to help reclaim estuarine habitat that had been lost to road development. This area provides seasonal rearing habitat for fish and provides important wildlife habitat attributes. The restored area is adjacent to mature forest, which provides extensive edge habitat. Edge habitat is important to numerous species of wildlife. For example, raptors will use edge habitat to assist in ambush hunting. The interface between the forested area and restored estuarine habitat was being actively used by a bald eagle during the assessment.

PHOTO 18: BALD EAGLE PERCHING IN THE INTERFACE HABITAT BETWEEN MATURE FOREST AND THE RESTORED ESTUARINE AREA NEAR THE DISCOVERY HARBOUR SHOPPING CENTRE. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

5.7 Forage Fish Habitat – Indicator Sites

In order to capture the current range of sediment sizes that occurs at the best available forage fish spawning habitat (using areas mapped as "Moderate" suitability in the 2011 NHC and Current Environmental Report as a guide), 5 Indicator Sites were chosen. Details of each site in terms of sediment size range and suitability of the habitat for SS and/or PSL spawning are discussed in the following sub-sections. Detailed descriptions of each site are included in Appendix 2.

The Indicator Sites will provide the opportunity for changes to foreshore sediment distribution to be monitored over time, which will inform changes to a component of the "Habitat" ecosystem service category (associated with the Cobble Foreshore and Backshore Riparian ecosystem types). As discussed, the "Habitat" ecosystem service category associated with forage fish spawning has inter-connections with many factors, including (but not limited to) food availability for predators such as Pacific salmon, and, further up the food chain, killer whales and humans. Economic values are also affected by forage fish habitat in the form of the provision of salmon for the recreational and commercial fisheries.

Any long-term changes to the sediment distribution will reflect potential sediment-size shifts due to SLR and any associated variations in coastal processes such as wave energy and scour. Negative impacts over time would be noticeable in terms of a shift in the availability of suitably sized spawning sediment in the preferred ranges for SS and PSL, as shown in Figures 10, 12, 14, 16, 18 and 20). To ensure consistency, any follow-up sampling to monitor the Indicator Sites should take place during the summer months during stable weather conditions and similar tide heights.

The data collected at each of the Indicator Sites (Appendix 2) can also be used to detect changes to the suitability of forage fish spawning habitat and changes to coastal processes by providing baseline attributes in terms of aspects such as beach slope, sediment depth, beach width, potential spawning locations and limiting sediment type. Descriptions of the backshore zone can be used to track changes to the availability and quality of marine backshore vegetation (Backshore Riparian ecosystem type) at each of the Indicator Sites.

In general terms, the sediment distribution in those areas of the Cobble Shore ecosystem type identified as having "Moderate" spawning habitat suitability in the 2011 NHC and

Current Environmental Report appears to offer potential spawning habitat for both SS and PSL. In addition to the previous suitability mapping project, other areas were determined to offer at least "Moderate" suitability. For example, the majority of the eastern shore of Tyee Spit, which was mapped as having "Low-Moderate" substrate suitability in the NHC and Current Environmental Report was shown to have at least "Moderate" substrate suitability. Also, significant lengths of beach that could be observed from public access points in the northern portion of the study area between Orange Point and McDonald Road displayed sediment that typified potential forage fish spawning habitat. This whole area was mapped as having "Low" substrate suitability in the 2011 NHC and Current Environmental Report. Based on lack of access and time constraints, no Indicator Sites were established in this area of potential spawning habitat. Potential forage fish habitat likely also exits in other un-surveyed areas indicated as having less than "Moderate" habitat suitability in the 2011 NHC and Current Environmental Report, but for the purposes of identifying Indicator Sites, the existing mapping and recent field verification were adequate.

The sieving results show that the sediment type at each of the Indicator Sites was more suited to SS, based on specific particle size preferences (Figure 10).

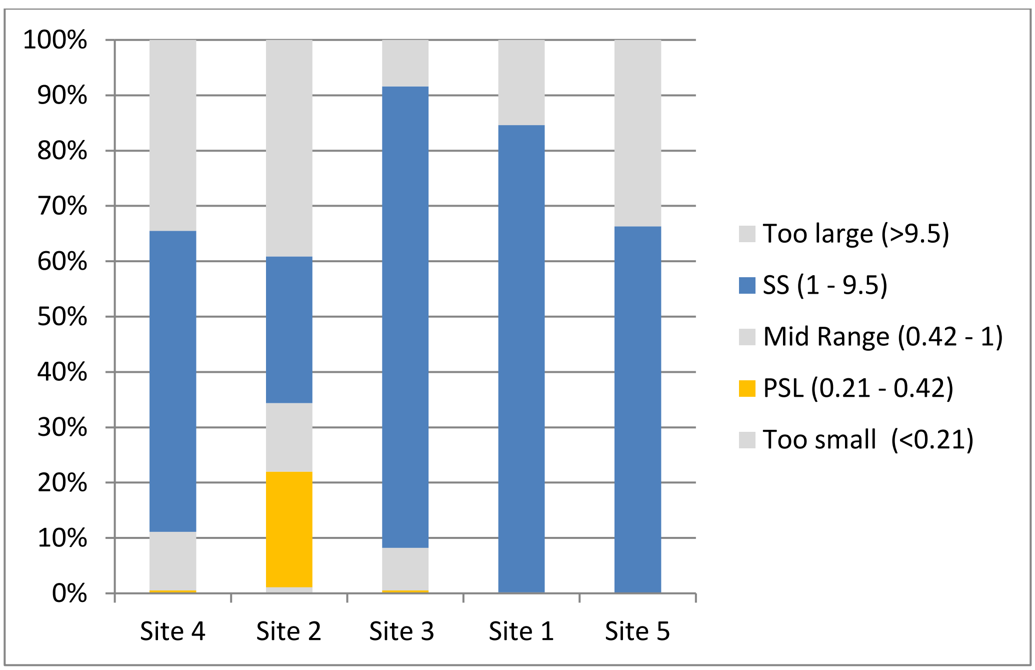

FIGURE 10: CAMPBELL RIVER - SUMMARY OF SEDIMENT SIZES AT INDICATOR SITES BASED ON SUITABILITY FOR SS AND PSL SPAWNING.

In terms of the current resilience of potential forage fish spawning habitat to SLR and changes in coastal sediment distribution processes, historical and on-going anthropogenic activities have generally eroded the stability of the system. The marine backshore zone exhibits a consistent lack of biological function, based on the proximity of hardened surfaces such as the Sea Walk, highway, parking areas and private developments. These features severely limit the ability of the marine backshore zone to provide positive benefits to forage fish habitat in the form of shading and wind shelter (thereby increasing the potential for forage fish eggs to become desiccated), bank stability, contaminant buffering and maintaining natural movements of sediment along the beach face. In addition, constructed coastal defences such as rip-rap and retaining walls have interrupted, and will continue to interrupt, the movement and distribution of sediment on the foreshore.

5.7.1 Forage Fish Indicator Site 1

This Indicator Site is located adjacent to the Ken Forde Park and boat ramp and provides a suitable representation of the best available habitat along the beach unit (Figure 11). The beach is gently-sloping, with what was assumed to be suitable spawning substrate for SS during the field assessment. The beach is fully exposed, with no shading or wind-shelter functions provided, due to the composition of the backshore habitat. The backshore area is composed of a narrow (approximately 10 m) vegetated buffer situated between the upper beach and hardened surfaces associated with a trail and parking area. Access points have been provided along the City owned frontage of the park to reduce encroachment into the marine backshore zone. The highway parallels the sampled beach unit within approximately 20 m of the upper beach. At Willow Point (immediately north of the assessment location), the foreshore has been impacted by a concrete boat ramp and rip-rap "breakwater". Suitable sediment appears to extend for at least 100 m to the south of the sediment sample location, but to the north of the boat ramp, the sediment progressively shifts to a predominantly cobble component.

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Figure 11: Forage Fish Habitat Indicator Sites -Site 1.

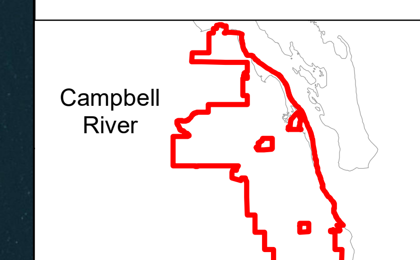
PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:1,800	October 10, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area
Watercourse
Forage Fish Habitat Indicator Site



0 10 20 40 60 Meters
1:1,800

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PHOTO 19: LOOKING SOUTH ALONG THE SITE 1 SAMPLING TRANSECT (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 20: LOOKING WEST ALONG THE BEACH FACE AT SITE 1 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 21: LOOKING EAST TOWARDS THE OCEAN AT SITE 1 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 22: LOOKING SOUTH ALONG THE VEGETATED STRIP IN THE MARINE BACKSHORE ZONE ADJACENT TO KEN FORDE PARK AT SITE 1 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 23: LOOKING SOUTH ALONG THE PAVED TRAIL ADJACENT TO THE NARROW STRIP OF BACKSHORE VEGETATION AT SITE 1 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 24: EXAMPLE OF A BEACH ACCESS TRAIL AT SITE 1 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 25: FORESHORE ENCROACHMENT CLOSE TO SITE 1 IN THE FORM OF A PUBLIC BOAT RAMP AT KEN FORDE PARK (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 26: LOOKING NORTH FROM SITE 1 SHOWING TYPICAL FORESHORE HARDENING AND ENCROACHMENT INTO THE MARINE BACKSHORE ZONE (AUGUST 7, 2019). NOTE SHIFT IN SUBSTRATE TYPE TO COBBLES AND BOULDERS.
Photo credit: Trystan Willmott

Currently, the range of sediment particles provides potential spawning habitat for SS at this Indicator Site. As per Figure 12, the majority of the sediment is comprised of particles in the 1 – 9.5 mm range, with very little variation.

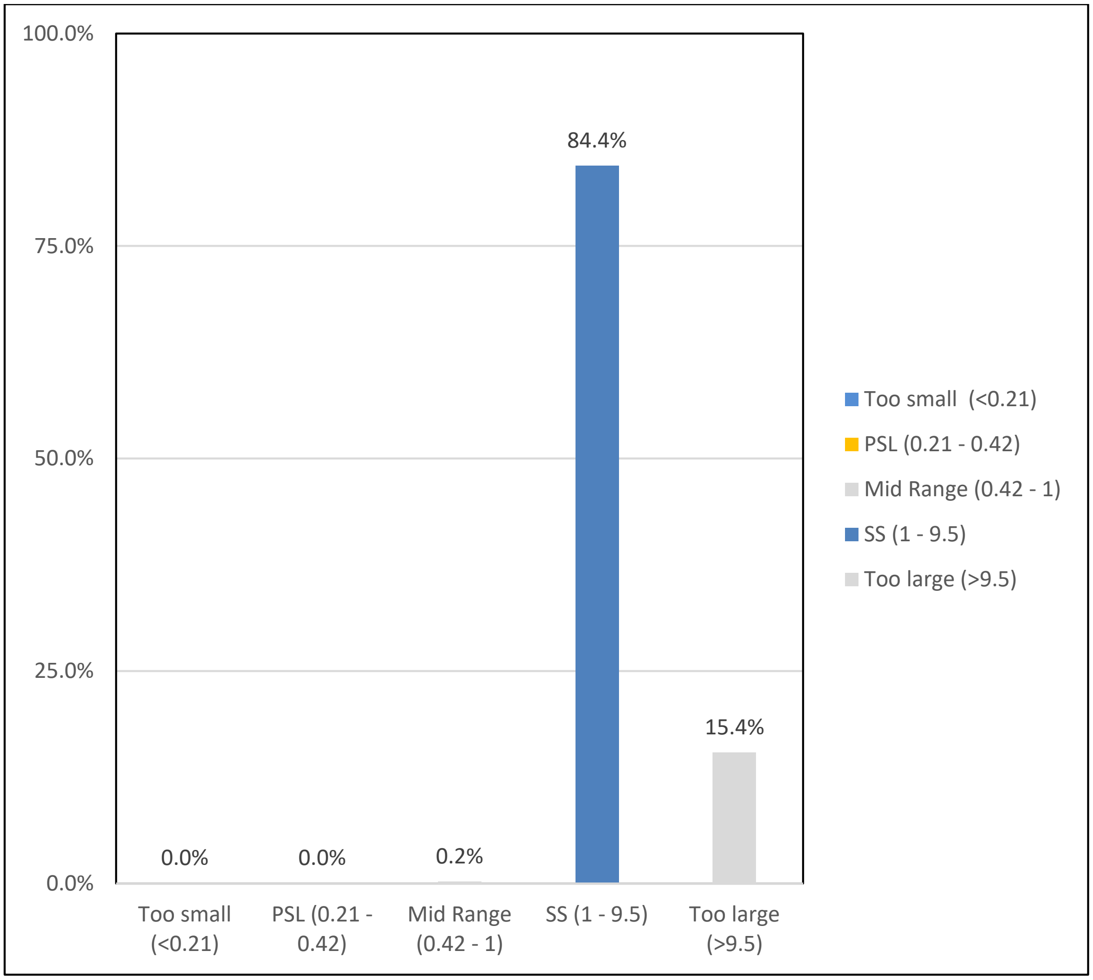

FIGURE 12: SEDIMENT SAMPLE BAR CHART FOR FORAGE FISH INDICATOR SITE 1 SHOWING SUITABILITY OF SEDIMENT FOR SS AND PSL SPAWNING.

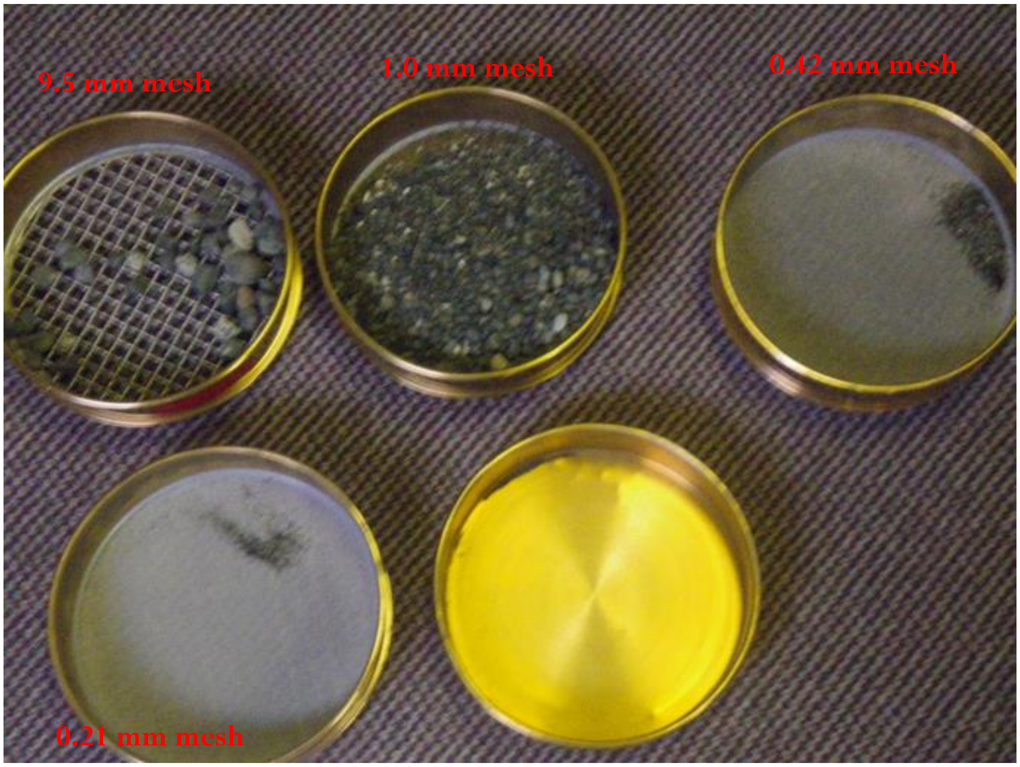

PHOTO 27: RETAINED FRACTIONS OF SEDIMENT PARTICLES FOLLOWING THE SIEVING ANALYSIS FOR SITE 1. NOTE PREDOMINANCE OF PARTICLES IN THE 1-9.5MM RANGE (MID-UPPER SIEVE).
Photo credit: Trystan Willmott

5.7.2 Forage Fish Indicator Site 2

This Indicator Site occurs between Frank James Park to the south and the Simms Creek estuary to the north and is located in an area that represents the best available habitat for forage fish spawning (Figure 13). During the field assessment, the beach was assumed to offer potential spawning habitat for both SS and PSL. The beach is gently sloping, with a narrow (approximately 10 m) vegetated buffer between the upper beach limit and hardened surfaces consisting of the Sea Walk, parking area and highway. The beach is generally exposed with little shading, but a continuous treed fringe approximately 100 m long does occur adjacent to the northern extent of the beach. The assessment location provides a suitable example of the best available habitat in this area.

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Figure 13: Forage Fish Habitat Indicator Sites - Site 2

PROJECT:
Sea Level Rise: Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE: 1:1,800	**MAPPING DATE:** October 10, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area
Watercourse
Forage Fish Habitat Indicator Site

Campbell River

0 10 20 40 60 Meters
1:1,800

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PHOTO 28: LOOKING SOUTH ALONG THE SITE 2 TRANSECT (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 29: LOOKING WEST ALONG THE BEACH FACE AT SITE 2 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 30: LOOKING EAST TOWARDS THE OCEAN AT SITE 2 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 31: LOOKING NORTH ALONG THE NARROW STRIP OF BACKSHORE VEGETATION AT SITE 2. THE TREED FRINGE TO THE NORTH EXTENDS FOR APPROXIMATELY 100 M (AUGUST 7, 2019).
Photo credit: Trystan Willmott

As shown by the sediment sieving analysis, this Indicator Site currently provides potential spawning habitat for both PSL and SS (Figure 14). This is because the 0.21 – 0.42 mm and 1 – 9.5 mm grain size proportions are both adequately represented.

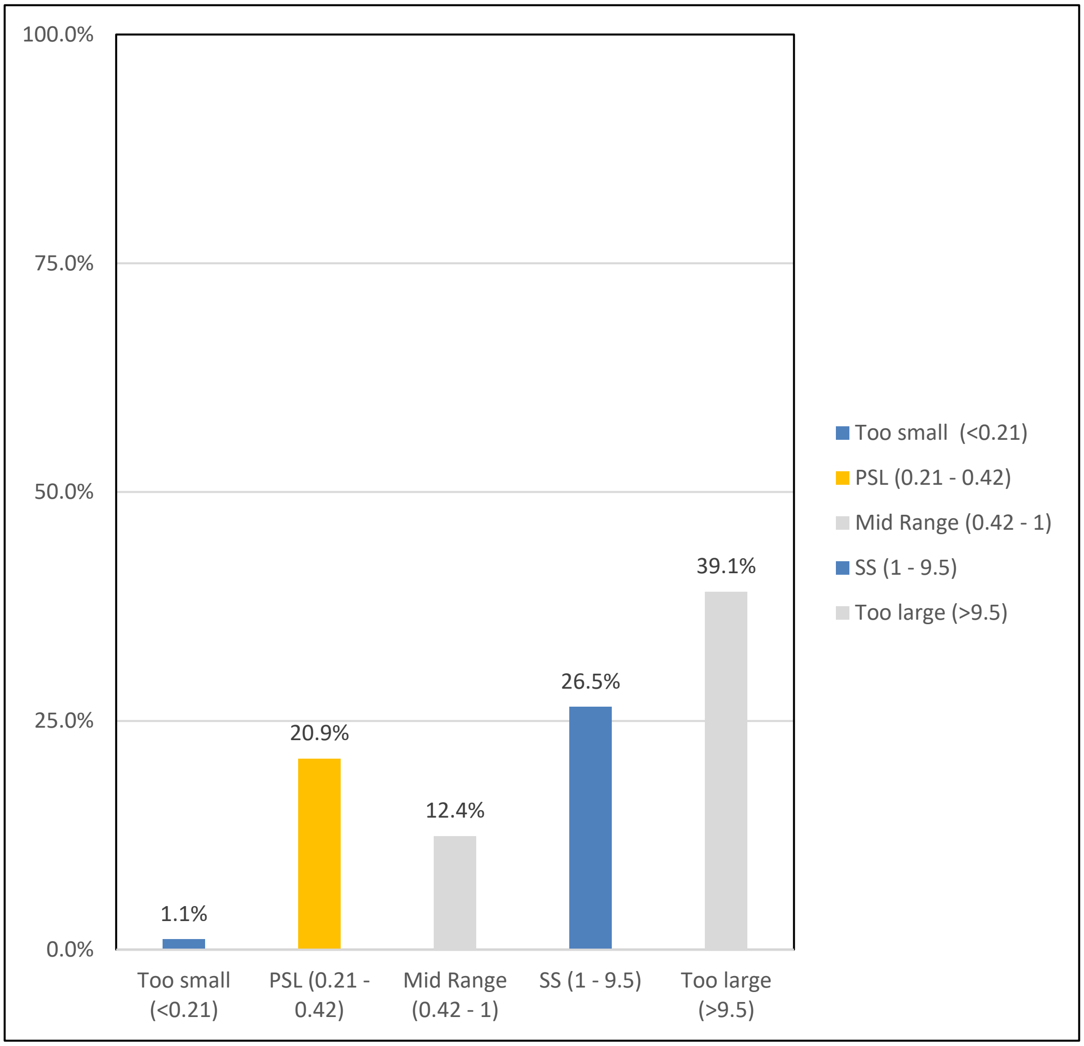

FIGURE 14: SEDIMENT SAMPLE BAR CHART FOR FORAGE FISH INDICATOR SITE 2 SHOWING SUITABILITY OF SEDIMENT FOR SS AND PSL SPAWNING

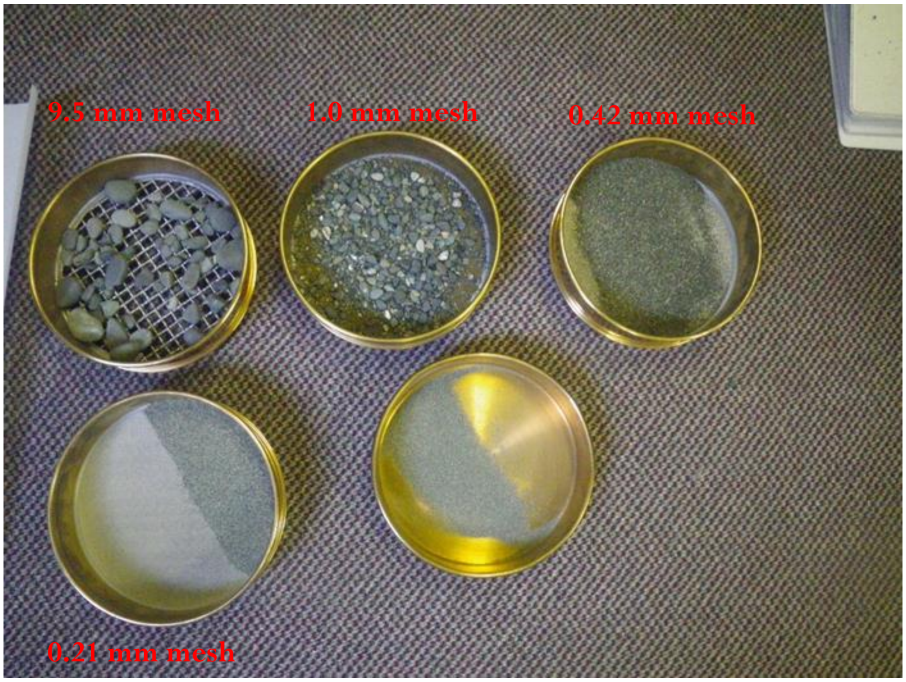

PHOTO 32: RETAINED FRACTIONS OF SEDIMENT PARTICLES FOLLOWING THE SIEVING ANALYSIS FOR SITE 2. NOTE PARTICLES IN THE 1-9.5MM RANGE (MID-UPPER SIEVE) AND 0.21 – 0.42 MM RANGE (BOTTOM LEFT SIEVE).
Photo credit: Trystan Willmott

5.7.3 Forage Fish Indicator Site 3

A pocket beach located adjacent to the Hidden Harbour strata development provides a suitable location for this forage fish spawning habitat Indicator Site (Figure 15). The assessment location provides a suitable representation of the best available habitat along the beach unit. The beach face is gently sloping, with a narrow (approximately 5 m) vegetated fringe between the upper limit of the beach and the adjacent landscaped strata development. The beach is fully exposed, with no shading or wind-shelter functions provided. The majority of the backshore area consists of manicured lawn and condominiums. The beach was assumed to offer potential SS spawning habitat during the field assessment.

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FIGURE 15: FORAGE FISH HABITAT INDICATOR SITES - SITE 3.

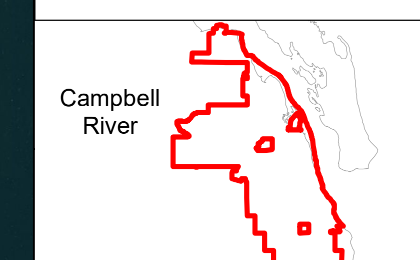
PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE: 1:1,800	**MAPPING DATE:** October 10, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area
Watercourse
Forage Fish Habitat Indicator Site



0 10 20 40 60
Meters
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N
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PHOTO 33: LOOKING SOUTH ALONG THE SITE 3 TRANSECT (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 34: LOOKING WEST ALONG THE BEACH FACE AT SITE 3 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 35: LOOKING EAST TOWARDS THE OCEAN AT SITE 3 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 36: LOOKING NORTH WEST OVER THE NARROW FRINGE OF BACKSHORE VEGETATION AT SITE 3. NOTE PROXIMITY OF DISTURBED HABITAT (AUGUST 7, 2019).
Photo credit: Trystan Willmott

Following the sediment sieving analysis, this Indicator Site was currently shown to provide potential spawning habitat for SS, based on an abundance of particles in the 1 – 9.5 mm size range (Figure 16). Little variation was noted in the grain size distribution.

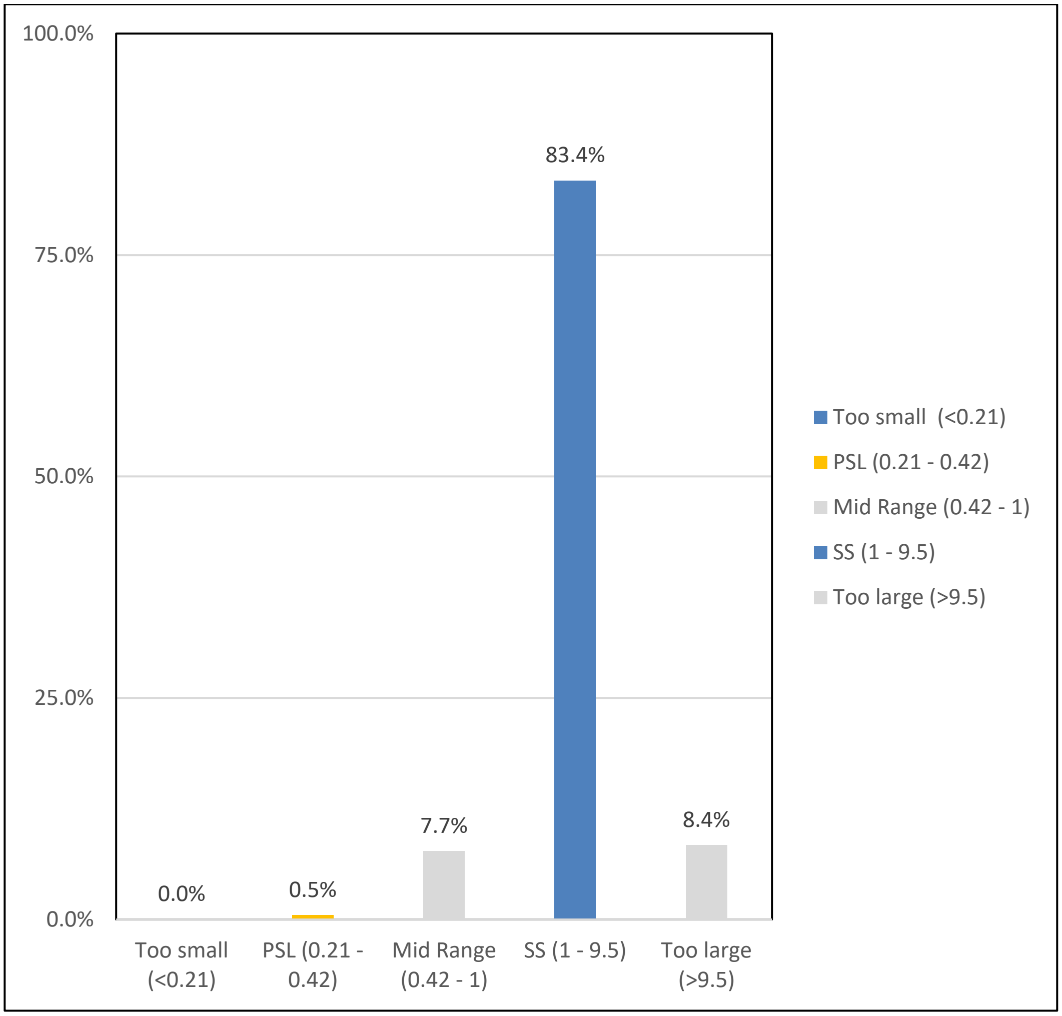


FIGURE 16: SEDIMENT SAMPLE BAR CHART FOR FORAGE FISH INDICATOR SITE 3 SHOWING SUITABILITY OF SEDIMENT FOR SS AND PSL SPAWNING.

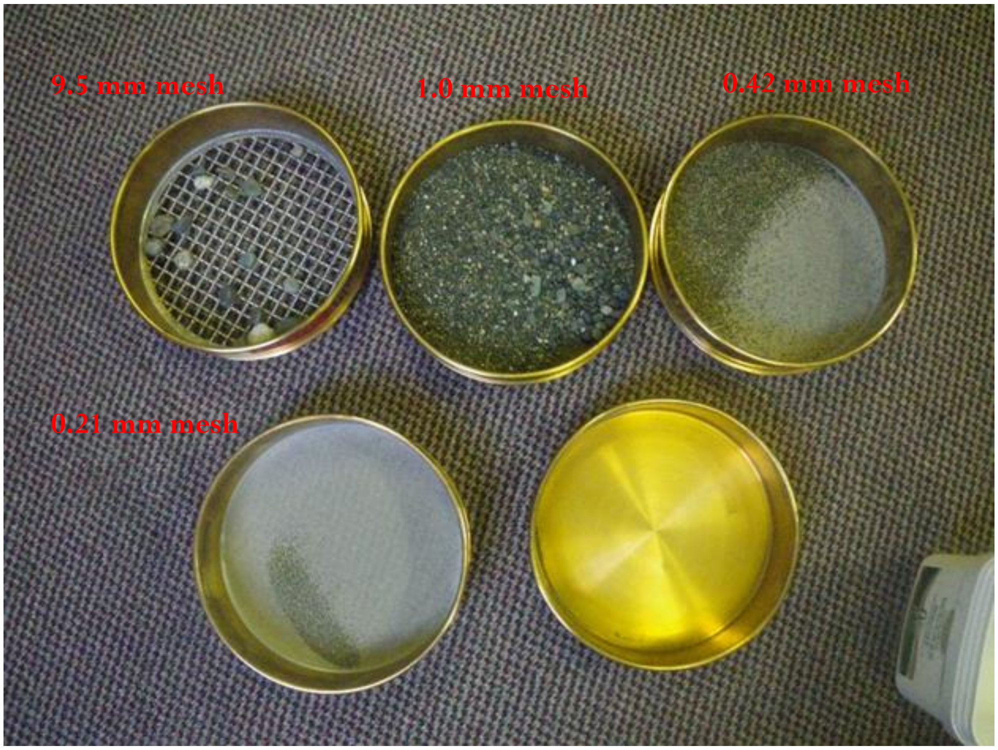


PHOTO 37: RETAINED FRACTIONS OF SEDIMENT PARTICLES FOLLOWING THE SIEVING ANALYSIS FOR SITE 3. NOTE ABUNDANCE OF PARTICLES IN THE 1-9.5MM RANGE (MID-UPPER SIEVE).
Photo credit: Trystan Willmott

5.7.4 Forage Fish Indicator Site 4

This Indicator Site is located on a "pocket beach" to the immediate south of the Discovery Pier development area and was assumed to provide potential spawning habitat for SS during the field assessment (Figure 17). The beach is gently sloping and provides a suitable representation of the best available habitat in the beach unit. The intertidal zone is almost completely exposed, but some tall shrubs and trees along part of the backshore zone provide some shading and shelter from wind. The northern segment of the beach is adjacent to the hardened surfaces of the Discovery pier parking area and the rip-rap breakwater protecting the Discovery Marina.

Figure 17: Forage Fish Habitat Indicator Sites -Site 4

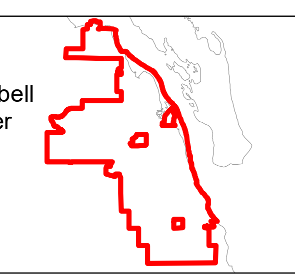
PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:1,800	October 10, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area
Watercourse
Forage Fish Habitat Indicator Site



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1:1,800

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PHOTO 38: LOOKING SOUTH ALONG THE SITE 4 TRANSECT (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 39: LOOKING WEST ALONG THE BEACH FACE AT SITE 4 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 40: LOOKING EAST TOWARDS THE OCEAN AT SITE 4 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 41: LOOKING NORTH TOWARDS THE BREAKWATER ASSOCIATED WITH THE DISCOVERY MARINA CLOSE TO SITE 4 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

Indicator Site 4 was shown to provide potential spawning habitat for SS after the sediment sieving analysis. This was based on the relative number of particles in the 1 – 9.5 mm range (Figure 18).

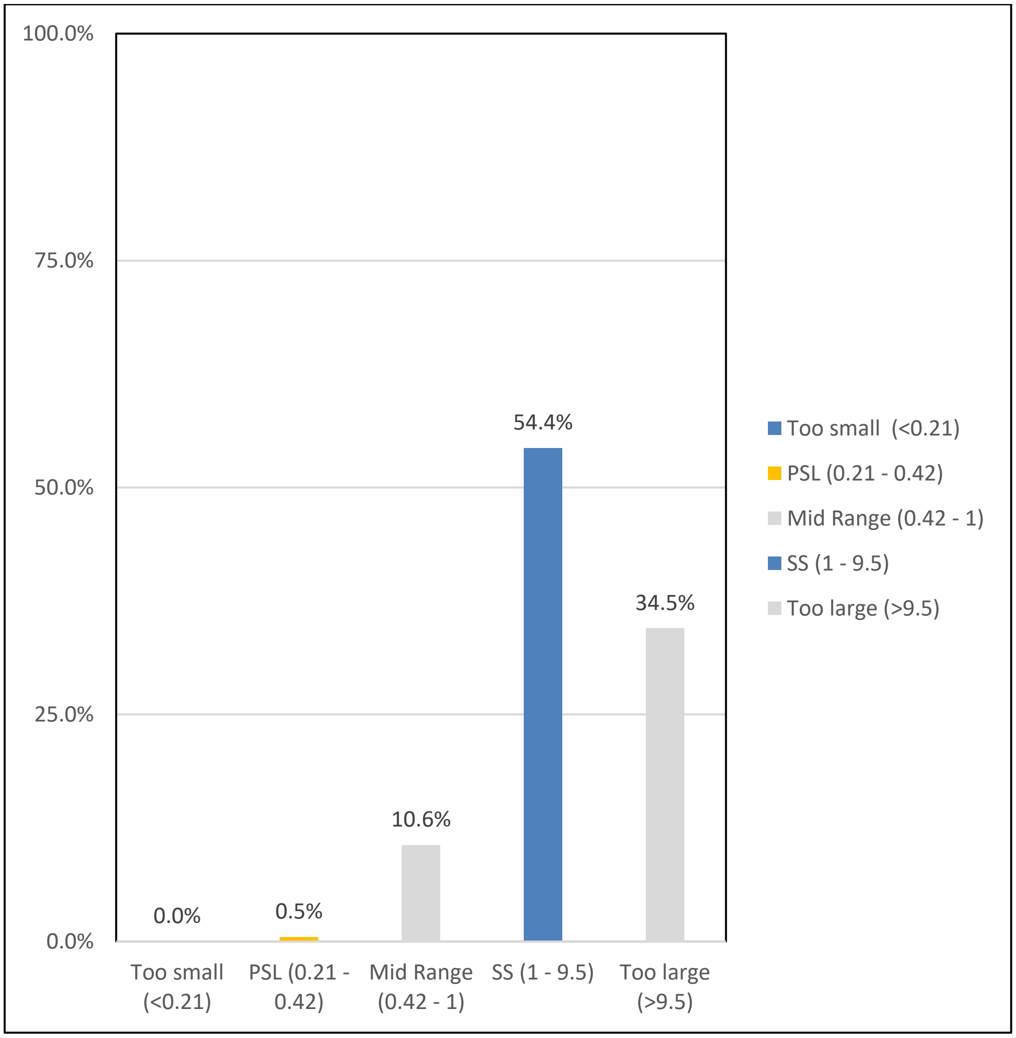

FIGURE 18: SEDIMENT SAMPLE BAR CHART FOR FORAGE FISH INDICATOR SITE 4 SHOWING SUITABILITY OF SEDIMENT FOR SS AND PSL SPAWNING

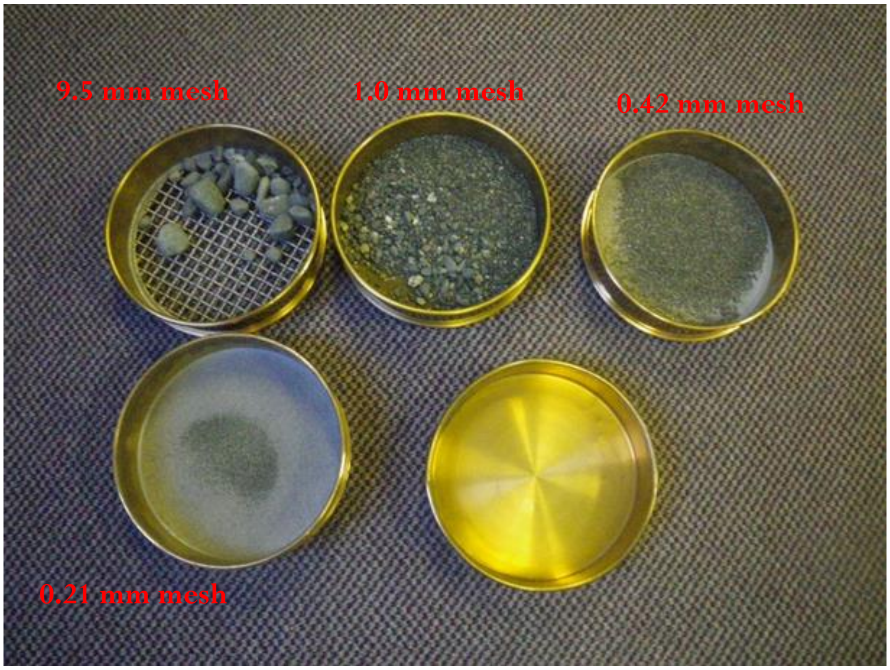

PHOTO 42: RETAINED FRACTIONS OF SEDIMENT PARTICLES FOLLOWING THE SIEVING ANALYSIS FOR SITE 4. NOTE ABUNDANCE OF PARTICLES IN THE 1-9.5MM RANGE (MID-UPPER SIEVE).
Photo credit: Trystan Willmott

5.7.5 Forage Fish Indicator Site 5

Indicator Site 5 was chosen as the best location to represent the potential forage fish spawning habitat that occurs along the eastern shore of Tyee Spit adjacent to Dick Murphy Park (Figure 19). The gently sloping beach leads up to a backshore riparian zone consisting of shrubs and grasses. The beach is exposed, due to the composition of the backshore riparian zone, which is composed of shrubs and grasses typical of sand-dominated ecosystems. Beyond the immediate vegetated backshore fringe (a strip of approximately 5-8 m), the backshore zone supports a City owned public park, with hiking trails, parking areas and maintained lawns.

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Figure 19: Forage Fish Habitat Indicator Sites - Site 5

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:1,800	October 10, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area
Watercourse
Forage Fish Habitat Indicator Site

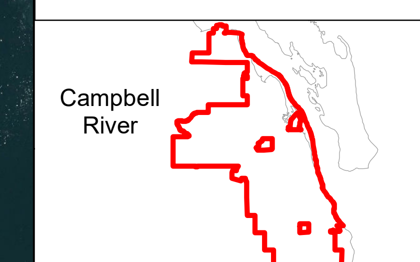

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PHOTO 43: LOOKING SOUTH ALONG THE SITE 5 TRANSECT (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 44: LOOKING WEST ALONG THE BEACH FACE AT SITE 5 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 45: LOOKING EAST TOWARDS THE OCEAN AT SITE 5 (AUGUST 7, 2019).
Photo credit: Trystan Willmott

PHOTO 46: LOOKING NORTH WEST OVER THE NARROW STRIP OF VEGETATED BACKSHORE AT SITE 5 IN DICK MURPHY PARK (AUGUST 7, 2019).
Photo credit: Trystan Willmott

The sediment size range at Indicator Site 5, as per the sieving analysis, shows a predominance of sediment in the 1 – 9.5 mm range. This represents suitable spawning habitat for SS (Figure 20).

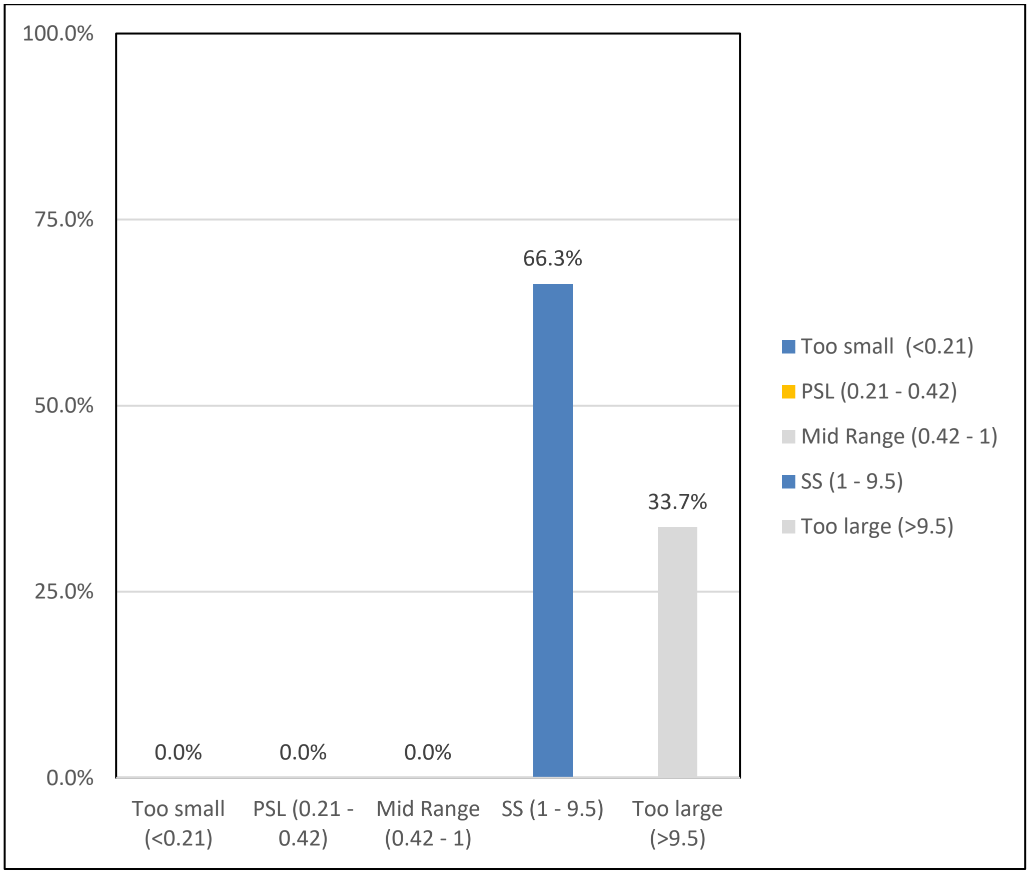

FIGURE 20: SEDIMENT SAMPLE BAR CHART FOR FORAGE FISH INDICATOR SITE 5 SHOWING SUITABILITY OF SEDITMENT FOR SS AND PSL SPAWNING.

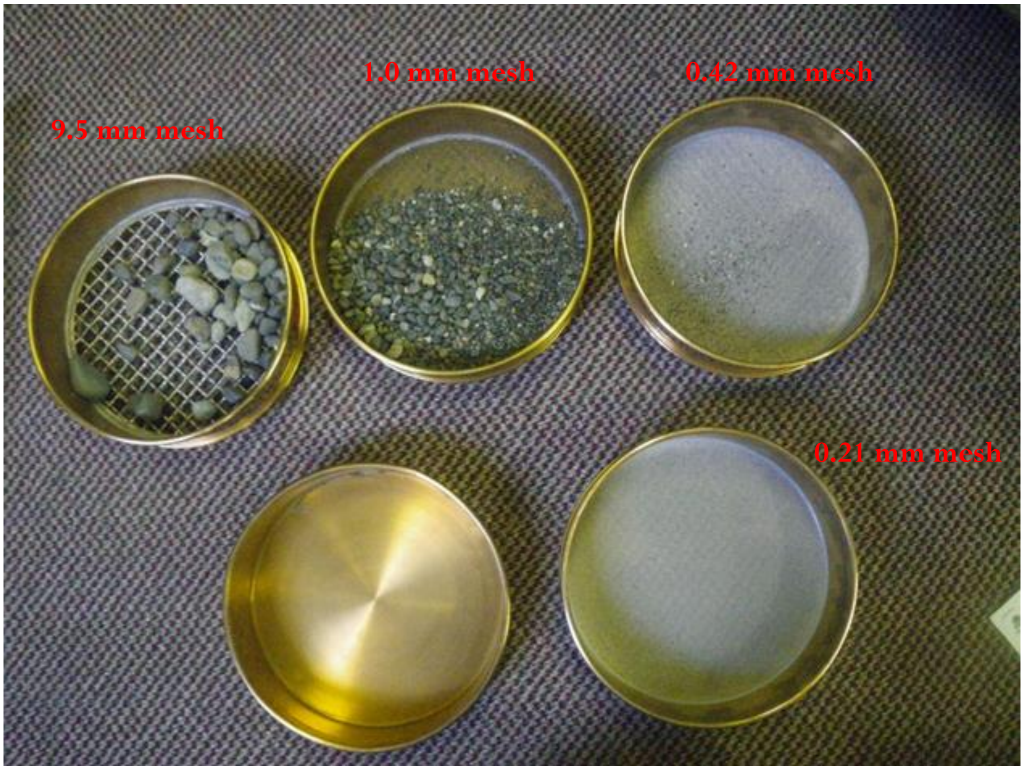

PHOTO 47: RETAINED FRACTIONS OF SEDIMENT PARTICLES FOLLOWING THE SIEVING ANALYSIS FOR SITE 5. NOTE ABUNDANCE OF PARTICLES IN THE 1-9.5MM RANGE (MID-UPPER SIEVE).
Photo credit: Trystan Willmott

5.8 Willow Creek and Simms Creek - Reach Indicator Sites

The objective in identifying index stream reaches is to provide measurable data that can help to identify long term trends in the quality of freshwater fish habitat in areas that would be susceptible to SLR. The reach assessments provide a current level of habitat suitability and provide an indication as to the resilience of the habitat to changing conditions, mainly in relation to the "Habitat" ecosystem service category associated with the River Channel and Riparian ecosystem types.

In terms of the general quality of habitat in the assessed streams, historical impacts from development, especially construction of the highway, have created systems that are already fragmented with poorly functioning estuarine areas. Above the estuaries, the habitat has been encroached upon by development in the form of vegetation removal, bankside armouring, driveway crossings and housing. Despite the impacts from development pressures, enhancement projects appear to have been successful in creating and maintaining rearing habitat in the form of deep, perennially wetted pools. Fish (mainly coho salmon) were confirmed to be using the streams during the field assessment. Detailed fish population studies would need to be conducted to determine trends in populations over the long term.

5.8.1 Willow Creek Habitat Indicator Reach

At the highway bridge (reach start point), rocks have been placed across the channel to create a type of weir to hold back water and create a deep pool. This enhancement has been successful in creating rearing habitat, as numerous coastal cutthroat trout and juvenile coho salmon were observed in this area. The channel is relatively straight, which is likely a legacy impact from being re-directed as part of the construction of the highway. In the first 50 m of the reach, riparian vegetation is generally providing proper biological function, with stable bankside trees that are creating stability and cover in the form of root structures that extend into the water.

The riparian zone opens up significantly in the mid portion of the reach, with associated lack of riparian biological function and unstable, eroding banks. Pool habitat units are still well represented, with stable Large Woody Debris (LWD) providing habitat complexing in pools that were being used by juvenile coho salmon during the field visit. Towards the upper segment of the reach, the channel becomes very unstable, with braided channels, debris jams and channel avulsion. This instability has been exacerbated by a lack of functioning riparian vegetation and bank instability. Through the avulsed segment, riparian vegetation is generally composed of grasses, shrubs and the invasive species policeman's helmet (*Impatiens glanulifera*).

Spawning habitat is generally well represented throughout the reach, with a range of material suitable for both resident species of trout and anadromous fish. Overhead vegetation, over the balance of the reach, provides the dominant cover, with deep pools providing the secondary cover type. Abandoned channels, avulsion, lack of functioning LWD, multiple channels and sediment wedges were seen as disturbance indicators, but these features were mainly encountered close to the upper segment of the reach. Refer to Appendix 3 for a complete record of reach parameters and Figure 21 that shows the location of the site.

PHOTO 48: LOOKING DOWNSTREAM TOWARDS THE START OF THE WILLOW CREEK INDEX REACH TOWARDS THE HIGHWAY BRIDGE CROSSING. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 49: LOOKING UPSTREAM FROM THE START OF THE WILLOW CREEK INDEX REACH. NOTE PLACEMENT OF ROCKS ACROSS THE CHANNEL TO CREATE A POOL HABITAT UNIT IMMEDIATELY UPSTREAM. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 50: EXAMPLE OF A POOL HABITAT UNIT AND FUNCTIONING LWD IN THE LOWER SEGMENT OF THE WILLOW CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 51: EXAMPLE OF AVAILABLE SALMONID SPAWNING GRAVEL IN THE MIDDLE SEGMENT OF THE WILLOW CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 52: EXAMPLE OF RIPARIAN ENCROACHMENT AND ASSOCIATED BANK EROSION IN THE MIDDLE SEGMENT OF THE WILLOW CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 53: PROLIFERATION OF POLICEMAN'S HELMET IN THE RIPARIAN ZONE OF THE MIDDLE SEGMENT OF THE WILLOW CREEK INDEX REACH. NOTE PROXIMITY OF DEVELOPMENT. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 54: EXAMPLE OF BANK EROSION AND LACK OF FUNCTIONING RIPARIAN VEGETATION IN THE UPPER SEGMENT OF THE WILLOW CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 55: FUNCTIONING LWD IN A POOL HABITAT UNIT IN THE UPPER SEGMENT OF THE WILLOW CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 56: CHANNEL AVULSION AND DEBRIS JAMS IN THE UPPER SEGMENT OF THE WILLOW CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

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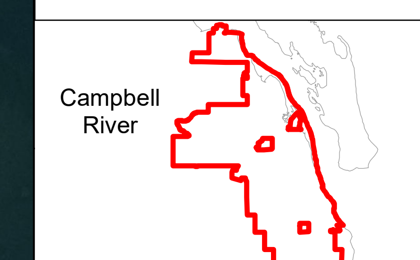
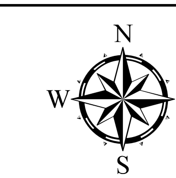
Figure 21: Willow Creek Index Reach

PROJECT: Sea Level Rise: Ecosystems and Species at Risk Study	
CLIENT: City of Campbell River	
GEOGRAPHIC AREA: Campbell River, BC	
MAP SCALE: 1:1,000	**MAPPING DATE:** October 10, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area
Watercourse
Reach Start & End Points
Index Reach (First 200m of Creek)



0 10 20 40 Meters
1:1,000



5.8.2 Simms Creek Habitat Indicator Reach

At the highway bridge (reach start point), the channel has been split underneath the bridge in what appear to be high and low flow channels. A concrete baffle along the edge of the wider high-flow channel is likely in place to protect the bridge from debris during extreme flow events. Immediately upstream of the baffle, boulders placed across the channel have been effective in creating a pool habitat unit, which was being used by numerous juvenile coho salmon during the field visit. This type of enhancement, where stone lines have been placed across the channel throughout the reach, have been effective in creating deep pools that represent good rearing habitat for fish that will remain wetted during the dry summer months.

The channel has been affected throughout the reach by legacy impacts associated with channel straightening and bankside armouring in the form of rip-rap and concrete. Eroding banks are evident in parts of the reach. Numerous driveways also cross the creek along the reach, but the crossings are clear-span structures, which allow the channel to remain in its natural state. Stable LWD is generally lacking, but some pools contain well-anchored LWD. The riparian fringe is generally providing proper biological function in the form of bank stability, provision of shade and nutrient input. Spawning gravels are well represented throughout the reach, but gravel deposits are generally filled in with fine sediment, which has led to some accretion of the gravels. It is expected that larger salmonid fish (*e.g.* anadromous species) would be able to dislodge this fine sediment and loosen the gravels for spawning.

Deep pools represent the dominant cover type for fish, which has resulted from the enhancement work (placement of cross-channel stone lines). Overhead vegetation forms the secondary cover type. Lack of functioning LWD and eroded banks were noted as the main disturbance indicators. Refer to Appendix 3 for a complete record of reach parameters and Figure 22 that shows the location of the site.

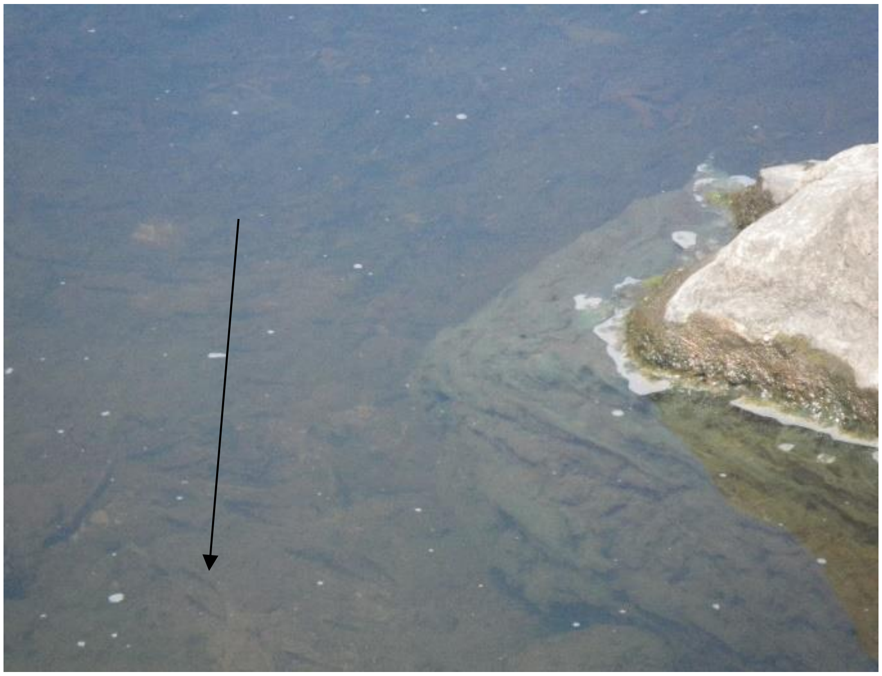


PHOTO 57:JUVENILE COHO SALMON USING THE DEEP POOL IN THE SIMMS CREEK ESTUARY CLOSE TO THE START OF THE INDEX REACH (ONE FISH HAS BEEN HIGHLIGHTED FOR REFERENCE). AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 58: HIGH FLOW CHANNEL AND BAFFLE LOCATED UNDER THE HIGHWAY BRIDGE AT THE START OF THE SIMMS CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 59: LOOKING DOWNSTREAM ALONG THE LOW FLOW CHANNEL UNDERNEATH THE HIGHWAY BRIDGE AT THE START OF THE SIMS CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

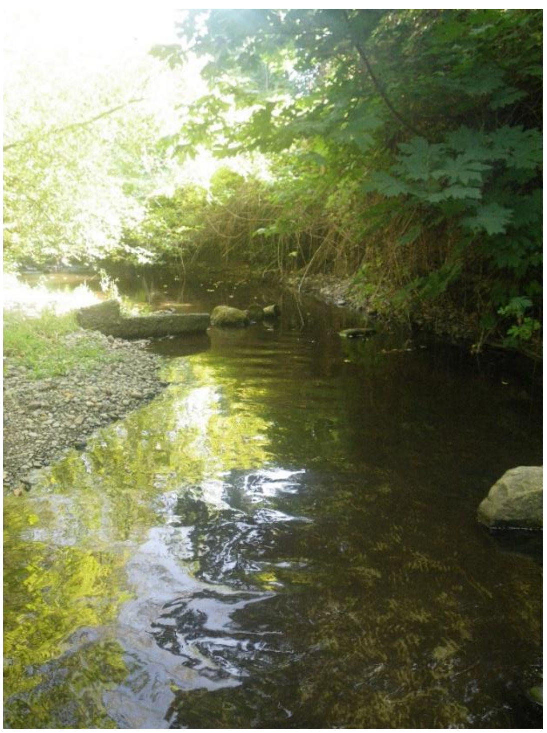


PHOTO 60: LOOKING UPSTREAM ALONG A DEEP POOL HABITAT UNIT IN THE LOWER SEGMENT OF THE SIMMS CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 61: LOOKING DOWNSTREAM TOWARDS A PLACED STONE LINE ACROSS THE CHANNEL IN THE MIDDLE SEGMENT OF THE SIMMS CREEK INDEX REACH. THIS FEATURE HAS CREATED POOL HABITAT UNITS. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 62: EXAMPLE OF LWD IN A POOL HABITAT UNIT IN THE UPPER SEGMENT OF THE SIMMS CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 63: EXAMPLE OF AVAILABLE SALMONID SPAWNING GRAVEL IN THE UPPER SEGMENT OF THE SIMMS CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 64: EXAMPLE OF BANKSIDE DISTURBANCE IN THE UPPER SEGMENT OF THE SIMMS CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 65: FUNCTIONING RIPARIAN VEGETATION TYPICAL OF THE MAJORITY OF THE SIMMS CREEK INDEX REACH. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

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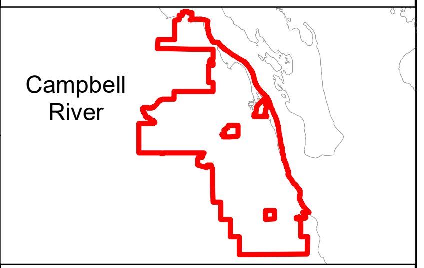
Figure 22: Simms Creek Index Reach.

PROJECT: Sea Level Rise: Ecosystems and Species at Risk Study	
CLIENT: City of Campbell River	
GEOGRAPHIC AREA: Campbell River, BC	
MAP SCALE: 1:1,250	**MAPPING DATE:** October 10, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area
Watercourse
Reach Start & End Points
Index Reach (First 200m of Creek)



0 10 20 40 Meters
1:1,250

N W E S

5.9 Bald Eagle Breeding Success Indicator

The information gathered for bald eagle breeding activity can be used to monitor trends in bald eagle nesting success (Table 9). This table shows the 16 territories that were active in 2019 and the associated nest name and ID. In some cases, the territory was active in 2019, but the nest is no longer standing. A total of 5 chicks were known to have been raised in 2019, which compares to 18 chicks raised in 2017. It is important to note that 8 nests were recorded as being down or partially fallen in 2018 – 3 of these nests raised a total of 5 chicks in 2017.

While the rate of success may have a direct association with the quality of the Backshore Riparian ecosystem in providing nesting habitat, the success of bald eagle nesting would also be linked to other ecosystem services to help provide a general “canary in the coal mine” indication of ecosystem health. In order to use these nesting territories as specific indicators, the City can make use of an established annual contract with WiTS that monitors breeding success. It is currently unknown whether the apparent lack of success in 2019 is a trend that will continue or not. A declining trend over subsequent years would indicate potential changes to ecosystem services such as, but not limited to the “Habitat” ecosystem service category.

TABLE 9: SUMMARY OF BALD EAGLE (BAEA) TERRITORIES AND ASSOCIATED NESTS OCCUPIED IN 2019 IN THE CAMPBELL RIVER STUDY AREA.

Territory	Nest #	Nest Name	Location	Notes from Wildlife Tree Stewardship (WiTS)
Active territories with viable nest				
SRD-T53	110-564	Hudson Farm - F	South of McDonald Rd	One chick raised in 2015. Occupied nesting territory in 2019.
SRD-T50	110-018	Raven Channel - C	Raven Park	**One eagle chick raised in 2019.** Used every year since it was built in 2015
SRD-T51	106-374	Estuary Log Pocket	Nunns Creek in IR#11 north of Island Hwy	Newly discovered in 2018 no chicks raised. **One chick raised in 2019**
SRD-T35	106-372	Greenwood Road - B	Junction of Greenwood St and 8th Ave	Newly discovered in 2018 no chicks raised. **One chick raised in 2019**
SRD-T34	106-277	Centennial Park - C	Centennial Park	Known since 2004. Last known 2 chicks in 2015. Used but no chicks each year since.
SRD-T33	106-366	South Island Highway	South Island Hwy near Pinecrest Rd	2 chicks in 2018. No sign in 2019.
SRD-T32	106-251	Ash Street	Simms Creek between Ash St and S.I. Hwy	Known since 1999. Chick raised most years. 3 chicks in 2017. Nest fell and rebuilt in 2019
SRD-T31	106-349	Galerno Road - E	South of Rockland Rd, East of Galerno Road	**1 chick in nest in 2019.**
SRD-T17	106-363	Willow Point - B	Near Campbell River Adult Care	2 chicks in 2017. 1 chick in nest in 2018. Failed attempt in 2019.
SRD-T15	106-356	Barlow Road	Near junction of Barlow Rd with S.I. Hwy	Known since 2013. 1 chick raised in 2018. Nest used but no chicks in 2019.
SRD-T14	106-368	Colorado Drive	east of Island Hwy near Ocean Grove Rd.	Nest in poor shape in 2019. Eagles seen since 2016 but no chicks raised.
SRD-T13	106-360	Finch Road - B	south of Jubilee Parkway near Island Hwy	2 chicks raised in 2017. **1 chick observed by local resident in 2019.**
Active Territories with no viable nest				
SRD-T39	106-364	Tyee Spit	Nunns Creek in IR#11 north of Island Hwy	Territory occupied in 2019 but nest down. 2 chicks raised in 2017.
SRD-T38	106-310	Campbell River Estuary - E	IR#11 along Island Hwy	Territory occupied in 2019 but nest down. 2 chicks raised in 2017.
SRD-T16	106-334	Larwood Creek - B	Larwood Creek/Harrogate Road	3 nests within territory down in 2018. Last chick raised in 2017. Territory occupied in 2019 near nest 106-334.
SRD-T52	110-500	Vanstone Road	North of Vanstone Rd along shoreline	The nest fell in 2017. Considered an occupied nesting territory and a frequent perch tree.

6 Geoscience and Hydrology: Erosion Potential and Impacts of Elevated Sediment Levels

6.1 Introduction

Water plays a key role in the sediment cycle as it creates the physical mechanism for both erosion, transportation and eventual deposition of sediment. SLR has been shown to drive coastal erosion (Leatherman *et al*. 2000), which is corollary to an increased potential for transport and deposition of mobilized sediment from shorelines and susceptible areas to nearshore and inland locations due to increased volume and flow at higher elevations (FitzGerald *et al*. 2008). Moreover, the potential for erosion, particularly in nearshore and inland locations where there was minimal risk in the past, is expected to increase with the shoreline ('natural boundary'[4]) transitioning to higher elevations (Davidson 2005). The Government of Canada (1992) has identified several impacts of increased sediment transportation and deposition which include:

- The health of fisheries/aquatic habitat as suspended sediment can decrease light penetration into water, irritate gills of fish, increase water temperature, dislodge plants, invertebrates and insects (major food sources) in streambeds, and bury and suffocate fish eggs;
- The transport and fate of pollutants and toxic substances which can become attached, or adsorbed to sediment particles;
- The effectiveness of how water is delivered as suspended sediment can wear out the pumps and turbines used to transport water from streams and lakes for domestic, industrial, and agricultural purposes; and
- The decrease in water depth of rivers and lakes which can make navigation difficult or impossible.

[4] The common definition of natural boundary is "the visible high water mark of any lake, stream, or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river/stream, or other body of water a character distinct from that of the banks, both in vegetation and in the nature of the soil itself" (BC Land Act). In marine systems, the natural boundary is generally determined as the lower elevation of terrestrial vegetation or the upper boundary of distinctive aquatic vegetation.

Although there has been extensive research examining the broader impacts of increased erosion and sediment deposition from rising sea level, based on a review of publicly available documents, few coastal municipalities in Canada have modelled potential erosion risk, sediment transport and detailed consequences in a local and regional context. This component of Madrone's assessment for the City of Campbell River aims to fill the identified gap in knowledge in order to inform climate change adaptation policies and water quality management at the municipal level.

There are two physical processes that are likely to affect the channel morphology of the Campbell River with rising sea level – erosion and aggradation. Erosion is the removal and transportation of material, while aggradation is the deposition and accumulation of eroded material into a river, stream or floodplain. These processes depend on velocity of moving water and the diameter of material (Figure 23). With erosion and aggradation processes acting with each other, there is the potential for stretches of the river to be widened as stream banks are eroded and decrease in depth as material is deposited on the riverbed.

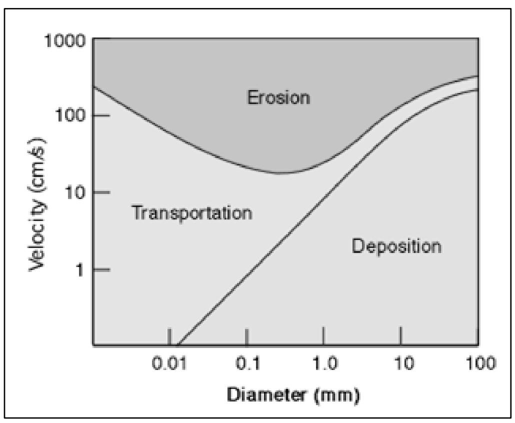


FIGURE 23: RELATIONSHIP BETWEEN FLOW VELOCITY AND MATERIAL DIAMETER WITH EROSION, TRANSPORTATION AND DEPOSITION (COLUMBIA UNIVERSITY [N.D.]).

6.2 Assessment Objectives

The objectives of this assessment component are as follows:

- Identify key surface characteristic parameters for coastal and stream soil erosion risk prediction within the City of Campbell River;
- Develop a GIS-based raster model, to be used at the landscape-scale, that considers multiple parameters and rankings for erosion potential prediction; and

- Based on model results, sea level rise scenarios and available aquifer and water well mapping, discuss the general impacts to channel morphology, water quality, and aquatic habitat and aquatic species in Campbell River from the presumed movement of sediment to near-shore and inland locations and the erosion risk to these areas with SLR.

6.3 Methodology

The methodology used for Madrone's surface erosion potential assessment of Campbell River is adapted from Weikmann (2017) and Dymond *et al* (2018) who used a GIS-based modelling approach to determine a surface erosion potential for an urban environment by developing a raster model (1.0 m pixel resolution) with geospatial data (parameters) including slope, soil texture, and land cover; land cover was based on zoning mapping from the City of Campbell River Official Community Plan (2017). We also used the parameter of proximity to open coast in our model, with risk rankings adapted from Fitton *et al* (2016) and Alves *et al* (2011) who developed a coastal erosion susceptibility model using a similar GIS-based approach. The parameters rankings developed by the aforementioned studies (1 to 10; 1 being least erosive and 10 being most erosive) were applied to Campbell River to develop a final erosion risk map for the city.

The erosion potential map was produced when slope, soil texture, land-use (theoretical based on zoning) and proximity to coast were overlain and summed to show relative erosion risk for different areas of the City. Sea level rise elevations (based on 0.5 m and 1.0 m sea level rise scenarios; see Section 2.3) were applied to the final risk map to show the projected extent of shoreline and inundated areas. Table 10 summarizes data sources used for model input, while Tables 11 to 14 shows how parameters were ranked.

TABLE 10: DATA SOURCES FOR EROSION RISK MODELLING

Data	Source
Slope	City of Campbell River; derived from LiDar data (n.d.)
Soil texture	BC Ministry of Forests, Soils of Southern Vancouver Island (1995)
Land cover (theoretical based on zoning)	City of Campbell River Official Community Plan (2012)
Contour elevations	City of Campbell River (n.d.)

TABLE 11: SLOPE RANKING FOR EROSION POTENTIAL

Slope (°)	Rank
0 to 6	1
7 to 12	2
13 to 17	3
18 to 21	4
22 to 27	5
28 to 31	6
32 to 35	7
36 to 39	8
40 to 42	9
43+	10

TABLE 12: SOIL TEXTURE RANKING FOR EROSION POTENTIAL.

Soil texture	K Factor (relative susceptibility to erosion)	Rank
Coarse fragments	-	1
Sand	0.04	2
Loamy sand	0.07	3
Sandy clay	0.09	3
Sandy clay loam	0.10	4
Sandy loam	0.11	5
Clay	0.14	5
Clay loam	0.14	5
Loam	0.14	6
Heavy clay	0.18	7
Silt loam	0.22	7
Silty clay	0.22	7
Silty clay loam	0.22	8
Silt	0.55	10

TABLE 13: LAND COVER (THEORETICAL BASED ON ZONING) RANKING FOR EROSION POTENTIAL

Land cover	Rank
Business and Industrial Service	1
Downtown	1
Estate	1
Neighbourhood (proposed & existing)	1
Village	1
Waterfront	1
Federal Indian Reserve	5
Rural Neighbourhood	5
Rural Resource	5
Natural Areas and Protected Lands	10

Please note that the reason why land-cover such as "Natural Areas and Protected Lands" would have a higher erosional potential than "Waterfront" in this context is due to the density of constructed infrastructure – either municipal, commercial or residential – which tend to have less exposed sediment for erosion. Proximity to coastline is taken into consideration for "Waterfront" areas in the next ranking (Table 14). Also, please note that a land-cover or land-land use map was not available from the City, thus a zoning map was used as theoretical land cover based. This is the reason why certain areas in the output maps (see Section 6.4) appear as blocky (*i.e.,* polygons) as they conform to zoning boundaries.

TABLE 14: PROXIMITY TO ADJUSTED COAST RANKING FOR EROSION POTENTIAL

Proximity to adjusted coast under sea level rise scenarios	Rank
>400 m	1
300 to 400 m	3
200 to 300 m	5
100 to 200 m	7
<100 m	10

To assess potential impacts to well water quality from potential sediment and/or saltwater contamination, publicly available data showing well locations and associated aquifers were overlain on SLR scenario maps. Table 15 contains the reported median static water depths and well depths for each of the aquifers, along with a Vulnerable to Contamination ranking provided by the government of British of Columbia.

TABLE 15: AQUIFERS AND REPORTED WELLS IN THE CITY OF CAMPBELL RIVER

Aquifer ID	Aquifer description	# of wells correlated to aquifer	Reported static water depth (m)	Reported well depth (m)	Vulnerability to Contamination[5]
847	Confined glacio-fluvial sand and gravel underneath till, in between till layers, or underlying glacio-lacustrine deposits	62	3.05	5.49	Moderate (B)
852		9	n.d.	n.d.	High (A)
853		21	2.29	4.57	Moderate (B)
857		10	1.83	21.79	Low (C)
975	Unconfined glacio-fluvial sand and gravel underneath till, in between till layers, or underlying glacio-lacustrine deposits	7	31.24	45.42	High (A)
976	Confined glacio-fluvial sand and gravel underneath till, in between till layers, or underlying glacio-lacustrine deposits	3	n.d.	n.d.	Low (C)

6.4 Results

Maps have been produced to show erosion potential rankings for slope (Figure 24), soil texture (Figure 25), land cover (Figure 26) and proximity to the adjusted coastline based on 0.5 m and 1.0 m sea level rise scenarios (Figures 27 and 28). The final risk maps are shown at the two scales: 1:90,000 (Figures 29 and 30) and 1:10,000 with a focus on the estuary (Figures 31 and 32). Additionally, risk maps at a 1:10,000 scale were produced for seven areas along the foreshore; these maps are included in Appendix 4 of this report.

The areas with the highest erosion potential and proximal to the adjusted shoreline under both the 0.5 m and 1.0 m SLR scenarios are:

1. Along the coastline of the City of Campbell River, particularly (i) directly north of the estuary and immediately west from the edge of the spit of Dick Murphy Park, (ii) at Duncan Bay, and (iii) the northern tip of the study area to the east of the North Island Highway (Figures 29 and 30);
2. Along the northern and southern banks of the Campbell River along the stretch that flows directly into Elk Falls Provincial Park and the estuary, immediately west of the North Island Highway bridges (Figures 31 and 32); and
3. Immediately south of the estuary at Nunns Creek Park (Figures 29 and 30).

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[5] Pre-existing classification via the DRASTIC aquifer vulnerability assessment method. https://catalogue.data.gov.bc.ca/dataset/drastic-aquifer-intrinsic-vulnerability

Within the City of Campbell River and vicinity, approximately 15 groundwater wells in Aquifers 852 and 853 are located in the risk areas under the 0.5 m and 1.0 m SLR scenario (Figure 33 and 34). Wells which are predicted to be inundated are along the coastline where erosion potential has been modeled as relatively high (Figures 29 and 30).

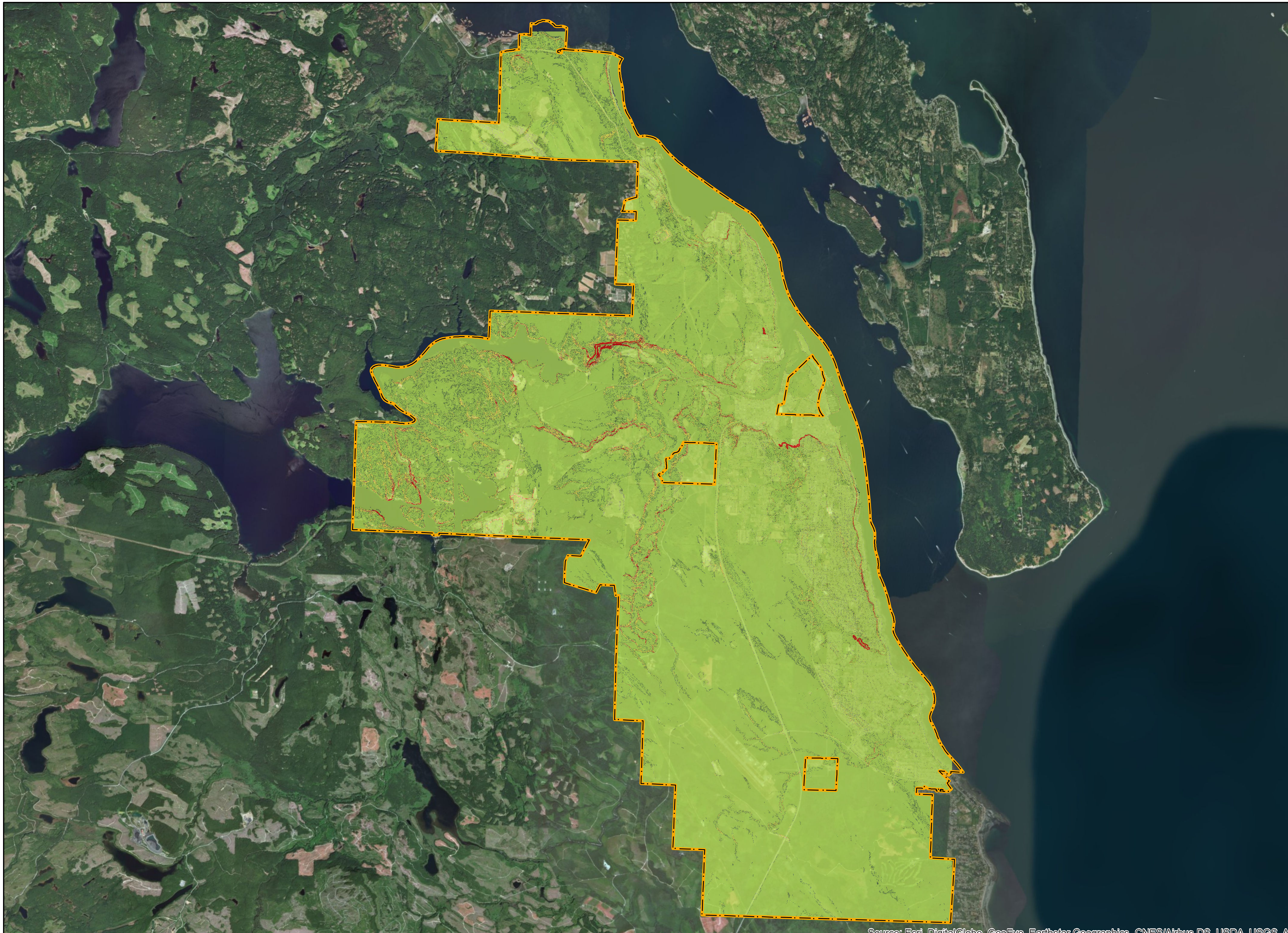

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Figure 24: Slope Hazard

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

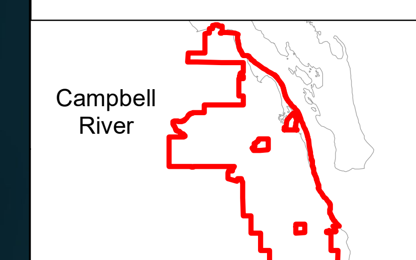
CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:90,000	October 10, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area

Slope (degrees)	Rank
0 - 6	1
7 - 12	2
13 - 17	3
18 - 21	4
22 - 27	5
28 - 31	6
32 - 35	7
36 - 39	8
40 - 42	9
43 +	10
No Data	



0 0.5 1 2
Kilometers
1:90,000

N
W E
S

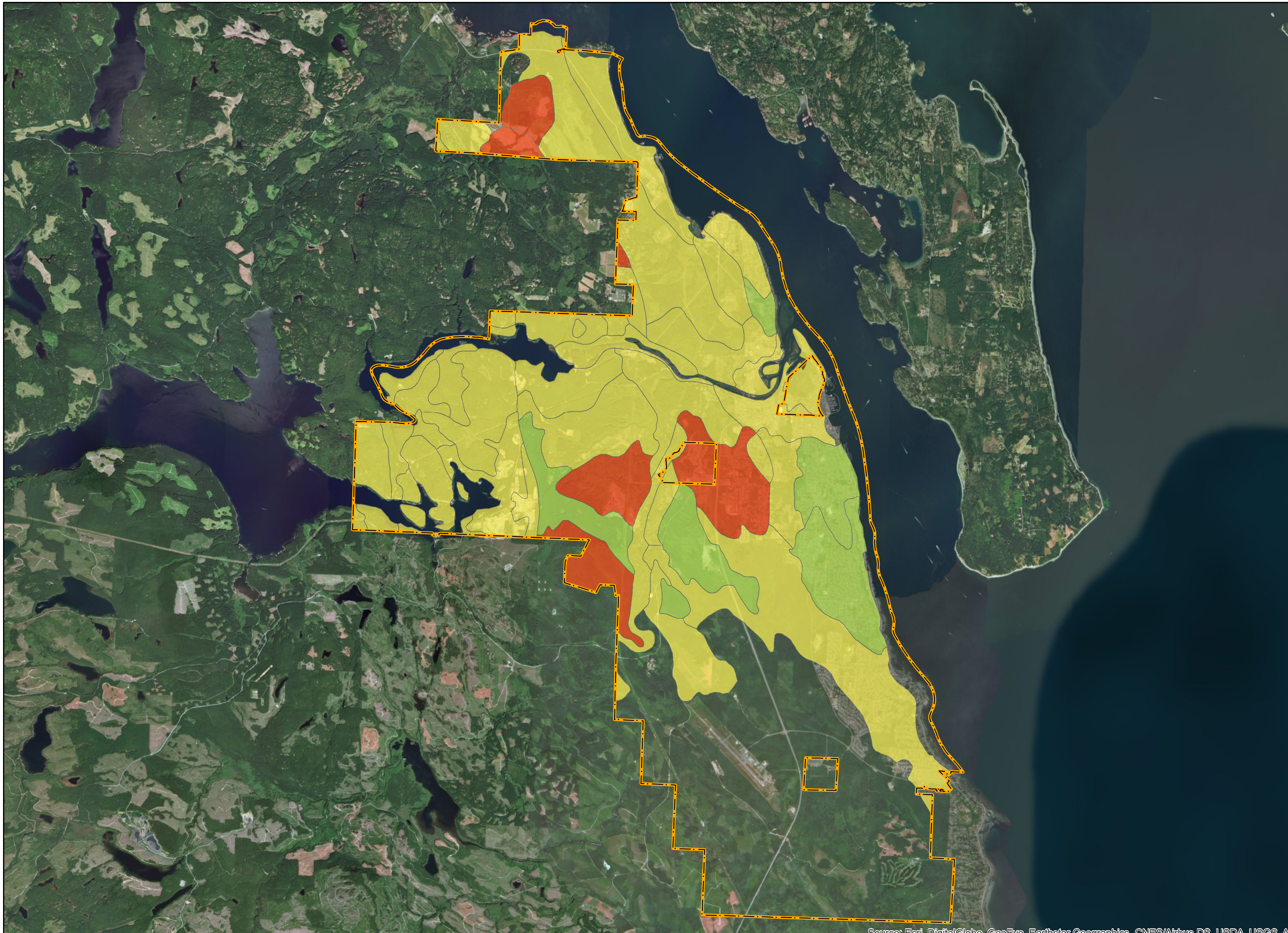


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Figure 25: Soil Erodibility

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

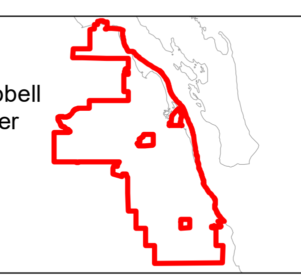
CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:90,000	October 9, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area

Texture	**Rank**
Sand	2
Loamy Sand	3
Silty Clay Loam	4
Sandy Loam	5
Loam	6
Silt Loam	7



0 0.5 1 2
Kilometers
1:90,000

N
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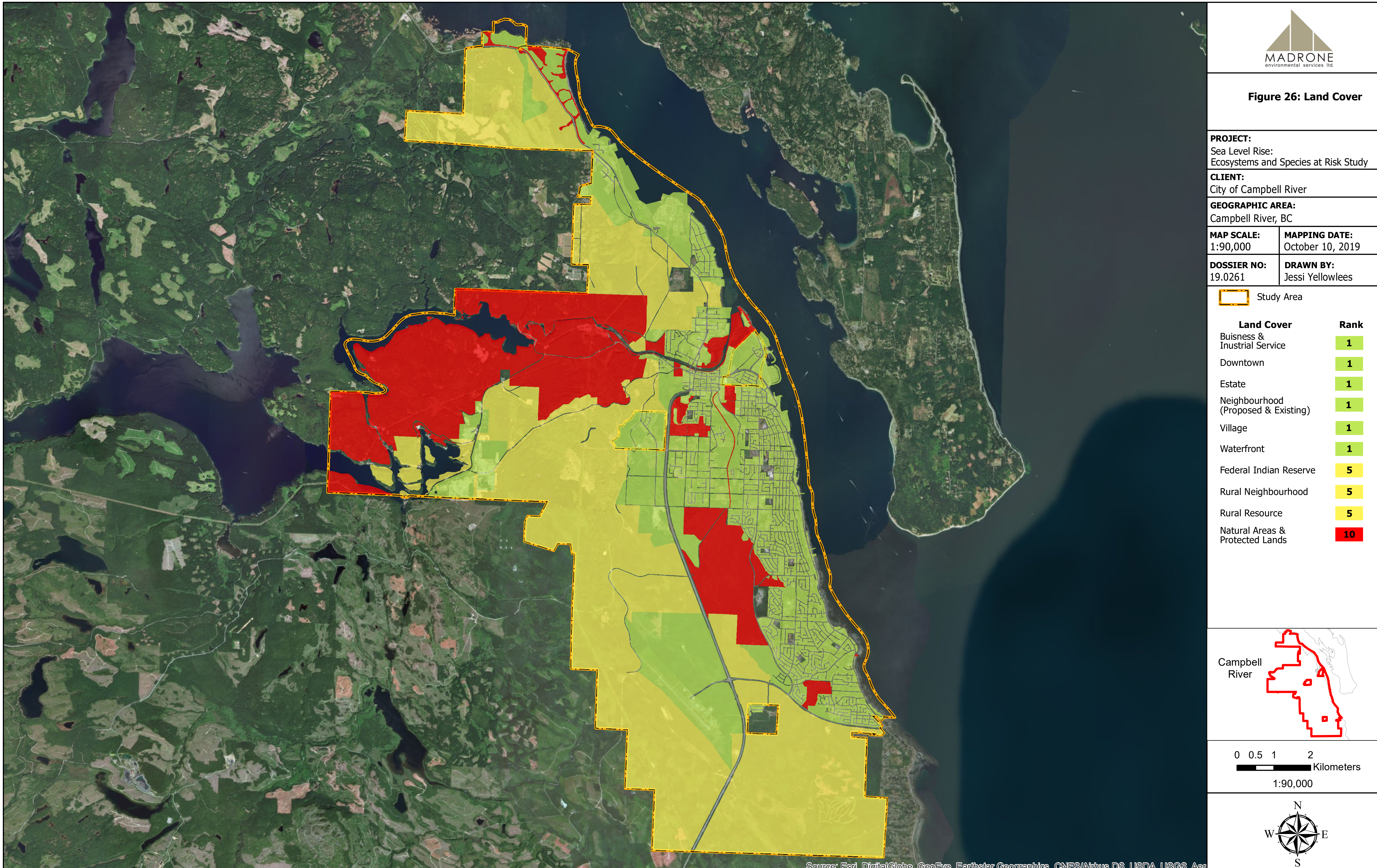
MADRONE
environmental services ltd.
Figure 26: Land Cover
PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study
CLIENT:
City of Campbell River
GEOGRAPHIC AREA:
Campbell River, BC
MAP SCALE:
1:90,000
MAPPING DATE:
October 10, 2019
DOSSIER NO:
19.0261
DRAWN BY:
Jessi Yellowlees
Study Area
Land Cover
Rank
Buisness & Inustrial Service 1
Downtown 1
Estate 1
Neighbourhood (Proposed & Existing) 1
Village 1
Waterfront 1
Federal Indian Reserve 5
Rural Neighbourhood 5
Rural Resource 5
Natural Areas & Protected Lands 10
Campbell River
0 0.5 1 2
Kilometers
1:90,000
N
W
E
S
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, Aer

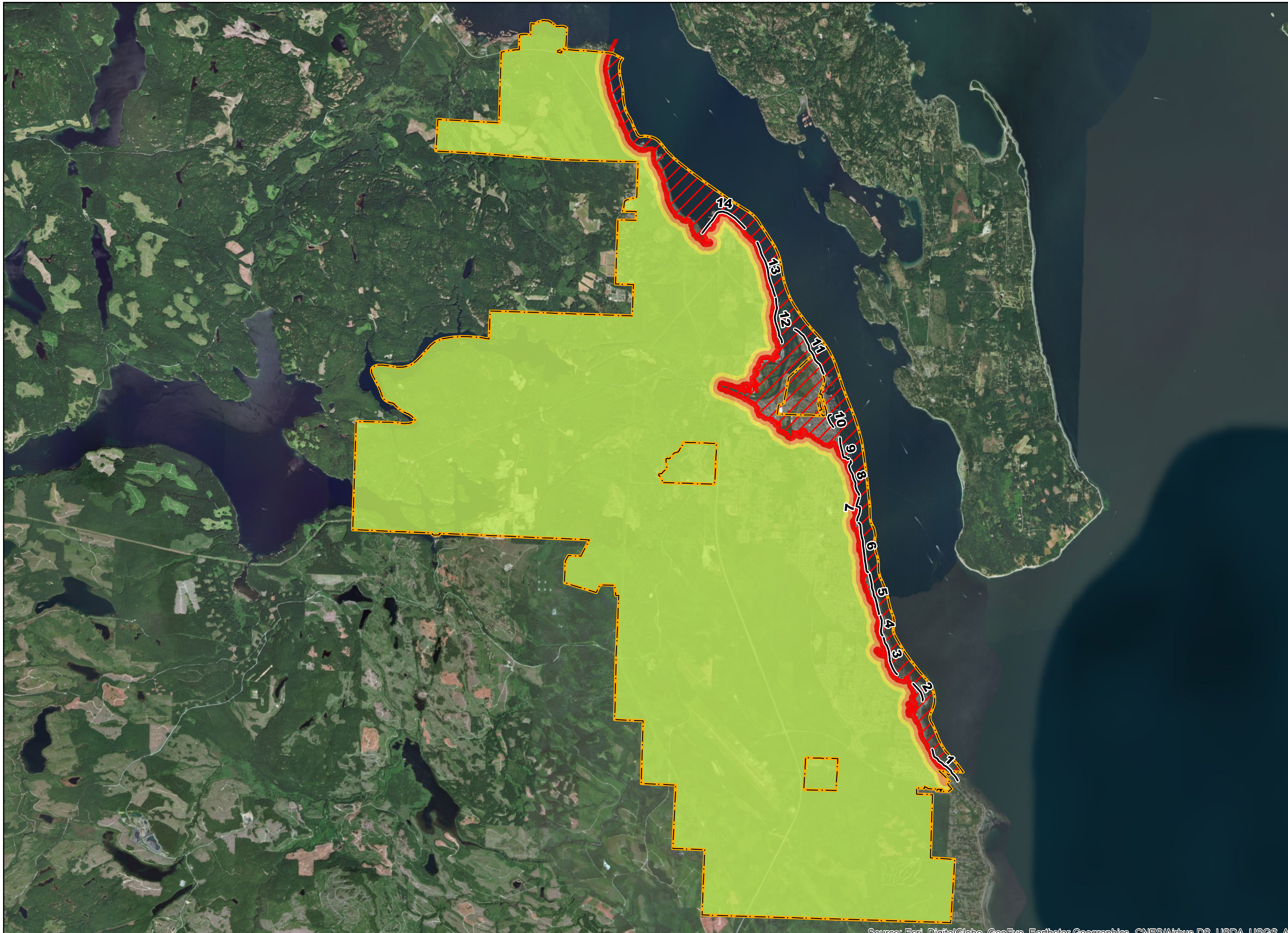

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Figure 27: Proximity to Open Coast 0.5m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

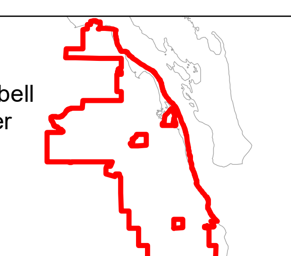
CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE: 1:90,000	**MAPPING DATE:** November 20, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area
Areas Impacted by 0.5m Sea Level Rise
Foreshore Section

Open Coast Proximity	Rank
> 400m	1
300 - 400m	3
200 - 300m	5
100 - 200m	7
< 100m	10



0 0.5 1 2
Kilometers
1:90,000

N
W E
S

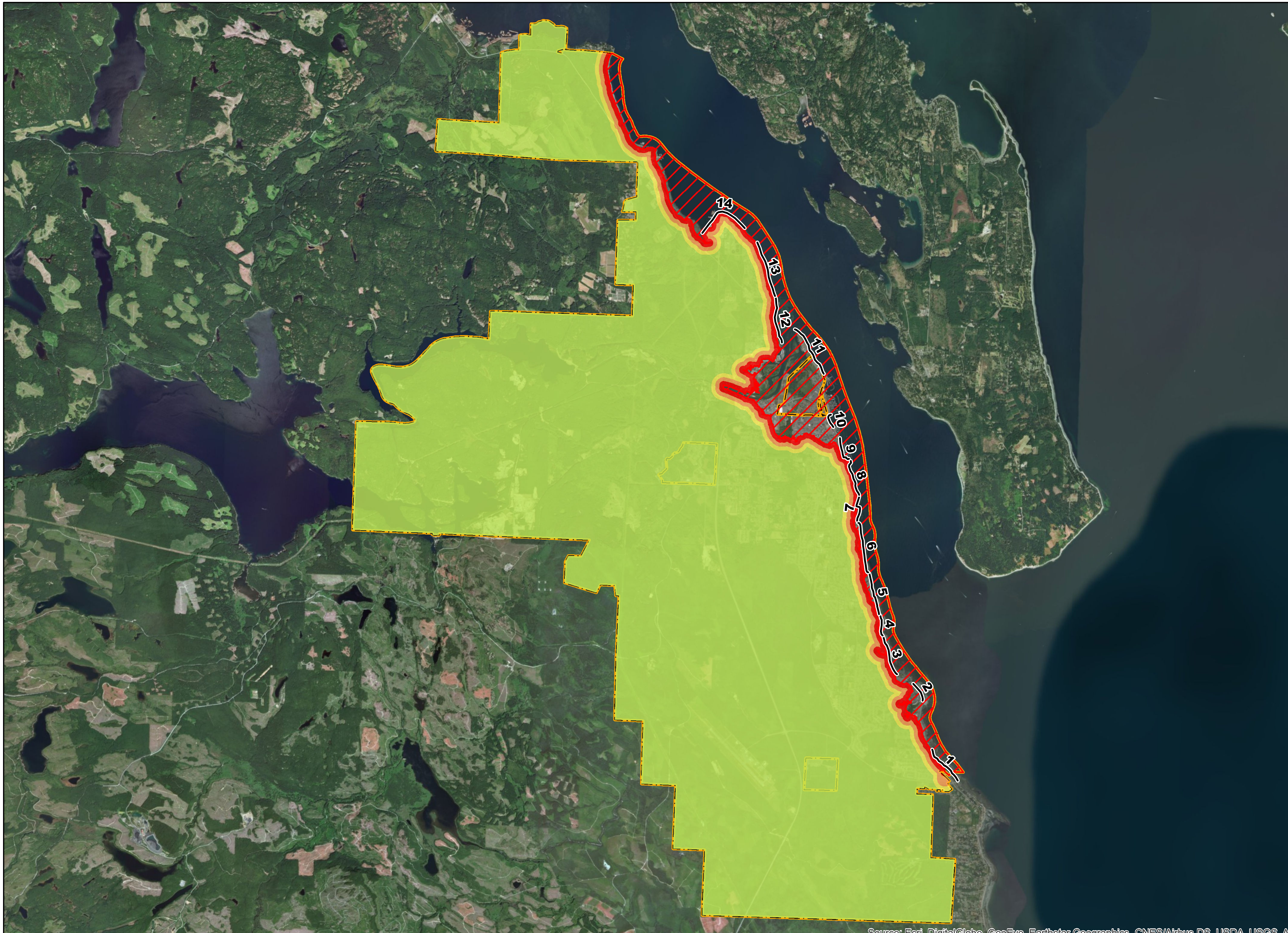


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Figure 28: Proximity to Open Coast 1m Sea Level Rise

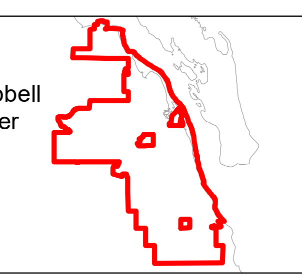
PROJECT: Sea Level Rise: Ecosystems and Species at Risk Study	
CLIENT: City of Campbell River	
GEOGRAPHIC AREA: Campbell River, BC	
MAP SCALE: 1:90,000	**MAPPING DATE:** November 20, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area

Areas Impacted by 1m Sea Level Rise

Foreshore Section

Open Coast Proximity	Rank
> 400m	1
300 - 400m	3
200 - 300m	5
100 - 200m	7
< 100m	10



0 0.5 1 2 Kilometers

1:90,000

N W E S

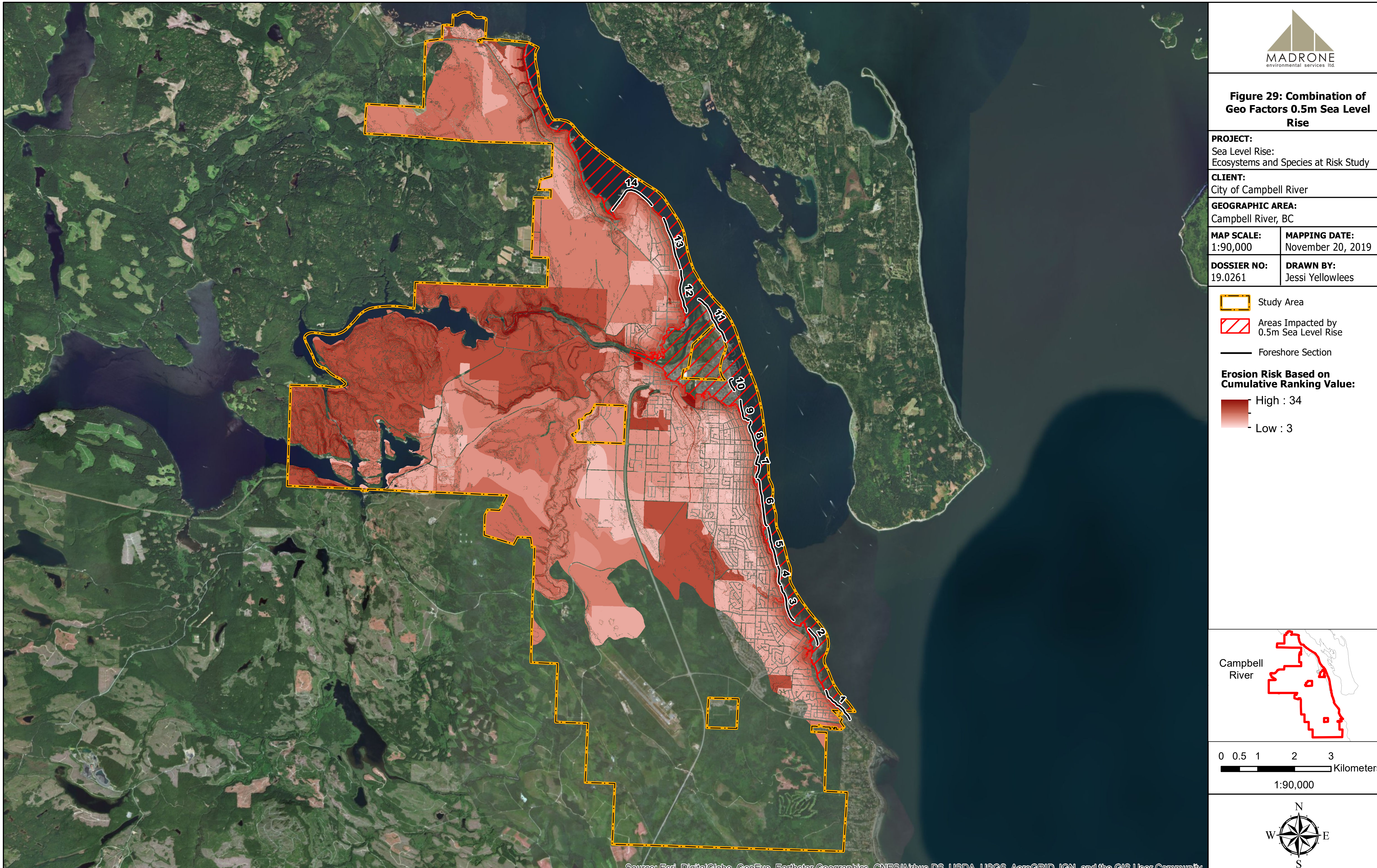


Figure 29: Combination of Geo Factors 0.5m Sea Level Rise

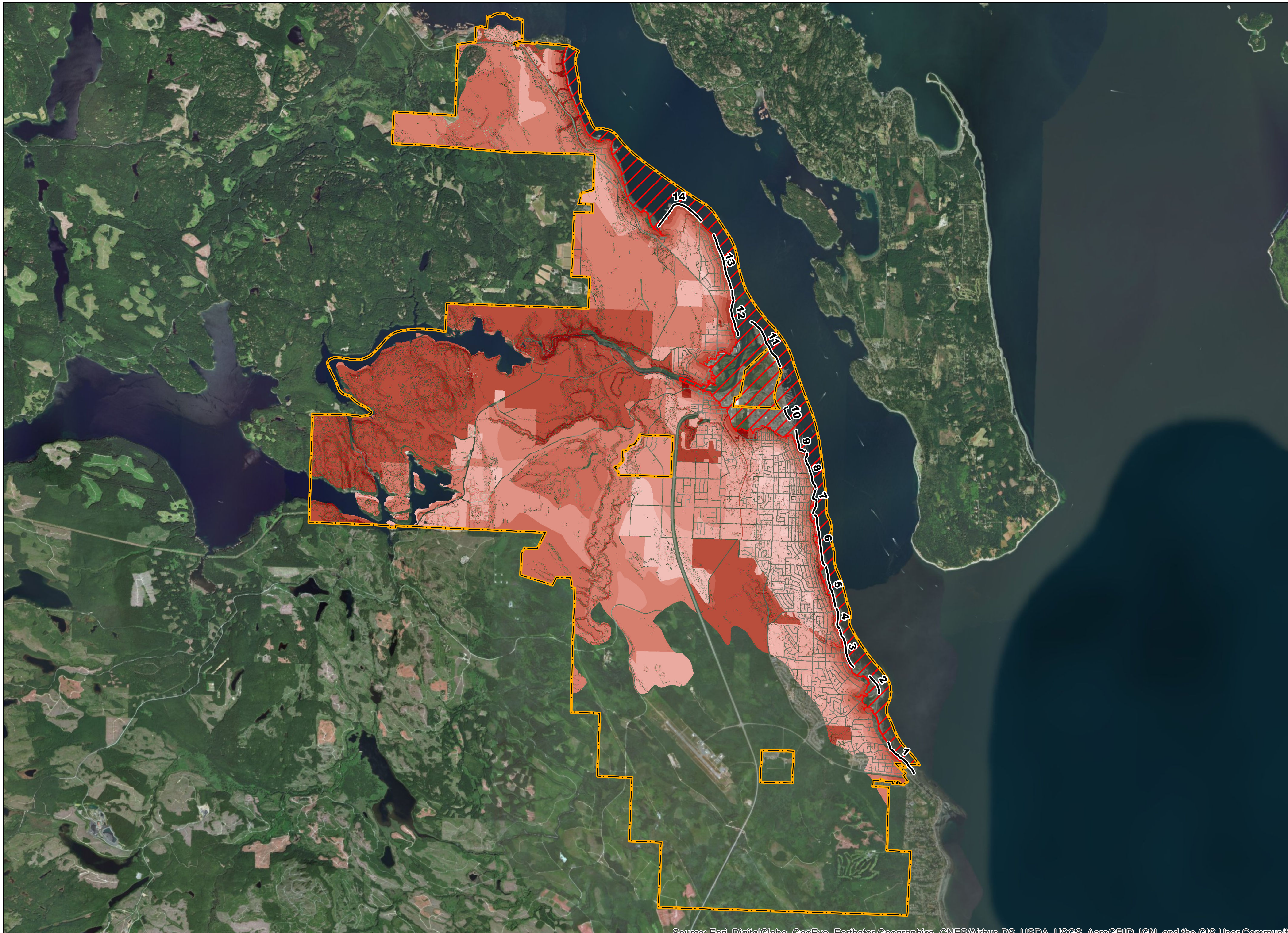


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Figure 30: Combination of Geo Factors 1m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:90,000	November 20, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area

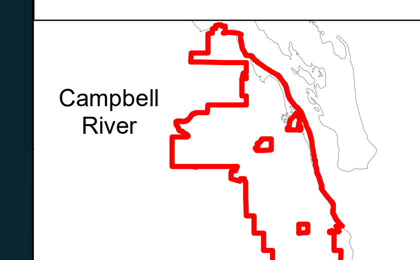
Areas Impacted by 1m Sea Level Rise

Foreshore Section

Erosion Risk Based on Cumulative Ranking Value:

High : 35

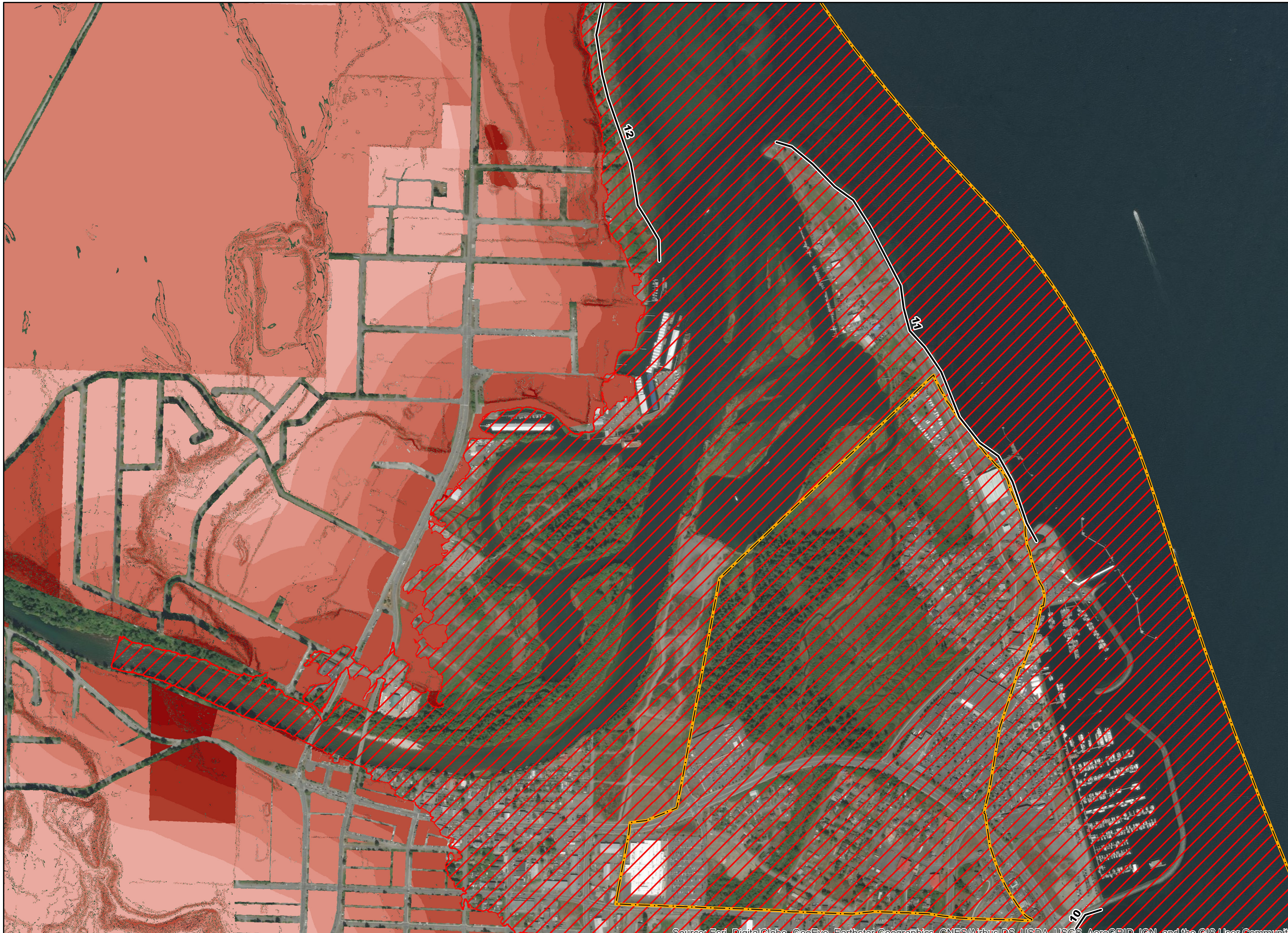
Low : 3



0 0.5 1 2 3 Kilometers

1:90,000

N
W E
S



MADRONE
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Figure 31: Combination of Geo Factors 0.5m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:10,000	November 20, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area

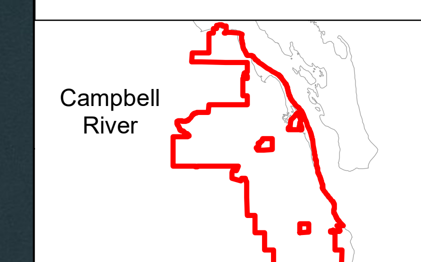
Areas Impacted by 0.5m Sea Level Rise

Foreshore Section

Erosion Risk Based on Cumulative Ranking Value:

High : 34

Low : 3



0 100 200 400 Meters

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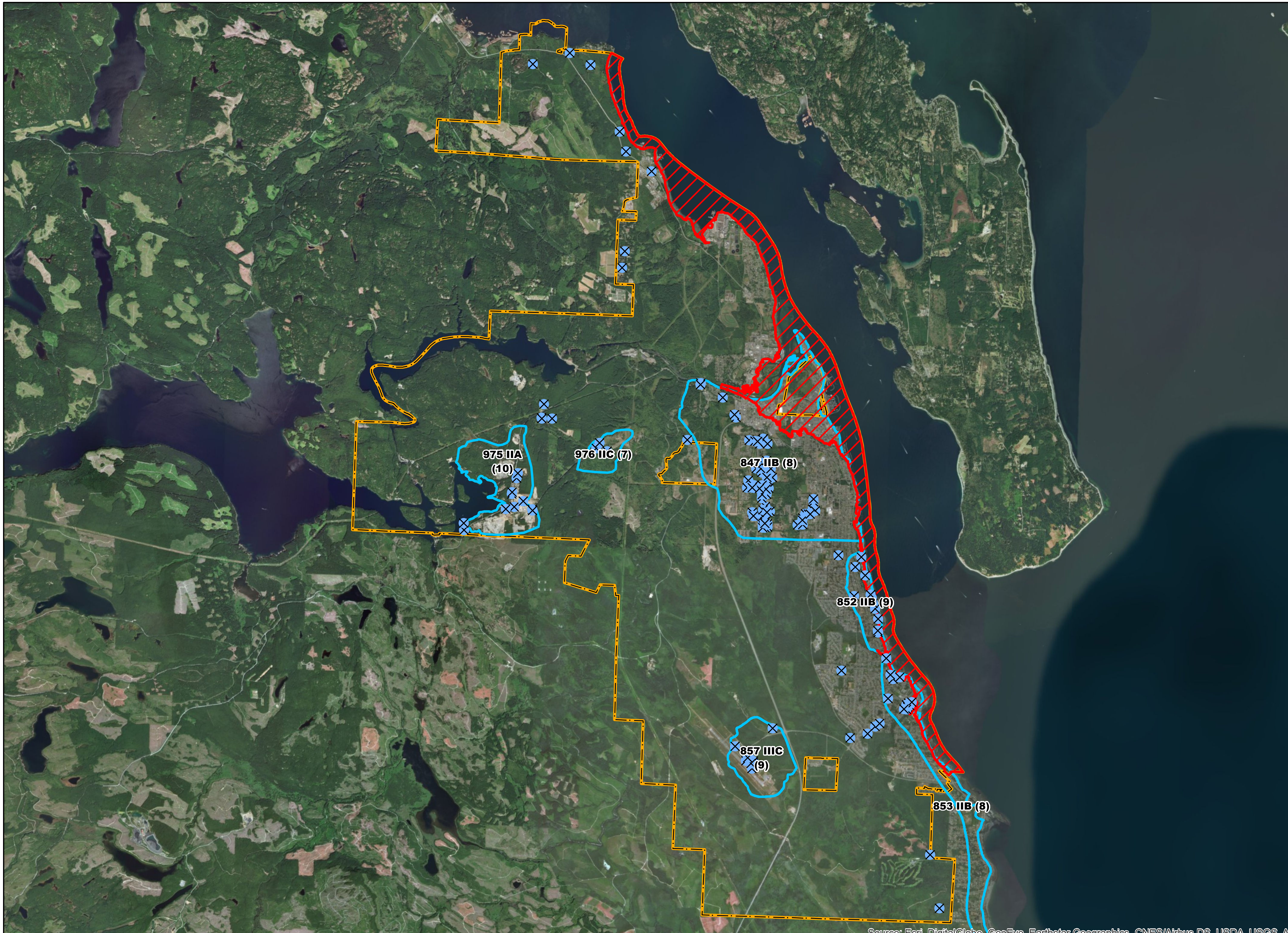
MADRONE
environmental services ltd.
Figure 32: Combination of Geo Factors 1m Sea Level Rise
PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study
CLIENT:
City of Campbell River
GEOGRAPHIC AREA:
Campbell River, BC
MAP SCALE:
1:10,000
MAPPING DATE:
November 20, 2019
DOSSIER NO:
19.0261
DRAWN BY:
Jessi Yellowlees
Study Area
Areas Impacted by 1m Sea Level Rise
Foreshore Section
Erosion Risk Based on Cumulative Ranking Value:
High : 35
Low : 3
Campbell River
0
100
200
400
Meters
1:10,000
N
W
E
S
12
11
10
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



MADRONE
environmental services ltd.

Figure 33: Wells & Aquifers
0.5m Sea Level Rise

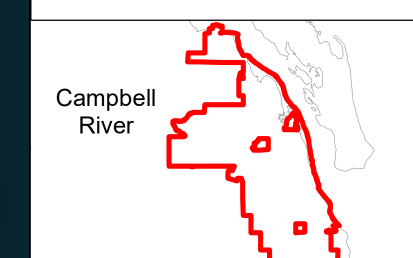
PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE: 1:90,000	**MAPPING DATE:** December 2, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area
Aquifer
Well Location
Areas Impacted by 0.5 m Sea Level Rise



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Kilometers
1:90,000

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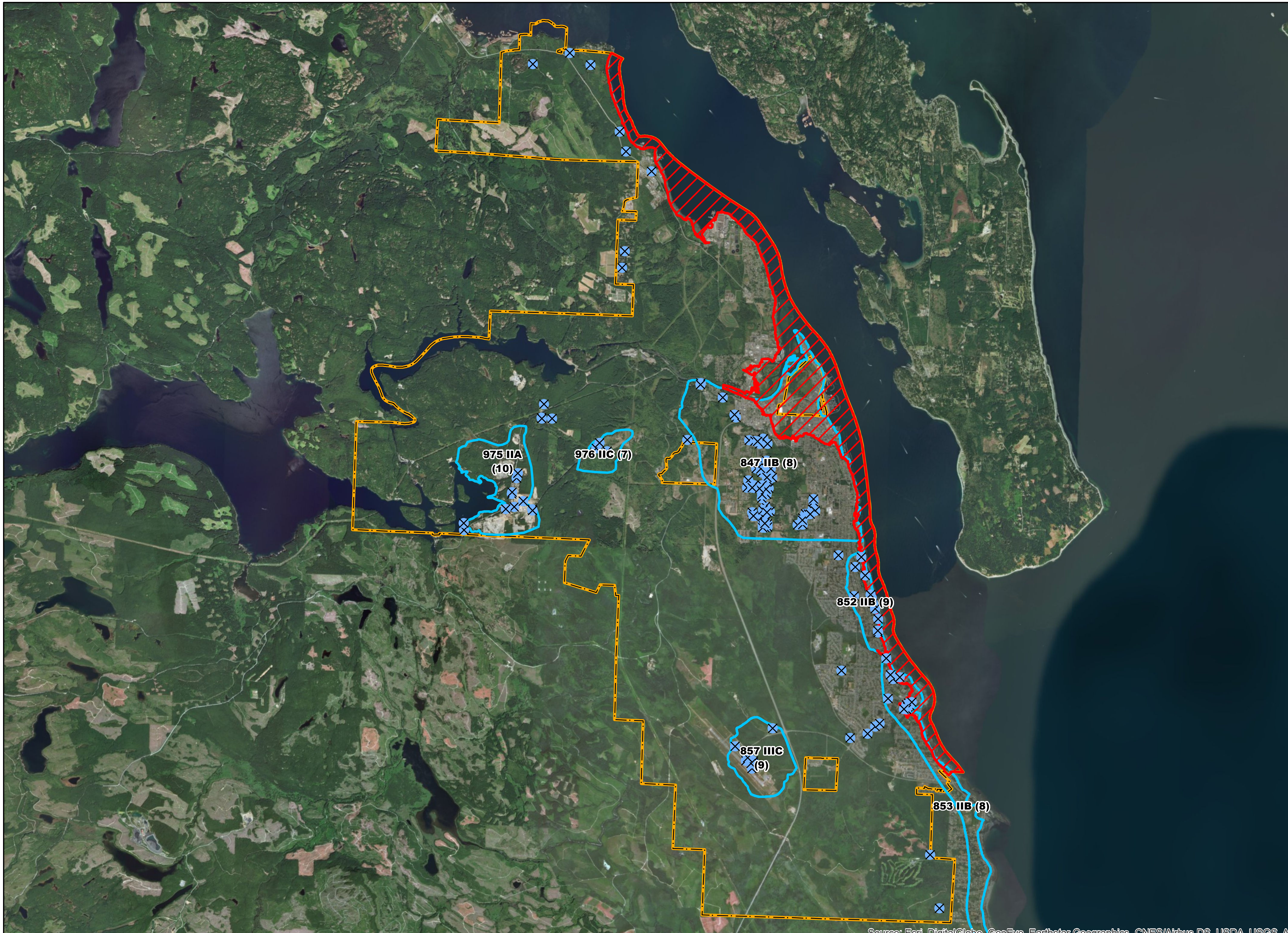


MADRONE environmental services ltd.

Figure 34: Wells & Aquifers 1m Sea Level Rise

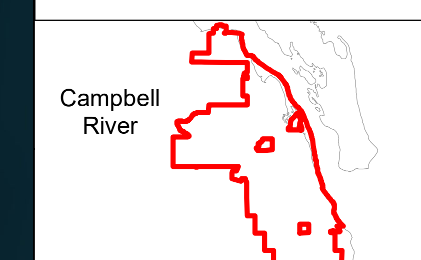
PROJECT: Sea Level Rise: Ecosystems and Species at Risk Study

CLIENT: City of Campbell River

GEOGRAPHIC AREA: Campbell River, BC

MAP SCALE: 1:90,000	**MAPPING DATE:** December 2, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area
Aquifer
Well Location
Areas Impacted by 1m Sea Level Rise



0 0.5 1 2 Kilometers

1:90,000

N W E S

6.5 Quality Assurance

Results from Madrone's model was compared to the shoreline study prepared by Mak (2017) for Campbell River. We found a high degree of conformance between the two products, which extends reliance to both works. Specific correlation includes the area directly north of the estuary and immediately west from the edge of Tyee Spit, wherein Appendix E of the Mak report identified this area as being susceptible for erosion; our model shows this area as being one of the higher risk areas along the entire shoreline of Campbell River (Figures 31 and 32).

6.6 Discussion

With the goal to present new knowledge to the City of Campbell River regarding erosion risk and sediment transport/deposition, our erosion potential model operates at a scale beyond the immediate shoreline and assesses the inland areas of the City, including the sensitive habitats of the estuary and along the shores of the hydrological network draining from Campbell Lake to the Salish Sea.

Based on our results, we present potential impacts based on 0.5 m and 1.0 m SLR scenarios, thus creating hydrological conditions where erosional processes can occur due to the presence of water (*i.e.*, shifting shoreline to higher elevation areas), and where sediment can be mobilized and deposited because of water acting as a transportation mechanism.

6.6.1 Potential Impacts to Channel Morphology

Based on our modelling results, there is high potential for erosion along the banks of the Campbell River at the maximum extent of SLR (*i.e.,* the adjusted shoreline) for both the 0.5 m and 1.0 m rise scenarios. Satellite imagery (Google Maps 2019) indicates that these high-risk areas are proximal to roads, bridges, residences and commercial complexes, which could result in damage to buildings and infrastructure. We recommend that the City explore shoreline erosion mitigation (*e.g.*, installing erosion control matting or stone rip-rap) for low lying areas adjacent to the river.
With regards to aggradation, sediment would normally be deposited on the inner bend of a stream channel due to decreased velocity compared to the centre of the channel. This would be the case for the stretch of the river east of the North Island Highway bridges; however, projected inundation of this area makes it challenging to determine where sediment will be deposited in the (former) channel. Under the 0.5 m and 1.0 m SLR

scenarios, it is likely that sediment would be deposited on the west facing slopes or surface features such as the west side of Baikie Island, the spit where the Myrt Thompson Trail is located and Dick Murphy Park. The reason for this is that any eroded material from upslope areas would be transported eastward towards the Salish Sea. Water velocity would decrease towards the western shoreline of the aforementioned features, thus depositing materials at these locations. Other features, either natural or anthropogenic (*e.g.*, dense vegetation cover, buildings), which would reduce velocity would also be locations where aggradation would occur.

6.6.2 Potential Impacts to Water Quality and Availability

Our results indicate that groundwater wells located near the coast in Aquifers 852 and 853 are most at risk for contamination by sea water and/or suspended sediment which could enter the wells at the surface with SLR inundation. Wells in Aquifer 852 are at particular risk as the Vulnerability for Contamination is High (A) as ranked by the Province of British Columbia (2002). As defined in Figure 35, a High (A) ranking is applied to an aquifer that is vulnerable to contamination from surface sources and have little natural protection against contamination introduced at the ground surface. Thus, Aquifer 852 should be given priority for the implementation of quality protection measures.

Vulnerability	Interpretation
High A	• Highly vulnerable to contamination from surface sources, A aquifers have little natural protection against contamination introduced at the ground surface. • Existing land uses or future additional developments, which may introduce a contaminant to the land surface, should initiate measures to protect against introducing contaminants. • A aquifers should be given first priority for the implementation of quality protection measures.
Moderate B	• Moderately vulnerable to contamination from surface sources, B aquifers have limited natural protection against contamination introduced at the ground surface. Degree of natural protection may vary across an aquifer. • Existing land uses or future additional developments, that could introduce a contaminant to the land surface, should initiate measures to protect against introducing contaminants. • B aquifers should be given priority over C aquifers when it comes to implementing quality protection measures.
Low C	• Generally not considered very vulnerable to contamination from surface sources, C aquifers are more protected against contamination introduced at the ground surface. • C aquifers have the lowest vulnerability rating and are the least likely to become contaminated. • A rating of C does not imply that all C aquifers are immune to contamination. All aquifers are vulnerable to contamination to a certain degree, especially if there are "windows" exposing the underlying aquifer or if the land-use activity breaks through the overlying confining layer.

FIGURE 35: VULNERABLE TO CONTAMINATION RATINGS AS DEFINED BY THE PROVINCE OF BRITISH COLUMBIA.

Another pathway for saltwater contamination of groundwater wells is via the subsurface through saltwater intrusion. Saltwater intrusion refers to the process by which sea water infiltrates coastal groundwater systems, thus mixing with the local freshwater supply[6]. This "mixing" occurs in an interface zone where saline groundwater intrudes beneath fresh groundwater (Figure 36). SLR is likely to lead to increased risk of intrusion and well contamination; however, the exact nature of this relationship – precisely how much risk will increase as a result of SLR – is still not well understood (Werner and Simmons, 2009).

Within the data and budget constraints of this project, Madrone is unable to determine a spatial extent of saltwater intrusion impacts on groundwater wells (*i.e.*, how far inland is saltwater intrusion expected to occur with SLR) other than stating that the wells near the coast are more at risk than those further away, and that aquifers which extend beyond the natural boundary without full confinement have increased susceptibility. As such, a more detailed investigation including geophysical field survey, groundwater sampling and/or GIS component is required to further comment on the risk from saltwater intrusion.

[6] Best Practices for Prevention of Saltwater Intrusion. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-wells/saltwaterintrusion_factsheet_flnro_web.pdf

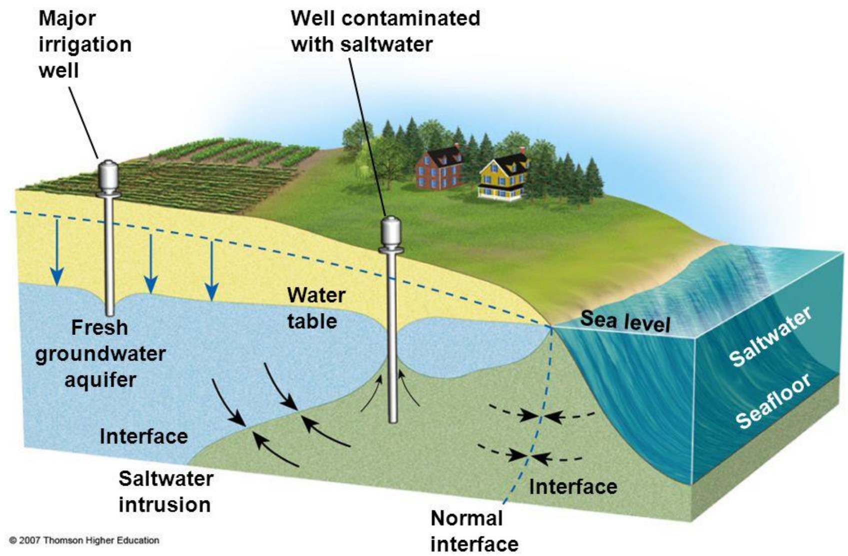


FIGURE 36: VISUALIZATION OF SALTWATER INTRUSION (PROVIDED BY NORTH CAROLINA STATE UNIVERSITY [N.D.]) SHOWING THE RISK TO GROUND WATER PUMPING NEAR COASTAL REGIONS WHERE SALINE GROUND WATER MIXES WITH FRESH GROUND WATER (INTERFACE ZONE).

Additionally, we would like to note that Madrone considered SLR impact potential to the water quality of John Hart Lake, a human-made lake northwest of Campbell River and the primary source for municipal water. The elevation of John Hart Lake is approximately 140 m above sea level and thus the risk of contamination from sea water or disturbance from sea level rise-related erosion/sediment deposition would be extremely low, if not impossible, under current climate change projections.

6.6.3 Potential Impacts to Freshwater Aquatic Habitat and Aquatic Species

As discussed in Section 5, Campbell River provides documented habitat for a range of species including chinook salmon, coho salmon, chum salmon, pink salmon, sockeye salmon, steelhead, anadromous coastal cutthroat trout, rainbow trout, Dolly Varden, coastrange sculpin, prickly sculpin, slimy sculpin and threespine stickleback.

According to the Department of Fisheries and Oceans Canada (DFO), elevated levels of sediment and turbidity (water clarity) can reduce the productivity of aquatic systems by decreasing light penetration into water and increasing water temperature, which has the potential to decrease primary productivity (*i.e.*, plant growth), secondary productivity (*i.e.*, organisms that feed on plant growth) and the energy flow to higher trophic levels (DFO Pacific Region, 2000). The DFO reports that elevated levels of sediment and turbidities can alter predation risk, access to food, egg development and survival for many freshwater fish species. Furthermore, fish gills, which are delicate and easily damaged by fine sediment, are at risk of being physically damaged and/or clogged under elevated levels of sediment with prolonged exposure causing death.

Although different fish species have different tolerances for suspended sediment concentrations, levels determined to be acutely lethal to fish typically range from the hundreds to hundreds of thousands of mg L^{-1} of sediment while sublethal effects are in the tens to hundreds of mg L^{-1} of sediment (DFO Pacific Region, 2000); these ranges should be considered when monitoring aquatic habitats in the City; 1 mg L^{-1} is equivalent to 3 Nephelometric Turbidity Units (NTU).

Elevated sediment levels also directly affect the health of invertebrates such as insects, snails, worms and crayfish. Sediment clogs filter mechanisms of species that filter feed and abrades the gills of other species, impairing respiration (Newcombe and MacDonald 1991). Excess deposition of sediment on coarse gravel substrates can also eliminate invertebrate habitat (Gammon 1970).

7 Sea Level Rise and Potential Contaminated Sites Risk

7.1 Overview

This section considers the presence of contaminated sites in the City of Campbell River, how they may be affected by (SLR, and the resulting potential risk of increased deleterious impact on surrounding ecological receptors.

7.2 Contaminated Sites and Environmental Contaminants Defined

Contaminated sites in the City of Campbell River are locations identified by provincial and federal regulators as suspected or known sources of environmental contamination impact in soils and water, based on evidence generated through regulatory filings, environmental investigations, or notices of independent remediation to regulators. Contaminated sites contain environmentally deleterious concentrations of organic and inorganic substances in soil, soil vapour and/or water, which depending on source conditions and potentially operative migration pathways, can be harmful or hazardous to sensitive ecological receptors. The range of potentially affected ecological receptors can span one or more of humans, plants, and vertebrates/ invertebrates in the avian, terrestrial, and aquatic (marine or freshwater) realms.

In B.C., contaminants are specifically defined as substance concentrations that exceed numerical standards for soil, soil vapour and water (marine and freshwater), as listed under the *Contaminated Sites Regulation* (part of the *Environmental Management Act)*. Contaminant threshold concentrations in ambient receiving environments such as freshwater, estuarine and marine environments are provided by the B.C. Approved and Working Water Quality Guidelines (BCAWQG). Additional contaminant threshold concentrations are also provided by the Canadian Council of Ministers of the Environment (CCME) for lands and waters under Indigenous/First Nations and federal government jurisdiction.

7.3 Methodology

To assess the potential implications of SLR on contaminated sites in the City of Campbell River and meet the objectives of this report, the following tasks were completed:

- Inventory of known contaminated sites locations in the City of Campbell, based on a review of web-based regulatory contaminated sites databases, including those of iMapBC for lands and waters under B.C. provincial environmental jurisdiction, and the Federal Contaminated Sites Inventory (FSCI) for lands and waters under Indigenous/First Nations and federal government jurisdiction;

- Identification of ambient environment processes that are likely most significantly at play on contaminated sites in the City of Campbell River (see also Section 6), and summary on how ambient conditions and processes may change with SLR and potentially affect broader ecological values; and
- Generation of a lowest-to-highest ranking of potential contaminated sites risk to ecological receptors in the City of Campbell River, related to SLR - generated by merging contaminated sites locational data with GIS polygons of predicted changes to coastal soil/sediment erosion, transport, and re-deposition, generated in Section 6.

7.4 Inventory of Contaminated Sites – City of Campbell River

To identify and locate all known or suspected contaminated sites in the City of Campbell River, data were obtained from the following web-based primary data sources:

- **iMap BC** – searching under the layer "Waste/Environmental Remediation Sites". Contaminated sites information available on the iMap BC is generated from data registered on the online environmental Site Registry, which is managed by the B.C. Ministry of Environment and Climate Change Strategy (MoECCS). The Site Registry is an electronic file repository of all environmental notations, notices, legal instruments, and investigation and remediation details that have been filed with or by the B.C MoECCS, on a property-specific basis.

A total of forty-nine (49) B.C. MoECCS SITE file properties are currently identified in the City of Campbell River; most are situated in the downtown/estuary area, with the ten (10) remaining SITEs situated along the coastal foreshore corridor along Highway 19A, south of the City downtown (see Figures 37 and 38). A similar tally was previously reported by Mak (2017).

<u>DATA LIMITATION NOTE</u>: The receipt of environmental property documentation by the MoECCS typically results in the creation of a numerical 'SITE' identification file on the electronic Site Registry, regardless of the nature of the documentation, be it a simple Site Profile form or a Notice of Independent Remediation. The occurrence of a SITE file on a property does not necessarily confirm that it is a contaminated site, as is commonly inferred. Verification of suspected or actual contamination on a property can only be determined by obtaining a 'Detailed Report' from the Site Registry on a per report cost basis, and by reviewing the notation details provided by the Detailed Report – something

not possible under this report's scope and budget. In the absence of scrutinizing all current Site Registry Detailed Report files, the total number of 'contaminated sites' in Campbell River (as identified by the iMap BC Waste layer and this report), may be over-represented.

A more accurate inventory of suspected or actual B.C. MoECCS contaminated sites in Campbell River would therefore need to be completed as a future follow-up effort to this report, with additional scope and budget provided for the acquisition and review of all property Detailed Reports from the environmental Site Registry.

- **Federal Contaminated Sites Inventory** – Occurrences of contaminated sites on Indigenous/First Nations and federally regulated properties are systematically assessed, classified on a priority-rank basis, and are registered into the FSCI by the specific federal government department and/or Indigenous/First Nation that act in the administrative role of 'custodial steward' for the land being reported on.

A total of thirteen (13) FSCI-registered contaminated properties are reported within the City of Campbell River study area (see Figures 39 and 40). Five (5) contaminated site locations occur on estuary lands, while another eight (8) are situated along coastal foreshore/harbour settings.

7.5 Sea Level Rise Impacts Affecting Contaminated Sites

SLR has the potential to destabilize known and any as-yet undetected contaminated sites within the coastal foreshore and river estuary in the City of Campbell River, which can result in the physio-chemical mobilization of contaminant substances, and their transport, deposition and attenuation in sediment and water beyond their existing areas of impact. The re-distribution of contaminants in sediments, groundwater and in shallow littoral marine and estuarine environments therefore has the potential to impart more widespread negative impacts on ecological receptors and values.

SLR impacts on contaminated sites and coastal processes, by which contaminants can be de-stabilized and re-distributed, have been summarized, among others, by the U.S. Environmental Protection Agency (US EPA 2014), and previously for the City of Campbell River by Northwest Hydraulics Consultants Ltd. (2019) and Mak (2017).

In summary, SLR can affect contaminated sites through the following effects:

- Inundation by rising marine waters, resulting in littoral erosion and redistribution of soils/sediments by tidal action acting on previously non-inundated surfaces;
- Storm surge and wave 'run-up' to higher elevations, resulting in erosion of new soils and slopes previously not affected, mobilization and resulting re-distribution of new sediments; and
- Saltwater intrusion in the subsurface - resulting in displacement of fresh groundwater inland, altered hydrostatic pressure and groundwater flow gradients, and chemical changes due primarily to increased salinity.

Geomorphic context to the effects of SLR on contaminated sites in the City of Campbell River lands is provided in Section 6, which illustrates and ranks the potential degree of impacts on patterns of net inferred soil/sediment erosion, mobilization/transport and deposition.

This report's scope considers potential SLR impacts on currently known contaminated sites. However, future focus should also be placed on compiling known locations of bulk petroleum hydrocarbon fuels storage within the City of Campbell River, such as retail gas bars and bulk fuel depots, that may be present within zones of projected 0.5 m to 1.0 m SLR. The work is warranted as future risks to fuel containment systems integrity could increase for underground storage tanks and fuel containment infrastructure systems, as they slowly and invisibly come under greater hydrostatic groundwater pressures, hydrochemical fluxing and/or inundation effects, in the face of gradually rising sea levels. Destabilization of buried fuel systems, due to increasing corrosion rates and/or tank buoyancy uplift pressures, represent increased risk for potential fuel infrastructure failures and large-volume leaks or spills of petroleum hydrocarbons to soils, sediments and groundwater, with negative impacts to sensitive biological receptors.

7.6 Known Contaminated Sites – Risk-ranking Based on Potential Sea Level Rise Impact

As a first-pass assessment of potential risk in the face of SLR, contaminated site inventory data for the City of Campbell River was superimposed over geoscience GIS data generated by Madrone, linking the intensity of littoral marine processes on different soil polygons under the 0.5 m and 1.0 m sea level rise scenarios.

Figures 37 through 40 illustrate all known contaminated sites within the City, relative to inferred net new erosion, transport and redeposition of sediment erosion – highlighting those areas that consequently could have the greatest potential for uncontrolled re-distribution of contaminants and impact upon sensitive ecological receptors. The ranking provides a focus to identifying contaminated sites and zones within the City of Campbell River that warrant more follow-up and refinement of contaminated site risk, via detailed reviews of specific MoECCS 'SITE' files.

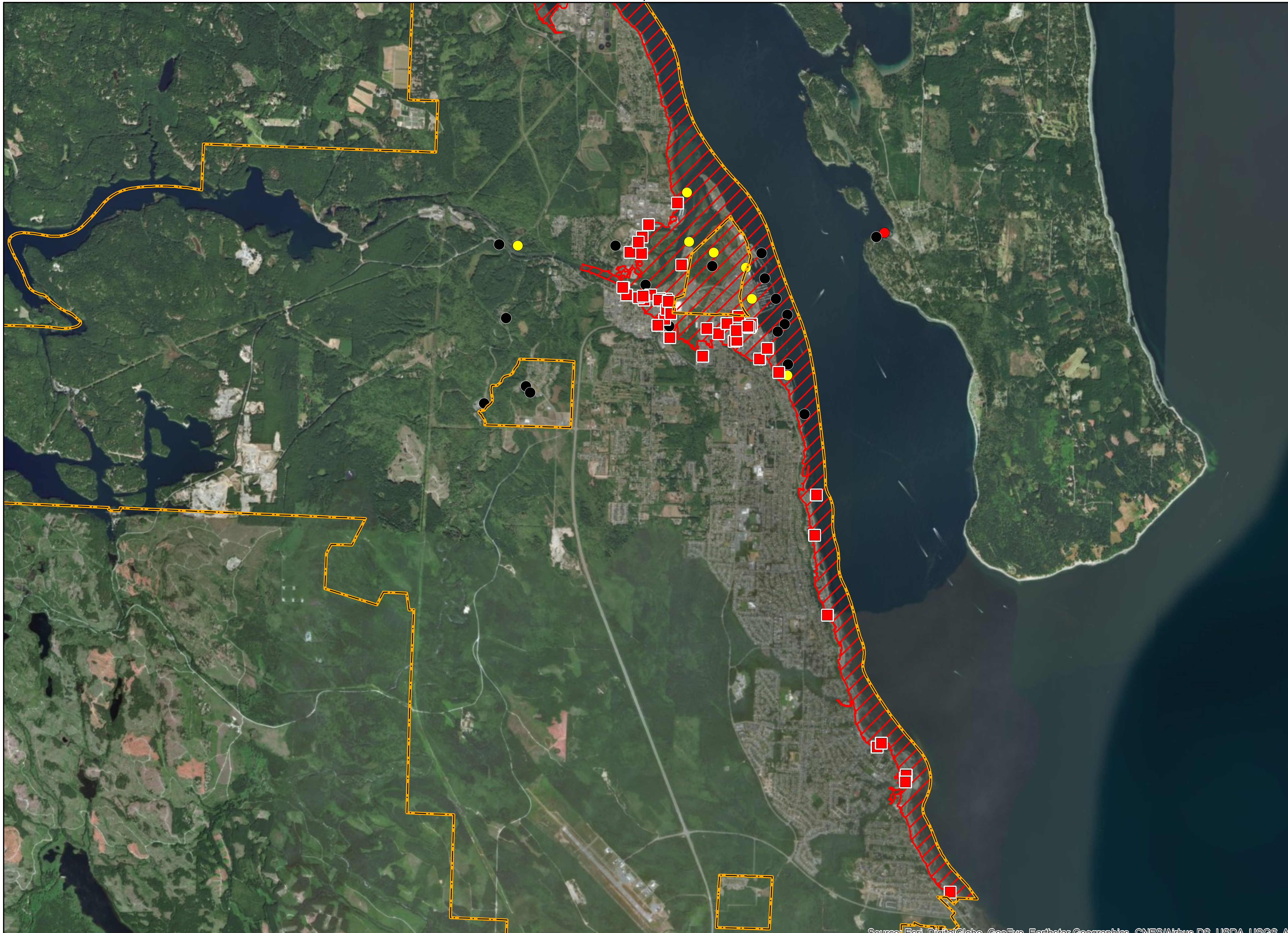


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Figure 37: Known B.C. & Federal Contaminated Sites 0.5m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE: 1:55,000	**MAPPING DATE:** November 20, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area
Areas Impacted by 0.5m Sea Level Rise
B.C. MoECC 'SITE' file

Federal Contaminated Sites Inventory file

Suspected
Active
Closed

* Contaminated Sites information Obtained From:
iMapBC:
https://maps.gov.bc.ca/ess/hm/imap4m
Layer : Waste - Environmental Remediation Sites

Federal Contaminated Sites Inventory:
https://map-carte.tbs-sct.gc.ca/map-carte
/fcsi-rscf/map-carte.aspx?
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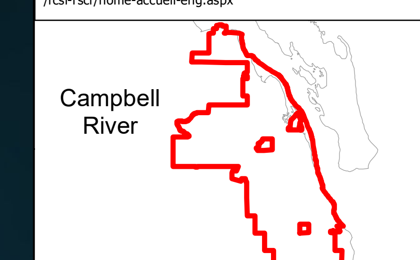
/fcsi-rscf/home-accueil-eng.aspx



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Kilometers
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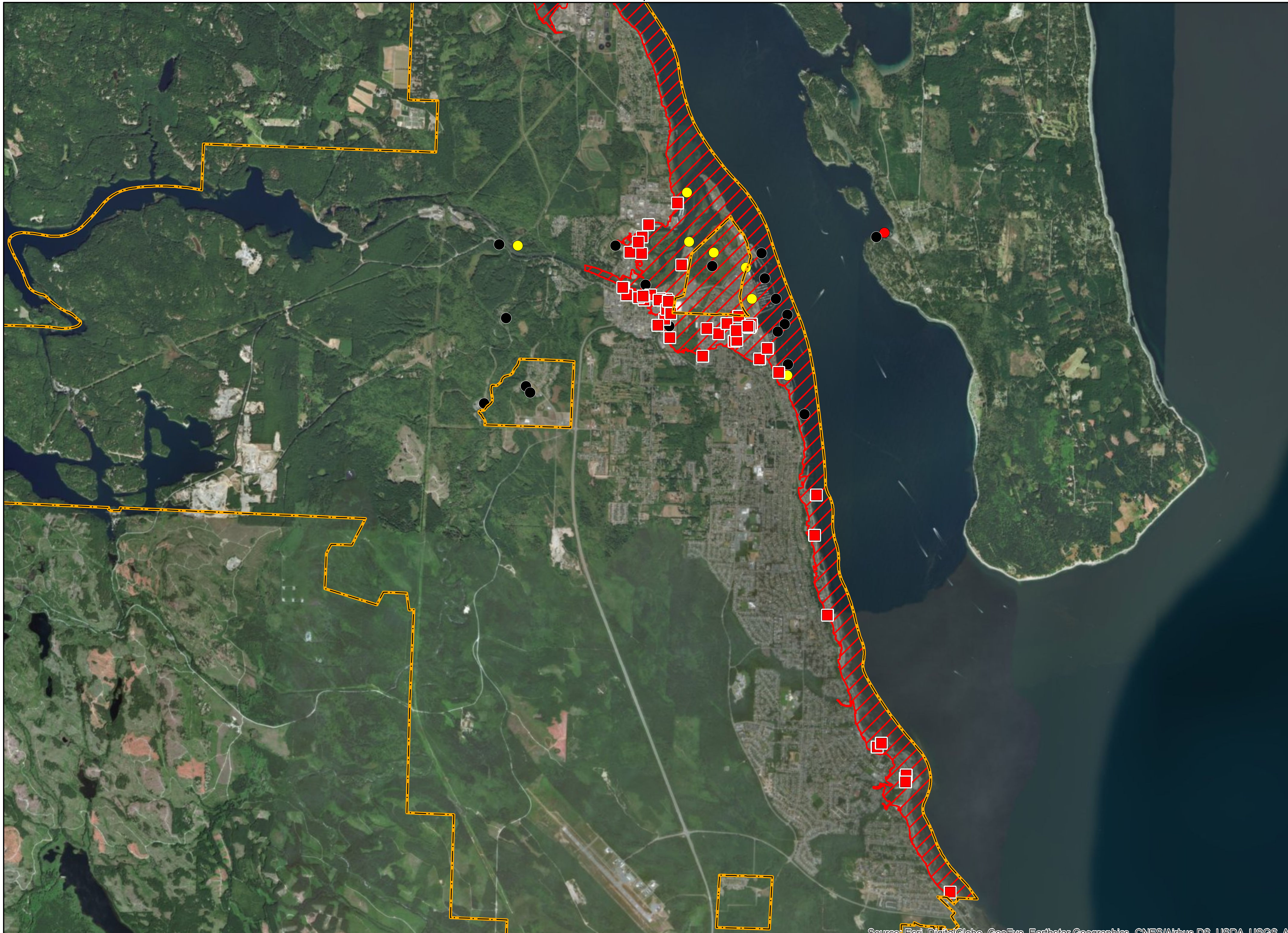

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Figure 38: Known B.C. & Federal Contaminated Sites 1m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE: 1:55,000	**MAPPING DATE:** November 20, 2019
DOSSIER NO: 19.0261	**DRAWN BY:** Jessi Yellowlees

Study Area

Areas Impacted by 1m Sea Level Rise

B.C. MoECC 'SITE' file

Federal Contaminated Sites Inventory file

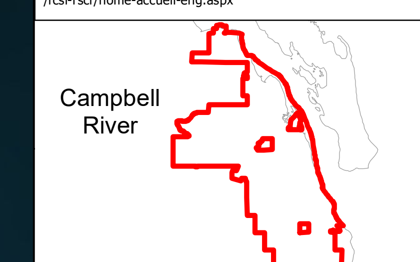
Suspected

Active

Closed

* Contaminated Sites information Obtained From:
iMapBC:
https://maps.gov.bc.ca/ess/hm/imap4m
Layer : Waste - Environmental Remediation Sites

Federal Contaminated Sites Inventory:
https://map-carte.tbs-sct.gc.ca/map-carte/fcsi-rscf/map-carte.aspx?Language=EN&backto=www.tbs-sct.gc.ca/fcsi-rscf/home-accueil-eng.aspx



0 0.5 1 2
Kilometers

1:55,000

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MADRONE
environmental services ltd.

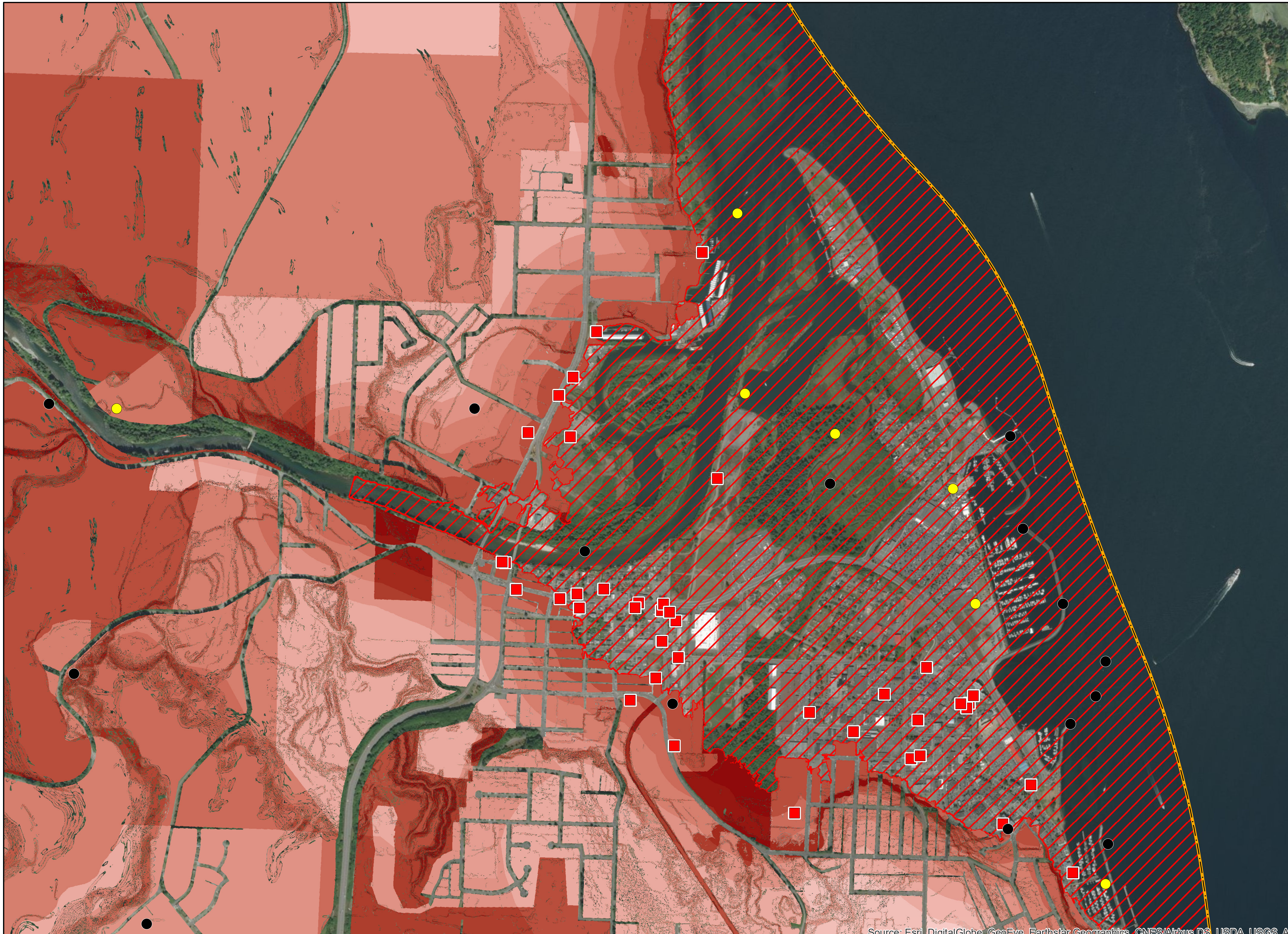
Figure 39: Combination of Geo Factors & Known B.C. & Federal Contaminated Sites 0.5m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:15,000	November 20, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees



Study Area
Areas Impacted by 0.5m Sea Level Rise

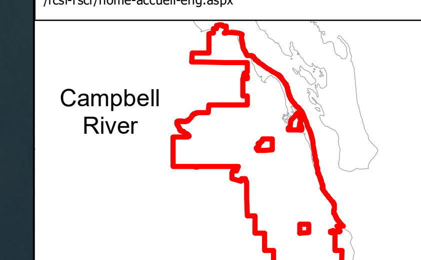
Erosion Risk Based on Cumulative Ranking Value
High : 34
Low : 3

B.C. MoECC 'SITE' file

Federal Contaminated Sites Inventory file
Suspected
Active
Closed

* Contaminated Sites information Obtained From:
iMapBC:
https://maps.gov.bc.ca/ess/hm/imap4m
Layer : Waste - Environmental Remediation Sites

Federal Contaminated Sites Inventory:
https://map-carte.tbs-sct.gc.ca/map-carte
/fcsi-rscf/map-carte.aspx?
Language=EN&backto=www.tbs-sct.gc.ca
/fcsi-rscf/home-accueil-eng.aspx



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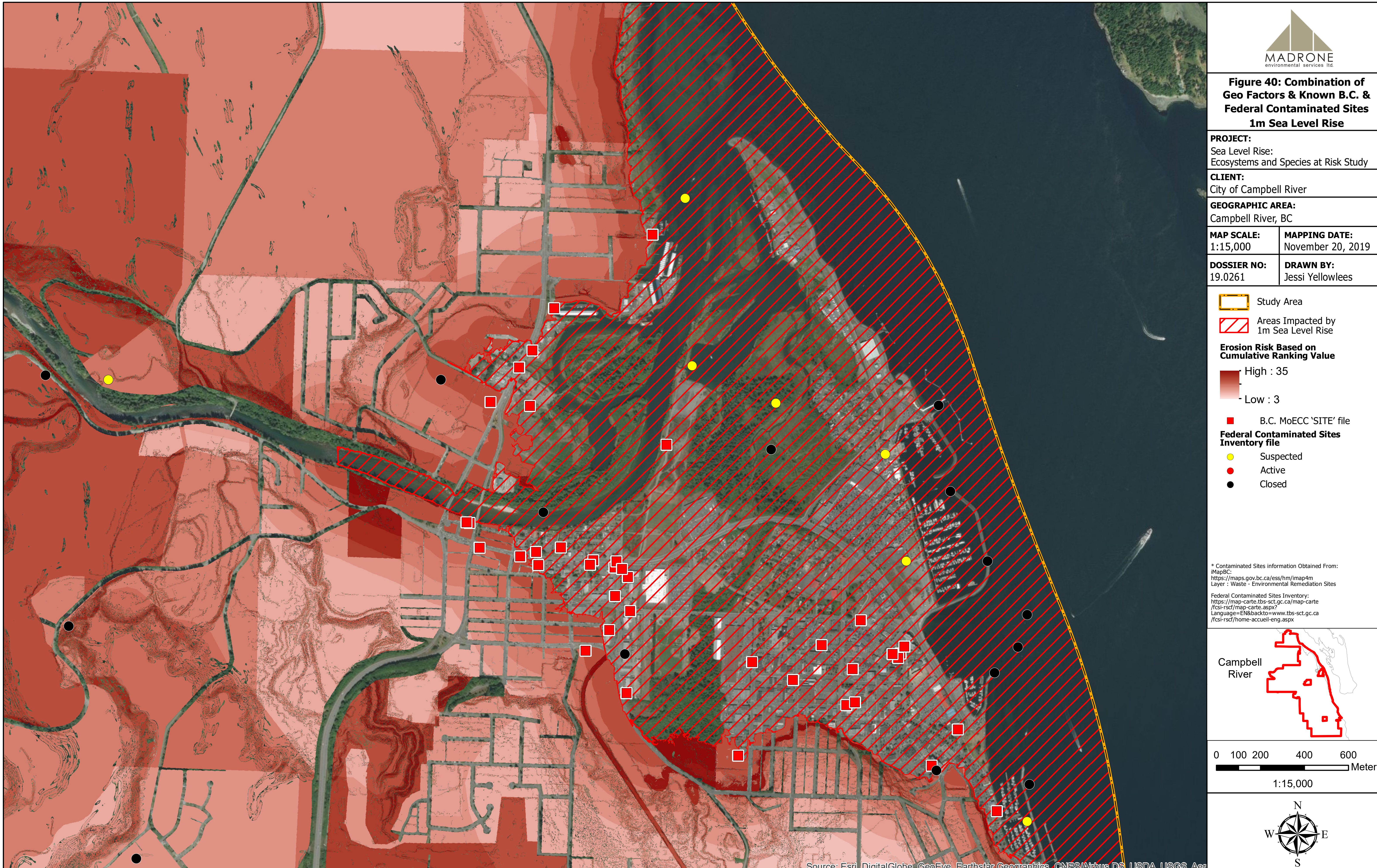

Figure 40: Combination of Geo Factors & Known B.C. & Federal Contaminated Sites 1m Sea Level Rise

8 General Discussion

8.1 Anthropogenic Disturbance and Importance of Protecting Existing Ecosystem Services

Based on the general implications of coastal squeeze, the current distribution of infrastructure and the current status of ecosystems, future impacts from SLR will likely be exacerbated in comparison with other coastal areas that currently support functioning ecosystems. Ecosystem services associated with the “Regulating” category along the majority of the City of Campbell River’s seafront have generally been eroded over time due to the construction of sea walls, roads and housing, landscaping activities and industrial development. In addition, activities involving foreshore hardening are contributing to impacts of coastal erosion due to increased scour and changes to the natural dynamics of sediment movement along the foreshore.

Attitudes towards development that potentially exacerbate coastal erosion must become more sympathetic to the protection of ecosystem services. Consequences to actions that degrade ecological integrity must be understood if the City of Campbell River is to maintain its multiple inherent values and avoid additional infrastructure costs. For example, maintaining the claim of being Salmon Capital of the World and collecting the benefits that this title allows must be backed up by the protection of all the ecosystem services that help to maintain those benefits. The links between actions such as encroaching upon foreshore habitat or removing backshore riparian vegetation and impacts to forage fish and ultimately salmon productivity must be appreciated.

PHOTO 66: EXAMPLE OF FORESHORE HARDENING AND ENCROACHMENT INTO THE BACKSHORE RIPARIAN ZONE ALONG THE CAMPBELL RIVER OCEANFRONT. AUGUST 7TH, 2019
Photo credit: Trystan Willmott

PHOTO 67: EXAMPLE OF FORESHORE HARDENING AND ENCROACHMENT INTO THE BACKSHORE RIPARIAN ZONE ALONG THE CAMPBELL RIVER OCEANFRONT. AUGUST 7TH, 2019
Photo credit: Trystan Willmott

Due to the importance of ecosystem services in providing benefits to people, it is of paramount importance not to separate ecological integrity from economic prosperity. The two systems are inextricably linked, and it is necessary to change the general way of thinking that economic development trumps the protection of ecological systems. A functioning economy cannot occur without the provision of ecosystem services. Without delving into philosophical issues in detail, it should be further noted that the constant search for possessions and financial gain that ultimately result in the over-exploitation of natural resources and an associated loss in the provision of ecosystem services do not necessarily result in contentment or increased levels of "happiness". A shift needs to take place to ensure that long term benefits derived from ecosystem services are not lost, perhaps by establishing a culture that reflects a more minimalistic approach to living, which would ultimately lead to increased human well-being.

8.2 Civic Planning into the Future

Efforts should be made in order to avoid impacts on natural capital biodiversity (Phalan *et al* 2018). "Natural capital biodiversity" refers to the generative capabilities of natural systems toward providing for the well-being of people, which is essentially the same concept as ecosystem services. This is clearly an anthropocentric instrumental, appropriative, view of nature, which typically results in natural capital (ecosystem services) being undervalued, and in many instances preferentially consumed; or not accounted for when lost under the strain of a changing climate.

Natural capital biodiversity (ecosystem services) will undoubtedly be under downward pressure through imposed ecosystem development – through which we recommend strengthening the initial step of ecosystem services decision making through first seeking to avoid impacts wherever possible. Subsequent and supporting efforts to minimize or reclaim impacted services, and ultimately to offset any unavoidable impacts will generally complete an adaptive approach to SLR and climate change.

Coastal fringe areas are becoming hazardous areas for humans to inhabit, which is similar to historical development on other hazardous lands that are attractive for development, such as floodplains. Local governments could feasibly become pioneers (through appropriate development strategies) for the long-term planning of responsibly sited settlements that are located away from potential hazard lands. The key would be to take an adaptive approach, where local governments could take a leading role in helping to prepare for change. The following statement by Wong *et al.*, 2014 (cited in Lemmen *et al.,* 2016), which is associated with general climate change concerns, highlights the importance of proactive planning that considers an adaptive approach: "*Planning by coastal communities that considers the impacts of climate change reduces the risk of harm from those impacts. In particular, proactive planning reduces the need for reactive response to the damage caused by extreme events. Handling things after the fact can be more expensive and less effective*".

Current legislation such as the Riparian Areas Protection Regulation and equivalent regulations will help to provide some harm reduction to sensitive areas. The *Water Sustainability Act* further helps to provide a legislative framework for the protection of sensitive habitat. Recent changes to the federal *Fisheries Act*, and the fact that the protection of habitat is now at the forefront of the *Act* will also help to provide more of a legislative backbone to regulate development proposals in sensitive areas.

The City of Campbell River is aware of the impacts of SLR and the importance of maintaining ecosystem services. Mechanisms are in place that address development activities in sensitive areas, which are perhaps more important than other higher levels of provincial and federal legislation in controlling local issues. Forward-thinking initiatives that continue to restrict impacts on sensitive and vulnerable habitat types will help to address some of the concerns and will ultimately provide education as to the importance of maintaining ecosystem services. However, a cultural shift is also required to change development attitudes and instill more of an understanding of ecosystem services and the associated human benefits. Ongoing investment by the City into initiatives such as the SLR action plan that contain a significant level of public input and education should continue over the long term to help change current development attitudes.

Planning for rising sea levels and other impacts of climate change will be an ongoing challenge for the City. The City will be obliged to grapple with budget, policy, bylaws and public opinion. Difficult decisions will be required when deciding what shoreline areas to maintain with "traditional" engineering, and which to restore to a more natural state. Conservation programs are often contentious - people may be genuinely concerned about the environment, and may think favourably regarding environmental programs, on the condition that there are no costs involved (financial or otherwise). For example, people living along the seashore in Campbell River (and elsewhere on Vancouver Island) may be concerned about fish habitat, but this is trumped by a desire to have an ocean view unimpeded by vegetation. In reality, a failure of ecosystem services generally leads to increased financial burden related to numerous processes – *e.g.* saltwater inundation of wells, increased erosion potential and loss of property.

The rise in sea level is very gradual and will not be very noticeable from year to year. This could result in a lack of civic initiative to start planning – and understandably so, because the full effects of sea level change will unfold over several hundred years. Future land use planning that considers hazardous areas will ultimately help to reduce the levels of impact and vulnerability over the long term.

8.3 Restoration Potential

Ecosystem services depend on complex linkages and diversity among and within species, to ensure species richness can provide a reservoir of biological options that can help an ecosystem respond to some level of disturbance without catastrophic failure (Palumbi *et al* 2009). Marine ecosystems with a high diversity have shown slower rates of fisheries collapse and higher rates of recovery than marine ecosystems with lower diversity (Palumbi *et al* 2009). Increased resiliency with greater diversity is true for other ecosystems too. Therefore, increasing the diversity in areas that have been degraded can enhance the capacity of cities to respond and adapt in the face of disturbance and change (Elmqvist *et al* 2015). Investments into restoring, reducing harm to ecosystems and their services is not only socially desirable but also economically viable. The greatest cost-benefit ratios were found for restoring grasslands, followed in decreasing order by woodlands, inland wetlands, urban woodland, coastal wetlands, freshwater, and coastal systems (most cost for least benefit) (Elmqvist *et al* 2015).

While restoration potential in Campbell River may be limited by constrictions imposed by current infrastructure such as the Sea Walk, Highway 19A, housing and industry, it is important to consider success stories. For example, the work conducted in the Campbell River estuary by the City, Greenways Land Trust and others, provides a positive example of what can be achieved with appropriate organization and a willingness to contribute.

It also highlights the importance of community involvement, as restoration includes the application of a significant amount of volunteered time, which helps to instill a sense of well-being. This in itself is a human benefit ultimately derived from the "Cultural" ecosystem service category. This type of community involvement was readily apparent along the Myrt Thompson Trail in the Campbell River estuary, where restoration efforts were evident in the form of invasive plant removal and riparian planting. This trail provides further benefits to the "Cultural" ecosystem service category, based on the public use the trail receives for multiple activities such as hiking, dog walking, photography and wildlife viewing (most notably bird watching).

PHOTO 68: THE MYRT THOMPSON TRAIL PROVIDES PUBLIC ACCESS FOR NUMEROUS ACTIVITIES WHILE ALSO PROVIDING OPPORTUNITIES FOR VOLUNTEER CONTRIBUTIONS TO ECOSYSTEM RESTORATION. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

Baikie Island Nature Reserve is an excellent example of how restoration, coupled with the inherent resilience of the natural world, can result in the transformation of a landscape from an industrial site to a network of functioning ecosystems. The City should be commended for the initiatives taken to restore and maintain this Nature Reserve over the long term.

PHOTO 69: THE RESTORED MILL POND IN THE BAIKIE ISLAND NATURE RESERVE IS A SHARP CONTRAST TO ITS FORMER INDUSTRIAL USE. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

PHOTO 70: CULTURAL ECOSYSTEM SERVICES ARE PROVIDED FOR IN THE RESTORED BAIKIE ISLAND NATURE RESERVE. AUGUST 8TH, 2019
Photo credit: Trystan Willmott

Incentives for restoration (*e.g.* tax break incentives) would help to create positive reasons for converting poorly functioning or non-existent ecosystems into areas that provide biological function and ecosystem services. Such incentives would also help to curb encroachment into currently functioning ecosystems.

In terms of the Backshore Riparian ecosystem, it will be extremely important, wherever possible, to re-vegetate or complement existing vegetation by implementing restoration programs. In many cases, once established, vegetation will colonize new areas if space is available and no disturbance occurs. It is important to use plants that are tolerant of salt spray – especially in shoreline areas. A list of sea-spray tolerant plants that could potentially be used in the restoration of Backshore Riparian areas is presented in Table 16 (Wash. State Univ. 2010). Most of these plants are available at native plant nurseries, and some of them may establish naturally.

TABLE 16: SALT SPRAY TOLERANT NATIVE PLANTS.

Life-form	Common name	Latin name	Priority species	Planting information
fern	bracken fern	*Pteridium aquilinum*	moderate	may establish naturally
fern	sword fern	*Polystichum munitum*	high	plant in shady areas under established shrubs and trees
herb	beach pea	*Lathyrus japonicus*	high	important for nitrogen fixation
herb	coastal strawberry	*Fragaria chiloensis*	high	may establish naturally
herb	common yarrow	*Achillea millefolium*	high	may establish naturally
herb	dune grass	*Elymus mollis*	high	upper beach zone
herb	false lily-of-the-valley	*Smilacina racemosa*	high	semi-shade
herb	fireweed	*Epilobium angustifolium*	moderate	may establish naturally
herb	giant vetch	*Vicia gigantea*	high	important for nitrogen fixation
herb	Puget Sound gumweed	*Grindelia integrifolia*	high	upper beach zone
herb	red clover	*Trifolium pratense*	high	important for nitrogen fixation
herb	seashore lupine	*Lupinus littoralis*	high	upper beach zone
herb	silver burweed	*Ambrosia chamissonis*	high	upper beach zone
shrub	black hawthorn	*Crataegus douglasii*	moderate	Gaps and open areas
shrub	black twinberry	*Lonicera involucrata*	moderate	semi-shade
shrub	common snowberry	*Symphoricarpos albus*	moderate	may establish naturally
shrub	dull Oregon grape	*Mahonia nervosa*	moderate	open to semi-shade
shrub	mountain ash	*Sorbus sitchensis*	moderate	open to semi-shade
shrub	Nootka rose	*Rosa nutkatensis*	high	gaps and open areas

Life-form	Common name	Latin name	Priority species	Planting information
shrub	ocean spray	*Holodiscus discolor*	high	may likely establish naturally
shrub	Pacific crabapple	*Malus fusca*	high	gaps and open areas, moist soil
shrub	Pacific nine-bark	*Physocarpus capitatus*	high	gaps and open areas, moist soil
shrub	red-flowering currant	*Ribes sanguineum*	high	open to semi-shade
shrub	red-osier dogwood	*Cornus stolonifera*	high	open to semi-shade
shrub	salal	*Gaultheria shallon*	high	plant in open to semi-shade
shrub	salmon berry	*Rubus spectabilis*	high	moist areas
shrub	saskatoon berry	*Amelanchier alnifolia*	high	open areas, well-drained soil
shrub	Scouler's willow	*Salix scouleriana*	high	open areas, well-drained soil
shrub	Sitka willow	*Salix sitchensis*	high	open moist areas,
shrub	tall Oregon grape	*Mahonia aquifolium*	high	open areas, well-drained soil
shrub	thimbleberry	*Rubus parvifolium*	high	may establish naturally
shrub	trailing blackberry	*Rubus ursinus*	high	may establish naturally
shrub	wax myrtle	*Myrica gale*	moderate	plant in estuaries and marsh areas
shrub	western trumpet honeysuckle	*Lonicera ciliosa*	high	open to semi-shade
tree	arbutus	*Arbutus menziesii*	moderate	full sun and well-drained soil
tree	big-leaf maple	*Acer macrophyllum*	high	open to semi-shade
tree	Douglas-fir	*Pseudotsuga menziesii*	high	important tree for eagles and other birds
tree	grand fir	*Abies grandis*	high	open to semi-shade
tree	pacific yew	*Taxus brevifolia*	moderate	semi-shade
tree	red alder	*Alnus rubra*	high	important for nitrogen fixation
tree	shore pine	*Pinus contorta*	high	often stunted
tree	Sitka spruce	*Picea sitchensis*	high	important tree for eagles and other birds
tree	western hemlock	*Tsuga heterophylla*	moderate	semi-shade
tree	western redcedar	*Thuja plicata*	moderate	semi-shade (recommended only in moist locations, due to apparent recent impacts from intense summer droughts)
tree	western white pine	*Pinus monticola*	moderate	full light

Reference: Washington State University Extension, Shore Stewards, 2010.

8.4 Public outreach

We noticed high public use of the Campbell River estuary and shoreline areas during field work, and it is apparent that local citizens enjoy these areas (an indication of the value of the "Cultural" ecosystem service category). This appreciation can hopefully be harnessed into support for programs that aim to restore ecosystems and associated services.

It is important to advise the public of the services that local ecosystems provide, and which have a direct influence on quality of life. Ecosystem services need to be considered in association with the economy, and not separate to it. Tourism, fishing, and forestry all depend on healthy ecosystems.

Using shoreline areas as an example and specifically the need to preserve backshore vegetation, public outreach will be required to address the on-going clearing of trees and plants to accommodate ocean views. The public should be aware of the critical importance of shoreline and backshore vegetation, forage fish spawning habitat, and hardened versus soft shorelines. Creating modest view windows is reasonable; however, in these situations it is common for pruning to exceed what would be considered "modest". In these cases, fines or required replanting may be in order.

9 Recommendations

The City has already commissioned a number of reports related to SLR, and the City should continue in its efforts to obtain sound scientific data with which to inform policy decisions through initiatives such as the SLR action plan. Many goals can be achieved with modest-sized budgets - goals that will dovetail and inform the work of future generations. Examples include:

- Detailed mapping of areas along the shoreline and estuary that will be flooded by SLR;
- Confirmation of the potential for ecosystem migration (*i.e.* into areas under 6 m above current seal level heights);
- Acquiring properties along the shoreline by extending the City's property acquisition strategy (established in 2015) to prioritize acquisition based on ecosystem services in areas that will help ameliorate SLR impacts;
- Continuing to implement the Memorandum of Understanding between the City and DFO (set up in 2012) to encourage restoration of foreshore and backshore zones

through "soft engineering" techniques. This work needs to be monitored for compliance and effectiveness; and

- Public education on the challenges facing the City and recommended practices that people should follow – particularly those close to the shoreline.

It appears that a multi-pronged approach will be most effective for protection and conservation:

- Continued City support of volunteer groups such as Greenways Land Trust;
- Further mapping of areas of concern, such as backshore vegetation, and areas where future backshore may be established;
- Identification of candidate restoration areas;
- Continued and strengthened implementation of Development Permit (DP) regulations for shoreline and backshore areas through increased enforcement of applicable bylaws and integration of SLR action plan into the DP;
- Public outreach; and
- Tax and other incentives for restoration or conservation.

With regard to developing incentives for the protection of ecosystem services, we can borrow from initiatives started in California through the California Roundtable on Agriculture and the Environment Guidelines for Ecosystem Services Incentive Programs and Policies (the "CRAE Guidelines"). In California, as a proxy example, an increased recognition of the importance of natural capital (ecosystem services) has led to stewardship initiatives, particularly when looking at conserving working landscapes – such as coastal wetlands. We recommend adopting guidelines developed by the CRAE for scoping and incentivizing programs and policies to retaining and fostering natural capital (Table 17).

Any scoping of ecosystem services natural capital programs must address the interlinked challenges of:

1. How the flow of useful ecosystem services depends on stocks of natural capital;
2. Quantifying and estimating values for natural capital;
3. Incorporating these into policy;

4 Creating or realizing markets and incentives for resource users to conserve ecological assets; and

5 Understanding when investments in ecosystem services can exacerbate the problem they are designed to overcome.

TABLE 17: CRAE GUIDELINES FOR ECOSYSTEM SERVICE INCENTIVE PROGRAMS AND POLICIES.

Eligible Activities	Ecosystem services may be fostered/reinforced as benefits from climate adaptation activities and from conservation activities on private and public lands
Reward Levels	Ecosystem service providers may be compensated for actions that do not necessarily have permanent or long-term impacts, provided that outcomes that garner benefits can be demonstrated. Generally, higher rewards will correspond to longer service provision and greater benefits
Stacking Credits	Practices generating multiple environmental benefits should not be precluded from qualifying for multiple streams of compensation
Minimum Bar	Ecosystem services programs should reward provision of services that are above and beyond an established baseline or regulation and provide mechanisms that recognize early adopters
Value of Transaction	Ecosystem services must have at least one identified buyer or beneficiary to have value, either monetary or other (e.g. experiential).

Other nearby communities, such as Qualicum and Comox are dealing with similar issues and undertaking similar projects to those in Campbell River. While these projects were not examined for this report, the City might consider having meetings with these other jurisdictions to share knowledge and ideas.

10 Closing

The fact that the Haig-Brown House Heritage Site overlooks the Campbell River is perhaps a stoic reminder of the importance of maintaining and enhancing the range of ecosystem services that functioning habitats provide. Haig-Brown's deep understanding of the natural world allowed him to appreciate the fragility of natural systems and develop a forward-thinking conservation ideology, the concepts of which are applicable to the present day. By observing changes over time to his home river, the Campbell River, Haig-Brown understood the need to conserve resources and protect important habitats. We should heed the early warnings and implement the conservation strategies developed by Haig-Brown if we are to maintain the essential services that functioning ecosystems provide.

One of Haig-Brown's well-known quotes from his book Measure of the Year (1950) epitomizes the importance of conservation, which is directly applicable to the long-term protection and enhancement of functioning ecosystems and the services they provide:

> "*I have been, all my life, what is known as a conservationist. It seems clear beyond possibility of argument that any given generation of men can have only a lease, not ownership, of the earth; and one essential term of the lease is that the earth be handed down on to the next generation with unimpaired potentialities. This is the conservationist's concern*."

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APPENDIX I

Species at Risk List

Scientific Name	English Name	Prov Status	Prov Status Change Date	COSEWIC	BC List	SARA	Name Category
Accipiter gentilis laingi	Northern Goshawk, *laingi* subspecies	S2	16-Jun-97	T (Apr 2013)	Red	1-T (Jun 2003)	Vertebrate Animal
Allium amplectens	slimleaf onion	S3	07-Mar-01		Blue		Vascular Plant
Aneides vagrans	Wandering Salamander	S3	30-Dec-16	SC (May 2014)	Blue	1-SC (Feb 2018)	Vertebrate Animal
Ardea herodias fannini	Great Blue Heron, *fannini* subspecies	S2S3B,S4N	23-Jan-09	SC (Mar 2008)	Blue	1-SC (Feb 2010)	Vertebrate Animal
Asio flammeus	Short-eared Owl	S3B,S2N	01-Jun-96	SC (Mar 2008)	Blue	1-SC (Jul 2012)	Vertebrate Animal
Balsamorhiza deltoidea	deltoid balsamroot	S2	30-Apr-19	E (Apr 2009)	Red	1-E (Jun 2003)	Vascular Plant
Bidens amplissima	Vancouver Island beggarticks	S3	07-Mar-01	SC (Nov 2001)	Blue	1-SC (Jun 2003)	Vascular Plant
Brachyramphus marmoratus	Marbled Murrelet	S3B,S3N	18-May-10	T (May 2012)	Blue	1-T (Jun 2003)	Vertebrate Animal
Butorides virescens	Green Heron	S3S4B	30-Jun-98		Blue		Vertebrate Animal
Callophrys eryphon sheltonensis	Western Pine Elfin, *sheltonensis* subspecies	S3	15-Jan-07		Blue		Invertebrate Animal
Cardamine angulata	angled bittercress	S3	30-Apr-19		Blue		Vascular Plant
Carychium occidentale	Western Thorn	S3	01-Dec-15		Blue		Invertebrate Animal
Cerastium fischerianum	Fischer's chickweed	S3	29-Apr-15		Blue		Vascular Plant
Cercyonis pegala incana	Common Wood-nymph, *incana* subspecies	S2			Red		Invertebrate Animal
Cervus elaphus roosevelti	Roosevelt Elk	S3S4	03-Dec-10		Blue		Vertebrate Animal
Claytonia washingtoniana	Washington springbeauty	S2	31-Mar-17		Red		Vascular Plant
Contopus cooperi	Olive-sided Flycatcher	S3S4B	26-Jan-09	SC (May 2018)	Blue	1-T (Feb 2010)	Vertebrate Animal
Corynorhinus townsendii	Townsend's Big-eared Bat	S3S4	27-Apr-15		Blue		Vertebrate Animal

Scientific Name	English Name	Prov Status	Prov Status Change Date	COSEWIC	BC List	SARA	Name Category
Cypseloides niger	Black Swift	S2S3B	21-Apr-15	E (May 2015)	Blue	1-E (May 2019)	Vertebrate Animal
Deroceras hesperium	Evening Fieldslug	SH		DD (Nov 2003)	Red		Invertebrate Animal
Euonymus occidentalis var. *occidentalis*	western wahoo	S1	11-Feb-00		Red		Vascular Plant
Euphydryas editha taylori	Edith's Checkerspot, *taylori* subspecies	S1	15-Jan-07	E (May 2011)	Red	1-E (Jun 2003)	Invertebrate Animal
Euphyes vestris	Dun Skipper	S2	31-Mar-13	T (Apr 2013)	Red	1-T (Jun 2003)	Invertebrate Animal
Falco peregrinus pealei	Peregrine Falcon, *pealei* subspecies	S3S4	15-May-19	SC (Dec 2017)	Blue	1-SC (Jun 2003)	Vertebrate Animal
Fratercula cirrhata	Tufted Puffin	S2S3B,S4N	22-Apr-15		Blue		Vertebrate Animal
Geum schofieldii	Queen Charlotte avens	S3	30-Apr-17		Blue		Vascular Plant
Glaucidium gnoma swarthi	Northern Pygmy-owl, *swarthi* subspecies	S3S4	01-Jun-18		Blue		Vertebrate Animal
Gulo gulo luscus	Wolverine, *luscus* subspecies	S3	30-Jun-98	SC (May 2014)	Blue	1-SC (Jun 2018)	Vertebrate Animal
Gulo gulo vancouverensis	Wolverine, *vancouverensis* subspecies	SH	17-Sep-01	SC (May 2014)	Red	1-SC (Jun 2018)	Vertebrate Animal
Hesperia colorado oregonia	Western Branded Skipper, *oregonia* subspecies	S1	31-Mar-13	E (Nov 2013)	Red		Invertebrate Animal
Hirundo rustica	Barn Swallow	S3S4B	29-Nov-05	T (May 2011)	Blue	1-T (Nov 2017)	Vertebrate Animal
Lasthenia maritima	hairy goldfields	S3	30-Apr-19		Blue		Vascular Plant
Megascops kennicottii kennicottii	Western Screech-Owl, *kennicottii* subspecies	S2S3	16-May-17	T (May 2012)	Blue	1-T	Vertebrate Animal
Mitellastra caulescens	leafy mitrewort	S3	31-Mar-18		Blue		Vascular Plant
Montia chamissoi	Chamisso's montia	S3	31-Mar-18		Blue		Vascular Plant
Mustela erminea anguinae	Ermine, *anguinae* subspecies	S3	30-Nov-95		Blue		Vertebrate Animal

Scientific Name	English Name	Prov Status	Prov Status Change Date	COSEWIC	BC List	SARA	Name Category
Nearctula sp. 1	Threaded Vertigo	S3	01-Dec-15	SC (Apr 2010)	Blue	1-SC (Jul 2012)	Invertebrate Animal
Oreamnos americanus	Mountain Goat	S3	27-Apr-15		Blue		Vertebrate Animal
Oxypolis occidentalis	western cowbane	S3	30-Apr-16		Blue		Vascular Plant
Pachydiplax longipennis	Blue Dasher	S3S4	10-Mar-04		Blue		Invertebrate Animal
Parnassius smintheus olympiannus	Rocky Mountain Parnassian, *olympiannus* subspecies	S2S3	15-Jan-07		Blue		Invertebrate Animal
Patagioenas fasciata	Band-tailed Pigeon	S3S4	06-Oct-00	SC (Nov 2008)	Blue	1-SC (Feb 2011)	Vertebrate Animal
Pekania pennanti	Fisher	S3	27-Apr-15		Blue		Vertebrate Animal
Phalacrocorax auritus	Double-crested Cormorant	S3S4	11-Jan-13	NAR (May 1978)	Blue		Vertebrate Animal
Pinicola enucleator carlottae	Pine Grosbeak, *carlottae* subspecies	S3	30-Jun-98		Blue		Vertebrate Animal
Platanthera ephemerantha	white-lip rein orchid	S3	30-Apr-19		Blue		Vascular Plant
Plebejus saepiolus insulanus	Greenish Blue, *insulanus* subspecies	SH	06-Dec-99	E (May 2012)	Red	1-E (Jun 2003)	Invertebrate Animal
Pristiloma johnsoni	Broadwhorl Tightcoil	S3	01-Dec-15		Blue		Invertebrate Animal
Progne subis	Purple Martin	S3B	23-Apr-15		Blue		Vertebrate Animal
Prosartes smithii	Smith's fairybells	S2S3	29-Apr-15		Blue		Vascular Plant
Ptychoramphus aleuticus	Cassin's Auklet	S2B,S3N	28-Apr-18	SC (Nov 2014)	Red	1-SC (May 2019)	Vertebrate Animal
Rana aurora	Northern Red-legged Frog	S3	31-Dec-16	SC (May 2015)	Blue	1-SC (Jan 2005)	Vertebrate Animal
Sidalcea hendersonii	Henderson's checker-mallow	S3	07-Mar-01		Blue		Vascular Plant
Sorex navigator brooksi	Western Water Shrew, brooksi subspecies	S2S3	31-May-18		Blue		Vertebrate Animal

Scientific Name	English Name	Prov Status	Prov Status Change Date	COSEWIC	BC List	SARA	Name Category
Speyeria zerene bremnerii	Zerene Fritillary, *bremnerii* subspecies	S2	15-Jan-07		Red		Invertebrate Animal
Tanypteryx hageni	Black Petaltail	S3	16-Oct-00		Blue		Invertebrate Animal
Tyto alba	Barn Owl	S2?	24-Apr-15	T (Nov 2010)	Red	1-T (Jun 2018)	Vertebrate Animal
Uria aalge	Common Murre	S2B,S3S4N	24-Apr-15		Red		Vertebrate Animal
Ursus arctos	Grizzly Bear	S3?	28-Apr-15	SC (May 2002)	Blue	1-SC (Jun 2018)	Vertebrate Animal
Viola praemorsa var. *praemorsa*	yellow montane violet	S1	30-Apr-19	E (Nov 2007)	Red	1-E (Jun 2003)	Vascular Plant

Search Criteria

- Animals OR Plants
- AND BC Conservation Status:Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern)
- AND Forest Districts:Campbell River Forest District (DCR) (Restricted to Red, Blue, and Legally designated species)
- AND Habitat Subtypes: Bog,Conifer Forest - Dry,Conifer Forest - Mesic (average),Conifer Forest - Moist/wet,Deciduous/Broadleaf Forest,Fen,Grassland,Gravel Bar,Industrial,Marsh,Meadow,Mixed Forest (deciduous/coniferous mix),Riparian Forest,Riparian Herbaceous,Riparian Shrub,Roadside/Ditch,Rock/Sparsely Vegetated Rock,Shrub - Logged,Shrub - Natural,Stream/River,Swamp,Urban/Suburban (Restricted to Red, Blue, and Legally designated species)
- AND BGC Zone:
- Sort Order:Scientific Name Ascending
- Open Government License– BC

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APPENDIX II

Forage Fish Data

	Willow Point	Simms Creek Beach	Hidden Harbour Beach	Beach near Discovery Pier	Tyee Spit - East Side
Site Number	1	2	3	4	5
UTM_Zone	10	10	10	10	10
Northing	5536981.0	5538334.0	5541786.0	5543183.0	5546322.0
Easting	341610.0	340822.0	340004.0	339799.0	338697.0
General Comments	Potential Forage Fish spawning habitat located adjacent to Ken Forde Park and boat ramp to the immediate south of Willow Point. Gently-sloping beach, with suitable spawning substrate for SS. Fully exposed, with no shading or wind-shelter functions provided, due to the composition of the backshore habitat. Backshore area is comprised of a narrow (~ 10 m) vegetated buffer situated between the upper beach and hardened surfaces. At Willow Point (immediately north of the assessment location), the foreshore has been impacted by a concrete boat ramp and rip-rap "breakwater". Suitable sediment appears to extend for at least 100 m to the south, but to the north of the boat ramp and Willow Creek estuary, the sediment progressively shifts to a predominantly cobble component. The assessment location provides a suitable representation of the best available habitat along this beach unit.	This beach area located between Frank James Park to the south and the Simms Creek estuary to the north offers potential Forage Fish spawning habitat. Substrate mix appears to offer potential spawning habitat for both SS and PSL. Gently sloping beach face with a narrow (~10 m) vegetated buffer between the upper beach limit and hardened surfaces (paved bike/walking trail, parking area and HWY). Generally exposed beach, but a continuous treed fringe approximately 100 m long does occur adjacent to the northern extent of the potential habitat. The assessment location provides a suitable example of the best available habitat in this area.	Small embayment providing potential Forage Fish spawning habitat located adjacent to the Hidden Harbour strata development. The assessment location provides a suitable representation of the best available habitat on this beach. The beach face is gently sloping, with a narrow (~ 5 m) vegetated fringe between the upper limit of the beach and the adjacent landscaped strata development. Beach is fully exposed, with no shading or wind-shelter functions provided.	Small "pocket beach" located to the immediate south of the Discovery Pier development area. Gently-sloping beach with potential Forage Fish spawning habitat. The assessment site provides a suitable representation of the best available habitat on this beach. The intertidal zone is almost completely exposed, but some tall shrubs and trees along part of the backshore zone provide some shading and shelter from wind. The northern segment of the beach is adjacent to the hardened surfaces of the Discovery pier parking area and the rip-rap breakwater protecting the Discovery Marina.	Potential Forage Fish spawning habitat is located along the majority of the eastern side of Tyee Spit adjacent to Dick Murphy Park. The gently-sloping beach leads up to a backshore riparian zone consisting of shrubs and grasses. The assessment site is representative of the overall potential spawning area. Fully exposed beach area, based on the vegetation assemblage (typical for this type of ecosystem).

	Willow Point	Simms Creek Beach	Hidden Harbour Beach	Beach near Discovery Pier	Tyee Spit - East Side
Assessment Time	9:10	11:48	13:45	14:10	14:50
Assessment Date	2019-08-07	2019-08-07	2019-08-07	2019-08-07	2019-08-07
Species most likely to occur Based on Sediment Type	SS	SS/PSL	SS	SS	SS
Degree of Anthropogenic Influence and Type of Disturbance in Foreshore and Backshore Zones	HWY 19A parallels the assessment site within approximately 20 m of the upper beach, with a paved parking area and trail located within ~ 10 m of the upper limit of the beach. Ken Forde boat ramp and associated armouring (rip-rap and mini "breakwater") extend through the upper and mid intertidal zones to the immediate north of the assessment site.	HWY 19A parallels the assessment site within approximately 20 m of the upper beach, with a paved trail and parking area located within ~ 10 m of the upper limit of the beach.	Backshore consists of manicured lawn and condominiums (Hidden Harbour strata development) behind the fringe of shrubs/grasses in the immediate backshore zone.	The backshore zone is generally impacted with rip-rap, paved parking areas, buildings and retaining wall structures. Parts of the foreshore area are also encroached upon by rip-rap.	Beyond the immediate vegetated backshore fringe (~5-8 m), the backshore zone supports a public park, with hiking trails, parking areas and maintained lawns.
Sediment Type Limiting Overall Habitat Value	Cobble	Cobble	Cobble	Cobble	Cobble
Primary Sediment Type Over 30 m Representative Transect	Fine Gravel	Coarse Gravel	Fine Gravel	Coarse Gravel	Coarse Gravel
Secondary Sediment Type Over 30 m Representative Transect	Coarse Gravel	Fine Sand	Coarse Sand	Fine Gravel	Fine Gravel

	Willow Point	Simms Creek Beach	Hidden Harbour Beach	Beach near Discovery Pier	Tyee Spit - East Side
Tertiary Sediment Type Over 30 m Representative Transect	Coarse Sand	Fine Gravel	Coarse Gravel	Coarse Sand	Coarse Sand
Degree of Shading/Wind Shelter from Backshore Vegetation	Assessment site is fully exposed, with desiccation of Forage Fish eggs/embryos extremely likely during the summer months. Any winter-spawning SS or PSL would not be subject to the same degree of desiccation.	The majority of the assessed beach unit is fully exposed, with desiccation of any summer-spawning Forage Fish eggs/embryos very likely. Any fall/winter-spawning SS and PSL would not be impacted by the same degree of desiccation. Towards the northern segment of the potential zone of spawning habitat, a stand of Douglas-fir and Sitka spruce provides some shading over the upper beach (including potential spawning areas) late in the day.	Fully exposed beach, with desiccation of any Forage Fish eggs/embryos likely during the summer months. Any fall/winter spawning SS and PSL would not be impacted by the same degree of desiccation.	The majority of the beach is exposed, with minimal shading/wind sheltering from shrubs and trees. Any Forage Fish eggs/embryos would be subject to desiccation during the summer months. Any fall/winter spawning SS or PSL would not be affected by the same degree of desiccation.	The beach is exposed, due to the composition of the backshore riparian zone (shrubs and grasses typical of sand-dominated ecosystems). The desiccation of eggs/embryos from any summer-spawning Forage Fish is likely, but fall/winter spawning SS and PSL would not be subjected to the same desiccation impacts.
Backshore Vegetation Description	Narrow fringe of small shrubs and grasses approximately 10 m wide between the paved trail and the upper beach limit.	Along the majority of the assessment site, backshore vegetation is comprised of a narrow fringe (~ 10 m) of shrubs and grasses. In the northern segment of the assessment area, Sitka spruce and Douglas-fir become mixed in with the shrubs and grasses, providing a treed fringe along part of the beach unit.	Narrow fringe (~ 5 m) of shrubs and grasses adjacent to the upper beach, dominated by invasive Himalayan blackberry. Manicured lawn extends for approximately 20 m beyond the shrub/grass zone up to the footprint of the condominiums. There is ample room to plant native shrubs and small trees.	Beyond the footprint of the Discovery Marina breakwater and parking area, the backshore riparian zone consists of tall shrubs and interspersed trees (mainly comprised of introduced ornamental trees (such as cherry) and invasive Himalayan blackberry).	Narrow fringe (~5-8 m) of shrubs and grasses situated between the upper beach limit and the park infrastructure.
Beach Slope (%)	12	14	12	8	14
Width of Beach in m at time of survey	25	20	20	20	25

	Willow Point	Simms Creek Beach	Hidden Harbour Beach	Beach near Discovery Pier	Tyee Spit - East Side
Sediment Depth in cm	> 20	> 20	> 20	> 20	> 20
Tide Height at Time of Sampling	2.7 m	3.2 m	2.8 m	2.8 m	2.6 m
Restoration Potential	Definite backshore restoration potential, based on the land use (park), that would improve upon various ecosystem services, including the protection/enhancement of habitat for Forage Fish. The incorporation of trees (e.g. Sitka spruce) would improve the overall biological function of the backshore riparian zone in terms of bank stability (erosion control) and also the control of storm run-off from adjacent hardened surfaces through contaminant removal (e.g. buffering of hydrocarbons being transported by surface run off along the impermeable road, parking area and trail). Based on the aspect of the beach (orientated North-South), any shade function would only be provided late in the day. Trees would help to decrease potential desiccation of Forage Fish eggs/embryos by providing shelter from wind. The width of potential enhancement is constrained by the adjacent hardened surfaces.	Previous restoration in the form of beach nourishment has occurred in this general area, with the introduction of sediment to the beach adjacent to Frank James park in 2014. Planting trees to add to and extend the existing fringe of Douglas-fir and Sitka spruce would be beneficial for erosion control and control of storm run-off from adjacent impermeable surfaces. The provision of shade over the foreshore by trees in the backshore riparian zone would only be a factor late in the day, due to the aspect of the beach unit (orientated north-south). The width of potential enhancement of the backshore zone is currently constrained by the hard surface disturbance footprints associated with HWY 19A and the paved trail.	The potential for restoration of the backshore zone is high, due to the fact that there is an extensive lawn between the condominiums and the upper beach (there are no hardened surfaces in this area). Conversion of this lawn to native functioning backshore riparian vegetation would provide a suite of ecosystem services, which would not only benefit Forage Fish, but would also provide long-term protection to the strata development. The removal of Himalayan blackberry and replacement with native shrubs and trees also represents potential restoration in this area.	The removal of Himalayan blackberry and planting of native species along the vegetated segment of this beach unit would improve the existing function of the backshore riparian zone in terms of the provision of bank stability, shading and shelter from wind. The provision of shade would be minimal, based on the aspect of the beach (generally faces towards the south). The potential for restoration along the northern segment of the beach would be constrained by the footprints of the Discovery Marina parking area and rip-rap breakwater.	Restoration efforts in Dick Murphy Park have been effective in reducing impacts to the sensitive backshore vegetation assemblages. Fencing and discrete beach access trails limit foot traffic from sensitive areas. These efforts should continue, to help preserve the biological function of the vegetated backshore.

APPENDIX III

Stream Reach Data

FISH HABITAT SITE CARD

STREAM NAME	Gazetted	Simms Creek	Local	N/A	Watershed Code	920-616300	
REACH #	Simms_1	SITE No.	1			SITE ACCESS	TRUCK
Waypoint-ID-DS	Simms_Start	NORTHING 5538647	EASTING 340682	Waypoint-ID-US	Simms_End	NORTHING 5538471 EASTING 340744	SURVEY LG (m) 200
DATE:	2019-08-08	TIME	15:59	AGENCY:	Madrone	CREW: TW	FISH FORM: NO

CHANNEL

PARAMETER	LOCATIONS MEASURED U/S FROM THE D/S SURVEY START							
DISTANCE U/S (M)	20	60	110	160	187	200	STAGE	L
CHANNEL WIDTH (M)	8	6.1	6.3	5.8	6	4.8	NO. VIS. CH	NO
WETTED WIDTH (M)	3.9	6	6	3.2	4.8	4	NCD	NO
RES. POOL DEPTH (M)	0.38	0.28	0.2	0.3	0.2	0.42	DRY/INT	NO
BANKFULL DEPTH (M)	0.7	0.6	0.6	0.7	0.7	0.7	DW	NO
GRADIENT (%)	1%	1	1	1	1	1	TRIBS	NO

WATER QUALITY

TEMP (°C)	COND. (µS/cm)	TURBIDITY	DO	pH
Not measured	Not measured	C	Not measured	Not measured

MORPHOLOGY

DOMINANT	C	PATTERN	ST	DISTURBANCE INDICATORS					01 - Beaver Dam - NO
SUBDOM.	G	ISLANDS	N	B1 - Abandoned Channel	NO	B2 - Eroded Bank	YES	B3 - Avulsion NO	D1 - Excess SWD - NO
D95 (cm)	30	BARS	SIDE	D2 - Lack of LWD	YES	D3 - Debris Jam	NO	C1 - Extensive Riffles NO	C2 - Lack of Pool Area - NO
D (cm)	14	COUPLING	PC	C3 - Elevated Bed	NO	C4 - Multiple Channels	NO	C5 - Disturbed Stone Lines NO	S1 - Homogenous Texture - NO
MORPH	RP	CONFINEMENT	FC	S2 - Finger	NO	S3 - Sediment Wedge	NO	S4 - Excessive Bars NO	S5 - Extensive Scouring - NO
FLOOD SIGNS	No								

COVER

	SWD	LWD	B	U	DP	OV	IV
TYPE	SWD	LWD	B	U	DP	OV	IV
AMT	T	T	T	T	D	S	T
LOC	P	P	P	P	P	P	P

TOTAL COVER: M
CR CLOSURE: 4

	LB	RB
SHP	S	S
TEXT	F	F
RIP VEG	M	M
STAGE	YF	YF

LWD FNC: F | DIST: E | INSTREAM VEG: N

FEATURES

TYPE	DIST U/S (m)	WPT	EASTING	NORTHING	HT (m)	LG (m)	Comments

HABITAT QUALITY

CATEGORY/TYPE	QUALITY	RATIONALE
REARING	M	Generally, moderate habitat suitability throughout the majority of the assessed reach for most life stages of salmonids. Legacy impacts from main highway construction and surrounding residential development (e.g. channelization/straightening/rerouting original channel location), with rip-rap armouring common along the assessed reach on both banks. Also, driveway accesses encroach through riparian area, but crossings consist of clear-span structures and the channel generally remains intact. Stable LWD is generally lacking, but some pools contain well-anchored LWD. In places, substrate is comprised of hard-packed clay, which limits the overall quality of spawning habitat. The substrate (gravels and cobbles) is embedded with fine sediments and is somewhat compacted/accreted, but larger salmonids (e.g. coho salmon) will be able to loosen these accretions while spawning. THe immediate riparian corridor is generally intact throughout the assessed reach, with overhanging and fringing vegetation providing biological function in the form of shade, nutrient input, bank stability and insect drop. Deep pools are common throughout the assessed reach, with adequate residual depths in most pool habitat units that will sustain perennial habitat through the summer drought conditions. Some evidence of eroded banks (likely exposed during high autumn/winter flows) in parts of the assessed reach. Staging/holding habitat is generally limited due to an absence of a functioning estuarine environment (legacy impacts from the construction of the highway), and is also limited in the stream itself, mainly due to the magnitude of the stream and physical dimensions of typical holding areas (e.g. pools and/or long, deep glides)
SPAWNING	M	
OVERWINTERING	M	
MIGRATION	M	
STAGING/HOLDING	L	

PHOTOS

CAM #	PHOTO #	TIME	DIST U/S (m)	DIR	COMMENT
TW	4561	16:03	0	U	Placed instream boulders (enhancement) immediately upstream of highway bridge.
TW	4562	16:03	0	X	Concrete "weir" - part of bridge structure at inlet of high-flow channel under highway bridge.
TW	4563	16:04	0	D	View through main wetted channel under highway bridge.
TW	4564	16:05	0	D	View through high-flow channel under highway bridge.
TW	4565	16:10	20	U	Typical riffle crest.
TW	4566	16:10	20	D	Typical pool habitat unit.
TW	4567	16:10	20	X	Typical spawning gravel.
TW	4568	16:12	70	U	River flow gauge?
TW	4569	16:20	90	U	Placed instream rock (enhancement).
TW	4570	16:20	90	U	Typical riparian corridor.
TW	4571	16:23	95	X	Example of functioning LWD.
TW	4572	16:25	110	X	Old bridge structure.
TW	4573	16:36	184	D	Driveway access bridge.
TW	4574	16:36	184	U	Driveway access bridge.
TW	4575	16:43	200	U	Deep pool - top of reach.

COMMENTS

Juvenile coho salmon were encountered throughout the assessment of the focus reach - mostly in deep pool habitat units. Assessed reach appears to represent important habitat for this species. Evidence of habitat enhancement throughout, with strategically-placed boulders and rocks creating natural "weir/riffle crest" structures. These crests create deep pool habitat units throughout the assessed reach, which increases the overall availability of cover for fish, while the placed boulders/rocks also provide cover for fish. Channel measurements were completed at locations that represented the best available freshwater habitat that would be subject to change/impacts from rising sea level (e.g. the best examples of stable riffle/pool sequences that generally contained the deepest pools and greatest proportion of useable perennially-available habitat). The reach start point was at the highway bridge.

FISH HABITAT SITE CARD

STREAM NAME	Gazetted	Willow Creek	Local	N/A	Watershed Code	920-614400				
REACH #	Willow_1	SITE No.	2						SITE ACCESS	TRUCK
Waypoint-ID-DS	Willow_Start	NORTHING	5537168	EASTING 341583	Waypoint-ID-US	Willow_End	NORTHING	5537053	EASTING 341393	SURVEY LG (m) 200
DATE:	2019-08-08	TIME	17:18	AGENCY:	Madrone	CREW:	TW		FISH FORM:	NO

CHANNEL

PARAMETER	LOCATIONS MEASURED U/S FROM THE D/S SURVEY START							
DISTANCE U/S (M)	20	35	60	130	180	200	STAGE	L
CHANNEL WIDTH (M)	6.8	8	6.9	9.6	11.2	9.8	NO. VIS. CH	NO
WETTED WIDTH (M)	3	3.7	3.9	5.9	3.1	4.1	NCD	NO
RES. POOL DEPTH (M)	0.46	0.2	0.18	0.5	0.47	0.49	DRY/INT	NO
BANKFULL DEPTH (M)	0.9	0.9	1.2	1	0.8	1.1	DW	NO
GRADIENT (%)	100%	1	1	1	1	1	TRIBS	NO

WATER QUALITY

TEMP (°C)	COND. (µS/cm)	TURBIDITY	DO	pH
Not measured	Not measured	C	Not measured	Not measured

MORPHOLOGY

DOMINANT	G	PATTERN	SI	DISTURBANCE INDICATORS						01 - Beaver Dam - NO
SUBDOM.	C	ISLANDS	F	B1 - Abandoned Channel	YES	B2 - Eroded Bank	YES	B3 - Avulsion	YES	D1 - Excess SWD - NO
D95 (cm)	15	BARS	SIDE	D2 - Lack of LWD	YES	D3 - Debris Jam	NO	C1 - Extensive Riffles	NO	C2 - Lack of Pool Area - NO
D (cm)	12	COUPLING	PC	C3 - Elevated Bed	NO	C4 - Multiple Channels	YES	C5 - Disturbed Stone Lines	NO	S1 - Homogenous Texture - NO
MORPH	RP	CONFINEMENT	OC	S2 - Finger	NO	S3 - Sediment Wedge	YES	S4 - Excessive Bars	NO	S5 - Extensive Scouring - NO
FLOOD SIGNS	Yes - area of braiding/avulsion ~ 150 m upstream of the reach start.									

COVER

					TOTAL COVER	M	LB SHP	S		RB SHP	S
TYPE	SWD	LWD	B	U	DP	OV	IV	TEXT	G	TEXT	G
AMT	T	T	T	T	S	D	T	RIP VEG	M	RIP VEG	M
LOC	P	P	P	P	P	P	P	STAGE	YF	STAGE	YF
CR CLOSURE	3							LWD FNC	F	DIST E	INSTREAM VEG V

FEATURES

TYPE	DIST U/S (m)	WPT	EASTING	NORTHING	HT (m)	LG (m)	Comments

HABITAT QUALITY

CATEGORY/TYPE	QUALITY	RATIONALE
REARING	M	Generally, moderate fish habitat attributes for most life stages of salmonids throughout the assessed reach. Coastal cutthroat trout were observed in pool habitat units, with juvenile coho salmon occurring throughout the reach, but mainly in pools. Has been impacted previously by HWY development and rerouting, with encroachment from development on both sides, creating unstable banks in places where riparian vegetation has been removed.For the most part, the riparian strip is lacking through the developed area, with steep, unstable banks. Habitat enhancement through the creation of pool/riffle sequencing at the start of the reach provides good rearing habitat that will remain wetted througout summer droughts, providing available perennial habitat. Close to the end of the reach, the creek becomes very unstable, with avulsion and braiding. Debris jams and root wads appear to be diverting the stream into numerous channels and the unstable banks are exacerbating the problem. The invasive species "Policeman's Helmet" (*Impatiens glanulifera*) is well established throughout the upper segments of the reach.
SPAWNING	M	
OVERWINTERING	M	
MIGRATION	M	
STAGING/HOLDING	L	

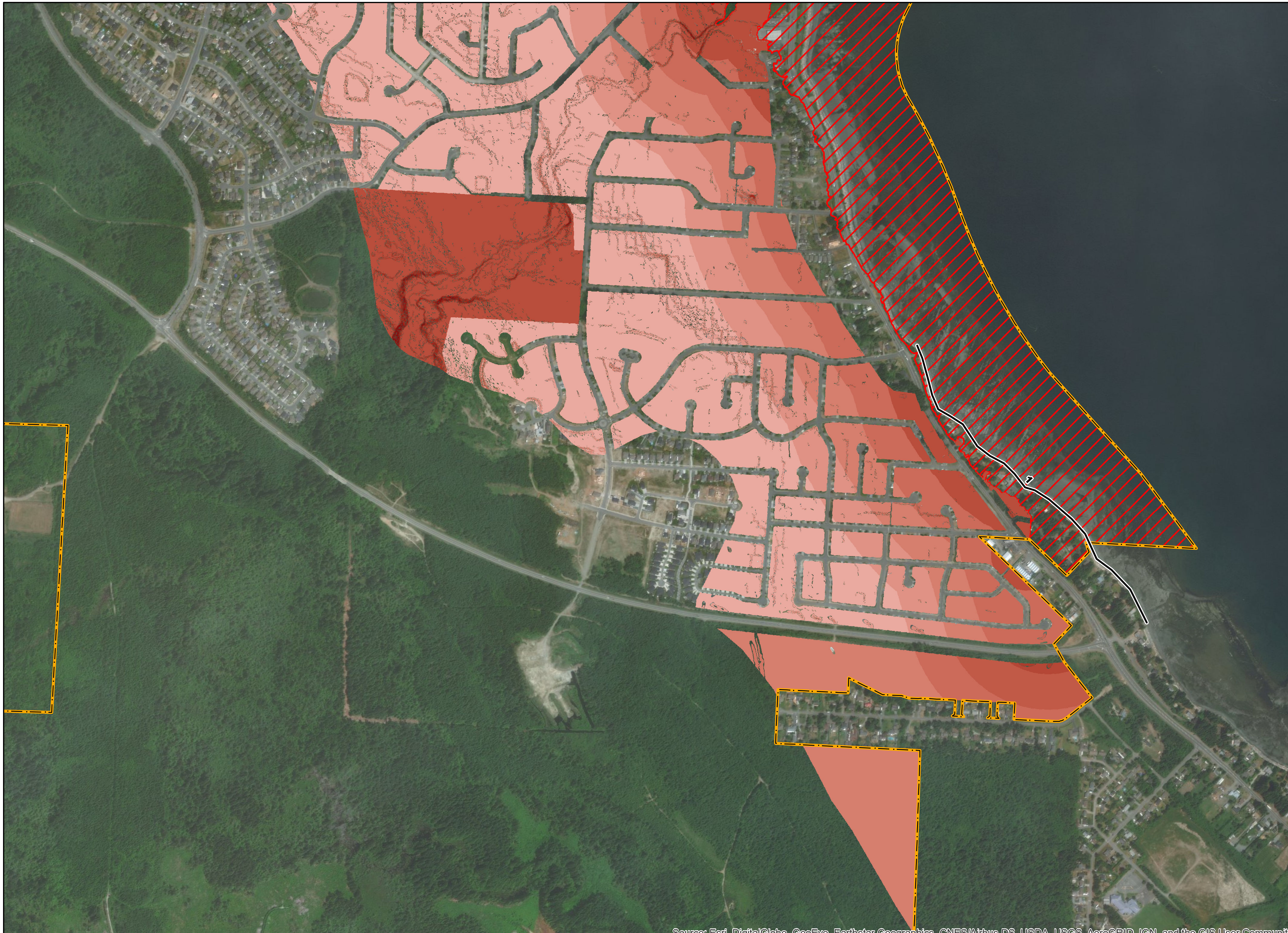
PHOTOS

CAM #	PHOTO #	TIME	DIST U/S (m)	DIR	COMMENT
TW	4578	17:20	0	D	Weir sequence - HWY bridge.
TW	4579	17:20	0	D	Weir sequence - HWY bridge.
TW	4580	17:21	0	U	"Spillway" - to create pool habitat units.
TW	4581	17:22	25	U	Example of pool Habitat Unit.
TW	4582	17:23	28	U	Example of side-bar (spawning potential).
TW	4583	17:30	28	X	Example of bank erosion and encroachment.
TW	4584	17:30	28	U	Open riparian area - lack of shade.
TW	4585	17:32	30	X	Invasive species abundance - "Policeman's helmet"
TW	4586	17:34	30	X	Example of bank erosion.
TW	4587	17:36	100	X	Example of stable LWD and pool habitat unit.
TW	4588	17:40	130	X	Erosion along left bank.
TW	4589	17:50	150	D	Braided/avulsed channel and debris jams.
TW	4590	17:55	185	X	Example of pool habitat unit and stable LWD.

COMMENTS

APPENDIX IV

Geoscience maps



MADRONE
environmental services ltd.

Combination of Geo Factors
0.5m Sea Level Rise

PROJECT:
Sea Level Rise:
Ecosystems and Species at Risk Study

CLIENT:
City of Campbell River

GEOGRAPHIC AREA:
Campbell River, BC

MAP SCALE:	**MAPPING DATE:**
1:10,000	November 21, 2019
DOSSIER NO:	**DRAWN BY:**
19.0261	Jessi Yellowlees

Study Area

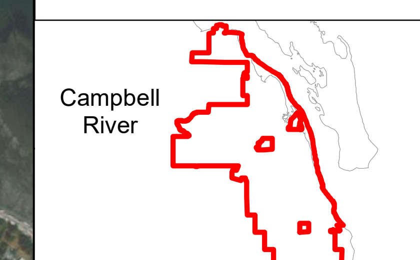
Areas Impacted by 0.5m Sea Level Rise

Foreshore Section

Erosion Risk Based on Cumulative Ranking Value:

High : 34

Low : 3



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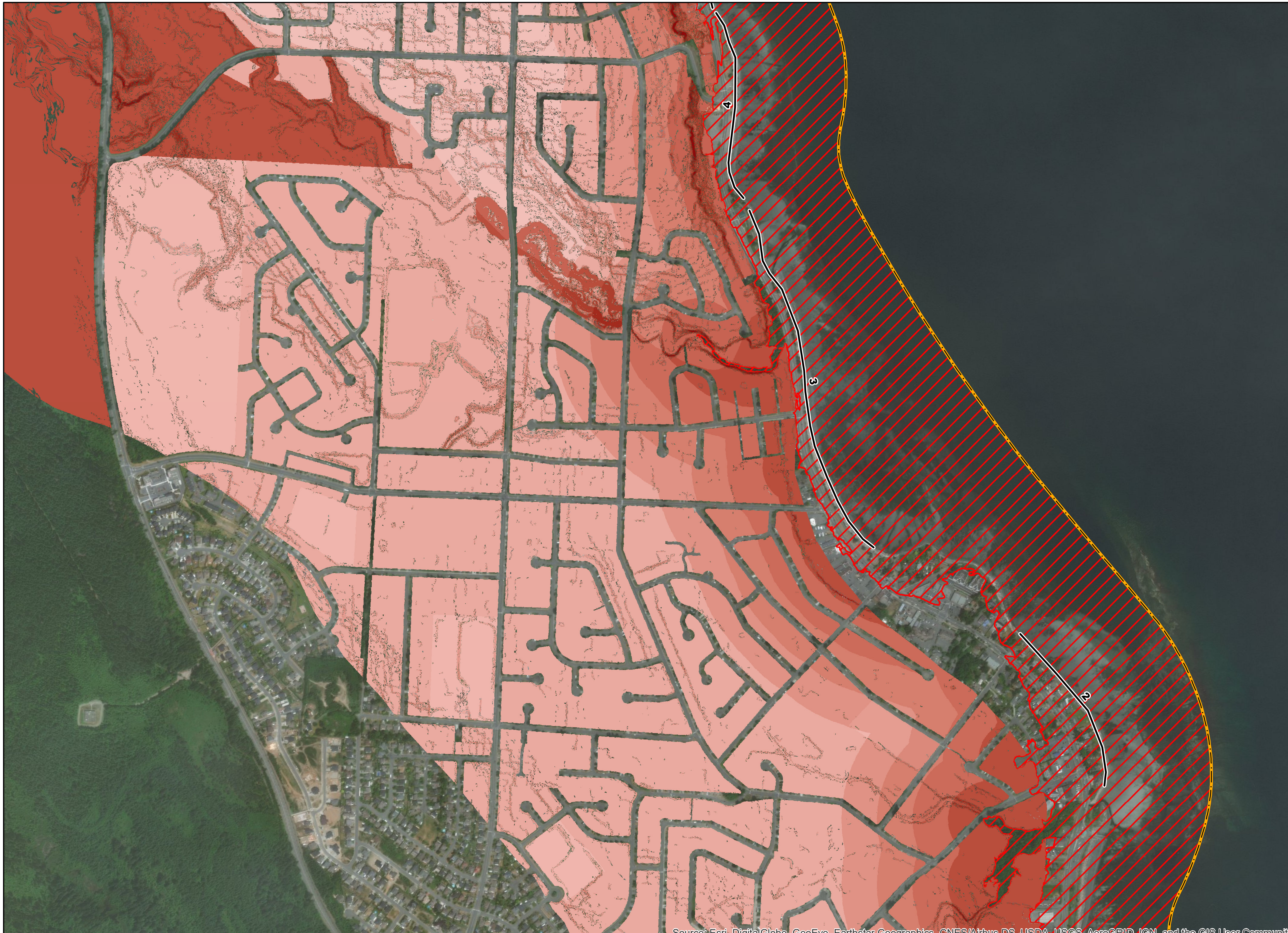

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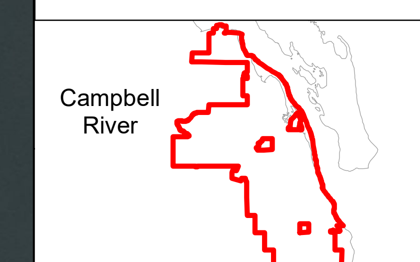

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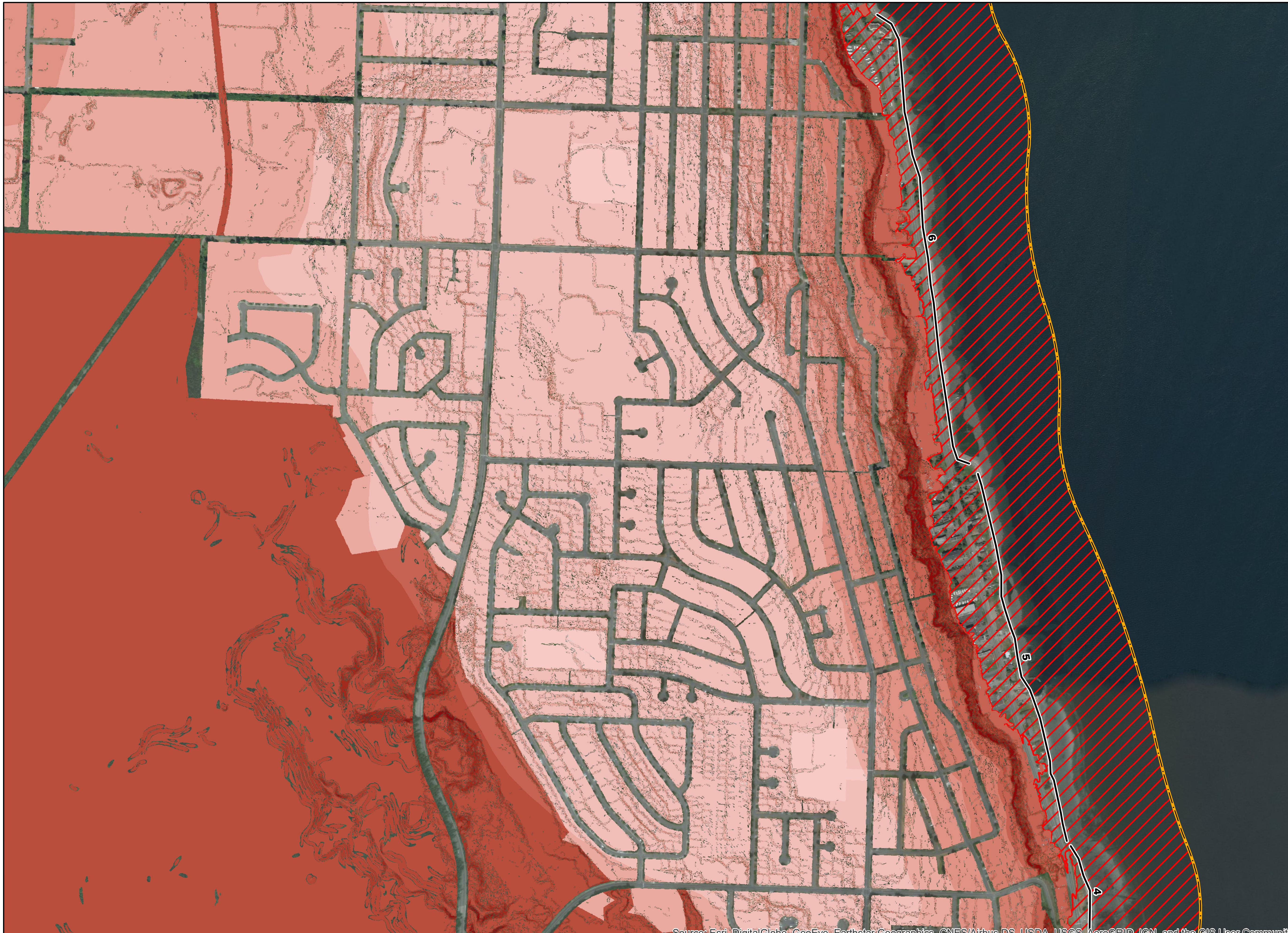

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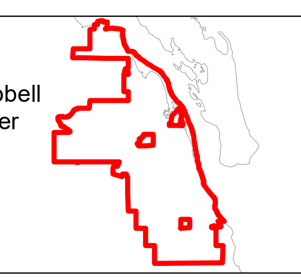

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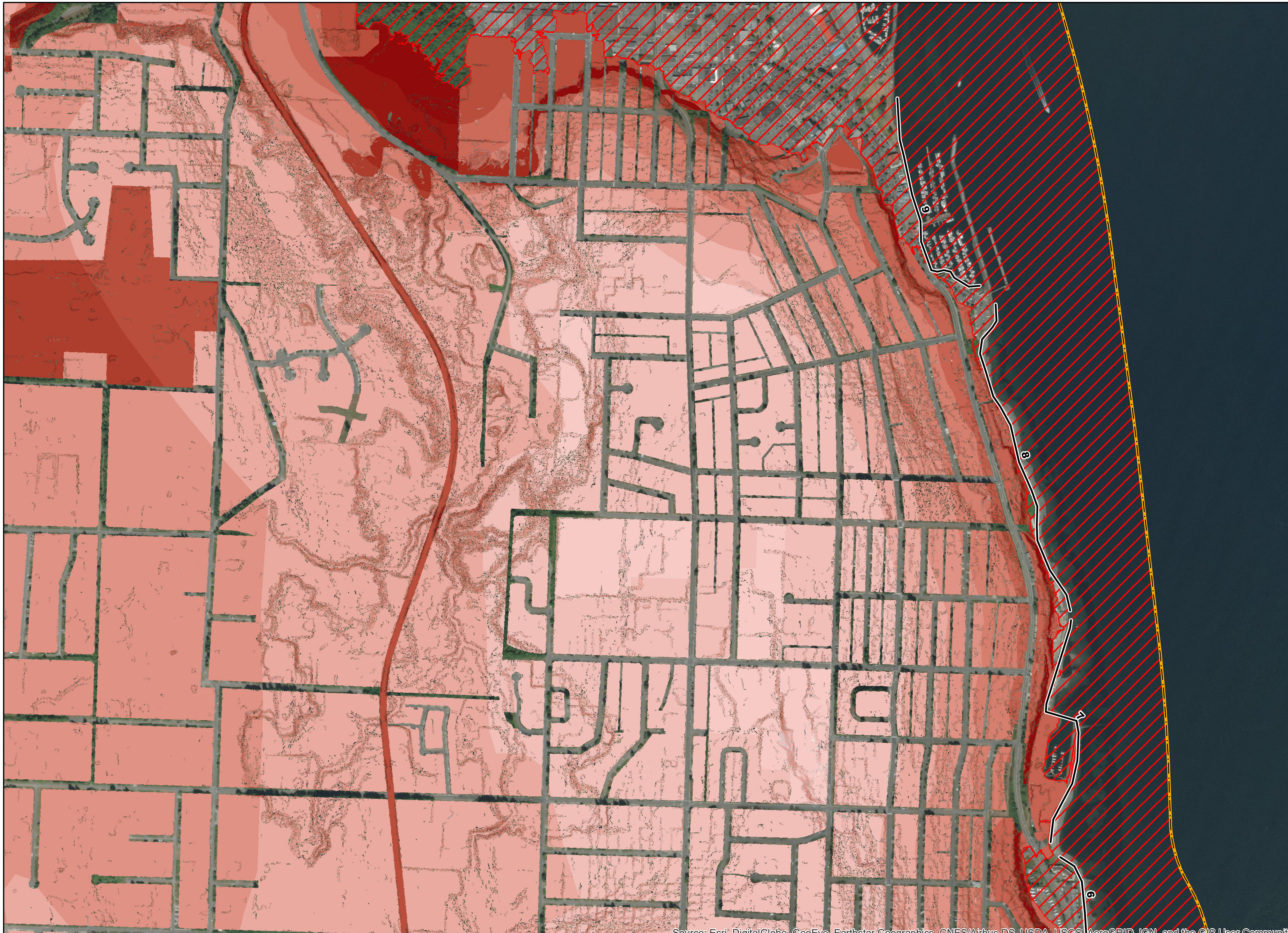

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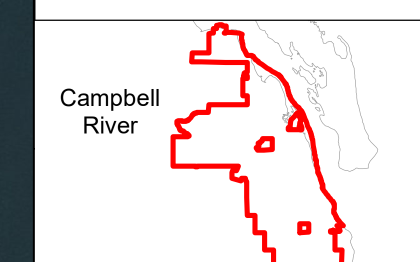

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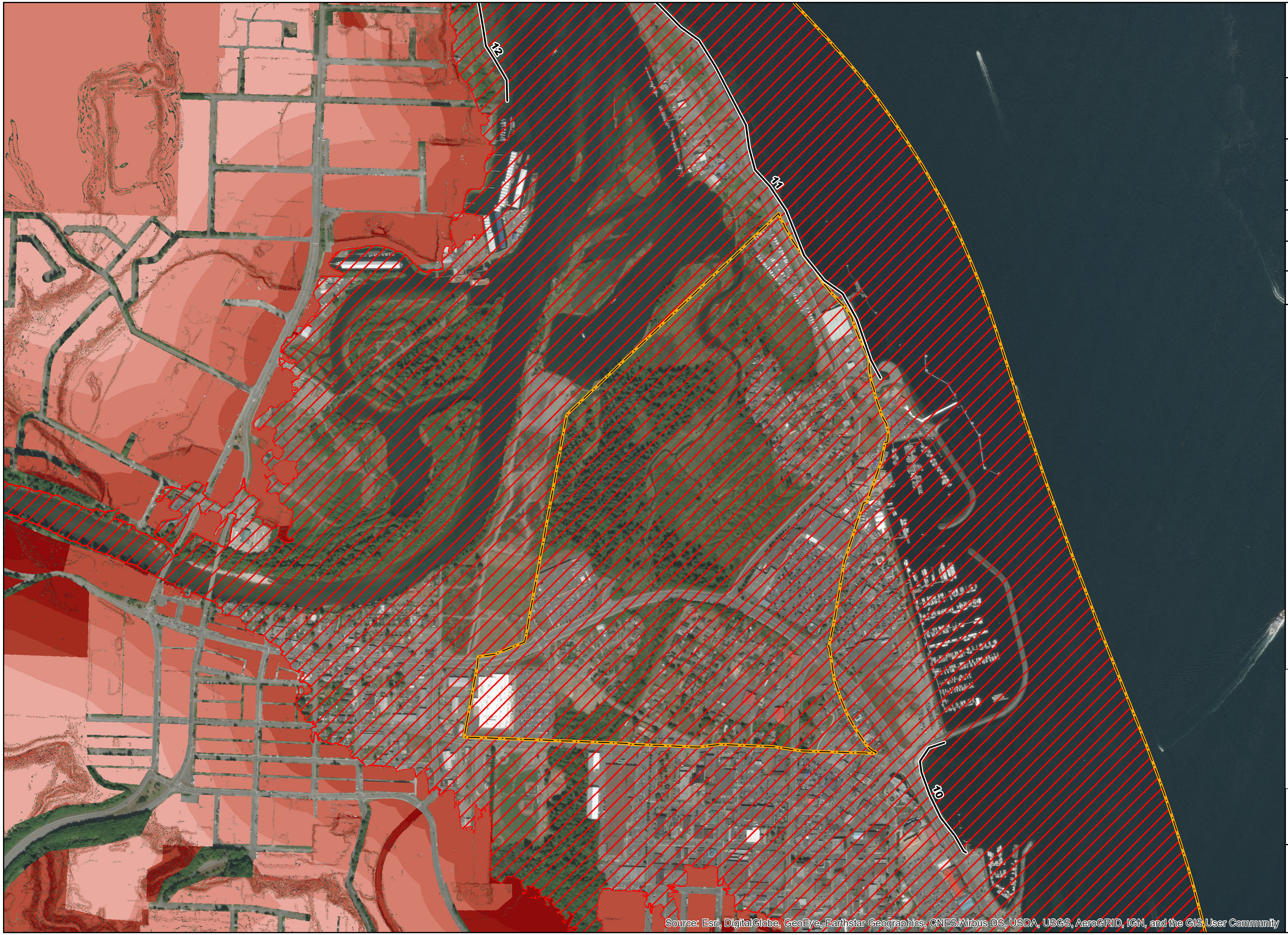

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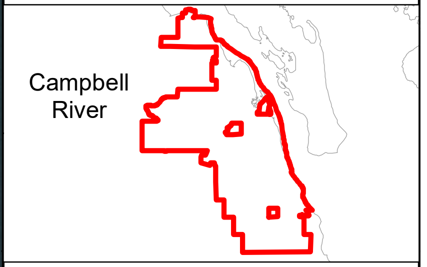

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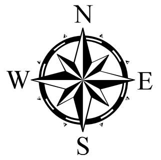

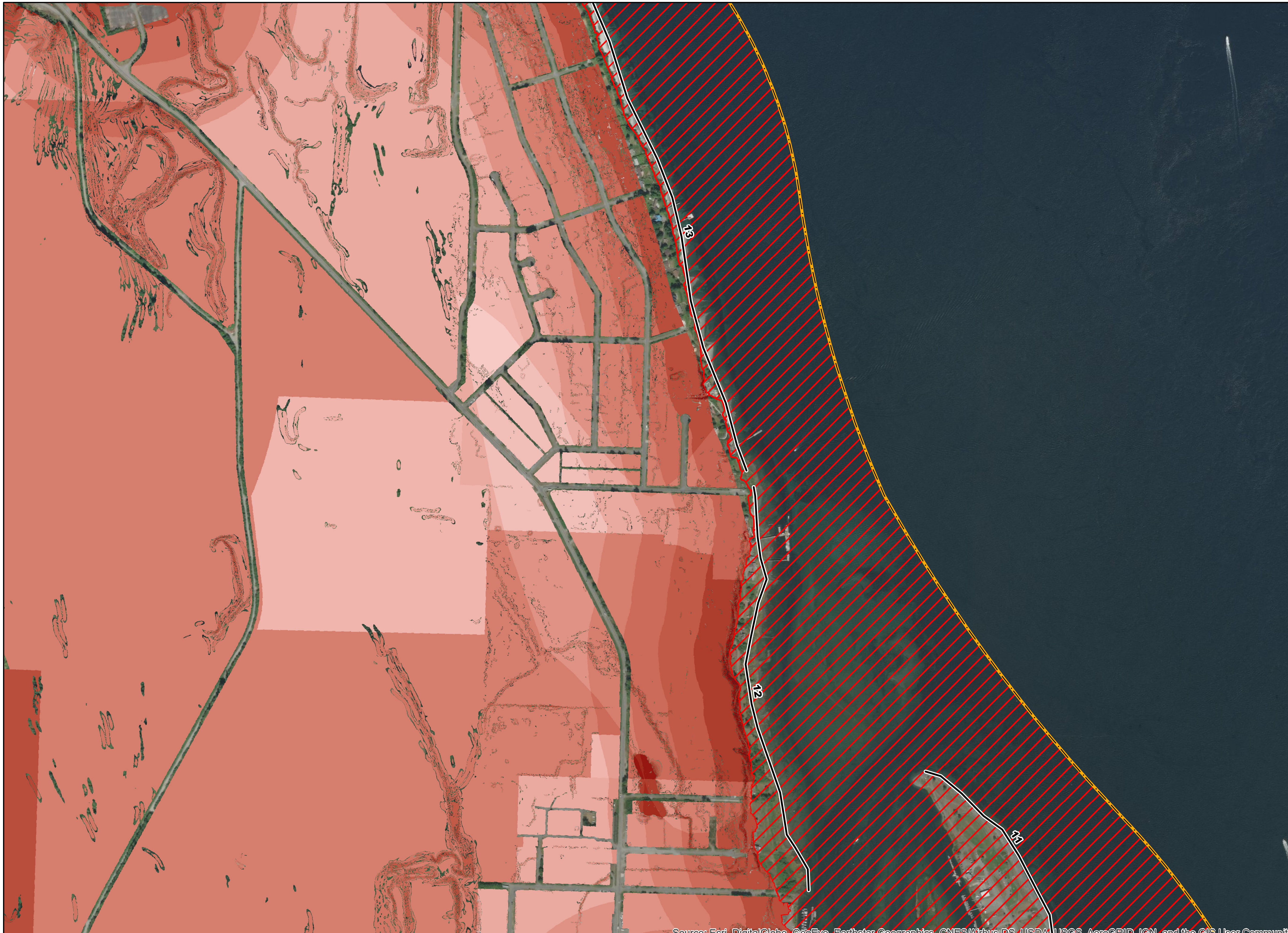

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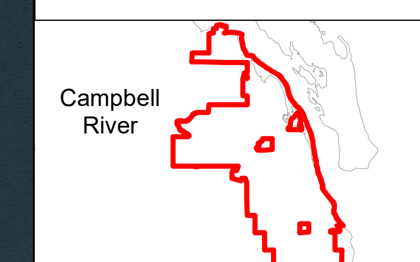

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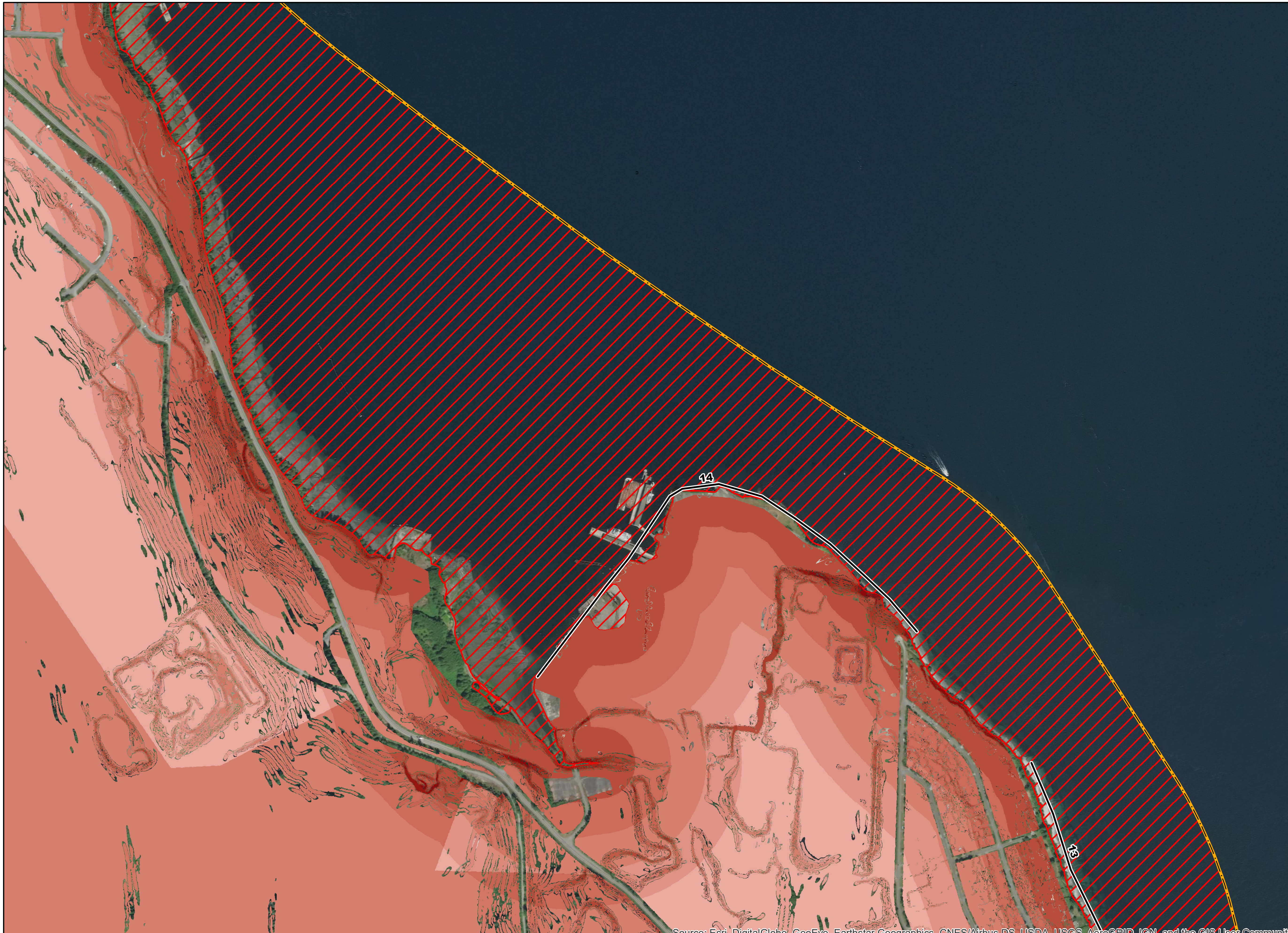

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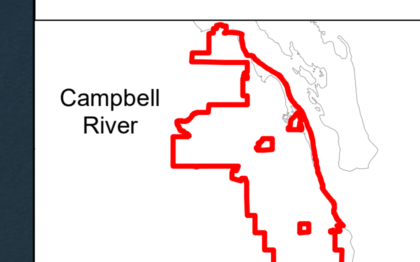

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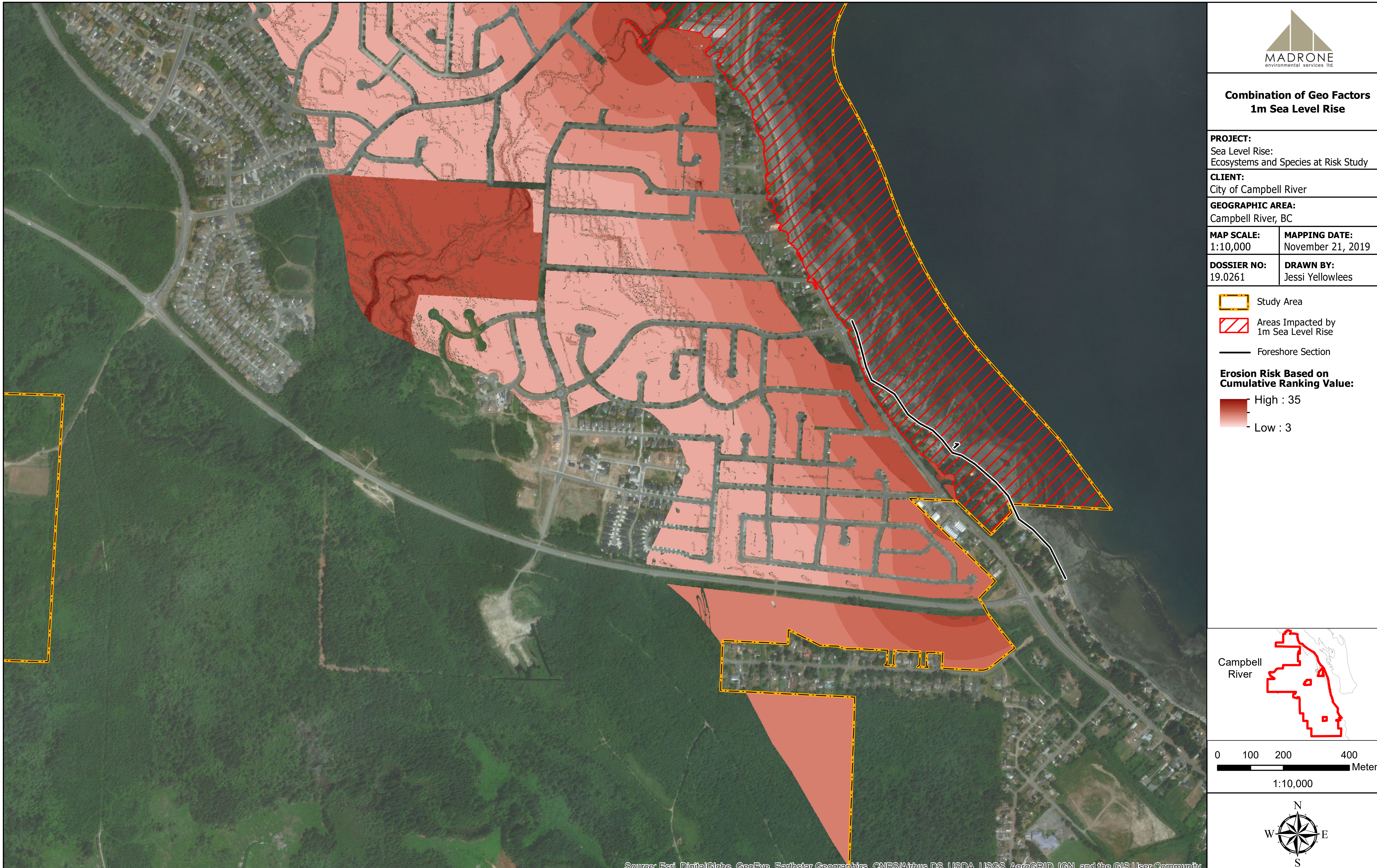

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Jessi Yellowlees
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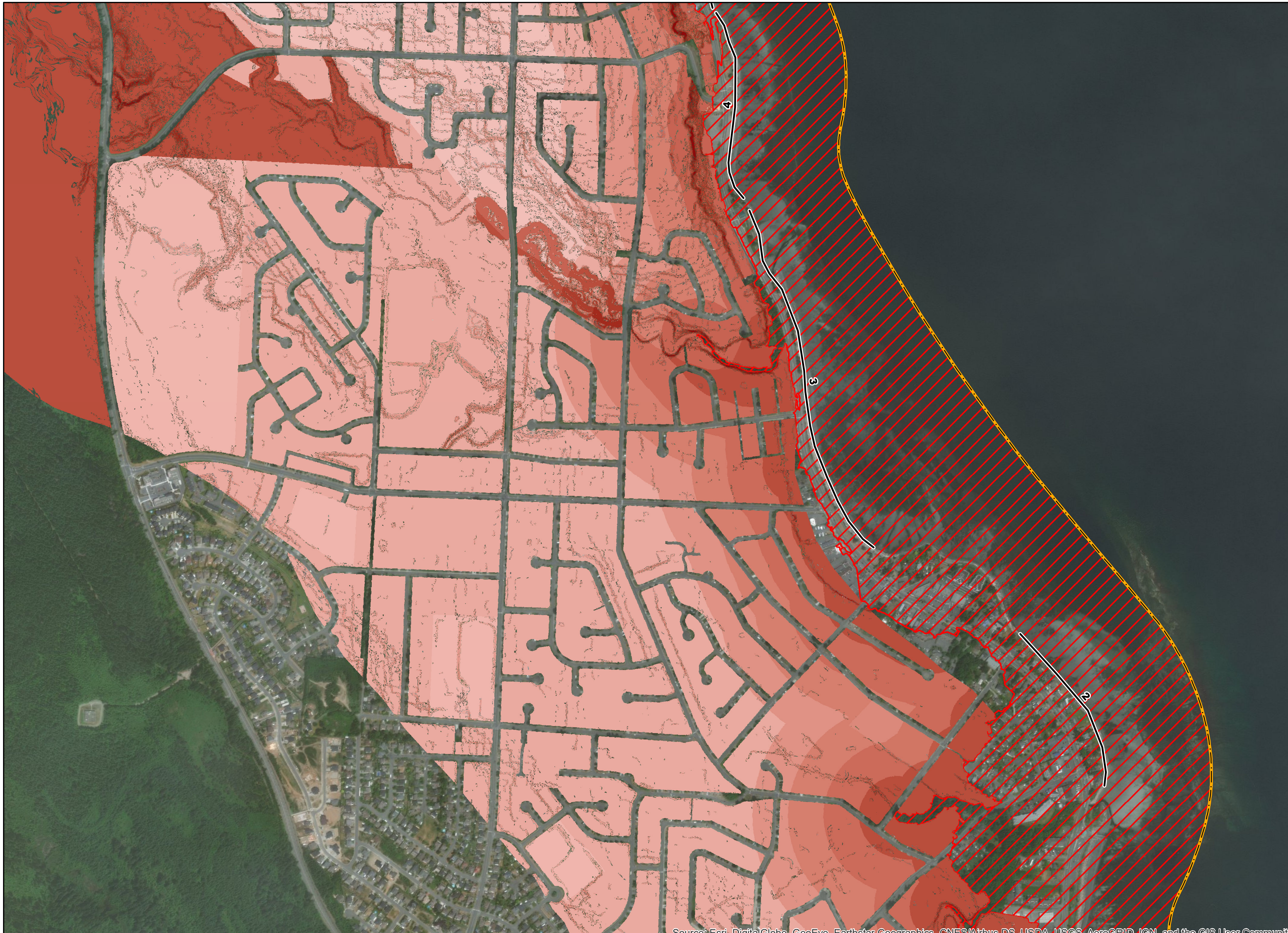

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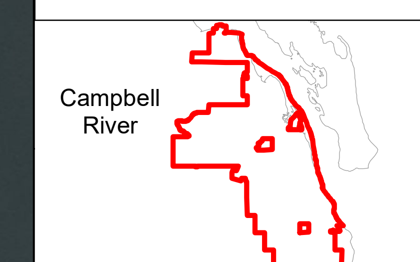

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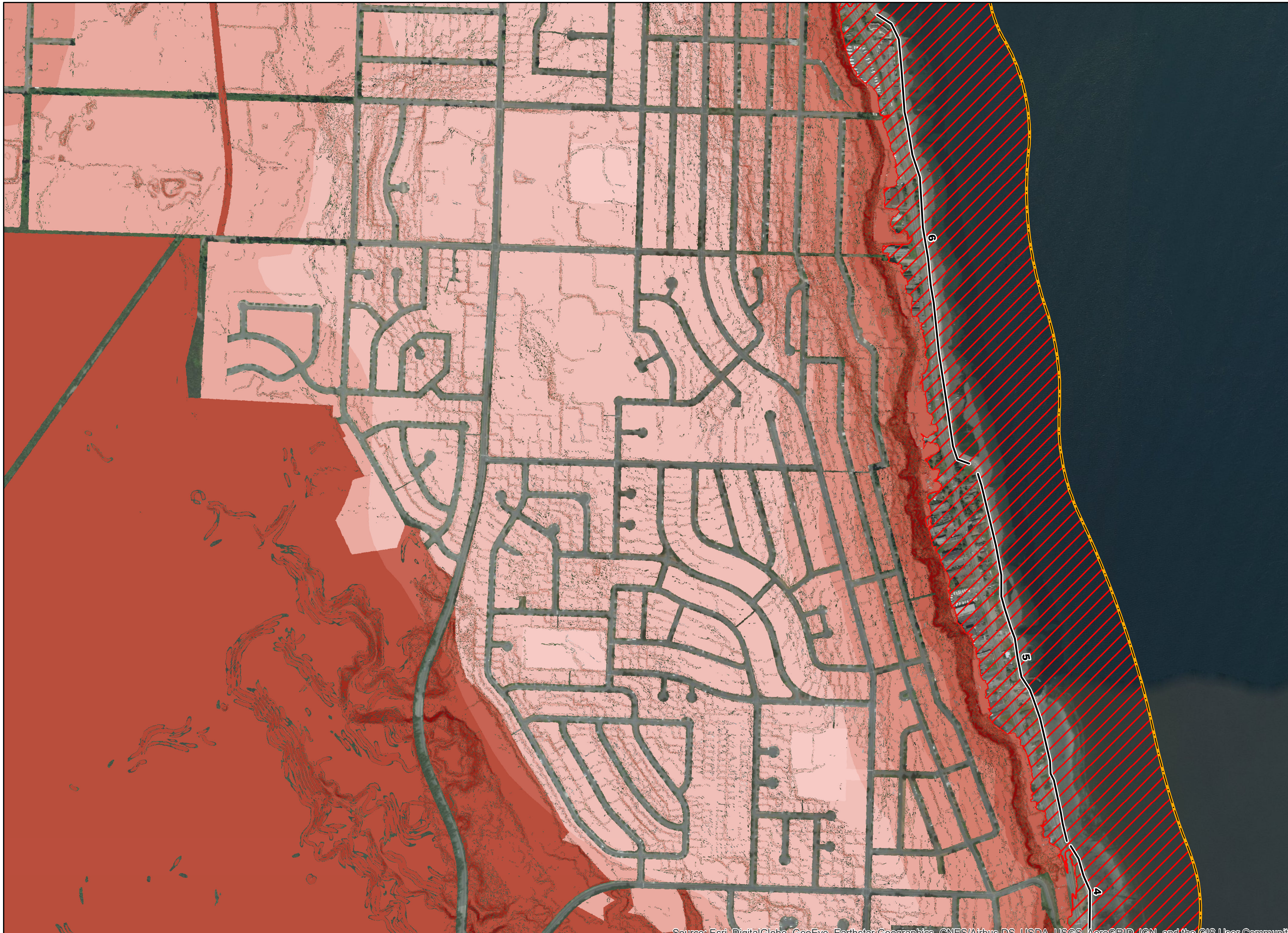

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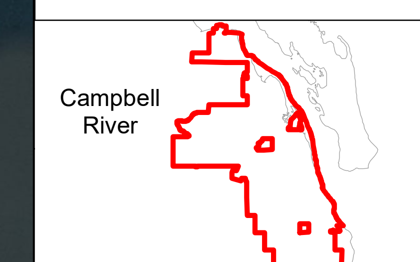

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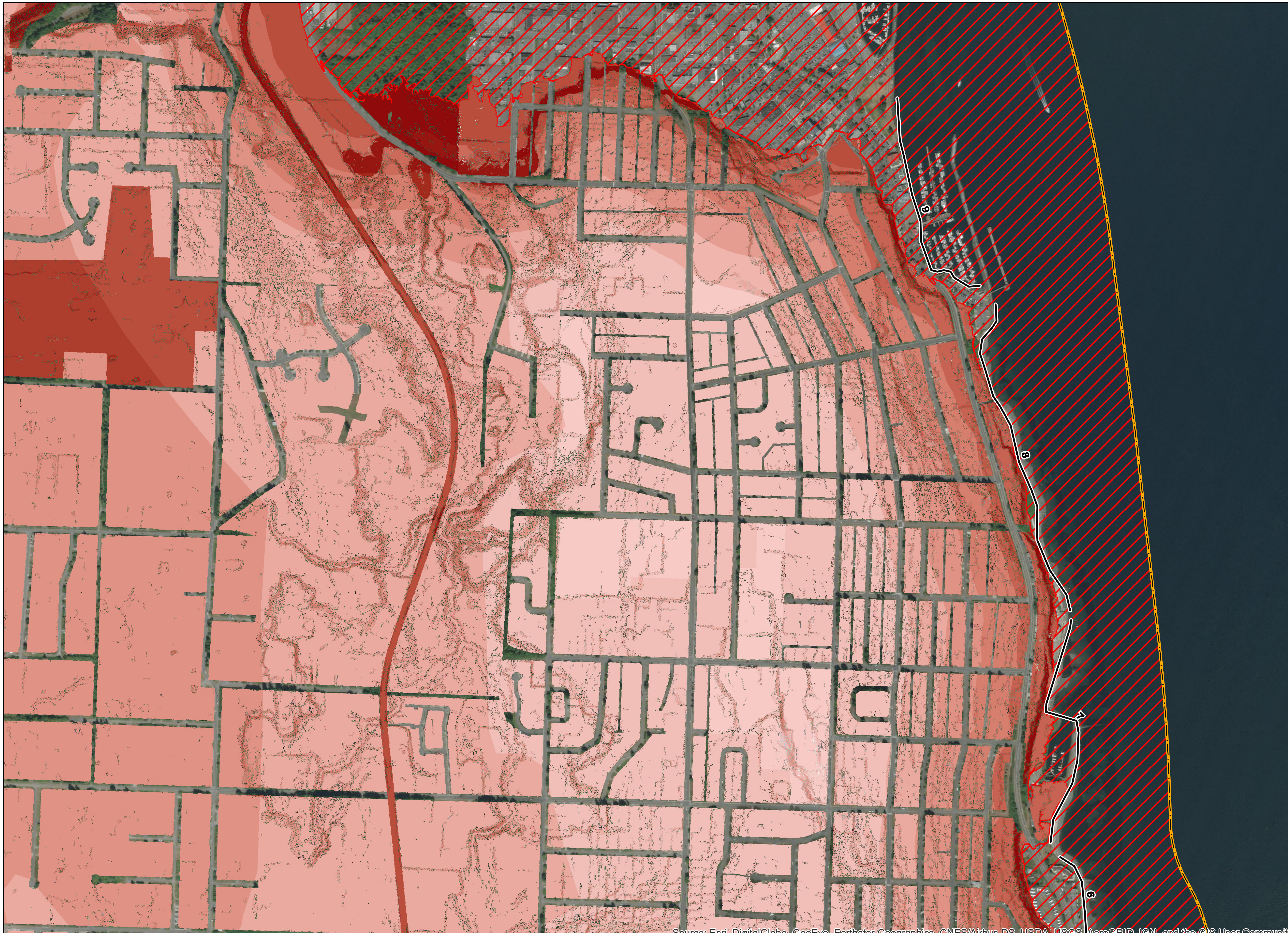

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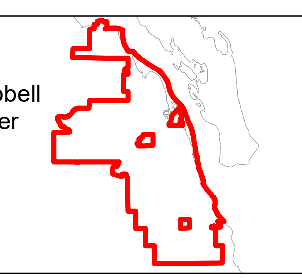

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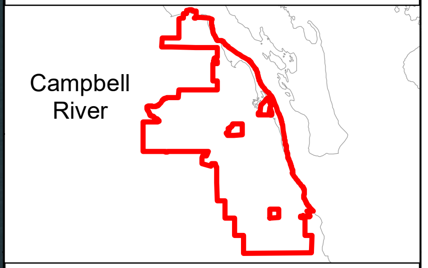

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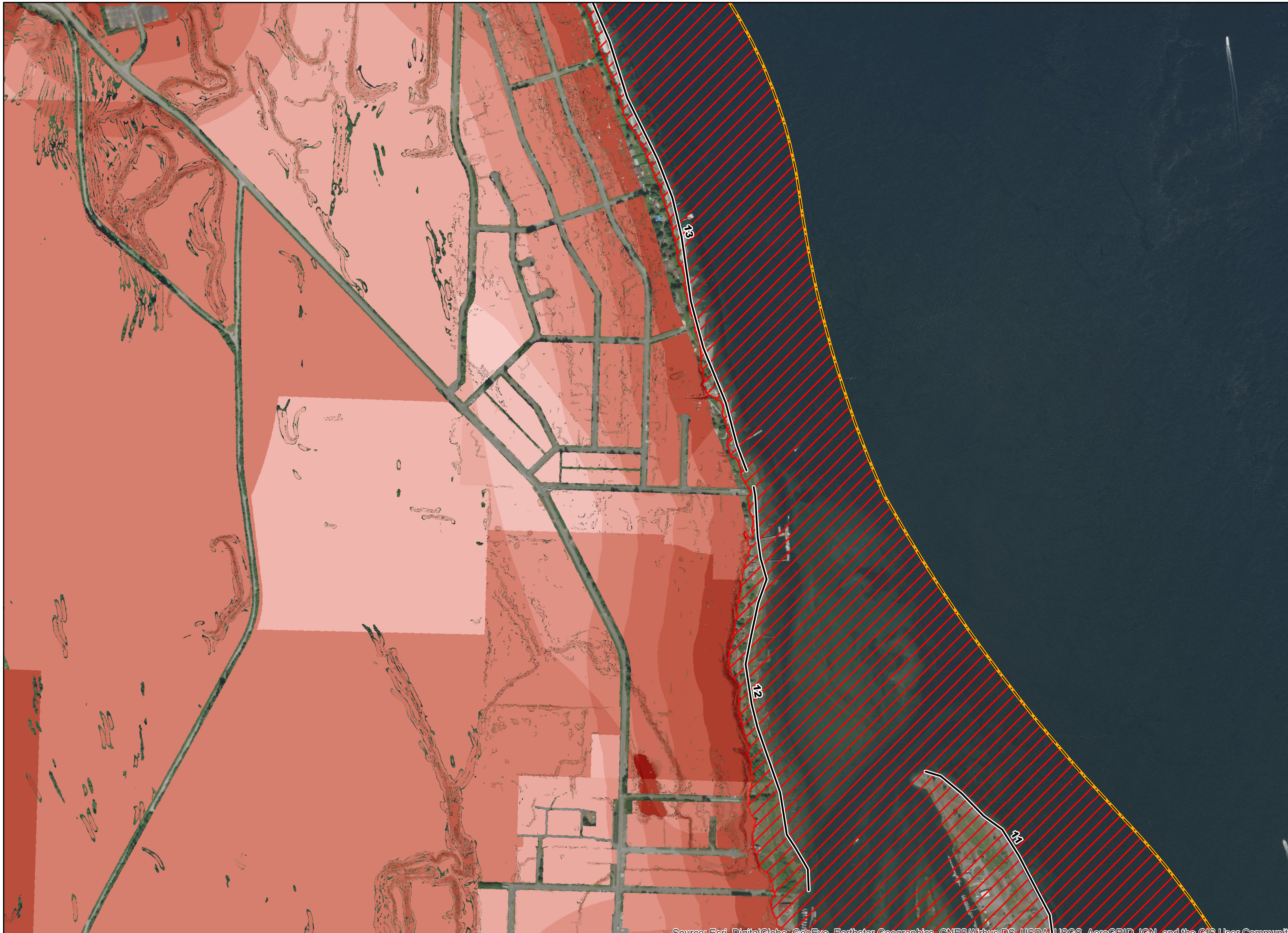

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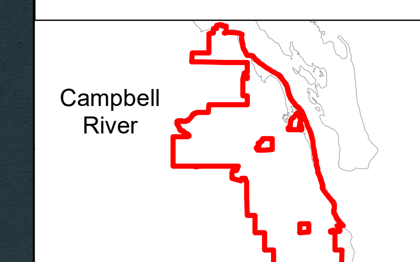

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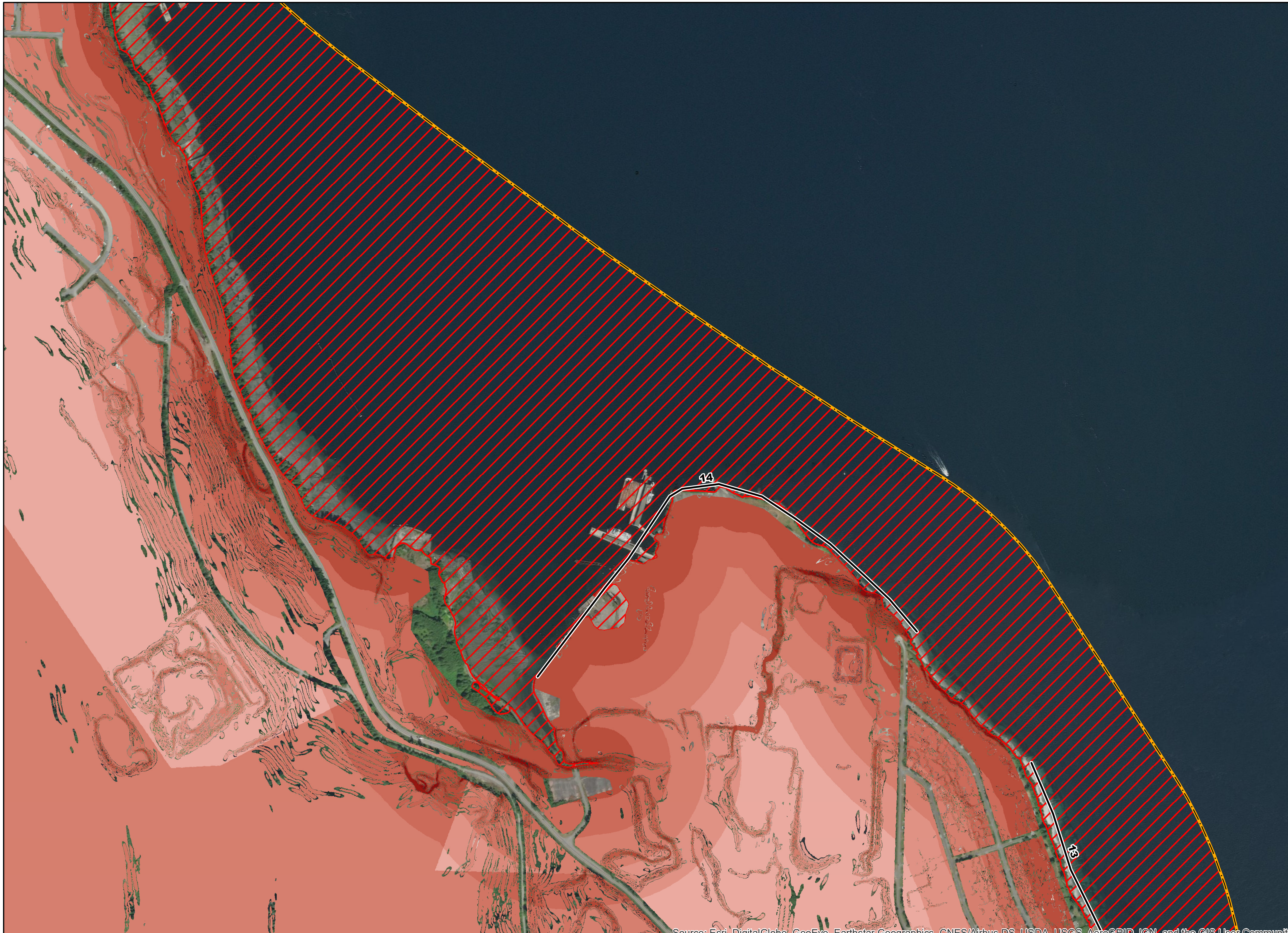

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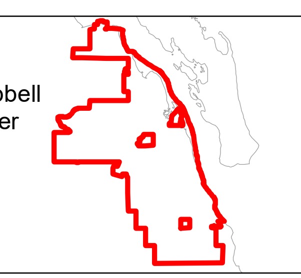

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