Data Preparation for Future Modelling of Gravel Extraction Impacts on Salmon Habitat and Flood Risks, and Evaluate Mitigation Strategies

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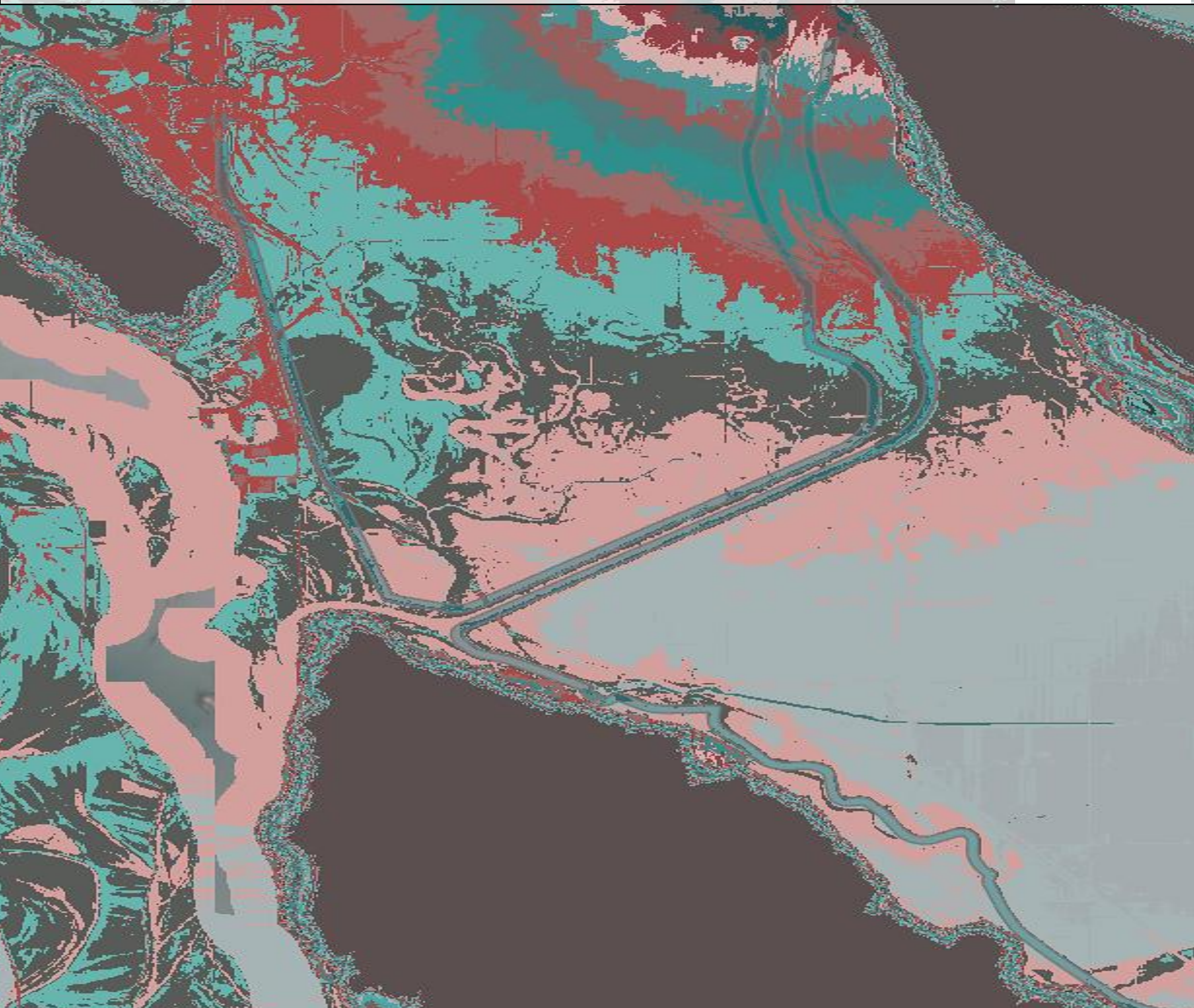
WATERSHED WATCH SALMON SOCIETY



Disclaimer

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Contents

List of Figures and Tables

Executive Summary

This report presents the preparation, assessment, and integration of multiple datasets to support future flood modelling and impact assessments in salmon-bearing river systems affected by gravel extraction. This report presents the second phase of research into the Chilliwack/Vedder River system, with a focus on assessing the impact of gravel extraction on salmon habitat and flood risks. It outlines the approach taken to gather and process key data sets necessary for future scenario modelling, evaluates alternative flood mitigation options, and offers recommendations. Data sources include LiDAR-derived Digital Elevation Models (DEMs), satellite-based flood extent mapping, climate model–driven streamflow simulations, and hydrometric station records from the Water Survey of Canada (WSC). Particular attention has been given to the November–December 2021 flood event, for which flood extent data were compiled for 23 individual days, combined into a composite map, and cross-checked against other open-source global flood mapping algorithms. This work provides a foundational database and roadmap for integrated flood and habitat management in the Chilliwack/Vedder River. It offers a path forward that balances ecological integrity with community safety.

In addition to data preparation, this report explores a range of potential flood mitigation strategies relevant to gravel extraction sites and salmon habitats, including:

- **Engineered structures** such as setback dikes and dikes rising to both reduce flood risk and improve fish habitat.
- **Sediment removal** from the gravel bars to improve flow capacity within the river channel.
- **Floodplain reconnection** to improve storage capacity and reduce peak flows.

For **future modelling scenarios**, the datasets assembled here will be used to:

1. **Simulate baseline flood dynamics** under current climate and land-use conditions.
2. **Assess climate change impacts** on flood magnitude, frequency, and duration under RCP4.5 and RCP8.5 scenarios.
3. **Evaluate the effectiveness of proposed mitigation strategies** under both historical and projected future conditions.

The outputs from this data compilation and assessment phase will significantly enhance the accuracy of future flood hazard and habitat impact models. They will also inform decision-makers and stakeholders in designing effective, climate-resilient flood risk reduction and habitat conservation measures.

Abbreviations

CMIP6 – Coupled Model Intercomparison Project Phase 6

DEM – Digital Elevation Model

GIS – Geographic Information System

LiDAR – Light Detection and Ranging

NRCan – Natural Resources Canada

WSC – Water Survey of Canada

PCIC – Pacific Climate Impacts Consortium

VIC-GL – Variable Infiltration Capacity – Glacier Model

Introduction

In-river gravel mining—also referred to as in-stream or channel mining—involves the extraction of gravel directly from the beds and banks of rivers or streams. While gravel is a valuable natural resource used extensively in construction and infrastructure projects such as roads, its removal from active watercourses can have significant environmental consequences. In some cases, gravel removal has also been considered as a potential flood mitigation measure by increasing channel capacity.

The Chilliwack/Vedder River, located between Abbotsford and Chilliwack, is a notable source of high-quality gravel originating from the Chilliwack River Valley. The Chilliwack/Vedder River is a dynamic waterway critical to both human settlement and salmon habitat. The Chilliwack River flows into the Vedder River, which then passes through the Vedder Canal before joining the Fraser River in a section often referred to as the "Heart of the Fraser." This area is predominantly composed of gravel and is one of the most productive salmon habitats in the region. Notably, during "odd years," millions of pink salmon return to spawn in the mainstem, side channels, and tributaries of the Fraser River, including the Chilliwack/Vedder River system—further underscoring the ecological importance of maintaining the integrity of these habitats.

Historically altered to support colonial land development and local infrastructure, the river continues to face significant ecological pressures. Gravel extraction has long been used as a method of flood control, but its ecological costs—particularly to salmon habitat—demand a re-evaluation of strategies. This river system is ecologically significant, serving as critical habitat for multiple salmon species, including chinook, coho, chum, and pink salmon. However, gravel extraction within the river can degrade spawning habitat, increase egg mortality, alter natural flow patterns, elevate turbidity, change water temperatures, and fragment habitats. These combined effects can be particularly detrimental to pink salmon populations, making it more difficult for them to survive, reproduce, and sustain healthy numbers.

The Chilliwack/Vedder River is not only a source of high-quality gravel for construction but also a highly valued area for recreational fishing, agriculture (as a source of irrigation water), and other community uses. Economically, socially, and ecologically, the river system supports a wide range of important needs. Gravel mining within this system has long been a contentious issue. While some view gravel extraction as a flood mitigation tool, others raise concerns about its environmental impacts—particularly on salmon habitat. Watershed Watch, along with other partners in the Fraser Valley, has been working to promote flood resilience by exploring governance improvements, nature-based flood management approaches, and opportunities to reconnect waterways currently affected by aging flood infrastructure. In the Chilliwack/Vedder specifically, gravel extraction continues to be promoted as a flood solution (VERMAC, 2025), but with highly mixed reviews regarding its effectiveness and environmental consequences (FBC, 2019; Bhattacharyya, 2024).

The potential impacts of gravel mining extend beyond the immediate river channel. In the Fraser River and its tributaries, such activities can influence sedimentation patterns, turbidity, fish habitat quality, channel morphology, bird habitats, and navigation safety. They can also increase the need for downstream dredging in the Fraser Estuary, a region of high ecological importance. These impacts are often cumulative. Making clear and informed decisions on what is best for the ecosystem and neighbouring communities is critical.

Project Goals and Scope

During Phase 1 of the project, we examined the ecological effects of in-river gravel mining on salmon and their habitat. This included the identification of nature-based flood mitigation alternatives for the Chilliwack/Vedder River. The findings informed more sustainable approaches to flood risk management that can safeguard both communities and salmon populations.

Phase 2 of the project aims to build a comprehensive database to support hydrological and habitat modelling. It focuses on collecting and organizing key data needed to simulate scenarios that balance flood mitigation with salmon habitat preservation. The work builds upon Phase 1 findings and integrates feedback from the 2024 UBC Scholar to inform future research directions.

The purpose of this project is to assess the impacts of gravel extraction on salmon habitat and flood risks in the Chilliwack/Vedder River system and to evaluate a range of flood mitigation strategies. This work builds on the 2024 UBC Sustainability Scholar's research, expanding into a more detailed, data-driven approach that will support hydrodynamic modelling under current and future climate conditions. The long-term goal is to develop robust scenario analyses that inform sustainable, habitat-friendly flood management solutions for the region.

Scope of Work:

1. **Data Compilation and Assessment** – Identify, collect, and quality-check all datasets required to support hydrodynamic and habitat modelling. This includes (but is not limited to):
    - Historical and real-time flow records (daily and hourly) from Water Survey of Canada.
    - Downscaled global climate model outputs and future climate projections (CMIP6).
    - LiDAR-derived Digital Elevation Models (DEMs) for floodplain topography.
    - Historical and recent flood extent maps, including satellite-derived SAR products.
2. **Scenario Planning and Modelling Preparation** – Organize the collected datasets into a modelling-ready format, enabling the creation of multiple scenarios. Scenarios may include:
    - Different gravel extraction rates and locations based on previous sediment removals
    - Climate change-driven flow and sediment transport conditions
    - Flood mitigation scenarios (e.g., dike setbacks, sediment management, connecting wetlands and purpose)

Methodology

We conducted an exhaustive review of data needs, including flow records, digital elevation data, past channel bathymetric surveys, and historical gravel extraction from available reports. Climate change projections relevant to the Lower Mainland were included to support modelling based on future climate change-induced impacts on flood levels.

Data Inventory and Knowledge Base

Compiled data includes LiDAR-derived digital elevation models, historical and projected streamflow, past sediment removals, and project climate scenarios.

LiDAR-Derived Digital Elevation Models (DEMs) provide highly accurate, high-resolution representations of the Earth's surface by using laser pulses to measure distances between the sensor and ground features. For flood modelling, LiDAR DEMs are invaluable because they capture fine-scale variations in terrain, such as levees, dikes, channels, and floodplain features, which significantly influence water movement during flood events. The precision of LiDAR data allows hydraulic and hydrodynamic models to more accurately simulate overland flow, identify flood-prone areas, estimate inundation depths, and evaluate the performance of mitigation measures. This detailed topographic information is essential for creating reliable baseline models, calibrating simulations, and improving flood risk assessments under both current and future climate scenarios.

Here we used LiDAR from two different sources (i) BC LiDAR Program and (ii) Washington LiDAR Portal. The British Columbia LiDAR Program provides publicly available, high-resolution elevation data covering significant portions of the province. Both of these LiDAR have a horizontal resolution of 1m. These datasets are an essential resource for hydrologic and flood modelling, geomorphic studies, and habitat mapping. South of the border, the Washington LiDAR Portal offers similar high-quality LiDAR coverage for Washington State. This cross-border availability of LiDAR data is particularly valuable in the Chilliwack/Vedder watershed context, as its floodplains are connected with the Suman River and Former Sumas Lake, where hydrologic and geomorphic processes operate across jurisdictional boundaries. Combining these two separate LiDAR datasets, a high-resolution (1m) DEM is generated that was further used for high-precision terrain modelling and building scenarios.

Streamflow Data

Long-term daily streamflow records from the Water Survey of Canada (WSC) are available for the study area, with temporal coverage at some stations extending back to 1911 (Table 1). In addition, hourly discharge data are available for these stations for a shorter period (post-2010). These higher-temporal-resolution datasets are particularly important for hydrodynamic modelling, as they allow accurate specification of time-varying boundary conditions during extreme flow events, such as the November 2021 flood.

Daily flow data are valuable for characterizing baseline hydrological conditions, identifying long-term trends, and calibrating flow–frequency relationships (Figure 1). Meanwhile, hourly data enable the capture of rapid changes in discharge and stage, which is essential for simulating peak flow dynamics, flood wave propagation, and channel–floodplain interactions in 1D or 2D hydraulic models. Both datasets have been accessed, quality-checked, and stored for integration into subsequent hydrodynamic simulations aimed at reproducing past flood events and evaluating future scenarios.

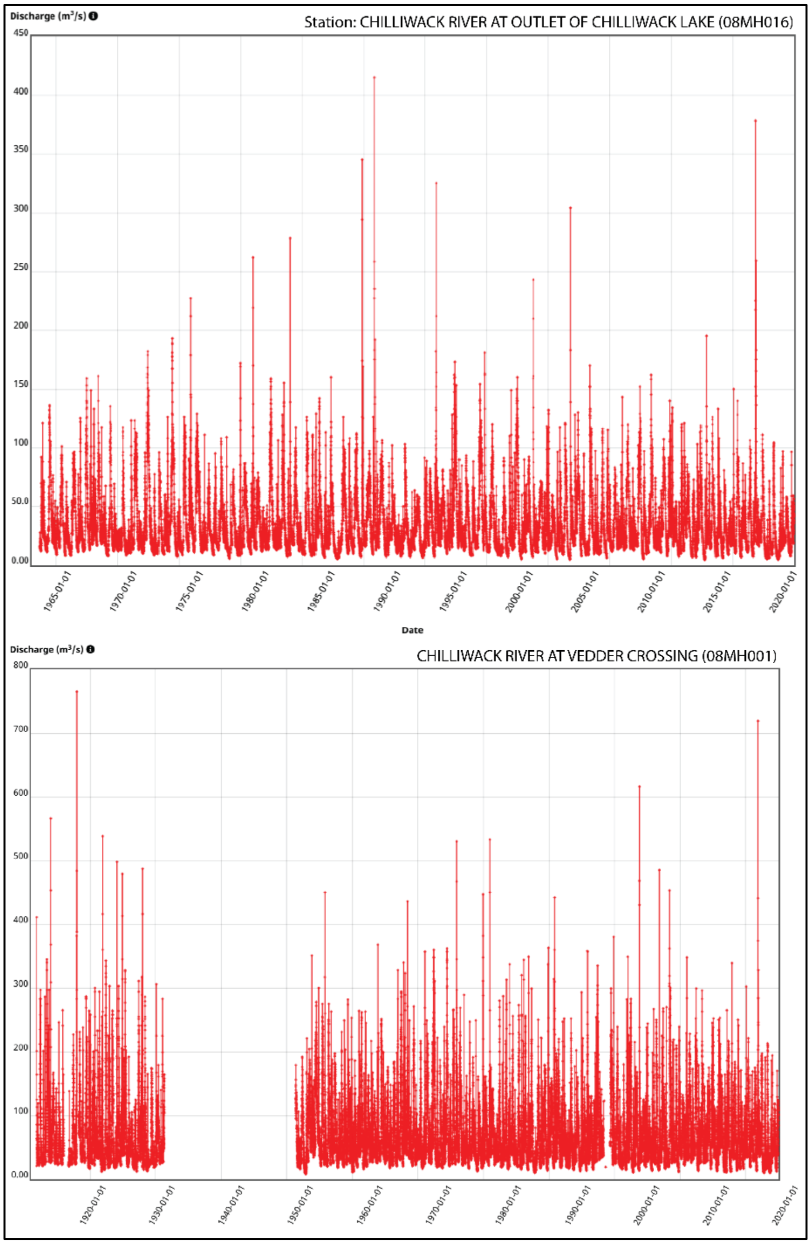

Figure 1 Daily discharge for two gauging stations at Chilliwack/Vedder River (last accessed on 15th July 2025).

Simulated streamflow data for projected climate scenario using CMIP5 is available from the Pacific Climate Impacts Consortium (PCIC). The dataset includes both observation-based simulations (1945–2012) and projections (1945–2099) generated using six statistically downscaled CMIP5 global climate models under moderate (RCP4.5) and high (RCP8.5) emission scenarios (Appendix A). Streamflow simulations were produced using the Variable Infiltration Capacity – Glacier Model (VIC-GL) coupled with the RVIC routing model, representing naturalized flow conditions where regulation exists. Data are available at daily resolution in cubic metres per second and can support hydrologic model calibration, climate change impact assessment, and flood risk analysis by enabling historical-to-future streamflow comparisons.

Table 1 List of gauging stations and data availability for discharge (flow) and water surface elevation (level) in the Chilliwack Vedder river basin (source Environment and Natural Resources Canada).

Station Name	Years	Province	Station Number	Data Availability	Latitude	Longitude	Gross Drainage Area (km^2)
CHILLIWACK RIVER ABOVE SLESSE CREEK	1963-2024	BC	08MH103	Flow and Level	49°06'06" N	121°39'46" W	650
CHILLIWACK RIVER AT OUTLET OF CHILLIWACK LAKE	1923-2024	BC	08MH016	Flow and Level	49°05'01" N	121°27'30" W	335
CHILLIWACK RIVER AT VEDDER CROSSING	1911-2024	BC	08MH001	Flow and Level	49°05'50" N	121°58'02" W	1230
SUMAS RIVER NEAR HUNTINGDON	1935-2023	BC	08MH029	Flow and Level	49°00'08" N	122°13'56" W	144
SLESSE CREEK NEAR VEDDER CROSSING	1957-2024	BC	08MH056	Flow and Level	49°04'18" N	121°41'59" W	160

Flood Mapping Data Availability

During major flood events in Canada, the Emergency Geomatics Service (EGS) is responsible for rapidly producing and sharing maps that illustrate the extent of flooding (Olthof and Rainville, 2020). Their mapping approach is designed for speed and reliability, enabling the timely release of flood information. At present, the primary data source for these maps is synthetic aperture radar (SAR) imagery acquired from RADARSAT-2 (Olthof and Rainville, 2020). Flood mapping data are available for 23 separate days between November 16, 2021 and December 13, 2021. Each daily dataset represents an individual flood extent map. These have been combined to produce a composite flood extent map for the period (Figure 2). It is important to note, however, that flood extent data are not available for several days within this timeframe. As a result, the composite map should be interpreted with this limitation in mind, as it may not capture short-term flood dynamics that occurred on missing dates.

The set of 23 individual daily flood extent maps also constitutes a valuable resource for calibrating and validating flood inundation models, allowing for more robust model performance assessment. Additionally, other open-source global flood mapping algorithms that utilize Synthetic Aperture Radar (SAR) imagery could be applied to generate supplementary flood extent snapshots for 2021, helping to fill temporal gaps and improve overall representation of the event.

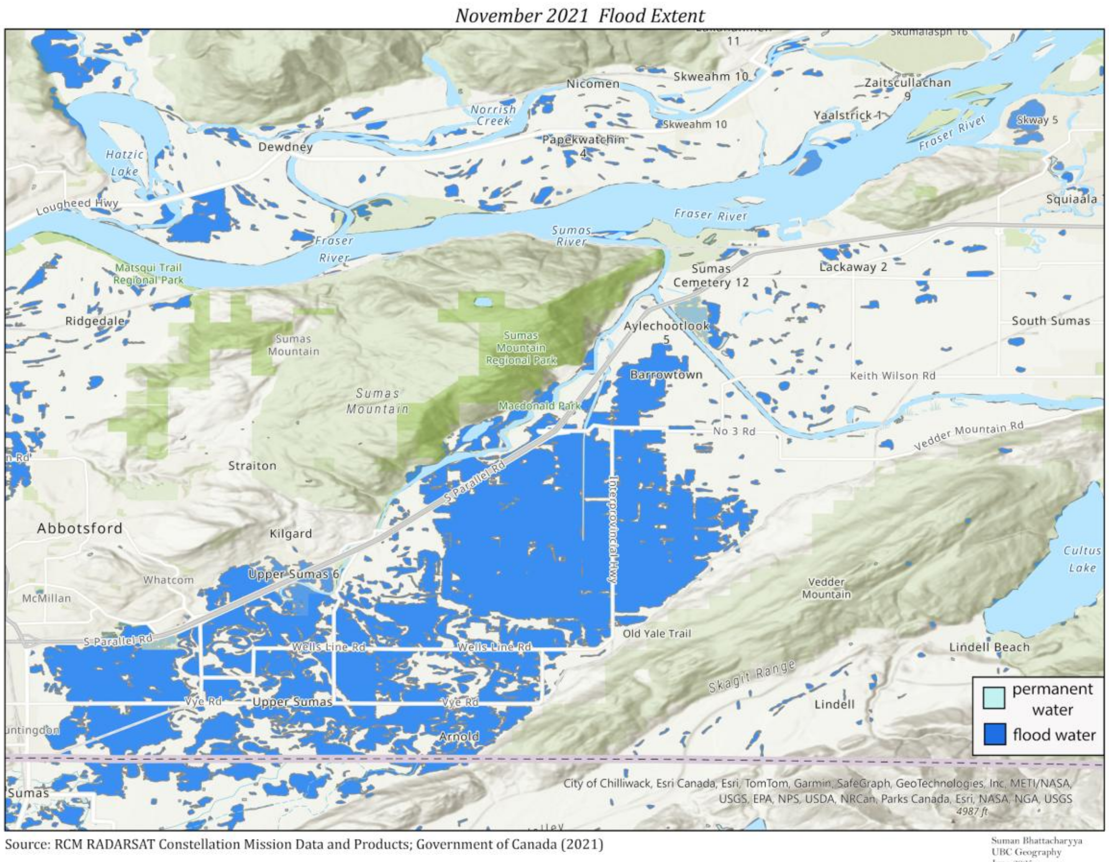

Figure 2 Flood map prepared by combining RCM RADARSAT satellite data during the November 2021 flood.

Projected climate scenarios

Climate models work at coarse scales, so their results need to be “downscaled” for local studies to provide more detailed, local information. Statistical downscaling uses real-world historical climate data to fine-tune climate model results so they better match observed conditions. This process ensures that the general patterns (averages, variability and extremes) are realistic for the past and then uses similar statistical model parameters to adjust projected climate variables. Here, bias-corrected climate data from ten CMIP6 climate models over BC are available from PCIC at a gridded resolution of approximately 10km (300 arc-seconds or 1/12°) for the simulated period of 1950-2100. For BC, recommended models are TaiESM1, NorESM2-LM, CNRM-ESM2-1, IPSL-CM6A-LR, MIROC-ES2L, MRI-ESM2-0, UKESM1-0-LL, EC-Earth3-Veg, MPI-ESM1-2-HR, and FGOALS-g3 (See Appendix B). These downscaled scenarios are generated using one univariate and another multivariate bias correction method: Bias Correction/Constructed Analogues with Quantile Mapping Reordering (BCCAQv2) and Multivariate Bias Correction, N-dimensional (MBCn) (Sobie et al., 2024). The MBCn method first adjusts each climate variable individually using Quantile Delta Mapping (QDM), then iteratively adjusts the dependence structure between variables. Adapted from an image processing algorithm, this process aligns the multivariate distribution of climate model data with that of the reference dataset. The result is downscaled historical simulations that closely match observed statistical properties and future projections that incorporate realistic changes in variable interdependence.

Scenario Planning and Modelling Potential

A range of potential flood mitigation strategies is generated for future modelling of flood scenarios to understand their capacity to reduce flood depth, extent, and associated risks in the Chilliwack area through hydrodynamic modelling. These scenarios provide a technical basis for assessing trade-offs, costs, and feasibility before implementation. Future work will include scenario-based modelling using indicators such as salmon spawning success, gravel bar migration, floodplain connectivity, and channel stability. Proposed scenarios include:

Dike Raising – Increasing the height of existing dikes to meet or exceed provincial flood protection standards. This reduces the likelihood of overtopping during extreme flow events. Here, the existing dikes are raised by 1m, 2m and 3m for flood modelling under climate change scenarios.

Dike Setbacks – Relocating dikes further inland to create additional floodplain storage and improve river conveyance. In areas where riverbanks are tightly confined by dikes, setback scenarios resulted in modest reductions in floodwater levels. In this study, dike setback scenarios were developed by considering existing land use and built-up areas along the Vedder and Sumas Rivers. For the Vedder River, both right and left bank dikes were set back up to 1 km (500 m on each side), with additional scenarios modelled at regular setback distances of 100 m, 200 m, 350 m, and 500 m from each bank (Figure 3). For the Sumas River, the maximum setback was established along North Parallel Road, adjacent to Highway 1(Table 2).

Table 2 Description of dike setback scenarios with distance from existing dikes and resulting available areas.

Dike Scenario	Set-back distance (m)	Floodplain area (m^2)
Right side dike setback on Vedder Canal	100	470335.4
	200	983613.6
	350	1692956.3
	500	2396403.8
	1000	4835167.7
Left side dike setback on Vedder Canal	100	429916.4
	200	834629.5
	350	1379045.7
	500	1872337.9
	1000	3303091.1
Sumas River	Variable - along Highway 1	3364469.0

Sediment Removal – Removing accumulated sediment or gravel from the tops of gravel bars to increase channel capacity, improving flow conveyance and potentially lowering flood stages in constricted reaches. The effectiveness depends on location, sediment transport rates, and environmental considerations. In a modelling study of the Fraser River (FBC, 2019), a significant amount of sediment (about 2 million cubic metres) was removed from gravel bars between the

Agassiz-Rosedale Bridge and the Harrison River, resulting in a 0.2 m reduction of local water levels, suggesting limited potential in reducing flood water levels. During high flows, the sediment removal sites could gain new sediments from upstream, therefore, not providing a permanent benefit in lowering floodwaters. In this analysis, we first review all past sediment removal reports and then develop hypothetical scenarios in which sediment is removed from each historical extraction site at twice the previously approved volumes. These scenarios are used to evaluate the potential effectiveness of increased sediment removal in reducing floodwater levels.

In addition to the other scenarios, the study will explore the potential for straegic flooding ofprivate lands, with particular consideration of using the former Sumas Lake area as temporary floodwater storage. This approach would also provide an opportunity to evaluate other nature-based flood adaptation measures, such as elevating buildings and infrastructure or implementing managed retreat strategies during extreme flood events.

Each mitigation option involves specific engineering, environmental, and regulatory considerations. Land use constraints, jurisdictional responsibilities, and First Nations' title and rights must be addressed in the planning and design phases. In Chilliwack's and Abbotsford's cases, effective flood risk reduction is likely to require a combination of these strategies, integrated with long-term monitoring and adaptive management to respond to changing climate and hydrologic conditions

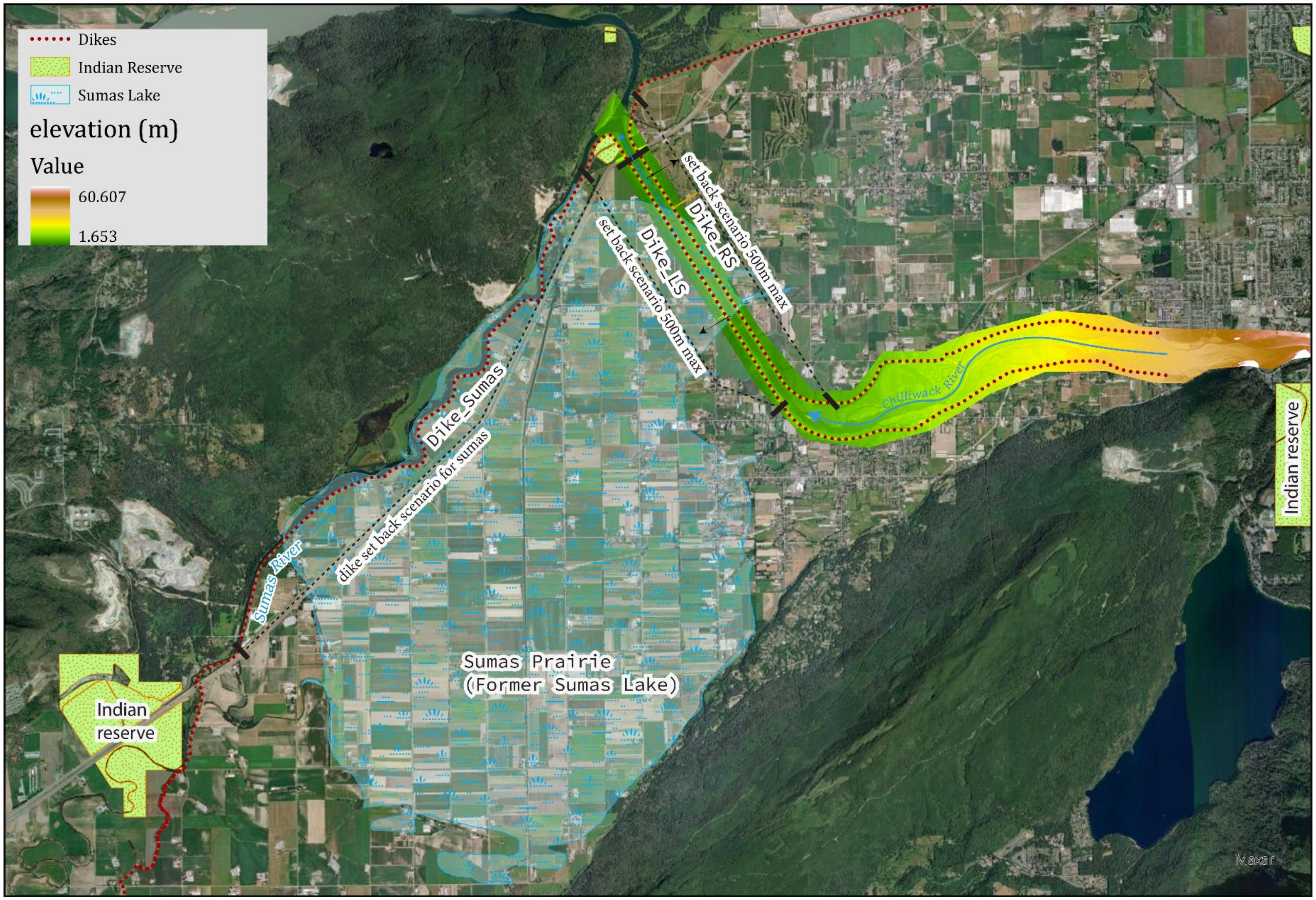

Figure 3 LiDAR-derived digital elevation model for the Chilliwack/Vedder River section along with existing dikes (red dots) in the study area. Hypothetical dike setback scenarios are in black dotted lines.

Recommendations and Next Steps

This work will continue to complete the modelling of these scenarios through Phase 3. Regarding the flood modelling, key next steps are:

Conversion of these datasets to model-specific formats as required by the hydrological and hydrodynamic models. Besides, depending on specific flood scenarios, there is a need to adjust the river bathymetric profiles. Long-term goals include exploring individual scenarios like setback dikes as well as combining multiple scenarios like dike rising and wetland reconnection to assess the joint potential of different mitigation scenarios.

Communication of flood modelling and mapping results is also necessary to raise awareness of flood hazards, levels of exposure, and potential mitigation options.

Incorporating salmon habitat metrics into flood modelling to understand ecological as well as hydrological outcomes.

Evaluation of trade-offs to assess costs, feasibility, and potential unintended impacts of each mitigation option, particularly where flood mitigation intersects with agricultural use and habitat conservation.

Considerations of climate change impacts, sediment dynamics, and long-term maintenance requirements when prioritizing mitigation investments.

In addition to the individual mitigation scenarios proposed in this study, future work could explore the combined effects of multiple strategies through integrated modelling. Assessing these combinations will provide a more realistic understanding of their cumulative benefits and potential trade-offs. The implementation of such combined approaches would require comprehensive planning and close coordination among multiple stakeholders across the floodplain, including local governments, First Nations, regulatory agencies, and community groups.

References

Bhattacharyya, S. (2024, August). *In-River Gravel Mining as a Flood Mitigation Tool: Impacts on Pacific Salmon and Alternative Solutions*. UBC Sustainability Scholars. https://sustain.ubc.ca/sites/default/files/2024-024_In_River_Gravel_Mining_Bhattaccharyya.pdf

Curry, C. L., Ouali, D., Sobie, S. R., & Zwiers, F. W. (2023). Downscaled CMIP6 climate model subset selection.

Fraser Basin Council. (2019, July). *Flood Modelling and Mapping in BC's Lower Mainland: A Project Primer* (Lower Mainland Flood Management Strategy). Vancouver, BC: Fraser Basin Council.

Olthof, I., & Rainville, T. (2020). Evaluating simulated RADARSAT constellation mission (RCM) compact polarimetry for open-water and flooded-vegetation wetland mapping. *Remote Sensing*, *12*(9), 1476. https://doi.org/10.3390/rs12091476

Pacific Climate Impacts Consortium, University of Victoria, (February 2020). VIC-GL BCCAQ CMIP5 RVIC: Station Hydrologic Model Output. Downloaded from https://data.pacificclimate.org/portal/hydro_stn_cmip5/map/ on 10 July 2025.

Pacific Climate Impacts Consortium, University of Victoria, (Dec. 2021). Statistically Downscaled Climate Scenarios. Downloaded from https://data.pacificclimate.org/portal/downscaled_cmip6/map/ on 10 July 2025: BCCAQv2.

Pacific Climate Impacts Consortium, University of Victoria, (July 2023). Statistically Downscaled Climate Scenarios. Downloaded from https://data.pacificclimate.org/portal/downscaled_cmip6/map/ on 10 July 2025: MBCn.

Sobie, S. R., Ouali, D., Curry, C. L., & Zwiers, F. W. (2024). Multivariate Canadian Downscaled Climate Scenarios for CMIP6 (CanDCS-M6). *Geoscience Data Journal*, *11*(4), 806-824. https://doi.org/10.1002/gdj3.257

Vedder River Management Area Committee (VRMAC). *Reports*. City of Chilliwack, n.d. Web. 14 Aug. 2025. https://vedderriver.chilliwack.com/reports/.

Appendices

Appendix A

Table projected streamflow based on CMIP5 models

Model Name	Realization	Scenario
ACCESS1-0	r1i1p1	RCP4.5
CanESM2	r1i1p1	RCP4.5
CCSM4	r2i1p1	RCP4.5
CNRM-CM5	r1i1p1	RCP4.5
HadGEM2-ES	r1i1p1	RCP4.5
MPI-ESM-LR	r3i1p1	RCP4.5
ACCESS1-0	r1i1p1	RCP8.5
CanESM2	r1i1p1	RCP8.5
CCSM4	r2i1p1	RCP8.5
CNRM-CM5	r1i1p1	RCP8.5
HadGEM2-ES	r1i1p1	RCP8.5
MPI-ESM-LR	r3i1p1	RCP8.5

ACCESS1-0 – Australian Community Climate and Earth System Simulator, version 1.0

CanESM2 – Second Generation Canadian Earth System Model

CCSM4 – Community Climate System Model, version 4

CNRM-CM5 – Centre National de Recherches Météorologiques Climate Model, version 5

HadGEM2-ES – Hadley Centre Global Environmental Model, version 2 – Earth System

MPI-ESM-LR – Max Planck Institute Earth System Model, Low Resolution

Appendix B

Recommended models for BC as per PCIC

TaiESM1 – Taiwan Earth System Model, version 1

NorESM2-LM – Norwegian Earth System Model, version 2, low resolution

CNRM-ESM2-1 – Centre National de Recherches Météorologiques Earth System Model, version 2.1

IPSL-CM6A-LR – Institut Pierre-Simon Laplace Climate Model, version 6A, low resolution

MIROC-ES2L – Model for Interdisciplinary Research on Climate, Earth System version 2 for Long-term simulations

MRI-ESM2-0 – Meteorological Research Institute Earth System Model, version 2.0

UKESM1-0-LL – UK Earth System Model, version 1.0, low resolution

EC-Earth3-Veg – European Community Earth Model, version 3 with dynamic vegetation

MPI-ESM1-2-HR – Max Planck Institute Earth System Model, version 1.2, high resolution

FGOALS-g3 – Flexible Global Ocean–Atmosphere–Land System Model, grid-point version 3