SEA LEVEL RISE ADAPTATION

BACKGROUND REPORT

Regional Growth Strategy
Implementation

Regional District of Nanaimo

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Cover photo: Qualicum Bay during a December 2010 storm, Colin Kearns

1 Introduction

Sea level rise is driven by a global increase in average temperature which is causing glaciers and ice sheets to melt and ocean waters to expand. In British Columbia, average temperature has increased 1.4°C since 1900. By 2100 or sooner we can expect a global sea level rise of 1.0 meters which for central Vancouver Island translates to 0.8 metres after taking into account local land uplift. At the same time, storms are expected to become more severe and more frequent. A significant wind storm causing storm surge concurrent with high tide will result in wave run-up further inland and flooding that could become increasingly more severe. Some extremely low lying coastal areas will become regularly inundated as sea levels continue to rise. There is a need to understand and prepare for future sea level rise in the region, a process referred to as "adaptation".

The purpose of this background report is to provide an overview of the drivers, impacts and science behind sea level rise and its local impact as well as to describe the process of adaptation, what other local governments are doing and how the Province is supporting this work.

2 Physical Oceanography of the Strait of Georgia

The coastline and marine waters of the RDN are located in the central Strait of Georgia which is a semi-enclosed waterway connected to the Pacific Ocean to the north and the south. The primary influences on the physical Strait of Georgia are tides, river discharge, and meteorological factors such as wind and atmospheric pressure[1]. The most damaging storms in the area are typically during winter high tide and storm surge events and this section provides some background on the processes that contribute to these events.

2.1 Tides

Tides are easily observed at the shoreline throughout the day, and in the Strait of Georgia there are typically two highs and two lows in one day. The highest tides of the year occur during the summer and winter solstice. The term "King Tide" is often used to refer to these highest tides of the year, and there local initiatives throughout the world bringing citizen scientists together to monitor and photograph the impact of these high tide events to envision what impacts might be experienced with rising sea levels.

2.2 Wind

Wind in southern British Columbia is predominantly from the southeast in the winter and the northwest in the summer, with stronger winter winds on average than summer. The relatively short fetch (distance travelled by wind or waves over open water) in the Strait of Georgia limits the height of wind wave and

[1] Thomson, R. 2014. *The Physical Ocean* in *The Sea Among Us the Amazing Strait of Georgia*. Eds Beamish, R., MacFarland, G. Harbour Publishing Co. Ltd. Madeira Park, BC.

swell compared to the outer coast. The strongest wintertime winds and largest waves are found in the northern Strait of Georgia, in the northern areas of the RDN and up to Campbell River due to the longer fetch for southeasterly winds. Wave heights are typically less than 0.5 m in summer and can exceed 1.5 m in winter[2].

2.3 Storm Surge

Storm surge is the term used to describe an event where the water level is higher than the tidal prediction due to a combination of atmospheric and storm conditions. Low atmospheric pressure causes a rise in sea level in combination with the forcing of wind and waves. The highest storm surge recorded at Point Atkinson (West Vancouver) is 0.9 m during a December 1982 storm with high winds and low pressure and also influenced by the 1982-83 El Nino event during which there was a coastal sea level rise of approximately 0.2 m.

More recently, on December 9, 10 and 11 of 2014 three significant storms at the same time as some of the highest tides (but not the highest) of the year brought a 70 - 80 cm storm surge causing major flooding in the Courtenay/Campbell River area. The storms coincided with high river flows that in many cases were 1:50 and 1:100 events[3].

2.4 River Discharge

River discharge on Vancouver Island is highest from late fall to early spring and is influenced almost entirely by rainfall. This is in contrast with mainland rivers that are influenced by snow and glacier melt, and peak from late spring to early summer.

In summary, wintertime high tides combined with storm surge and intense rainfall events create the conditions for flooding along the coast and tidally influenced river floodplains. Climate change projections have the frequency and severity of these events increasing along with a rise in mean sea level.

3 Sea Level Rise Projections

Recorded average atmospheric temperatures have increased globally and locally over the past century. This rise in temperature drives a number of other processes such as melting of glaciers and expansion of ocean water, which in turn drive sea level rise.

This section provides a synopsis of changes to the climate that have been recorded globally and locally, which provide part of the basis for projecting sea level rise into the future.

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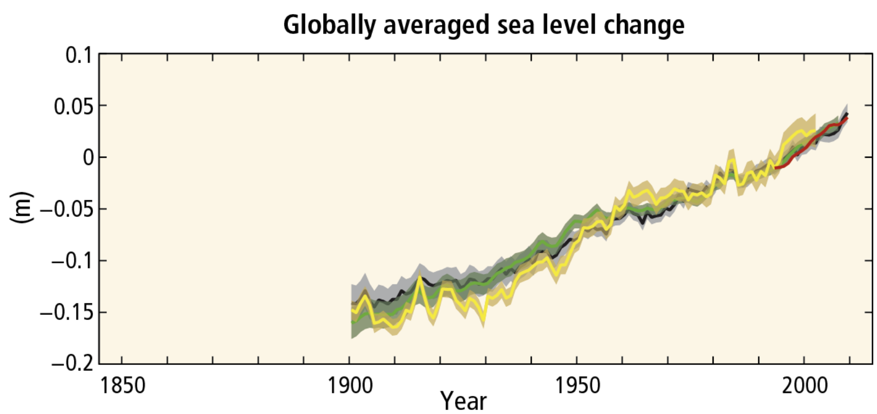
[2] Thomson, R. 2014. *The Physical Ocean* in *The Sea Among Us the Amazing Strait of Georgia*. Eds Beamish, R., MacFarland, G. Harbour Publishing Co. Ltd. Madeira Park, BC.
[3] Tinis, S. 2015. BC Storm Surge Forecasting System 2014-15 Midseason Update. Online [www.stormsurgebc.ca].

3.1 Global Climate Change Projections

The Intergovernmental Panel on Climate Change's (IPCC) most recent Fifth Assessment Report (AR5) released in 2013 and 2014 states that "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen."

Globally averaged, sea level has risen 0.19 metres from 1901-2010 and the IPCC AR5 states with high confidence that the rate of sea level rise since the mid-1900's has been larger than the rate over the previous two millenia (Figure 1). This means that not only will seas continue to rise, but over the next century they will do so at a rate faster than the last.

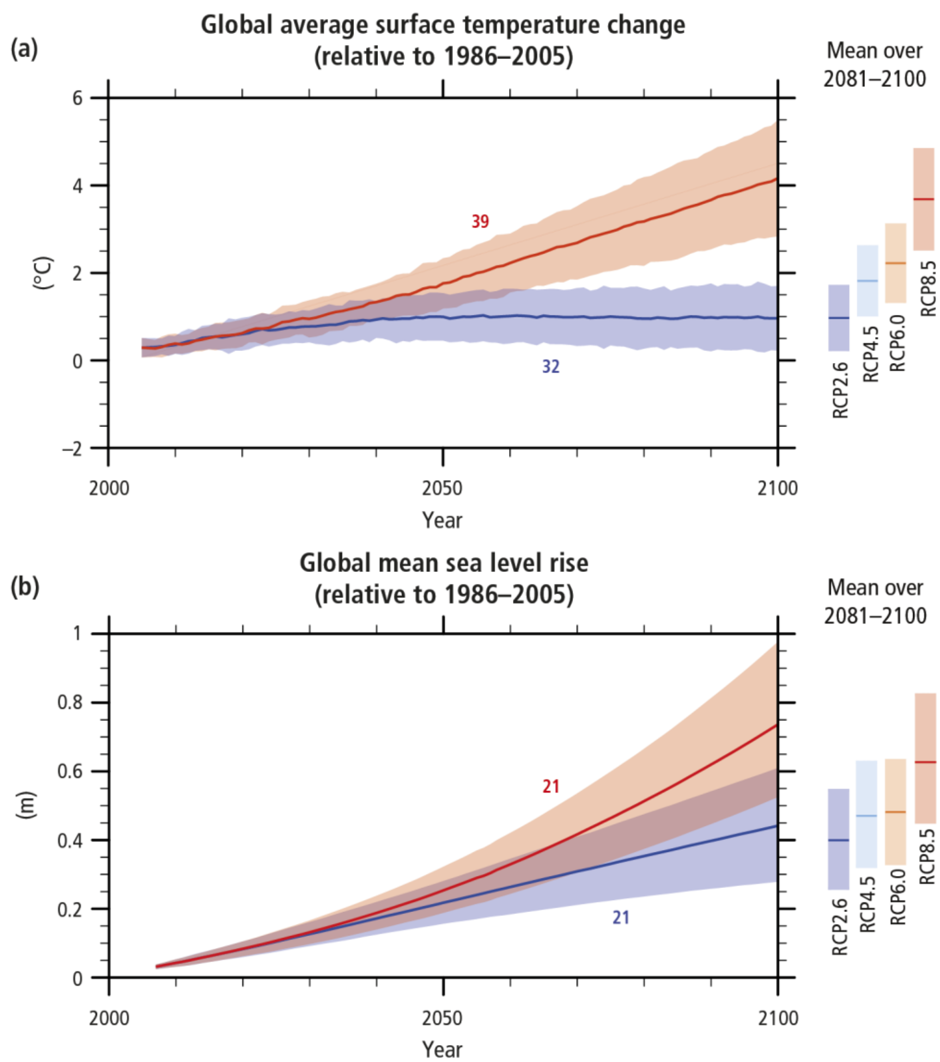
Figure 1 Sea level change 1901-2010 from IPCC, 2013



Sea level rise is driven by a global increase in average temperature which is causing glaciers and ice sheets to melt and ocean waters to expand. Global temperatures are increasing due to higher concentrations of carbon dioxide in the atmosphere. While climate scientists believe it is extremely likely that greenhouse gas emissions from human activity are the dominant cause of climate warming since the mid-1900's, halting all greenhouse gas emissions now will not stop the warming trend due to the accumulations already in the atmosphere.

Projecting future sea level rise is a complex science and includes a combination of observed trends and different scenarios of concentration of atmospheric carbon dioxide into the future. The IPCC AR5 projections below show the highest and lowest projected scenarios for temperature and sea level rise (Figure 2). The legends to the right of the graphs refer to "Representative Concentration Pathways" (RCP), with 2.6 being a very high reduction in greenhouse gas emissions in the future and 8.5 being a very low reduction. The shaded area around the lines on the graph represents a range of uncertainty associated with the projections. The lowest sea level rise projection for 2100 of approximately 0.3 metres depends on a stringent emission reduction scenario. The highest projection of just under 1.0 metres is the likely sea level rise under a scenario of little to no emissions reduction.

Figure 2 Temperature and sea level rise projections to 2100 from IPCC, 2013



3.2 Indicators of Climate Change for British Columbia

The BC Ministry of Environment published a 2015 update to their "Indicators of Climate Change for British Columbia" report that provides climate data trends from 1900-2013. The report shows trends across the province for numerous indicators including annual temperature and precipitation increases, glacier retreat and sea level rise.

On the next page there are several indicators from the report for the Georgia Depression Ecoprovince where the Regional District of Nanaimo is located.

Indicator		Reporting period	Change
Average annual temperature		1900-2013	+ 0.8°C
Average annual precipitation		1900-2013	+ 14%
Glacier retreat		1985-2005	- 34%
Sea Level Rise –	Victoria	1909-1999	+ 8 cm
	Vancouver		+ 4 cm
	Prince Rupert		+ 12 cm
	Tofino		- 13
Sea surface temperature – Georgia Basin		1914-2001	+ 1.8°C

The report also notes that the height of storm surge in the Strait of Georgia has increased at a much faster rate than mean sea level has increased; it increased by 16 cm per year at Vancouver, and 34 cm per year at Point Atkinson (West Vancouver).

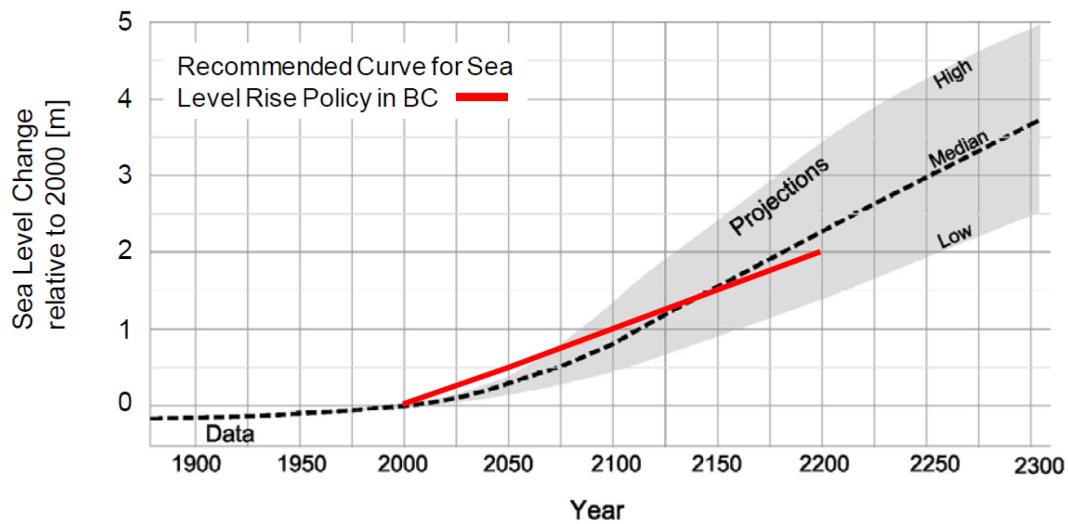
3.3 Climate Change Projections for British Columbia

Sea level rise is an impact of climate change with atmospheric temperature being the main driver. The Pacific Climate Institute Consortium (PCIC) at the University of Victoria conducts quantitative studies on the impacts of climate change and climate variability in the Pacific and Yukon Region. They provide climate change projection information divided by regional districts in BC through their online tool Plan2Adapt. To 2080, they project a median temperature increase of 2.6°C for the Regional District of Nanaimo, and a precipitation increase in winter and decrease in summer. PCIC provides other information such temperature projections divided by season, precipitation, snowfall, and frost-free days.

3.3.1 Sea Level Rise Projections

Sea level is expected to continue to rise even if greenhouse gas concentrations in the atmosphere stabilize. The Province of BC's recommended curve for sea level rise policy in BC is a 1.0 m rise by 2100 and 2.0 m by 2200. This section describes where this policy recommendation comes from and how it relates to the range of sea level rise projections.

Figure 3 Recommended Global Sea Level Rise Curve for Planning and Design in BC (Ausenco Sandwell, 2011)



The recommended curve for sea level rise policy in BC was first published in a 2011 report by Ausenco Sandwell for the BC Ministry of Environment[4] and based on a 2008 report, "An Examination of the Factors Affecting Relative and Absolute Sea Level Rise in Coastal British Columbia"[5]. This 2008 report published an extreme high projected sea level rise for Nanaimo of 0.8 m by 2100, a mean estimate of 0.11 m and an extreme low of -0.04 m. The recommended sea level rise curve is intended to communicate reasonable information to government for planning purposes in light of the range of projections in the scientific community. The curve uses the extreme high sea level rise from the 2008 report, which is considered to be prudent and consistent with more recent estimates. Taking land uplift into account, a 0.8 m sea level rise by 2100 for the RDN is consistent with the BC curve that projects a 1.0 m rise by 2100; land in this region is lifting at a rate of approximately 0.2 m per century.

The BC sea level rise planning curve is based in part on the IPCC AR4, 2007 projections. In 2014, IPCC released revised sea level rise projections as part of their Fifth Assessment Report (AR5). Natural Resources Canada (NRCan) released a new report in 2014, "Relative Sea-level Projections in Canada and the Adjacent Mainland United States" that takes into account the IPCC AR5 projections[6]. The 2014 NRCan report indicates that the BC sea level rise planning curve is higher than the IPCC AR5 projections, but that

[4] Ausenco Sandwell, 2011. Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land use. BC Ministry of Environment.

[5] Thompson, R.E., Bornhold, B.D., and Mazzotti, S. 2008. An Examination of the Factors Affecting Relative and Absolute Sea Level Rise in Coastal British Columbia. Fisheries and Oceans Canada.

[6] James, T.S., Henton, J.A., Leonard, L.J., Darlington, A., Forbes, D.L., and Craymer, M., 2014. Relative Sea-level Projections in Canada and the Adjacent Mainland United States; Geological Survey of Canada, Open File 7737, 72 p. doi:10.4095/295574

there are other emerging scenarios that project reaching 1.0 metres of global sea level rise before 2100 based on a much larger contribution from melting of West Antarctica ice sheets. As such, the 2100 sea level rise could be significantly above the BC planning recommendation of 1.0 metre. The NRCan report recommends that the BC sea level rise planning curve be retained for policy development as it is consistent with the precautionary principle and allows for some of the potential additional sea level rise. The report also recommends that scientific progress in understanding the upper limit of sea level change continue to be monitored.

4 Assessing Local Vulnerabilities

The Province of BC provides a number of resources to guide local governments in adapting to sea level rise including their recommended curve for sea level rise policy in BC, but it is up to local governments to identify local areas that will be impacted. In the RDN, many residents can likely pinpoint some of the low-lying coastal areas that are vulnerable to sea level rise without any special mapping or analysis. Well known landmarks such as estuaries and the relatively dense residential development on their floodplains are some of the most vulnerable areas. However, it is necessary to also have a scientific basis for planning for sea level rise, which begins with a detailed mapping exercise.

4.1 Coastal Floodplain Mapping

Floodplain maps provide information on the spatial distribution of flood construction levels (FCL), and allow local governments to define sea level rise planning areas which will facilitate land use planning and development decisions. FCL is the minimum elevation required for the underside of a wooden floor system or the top of a concrete slab for habitable buildings.

There are three designated floodplain areas in the RDN that were mapped by the Province in 1984 (Nanaimo River and Englishman River) and 1997 (Little Qualicum River), with established FCLs. For all other watercourses and waterbodies, setbacks and FCLs are indicated in the text of the RDN Floodplain Bylaw (no. 1469). In 2004, the Province transferred responsibility for all aspects of floodplain management to local governments, including preparation of floodplain maps.

The Province recommends that local governments undertake new floodplain mapping for all coastal areas in order to implement new FCLs based on a 1.0 m sea level rise by 2100, and to define a 2200 sea level rise planning area based on 2.0 m rise. An amendment to the provincial Flood Hazard Area Land Use Management Guidelines has been drafted to reflect a new requirement that sea level rise is taken into account when establishing FCLs. In accordance with the changes, local governments will have to develop their own approach based on provincial guidelines, and fund this work themselves.

Developing new coastal floodplain maps involves four basic steps:

1. Acquisition of detailed floodplain topography – *RDN completed 2017*
2. Coastal engineering analysis to estimate the water level components associated with the design condition, and the associated Flood Construction Levels
3. Preparation of Floodplain maps indicating areas subject to flood hazard(s) and the magnitude of the hazard(s)
4. Preparation of Design Brief to document the analysis

4.1.1 Coastal Floodplain Mapping Project

In December 2017, the RDN was awarded provincial funding to acquire coastal floodplain mapping. The project is jointly funded by the Union of BC Municipalities' Community Emergency Preparedness Fund (CEPF) and the RDN. When completed, the mapping information will be used to update land use regulations relating to the management of lands in coastal areas and bring the RDN into compliance with the Provincial Flood Hazard Area Land Use Management Guidelines. Further to this, this information will be used to inform the flood hazard risk assessment project being undertaken by the RDN's Emergency Services as well as future assessments, policies and plans regarding sea level rise (SLR) adaptation.

The CEPF funding has made it possible to accelerate the project work plan and increase the size of the geographical area scheduled for mapping 10 2018. While the funding is significant, it is not enough to complete the required mapping for the entire RDN coastline. Due to this budget consideration, the project is anticipated to be completed in two phases.

Phase 1 includes the marine coastal areas associated with Electoral Areas E, G and H, the Town of Qualicum Beach and the City of Parksville and is scheduled to be completed in February 2019.

Phase 2 includes the marine coastal areas associated with Electoral Areas A and B, and the District of Lantzville. Phase 2 is anticipated to be initiated on the completion of Phase 1 and will be completed as funding becomes available.

4.2 Acquiring Detailed Floodplain Topography

The topographic data required for coastal floodplain mapping is a digital elevation model to 0.5 metres accuracy. This digital elevation model will allow scenarios of various water levels to be overlaid on a map or air photo at 0.5 m intervals in order to visualize and plan for sea level rise.

The recommended method of capturing this data for the type of environment and tree cover in the RDN is through LiDAR. LiDAR is a system where an aircraft directs a laser to the ground below and from the time it takes for the laser to reflect back, the ground elevation can be determined to an extremely high degree of accuracy. This method is cost effective when a high level of detail, such as for coastal floodplain mapping, is required. Within the RDN the Town of Qualicum Beach has a LiDAR-derived digital elevation model to the required level of accuracy for coastal floodplain mapping, and the City of Nanaimo has this data to a slightly lesser degree of accuracy. As of June 2017, the electoral areas of the RDN now have 0.5 metre contour mapping data.

4.3 Low-Lying Shoreline Mapping vs Floodplain Mapping

With detailed topographic mapping it is possible to identify area of low-lying land based on the LiDAR data such as 0.5 meters and 1.0 meter contours. This is often an interim step prior to coastal floodplain mapping, especially for areas with extensive coastline such as the RDN. This information is used as part of a preliminary coastal floodplain assessment to help identify areas at greater risk in terms built-up areas that are low lying. While low-lying shoreline mapping is not considered an end product on which to base floodplain bylaws for FCLs, it can be used to pinpoint areas of higher impact and prioritize areas for coastal floodplain mapping.

Coastal floodplain mapping takes low-lying shoreline mapping further to account for local wave and storm effects, and shoreline character to provide a more accurate understanding of the areas that would be impacted under sea level rise combined with storm surge and high tide events. These factors can be estimated and given a conservative number (resulting in a higher FCL) or a thorough coastal engineering examination can be done which would result in more accurate numbers and likely resulting in a lower FCL.

The Town of Qualicum Beach has undertaken the engineering analysis for a very detailed understanding of the sea level rise and coastal erosion impacts that can be expected in the future. This work was done by consulting engineers with the use of high powered computers that run comprehensive models, and is expected to be released to the public in the fall of 2015. This work is costly and was possible for Qualicum Beach through a $150,000 grant from the Federal Gas Tax Fund.

4.4 Flood Hazard Area Land Use Management Guidelines Amendment

The Province of BC published Flood Hazard Area Land Use Management Guidelines ("the Guidelines") in 2004 that are intended to "help local governments, land-use managers and approving officers develop and implement land-use management plans and make subdivision approval decisions for flood hazard areas." The Guidelines state that "experience has shown that regulating land development to keep people out of harm's way is the most cost effective and practical way" of achieving the goals of reducing or preventing injury, human trauma and loss of life, and to minimize property damage during flooding events. The Province updated the Guidelines to include considerations for land development in areas that will be affected by sea level rise. The amendments that came into effect January 1, 2018, are based on a series of technical studies as well as discussion with local governments and stakeholders.

The amendment to the Guidelines will have to be considered by the Regional District of Nanaimo pursuant to Section 910 of the *Local Government Act*, including revision of bylaws that refer to or follow the old guidelines. The amendment says that all lots created by subdivision should have viable building sites on the natural ground that is above the year 2100 FCL. This is likely to make some lots with subdivision potential under the current regulations unable to be subdivided. For existing lots below the 2100 FCL, development can occur if supported by a geotechnical report, and if a restrictive covenant is registered on the property. The amended Guidelines also provide a new formula for calculating the FCL and recommend the following scenarios for sea level rise: allow 0.5 m by 2050, 1.0 m by 2100 and 2.0 m by 2200[7].

Simply put, taking a 1.0 m sea level rise into account raises the FCL by approximately 1.0 m. The new system of calculating FCL is needed because under the old system, natural boundary is defined by visual observation and a future natural boundary cannot be observed today.

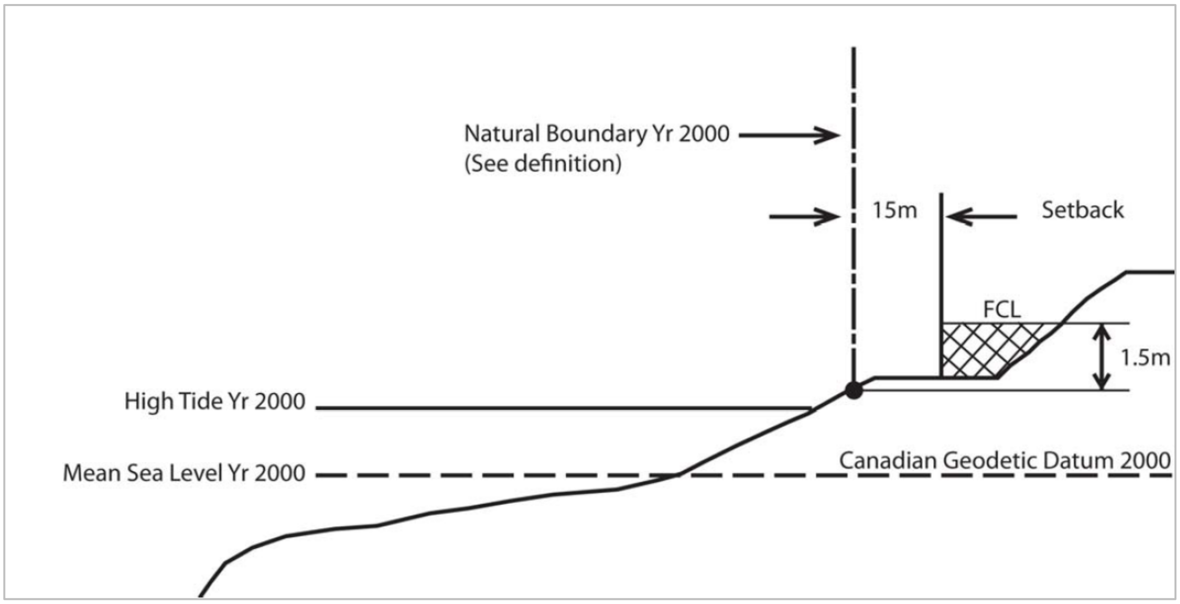
Historically, the coastal FCL was defined as the present natural boundary + 1.5 m, where natural boundary is the visible high water mark characterized by a change in soil and vegetation from upland to marine. This becomes problematic when considering sea level rise, because a future sea level cannot be observed in the field. Therefore a new approach was developed to approximate the location of the natural boundary with a rising sea. In order to determine a future natural boundary under sea level rise scenarios, mean sea level (Canadian Geodetic Datum (CGD)) is used as the baseline onto which several factors are added, as listed below (as per the draft Guidelines, 3rd amendment dated July 7, 2015):

- The 1:200 or 1:500 Annual Exceedance Probability (AEP) water level as determined by probabilistic analyses of high tides and storm surge;
- Allowance for future sea level rise to the year 2100;
- Allowance for regional uplift, or subsidence to the year 2100;
- Estimated wave effect associated with the Designated Storm with an AEP of 1:200 or 1:500; and
- A minimum freeboard of 0.6 metres.

This new approach systematizes the informal, historical approach of establishing the FCL; when the new system is used to calculate a present-day FCL (without adding an allowance for future sea level rise) the result should be very close to the elevation resulting from a natural boundary + 1.5 m calculation. However, a FCL arrived at under the new system cannot be compared straight across to the FCL arrived at under the old system because the starting point, or "zero" is different. The starting elevation under the new system is mean sea level which is much lower than the natural boundary starting point under the old system (see figure 4). This has the effect of FCL's under the new system looking much higher than the old. Simply put, taking a 1.0 m sea level rise into account raises the FCL by approximately 1.0 m. The new system of calculating FCL is needed because under the old system, natural boundary is defined by visual observation and a future natural boundary cannot be observed today.

[7] Ausenco Sandwell, 2011. Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land use. BC Ministry of Environment.

Figure 4 Existing definitions for FCL and setback (Ausenco Sandwell, 2011)



Keeping the above in mind preliminary calculations under the new system, based on generalized numbers for storm surge and wave effect and the high tide at Cowichan Bay, provide the following FCL for east Vancouver Island based on mean sea level:

Global SLR allowance	1.0 m
Regional adjustment	-0.17
High tide (HHWLT m CGD)	1.6 m
Wave Effect	0.65 m
Freeboard	0.6 m
Flood Construction Level (FCL)	**5.0 m**

The preliminary calculations for east Vancouver Island above are provided for guidance and are not intended to be used to establish FCLs due to variations in site specific factors such as the local rate of crustal uplift or subsidence, the nature of the tides, anticipated local storm surge effects that depend on local bathymetry and the particulars of the anticipated storms associated with the storm surge. For example, the rate of uplift for the RDN region is 2.1 mm / year compared to the 1.7 mm/year used in the example, and the wave effects would be quite different for that area given the much greater fetch than in protected Cowichan Bay.

5 Understanding Mitigation & Adaptation

The fourth IPCC assessment report released in 2007 helped to shift the perception that climate change adaptation was an admission of defeat to an acknowledgment that adaptation was now a necessary response to climate change; even if greenhouse gas emissions stop immediately, the impacts of climate change will continue into the foreseeable future. The Province of BC's draft amendments to its Flood Hazard Area Land Use Management Guidelines provide some guidance to local governments in both mitigation and adaptation to sea level rise for land development in areas that will be affected. This section describes climate change mitigation and adaptation in general and focuses in on sea level rise adaptation, how a process could be undertaken for the RDN, and how the provincial Guidelines fit in to the larger picture.

5.1 Climate Change Mitigation and Adaptation in the RDN

Climate change mitigation refers to the ongoing attempts to prevent significant climate change through the reduction of greenhouse gasses (GHG) in the atmosphere. The RDN has been involved in climate change mitigation for nearly a decade; in 2007 the RDN Board approved a Corporate Climate Change Plan for its operations which identifies energy and GHG emission reduction measures, and in 2013 adopted a Community Energy and Emissions Plan. The RDN has reduced GHG emissions in its corporate operations, and has been engaged in green building initiatives for several years.

Adaptation refers to actions taken to respond to the impacts of climate change by reducing the associated risks. Examples of adaptation actions include modifications of coastal development to account for sea level rise, changes to agricultural crops better suited to hotter and drier summers, or reduction of water use. The RDN has not yet undertaken a coordinated assessment of the anticipated climate changes in the region, associated impacts, and potential adaptation actions.

Changes to climate and extreme weather events are already being experienced and some adjustments and plans for adaptation are being made through individual initiatives such as the Team WaterSmart program for water conservation. The 2007 Drinking Water and Watershed Protection Action Plan identifies climate change as one of seven guiding programs, and the Wastewater Services department has undertaken a preliminary scan of vulnerable coastal infrastructure.

Of the RDN's municipalities, the City of Nanaimo and Town of Qualicum Beach have taken steps towards sea level rise adaptation. Nanaimo has completed an internal mapping exercise to identify areas subject to coastal inundation in different sea level rise, storm surge and tsunami scenarios. Qualicum Beach is currently undertaking a Waterfront Master Plan project that includes a detailed engineering study of local coastal conditions with recommendations for adaptation to projected impacts of

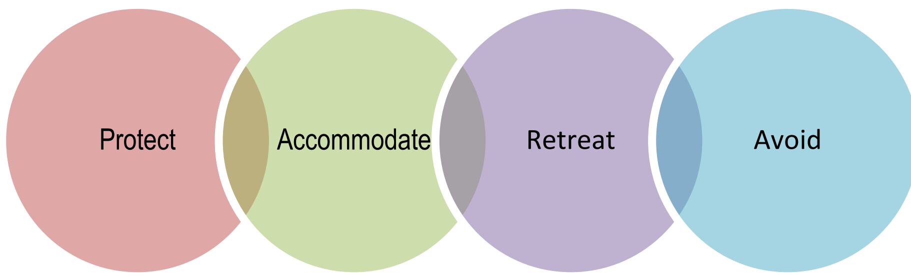
Adaptation refers to actions taken to respond to the impacts of climate change by reducing the associated risks. In other words, it means being well prepared.

climate change. Both of these projects were possible as they already have high resolution elevation data from LiDAR imagery.

5.2 How does the RDN Prepare for Sea Level Rise?

With a technical basis to understanding the geographic extent of sea level rise impacts, the RDN will be in a position to assess the vulnerability and risk of these areas and create a plan to adapt. Adaptation actions can be categorized into four approaches: protect, accommodate, retreat and avoid (figure 5). A sea level rise adaptation plan for the RDN would likely include all four approaches depending on the impact, location, land use or policy tool used.

Figure 5 Range of adaptation strategies



A vulnerability and risk assessment is a structured process to evaluate sensitivity, adaptive capacity, likelihood and consequence. Each RDN department may have different vulnerable areas and risks. For example, Liquid Waste may be interested in coastal pump stations, Emergency Planning in low lying neighbourhoods with vulnerable access, Drinking Water in saltwater intrusion of wells, Building and Planning in changes to flood construction levels, and Parks in increasing erosion and damage to waterfront parks and trails.

Vulnerability is a function of a department’s sensitivity to sea level rise and its capacity to adapt to impacts with little to no cost or disruption. Risk is a function of the likelihood and consequence of an impact where likelihood refers to the known or estimated effects of a particular impact.

Taking a simple example, waterfront park benches may be highly sensitive to impacts of sea level rise, but because the Parks department has a high capacity to adapt by moving the benches further back or to higher ground at low cost, the overall vulnerability is considered medium.

Vulnerability = Sensitivity x Adaptive Capacity

The likelihood of a storm event that would damage park benches is high under sea level rise scenarios, but the consequence is relatively low (considering public safety, cost of damage), therefore the risk is in the medium range.

Risk = Likelihood x Consequence

The vulnerability and risk assessment feeds into the adaptation strategy; vulnerabilities and risks can be ranked and categorized in order to determine prioritized actions. This set of prioritized actions is the adaptation strategy. Obtaining detailed mapping of areas that will be impacted by sea level rise is key information for the vulnerability and risk assessment, as the sensitivity and likelihood of impacts is highly dependent on location and elevation.

5.3 "No Regrets" Climate Change Adaptation

Planning for an uncertain future can be challenging. With a range of projections for sea level rise there is uncertainty about its timing and extent. It can be difficult to motivate adaptation in the face of uncertainty, especially when it is costly to the community or individuals.

The "no regrets" approach to climate change adaptation involves identifying actions that build on existing activities to improve community resiliency and generate benefits whether the extent of anticipated climate change materializes or not. An example of this is integrating retrofit or design for the impacts of sea level rise into pre-existing asset management cycles.

6 Resources and Financial Assistance to Local Governments

Sea level rise adaptation has been taken up by provincial and federal governments as an emerging and highly likely future that needs to be prepared for, who have recognized that much of this work currently falls to local governments and can be an extremely costly undertaking. This section lists resource and potential grant funding for local governments.

6.1 Provincial Initiatives and Resources

In Section 3 of this Background Report, the Province's initiatives to develop local sea level rise projections for BC and their development of the recommended curve for sea level rise policy in BC were outlined. The Province has also been involved in developing a number of other resources for local governments related to climate change adaptation, or sea level rise adaptation specifically. This section lists these key documents.

Title of report or project	Prepared by	Purpose
Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use, 2011	Ausenco Sandwell	Technical studies to provide a basis for amendments to the Flood Hazard Area Land Use Management Guidelines. Includes two associated reports: • *Guidelines for Management of Coastal Flood Hazard Land Use; and* • *Draft Policy Discussion Paper.*
Coastal Floodplain Mapping – Guidelines and Specifications, 2011	Ker Wood Liedal	"to provide a technically sound basis for local governments to develop coastal floodplain maps".
Preparing for Climate Change, an Implementation Guidebook for Local Governments, 2012	West Coast Environmental Law	"designed to assist local government elected officials and staff, including planners, engineers, chief administrative officers, financial officers, and others, to plan and act in ways that will make their communities more resilient to the impacts of climate change"
Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC, 2012	Association of Professional Engineers and Geoscientists of BC	"to guide professional practice for flood assessments, to identify the circumstances when risk assessments are appropriate and to emphasize the need to consider climate change and land uses in such assessments."
Sea Level Rise Adaptation Primer, 2013	Prepared for the BC Ministry of Environment (by several consultants)	This is a toolkit for coastal management authorities (mainly local government) to help identify, evaluate and compare options for adaption to the impacts of sea level rise and associated coastal hazards.
Pacific Climate Impacts Consortium(PCIC)	Regional climate service center at the University of Victoria	The center conducts a broad array of studies on the impacts of climate change in the Pacific and Yukon region.

6.2 Potential Sources of Grant Funding 2017-2019

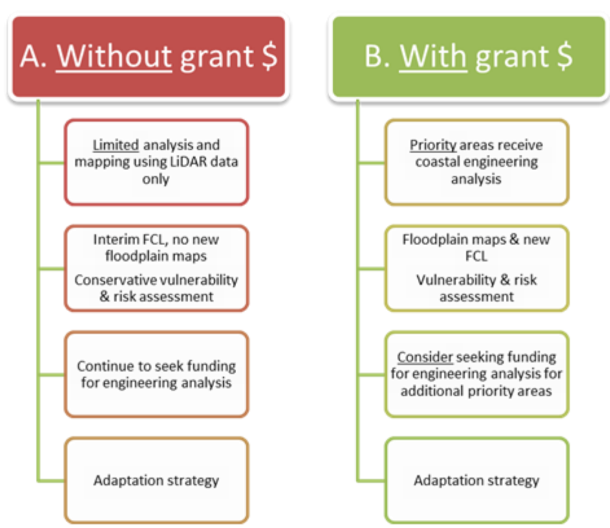
Grant Program	Deadline
Real Estate Foundation of BC	February 28, 2018 and September 2018
Green Municipal Fund	Announced a new funding offer in April, 2015 no deadline.
Federal Gas Tax Fund – Strategic Priorities Fund	deadline in spring
Federal Gas Tax Fund – Community Works Fund	Annual allocation to RDN, internal decision on how funds are allocated.
Natural Disaster Mitigation program	Closed for 2015
Regional Adaptation Collaborative (NR Can)	No deadline
Community Emergency Preparedness Fund (UBCM)	October 27, 2017 & February 22, 2018
Municipalities for Climate Innovation Program (FCU)	January 1, 2020
BC Climate Action Toolkit – Funding for Local Governments webpage	Ongoing

6.3 Tasks and Timeline

The timing of this project is dependent on the RDN's success in receiving grant funds. It is envisioned that this Terms of Reference will be used in support of grant applications, and as such the ideal project timeline if fully funded shown in Table 1 below.

Should no grant funding be obtained initially, the project can still proceed but in a limited or more phased scope as shown in Figure 1 compared to the ideal scenario with grant funding. If some but not all of the fully budgeted amount of grant funding is obtained, the engineering analysis of priority areas will be scaled or phased as needed.

Figure 6 PROJECT UNDER TWO FUNDING SCENARIOS



7 LOCAL GOVERNMENT ADAPTATION STRATEGIES

The RDN can learn from other local governments who have been early adopters of sea level rise planning. This section provides a brief description of some local governments in the Strait of Georgia who have begun to plan for sea level rise.

7.1 CAPITAL REGIONAL DISTRICT

With funding from NRCan, the Capital Regional District (CRD) completed a "Coastal Sea Level Rise Risk Assessment" in early 2015 that included the following two tasks:

1. to identify and map areas that are potentially vulnerable to sea level rise; and
2. to understand the potential economic consequences of sea level rise.

The mapping component of the project produced maps for 23 focus areas of the CRD showing 6 scenarios: 50, 100 and 200 year sea level rise for both static sea level rise and sea level rise plus a 1 in 500 year storm surge event. The study did not involve an engineering analysis of wave effects and shore type, and the associated physics of overland flow, wave dissipation, levee overtopping, or potential shoreline erosion associated with extreme water levels and waves.

In the second phase of this project, the CRD will develop recommendations for adaptation tools to respond to the coastal hazards due to sea level rise.

7.2 COWICHAN VALLEY REGIONAL DISTRICT

The Cowichan Valley Regional District (CVRD) completed an internal GIS mapping exercise to identify low-lying coastal areas affected by projected sea level rise using high accuracy LiDAR elevation data. This mapping has been used as a communications tool with staff and the CVRD Board.

The CVRD is focusing on private coastal land stewardship and is a Green Shores for Homes pilot community, a program of the Stewardship Centre of BC.

7.3 CITY OF COURTENAY

In response to significant flooding events in 2009 and 2010, the City of Courtenay updated their floodplain mapping, undertook hydrologic modelling, and had new flood protection works designed. In 2011, Courtenay's floodplain bylaw was amended to add 0.8 m to the Flood Construction Level in existing floodplain areas that are tidally influenced as an interim sea level rise adaptation measure. Further amending the floodplain bylaw to include the new floodplain map is one of the next steps in the project.

Coastal areas outside of the currently-mapped floodplain have not been mapped to anticipate future sea level rise.

7.4 City of Campbell River

The City of Campbell River completed an internal GIS mapping exercise to identify low-lying coastal areas affected by projected sea level rise using high accuracy elevation data. As part of an upcoming official community plan review, they may consider including policies related to sea level rise.

7.5 City of Vancouver

Although one of Canada's largest urban areas has many differences from the RDN, some very relevant information and examples can be learned from their experience. The City of Vancouver was the first Canadian city to adopt a comprehensive climate change adaptation strategy in 2012 and introduced an interim FCL of 4.5 m (up from the previous 3.5 m, based on Greater Vancouver Geodetic Datum) in response to Provincial warnings about projected sea level rise.

In 2014, Vancouver undertook a sea level rise modelling project that maps expected sea level to 2100 and areas that wave effects will impact. This sea level rise modelling project resulted in a FCL of 4.6 m, which was subsequently incorporated into a bylaw amendment to formally change the FCL to 4.6 m.

The City of Vancouver is now continuing with other actions related to sea level rise that were identified in their Climate Change Adaptation Strategy: location-based responses, leveraging large-site redevelopments, and immediate actions in impacted areas.

7.6 City of Surrey

Launched in 2016 to help their coastal communities become more resilient, the City of Surrey is developing a Coastal Flood Adaptation Strategy (CFAS) for Surrey's coastal floodplain area. CFAS takes a participatory, community-driven planning approach directly engaging residents, stakeholders, and other partners, including First Nations, community and environmental organizations, business associations and groups, senior governments, farmers, the agricultural community, and neighbouring jurisdictions to identify short, medium and long-term options to adapt. The CFAS is broken into five phases that involved undertaken education, awareness building before exploring adaptation option. As of spring/summer 2018 the technical climate information and extensive community input is being used to develop a preferred strategy, which is expected to be completed in late 2018.