Salmon and White River Flood Mapping Study

DRAFT

September 2021

Submitted to: The Village of Sayward & The Strathcona Regional District

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Executive Summary

The Sayward Valley has experienced numerous flood events over its history. Flood inundation maps for the Sayward Valley were published in 1980 and a later 1995 study confirmed the maps inundation values. In 2019 McElhanney completed a flood risk assessment report and produced flood risk maps. The report made several recommendations to the SRD, including that they produce updated flood inundation and hazard maps utilizing modern modelling techniques and review Sea Level Rise estimates. Understanding that the field of hydraulic modeling has made significant advancements over the past 40 years, recognizing that the effects of climate change are having significant impacts on our environment, and knowing that the potential for future SLR must be accounted for, the Village of Sayward and the SRD requested that the flood inundation maps be updated, and additional flood hazard maps be produced.

In 2019, McElhanney completed a flood frequency analysis which re-examined the hydrology of the entire Salmon River drainage area and made new estimates of peak flow rates. This was necessary to account for an additional 25 years of hydrometric data collected within the watershed. The update also included the possible impacts of the recently decommissioned Salmon River Diversion Structure, which up until 2017 diverted a portion of water in the Salmon River to the Campbell River System.

Subsequently, discharge estimates from the 2019 frequency analysis have been used to simulate 1:200 flood events for current 2021 and future 2100 conditions. LiDAR data collected in 2019 with supplemental topographic and bathymetric survey data has been used to develop a two-dimensional hydrodynamic computer model (*HEC-RAS*). Before the model was used to simulate large flood events in the Valley, it was verified by comparing real-time hydrometric discharges and water levels (at Kelsey Bay, Hwy 19 Bridge and Big Tree Main Bridge). The model results were also compared to anecdotal inundation maps provided by the SRD for a recent flood event in January of 2016. With good agreement at these discharges further simulations for future large floods was possible

GreatPacific Engineering & Environment completed a coastal analysis for water level conditions at the mouth of the river (Kelsey Bay). The resultant peak tide level elevation of 3.46m (geodetic elevation) was incorporated into the hydrodynamic model as a boundary condition for the current 2021 condition.

Simulations were conducted for the current 1:200 year estimated flood and future 1:200-year flood event for the year 2100 scenario which included a net Sea Level Rise amount of 0.71m and an additional 10% runoff added to the peak instantaneous flows to account for probable climate change conditions. The resulting floodplain maps include an allowance of 0.3m of freeboard and show extensive flooding throughout the valley.

Compared to the previous study maps, the updated inundation areas are more refined but are similar in extent with marginally higher predicted water surface elevations. These results are expected as the peak flow rates from the 2019 frequency analysis are comparable to those estimated in the 1995 study. The new modelling and map products can be used with confidence for future planning in the Valley both on an emergency basis and for any potential development(s).

Flooding in the Valley is a well known and excepted condition of those residing there. During the public consultations as part of the 2019 hazard assessment and this study, the main feedback from valley residents was the need for better access and egress to and from the Valley during a flood event, which typically closes the Main Sayward Road (owned and operated by the Ministry of Transportation and Infrastructure (MOTI)) and the Salmon River Main (operated by Western Forest Products), On this basis, recommendations with associated construction cost estimates to raise the following sections of roads have been made in order of priority:

Option A – Raise Highway 19 West of Salmon River Bridge, **$2,398,000**
Option B – Raise Salmon River Main, **$1,088,000**
Option C – Raise Salmon River Rd Near Hammond Bridge, **$815,000**
Option D - Raise Salmon River Rd for 2.8km North of the Bailey Bridge, **$5,138,000**
Option E – Raise Salmon River Rd for 942m North of Highway 19, **$1,745,000**

All of the above estimates are considered Class 'D' and carry a 40% contingency and a 15% allowance for engineering and construction inspection, as they require further refinement through the detailed design process if they are to be implemented. Detailed design would include the need to assess local flood impacts of raising the roads, especially Hwy 19, which is likely to require additional flood relief culverts to ensure upstream properties are not affected by significant water level increases from a raised road structure, which is apt to act like a more significant dam across the Valley.

Some residents of the Valley have adapted to the flooding situation along the Salmon River by raising the living space of their homes above flood levels, among other initiatives. There has been little in the way of a community-based flood improvement project as the main Village is primarily above flood levels, and the low density of housing in the valley does not justify large scale protection projects such as diking. There are four avenues to address floodplain management, namely Protect, Adapt, Retreat, and Avoid (PARA) . The community has largely adapted to the flood prone area, should the Village and SRD decide to formalize the remaining two elements of the framework, and it is suggested to do so by implementing policy that will:

- Accommodate flooding for redeveloped structures that could possibly limit habitable floor areas above the predicted flood levels, leaving streets and lower levels to be flood resistant construction, and subject to periodic flooding
- Retreat from flood hazard areas by implementing policy that limits development in the flood zone to more compatible uses, such as parks, trails and/or agricultural uses
- Avoid the flood hazard areas by limiting any further development in these areas

Regardless, the Village of Sayward should address flooding and flood mitigation within its OCP and both the Village and the SRD Floodplain Bylaws should be updated to include the most updated Flood Construction Levels along the inlet and within the natural environment as determined through this study.

As the science of climate change progresses, the Village and RD are encouraged to review the results of this study routinely and adapt policy and regulation to suit the changing environmental factors that may limit the habitable use of the floodplain.

1. Introduction

1.1. GOALS AND OBJECTIVES FOR THE FLOOD MAPPING STUDY

The goal of the Flood Mapping Study is to increase awareness and preparation for the Strathcona Regional District, the Village of Sayward, and the citizens inhabiting the Salmon River and White River Floodplains, with the goal of adopting responses to future flooding risks and to be used for development planning.

Specific objectives and deliverables of the study included:

1. Review of all background information and data.
2. Integration of detailed topographic survey (river bathymetry and LiDAR imaging) into a digital terrain model (DTM).
3. Technical modeling of rivers and sea interactions with various storm events (current 2021 conditions, Year 2100 projections) based on the results of the previous 2019 hydrologic analysis and coastal boundary conditions.
4. Provide results of the fluvial geomorphology assessment.
5. Flood hazard (extent, depth, velocity) maps (both print ready and digital GIS files) showing geomorphic and flood inundation hazards for up to four conditions at an appropriate scale with base mapping.
6. Flood inundation maps showing flood extents and recommended flood construction levels.
7. Results of the hydraulic model will be exported into the appropriate GIS formats and provided to the SRD and Village of Sayward.
8. Review of existing land uses and proposed land use designations that might be affected by these new flood levels.
9. Develop options, at the conceptual level, to adapt to the flood risks.
10. Development of a long-term strategy to reduce impacts of flooding on the community while protecting the ecological, economic and cultural values of the river and floodplain.

1.2. COMMUNITY ENGAGEMENT

One Committee of the Whole (COW) meeting and two public information meetings were held to provide a forum to share information as the project progressed from start to finish. The meetings, held virtually, were intended to present preliminary and final results of the flood mapping study and encourage the public to bring forward comments or questions.

1.2.1. Committee of the Whole Meeting (June 8, 2021)

On March 12, 2019, from 7:00 to 8:30 p.m., the Sayward Village Council hosted an online, virtual Committee of the Whole Meeting and invited McElhanney to present simulations of preliminary flood model animations as a precursor to an upcoming public engagement event to be hosted by the SRD. Content of the presentation is attached in Appendix E.

1.2.2. Public Engagement Meeting No.1 (June 22, 2021)

On June 22, 2021, from 7:00 to 8:30 p.m., the SRD hosted a virtual introductory public engagement event. All interested parties were welcome to attend a presentation (similar to that of the June 8th meeting) which expressed the need to develop updated floodplain and hazard maps, present preliminary flood model animations. Content of the presentation is attached in Appendix E, and the intent of the meeting was to inform the public of the scope of the project and review past flooding in the Village to garner historical information from citizens that were in the Sayward Valley during past floods.

1.2.3. Public Engagement Meeting No.2

As of the date of this Draft Report the second public engagement meeting has not taken place, in lieu of waiting for input from staff, council and SRD directors on the Draft Results and Recommendations.

2. Study Area

As described in the previously developed 2019 Salmon and White Rivers Flood Frequency Analysis report, the last comprehensive floodplain study for this area was completed in 1995 (BC Ministry of Environment, 1995). The 1995 study confirmed 200-year flood extents and elevations for the two rivers.

The current study area is that same as in 1980 and 1995, see **Figure** 1, which covers the floodplain of the Salmon River up to 25km from the tidewaters at Kelsey Bay to above the confluence of Memekay River.

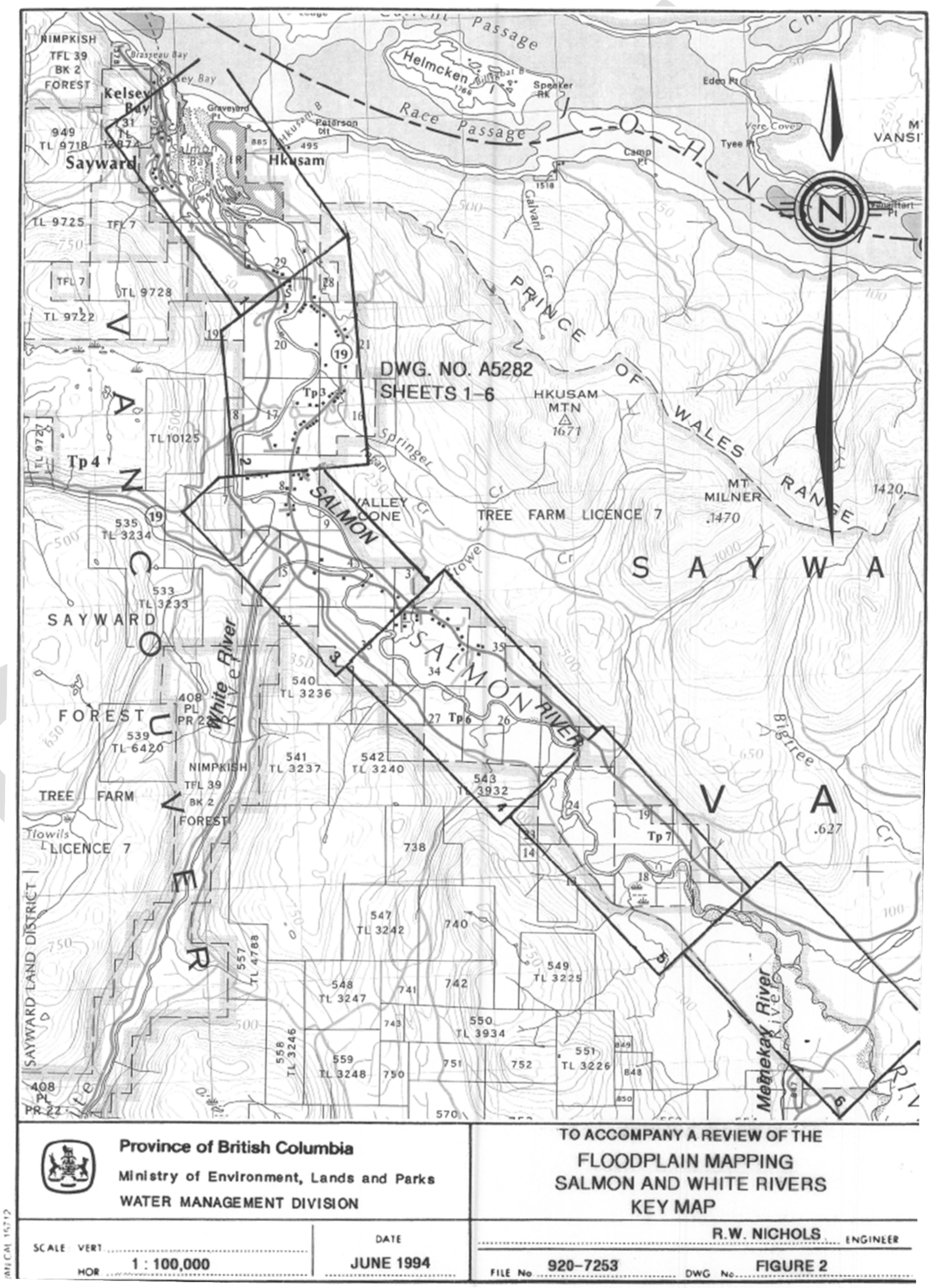

Figure 1: Floodplain Mapping Extents from 1995 Study

2.1. MAPPING

New analytical tools used in this study demand, and benefit from, greater precision in representation of the surface topography. As a result, the study area was newly mapped with digital aerial photography and topographic mapping using Light (or Laser Imaging) Detection and Ranging (LiDAR) equipment. The LiDAR scanner is housed in an aircraft along with the aerial photography equipment and scans the land over the flight path. Thousands of data points are collected to produce a digital elevation model (DEM) of the valley.

LiDAR does not produce data below water surfaces, so to supplement the LiDAR data, bathymetric data was collected with sonar sounding surveys.

Limited conventional surveys of the rivers and floodplains were completed. This included the confirmation of a number of bridge piers and abutments on both rivers. The accuracy of the Lidar was also confirmed with these surveys.

3. Flood Plain Management Tools

3.1. MUNICIPAL LEVEL

The study area includes lands within the Village of Sayward and the SRD, and floodplain management is generally provided by a combination of Zoning Bylaw Regulations and an Official Community Plan (OCP) for the Village of Sayward.

3.1.1. Official Community Plans

The Village of Sayward is in the process of updating its OCP to provides a land use and infrastructure policy framework to guide development in the Village. The results of this study and floodplain maps will be an aid in drafting policies for the community development as it relates to land use in the floodplain.

The SRD does not currently have an OCP for the Sayward Valley.

3.1.2. Zoning Bylaws

The Village of Sayward and the SRD Floodplain Management Bylaws No.311 and No.2782 respectively address various new building setback conditions and construction levels in terms of 200-year flood elevations shown on the most current maps. Both bylaws do not currently identify or designate areas of potential flood hazard.

3.2. PROVINCIAL LEVEL

The Environmental Management Act[1] provides the Ministry of Forest, Lands and Natural Resource Operations (FLRNO) with broad powers to establish guidelines, regulations and hazard management plans with respect to flood protection, dikes and the development of land subject to flooding.

Through the Act, FLNRO has established the Integrated Flood Hazard Management Program. The objective of the program is to reduce the impacts of flooding on people, communities and infrastructure through the development of policies, guidelines, and information to assist local governments. The program provides guidance in three primary areas:

1. Managing land use within the floodplain;
2. Managing flood protection systems; and
3. Preparing for and responding to emergencies.

Effective flood management practice integrates all three of these components. Although flood protection works, such as dikes, provide protection from flood damage, they require on-going maintenance and periodic upgrades to be effective over time. It is, typically, not cost effective to rely solely on constructed flood protection works to control the threat of flooding. It has been shown that appropriate land use management and flood mitigation are the most practical and cost-effective ways to reduce flood damage. Finally, in the event that flooding does occur, communities having an effective emergency planning and response program can reduce the risk of loss of life and trauma as well as improve recovery times.

[1] BC Environmental Management Act, SBC 2003, Chapter 53

3.2.1. Floodplain Land Use Management

The provincial Flood Hazard Area Land Use Management Guidelines[2] provide guidance for local government, land use managers and approving officers to develop and implement land use management plans and subdivision approvals for floodplain areas.

Land Use Management Policies

The guidelines suggest that general land use policy statements regarding flood hazard management and maps showing areas of flood hazard, should be included in Official Community Plans. The guide provides general examples of policy statements. Under sections of the Local Government Act[3], local governments may incorporate requirements for flood protection measures or restrictions on floodplain development through floodplain bylaws, land use bylaws and development permit areas. The guideline provides example bylaws that local governments can use.

During the subdivision approval process for lands that are deemed subject to flooding or erosion, the approving officer can require an engineering certification that the land may be used safely for its intended purpose. The provincial government has prepared a guide to selecting qualified professionals for preparation of flood hazard assessment reports. The Engineers and Geoscientists of British Columbia (EGBC) have published Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in BC[4], which provide qualified professionals with guidance on flood standards and methodologies to use when reviewing flood hazards for land development.

Where land may be subject to flood hazard beyond what is considered safe for the intended use, a restrictive covenant can be used to restrict development within all or part of the land parcel. The guidelines provide a summary of specific conditions that should be included in a restrictive covenant for flood hazard management as well as examples.

Floodplain Mapping

Local governments must consider relevant floodplain mapping in the development of flood hazard bylaws and other land use management policies. Floodplain maps show the route and limits of water courses, surrounding features, ground elevations, flood levels and floodplain limits. One of the primary purposes of the Salmon and White River Flood Mapping Study has been to update the floodplain mapping for purposes of land management planning.

The impacts of Climate Change and Sea Level Rise must now be considered in the preparation of floodplain mapping. The Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard

[2] BC Ministry of Water, Land and Air Protection, Flood Hazard Area Land Use Management Guidelines, May 2004
[3] BC Local Government Act, RSBC 2015, Chapter 1
[4] Engineers and Geoscientists BC, Legislated Flood Assessments in a Changing Climate in BC, Version 2.1, August 2018

Land Use and Coastal Floodplain Mapping Guidelines[5] recommend that a 1.0m increase in average sea level should be used for planning purposes for the Year 2100 timeline.

Recommended Minimum Flood Hazard Reduction Requirements

The Flood Hazard Area Land Use Management Guidelines[6] also provide a list of minimum requirements for higher flood risk areas, where detailed floodplain mapping has not yet been prepared. Some of these requirements include:

- Establishing floodplain setbacks, ensuring development is kept away from areas of potential erosion and avoiding restriction of flow capacity. The minimum recommended setback for rivers is 30m.
- Flood Construction Levels (FCL) are used to keep living spaces and areas used to store goods that could be damaged by flooding above the established flood levels. The minimum recommended Flood Construction Level is either 0.6 m above the designated flood water level or 3.0 m above the natural ground level adjacent to the water course if no flood levels have been established.
- The designated flood is the flood having an average recurrence interval of 200 years or that has an average 0.5% likelihood of occurring in any given year.

The guidelines also provide suggestions intended to reduce flood hazards by land use type and recommendations on access and egress requirements from the floodplain during flood events.

Legislated Flood Assessment Guidelines

The Engineers and Geoscientists BC, in conjunction with Provincial Ministry of Forest, Lands and Natural Resource Operations and Natural Resources Canada, have developed a professional practice guideline for "Legislated Flood Assessments in a Changing Climate in BC"[7]. The purpose of this guideline is to provide a framework for communities and professionals to define the roles and scope of flood assessments required for building permits, subdivision approvals and other land development activities that are reviewed by Approving Authorities. The scope of the guidelines provides recommendations on how to:

- Undertake flood assessments consistently and transparently;
- Provide for appropriate consultation with approving authorities;
- Use a level of effort and approach appropriate for the nature of the elements at risk;
- Standardize the flood assessments to make them directly comparable within BC;
- Consider existing regulations and the level of protection provided by structural mitigation works;
- Increasingly consider "risk management" and "adaptation" as opposed to solely "protection" and "defense";
- Consider a broader range of issues and analytical techniques to help achieve improved social and environmental outcomes as part of development;

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[5] Ausenco Sandwell, Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use Guidelines for Management of Coastal Flood Hazard Land Use, January 2011

[6] BC Ministry of Water, Land and Air Protection, Flood Hazard Area Land Use Management Guidelines, May 2004

[7] Engineers and Geoscientists BC, Legislated Flood Assessments in a Changing Climate in BC, Version 2.1, August 2018

- Include predicted changes in the hydroclimate as well as natural and anthropogenic changes to channel morphology and watersheds in the flood assessment; and
- Identify situations that require expert input.

Although the guidelines have been primarily developed as a tool for qualified flood assessment professionals, the document also provides guidance on how local governments can better define flood assessment requirements as part of their land development approval processes.

3.2.2. Flood Emergency Management

Emergency Management BC (EMBC) is the primary provincial government agency responsible for coordinating flood response. This said, emergency planning and response should be coordinated from within households, local governments and higher levels of government. Through the Integrated Flood Management Program, the provincial government has prepared several guidance documents to help local governments and households prepare for flood emergencies:

- British Columbia Flood Plan, 2012;
- Flood Planning and Response Guide for British Columbia;
- Flood Precautions;
- Local Authority Planning Guide;
- BC Tsunami Warning Plan; and
- Other Hazard Specific Plans.

The BC Flood Plan provides specific recommendations and guidelines to assist in preparing for flood emergencies, both at the local and provincial level. It identifies some of the specific issues associated with flood events, including:

- Flash flooding without warning, which can be extremely hazardous and pose significant risk to infrastructure and loss of life;
- Flooding which can occur across a wide geographic area or at several locations across the province at the same time, which can overwhelm provincial and local resources;
- Health risks associated with flooded sewage systems or other hazardous waste and contaminated drinking water supplies;
- River forecasting, which can allow for advanced planning in locations where snowmelt dominates the flood process and issues advisories and warnings;
- Dike authorities (such as those of a local government), who actively monitor flood protection works;
- Waterways which should be monitored for hazardous materials and debris; and
- Potential need to implement site-specific flood protection measures, such as sandbags or other temporary structures.

3.3. FEDERAL LEVEL

3.3.1. Flood Damage Reduction Program

Under the Canadian Constitution, floodplain management falls under the jurisdiction of the provinces. However, the federal government's role is to reduce major disruptions to regional economies and to reduce disaster assistance payments through the Flood Damage Reduction Program. Generally, this program has provided funding of flood protection works, such as the recent partial funding of the provincial Flood Protection Program, which has provided funding to upgrade and construct new flood protection works across BC. In addition, specific programs are supported federally such as the Provincial-Federal Floodplain Mapping Program carried out from 1987 to 1998.

3.3.2. Public Safety

Under the Emergency Management Act[8] (EMA), the Federal Government provides overarching Emergency Management Planning and Disaster Mitigation support in the event of disasters of national importance to protect critical infrastructure. As emergencies most often have the greatest impact at the local level, the Act provides clear guidance on working collaboratively and sharing information with provincial and local emergency management agencies. Public Safety Canada, which administers the EMA, has developed high level emergency planning and recovery policies and guidance for provincial and local governments.

3.3.3. Other Relevant Federal Legislation

Often flood protection works require alterations of stream channels or construction near watercourses that could have impacts to fish habitat. Under the Federal Fisheries Act[9], administered by the Department of Fisheries and Oceans (DFO), any potential Harmful Alteration Disruption or Destruction (HADD) of fish habitat requires prior approval from DFO. Should DFO determine that proposed flood protection works result in HADD, compensation is typically required in the form of construction of habitat enhancement works. During design and planning of flood protection works, opportunities for potential habitat enhancement should be identified to compensate for HADD.

In addition to the Fisheries Act, the approvals under the following legislation may also be required for flood protection works:

- Navigation Protection Act[10], should works impact navigability of waterways
- Environmental Assessment Act[11], if works are partially funded through Federal Grants
- Species at Risk Act[12], if works could impact species identified on the list of wildlife species at risk

3.4. FLOOD MANAGEMENT PRACTICES AND STRATEGIES

Figure 2: Flood Management Solution Space

The “solution space” for flood management (see **Figure 2**) moves from “resistance strategy” to one of “avoidance” depending on the risk and the values assigned to the cost and benefit of the resistance

[8] Canada Emergency Management Act, S.C. 2007, Chapter 15
[9] Canada Fisheries Act, R.S.C. 1985
[10] Canada Navigation Protection Act, R.C.S 1985
[11] BC Environmental Assessment Act, SBC 2002, Chapter 43
[12] Canada Species at Risk Act, S.C. 2002

method[13]. As shown to the left, the paradigm moves from the “protect” to the “avoid” space with the added intermediate solutions of “accommodate” and “retreat”. Thus, local governments can choose depending on resources and local values how they want to deal with predicted floods and flood damages and, to some extent, determine the survival of their communities. Is it better to resist, or get out of harm’s way? The following sections provide brief summaries for both conventional (“protect”) and more recently adopted practices (“accommodate”, “retreat” and “avoid”) in flood mitigation, as they pertain to the Salmon and White River Floodplain situation.

3.4.1. Dikes, Levees, and Flood Walls (“Protect”)

The conventional method of protecting private and public assets is to provide an engineered solution such as dikes, levees and flood walls. As described above, there are regulations for the development of these structures and typically other constraints, such as costs and environmental impacts, which need to be considered. Structures like these will continue to require maintenance if the near bank land use and managing risks to property are of consequence to the Village.

3.4.2. Flood Proofing of Buildings (“Accommodate”)

The Village of Sayward and the SRD should consider revising bylaws such that existing structures (similar to new buildings) need to be built to a set Flood Construction Level. Such a bylaw would allow for filling of land to achieve this elevation. As sea levels rise, it may be necessary to raise the living areas of buildings further as depicted in **Figure 3** below, which shows some buildings on raised “pads” of earth, and some with raised habitable areas above flood levels. These techniques are considered as methods for “flood proofing” buildings within floodplain areas. More novel techniques like floating houses have been implemented in other jurisdictions successfully and could be considered as an option in the Sayward Valley for future re-development within the floodplain area.

Restrictive covenants for lots within the floodplain and Section 219 covenants could be established for developments wanting to vary from required flood construction levels, which would indemnify the SRD, Village, or Province of any responsibility for flood damage to properties developed below recommended floodplain levels.

[13] British Columbia Ministry of Environment, Sea Level Rise Adaptation Primer, A Tool Kit to Build Adaptive Capacity on Canada’s South Coasts, Fall 2013

Figure 3: Examples of Raised Building Pads for Foundations[14]

3.4.3. Managed Retreat ("Retreat" and "Avoid")

From a longer-term perspective, adaptation to increased flood risks is a preferred approach, and the solutions for flood mitigation tend to move away from the engineered flood protection structures such as dikes and levees. A balance needs to be achieved between the uses of the land today and future uses, which include assessment of environmental and socio-economic values, potentially returning the land to a more natural state. Termed "managed retreat", the mitigation strategy involves zoning and land use designations to be "downgraded" as properties are brought forward for re-development, preventing re-development of the land. The land is effectively returned to the SRD or Village and managed as a natural floodplain area, or for more flood tolerant uses such as agriculture, as illustrated in **Figure 4**.

In the case of the Saward Valley, it may be prudent to consider restrictions on redevelopment in the most flood prone areas to mitigate damages from future flood events. There are strategic areas which can be re-developed to higher Flood Construction Levels, but there are better long-term residential opportunities on the north-east side of the river along Highway 19.

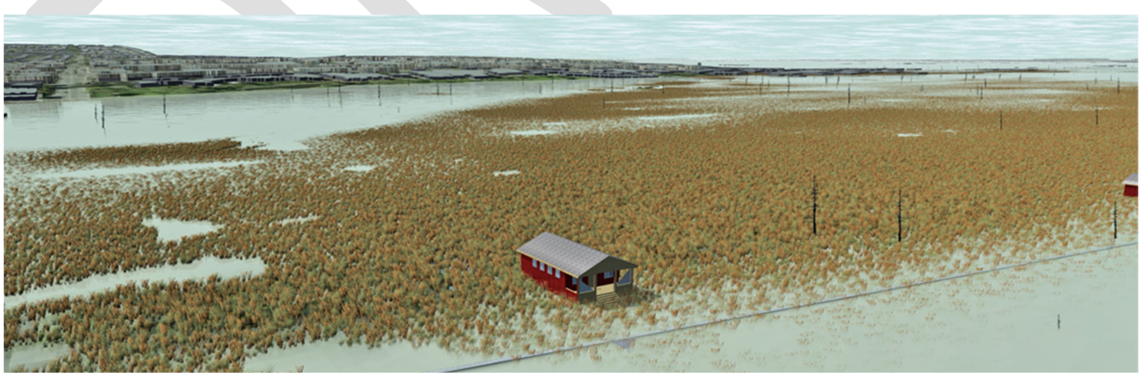

Figure 4: Illustration of Managed Retreat Strategy

[14] UBC Faculty of Forestry, Collaborative for Advanced Landscape Planning, http://calp.forestry.ubc.ca/, Accessed April 2019

4. History of Flooding on the Salmon River

4.1. THE WATERSHED

The Salmon River extends from the Village of Sayward from its mouth in Kelsey Bay at the Johnstone Strait for 78 km to its headwaters. The total drainage area of the Salmon River is 1323.6 km^2, including the 366.7 km^2 White River catchment area, which has its confluence with the Salmon River just upstream of the Salmon River Bridge on Highway 19. The Salmon River watershed ranges from sea level up to 1,849m at the peak of Crown Mountain which is within Strathcona Provincial Park.

The White River flows for 45.4 km from its confluence with the Salmon River. The White River watershed topography ranges from about sea level up to 2,163m at Victoria Peak. An overview of both watersheds is show on **Figure 5**.

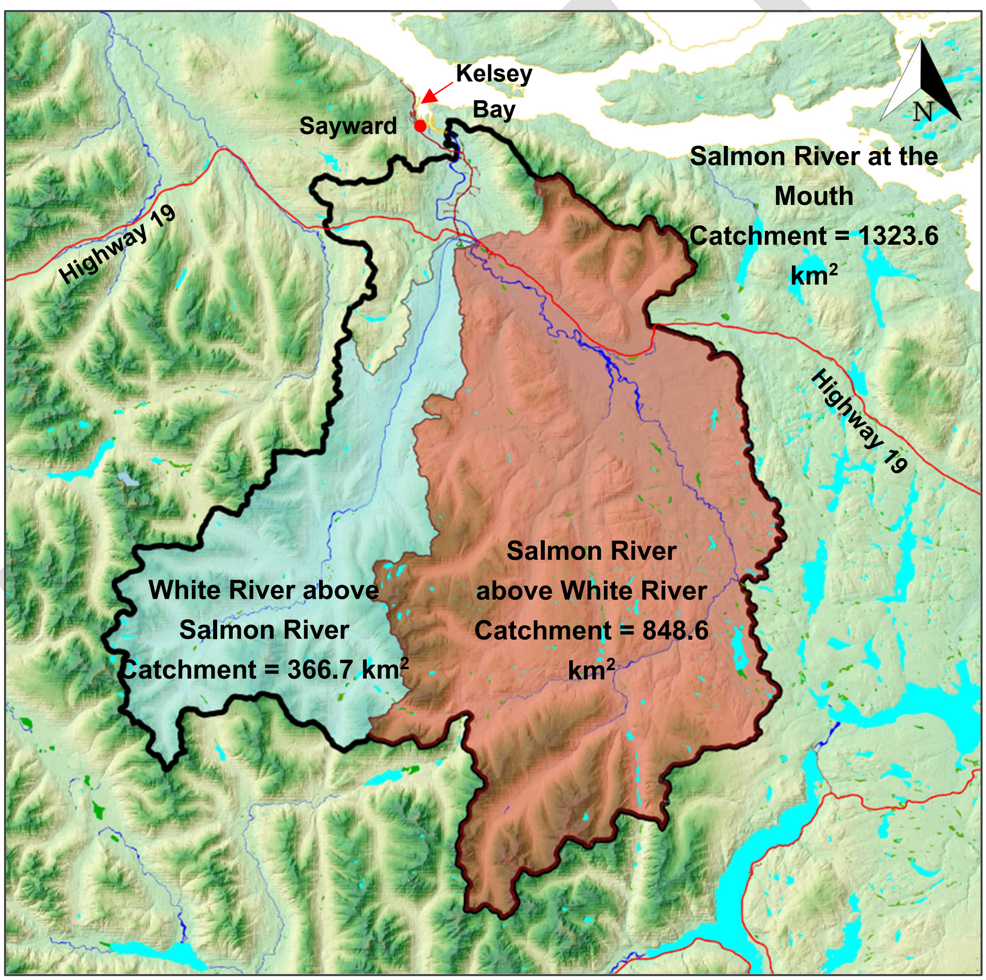

Figure 5: Salmon and White Rivers Catchment Areas

Significant snowpack can accumulate in both the Salmon and White River watersheds at higher elevations during the winter months. However, peak discharges, resulting from spring snowmelt, are generally smaller than those peak flows associated with heavy rainfall events, during large frontal storms from the Pacific Ocean in late fall and/or early winter. As a result, peak flows in the Salmon and White River system occurs most frequently between October and February when higher precipitation is prevalent.

4.2. PAST FLOODING AND FLOOD MITIGATION

Review of a Ministry of Environment document “Flooding and Landslide Events Southern British Columbia 1808-2006” by D.Septer makes reference to flooding in the Sayward area in 1867, when a member of the Slocan band was referenced in the Daily Colonist on June 23, 1894 as having experienced flooding where river levels in the Pend d’Oreille River, near Sayward reached levels some 30ft above the high water mark reached during the 1894 flood.

The same report references a Louis Merigner, a Colville Valley farmer in the same newspaper as referencing flooding in 1877 in the Pend d’Oreille River, near Sayward, where water levels were as high as the 1882 level. The report references the 1882 event in the Sayward area. The 1882 event occurred in June 7-14, 1882. The report details that the 1867, 1877 and 1882 floods were all as a result of spring runoff.

The report highlights flooding experienced December 30- January 3, 1927, when rain on snow resulted in widespread flooding in the area, specifically on January 4, warm rain melting snow in the mountains resulted in heavy flooding, with the Sayward Valley experiencing a severe flood after the Salmon River overflowed its banks.

One flood of particular note that the report details is in 1949 (November 26 – December 3) when a Sayward resident was drowned in a raging creek (unspecified name).

Additionally at the public consultation, there were anecdotal reports, photos & newsprint articles regarding flood events in 1975, 1990, 2008, 2011, 2014 and 2018.The public consultation highlighted that these historical flooding events are not restricted to forgotten “history”, with flooding occurring on a semi-regular basis, with most residents able to recall several flood events which had personally affected either their properties, or their access in and out of the Sayward Valley.

4.3. SUMMARY OF FLOOD RISK REPORT

The 2019 flood risk assessment (see Appendix G) for the Salmon and White Rivers through the Village of Sayward, which was commissioned by the Strathcona Regional District, was prepared using available information, including flooding locations and photographs. Historical information was used as a baseline for the assessment. It was clear from this anecdotal evidence that the greatest risk posed is a lack of safe emergency access and egress during flood events. This lack of access has the potential to impact most of the community, with previous incidents of evacuation from roofs required by helicopter. There is a perception from the community that action is needed to mitigate against these risks.

Anecdotal evidence provided by residents indicated that the more frequent, smaller storm events cause frequent, localized flooding within the community. It is these events that appear to have the most impact. Larger storms are likely to have higher consequence.

The risk assessment included a review of the 12 impact categories within 5 impact classes which were presented in the Risk Assessment Information Template (RAIT) which was required under the National Disaster Mitigation Program. The risk assessment report and RAIT was intended to support the SRD when developing their own initiatives including emergency preparedness planning, input into GIS systems, budgeting for future investigations or mitigation, and land use planning.

4.4. THE EFFECT OF CLIMATE CHANGE, SEA LEVEL RISE, AND LAND USE ON FLOODING

Current practice for establishing Flood Risk Hazards in BC require consideration for climate change. Though the science is still evolving, global climate change models used in the prediction of potential Sea Level Rise and changes in long-term weather patterns have been refined and are a requirement of planning for Developers, Municipalities and Provincial and Federal Agencies. In BC, the Pacific Climate Impacts Consortium (PCIC) is a regional climate service centre at the University of Victoria that provides practical information on the physical impacts of climate variability and change in the Pacific and Yukon Region of Canada. The tools provided by PCIC and the two reference guidelines published by the Engineers and Geoscientists BC (EGBC) and the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD)[15] form the basis for year 2100 estimates for changings in precipitation and Sea Level Rise.

In 2011, the then BC Ministry of Environment (MoE) published a "Draft Policy Discussion Paper" based on assessments produced by Ausenco Sandwell. The *"Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use, Draft Policy Discussion Paper"*[16] was the leading report to address Sea Level Rise, and the recommended planning levels from that paper, as shown on **Figure 6** , has become the standard to which planning studies in BC need to adhere to. While research has advanced somewhat, the Policy remains in place, and the recommended 1m Sea Level Rise estimate has been incorporated into the assessment of the Salmon and White Rivers

[15] Legislated Flood Assessments in a Changing Climate in BC, BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (MFLNRORD), and Professional Practice Guidelines – Flood Mapping in BC (Engineers and Geoscientists BC 2017a)
[16] Ausenco Sandwell, Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use Guidelines for Management of Coastal Flood Hazard Land Use, January 2011

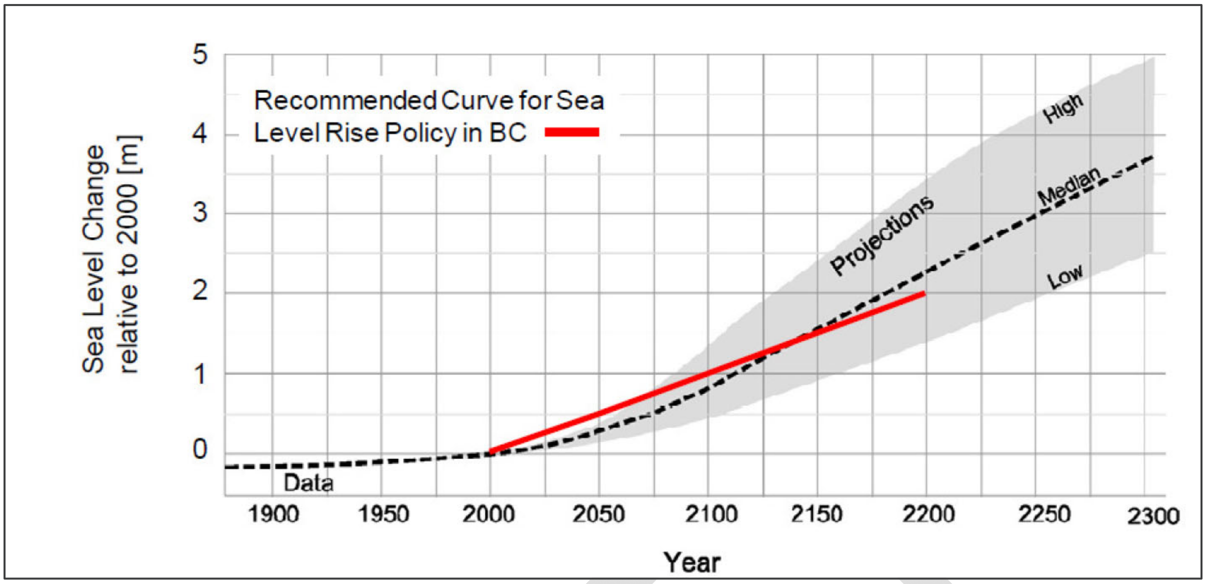

Figure 6: Provincial SLR Policy in BC

For the purposes of this study, Sea Level Rise needs to be considered in relation to isostatic rebound (lifting of the earth's crust after the last glacial age). Isostatic rebound will be counter to Sea Level Rise, reducing its net effect on the rising ocean levels. In the process of determining appropriate ocean levels, Sea Level Rise and isostatic rebound need to be considered with appropriate allowances for other ocean level dynamics such as storm surges and the effects of tides and wave environments. Since most flooding in Sayward Valley is a result of significant storm activity generating significant rainfall accumulations, it makes sense to consider the effect of all probable phenomena at the receiving ocean inlet coincident with the peak flood waters discharging from the two rivers. The work to estimate the conditions at the inlet for present day mean sea levels, as well as future Sea Level Rise, has been completed by GreatPacific Consulting and is addressed in their report included in Appendix D.

As the climate warms, weather patterns are expected to change, which will affect natural systems to varying degrees. The PCIC has developed several local models for predicted climate change and its effect on weather. The local estimates for Sayward and the Valley are provided on **Table 1** below and show increases of rainfall in the fall and winter with drier summers.

Table 1: Summary of Climate Change for Strathcona in the 2080s[17]

Climate Variable	Season	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range (10th to 90th percentile)
Temperature (°C)	Annual	+4.5 °C	+3.4 °C to +6.0 °C
Precipitation (%)	Annual	+6.2%	+1.3% to +12%
	Summer	-25%	-48% to -2.2%
	Winter	+9.6%	+0.88% to +18%
Precipitation as Snow* (%) *CAUTION: This variable may have a low baseline. See note 2 below.*	Annual	-58%	-71% to -47%
	Winter	-61%	-70% to -45%
	Spring	-50%	-80% to -35%
Growing Degree-Days* (degree-days)	Annual	+1070 degree-days	+762 to +1520 degree-days
Heating Degree-Days* (degree-days)	Annual	-1490 degree-days	-1930 to -1160 degree-days
Frost-Free Days* (days)	Annual	+76 days	+62 to +87 days

Notes:

1. Climate variables marked with * are derived from temperature and/or precipitation values, and are not direct outputs of the climate models.
2. CAUTION: Percent changes from a low baseline value can result in deceptively large percent change values. A small baseline can occur when the season and/or region together naturally make for zero or near-zero values. For example, snowfall in summer in low-lying southern areas.

The additional 10% rainfall in the winter is considered to be in exchange for a 61% decrease in snowfall for the most part. The chosen scenario is the Mean predictions from the various models, which represents a reasonable forecast at this time. Like any predictions about climate and weather, these are continuously being researched and updated. Moving forward, the Village and SRD should re-visit the science and predictions to update the floodplain model on a more routine basis. The model can then be better calibrated and used for the intended purpose of planning for development policy in the floodplain.

4.5. THE RIVER CHANGES WITHIN THE FLOODPLAIN

The fluvial geomorphologic assessment in this report is a high-level analysis of the channel reaches within the boundaries of the study area and is by no means a detailed geomorphologic assessment of the entire river network. The time scale for which this analysis is relatively small (50-100 years) but is fitting for the purpose of land use and flood risk and hazard planning. The analysis used images from Google Earth and Bing Maps taken from 1985 up to 2015. **Figure 7** shows some of the images used in the analysis.

[17] www.pacificclimate.org, Plan2Adapt Tool Kit, September 2021

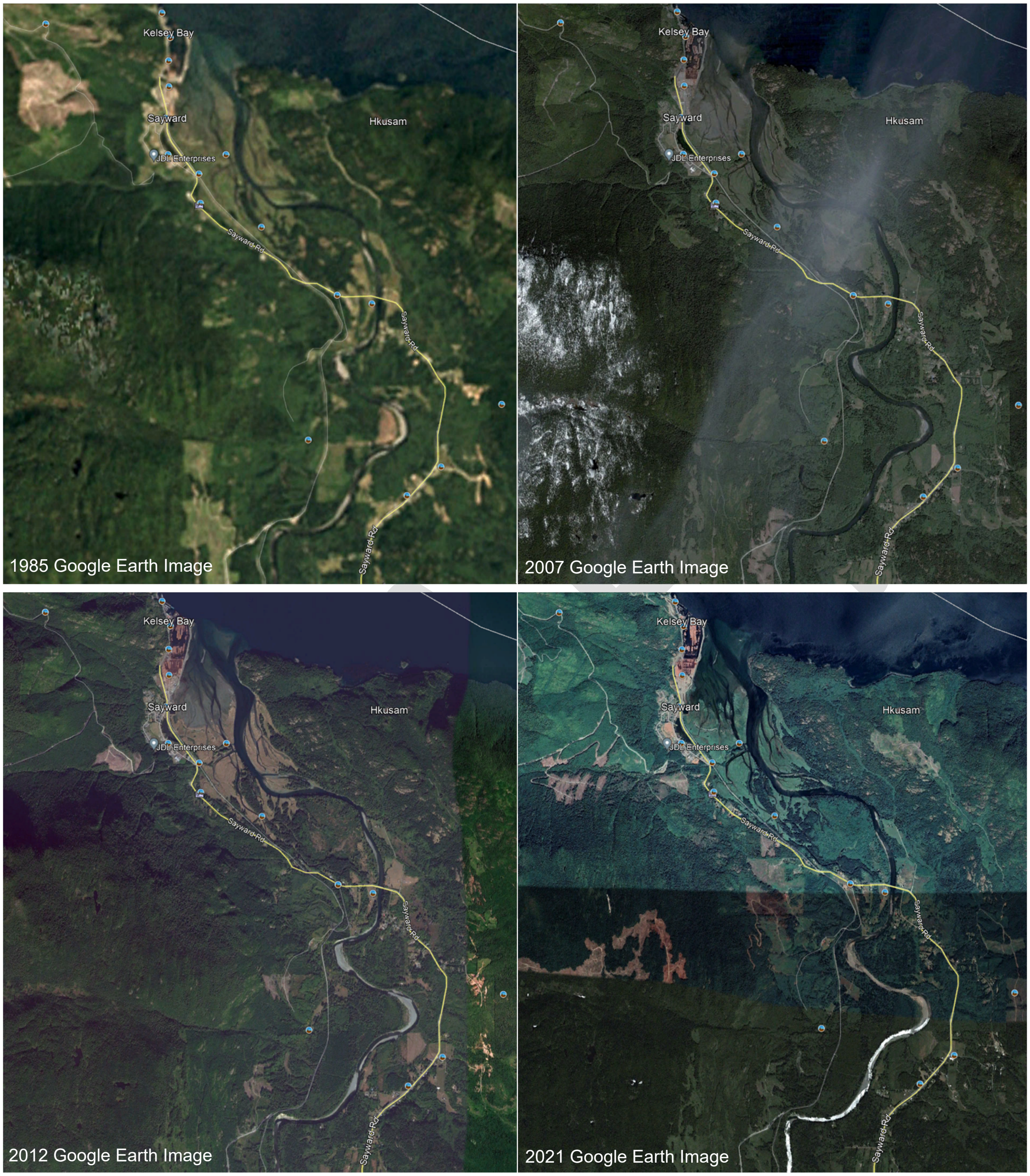

Figure 7: Sample Aerial Images from 1985 - 2021

The Salmon and White Rivers are healthy, natural river channels that appear to have no human engineered influences in regard to trained channels or erosion prevention measures. The exception being the various bridge abutments and piers along both rivers. Both rivers continue to behave and evolve as they have for thousands of years.

The White River is a predominantly well confined river channel with the exception of its end near the confluence with the Salmon River. This confinement is typical, given the steep and rocky mountain terrain within which this river flows. There is very little sediment deposition within the White River with most of the transported sediment being deposited into the Salmon River.

The Salmon River and the lower end of the White River are meandering and braided channels within the flood plain which is confined by the mountain slopes of the Sayward Valley. The most active reach in the study area is that upstream of the Highway 19 bridge. In this region the river channel meanders in a braided fashion across the valley floor over very long periods of time. Then channel's flow through predominantly highly erodible granular earth forms braided rivulets at low flow periods. Braids tend to morph more quickly over geological time, while the mainstream (the thalweg) tends to meander within broader embankments, over longer periods. This phenomenon is evident within the period of aerial photos as the main thalweg of the river remains relatively confined within the main channel banks, while gravel bars migrate within that zone over the same period.

Meander cut-offs are evident but much less frequently occurring and generally within the valley between bedrock forms from adjacent confining mountains.

The relatively unconfined channels will progressively erode the outer bend of riverbanks and deposit sediments on the inner bends downstream forming gravel and sand bars. Over time, deposition along these bends has the potential to build up become cut off from the main channel forming oxbow lakes. **Figure 8** shows examples on the Salmon River of a relatively recent oxbow which has formed just downstream of the Big Tree crossing.

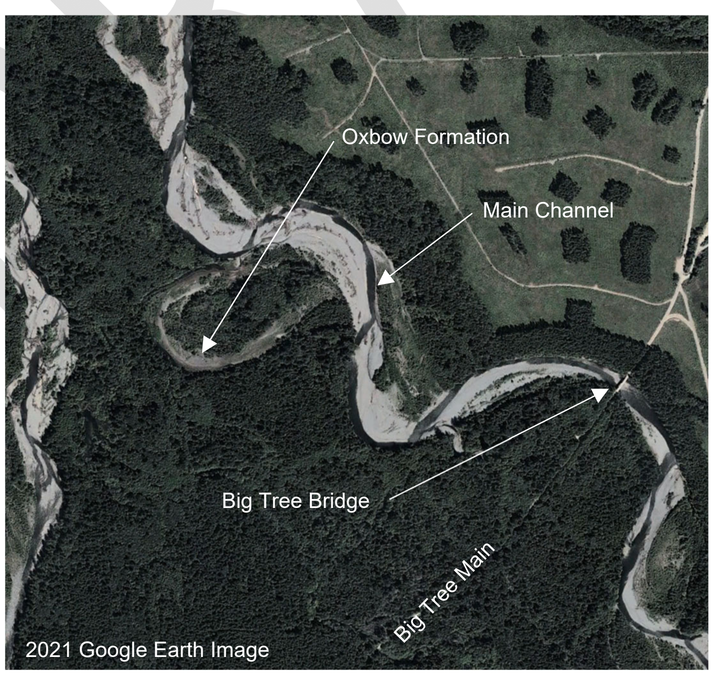

Figure 8: Oxbow Formation Downstream if Big Tree Bridge

Figure 9 shows a much older oxbow lake east of the Salmon River Main and C Brach junction which is now entirely cut-off from the main channel.

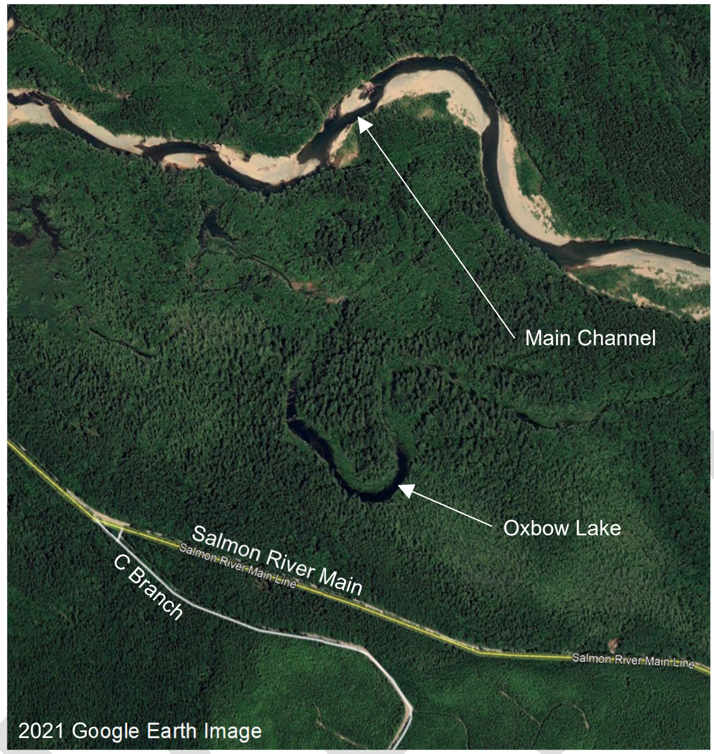

Figure 9: Oxbow Lake Near Salmon River Main and C Branch Intersection

South of the Highway 19 bridge, the river channel is less active in terms of erosion movement across the valley floor. Here the channel tends to have straighter runs with much larger bends and deposition bars (See **Figure 10**). This is typical given the channel is wide and deep and the slope in this area is more flat compared to the upper reaches.

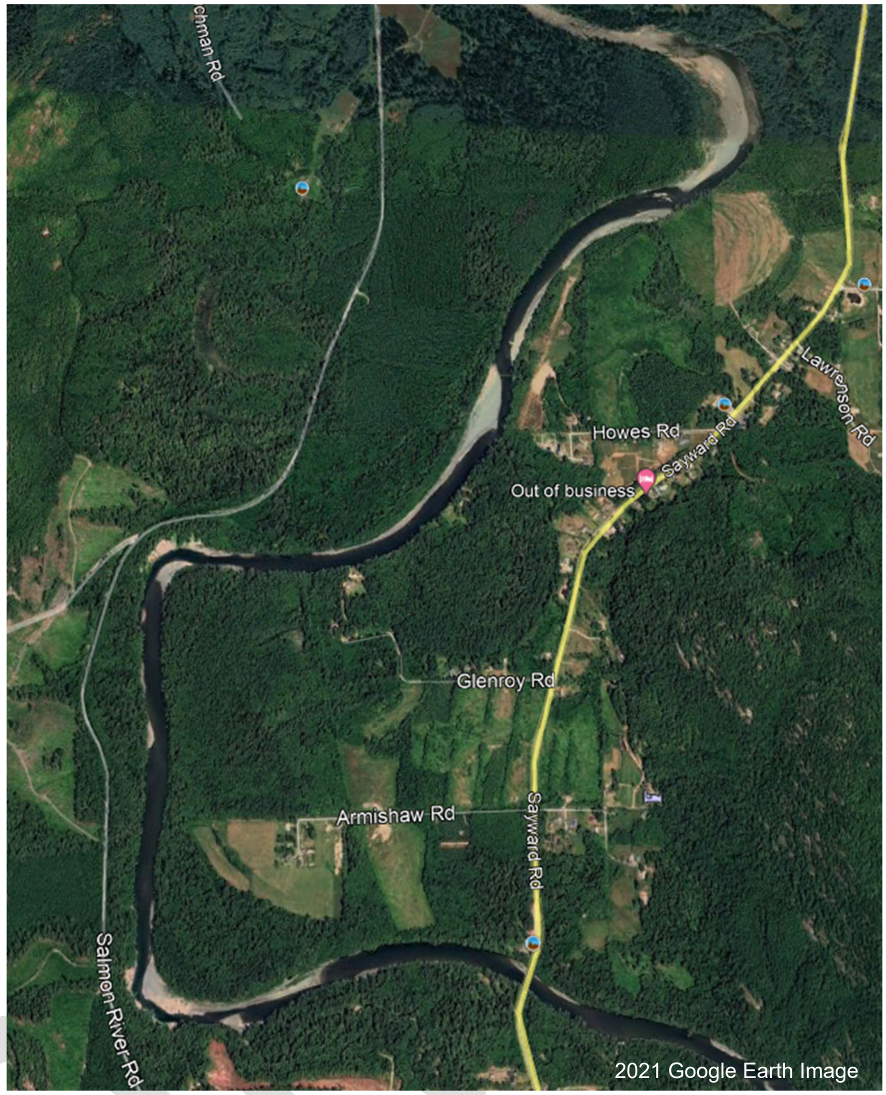

Figure 10: Salmon River Downstream of Highway 19 Bridge

At the mouth of the Salmon River and within the Village of Sayward, the river becomes a braided estuary. This region sees various side channels and small islands that have formed because of ongoing tidal backwatering, low gradient, and the significant deposition of material from upstream reaches of the White and Salmon Rivers (see **Figure 11**). This deltaic effect stretches across the entirety of the valley bottom on this region, typical of natural river mouths.

Figure 11: Braided Estuary at the Mouth of the Salmon River

The sediment transport and deposition within the Salmon River floodplain appears to be balanced given the time scale of the analysis, with no considerable signs of channel scour or aggradation. Gravel bars merely shift over the years. At the mouth of the Salmon River however, the sediment deposition appears to be significant but as expected given the natural sediment transport process of a drainage area of this size and location.

In discussion with the Village concerns were expressed that conservation areas withing the floodplain may be at risk of erosion along the riverbanks, and it was asked that this erosion potential be addressed in the study. As mentioned previously, the process of erosion and deposition is a natural phenomenon that is part of a healthy river system and part of a larger geological process that continues over vast periods of time. The potential bank erosion and sediment deposition that occurs within the floodplain conservation areas is expected and should be valued as the natural process of floodplain evolution over time.

4.6. DEBRIS LOAD AND IMPACTS

During the public consultation process, concerns over the impacts of significant debris loads moving down the river where raised. Residents and stakeholders pointed out that large trees and root wads are frequently transported downstream which cause hazards in terms of navigating the water way and causing blockages around bridge piers and abutments, exacerbating local flood conditions.

Detailed assessment and impacts of significant debris jams on potential large scale flood events is beyond the scope of this study. As the effects of debris jams can be significant during a large 1:200-year flood event, they are likely to affect more localized areas directly upstream of the jam location. The guidelines for flood inundation studies such as this generally consider a “freeboard” allowance of flood calculations to account for unknowns in the phenomena such as debris jams. In the case of British Columbia, the flood inundation levels are to be calculated as the more extreme condition (the higher level) calculated by adding 0.6m of freeboard to peak daily flows, or 0.3m of freeboard to levels calculated at the peak instantaneous rate.

Large debris jams likely pose more risk to damaging bridge structures rather than significantly increasing already high river levels. **Figure 12** below shows debris build up on newly constructed bridge piers during the 1990 flood event.

Figure 12: Debris Jam During 1990 Construction of the Sayward Road Bridge Near Sayward

Based on the concerns expressed during public consultation, the Village and the SRD may want to explore moving ahead with a debris load assessments and potential mitigation options such as maintenance plans and strategies as future funding streams become available.

5. The Hydrology of the Floodplain

5.1. PREVIOUS HYDROLOGIC ANALYSIS RESULTS

The 2019 frequency analysis for the Salmon and White Rivers was conducted to provided updated estimated peak flow rates due to the 2017 decommissioning of the Salmon River diversion dam. The results of the 2019 study were comparable to the results of previous studies, with estimates within 0.1 – 18.8% of those estimated in 1995. The Salmon River sees high flows due in part to the watershed experiencing large magnitude rainfall events coupled with runoff from high elevation snowpack. The reintroduction of previously diverted flows, though not insignificant, did not appear to have a substantial impact on the watershed in terms of peak flow rate estimates. Larger and additional available flow data sets resulted in an updated discharge-area relationship which led to different current peak flow predictions than those in 1995. However, the results were similar, as anticipated.

Table 2 below summarizes the results of the 2019 hydrologic analysis results with peak 20- and 200-year flow rates for various Salmon and White River catchments.

Table 2: 2019 Hydrologic Analysis Results

Catchment	Catchment Area (km^2)	2019 Peak Instantaneous Discharge (m^3/s)	
		20-Year	200-Year
White River at the confluence with Salmon River	367	644	877
Salmon River at the confluence with White River	849	1253	1662
Salmon River at the Mouth	1324	1783	2331

6. Simulating Flood Events in the Valley

6.1. HYDRAULIC MODEL DEVELOPMENT: HEC-RAS

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) is a hydrodynamic computer modeling software developed by the US Army Corps of Engineers for floodplain modeling. It is an integrated tool for river channel, floodplain, and coastal flood studies, and it is widely regarded as the industry standard in river flood modeling software. HEC-RAS is capable of simulating 2-dimensional unsteady flow through a full network of open channels, floodplains and alluvial fans. For this floodplain study, the most recent version of HEC-RAS (Version 6.0) was utilized. Version 6.0 allowed for the inclusion of bridge piers into the 3-dimensional terrain surface.

The HEC-RAS model for the Salmon and White River watersheds is a two-dimensional unsteady flow model in the floodplain and coastal areas. The model covers the following extents:

- Salmon River from tide water at the Kelsey Bay to 26 km upstream just above the Memekay River at the Big Tree Main Bridge Crossing.
- White River 2.1 km upstream from its confluence with the Salmon River.
- Elk River 2.0 km upstream from its confluence with the Salmon River.

The limits of the model are shown on **Figure 13** and are consistent with the limits of the 1995 study area. A 2-dimensional hydraulic mesh is generated and paired with the 3-dimensional terrain to complete the computations in the study area.

Figure 13: 2-Dimensional Mesh in Study Area

The physical geometry of the modeled area was represented by detailed bathymetric soundings and bridge pier and abutment topographic surveys completed in April 2021, combined with floodplain topography based in LiDAR data collected August 6, 2019.

6.2. COASTAL ANALYSIS

The coastal analysis was completed by Great Pacific. Their report dated Sept 21, 2021 is include with this report as Appendix D. The intent behind their coastal analyses is to provide a downstream boundary condition for the hydraulic modelling process. The coastal analysis included the following variables:

- Tides
- Storm Surge
- Climate Change (Sea Level Rise)

Wave effects are not included in the coastal analysis as they are deemed to be of low significance due to the large areas of flat, shallow water which limits large waves from reaching inland. Consideration for wave effects is needed in cases where flood construction levels are being calculated for coastal areas, or for coastal dike crest construction, or other similar engineering purpose of coastal structures. The sea level rise for this location in 2100 is projected to be 71 cm higher than the current 2021 levels.

For determining the peak water levels in the strait, consideration was given to the type of high tide and level of storm surge and the corresponding return period flow rate in the Salmon River. As a 1:200-year return period flow event and 1:200 return period surge event are highly unlikely, alternate downstream boundary conditions were analyzed. These alternatives include:

1. 1:20 storm surge with higher high-water level, large tide (HHWLT) for year 2021 – 3.5m
2. 1:200 storm surge with higher high-water level, mean tide (HHWMT) for year 2021 – 2.9m
3. 1:20 storm surge with HHWLT for year 2100 – 4.2m
4. 1:200 storm surge with HHWMT for year 2100 – 3.6m

Therefore, due to the probability of a 200-year return period storm surge and 200-year return period flow rate being unreasonably high, alternative 1, was utilized with the 200-year flow rate. It was deemed reasonable to expect at least one (1) HHWLT during the flooding scenario as these peak flood levels can extend many hours and during which time a high tide would occur. Since flooding in The Valley is primarily caused by heavy rainfall (rainfall in the winter season), and this is when HHWLTs (commonly referred to as "King" Tides) occur, the 200-year return period is combined with the HHWLT and subsequently the 20-year storm surge to determine the peak downstream water level. Its understood that this is a conservative approach to result in slightly elevated water levels. However, the 1980 study used 3.2m (3.8 – 0.6m freeboard), which is inline with the current value of 3.5m.

Estimates for the 2021 and 2100 Coastal Flood Construction Levels (CFCL) were based on the HHWLT and the 1:200 return period storm surge estimated by GreatPacific. **Table 3** below summarizes and sums the CFCL components for the current 2021 and future 2100 conditions.

Table 3: 2100 Flood Construction Levels Estimated for Kelsey Bay

CFCL*** Component	2021	2100
HHWLT (m-GSC)*	2.4m	2.4m
1:200 -Year Storm Surge	1.3m	1.3m
Sea Level Rise	/	0.7m
Freeboard	0.6m	0.6m
CFLC* (m-GSC)***	**4.3m**	**5.0m**

*m-GSC equals metres above geodetic datum
**HHWLT = Higher High Water Large Tide
***CFCL = Coastal Flood Construction Level

6.3. MODEL CALIBRATION AND VERIFICATION

The hydraulic model was calibrated by comparing model results to known field measurements using Water Survey of Canada (WSC) historic real-time gauge flow and surface water data. A particularly large flood event from January 2016 was simulated using the measured flow rates and the resultant stages were compared to those measured by the WSC. A flow hydrograph was developed and scaled to match the measured peak flow during the measured event. The hydrograph was used to run a simulated event and then the various Manning's roughness coefficients were adjusted within the model regions until the model's stage results matched those of the real-time WSC stage data at the gauge location. The measured and developed hydrographs and measured and model resultant stages are shown in **Figure 14**.

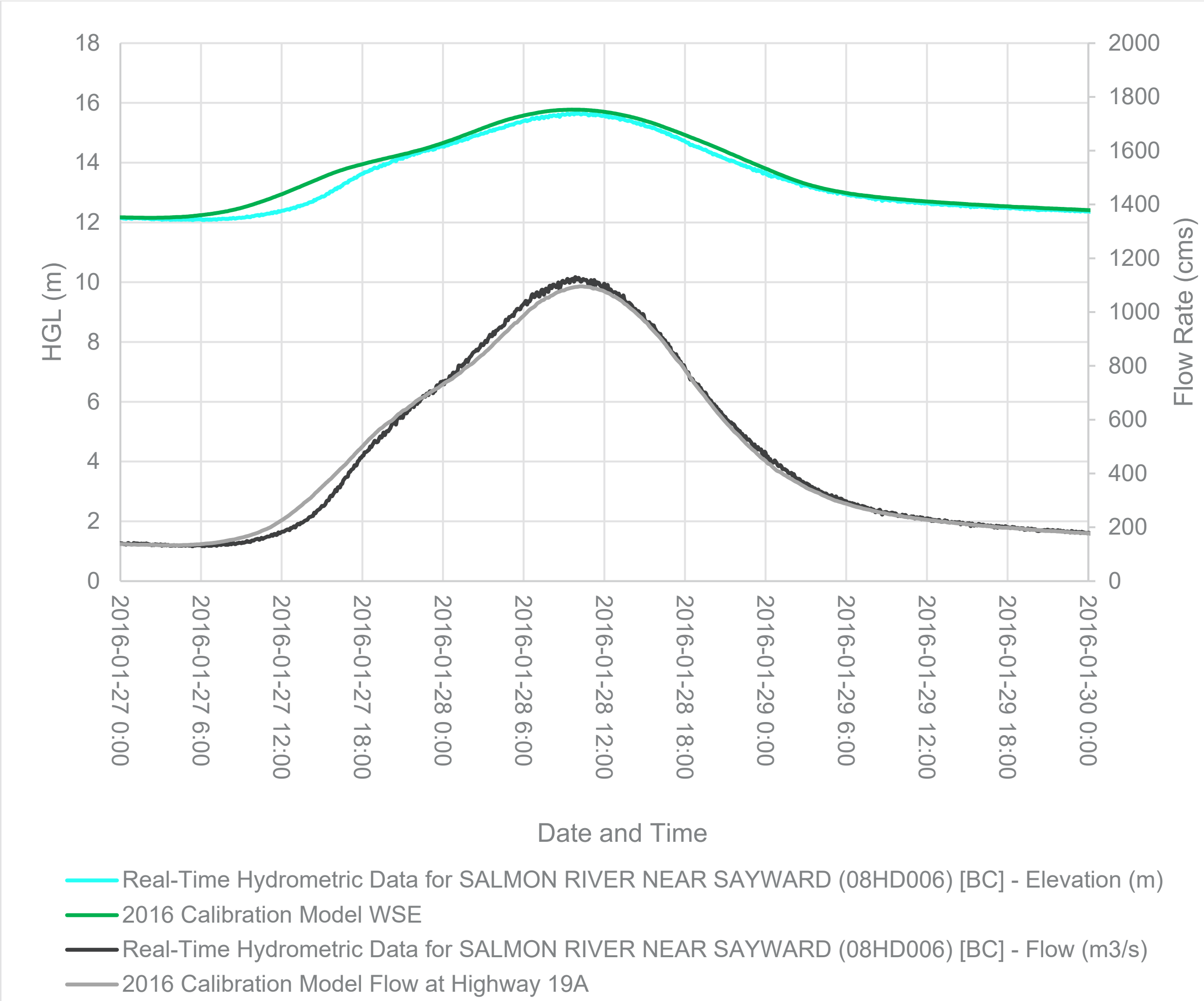

Figure 14: 2016 Calibration Results vs. the Real-Time Hydrometric Data for 08HD006

Lastly, extents of the flood inundation for the January 2016 event were recorded by local accounts and mapped as a record. This anecdotal record of flood extents was compared to the model inundation results and verified that the simulation was producing reasonably accurate predictions of inundation extents. **Figure 15** shows the approximate extent of flooding for the 2016 event on the left compared to the model inundation extents on the right.

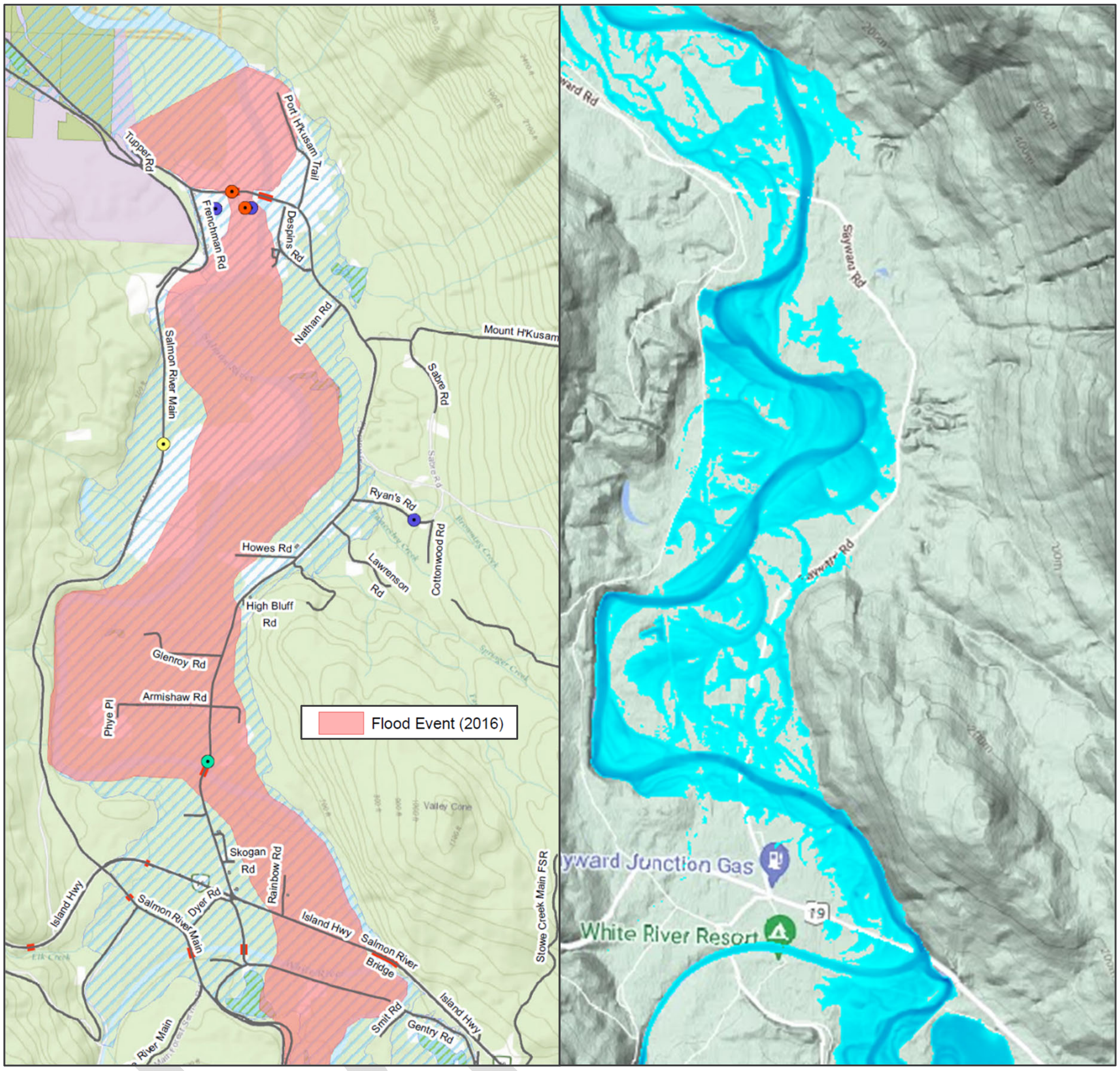

Figure 15: Comparison of January 2016 Flood Extents by Local Accounts (left) and Flood Model Simulation (right)

6.4. 200-YEAR RETURN PERIOD DESIGN FLOOD ANALYSIS

Flooding in the Sayward Valley is primarily driven by high river flows. Not surprisingly, flooding in the upper part of the study area is mainly controlled by peak flows. Flooding in the lower section of the study area is driven by high tide levels. Flooding in the middle sections of the study area are a result of the combined effects of high flows and high tides. To develop a design flood event model with the expected return 200-year period for the entire study area, both the design river flows, and tide data were used.

The peak downstream water level at Kelsey Bay for the 200-year river flood events was assumed to be the combination of select period storm surge and high tide events. The 200-year return period tide and river flows, under current climate and sea level conditions, were modeled to determine the floodplain mapping levels of the Salmon and White Rivers.

Flooding at both rivers is comparable to the previous results in comparison to both extent and depth. Areas that were previously at risk of flooding, primarily within the rural properties are still at risk at similar flood depths and duration. The sections below provide more detail of the results in terms of flood extents, depths and velocities that lead to an assessment of flood risks and hazards related to the Salmon and White Rivers. This result is not surprising, given the similarities in predicted design flood peak discharges.

The 2100 200-year flood analysis showed slightly higher flood elevations across the floodplain due to the increase in the flow rate in the rivers. This change in flood elevations however did not in turn significantly impact the inundation area as the current 200-year flood scenario does already encompass the floodplain area.

6.5. HAZARD MAPPING

The EGBC Guidelines on Flood Mapping in BC define Flood Hazard Maps as "Maps that go beyond inundation maps by providing information on the hazards associated with defined flood events, such as water depth, velocity and duration of flooding and Flood Risk Maps as "Maps that reflect the potential damages that could occur as a result of a range of flood probabilities, by identifying populations, buildings, infrastructure, residences and the environment, cultural and other assets that could be damaged or destroyed.".

The mapping produced as part of this report used previous risk mapping GIS data and flood modeling data for the 200-year flood event.

6.5.1. Flood Hazard Maps

The EGBC Guidelines on Flood Mapping in BC outlines a formulaic method of hazard rating developed by the UK Department of Environment[18]. The hazard ratings are a function of the flood depth and flood velocity applied in the following formula:

$$HR = d \times (v + 0.5) + DF$$

Where: HR = Flood hazard rating, see **Table 4** below.

d = depth of flooding, in m

v = Velocity of floodwaters, in m/s

DF = Debris Factor, either 0, 0.5, or 1 depending on the probability that debris will lead to a significantly greater hazard.

Table 4: Hazard to People Classification

Hazard Rating	Hazard to People Explanation
< 0.75	Low - Very Low Hazard (caution)
0.75 – 1.25	Moderate - Danger for Some (includes children, the elderly, and the infirm)
1.25 – 2.00	Significant - Danger for Most (includes the general public)
> 2.00	Danger for All (includes emergency services)

[18] HR Wallingford, Flood Risks to People – Phase 2 FD2321/TR2 – Guidance Document, UK Department of the Environment, 2006

Once determined, hazard ratings are illustrated as a color gradient within flood inundation extents. These hazard rating gradients, coupled with the plan locations of assets and infrastructure (schools, hospitals, wastewater plants, etc.), make it easier to visually identifying and quantify risks to the community at large. The complete Hazard & Risk Maps for the study area are attached herewith in the full-scale Map section at the end of this report. The flood hazard maps are attached in Appendix B.

6.6. FLOOD INUNDATION MAPPING

The Flood Inundation Map, found in Appendix B at the end of this report, illustrates the difference in in flood profile elevations with similar isolines to that of the flood map produced for the 1980 flood study. It also identifies the current 2021 and 2100 200-year flood extents within the study area.

The area of potential flooding throughout the Valley is extensive, as evident on the Flood Map. As there are no dedicated flood mitigation measures currently in place (i.e. Dikes/Floodwalls). Some residents of the Valley have adapted to the flooding situation along the Salmon River by raising the living space of their homes above flood levels, among other initiatives. There has been little in the way of a community-based flood improvement project as the main Village is primarily above flood levels, and the low density of housing in the valley does not justify large scale protection projects such as diking. Community members expressed a need for improved road access and egress during a flood, and flood mitigation measures for The Valley are focussed on this request. Suggested flood mitigation options are outlined later in Section 7 of this report.

The Village does not get inundation from Salmon River flooding, but there is well documented history of flooding within the village from the local drainage network, which is being studied and addressed by others.

6.7. COMPARISON TO PREVIOUS FLOOD MAPPING

Model results show generally higher flood levels overall in the Salmon River and lower flood level in the White River. As the downstream boundary condition of the 2021 model area (tide level) is also similar to that used in the previous studies, flood levels near the Kelsey Bay estuary are also similar to the reported levels in previous studies.

Table 5 provides a summary of peak 200-year return period flood levels compared to those of the 1995 study levels at key locations along the rivers. These are based on existing conditions in the floodplain and do not include potential impacts of future flood protection works or future development in the floodplain.

Table 5: Estimated Peak Design Water Levels Comparison Between 2021 and 1995 Studies

Location	2021 200-Year Flood Level (m-GSC) *	1995 200-Year Flood Level (m-GSC) *
Salmon River		
@ Big Tree Main Bridge	61.2	61.7
Near South End of Sacht Road	19.4	20.3
@ Highway 19 Bridge	17.9	18.2
@ Sayward Road Bridge Near Highway 19 Junction	14.0	13.7
@ Howes Road	9.2	9.9
@ Sayward Road Bridge near Townsite	6.1	5.6
Salmon River at Kelsey Bay	3.5	3.5
White River		
Salmon River Main Bridge	21.9	22.6
Sayward Road Bridge	19.9	20.5

*m-GSC equals metres above geodetic datum
Note: The downstream boundary condition or Peak high tide level (3.95m) is set to match the peak runoff rate in the river

6.8. CLIMATE CHANGE IMPACT ANALYSIS

Global temperature records indicate a warming trend over the Earth's surface since the beginning of the 20th century, with more rapid acceleration of warming in recent decades. Over the past century, global average surface temperature increased by approximately 0.6°C. Coincident with the temperature increase, climate change impacts related to sea levels and precipitation are accepted to be occurring.

For this study, the modelling of the year 2100 scenario assumes that 10% increase in precipitation (discussed in Section 4.4) will result in 10% higher predicted river discharges. This estimation is conservatively high but deemed reasonable since it is likely that, during the most extreme events, the antecedent conditions in the watersheds will be at full saturation of soils, resulting in a direct increase in runoff.

As outlined in Section 4.4 and in GreatPacific's, predicted Sea Level Rise will be about 1.0m by 2100, with a net gain of 0.71m of Johnson Straight inlet water levels due to the median regional uplift adjust of 0.28m.

Coupling Sea Level Rise with estimated increases in precipitation of 10%, the HEC-RAS model was rerun to simulate future climate change scenarios for the 1:200-year flood for the year 2100. The Plan2Adapt range of projected winter precipitation for the Strathcona Region (which covers the Sayward Valley) is shown **Figure 16** below.

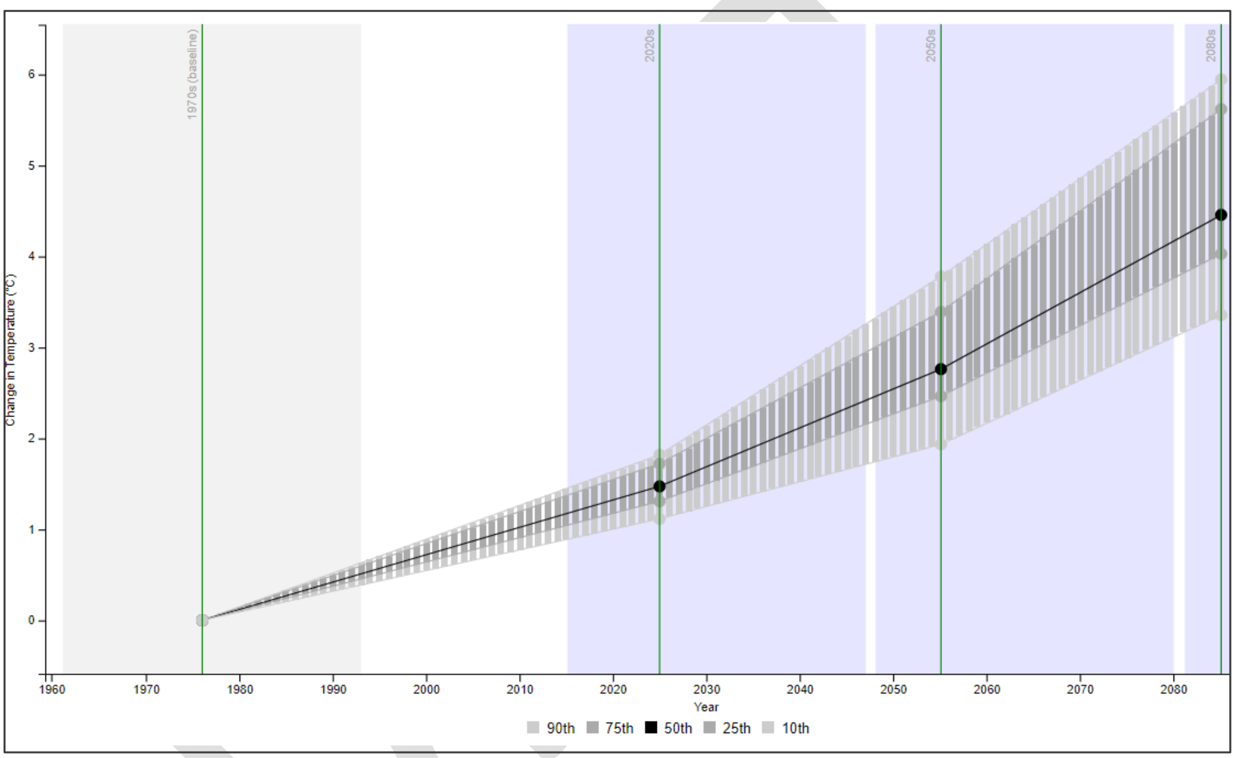

Figure 16: Plan2Adapt Strathcona Winter Precipitation Projections Graph

Accounting for climate change impacts in 2100, modelling results show little differences when comparing flood levels between the 2021 and 2100 200-year events. The most notable differences in flood water elevations are seen at the mouth of the Salmon River, which implies that SLR has a great impact on flooding than predictions of increased precipitation. Comparisons of various points along the Salmon and White Rivers are highlighted in **Table 6** below.

Table 6: Future Planning Flood Levels Due to SLR and Climate Change (Not Including Freeboard)

Location	200-Year Return Period Flood Level (m-GSC)*	2100 Climate Planning Flood Level (m-GSC)*
Salmon River		
@ Big Tree Main Bridge	63.9	64.0
Near South End of Sacht Road	19.4	19.7
@ Highway 19 Bridge	17.9	18.1
@ Sayward Road Bridge Near Highway 19 Junction	13.8	14.0
@ Howes Road	9.2	9.9
@ Sayward Road Bridge near Townsite	6.0	6.4
Salmon River at Kelsey Bay	3.5	4.2
White River		
Salmon River Main Bridge	21.8	22.1
Sayward Road Bridge	19.9	20.0

*m-GSC equals metres above geodetic datum

7. FLOOD MITIGATION ALTERNATIVES

The various options for flood mitigation were developed after thorough analysis of the flood and hazard maps. Based on the feedback from ongoing public consultation, the following options were developed with the needs of access and egress being the primary driver, as was expressed as the key concern of most residents in the Village and the Valley. Most people living in the valley are well aware of the flood risks and have adapted to these in risks in someway over the years. But when the valley floods and the roads get inundated, the public expresses greater concern about emergency egress to higher, safer ground while the flood passes. Given the sporadic and fairly sparse density of housing in the floodplain, neighbourhood or individual flood protection schemes were not considered, as these would only benefit a few private citizens rather then the public of the Valley as a whole. Emphasis is placed on protection measures for the greatest public benefit.

It needs to be emphasized that the options do not each afford the same level of flood protection or access. Ultimately, a combination of the outlined options may be considered and implemented based on the overall priorities of the Village and Regional District and the feasibility of such options with regard to budgeting.

7.1. ELEVATE ROADS AND REBUILD THE HAMOND BRIDGE

The following flood mitigation options are intended to ensure access and egress is maintained along major routes within the valley during a predicted 200-year flood event:

A. Raise a 1.44km section of the Highway 19 approximately 0.8m west of the Salmon River Bridge.

B. Raise a 1.60km section of the Salmon River Main approximately 1.0m south of Frenchman Road

C. Rebuild or raise the existing Hammond bridge and rase a 324m section of Salmon River Road approximately 2.4m between the bridge and Frenchman Road

D. Raise a 2.81km section of the Salmon River Road approximately 2.1m between 535 Salmon River Road and the bailey bridge

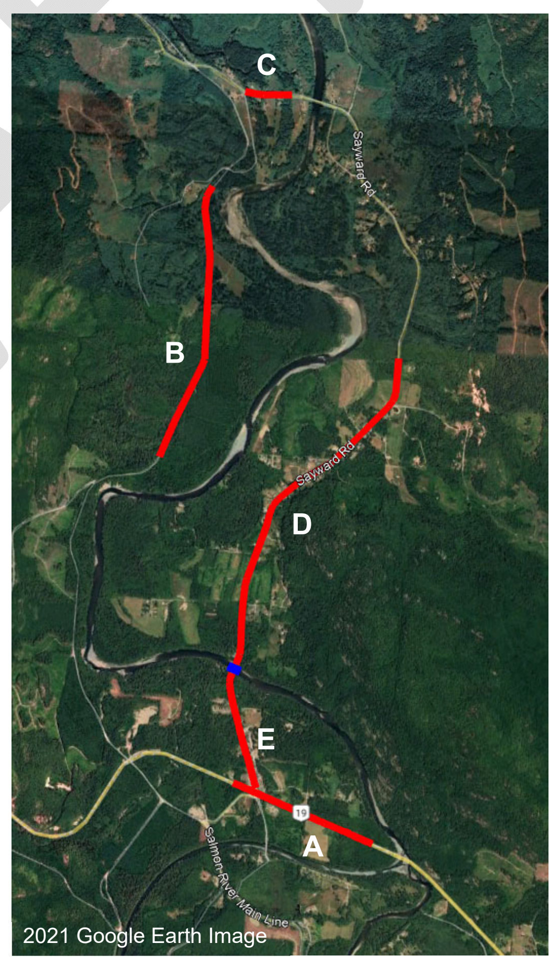

Figure 17: Proposed Road and Bridge Flood Improvement Options

E. Raise a 942m section of the Salmon River Road approximately 2.3m between the bailey bridge and Highway 19.

It should be noted that the above options are based on a high-level analysis and more detailed design is required to determine more accurate design extents and potential impacts of diverting flow within the flood plain. As elevated road corridors would act as a network of dikes, the flood elevations, inundation limits, and velocity/depth profiles would be altered if constructed. As such, additional internal drainage improvements such as increasing existing culvert sizes or bridge clearances or adding relief culverts may be necessary.

7.2. MANAGED RETREAT THROUGH ZONING AND OCP UPDATES

As discussed in Section 3.4.3, managed retreat may be an effective means of floodplain risk mitigation. Despite the value of land and assets, political sensitivities and social costs, financial limitations may make managed retreat a feasible option when other mitigation measures, such as dikes and flood walls, are not economically sustainable. The Village's Official Community Plan (OCP) can adopt a managed retreat strategy to guide land use and policy decisions within the floodplain. Hazardous areas identified on the flood and hazard maps can be outlined in the OCP as areas with restricted uses. This may result in parcels of land, both undeveloped and developed, being ineligible for new or reconstructed buildings. As such, the lands could be rezoned for lower risk use, like agriculture or seasonal uses where periodic flooding will not cause a significant amount of damage to property or the environment. Land may also be purchased by the Village and SRD and repurposed into park or nature lands. The implementation of managed retreat ultimately requires transparency by the Village through community engagement.

The Village and SRD should not be intimidated by the prospect of implementing a managed retreat policy, as there is time due to the slow increase of expected Sea Level Rise. It is recommended for the Village to pursue additional funding for further study and assessment of the planning and policy definition for initiatives like managed retreat. The study should as a minimum investigate:

- Current infrastructure condition and timing for redevelopment or needed property improvement in the floodplain area.
- Areas for relocation or development that can support the required relocation.
- Costs for development or improvement of lands to support relocation and potential sources for government assistance, such as local tax incentives or other mechanisms to support a policy for Managed Retreat.
- Re-zoning requirements.
- The mechanism for property transfer of floodplain properties to the Village, as may be required or desired.
- Timing and policy development to support Managed Retreat and its implementation.

The idea of Managed Retreat can be complicated, and further assessment requires that a more detailed planning study be completed to see if the transfer of the land from residential use to other uses makes sense and is achievable.

8. COSTS AND BENEFITS

8.1. ESTIMATED COSTS FOR CONSTRUCTION

The Class C capital cost estimates for the suggested options have been prepared at a conceptual level for this study without the benefit of detailed engineering. Where possible historical pricing in the region for similar roadway/civil earth structure construction has been used. The estimated construction cost estimates provided in this section include a 40% contingency, a 15% allowance for engineering, tendering, and construction supervision. All estimated prices exclude taxes. A breakdown of estimates for the three options is provided in Appendix C and summarized below in **Table 7**.

The intent of this study is to provide high-level analysis that is indicative of the Class D construction cost estimates below. These estimates are intended as aids for planning and funding purposes.

Table 7: Summary of Estimate Construction Costs

Mitigation Option	Construction*	Soft Costs**	Total
Option A – Raise Highway 19 West of Salmon River Bridge	$2,166,000	$232,000	$2,398,000
Option B – Raise Salmon River Main	$983,000	$105,000	$1,088,000
Option C – Raise Salmon River Rd Near Hammond Bridge	$736,000	$79,000	$815,000
Option D - Raise Salmon River Rd for 2.8km North of Bailey Bridge	$4,641,000	$497,000	$5,138,000
Option E – Raise Salmon River Rd for 942m North of Highway 19	$1,576,000	$169,000	$1,745,000
TOTAL	**$10,102,000**	**$1,082,000**	**$11,184,000**

* Construction includes a 40% Contingency

** Costs include engineering, environmental approvals, administration, and financing

8.2. ESTIMATED COSTS FOR FURTHER HYDRAULIC ANALYSIS

To move towards detailed design and construction of flood improvement measures, additional hydraulic analysis and assessment is needed to examine the impacts of such work on the floodplain itself and determine if additional improvement measures will be necessary.

As the effects of ongoing debris torrents are a concern for those residing in and around Sayward, further hydraulic study is needed to determine the impacts of debris jams on localized flooding.

8.3. BENEFITS

Monetary benefits to providing safe access and egress to Sayward Village and Valley Residents during a flood are not easily calculated, because they are not based on assets that are protected, but rather the safety and security of a community as a whole. On this basis, a cost-benefit analysis has not been conducted, but rather the cost of improving access should be measured against the potential for life saving access to citizens that may need emergency services during a flood disaster.

9. RECOMMENDATIONS

9.1. FLOOD MITIGATION

In the short-term, the Village and SRD should pursue a detailed hydraulic design study intended to identify the impacts of all proposed road improvements within the floodplain and to determine any additional internal drainage structure improvements or additions that may be required. This assessment would lead to a higher level of degree of certainty for the work and associated budgets to seek further funding opportunities.

Such a study should be followed up with detailed designs and construction of the recommended road improvements noted previously. The following order of flood access improvements options are listed in order of importance:

Option A – Raise Highway 19 West of Salmon River Bridge

As uninterrupted access along Highway 19A is vital to the Village of Sayward and the Sayward Valley including to all communities on the North Island, its recommend that improvements to this section of the highway be the highest importance.

Option B – Raise Salmon River Main

This route and requires the least amount of upgrade in order to provide the village and some in the valley safe access and egress to the highway which makes this option the next logical upgrade of importance.

Option C – Raise Salmon River Rd Near Hammond Bridge

Improving this section of Salomon River Road next ensures egress for those residents living along the approximate 3km stretch between Ryans Road and Frenchman Road

Option D - Raise Salmon River Rd for 2.8km North of Bailey Bridge

Raising this 2.8km section will provide egress for residents living on salmon river Road and closer access to those living on roads adjacent to it.

Option E – Raise Salmon River Rd for 942m North of Highway 19

This section is recommended last as most residents along this stretch are relatively close to the intersection with Highway 19.

The Village should begin to incorporate Sea Level Rise and climate change into its long-range flood mitigation strategy. This long-term planning should focus on methods and strategies (including bylaw and OCP changes) to return the floodplain to a more natural state, employing land use policies that are more tolerant of infrequent flooding (parks, agriculture and/or environmental reserves). More study in this regard is required, looking at the planning horizon for needed re-development in the floodplain in conjunction with potential development areas outside of the floodplain and costs, policies and implementation strategies to achieve a balance of the socio-economic values and viability of the Village of Sayward and the Sayward Valley.

9.2. DEBRIS IMPACTS AND MAINTENANCE

It is also recommended that the impacts of debris jams be assessed in greater detail through further study to address public concerns with localized flooding and damage to infrastructure. Such study results should be incorporated into emergency planning and routine maintenance programs. It's suggested that this be coordinated and developed with the appropriate provincial agencies responsible or the roads and bridges in the study area, namely MoTI and MFLNRORD.

9.3. BYLAW AND POLICY REVISIONS

Section 3.1 of this report introduces existing municipal tools to manage flood risk and related land use regulations/guidelines. New floodplain level information contained herein, including climate change risks, could lead to refinements to those municipal tools.

Official Community Plan

The Village is currently updating their OCP where fundamental decisions will need to be specific to areas withing the Salmon River floodplain, where flooding and Sea Level Rise are a risk. It is within these areas where new consideration of flood mitigation strategies will be warranted as the OCP is updated. Options to be considered include:

- Accepting flood risk and focusing on evacuation plans for rare events.
- Reviewing land use types to allow commercial (low risk to life) rather than residential uses (higher risk to life) on properties with higher flooding risk.
- Localized filling and diking to protect flood risk sites.
- Flood proofing of proposed buildings only, with parking/driveways allowed to flood occasionally
- Flood proofing by raising key roads, bridges, and emergency routes in the local areas where it is at risk.
- Public sector or non-government organization purchase of lands at risk for public use (parks, recreation, agriculture or environment).

The above options are best discussed in the context of broader land use, emergency preparedness and policy plans, where the multi-variant aspects of these decisions can be weighed in a thorough public process.

Three points are very important in addressing these climate change concerns:

1. Sea Level Rise will be very slow (averaging 1 cm per year), and therefore it is not urgent to move higher – there is time to adapt, to the extent that in most cases adaptation could be allowed to occur at the end of life of a building (at the time of redevelopment).
2. However, it is important to recognize the need to establish Sea Level Rise Planning Areas that include the areas potentially at flood risk both in the present day and in the Year 2100. Within these Sea Level Rise Planning Areas, land use decisions should include an acceptable strategy to either avoid flood risk impacts or adapt proposed land uses to the evolving risk at reasonable benefit to cost ratios.
3. It is very important that land use decisions be made with a full awareness of the evolving flood risk, so that there are adequate mechanisms in place to balance life and safety, environmental, economic and public/private investment responsibility. Applications for land use change in the

floodplain should provide a clear flood mitigation strategy prior to being formally considered by Council. Any additional Flood Risk Assessment carried out as part of land development applications should follow the EGBC Legislated Flood Assessment Guidelines where appropriate.

The flood risk information in this report provides scientific and societal values information to allow land use decisions to be made without passing large flood mitigation costs onto future generations in the Village and Regional District.

Floodplain Bylaw

In the short-term Flood Constructions Levels, as per the current Sayward and SRD floodplain bylaws, should be updated in accordance with the latest inundation maps produced at the time of this study. Coastal Flood Construction Levels identified in this study and reported on the flood inundation maps should be amended into existing Floodplain Bylaws or presented in any future coastal flooding bylaws if proposed.

Also, any new proposed construction within the floodplain should be assessed using the hydraulic model, prepared as part of this study, to ensure that the proposed development does not have any significant effects on neighbouring properties. Impacts due to the magnitude of the 1:200-year return period flood are likely to occur on neighboring properties, especially if the proposed development is of substantial size.

9.4. PUBLIC OUTREACH AND EDUCATION

Ongoing public outreach is advised to help landowners and the community understand the evolving flood risk, related to Sea Level Rise and to increases in river flow due to heavier rainfall, both of which result from climate change. This knowledge will allow the public and landowners to be prepared for emergency evacuation, if necessary, given the sudden onset of floodwaters predicted. This emergency preparedness education should include:

- Accessing flood and storm forecasting from reputable sources, such as the BC River Forecast Centre's Flood Warning and Advisories web page (http://bcrfc.env.gov.bc.ca/warnings).
- Developing household plans for emergency evacuation, including options for dwellings given the potential of long-term flood impacts to housing.
- Having emergency kits ready in case of short notice evacuation. Kits should be stocked with supplies including shelf stable food, water, medication, first aid kits, pet supplies, extra batteries and charging devices for phones and other critical equipment.
- Keeping important documents in waterproof containers.
- Obtaining satellite emergency communication devices such as satellite phones or handheld GPS devices available from manufacturers such as Garmin and SPOT.
- Keeping an emergency checklist that is easily accessible and includes last minute reminders for turning off building utilities.

To help landowners and community members better plan land use and development with knowledge of the risk and how to mitigate the impacts, key themes of public education should include:

- Major areas of the floodplain should continue to flood in large events (>20 – 200 year) – these areas could transition to agriculture, recreation and environmental uses.

- New structures would need to be designed to suit gradually rising flood levels (rising by Year 2100 and beyond) or be built in areas not at risk of flooding.
- Current BC policy is that new or replaced buildings would need to meet Flood Construction Levels for habitable floors.
- Non-habitable areas, if not raised to flood proof levels, buildings could be constructed of flood resistant materials.
- Storage of chemicals, fertilizers, fuels, and other deleterious substances should be stored in elevated and/or flood proof storge containers to ensure release into the downstream environment is avoided.
- Where not raised, local roads and parking would be flooded during design storm events as an accepted risk.

10. IMPLEMENTATION

Public entity adaptation to climate change in British Columbia is still developing as society grasps Climate Change and its effect on our lives. However, it is time to become aware and to prepare. It is especially important that the Village and SRD not make uninformed land use decisions that would result in flood risks and consequences worse than existing conditions, given the growing knowledge of Sea Level Rise. Four general actions are recommended below.

10.1. UPDATED OFFICIAL COMMUNITY PLAN TO REFLECT AREAS OF HIGH RISK

The Village is currently updating its Official Community Plan, which will provide opportunity to include the Flood mitigation recommendations into revised Official Community Plan policies and development permit guidelines for natural hazard areas.

10.2. INTEGRATION OF LAND USE CLIMATE ADAPTATION INTO ON-GOING PLANNING REVIEWS

During the Village's review of their Official Community Plan, it is recommended that evolving flood risks be carefully considered in any revisions. It is recognized that many objectives are balanced in these planning initiatives, but it is strongly encouraged that a clear strategy for adapting to the evolving flood risk is incorporated into policy and financial planning programs over time.

10.3. MONITORING AND ADAPTIVE MANAGEMENT

This study is another step toward local government adaptation to Sea Level Rise and climate-change flood risk analysis and planning. We expect much greater certainty and understanding of risks and, perhaps, adaptation strategies will become evident as our society undertakes further research.

The scale of the Sea Level Rise and climate change impacts around the world will mean that society in general, all levels of government and the private sector will need to refine programs and undertake adaptive strategies. Given this gradually evolving challenge, it is appropriate to begin planning now to minimize local consequences, risks and costs.

At the same time, it would be prudent not to react too quickly to issues of Sea Level Rise, but rather to monitor the evolving government programs and overall body of scientific understanding on the issue, setting the stage for focused adaptations. There remains time to discuss and refine a long-term strategy prior to major investments being made by Sayward and the SRD. In the meantime, immediate attention should focus on beginning flood improvement and protection works to maintain safe access to residents living in and around the Salmon River floodplain.

Appendix A - Statement of Limitations

Statement of Limitations

Use of this Report. This report was prepared by McElhanney Ltd. ("**McElhanney**") for the particular site, design objective, development and purpose (the "**Project**") described in this report and for the exclusive use of the client identified in this report (the "**Client**"). The data, interpretations and recommendations pertain to the Project and are not applicable to any other project or site location and this report may not be reproduced, used or relied upon, in whole or in part, by a party other than the Client, without the prior written consent of McElhanney. The Client may provide copies of this report to its affiliates, contractors, subcontractors and regulatory authorities for use in relation to and in connection with the Project provided that any reliance, unauthorized use, and/or decisions made based on the information contained within this report are at the sole risk of such parties. McElhanney will not be responsible for the use of this report on projects other than the Project, where this report or the contents hereof have been modified without McElhanney's consent, to the extent that the content is in the nature of an opinion, and if the report is preliminary or draft. This is a technical report and is not a legal representation or interpretation of laws, rules, regulations, or policies of governmental agencies.

Standard of Care and Disclaimer of Warranties. This report was prepared with the degree of care, skill, and diligence as would reasonably be expected from a qualified member of the same profession, providing a similar report for similar projects, and under similar circumstances, and in accordance with generally accepted engineering and scientific judgments, principles and practices. McElhanney expressly disclaims any and all warranties in connection with this report.

Information from Client and Third Parties. McElhanney has relied in good faith on information provided by the Client and third parties noted in this report and has assumed such information to be accurate, complete, reliable, non-fringing, and fit for the intended purpose without independent verification. McElhanney accepts no responsibility for any deficiency, misstatements or inaccuracy contained in this report as a result of omissions or errors in information provided by third parties or for omissions, misstatements or fraudulent acts of persons interviewed.

Effect of Changes. All evaluations and conclusions stated in this report are based on facts, observations, site-specific details, legislation and regulations as they existed at the time of the data collection and report preparation. Some conditions are subject to change over time and the Client recognizes that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site may substantially alter such evaluations and conclusions. Construction activities can significantly alter soil, rock and other geologic conditions on the site. McElhanney should be requested to re-evaluate the conclusions of this report and to provide amendments as required prior to any reliance upon the information presented herein upon any of the following events: a) any changes (or possible changes) as to the site, purpose, or development plans upon which this report was based, b) any changes to applicable laws subsequent to the issuance of the report, c) new information is discovered in the future during site excavations, construction, building demolition or other activities, or d) additional subsurface assessments or testing conducted by others.

Independent Judgments. McElhanney will not be responsible for the independent conclusions, interpretations, interpolations and/or decisions of the Client, or others, who may come into possession of this report, or any part thereof. This restriction of liability includes decisions made to purchase, finance or sell land or with respect to public offerings for the sale of securities.

Construction Cost Estimates. This construction cost estimate has been prepared using the design and technical information currently available. Furthermore, McElhanney cannot predict the competitive environment, weather or other unforeseen conditions that will prevail at the time that contractors will prepare their bids. The cost estimate is therefore subject to factors over which McElhanney has no control, and McElhanney does not guarantee or warranty the accuracy of such estimate.

Appendix B – Flood and Hazard Maps

Appendix C – Cost Estimate

McElhanney

Date: 2021-09-22
McElhanney Project No.: 2221-49378

Sayward & SRD - Flood Mitigation Options
Class D Construction Cost Estimate

	Quantity	Unit	Unit Cost	Cost
Option A - Raise Highway 19				
Asphalt, Granular Base (150mm), and Removals	1440	LM	$ 500	$ 720,000
Subbase	9454	CM	$ 55	$ 519,970
Driveway Restoration	1	EA	7500	$ 7,500
Intersection	1	EA	$ 50,000	$ 50,000
Flood Relief Structure Allowance	1	LS	$ 250,000	$ 250,000
			Subtotal	**$ 1,547,000**
Option B - Raise Salmon River Main South of Frenchman Road				
Road Capping	1599	LM	$ 165	$ 263,835
Subbase	7971	CM	$ 55	$ 438,405
			Subtotal	**$ 702,000**
Option C - Raise Salmon River Road Between Frenchman Road and Hammond Bridge				
Asphalt, Granular Base (150mm), and Removals	324	LM	$ 500	$ 162,000
Subbase	4701	CM	$ 55	$ 258,555
Driveway Restoration	6	EA	$ 7,500	$ 45,000
Flood Relief Structure Allowance	1	LS	$ 50,000	$ 50,000
			Subtotal	**$ 526,000**
Option D - Raise Salmon River Road Between 535 and Bailey Bridge				
Asphalt, Granular Base (150mm), and Removals	2813	LM	$ 500	$ 1,406,500
Subbase	27658	CM	$ 55	$ 1,521,190
Driveway Restoration	33	EA	$ 7,500	$ 247,500
Intersections	6	EA	$ 15,000	$ 90,000
Flood Relief Structure Allowance	1	LS	$ 50,000	$ 50,000
			Subtotal	**$ 3,315,000**
Opting E - Raise Salmon River Road Between Highway 19 and Bailey Bridge				
Asphalt, Granular Base (150mm), and Removals	942	LM	$ 500	$ 471,000
Subbase	9431	CM	$ 55	$ 518,705
Driveway Restoration	10	EA	7500	$ 75,000
Flood Relief Structure Allowance	1	LS	$ 50,000	$ 50,000
			Subtotal	**$ 1,126,000**

Sub-total	**$ 7,216,000**
Contingency (40%)	**$ 2,886,000**
Engineering and Construction Inspection (15%)	**$ 1,082,000**
Construction Cost	**$ 11,184,000**

Appendix D – Coastal Analysis

Appendix E – Public Engagement

Appendix F – 2019 Frequency Analysis

Appendix G – 2019 Flood Risk Assesment

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CANADA BEST MANAGED COMPANIES