Flood Mitigation in the Fraser Valley:

An exploration of passive water storage on agricultural land

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Disclaimer

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability and climate action across the region.

This project was conducted under the mentorship of Emergency Planning Secretariet (EPS) staff and members within the flood and disaster management field. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of EPS or the University of British Columbia.

Executive Summary

This report addresses the evolving challenges of floodplain management in British Columbia (B.C.), focusing on the potential integration of passive water storage techniques into existing management strategies. The report sheds light on the current challenges that face the Fraser Valley region in the face of a changing climate while advocating for new innovative floodplain management strategies that enhance the resilience of the region. This includes investigating the effectiveness of passive water storage as a floodplain management tool, identifying and assessing the inhibiting and assisting factors of the policy and regulatory landscape, and examining the funding mechanisms that can assist in the exploration and implementation of passive water storage. By highlighting both opportunities and obstacles to passive water storage implementation, the report provides a comprehensive overview of how B.C. can enhance its flood resilience in the face of increasing climate-related threats.

Chapter 1: Understanding Flood Risk in the Fraser Valley

The Fraser Valley and its extensive agricultural lands are particularly at risk of flooding, and recent floods have demonstrated devastating economic and social impacts. floodplain management in B.C. has traditionally relied on structural measures, specifically executed through the Fraser Valley dike system. These systems, though effective to an extent, are becoming increasingly inadequate due to the capacity challenges of their upkeep for local governments and the intensifying impacts of climate change. There are limitations of these conventional floodplain management strategies, including their reactive rather than proactive approach and their ability to increase flood risk.

Chapter 2: Literature Review on Passive Water Storage Techniques

Passive water storage is a method of floodplain management that can complement the Province's traditional floodplain management model. This floodplain management tool involves temporarily expanding the floodway during flood events, enhancing natural absorption, reducing the flow rate and river height and therefore mitigating flood risk. Typically leveraging various landscapes, such as wetlands, fields or basins, passive water storage could effectively be applied to agricultural land because of its abundance and proximity to the Fraser River. This report discusses two passive water storage methods, including the Waffle® system, which modifies existing infrastructure to create temporary storage areas, and setback dikes which are dikes built further off the riverbed increasing the available floodplain. By storing water during peak flow periods, these systems can mitigate flood risks while preserving the productive capacity of agricultural land and preventing devastating floods.

Chapter 3: Review of Governance Framework

Navigating the existing policy landscape poses significant challenges to implementation, as securing buy-in from multiple stakeholders and managing the intricate web of policies and regulations can be difficult. This analysis examines the current regulatory environment to identify frameworks that may either support or hinder these efforts. The landscape is shaped by a wide array of policies and regulations governing land use – including First Nations rights and title, the Agricultural Land Reserve, local government frameworks, farm use guidelines, riparian area protections, and water sustainability regulations – as well as floodplain management governance, such as the Dike Maintenance Act and the B.C. Flood Strategy. The governance framework strongly supports maintaining the current dike system, yet there is also great potential for implementing innovative floodplain management tools.

Chapter 4: Review of Potential Funding Mechanisms

Securing adequate funding is crucial for the successful implementation of passive water storage. Specific government and non-government assistance programs, along with their objectives, funding sources, and potential funding amounts, have been identified. Federal funding streams, such as the Disaster Mitigation and Adaptation Fund, Emergency Management Assistance Programs, and the First Nations Infrastructure Fund, as well as provincial funding streams like the Community Emergency Preparedness Fund, Disaster Resilience and Innovation Fund, and the Adaptation, Resilience, and Disaster Mitigation Program, provide essential financial support for projects that align with passive water storage. Additionally, the non-governmental organization Investment Agriculture Foundation of B.C. (IAF) offers multiple funding programs to promote sustainable agricultural practices. These programs are vital in overcoming the financial barriers that often hinder the adoption of innovative floodplain management tools. By effectively leveraging these resources, the implementation of passive water storage can become a more attainable and sustainable reality. However, struggles plague these programs, with some focusing on recovery rather than enhancing resilience, while many others have undependable and limited funding, forcing municipalities to compete and limiting long-term risk reduction planning.

Traditional floodplain management strategies in B.C. are necessary, but they are increasingly insufficient in the face of climate change and escalating flood risks. Passive water storage emerges as a practical, sustainable solution that can complement existing infrastructure and enhance flood resilience across the Province. However, successful implementation will require overcoming regulatory hurdles, securing consistent funding, and fostering collaboration among stakeholders, including local governments, non-governmental organizations and the agricultural community. Moving forward, efforts should focus on researching the most applicable passive water storage technique for the region, refining the governance framework to support innovative floodplain management strategies, increasing the availability and accessibility of funding and raising awareness among stakeholders about the benefits of passive water storage. Further research is needed to evaluate the short and long-term impacts of these systems on agricultural productivity and its community. B.C. can take significant steps towards building a more resilient and sustainable floodplain management system.

Territorial Acknowledgement

I want to acknowledge that the work for this project took place on the traditional unceded ancestral lands of the xwməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), Səl̓ílwətaʔ/Selilwitulh (Tsleil- Waututh), Stó:lō, sq̓əc̓iy̓aʔɬ təməxʷ (Katzie), Á,LEṈENEȻ ȽTE (W̱SÁNEĆ), Kwantlen, and Semiahmoo First Nations (*Native Land*, n.d.). As a settler, I am grateful for the opportunity to live and learn on these lands.

In reflecting on this, I recognize the pervasive role colonialism has played in shaping my experience in academics and research, often prioritizing Eurocentric viewpoints and marginalizing Indigenous perspectives and voices. This is evident in how land management practices and flood planning have been developed. The act of mapping, a tool frequently used to divide and dispossess, has imposed names, boundaries and land ownership concepts that do not align with First Nations understandings of territory and stewardship. The forced removal of many First Nations from their lands through floodplain management practices disrupted protocols and systems that supported balanced ecosystems and thriving communities.

This project has compelled me to critically examine the colonial legacies embedded in floodplain management and planning. I am committed to integrating this understanding into this research, my work and my personal life. Through continuous learning and unlearning, I aim to contribute to reconciliation and foster more inclusive and equitable approaches that honour and integrate Indigenous knowledge systems.

Acknowledgement

I would like to thank Mariah Mund, my mentor at the Emergency Planning Secretariet, for her support throughout this four-month project. I am grateful for the numerous hours of meetings to discuss the report and her meaningful contributions and feedback throughout this project.

Notes

This study acknowledges the indispensable role farmers play in supporting the economy and maintaining food security in the Fraser Valley and across B.C. Farmers often bear the brunt of flooding and its impacts, making their involvement in flood resilience critical. Although contributing to flood resilience can be burdensome, the agricultural sector's role in food security makes this responsibility essential. Investing in innovative passive water storage techniques can be impractical for farmers without adequate support. This study aims to highlight practices that enhance flood resilience while preserving agricultural productivity, and fostering collaborative relationships in floodplain management to benefit both farmers and the broader community.

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Chapter 1: Understanding Flood Risk in the Fraser Valley

Flooding is the world's most common disaster event, and climate change is increasing the intensity and frequency of all types of flooding. In British Columbia, riverine flooding of the Fraser River and its tributaries poses a significant risk to the safety of our communities, infrastructure and the economy. The Fraser Basin Council indicates that a flood similar to the most devastating flood in recorded history in 1894, could result in nearly $23 billion in economic losses for the region if floodwaters remained for four weeks (Fraser Basin Council, 2016).[1] This includes losses to buildings (residential, commercial, industrial and public), critical infrastructure, shipping, and agriculture.

In the Fraser Valley, agriculture is a dominant industry. The Fraser Valley Regional District (FVRD) contains 71, 675 hectares of farmland, mainly concentrated along the Fraser River (Northwest Hydraulic Consultants Ltd. et al., n.d.). Agriculture plays a role in one in five jobs in the region and produces over $3 billion in annual economic activity and more than $1 billion in gross annual income (*Fraser Valley Agriculture Flood Mitigation and Resiliency: Education Booklet*, 2024). The FVRD is the most productive regional district in the Province and holds some of the most productive land in the country (Chabanova, 2020). The Fraser Valley produces 33% of B.C.'s vegetables, 60% of its dairy cows and over half of the broccoli, brussels sprouts, cauliflower, hens, chickens, raspberries and turkeys (Northwest Hydraulic Consultants

[1] It is important to note that the Fraser Basin Council's (FBC) report only assessed the damages from the flooding of the Fraser River. It did not account for loss and damages from other rivers nor did it assess types of flooding beyond riverine flooding. This gap in research could indicate damages could be greater than valued by the FBC.

Ltd. et al., n.d.). To safeguard the industry, the resilience of farmland in the Fraser Valley is of the utmost importance.

Major floods in the Fraser Valley have previously devastated the agricultural community. Nearly 40% of agricultural land in the Fraser Valley is at risk of springtime freshet flooding (Northwest Hydraulic Consultants Ltd. et al., n.d.). The Fraser Basin Council estimates that a flood lasting four weeks could engender $1.6 billion in agricultural losses, with damage to 43,459 hectares, loss of sales, and damage to buildings, equipment and crops. The 2021 atmospheric river flood resulted in $5-7 billion in economic losses for the Province and caused B.C.'s largest agricultural disaster (Ministry of Water, Land, & Resource Stewardship, 2024). Given the profound social and economic impacts of the 2021 flood on the agricultural community, it is paramount to explore any potential solutions to mitigate future risk and protect the viability of the agricultural sector.

1.1 Flooding

The magnitude of flood events can be measured in various ways. A common and historic method of measurement is Annual Exceedance Probability (AEP). AEP is the long-term annual probability of a flood event. For example, the flood of 1894 is the largest flood in recorded history and it is nearly equivalent to a 1:500 AEP flood (Fraser Basin Council, 2016). This event has a long-term average of occurring once every 500 years, also referred to as a 0.2% annual probability. However, climate change is shortening the return periods of flood events, increasing their probability each year (Fraser Basin Council, 2016). A 1:500 AEP flood today could have a 50-year return period by 2100. AEP is therefore no longer a preferred flood measurement tool by some consultants, but it remains a constant in flood literature, legislation and research. Another way to measure flood events is through flow rate. Fraser River floods can be measured by the flow rate at the Hope gauge. The peak flow of the 1894 flood reached 17,000-m^3/s in Hope. Although this report supports measuring flood magnitude in peak flow (m^3/s), it will utilize the measurements available in existing reports. It is also important to note that flood measurements change depending on the type of flooding, such as freshets (springtime), atmospheric rivers (fall), and storm surges (winter). The magnitude of some floods may not be accurately reflected by measuring the peak flow of the Fraser River. For instance, the 2021 Atmospheric River Flood was caused by intense precipitation that overwhelmed the Nooksack River in Washington State, causing the river to cross the border into Abbotsford, B.C.

1.2 The Problem

Diking systems have been the primary choice for floodplain management in the Fraser Valley. A dike is defined as "an embankment, wall, fill, piling, pump, gate, floodbox, pipe, sluice, culvert, canal, ditch, drain, or any other thing that is constructed, assembled, or installed to prevent the flooding of land" (Ministry of Water, Land, & Resource Stewardship, 2024, pg 35). The dike system is composed of many tools such as floodgates, boxes, ditches and pumps. The Lower Mainland region is protected by

600 km of dikes, 400 floodboxes and 100 pumps built along the Fraser River (Fraser Basin Council, n.d.-a; Ministry of Environment and Climate Change Strategy, 2023). This dike infrastructure was built in response to the catastrophic 1894 and 1948 floods. The current system was designed to 1960s and 1970s standards, based on inaccurate and out-of-date assumptions, modelling, data, and methods (Ministry of Forests, Lands, and Natural Resources, 2015).

In the 2015 *Lower Mainland Dike Assessment Final Report*, the Province states that "the dikes generally do not meet current provincial standards and none fully meet or exceed the standards'' (Ministry of Forests, Lands, and Natural Resources, 2015, pg III). None of the dikes can withstand a 1:500 AEP flood. It continues that few can protect against a 1:200 AEP flood. Generally, the dike system can contain a 1:100 AEP flood, but some dikes are already overtopped in a 1:20 AEP flood event. The 1948 freshet flood is the second largest event after 1894, covering vast areas of the Fraser Valley and causing over a quarter billion dollars of damage, in 2024 currency (City of Abbotsford, 2019). The November 2021 atmospheric river floods had an AEP between 1:50 - 1:100, and the relative destruction is attributed to the rapid densification and construction of infrastructure in the Fraser Valley floodplain (University of Victoria, 2022).[2] Besides pressure from the hydrologic system, the dike system must also be resilient to seismic threats. Currently, 71% of the Fraser River dikes cannot meet seismic standards to withstand a 7.0 magnitude earthquake (or an earthquake with a 2475-year return period). The seismic standards in the remaining 29% of dikes could not be adequately measured (Ministry of Forests, Lands, and Natural Resources, 2015).

Dike standards have not been well maintained since 2003 when the Provincial Government transferred jurisdiction over floodplain management – and therefore dike construction and maintenance – to local governments. Municipalities struggle to maintain the dike quality necessary to manage flood risk (Fumano & Hoekstra, 2022) due to insufficient funding and capacity as well as gaps in knowledge of standards and regulations (Fraser Basin Council, 2021b; Fumano & Hoekstra, 2022). Dikes are expensive, and maintaining the quality of the existing infrastructure consumes already strained municipal budgets (Soltau, 2021). T It also forces municipalities to compete for limited grants and funding from senior levels of government (Fumano & Hoekstra, 2022). For example, three B.C. communities, including Abbotsford, that were impacted by the 2021 atmospheric river floods had their applications to the federal Disaster Mitigation and Adaptation Fund denied (Joannou, 2024). The funding, resource and capacity restrictions municipalities face leaves no room financially for the expansion or alteration of the diking system or the exploration of other options.

Diking systems have historically contributed to a public perception of enhanced safety, largely because of a misunderstanding of their role in mitigating flood risk (Breen et al., 2022). While these structures can reduce the likelihood of a flood event, they do not eliminate the risk entirely. When a flood does occur, the consequences can be far more severe due to the increased development encouraged by the perceived safety, a phenomenon known as the levee effect or safe

[2] A floodplain is defined as "An area of low-lying ground subject to flooding adjacent to a watercourse or lake" (Ministry of Water, Land, & Resource Stewardship, 2024, p.36).

development paradox that results in putting more people, property, and economic activity in harm's way (Breen et al., 2022). This false sense of security has spurred extensive settlement and infrastructure development in the floodplain, as well as the creation of thousands of hectares of productive agricultural land.

The current diking system can actually lead to increased risk. By restricting and straightening the river and reducing the floodplain's storage capacity, the dike system increases river depth, velocity and water levels (Havinga, 2020). As a result, the river requires less water – whether from precipitation or snowmelt – to increase the risk of flooding than it would without the dike system. Due to this alteration of a river's natural hydrology, dike systems also increase the potential for erosion and disrupt natural sediment management (Smith et al., 2017). Sediment naturally deposits at the mouth of rivers as the slope decreases. The dike system increases water velocity, leading to reduced sediment deposition upstream and increased deposition downstream. Amplified river velocity and height created by the dike system consequently increase the pressure on dikes, threatening their stability over time. In addition, increased velocity and volume multiply the risk when dikes are overtopped (Havinga, 2020). Research has also shown that diking systems can increase flood risk and costs for downstream communities (Wang, 2021). Specifically, increasing the height of dikes upstream equates to effectively lowering dikes downstream. Simply repairing and raising dike height to mitigate flood risk does not alleviate these challenges and may even exacerbate risk Dike's ability to increase and unequally distribute risk emphasizes the importance of cohesive and holistic floodplain management. These drawbacks suggest that other solutions must be considered as part of a responsible approach to floodplain management.

The current flood mechanisms – relying on dikes along the riverbed and municipal management – have demonstrated disastrous results for farmers in the Fraser Valley with costly disruptions and damages. While there have been calls and evidence to alter common practices, such as exploring nature-based options or managed retreat from the floodplain, solutions must consider the implications for farmers and food security. Research has shown support for more natural management of river systems (Bosshart, 2024). Specifically, this means finding ways for rivers to *breathe* and absorb the increasingly common higher water levels.

Since the 2021 flood, investments have been made in flood risk management and mechanical infrastructure. This includes significant dike repairs and a $76.6 million upgrade to the Barrowtown Pump, which drains water from the former Sumas Lakebed (Province of British Columbia, 2024a). However, these upgrades largely aim to *restore*, rather than improve, the operational capacity of the dike system and the 1983 pump station. The restoration of the dike system to its pre-flood condition, while necessary, does little to improve long-term resilience. Despite the recent occurrence of the 2021 flood, the probability of a flood of the same or higher magnitude remains unchanged. Indeed, climate change is shortening the return periods of major flood events(Fraser Basin Council, 2016). Therefore, farmers and communities in the Fraser Valley remain at the same risk of flooding as they were before the November 2021 floods (Lower Fraser Floodplains Coalition, 2023).

Elsewhere various practices are being adopted to reduce individual flood risks on farmland. Riparian area restoration and tree planting have mitigated flood risks by strengthening riverbanks, reducing flow rates, and deepening riverbeds (U.S. Department of Agriculture, 2019). These actions contribute to the overall resilience of the region. However, during major flood events, these measures alone may not suffice, and expanding and restoring the natural floodplain could be necessary. Despite their potential, these solutions, much like passive water storage, face significant challenges. Implementation requires active participation from landowners, financial backing from senior government, and further research to identify best practices, often resulting in a preference for maintaining the status quo.

There is growing sentiment that the next flood is inevitable – it is a question of “when” rather than “if”. A participant from a farm resilience workshop emphasized the need to "prepare to fail", to ensure farms can be resilient in the face of the next major flood (Anonymous, 2024). One approach to this challenge is passive water storage, a floodplain management technique that involves strategically designating certain areas to be intentionally flooded during high-water events.

Chapter 2: Literature Review of Passive Water Storage Techniques

2.1 What is Passive Water Storage?

Passive water storage is a technique that proactively designates specific areas of land to hold water when water levels are high to reduce risk. Passive water storage leverages landscapes, such as wetlands, fields, or dedicated basins, to absorb and slow water flow, reducing the pressure on downstream infrastructure and communities. This passive system relies on gravity, natural absorption and evaporation, unlike active systems that depend on mechanical interventions like pumps and gates (Kurz et al., 2007). Passive water storage offers a sustainable and effective way to manage flood risk while enhancing the resilience of ecosystems, communities, and agricultural land by permitting the floodplain to widen periodically.

This chapter explores two key floodplain management tools: setback dikes and the Waffle© system. The first section delves into setback dikes, detailing their benefits, limitations, and economic feasibility, and concludes with two implementation examples. The second section focuses on the Waffle© system, developed by the Energy & Environmental Research Center at the University of North Dakota (Kurz et al., 2007), examining its mechanisms, benefits, limitations, and economic viability. The chapter concludes with recommendations for further research to assess the suitability and effectiveness of setback dikes and the Waffle© system in the Fraser Valley, while also considering the importance of maintaining agricultural production in the region.

2.2 Setback Dikes

Setback dikes are constructed further inland, away from the river or shoreline, compared to traditional dikes (Fraser Basin Council, n.d.b). As shown in Figure 1, a setback dike is positioned away from the natural floodway, allowing the river to reconnect with its floodplain during floods (Fraser Basin Council, n.d.).[3] Traditional dikes have confined rivers, disconnecting them from their natural floodplain. This report often refers to setback dikes as expanding the floodplain which technically means ensuring floodways can access their floodplain. The area between the river and the dike, known as the batture, provides space for the safe overflow of water during high-water events. This design reduces direct pressure on dike systems, lowering the risk of overtopping. In addition to reducing flood risk, setback dikes offer several co-benefits, making them a favourable option among academics, scientists, policymakers, farmers, and ecologists.

[3] Floodway is defined as "the channel of the watercourse and those portions of the floodplains that are reasonably required to discharge the flood flow of a Designated Flood." (Ministry of Water, Land, & Resource Stewardship, 2024, p. 37).

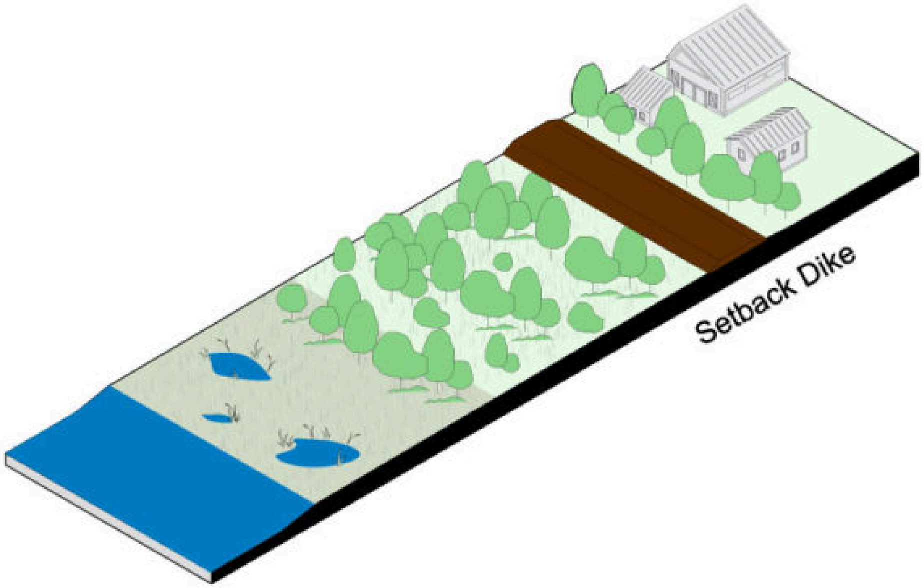

Figure 1: A setback dike is constructed off the natural floodway, permitting space for the river to naturally expand in times of high waters

2.2.1 Benefits

Setback dikes offer significant benefits for floodplain management, community protection and agricultural productivity. An increase in floodplain area significantly reduces flow velocities and volumes, which decreases the potential for dike scour, hydrologic loading (pressure on dikes), dike saturation and overtopping (Smith et al., 2017). By allowing rivers more space to expand, setback dikes can also be built on a more suitable and sturdy foundation, making them more stable, robust and less prone to failure. Consequently, this reduces the vulnerabilities of adjacent communities and infrastructure to flood damage. In regions like the Fraser Valley, where agricultural land is both highly productive and critical, the increased reliability of the dike system offers essential reassurance to farmers and landowners. Strengthened flood protection is crucial for sustaining agricultural activities, thereby safeguarding the local economy and food supply.

Flood protection, in comparison with traditional dikes, is not only maintained but increased by setback dikes (Smith et al., 2017). For example, in the Omaha District of the Missouri River Basin, dikes were setback, at least 100 feet and often more than 1000 ft which resulted in a reduction of the river's water level by 0.4 - 1.5 ft.[4] These setbacks enabled the dike system to withstand a 125-year flood, compared to their previous standard of an 80-year flood (Smith et al., 2017). There is a direct correlation between the increase in floodplain area and the average stage height decrease. Research on agricultural land showed that a 15 km^2 increase in floodplain area

[4] Stage height is the level of water in a river with respect to an arbitrary but designated reference point.

resulted in a 0.11 m reduction in water levels and a 38 km^2 increase in floodplain area reduced levels by 0.34 m (Dierauer et al., 2012). In a study by the Fraser Basin Council, modelling demonstrated a 0.15 reduction in flood water levels with 15 km of dikes being setback 400 m ((Fraser Basin Council, 2019).

Setback dikes are unique in that they are a structural solution, but because they are pulled back from the river they become a nature-based solution as well, enabling the natural restoration of ecosystem services within the floodplain. The decreased river velocity promotes river meandering, which improves sediment management and deposition, significantly enhancing salmon habitat and other aquatic species. This alteration to the river hydrology also encourages the growth of native vegetation, providing natural stabilization of riverbanks and promoting flourishing biodiversity. Indeed, public and private actors spend millions on projects to manage the repercussions of the current, traditional dike system, including but not limited to sediment removal, dredging, velocity management, dike stabilization, and environmental restoration projects (Emergency Management and Climate Readiness, 2023). Setback dikes improve the river's natural ability to manage sediment, stabilize banks, and support salmon spawning, diminishing the need for costly human intervention.

Setback dikes also offer a range of non-traditional benefits that are often unaccounted for in traditional and environmental cost-benefit analyses. These can include reducing damage to critical infrastructure, preventing damage to critical transportation routes and minimizing shutdown costs for businesses and agricultural services (Smith et al., 2017). Setback dikes can also result in cost savings related to emergency planning, evacuation, and cleanup operations due to the less frequent need for emergency services.

From an economic perspective, the cost-benefit ratio of dike setbacks reveals a favourable return on investment. Setback dikes can significantly reduce operation and maintenance costs, as well as expenditures related to repair, rehabilitation, and replacement (Smith et al., 2017). However, traditional cost-benefit analyses typically focus on the protection of structures, cropland, and contents, which often means other, less tangible or measurable benefits of setback dikes are grossly underestimated.

2.2.3 Limitations

Setback dikes, while effective in reducing flood risk, have limitations, particularly in agricultural areas. Most prominently, the acquisition of land to build setbacks presents practical and economic challenges. In the case studies, projects often came to fruition from buyouts of substantial acreages. For example, in the projects put forth by the US Army Corps of Engineers, land was purchased from large industrial farms (Smith et al., 2017). These buyout programs may be incompatible with the agricultural landscape in the Fraser Valley. This compensation method may be challenging for small-scale farming operations. Indeed, with 2,576 farms in the FVRD, the average farm size is nearly one-sixth of the provincial average of 24 hectares (Ministry of Agriculture, 2016).

Further complicating management, the Agricultural Land Commission heavily regulates non-farm use on ALR land (Agricultural Land Commission Act, 2019). The ALR accounts for 71% of the total land area in Abbotsford and 58% of Chilliwack (Fraser Valley Regional District, 2017). On top of the ALR, additional land is utilized for agriculture in these municipalities, for example, the City of Chilliwack is comprised of 67% farmland (City of Chilliwack, n.d.). These restrictions pose serious challenges to the transfer of operational management of these lands for passive water storage. In addition, farmers are generally opposed to buyouts of farmland. Yet, research from the US Army Corps of Engineers shows evidence that agricultural landowners may favour setback dikes if they can maintain overall ownership through easements, in addition to other compensatory methods like monetary payments and insurance premiums (Smith et al., 2017).

A major limitation to implementing setback dikes on agricultural land for passive water storage is the lack of understanding of how batture areas can be utilized for agricultural purposes. While some case studies show a permanent return of floodplains to the river, it remains unclear whether land can continue to be utilized, and in what ways (Stokkom et al., 2005). Further research must elucidate how batture can be viable for agriculture, what crops can be cultivated in this area and how to navigate the varied conditions. This is especially pertinent in the Fraser Valley because of the role of agriculture in the economy and the region's food security. Buy-in to creating setbacks from farmers is paramount. The agricultural benefits of increased flood resilience in addition to the advantages and disadvantages to crop growth and yield must be outlined and emphasized. Overall, highlighting the economic impact of setback dikes on farming communities and the risks they are forced to bear will be key.

2.2.4 Case Studies

Rhine River, the Netherlands

The Netherlands has been managing flood risk for centuries, but devastating floods in 1993 and 1995 that displaced over 250,000 people shifted the Dutch approach to floodplain management (Stokkom et al., 2005). The floodplain of the Rhine River in the Netherlands is home to many competing activities that include protecting populated areas, agricultural land, and biodiversity. There have also been growing calls to find an integrated approach to simultaneously improve flood protection, prevent riverbed erosion, increase biodiversity, and enhance water management (Havinga, 2020). Historically, the Dutch practiced traditional river training, a river management tool that aimed to increase flood protection and navigation by deepening, narrowing and straightening the river and building traditional dikes (Havinga, 2020). In contrast, the Dutch have now transitioned to work *with* the river.

Floodplain management in the Netherlands specifically aims to avoid the continued cycle of repairing and raising dike systems (Stokkom et al., 2005). Setback dikes to increase natural water storage capacity on agricultural land are one of many tools that make up the broader Room for the River (RfR) strategy. To install setback dikes, the Dutch government acquired agricultural land through buybacks. Although RfR received pushback from farmers in the early stages, the program's collaboration with the farming community has resulted in a positive mutual relationship (Jan Goossen, 2018). However, setback dikes were only needed in areas with particularly narrow floodplains (Stowa, n.d.).

The Dutch have pointed to many benefits of this project. Advantages include reduced water levels, lower probability of floods, enhanced biodiversity and habitats and improved recreational opportunities (Nature Based Solutions, n.d.). Additionally, projected warmer summers point to potential drought challenges that will be mitigated by increased water absorption into the soil permitted by the setback dikes.

Washington State (Floodplains by Design)

Floodplains by Design (FbD) is a program developed by Washington State to address flood risk, in response to recent and significant flood damages (Department of Ecology, 2019). The state has experienced $2 billion in flood damages from 1980 to 2019 and currently faces potential losses of up to $56 billion because of infrastructure that is exposed to flood risk in the floodplain. FbD aims to acknowledge and plan for the amplified severity and frequency of future flood events due to climate change. Through multi-partner collaboration, FbD projects are holistic and integrative, assessing flooding at a floodplain level. FbD seeks to protect and improve its rich and productive farmland, vital salmon habitat and recreational sites while decreasing flood risk for its vibrant communities.

Since 2013, this collaborative set of projects has mitigated risk for nearly 40 communities, restored 1,000 acres of historic floodplain and renewed salmon habitat in 16 km of river. Approximately fourteen of the 36 projects, from 2013-2019, included the augmentation or construction of setback dikes. In many, preserving agricultural productivity and land is a primary goal achieved through lowering the inundation risk with setback dikes. FbD emphasizes its cross-sector collaboration and highlights that all projects adjacent to agricultural land collaborate and engage with farmers to understand, balance, and accommodate agricultural interests.

2.3 Waffle© Storage

2.3.1 Context:

A flood mitigation technique was developed in the Red River Basin (RRB), called the Waffle©. This technique, and the accompanying case study from Kurz et al., elucidate interesting findings that suggest there may be potential to utilize Waffle© to mitigate risk in the Fraser Valley (2007).

As Kurz et al. explain, the Red River forms the boundary between North Dakota and Minnesota and stretches 883 km across the international border, ultimately draining into Lake Winnipeg. The RRB encompasses 116,500 km^2 of fertile terrain, three-quarters of which is agricultural land. The valley adjacent to the river is strikingly flat, with an average relief of just 0.5 feet per mile along the river's course. This region includes five population centres with over 10,000 residents each, including the 150,000 people in the Fargo-Moorhead area and the 750,000 residents in Winnipeg. The RRB experiences climatic extremes, from hot summers to cold winters, and receives only around 500 mm of precipitation annually. Despite topographic, demographic, and climatic differences from the Fraser Valley, the region is prone to major flood events. Since 1882, the basin has seen significant floods roughly every 4 to 6 years, with particularly devastating floods approximately once a decade. The 1997 flood stands out as the worst on record, inflicting up to $5 billion in damages.

2.3.2 The Waffle©:

After the disastrous 1997 flood, researchers in the RRB searched for innovative ways to manage flooding. The Waffle© is a flood mitigation strategy coined by the Energy & Environmental Research Center (EERC) and its director Gerlas Groenewold (Kurz et al., 2007). The concept aims to utilize existing flood management mechanisms – (dikes, levees, ditches and diversions) to temporarily retain and store water in the low-lying valley. Figure 2 demonstrates how retention areas can be created using the existing dike infrastructure and how water can be stored within those established low-lying areas (Kurz et al., 2007). As the elevation gradient decreases, more water is able to be stored in the retention area. These temporary retention pools can mitigate flow volumes and rates, potentially reducing flood damage and the need for flood infrastructure capacity downstream. The additional storage capacity of the Waffle©, through minor structural alterations, would reduce flood crest heights until the retained water can be gradually returned to the system.

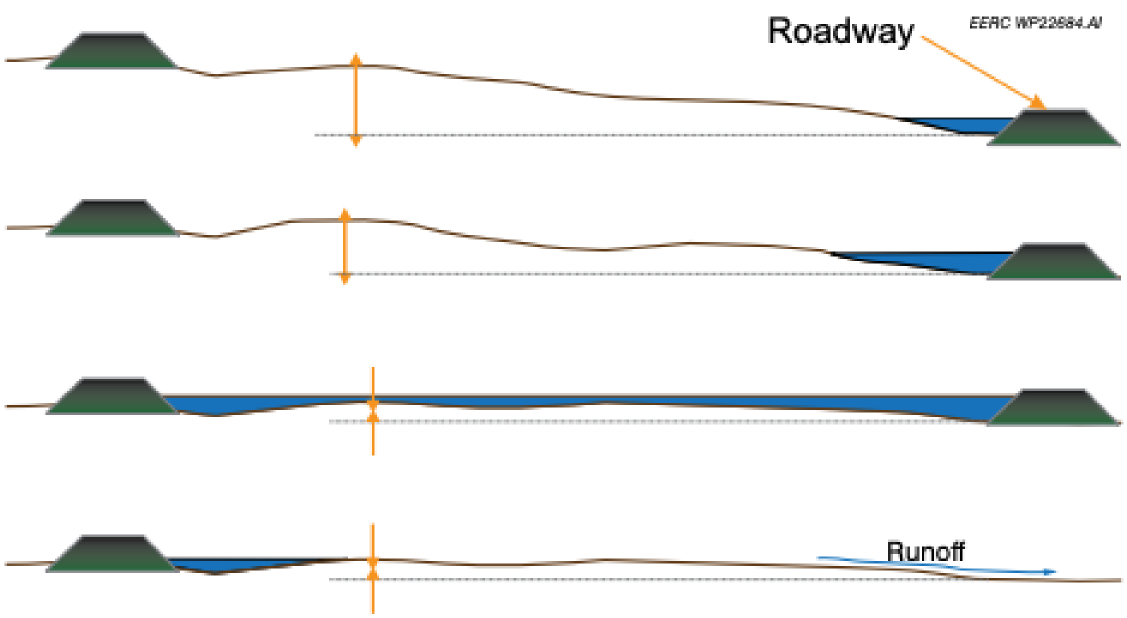

Figure 2: Retention areas are created by natural topographic depressions and bounded by existing or new dikes or raised roads. The capacity of a retention area depends on the elevation between dikes or raised roads

The Waffle storage concept was trialled on four sites by augmenting existing culverts with canal gates and overflow standpipes to allow water to flow into the low-lying areas for storage. As shown in Figure 3, gated culverts utilize gravity to move flood waters into the low-lying area cornered behind a raised road. Sensors were inserted to track and assess water flow, soil moisture, temperature and climate conditions (Kurz et al., 2007). Soil chemistry, water quality, crop yields, planting schedules and road stability were also monitored throughout this project. Each site had 145-200 acre-feet storage capacity, stored water for 5-14 days and drained in 1-2 days.

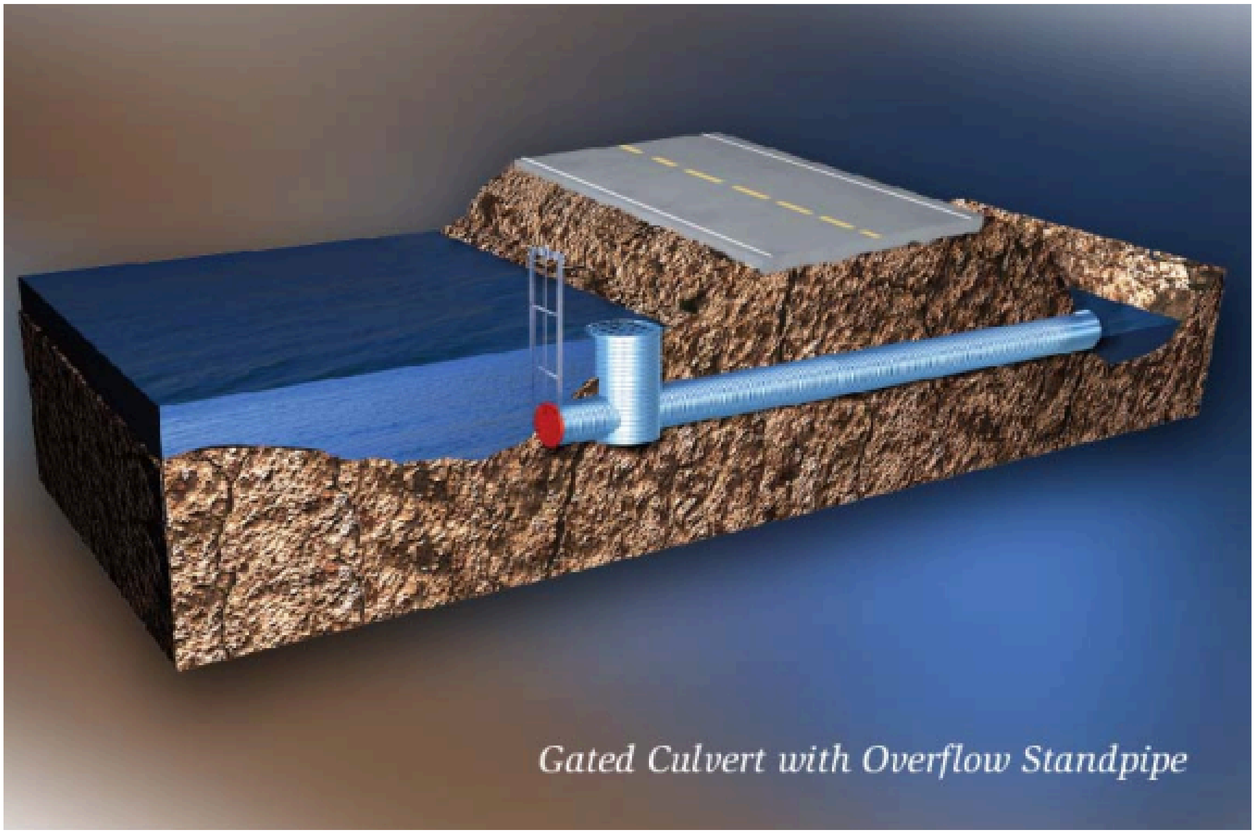

Figure 3: A gated culvert uses gravity to distribute flood waters from the waterway to a retention area. The raised road contains the water to be temporarily stored until it can be slowly released slowly back into the river.

Topographic modelling was conducted to determine how much land in the RRB could serve as Waffle© storage. Figure 4 illustrates how passive storage on agricultural land could be implemented using the Waffle©, it emphasizes the use of natural topographic depressions to store water while preserving much of the land from flooding (Kurz et al., 2007). Kurz et. al found that moderate volume estimates indicated the potential to store 2,188,400 acre-feet of water, while conservative estimates showed 583,400 acre-feet of capacity. This corresponds to 1.5 - 5.2% of the RRB area, much of which is sparsely inhabited farmland. Based on these estimates and the average depth of water, between 334,200 and 1,170,500 acres could be utilized. Hydrologic and hydraulic modelling of the 1997 flood, predicted that storing the moderate volume estimates could reduce peak flows by 6% to 96%, and storing the conservative volume estimates could reduce flows by 1% to 59%.

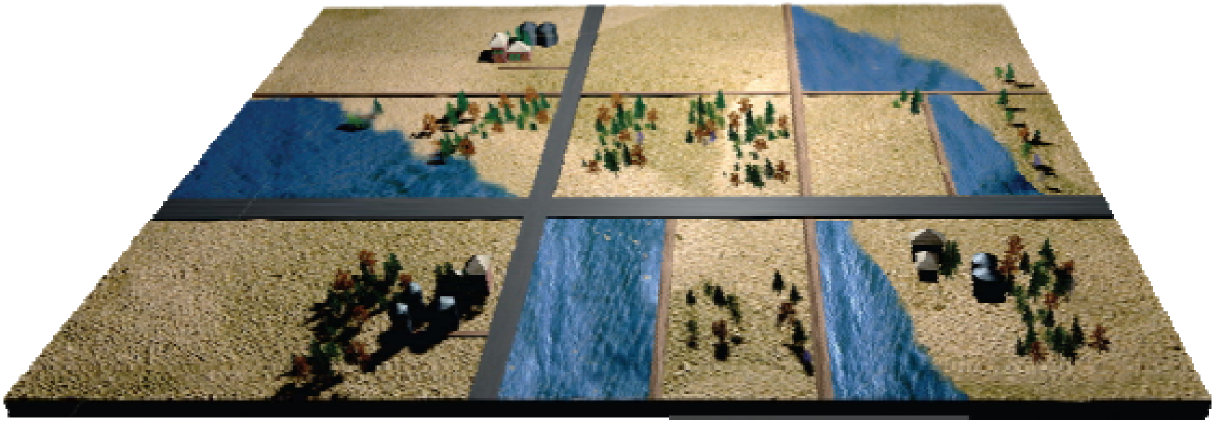

Figure 4: An example of the Waffle implemented. Water is contained by existing road or dike infrastructure.

2.3.3 Benefits:

The Waffle© is multi-beneficial. Research shows the Waffle© has the capacity to mitigate floods and the effects of drought (Kurz et al., 2007). Its augmentation of existing flood infrastructure can also bolster resilience in urban and rural land uses, and protect agricultural practices.

The four testing locations selected by Kurz et al. demonstrated that the Waffle© enhanced flood resilience with limited negative externalities. The findings include:

- **Peak flow rates were reduced** immediately downstream from the sites from 10 - 12% and **localized flows were reduced** by 20-30% (with a 7-14 day water holding period).
- Around 28% of the water stored was absorbed by **infiltration** and nearly 5% **evaporated**, which significantly reduced the amount of water released back into the waterways.
- **Soil temperature** measurements indicated a significant increase in frost thaw rates in the soil in flooded areas because higher water content insulated the soil.
- **Soil moisture** was maintained at a higher level longer into the growing season on the field sites that passively held water.
- No adverse impacts to **water quality** occurred as a result of water storage. No pesticides or herbicides were detected and there were negligible changes to salts and other mineral levels.
- **Crop yields** remained consistent with surrounding, non-flooded areas.

- **Soil nutrients** had no consistent pattern of change across the sites, while some areas exhibited a slight, negligible decrease in nitrate and phosphorus concentrations.
- **Road stability** evaluations indicated that frost depths in the roads adjacent to the sites are thick enough to prevent water seepage into the road.

2.3.4 Economic Viability:

Three separate cost-benefit assessments have been conducted for the Waffle in the case of the RRB. One was conducted by North Dakota State University (NDSU), and two were for the *Journal of Soil and Water Conservation.*

1. A cost-benefit analysis was conducted by the North Dakota State University's Department of Agribusiness and Applied Economics (Kurz et al., 2007). Costs include waffle construction, modification and maintenance, landowner reimbursements and enrollment and administrative costs. These were weighed with the potential for flood mitigation and elaborated on to include other physical and economic factors over a 50-year timeframe (2006-2055). 85% of the 108 modelled scenarios showed over $300 million in net benefits, and 50% produced net benefits of over $500 million. The study did not account for all the potential environmental benefits and flood mitigation effects accrued by smaller communities and rural communities, infrastructure and agricultural land.

2. The article, "Waffles are Not Just for Breakfast Anymore", for the *Journal of Soil and Water Conservation, summarizes another economic* analysis of the Waffle© (Manale et al., 2006). The study utilized the 1997 flood event as an example scenario and made assumptions about future flood events, including that they would follow a similar frequency and magnitude, farmers would be compensated for their losses (in the least), water would be stored for two weeks after peak flow (at max) and that crops would require two-weeks to plant post drainage. The analysis found that the 1997 flood would require 1.3 million acre-feet of water storage for the whole RRB. The required costs of Waffle© implementation, at $41.6 - $48.1 million, would be significantly less than the millions required for emergency management and post-disaster rebuilding. Researchers noted that their analysis does not account for the positive benefits of increased soil carbon, higher soil moisture and its mitigatory effects for drought, nutrient recycling, improved quality of water and benefits for wildlife.

3. Another analysis, by DeVuyst and Bangsund found similar results (2009). It modelled 12 factors, including varied levels of Waffle© land use scale, water storage capacity, projected populations and cost scenarios. Using an 11-year flood event as a baseline, it projected 132 scenarios. The scenario with the greatest gross benefits provided $1.02 billion in benefits, while the scenario with the least amount of gross benefits provided approximately $593 million in benefits. The net benefits in a baseline cost scenario range from $125 million to $707 million over 50 years. This research states that 85% of scenarios showed

net results of $300 million and two-thirds of scenarios resulted in net benefits of over $400 million. This emphasizes that even with varied scale and application of the Waffle©, the floodplain management tool can provide substantial net economic benefits (Bangsund & Leistritz, 2009). Furthermore, this analysis also found diminishing returns as the scale of the project increased, highlighting the success of projects with lower scale. This is an important finding as acquiring land is a significant barrier to this mechanism.

2.3.5 Limitations

The research from the Energy & Environmental Research Center provides valuable insight into possible opportunities within the emergency management field for flood mitigation (Kurz et al., 2007). The potential benefits, especially for agricultural land, have been outlined. There are also limitations to these findings concerning the generalizability, sample size and study duration that have potential impacts on the implementation of a similar program in the Fraser Valley.

External Validity

The Waffle© research was initiated in response to flooding experienced in the RRB and the envisioned solution was grounded in the unique location, its flat topography and existing grid-style flood infrastructure. EERC pilot projects used GIS and other topographical research tools to determine which parts of the RRB were viable for the Waffle©. These tools and research will be necessary to determine the eligibility of other floodplains and individual sites. This logic remains similar to the cost-benefit analysis of other potential locations. The results may vary with larger population centres, increased critical infrastructure in the floodplain, and varied existing flood infrastructure necessary to create the waffle patterns, and will depend upon eligible land for storage.

Therefore, the success of this mitigation strategy in environments with different topographic, climatic and riverine conditions, as well as varied economic and population circumstances has the potential to vary. The specific findings were tied to the dark clay and silty soils in the RRB, which generally have poor drainage. Different soil characteristics, with varied absorption and retention capabilities, cannot be assumed to yield similar results. Similarly to soil composition, the RRB has a distinctly flat valley floor creating a slow, meandering river with a broad floodplain. In contrast, the Fraser Valley is bound by mountains and contains lowlands and hills. Its soil composition is more diverse, which can mean improved drainage and stronger root growth, but can make crops less durable in wet conditions (Ciy of Abbotsford, 2017). The Fraser Valley is also more densely populated with significant constraints on land availability and therefore land available for flood mitigation is limited.

Sample Size

These EERC projects only analyzed four sites over two years. Of these test sites, three were conservation sites and one was an agricultural site. The analysis of only four sites is insufficient to be extrapolated to other land uses. Relying on data from just one agricultural site with specific crops is insufficient, as it does not account for the variability in practices, crop types and environmental conditions across different regions. This limited sample size restricts the study's ability to generalize findings to other agricultural sites, reducing the applicability of the results.

Study Duration

A longer time frame is needed to analyze patterns of change to assess the long-term impacts incremental changes could have on the system. The sunflower and corn results should be interpreted cautiously as the testing period was short. The study emphasizes negligible changes to soil nutrient levels, water quality and crop output, as well as a positive influence on soil moisture. However, the short study duration is inadequate to assert these changes as inconsequential. The concept was created and tested on springtime freshet flooding. Further testing would need to verify the compatibility of this system with other types of flooding and in other months and seasons. More research must be completed to assess if these findings could be repeated across longer timeframes and with varying topographic and climatic environments.

Other Challenges

There are significant challenges to implementing the Waffle© as a floodplain management tool. The foremost challenge is acquiring the necessary land to develop the Waffle© system into a strategy capable of significantly reducing flood impacts. Securing large tracts of land is crucial for creating sufficient flood storage capacity. This requires detailed hydraulic mapping of the region to assess the volume of water that needs to be stored to effectively reduce flood risk and to determine the magnitude of flood events that the Waffle can manage.

Once the necessary land is identified, achieving long-term buy-in from farmers is essential. Farmers must be convinced of the benefits and feasibility of converting portions of their land into flood storage areas. This will involve addressing concerns about potential disruptions to agricultural activities and ensuring that participation is both attractive and economically viable for farmers. To facilitate this, sustained funding from partner governments is critical. Long-term funding would support both the initial development and ongoing maintenance of the Waffle©. There will also be logistical and technical challenges. The design and construction of the Waffle© must be carefully planned to integrate the current infrastructure and new technology with existing agricultural practices.

2.4 Recommendations for Further Research

2.4.1 Mitigative Potential in the Fraser Valley

Available literature acknowledges that passive water storage is a newer flood mitigation tool and, therefore less tested. This literature review demonstrates the need to continue to explore the benefits and potential to manage flood risk in British Columbia. Despite the increasing occurrence of major flood events and the pressing need for effective floodplain management strategies, there is a notable lack of literature exploring the potential for passive water storage on agricultural land or in diverse environmental contexts using techniques such as waffle storage or setback dikes.

The Fraser Valley's densely populated cities, vast agricultural land, varied topography and wet climate could significantly alter the findings of the passive water storage techniques reviewed in this study. Understanding the quantity of land required to effectively reduce regional flood risk and identifying suitable areas for passive flood storage is critical. Hydraulic modelling of the region is necessary to analyze water dynamics, which will inform decisions on how much risk the region can absorb and how much agricultural land can and should be allocated for flood storage. It is also important to evaluate the level of risk mitigation that is necessary. While resilience can always technically be enhanced, determining the appropriate extent is vital. This requires a clear assessment of acceptable risk levels and establishing criteria for deciding the scale and location for future flood resilience projects. A regional analysis should assess potential economic benefits, including quantifiable factors like reduced flood risk, lower insurance costs, and decreased maintenance, repair and emergency service expenses. Additionally, the analysis should consider less quantifiable benefits, such as habitat restoration, natural vegetation growth and a reduced need for crop irrigation.

Given the economic and cultural significance of agriculture in the Fraser Valley, tailored studies that consider local farming practices, crops, community needs, ALR land, and historical land use patterns will be invaluable. Further research is necessary on whether common crops in the Fraser Valley can survive prolonged exposure to water. While it is unclear which crops could be resilient to these flood tools, mapping crop use across Fraser Valley farms could be beneficial for the implementation of passive water storage. Although there are maps with general land use (ie. livestock, fruit, vegetables, grain etc) more specific mapping will be helpful to assess which tracts of land could be viable. Due to the prominence of livestock farming in the region, these analyses must also include the impact on lands for livestock including the nearly 14 million chickens, over 100,000 cattle and 70,000 pigs (Ministry of Agriculture, 2016). There is a gap in research on whether lands utilized for passive water storage can be effective and compatible with livestock grazing. This must include an assessment of how many animals would need to be relocated, the speed at which they can and need to move and a location for safety.

2.4.2 Collaborating with Farmers

Floodplain management and its research often negate farmers as key actors in resilience-building and do little to garner their lived experience or integrate and build upon their knowledge. Research often focuses on one benefit of passive water storage, for example, its ability to reduce peak flow or its advantages for salmon habitat. Rarely is there an intersectional approach. The case studies reviewed in this chapter mention the use of agricultural land, but there is limited information on the practices, tools and skill sets that farmers will need to learn to maintain passive water storage solutions on their land.

There are critical knowledge gaps that can be filled by farmers. For instance, an analysis of which crops can thrive in areas designed to retain water or that may be periodically exposed to floods is needed. Crops vary in their ability to survive flood conditions. Currently, rice is the only crop that is fully resilient to floods and grains such as wheat and barley can survive underwater over short periods (Reynoso et al., 2019) The ability of plants to resist flooding depends greatly on the species, crop age, duration of flood and the temperature of the air, water and soil (Province of Manitoba, n.d.-b). While cooler temperatures underwater slow growth and reduce the need for sun and oxygen, increased time underwater raises threats of pathogens. Research shows annual crops can withstand one to two days in wet soil at maximum (Province of Manitoba, n.d.-b). Perennial crops under flood conditions, could mitigate flood damage. Their strong root system would minimize soil erosion and nutrient loss in flooded fields. Unfortunately, perennial crops cannot survive flood conditions. Understanding the resilience and adaptability of different crop types to flood conditions is essential for optimizing agricultural productivity and protecting food security. Along with crop resilience, best practices with sufficient drainage must be shared and built upon. The Fraser Valley's wet climate makes proper drainage of the soil necessary for crop growth. If passive water storage on farmland is considered, the B.C. Agricultural Drainage Manual must investigate how current practices will need to evolve (Ministry of Agriculture and Food, n.d.).

2.4.3 Collaborating with Indigenous Peoples

In addition to focusing on farmers, it is crucial to consider the role of First Nations in floodplain management. First Nations have been living and farming the land since time immemorial and First Nation knowledge can provide invaluable insights into the landscape and flood patterns. Most reserves in Canada exist in floodplains and outside diking infrastructure and operate with limited resources and government funding (Indigenous Corporate Training Inc., 2024). Social inequities and historical, political and infrastructural measures have increased First Nation's exposure to flood risk. Despite these challenges, their deep, historical understanding of the land has led to strong management practices and resilient relationships with flooding. Integrating this knowledge into modern floodplain management strategies can enhance the effectiveness and sustainability of these efforts.

Community engagement is a vital part of this process. Stakeholders must engage First Nations communities as rights holders and active partners in floodplain management research and planning. The new B.C. Flood Strategy aims to assist the incorporation of Indigenous knowledge into floodplain management and make First Nations active partners in the process. First Nation participation will enhance the cultural relevance and effectiveness of flood mitigation measures. This should include collaborating with First Nations to map areas historically known to be flood-prone or flood-resistant. This information can be integrated into current flood risk assessments and land-use planning. The federal government has released funding to explore Indigenous Traditional Knowledge for flood mapping in the Flood Hazard Identification and Mapping Program (Natural Resources Canada, 2024). Through these programs, floodplain management must seek ways to incorporate traditional land management practices into modern flood mitigation strategies. This might include the design and placement of passive water storage areas on agricultural land.

By including First Nations knowledge alongside scientific research on passive water storage on agricultural land, more holistic and effective floodplain management strategies that respect and utilize traditional ecological knowledge can be developed. This approach not only enhances flood resilience but also fosters stronger relationships with First Nations communities, recognizing their vital role in sustainable land management.

2.4.4 Environmental Impact

Future research should thoroughly investigate the environmental impacts of flood retention areas on actively farmed agricultural land. One key area of study should be the impact of flood retention areas on local ecosystems and biodiversity. Ecological studies are necessary to understand these shifts and develop strategies to minimize negative impacts. Another critical area of research is the effect of flood retention areas on water quality. Investigating the potential for retention areas to accumulate or spread contaminants, such as pesticides, is crucial for understanding their impact on both water quality and biodiversity. Lastly, evaluating the environmental sustainability of flood retention areas is essential. Research should assess how these areas affect natural processes such as water filtration, carbon sequestration and habitat provision. Understanding these effects can help balance floodplain management goals with the preservation of critical ecosystem functions. By addressing these research needs, we can develop floodplain management strategies that are both effective and environmentally sustainable.

Chapter 3. Review of Governance Framework

The literature review highlighted the possibility of passive water storage as a tool to enhance resilience to floods in the Fraser Valley. Despite the potential benefits to reduce flood risk and provide environmental co-benefits, a large inhibiting factor is the political landscape. The complex landscape of existing policies must be analyzed to assess which policies can inhibit or assist in the exploration and subsequent implementation of passive water storage. Implementing passive water storage requires a supportive governance framework that includes beneficial land-use policies, a focus on environmental protection and the willingness to explore new ideas.

This policy review will explore the current regulatory environment, identifying both enabling and restrictive elements of federal, provincial and local policy. This assessment also provides insight on opportunities for reform and advocacy to ensure that alternative floodplain management tools – such as passive water storage – can be effectively integrated into B.C.'s flood resilience efforts.

3.1 Policy Landscape

Floodplain management in British Columbia is a shared responsibility involving multiple actors across various levels of government and communities. The federal government is a significant actor that provides legislative direction (Fraser Basin Council, 2021a). It does so by providing research and recommendations through the creation of the *National Disaster Mitigation Strategy,* facilitating various funding programs and assisting in flood mapping, hydrometric monitoring, and climate expertise. Federal agencies such as Environment and Climate Change Canada, Natural Resources Canada, Public Safety Canada, Fisheries and Oceans Canada and others contribute expertise in weather, climate and environmental policy and protection

With constitutional jurisdiction over land use, water management and local works, the Government of B.C. is the main driver of flood policy development. It creates legislation, such as the 2024 B.C. Flood Strategy, which sets guidelines and standards for the provincial approach to floodplain management (Union of BC Municipalities, 2024a). The B.C Flood Strategy and other policies aim to cultivate collaboration, manage administration, conduct flood mapping, and provide funding and financial assistance programs. The Strategy is spearheaded by the Ministry of Water, Land and Resource Stewardship, but many ministries are involved in floodplain management within B.C. including the Ministry of Agriculture and Food, Emergency Management and Climate Readiness (EMCR) and Environment and Climate Change, among others. Floodplain management is also coordinated through the *Emergency and Disaster Management Act* headed by EMCR, which attempts to manage disaster risk through mitigation, preparation, response and recovery (Ministry of Public Safety and Solicitor General, 2024).

First Nations are integral to floodplain management on reserve lands and as rights holders within the Province. They facilitate flood risk assessments and mapping, create bylaws, operate and maintain dikes and conduct emergency preparation and response. Similarly, local governments are primary actors in floodplain management. They develop floodplain strategies and plans that prepare individual communities for hazards. Municipal and regional governments undertake risk assessments and flood modelling and mapping, operate and maintain critical flood infrastructure – including dikes – and collaborate with other stakeholders to ensure comprehensive management. These actors are critical because of their responsibility to implement and facilitate land use policies and floodplain management.

The various actors within floodplain management create a large web of legislation, policies and programs. Numerous policy areas can be utilized to advance floodplain management, while several policies and issues restrict the implementation of advanced floodplain management strategies in British Columbia. These policies include land use regulations and floodplain management policies.

3.2 First Nation Title

A major policy piece that affects land use in B.C. is First Nations rights to land. Within First Nation culture and Indigenous legal systems, rights are based on specific practices, customs and traditions of a particular Nation, and are not typically compatible with the ideas of ownership, property and occupation (Connell, 2023). Given that European settlers managed land through property and forced colonization upon Indigenous Nations across Canada, First Nations practices regarding land were lost. The government has now begun the process of correcting the wrongdoings, which has resulted in new ways of approaching First Nations rights to land.

In 1982, the Constitution was repatriated with an addition of section 35. Section 35 entrenched First Nations inherent rights to traditional land and territory, the rights that they have had since time immemorial (Hanson, n.d.). Within the Canadian legal framework, these rights manifest in property rights. As a form of land ownership, Aboriginal title to land permits the right to decide land use, exclusive use and occupation, economic benefits of the land and the right to manage the land (Lawrence, 2015). The 2014 legal case, *Tsilhqot'in Nation v British Columbia,* was instrumental in establishing Aboriginal title to traditional territory (*Tsilhqot'in Nation v. British Columbia*, 2014). In this case, the Tsilhqot'in Nation proved occupation of their traditional territory, without needing to prove exclusive use, and were granted title. This landmark ruling expanded the recognition of Indigenous title to land, allowing it to align more closely with traditional territories. It also clarified the relationship between senior governments and Nations with title. Specifically, restricting the Crown from economically benefiting from lands where First Nations have title rights (*Tsilhqot'in Nation v. British Columbia*, 2014). It is important to note that the Supreme Court of Canada affirmed that title rights granted to the Tsilhqot'in Nation do not transfer to privately owned property (Borrows, 2015).

The *United Nations Declaration on the Rights of Indigenous Peoples* (UNDRIP) is influential in Indigenous rights to land. UNDRIP was adopted by the Government of Canada in 2021, called the *United Nations Declaration Act* (UNDA) and by the Government of British Columbia in 2019, called the *Declaration on the Rights of Indigenous Peoples* (DRIPA) (Declaration on the Rights of Indigenous Peoples Act, 2019; United Nations Declaration on the Rights of Indigenous Peoples Act, 2021) UNDRIP, and effectively UNDA and DRIPA, grants Indigenous Peoples “the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used or acquired” and “the right to own, use, develop and control [those] lands, territories and resources” (United Nations, 2007, p. 19). Article 29 also states that “Indigenous peoples have the right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources,” (United Nations, 2007, p. 21).

In efforts to align the provincial legal framework with UNDRIP, the B.C. government has proposed amendments to the *Land Act*. These amendments would alter the ownership capacities of First Nations, permitting the direct purchase and ownership of land by First Nations (Depner, 2024). Additionally, amendments would allow for joint decision making power over publicly owned lands (Gage & Clogg, 2024). The Provincial Government would consult and cooperate with First Nations to obtain their free, prior and informed consent and to make decisions about publicly owned land together, in alignment with UNDRIP and DRIPA. With public land accounting for 95% of the provincial land mass, this could have major implications for floodplain management. However, after backlash from the business community, these amendments have been paused by the Provincial Government (Ball, 2024; Water Land and Resource Stewardship, 2024).

While the future of the B.C. Land Act is uncertain, both the Canadian and B.C. governments are committed to implementing UNDA and DRIPA. The Tsilhqot’in Nation v British Columbia case established a legal framework for proving title to land, but how this process will evolve with the full implementation of these federal and provincial acts remains unclear (Tsilhqot’in Nation v. British Columbia, 2014). This situation raises important questions: If title is legally returned to First Nations, how will floodplain management be affected? Will future flood management projects require FPIC from First Nations engaged in active title negotiations, from all First Nations with traditional territory in an area, or even from those without legal title? Will permits and referrals be necessary for project implementation, and what will that process entail? The S’ólh Téméxw Stewardship Alliance (STSA), composed of Stó:lō First Nations, is a group that screens referrals for all land and resource use projects on Stó:lo territories (S’ólh Téméxw Stewardship Alliance, n.d.b). STSA enforces the federal and Provincial Government’s duty to consult and assists the Stó:lo in making collective stewardship decisions. The STSA, through the People of the Rivers Referral Office, is currently engaged in consultation on the Trans Mountain Expansion Project (S’ólh Téméxw Stewardship Alliance, n.d.-a). The ongoing implementation of UNDA and DRIPA, alongside concurrent title negotiations, adds complexity to the policy landscape for floodplain management.

In the Fraser Valley region, the Katzie, Kwantlen and Semiahmoo First Nations have utilized the current political context to enter into negotiations with the federal government to assert title rights over 300 acres of crown land in Surrey (van Rooyen, 2024). This case is particularly interesting in the agricultural context because this land is currently under long-term land lease for farming. The current operators of the land advocated for the tract's inclusion in the ALR in 2023, arguing its importance in guaranteeing regional vegetable supply (Agricultural Land Commission, 2024; Heppell's Potato Corp., n.d.). In 2024, the ALC ruled that the lands would not be included in the ALR because the KSS pointed out that ALR inclusion would prevent their title claim (Agricultural Land Commission, 2024). In its decision, the ALC acknowledged the ALC Act is yet to be amended to align with DRIPA, but indicated a future duty to these principles as a reason for these lands' exclusion. Title negotiations for these lands are ongoing, but this case may inform future management of publicly owned land used for farming

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Evolving policies and the shifting political landscape profoundly impact floodplain management and the ability to implement passive water storage in B.C. As First Nations continue to assert rights and title to land, the requirement for FPIC, joint decision-making, and potential land title transfers introduce new layers of consideration for floodplain management projects. The uncertainties surrounding the future of the B.C. *Land Act* and the full implementation of UNDA and DRIPA could lead to significant changes in how floodplain management is approached, potentially permitting more collaborative, holistic and nature-based strategies that respect Indigenous rights and knowledge. This progressing landscape may complicate the planning and execution of flood mitigation measures, but it also presents opportunities for more sustainable and culturally respectful approaches to managing flood risks.

3.3 Land Use Regulations

Effective floodplain management in B.C. necessitates a comprehensive understanding of various land use regulations. Each regulation plays a crucial role in shaping land use practices and influencing the feasibility and implementation of passive water storage as a solution. Land use regulations are essential for maintaining a balance between development, sustainability and community well-being. They protect agricultural lands and promote responsible and efficient land use. Land use regulations also regulate the use of the floodplain to reduce risk and promote public safety. By exploring these land use regulations, this study aims to identify both the opportunities and constraints they present.

3.3.1 Agricultural Land Reserve

The *Agricultural Land Commission Act* (ALC Act) is the founding body that created the Agricultural Land Reserve (ALR) in 2002. The ALR restricts non-agriculture land use on certain private parcels of land to designate and protect the longevity of agricultural land in B.C. The Commission has a mandate to protect and preserve agricultural land and to encourage farming practices on the ALR. Specifically, the Commission has a duty to protect the size, integrity and continuity of the ALR

(Provincial Agricultural Land Commission, 2022a). In B.C., the ALR covers 5% of all land (Provincial Agricultural Land Commission, 2022b). In the Fraser Valley, specifically for upstream municipalities of the Lower Fraser River, the ALR is a dominant land-use designation as seen in Figure 5 (Emergency Planning Secretariat, 2024). The policies and regulations within the ALC Act take precedence over local bylaws as well as local and provincial land use policies or plans.

Often, the ALR is seen as a barrier to floodplain management, specifically because of Section 20(1). Section 20(1) states that ALR land must be used for farm use and is restricted for non-farm use. The ALC Act defines farm use as "an occupation or use of agricultural land for farming land, plants, mushrooms, truffles or animals" or "a farm operation as defined in the *Farm Practices Protection Act,"* (Agricultural Land Commission Act, 2002).[5] In contrast, non-farm use within the ALR is defined as anything "other than farm use, residential use or soil or fill use" (Agricultural Land Commission Act, 2002). Given that definition, the ALC Act seems to suggest that any flood mitigation activities would not be allowed to take place on the ALR.

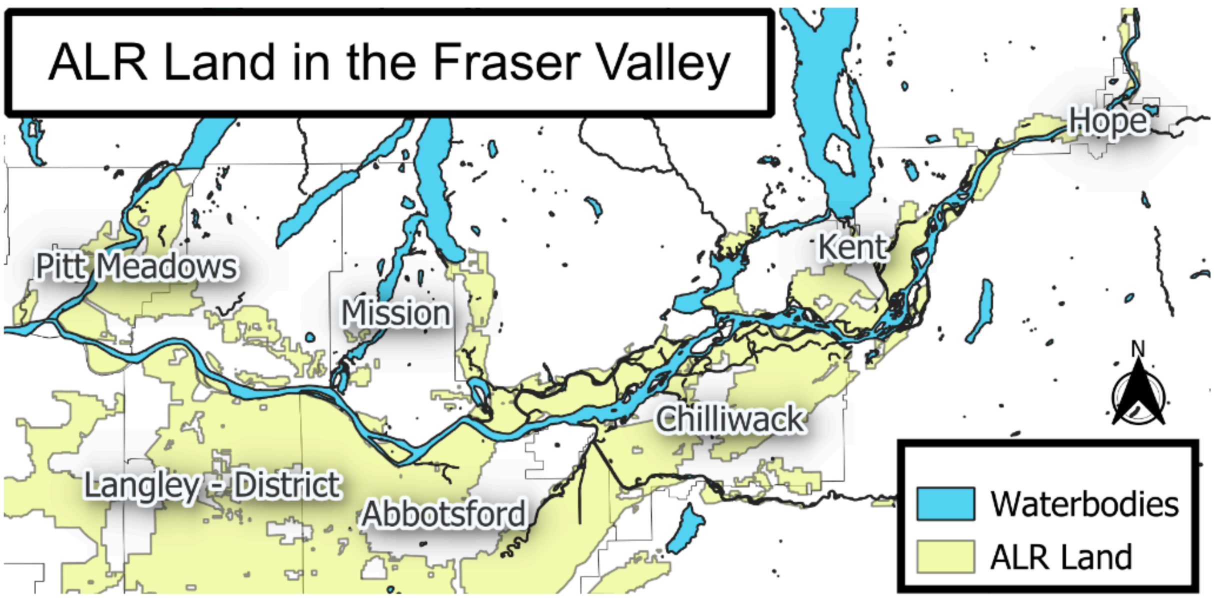

Figure 5: This map depicts agricultural land reserve and bodies of water in the Fraser Valley of British Columbia. ALR land dominates land use adjacent to the Fraser River.

It seems that Section 20(1) restricts floodplain management on ALR land, but other components of the ALC Act seem to provide a basis for the implementation of new floodplain management tools. In 2019, the *Agricultural Land Reserve Use Regulation* (B.C. Regulation 30/2019) was incorporated into the ALC Act (Agricultural Land Commission Act, 2019). Section 25(b) of the regulation permits the use of ALR

[5] The Farm Practices Protection Act defines farm practices as "growing, producing, raising or keeping animals or plants" as well as the practices associated with preparing the land for agriculture, including but not limited to the use of machinery and fertilizers (Farm Practices Protection (Right to Farm) Act, 1996)

land for "constructing, maintaining and operating [dikes and related pumphouses] for the purpose of drainage or irrigation or to combat the threat of flooding" (Agricultural Land Commission Act, 2019). This section authorizes the presence of the current diking system and may allow for the construction of new dikes on the ALR to mitigate flood risk. The definition of the term dike – "an embankment, wall, fill, piling, pump, gate, floodbox, pipe, sluice, culvert, canal, ditch, drain, or any other thing that is constructed, assembled, or installed to prevent the flooding of land" – is broad (Ministry of Water, Land, & Resource Stewardship, 2024, p. 35). This broad, inherently flexible, definition includes the mechanisms for passive water storage and does not seem to pose any restrictions for the implementation of passive water storage. This regulatory flexibility could be seized to promote passive water storage projects that demonstrate flood resilience and the ability to preserve agricultural productivity. The Agricultural Land Use Regulation provides a legal basis for passive water storage, but cannot mandate action on privately owned land in the ALR. To incentivize landowners, local governments can use bylaws, funding, grants and various programs to facilitate passive water storage projects.

There are other ways to permit non-farm land use on the ALR. Section 23(1) allows parcels under two acres to be exempt from land use regulations for non-farm use (Province of British Columbia, 2016). However, even with land use exemptions, the limited parcel size will negate any substantial mitigating impact of passive water storage. There are also ways to remove land from the ALR. Under section 30 of the ALC Act, the ALC may exclude land from the ALR, thus permitting non-farm use. Floods pose a serious risk to the size, integrity and continuity of farmland, so it may be in the best interest of the ALC to advocate for the removal of small tracts of land within the ALR to create passive water storage, thus protecting the ALR from flooding. The ALC, governments and citizens can apply to remove land from the ALR with the requirement of a public hearing (Provincial Agricultural Land Commission, 2024). However, land designated within the ALR has favourable tax provisions and thus reduced property costs (BC Assessment, 2021). Additionally, landowners are eligible for various agricultural programs, grants, subsidies and farm income stabilization programs (Province of British Columbia, 2024b). Consequently, due to the substantial individual benefit derived from ALR land designation, farmers would need significant incentives and convincing to be satisfied with their land being removed from the ALR.

3.3.2 Plans, Zoning and Bylaws

Under the *Local Government Act*, local governments in British Columbia are responsible for developing flood hazard area plans and bylaws. The Province of B.C. encourages local governments to draft their flood hazard area plans and bylaws in accordance with guidelines set by the Province, including the B.C. Flood Hazard Area Land Use Management Guidelines (Ministry of Water, Land, and Air Protection, 2004). However, provincial guidelines for local government policy development are often insufficient, as they typically provide only broad frameworks, leaving municipalities without the detailed, cohesive guidance necessary. Municipalities can create policies that benefit the jurisdictional boundaries of their own city, while exacerbating risk for other municipalities. The ability of local governments to independently determine policy has created a decentralized, siloed, uncoordinated approach to the region's floodplain management. Local government plans, zoning restrictions, bylaws and regulations vary greatly across municipalities in the Fraser Valley.

Local government control over implementing and facilitating floodplain management suggests they would initiate passive water storage projects. The provincial government could play a supportive role by amending the Flood Hazard Area Land Use Management Guidelines to use standardized approaches, facilitate inter-governmental coordination and ensure that local governments incorporate congruent bylaws and land use policies into their flood hazard area plans.

3.3.3 Farm Land Use Guides

The Province has a Guide for Bylaw Development in Farming Areas that sets standards for municipal bylaw development in the ALR and other areas zoned for agriculture (Ministry of Agriculture, Food, and Fisheries, 2020). This bylaw guide provides municipalities with optional frameworks that complement ALR regulations, related to zoning designations, lot size for permitted land uses, building setbacks, housing requirements and height limitations for buildings. The purpose of this guide is to protect and preserve the integrity of farmland and its practices. However, it does not provide guidance on floodplain management and floodproofing. This omission stems from the variability of flood risk across B.C., but it leaves municipalities to independently develop floodplain management strategies within local jurisdiction through bylaw creation. The flexibility within these guidelines can promote the uptake of diverse strategies by local governments.

The Flood Construction Levels and Setbacks for Farm Building Situations dictates the height of farm buildings and the distance at which they must be constructed from potential floodways (Ministry of Agriculture, 2008). The specific requirements, often enforced by bylaws or through flood mapping, change depending on an area's flood risk and topographic conditions. There are also generic guidelines, including a 30 m setback from watercourses and farm structure-specific requirements (Ministry of Agriculture, 2008). As demonstrated in Figure 6, these flood construction setbacks require a buffer from the floodway but do not restrict structures in the larger floodplain (Ministry of Agriculture, 2008). These regulations are designed to minimize damage to agricultural infrastructure during flood events by restricting structures in low-lying areas. Since these flood construction levels require buildings to be constructed a fixed distance from watercourses it creates a natural 'setback' area. This concept complements setback dikes. There is no predetermined width that makes a setback dike effective or successful for passive water storage. Therefore, the space created between watercourses and structures inherently creates space and potential opportunities for further passive water storage.

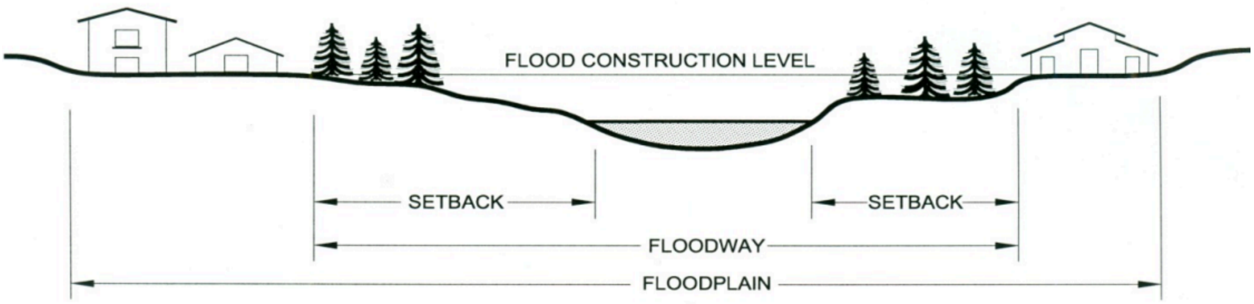

Figure 6: illustration of flood construction setback guidelines, including the designated floodway, floodplain, and required setback distances

The Agricultural Drainage Criteria is set by the B.C. Ministry of Agriculture to maintain proper levels of drainage on farmland (Ministry of Agriculture, 2002). Proper drainage is necessary to maintain adequate soil moisture levels for crop growth. The criteria require the removal of runoff of a five-day storm of a 10-year flood event within five days between November 1 to February 28 and the removal of a two-day storm of a 10-year flood event within two days between March 1 to October 31 (Ministry of Agriculture, 2002). Requiring the removal of water after storms may restrict the temporary storage of water from flooding and weather events on farmland. The *Agricultural Drainage Criteria* would thus require revision to permit passive water storage. Further research could inform policy changes to allow for passive water storage while ensuring practices that protect crop health. Adjusting the requirements could reduce flood risk for farmers, assist in downstream drainage and help manage drought conditions in the summer (Kurz et al., 2007).

3.3.4 Riparian Areas Protection Regulation

The B.C. *Riparian Areas Protection Regulation* (RAPR) aims to restore and protect the riparian areas of stream and river beds and prevent overdevelopment. The regulation governs any development or action within 30 m of a watercourse (Riparian Areas Protection Regulation, 2019). Riparian areas are the areas between land and waterways that host vegetation critical for maintaining ecosystem health, providing wildlife habitat and improving water quality (Riparian Areas Protection Regulation, 2019). Riparian areas also manage flood risk because their root systems enhance infiltration and slow water runoff, while vegetation slows flow and increases meandering (Division of Ecological Restoration, Massachusetts Department of Fish and Game, 2014). Passive storage projects, specifically dike setbacks, can include the reparation or creation of riparian areas to enhance passive storage as a floodplain management tool. The RAPR can therefore facilitate the implementation of passive water storage options within the current diking system and floodplain management space.

RAPR can only be utilized to advance passive water storage on non-ALR land (BC Ministry of Agriculture, Food and Fisheries, 2005). The ALR land-use regulations would need to be amended for riparian restoration to occur on ALR. This could involve amendments to include provisions for riparian protection and enhancement within agricultural areas. By aligning the objectives of riparian restoration and the ALC's goal to protect the integrity of agricultural land, it is possible to create an approach that supports both agricultural productivity and flood resilience.

3.3.5 Water Sustainability Act

B.C.'s *Water Sustainability Act* (WSA) regulates water diversion practices including the water diversion on agricultural land (Water Sustainability Act, 2014). Section 11 requires approval to alter any stream for water diversion. The permitted reasons for water diversion under the WSA include the use of groundwater, to extinguish fires, to drill a well or for the purposes of mining. Passive storage options often require water diversion or stream alteration, but this is not authorized under the WSA.

It is crucial to advocate for policy amendments that explicitly include floodplain management as a valid purpose for water diversion. The introduction of some passive water techniques (e.g. the Waffle©) would require the expansion of the WSA's list of authorized water uses to include floodplain management. This advocacy should substantiate the advantages of passive water storage for water sustainability and flood mitigation. By aligning the WSA with provincial floodplain management needs, B.C. can enhance its resilience to climate change whilst protecting its agricultural land from the increased threat of flooding.

3.4 Floodplain Management

Floodplain management regulations are critical to managing flood risk in the Fraser Valley as they protect communities, infrastructure and the environment. This section reviews key legislation that guides floodplain management in B.C. The *Dike Maintenance Act* mandates the upkeep and improvement of the dike system, while the new B.C. Flood Strategy is a move towards a more holistic approach to managing flood risk in the Province. Together these regulations comprise the key components of the Province's new floodplain management approach and influence how passive water storage can be integrated into the broader flood mitigation landscape.

3.4.1 Dike Maintenance Act

The *Dike Maintenance Act* (DMA) is the governing act of diking operations in the Province of B.C. It governs dozens of diking authorities – including local governments, diking districts and other government entities – who operate over 600 km of dikes, 400 floodboxes and 100 pumps in the Lower Mainland (Ministry of Environment and Climate Change Strategy, 2023). The DMA mandates the upkeep and improvement of the dike system and orders the routine inspection and reporting of the integrity of the dike system (Dike Maintenance Act, 1996).. Reports can trigger subsequent orders for inspection and any necessary construction, alteration and repair

The existing dikes in British Columbia, managed by the DMA, are outdated and inadequate, posing significant challenges to effective floodplain management. The management of the dike system was passed down to local governments in 2003 (Xu, 2023). Most local governments have failed to manage this responsibility. Dike maintenance is technically challenging, financially burdensome, and diking authorities have limited operational capacity for proper maintenance. Many diking authorities are overwhelmed by maintenance needs and often fail to comply with the Maintenance Act. As a result, dikes are not up to standard and diking authorities do not have additional capacity to even explore other flood solutions. Local governments are overburdened by dike maintenance and have failed to maintain the system, resulting in a heightened localized and regional vulnerability to flood risk.

A key aspect of the DMA's section 2(4) requires the written approval of the dike inspector to alter the dike system to include any of the following: new embankments, culverts, flood boxes, pipes, pump stations and excavations. This provision is critical to upkeeping the current system and implementing passive water storage. For example, the Waffle© would require approval from the dike inspector to alter embankments and culverts to create the Waffle's© containment areas. By leveraging section 2(4), there is potential for diking authorities to gain approval for necessary alterations to create passive water storages. This flexibility – to accommodate and include innovative strategies – can be essential to modernizing the diking system to build resilience to flood threats while retaining agricultural productivity.

3.4.2 B.C. Flood Strategy

The B.C. Flood Strategy, *From Food Risk to Resilience: a B.C. Flood Strategy to 2035*, is the provincial comprehensive flood plan (Ministry of Water, Land, & Resource Stewardship, 2024). This much-awaited plan was released in March 2024, but its implementation will be multi-phased and guided by an unreleased Flood Resilience Plan (Hoekstra, 2024; Ministry of Water, Land, & Resource Stewardship, 2024). The goal of the strategy is to holistically enhance provincial resilience to flooding through four key pathways, modelled after the Sendai Framework: 'Understanding Flood Risk', 'Strengthening Flood Risk Governance', 'Enhancing Flood Preparedness, Response, and Recovery' and 'Investing for Flood Resilience'. To fulfill the goals of each pathway, the strategy recommends a variety of actions. The Strategy was welcomed by stakeholders and rights holders as a step in the right direction, prioritizing collaboration, nature-based options and the development of provincial standards (Hoekstra, 2024). However, some emphasize that the lack of long-term, dependable funding and the continued burden of implementation on local governments threatens the Strategy's success.

There are aspects of the B.C. Flood Strategy that enable the exploration of new flood management tools, such as passive water storage. Enhancing Flood Preparedness, Response, and Recovery includes an action to "[enhance] pre- and post-disaster recovery planning," which involves exploring, designing and integrating climate-informed projects into flood planning to minimize future losses (Ministry of Water, Land, & Resource Stewardship, 2024, p. 30). This initiative highlights the need to review and adapt relevant codes and standards into evolving climate understandings, to facilitate the fortification of critical infrastructure from flood risk. Critical infrastructure is defined as “the systems, facilities, networks and assets essential to the health, safety, security or economic well-being of people and the effective functioning of government,” (Ministry of Water, Land, & Resource Stewardship, 2024, p. 35). This action item permits stakeholders to explore passive water storage as a means to improve flood resilience in pre-disaster planning. The flood governance model of this strategy also seeks to maximize environmental co-benefits, which can be enhanced through passive water storage.

The fourth pathway, “Investing for Flood Resilience,” provides tools for investment in new, holistic floodplain management tools. This pathway supports the integration of nature-based options that seek to maximize co-benefits, amplify holistic solutions, and upgrade the dike system. One recommendation focuses on enhancing flood avoidance investments to encourage the natural expansion and contraction of water and the natural storage of water on undeveloped floodplains. This support for nature-based options and the natural expansion of water supports passive water storage as a floodplain management tool. By leveraging the support, stakeholders in B.C. floodplain management can bolster flood protection for the Province, while capitalizing on the environmental co-benefits.

Investing for Flood Resilience also explores the potential of community-led managed retreat. The concept is understood as the proactive movement of assets within flood-prone areas that experience regular flooding. Managed retreat can include relocating people, residential areas, critical infrastructure or farming operations. It is often considered when the cost of mitigating flood risk exceeds the harm of returning land tracts to the floodplain. The B.C. Flood Strategy stimulates the exploration of the logistics and the financial assistance options necessary for managed retreat. Managed retreat, as a floodplain management option, could create ample space for passive water storage as people move away from the river, creating natural space for floodwaters. There have been calls to return land to the river. Stó:lō Tribal Council Chief Tyrone McNeil has said we need to provide room for the river to breathe and UBC researchers assessed the feasibility of Sumas Lake returning, concluding it was the best option to reduce flood risk (Bosshart, 2024; Gies, 2022). An economic analysis found that managed retreat of the Sumas lakebed would cost around $1 billion, while the continued management of the current diking system would cost the government $2.4 billion (Kearney, 2024). Managed retreat has been suggested as a potential option by some Fraser Valley municipalities and the B.C. Flood Strategy, but it has not been implemented and public opinion remains unclear (Currie, 2024). The concept will likely be met with resistance from other municipalities, residents and farmers who do not want to move away from their homes and land. The process is not only financially and politically burdensome but also emotionally onerous.

3.5 Discussion

The analysis of B.C.’s current governance framework and regulatory environment highlights both the opportunities and the challenges of integrating passive water storage as a floodplain management tool. The successful implementation of passive water storage is contingent upon navigating a complex political landscape and ensuring long-term, dependable funding. The analysis underscores the necessity of a supportive governance framework that includes beneficial land-use policies and both a willingness and flexibility to explore new, innovative floodplain management ideas.

There are aspects of current land use regulations, including those of the ALR, local government plans, farmland use guides, riparian area guides and the Water Sustainability Act, that strongly support the status quo of floodplain management. Yet, in each, there are prospects of amending policy and regulation to make space for passive water storage. Amendments and policy reform will be essential to create a conducive environment for passive water storage. Local governments and First Nations play critical roles in floodplain management, and their collaboration with provincial authorities is vital to a cohesive and holistic management strategy. Encouraging municipalities to incorporate congruent bylaws and land use bylaws into their flood plans can encourage the exploration of new ideas.

The policies and regulations that shape floodplain management in B.C. present both challenges and opportunities for the adoption of passive water storage. The DMA, which governs the upkeep of the B.C.'s dike system, imposes strict maintenance requirements on local governments, often straining their capacities. Despite these demands, the DMA does not explicitly prohibit other floodplain management techniques, offering a potential pathway for integrating passive water storage into the existing system. By leveraging specific provisions, such as section 2(4), there is potential to modernize the dike system and incorporate passive water storage to enhance flood resilience while supporting agricultural productivity. However, the provincial inspector of dikes has exclusive authority to approve the alteration and construction of new diking projects (Ministry of Environment and Climate Change Strategy, 2024). This centralization of power leaves ambiguity regarding the extent to which modernization and innovation can be pursued in future projects. The *B.C. Flood Strategy* provides a promising path forward, enabling the advancement of innovative floodplain management techniques to enhance resilience and sustain productive farming in the face of climate change. By promoting investments in flood avoidance and nature-based options, the B.C. Flood Strategy supports the development of projects that leverage holistic, natural processes to manage water. Although there are strong actionable items in this Strategy, the lack of sufficient, long-term funding for municipalities, who bear the brunt of implementing new ideas and maintaining the existing dike system, cast doubt on the potential success of the B.C. Flood Strategy.

The integration of passive water storage into B.C.'s floodplain management requires a supportive governance framework that can foster financial investment and intergovernmental collaboration. Introducing passive water storage into the policy landscape has the potential to address the increasing flood risks posed by climate change while preserving agricultural productivity. Collaborative efforts between provincial and local governments, along with input from agricultural and environmental stakeholders will be essential in developing a regulatory environment that supports sustainable farming and effective floodplain management.

The policies and regulations that shape B.C.'s floodplain management are both hurdles for passive water storage uptake as well as having the potential to create space. The DMA guides floodplain management in B.C. by governing the quality of the dike system. While the DMA's strict maintenance requirements on local governments burden capacity challenges, it does not explicitly prevent the adoption of innovative floodplain management techniques like passive water storage.

Chapter 4. Review of Potential Funding Mechanisms

Adequate funding for floodplain management projects is a persistent and substantial challenge. There has been an increased focus on climate mitigation and adaptation funding in recent years. The 2021 atmospheric floods spurred increased awareness, planning and funding for flood recovery, including the Disaster Financial Assistance Arrangement (Public Safety Canada, 2024). Yet, many projects, farms and municipalities suffer from budget constraints, limiting their ability to advance floodplain management strategies.

Effective floodplain management not only requires strong management tools and robust policies but also strong incentives for implementation. Compensation and incentive mechanisms are vital in encouraging farmers to adopt passive water storage techniques on agricultural land. These mechanisms can be financial incentives, grants and subsidies from governmental and non-governmental bodies. Many programs are aimed at mitigating the costs associated with implementing practices that reduce hazard and flood risk, promote sustainability and encourage innovation.

With economic and political support, funding programs help ensure farmers can contribute to local, regional and provincial flood resilience while maintaining their financial livelihoods. Understanding the variety and scope of compensation and incentive mechanisms is crucial for encouraging the widespread adoption of passive water storage solutions, ultimately enhancing both agricultural productivity and risk management practices.

4.1 Government Assistance

Government assistance programs, both federal and provincial, offer a range of financial incentives, grants and subsidies aimed at reducing the costs associated with implementing sustainable farm practices, enhancing agricultural productivity and integrating mitigative floodplain management tools. Understanding the availability and scope of government assistance programs is essential to overcoming financial barriers and advancing comprehensive and holistic floodplain management strategies.

4.1.1 Federal Government

Disaster Mitigation and Adaptation Fund

The Disaster Mitigation and Adaptation Fund (DMAF) is a federal funding program through Housing, Infrastructure and Communities Canada (Infrastructure Canada, 2018a). It aims to support the federal government's climate action efforts including the Canada Adaptation Action Plan and the National Adaptation Strategy. This funding stream supports the construction and repair of public infrastructure to build community resilience against disaster and climate-related risks.

The DMAF was launched in 2018 and has a budget of more than $3.8 billion from 2018 until 2032 (Infrastructure Canada, 2022). Applications must include projects valued over $1 million and can receive funding support of up to 50% for provincial projects, 40% for municipal projects and 100% for First Nations projects (Infrastructure Canada, 2022). This fund has previously supported projects involving water diversion, wetland restoration and setback dikes (Province of Manitoba, n.d.-a). Successful applications demonstrate how a project can reduce community risk, mitigate future losses and provide co-benefits (Infrastructure Canada, 2018a). The DMAF also selects projects that offer innovative solutions incorporating natural infrastructure. Passive water storage solutions could be instituted through this fund because of the tool's ability to meet many of these criteria.

Emergency Management Assistance Programs

Through Indigenous Services Canada (ISC), the Emergency Management Assistance Programs (EMAP) provide financial assistance for emergency management including hazard mitigation, preparedness, response and recovery (Indigenous Services Canada, 2018). This grant supports First Nations to increase on-reserve resilience to hazard events, including wildfires, floods, storms, earthquakes and health emergencies. EMAP supports First Nations to mitigate risk and prepare for hazards through non-structural projects.

This non-structural funding may not necessarily cover all the aspects of implementing passive water storage, because it may require some structural components. However, through the mitigation and preparedness pillars, EMAP can fund projects that include hazard risk assessment and management plan development. This funding can also be used on agricultural land that is on reserve. First Nations can apply for reimbursement for project costs. From 2012 to 2023, EMAP covered $175 million in project costs in these two categories (Indigenous Services Canada, 2018) .

First Nation Infrastructure Fund

The First Nation Infrastructure Fund (FNIF), offered by ISC, can be utilized to upgrade and build infrastructure resilience within First Nation communities. Projects can occur "on reserves, on Crown land and on land set aside for the use and benefit of a First Nation", and off-reserve so long as the primary beneficiary is a First Nation community (Indigenous Services Canada, 2022). Applicants can include any Indigenous beneficiaries, organizations, and certain private and public groups. Funding can be applied to nine categories of projects. Of the nine project categories, FNIF can support passive water storage by financing structural mitigation projects, previously called 'disaster mitigation' projects (Indigenous Services Canada, 2022). Funding under the structural mitigation stream of FNIP can be accessed so long as the project cannot be funded by EMAP. The goal of FNIP structural mitigation projects is to support community health, safety and resilience by altering the design and construction of infrastructure to be more resilient to hazards. This annual funding stream aims to support the completion of long-standing infrastructure needs and can provide up to $10 million annually (Indigenous Services Canada, 2022). Successful applications to this funding stream must have a First Nation Infrastructure Investment Plan that expands on the extent and details of the project.

4.1.2 Provincial Government

Emergency Management Financial Supports

The Emergency Management Financial Supports is a suite of four funding programs available for local governments and First Nations and offered by the Province of B.C (Ministry of Emergency Management & Climate Readiness, 2024b). These four programs aim to enhance community resilience and preparedness against various natural hazards, providing crucial financial resources to support the implementation of effective emergency management strategies. The funding streams within this suite cater to different aspects of disaster management, ensuring comprehensive coverage for prevention, preparedness, response and recovery activities. Of the four streams, the Community Emergency Preparedness Fund, Disaster Resilience and Innovation Funding Program and the Adaptation, Resilience and Disaster Mitigation Program (Green Infrastructure), attempt to mitigate flood hazards. These three programs will be discussed below.

Community Emergency Preparedness Fund (CEPF)

The Community Emergency Preparedness Fund (CEPF), offered through the Union of British Columbia Municipalities (UBCM), aims to help local governments, regional governments and First Nations build capacity, enhance preparedness for disasters, and mitigate risks from natural hazards. Since its inception in 2017, the CEPF has adapted its funding categories to address evolving needs. The 2024/25 CEPF includes six funding streams, with the "disaster risk reduction - climate action" (DRR-CA) stream applicable to floodplain management and passive water storage projects (UBCM, 2024).

The DRR-CA stream assists applicants in reducing risks from future disasters caused by natural hazards and climate-related risks. It focuses on developing knowledge of natural hazards and implementing effective strategies to prepare for, mitigate and adapt to these risks (UBCM, 2024). The DRR-CA funding can be applied to three categories: foundational activities (e.g. knowledge building, risk mapping), non-structural activities (e.g. land use planning, temporary mitigation equipment) and small-scale structural activities. Funding can total $150,000 for the first two categories and up to $5 million for the third category (UBCM, 2024). The program defines small-scale structural projects as the “new construction and/or modification or reinforcement of existing publicly, provincially, and First Nations owned Critical Infrastructure, First Nations owned buildings, or publicly owned buildings, including natural infrastructure” (UBCM, 2024, p. 7). CEPF projects could include installing structural flood protection works, upgrading and modernizing existing structural flood protection works, constructing flood conveyance works, decommissioning of dams or dikes and restoring floodplains and wetlands. This fund is highly compatible with the technical needs of passive water storage.

Disaster Resilience and Innovation Funding Program

The Disaster Resilience and Innovation Funding Program (DRIF) is an annual program that supports local governments and First Nations to enhance resilience to disaster events. It has two main objectives. Firstly, it aims to fund activities that build community resilience through gathering data, building partnerships and supporting adaptation planning (Ministry of Emergency Management & Climate Readiness, 2024a). Secondly, the DRIF funds structural and non-structural disaster risk reduction projects. Eligible proponents, local and First Nation governments, can prepare applications, called an Expression of Interest. Passive water storage can be advanced through this stream by its ability to fund structural projects (e.g. construction or upgrading of dikes, retention ponds and floodwalls and natural infrastructure projects such as wetland restoration). This funding program will cover 100% of eligible costs up to $400,000 for non-structural projects and up to $15 million for structural projects.

Adaptation Resilience and Disaster Mitigation Program

The Adaptation, Resilience and Disaster Mitigation (ARDM) Program is offered as part of the Government of B.C.'s larger Green Infrastructure Program. The ARDM specifically supports projects that enhance the structural and natural capacity to adapt to the impacts of flood events. Applicants can include individual municipalities or First Nations and joint applications from regional districts, promoting a holistic, united approach to floodplain management (Emergency Management BC, 2022). Eligible projects can involve building and reinforcing public infrastructure, or bolstering natural infrastructure, to prevent, mitigate or protect against floods. This can include constructing flood conveyance works, improving and modernizing existing permanent structural flood protection works and other projects. Passive water storage solutions can be supported by this program due to their ability to enhance flood resilience and mitigate flood risk.

The ARDM was initiated in 2018 and planned to invest nearly $82 million over five years (Emergency Management BC, 2022). Local governments and First Nations were eligible to apply and receive up to $10 million and joint applications (between more than two entities) could receive $20 million. This program was offered as a joint cost-sharing fund where the federal and provincial governments covered up to 73.33% of a project's costs for local governments and 90% of the costs of projects by Indigenous recipients. The program began intake in 2022, and projects began in 2024 and must be completed by 2027. The ARDM has committed all of its funding, and though it is currently closed it is unclear if it will reopen.

Community Works Fund

The Community Works Fund (CWF) is a component of the Canada Community-Building Fund (CCBF), managed through the UBCM. The CWF, and the CCBF broadly, is an annual, predictable and automated stream of funding. Over a 10-year period, UBCM will facilitate the automatic, annual transfer of the CWF to local governments, totaling $1.3 billion (Union of BC Municipalities, 2022). The CWF gives local governments the agency and discretion to select and approve projects that align with their community needs. The CWF supports a wide range of projects, particularly those enhancing community resilience to climate-induced events. Resilience projects increase a community's ability to endure, respond to, and recover from damage caused by such events (Union of BC Municipalities, 2022). Eligible resilience projects include the new construction, modification and reinforcement of public and natural infrastructure to prevent, mitigate, or protect against climate-induced disasters. Recently, the resilience category was expanded to permit the construction of dikes and the restoration of wetlands and natural infrastructure to reduce flood risks among other projects (Union of BC Municipalities, 2024b). This fund can therefore support the introduction of passive water storage as a floodplain management tool in the Fraser Valley, helping store excess water and mitigate the impact of flooding.

4.2 Non-Government Assistance

Investment Agriculture Foundation

Investment Agriculture Foundation of B.C. (IAF) is a non-profit organization supported financially by the Province of B.C. Its mission is to facilitate funding programs that encourage successful B.C. agriculture operations and a thriving food sector. The organization is composed of various partners across the agriculture industry, including those from agribusiness, food and beverage processing, general farm interest, grains and seeds, horticulture, livestock, fruits, and other partners (Investment Agricultural Foundation, n.d.-a). Its funding is sourced from the Agri-Foods Futures Fund (AFFF), Co-created by the federal and provincial governments, The AFFF strives to keep food production viable and stable through the changing climate and aims to support environmental best practices (Agriculture and Agri-Food Canada, 2010) The subsequent five subsections discuss programs offered within the scope of the IAF.

Environmental Farm Plan

The Environmental Farm Plan (EFP) Program assists farmers in reducing the environmental impact of agriculture and encourages sustainable practices (Ministry of Agriculture and Food, 2022). Ranchers, farmers and First Nation agricultural operators can apply for a farm assessment to join the program. The program matches advisors, on a farm-by-farm basis, to complete an agri-environmental risk assessment. The advisor assists with the completion of a workbook to identify potential regenerative agriculture, environmental and climate risks (Investment Agriculture Foundation, n.d.c). Each participating farmer is also given a multi-chapter reference guide detailing the environmental concerns, relevant legislation and beneficial management practices (BMP) associated with specific farm practices. It defines BMP as "a farm practice which, from experience, provides environmental protection when used to carry out a particular farm activity" (BC Ministry of Agriculture, Food, and Fisheries, 2021, pp. 1-4). The EFP encourages projects that focus on farmsteads, livestock, crops, pest management, nutrient application, biodiversity, soils, water, air, stewardship areas and climate change. There is no cost to the risk assessment and farmers can voluntarily choose to implement their plan. The benefits of the EFP include increased knowledge of sustainable farmland management and practices, EFP Farm status and positive relationships with environmental agencies (Ministry of Agriculture and Food, 2022). Perhaps the most substantial benefit to the EFP, is that an active EFP is required to be eligible for BMP Program funding.

Beneficial Management Practices Program

The BMP program is offered through the EFP Program. It is a cost-share incentive program that is designed to encourage environmental consciousness and sustainable farming practices by implementing the EFP (Ministry of Agriculture and Food, 2024a). The BMP Program seeks to both protect farmers from adverse environmental challenges and incentivize the use of technologies and practices that encourage agricultural sustainability and climate mitigation and adaptation (AgriService BC, 2023a). The BMP program supports seven categories of projects, four of which can assist the implementation of passive water storage – plans, technical assessments or engineered designs, riparian & grazing projects, and water infrastructure projects (Investment Agriculture Foundation, n.d.c). By supporting water infrastructure projects, the BMP program enables farmers to develop and maintain systems that can store excess water during flood events, thereby mitigating the impact of flooding on agricultural land. This not only protects the farms from immediate damage but also contributes to long-term climate resilience. The BMP program has $3.5 million in available funding for the 2024/25 year (Investment Agriculture Foundation, n.d.-a).

Fraser Valley Flood Mitigation Program

The Fraser Valley Flood Mitigation program is a subprogram of the BMP funding specifically for high flood-risk areas within the Fraser Valley. This multi-year flood mitigation funding, provided by the IAF through the Ministry of Agriculture, has two streams (Investment Agriculture Foundation, n.d.-a). The first stream is for mitigation planning and community mitigation projects, including but not limited to, floodwater mitigation, floodgate or culvert improvements and the redesign and replacement of infrastructure. It permits community-scale projects but does not fund integrated, full-scope flood mitigation plans. The second stream supports on-farm resilience projects, including projects like riparian, ecosystem and habitat restoration (Investment Agriculture Foundation, n.d.-a). Projects must take place within the geographic areas of BC Electoral Areas B-H, Hope, Kent, Harrison Hot Springs, Chilliwack, Mission, Abbotsford and the Township of Langley. This sub-program differs from the BMP program because it offers a greater cost-shared ratio as it will cover 90% of project costs from $10,000 up to $100,000 (Ministry of Agriculture and Food, 2024a).

This program can be instrumental in passive water storage implementation because it supports floodwater mitigation planning and projects, and infrastructure redesign. The funding stream's dedication to communities within the Fraser Valley means that there will be less competition for critical flood mitigation funding. This investment in regional flood resilience projects will also produce benefits for all adjacent communities.

Extreme Weather Preparedness for Agricultural Program

The Extreme Weather Preparedness for Agriculture (EWP) Program supports farmers in building climate resilience within their agricultural operations (Ministry of Agriculture and Food, 2024b). Its primary goal is to help mitigate the costs of necessary infrastructure to prepare for, withstand and recover from extreme weather events. The EWP encompasses four funding streams: wildfire preparedness, flood preparedness, extreme heat preparedness and innovation projects (Investment Agriculture Foundation, n.d.-b). Passive water storage can be advanced as a mitigation tool in both the flood preparedness and innovation streams. The program operates on a cost-sharing basis, with the province covering 40% of the infrastructure funding. After its launch in 2022, the EWP program has allocated nearly $4 million to various projects, including over $2 million in 2024, each receiving up to $35,000 (Townsend, 2023). In 2023/24, four flood preparedness projects and nine innovation projects were approved, making up 8% of the funded initiatives (AgriService BC, 2023b). Although the application process for the 2023/34 year is closed, it may reopen for the 2024/25 year if additional funding is secured (Ministry of Agriculture and Food, 2024b).

Farmland Advantage

Farmland Advantage is a program offered through IAF that provides compensation for ecosystem restoration, called Payment for Ecosystem Services (Investment Agricultural Foundation, n.d.-b). The program facilitates projects that aim to protect, enhance and restore natural areas on farms that can help purify water, support salmon species, retain carbon and clean the air. Past projects include but are not limited to, establishing stream setbacks, undertaking reforestation or removing debris (Investment Agricultural Foundation, n.d.c). These projects may not directly create passive water storage outcomes, but they have co-benefits that complement passive water storage.

In addition to the benefits returned to farms through increased environmental and farm sustainability, Farmland Advantage provides farmers with annual monetary compensation for successfully implemented projects. Individual farmers and First Nation agricultural operators within priority regions (i.e. Kootenay/Boundary, South Coast, Thompson/Okanagan, West Coast) can apply to partner with Farmland Advantage (Healthy Watersheds Initiative, 2021). The program is primarily funded by Environment and Climate Change Canada's Species at Risk Partnerships on Agricultural Lands program and the Community-Nominated Priority Places for Species at Risk initiative (Ayers, 2023). Between 2021 and 2025, Farmland Advantage will distribute nearly $600,000, with applicants eligible to receive between $1,500 and $3,000 per project (Ayers, 2023).

4.3 Discussion

Funding mechanisms offered by the federal and provincial governments and non-government organizations that could be utilized to advance passive storage in the Fraser Valley are limited. Some of these programs focus solely on the recovery aspects of floodplain management, maintaining the status quo without significantly enhancing the resilience to future floods, thereby limiting passive water storage opportunities. The DMAF, for instance, is designed to increase the "preparedness and readiness [of local governments] to respond to disasters and emergencies" (Public Safety Canada, 2022). However, much of the allocated $2 billion was distributed to repair damaged infrastructure to previous conditions, rather than improving existing infrastructure to better withstand future events. With this focus, the DMAF denied the applications from three B.C. municipalities seeking to restore and improve infrastructure destroyed by the 2021 floods (Joannou, 2024). Furthermore, much of the funding was allocated to structural and mechanical solutions, with only a small percentage supporting innovative projects and nature-based options (Infrastructure Canada, 2018b) As flood events become more frequent and intense due to climate change, the limited funding available forces municipalities to compete for critical resources, with potentially disastrous implications.

Beyond the competition for funding among local governments, some programs struggle to maintain sustained financial support. The DMAF is on track to exhaust its funding before its scheduled end date (Infrastructure Canada, 2018a; Major, 2022). The EWP was open for two years but has yet to announce whether it will be renewed for 2025 (Ministry of Agriculture and Food, 2024b). Similarly, the ARDM program, which supported projects slated to finish in 2027, has yet to announce a second application phase (Emergency Management BC, 2022). Municipalities, especially in B.C. that are required to maintain flood resilience through DMA, need reliable funding sources to effectively plan and address all aspects of emergency management including mitigation, preparedness, response and recovery.

Chapter 5: Conclusion

Understanding Flood Risk in the Fraser Valley

Floodplain management in the Fraser Valley involves a complex interplay of governance structures, agricultural practices and socio-economic considerations. The region is highly vulnerable to flood risk, shaped by its geography, climate and proximity to the Fraser River and its tributaries. This risk underscores the need for cohesive, innovative and adaptable strategies. The concept of passive water storage, where agricultural land can act as natural reservoirs, offers a promising approach to mitigating flood risks while maintaining agricultural productivity and resilience. However, to effectively integrate this strategy, a deeper understanding of local vulnerabilities and flood dynamics is essential.

Literature Review of Passive Water Storage Techniques

The technical aspects of passive water storage highlight the need for a tailored approach that accounts for the Fraser Valley's unique risk of flooding and its physical capacity for passive water storage. Research must account for the potential benefits and limitations of passive water storage in the agricultural sector. Collaboration with farmers is key to understanding its impact on the ability to grow certain crops, their yields and wider impacts on soil and water. First Nations must be meaningfully engaged in this process to ensure that floodplain management strategies are both culturally relevant and effective, integrating traditional ecological knowledge with modern techniques for a more holistic approach. By carefully balancing these factors, passive water storage can become a significant component of floodplain management in the region. Ongoing research will be crucial in adapting the application of passive water storage, ensuring it meets the goals of flood control, agricultural sustainability, and a thriving floodplain.

Review of Governance Framework

Effective floodplain management in the Fraser Valley requires a robust governance framework that coordinates efforts across the local, provincial and federal levels and with First Nations. The current policy landscape does not explicitly restrict the use of passive storage. There are aspects of various policies and regulations that can be leveraged to encourage its implementation. Specifically, the B.C. Flood Strategy offers a promising future for B.C. The successful adoption of strategies like passive water storage depends on the flexibility of the governance framework, the degree of cohesive collaboration among all stakeholders (including farmers) and dependable funding.

Review of Potential Funding Mechanisms

Funding and incentive mechanisms are vital in supporting the implementation of all floodplain management strategies including passive water storage. Government assistance programs, both federal and provincial, along with non-governmental funding initiatives, provide the financial resources necessary to advance these projects. By offering targeted incentives, such as grants and subsidies, these mechanisms encourage the adoption of sustainable practices that simultaneously contribute to both flood resilience and agricultural viability. Future efforts should focus on expanding and diversifying funding sources, ensuring that farmers and local governments have the support they need to implement effective passive water storage solutions. Continued investment in these mechanisms will be crucial for scaling up innovative strategies and achieving long-term flood resilience in the Fraser Valley.

Discussion

These collective insights into the technical considerations of passive water storage and existing floodplain management strategies, governance frameworks and financial mechanisms point to a future where the Fraser Valley can achieve greater resilience against flood risks. Through ongoing research, collaboration and policy refinement, there is potential to develop a comprehensive approach that balances flood resilience with agricultural productivity. A step already identified is using GIS technology to facilitate the overlay of various data layers, including topography, agricultural lands like the ALR, infrastructure, buildings, and population distribution to combine and analyze these datasets to identify potential areas viable for passive storage. This approach is essential to enhance flood resilience while considering the region's agricultural needs. A sustained commitment to innovation and adaptability will be key to securing a resilient and sustainable future for the region.

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