Weathering the Storm: Advancing the Implementation of Nature-Based Solutions for Flooding Due Extreme Weather in British Columbia

by

Melissa Lappage

B.A. (Hons., Political Science), University of New Brunswick, 2021

Project Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Public Policy

in the
School of Public Policy
Faculty of Arts and Social Sciences

SIMON FRASER UNIVERSITY
Spring 2023

Declaration of Committee

Name:	**Melissa Lappage**
Degree:	**Master of Public Policy**
Title:	**Weathering the Storm: Advancing the Implementation of Nature-Based Solutions for Flooding Due to Extreme Weather in British Columbia**
Committee:	**Chair: Grace Jaramillo** Term Assistant Professor, Public Policy
	Alaz Munzur Supervisor Term Assistant Professor, Public Policy
	Mohsen Javdani Examiner Associate Professor, Public Policy and Urban Studies

Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University

or has conducted the research

c. as a co-investigator, collaborator, or research assistant in a research project approved in advance.

A copy of the approval letter has been filed with the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Simon Fraser University Library
Burnaby, British Columbia, Canada

Update Spring 2016

Abstract

The increasing frequency of extreme weather events such as heat domes and flooding is evidence of British Columbia's lack of effective climate adaptation. One measure to improve the region’s resiliency to the impacts of climate change is through the utilization of nature-based solutions (NbS). However, the implementation of NbS is hindered by a range of barriers that need to be overcome to increase its adoption. This study aims to better understand the specific barriers that BC is experiencing when it comes to implementing NbS and what can be accomplished to advance the use of NbS for flooding caused by extreme weather. A combination of qualitative approaches, including a literature review, semi-structured interviews, jurisdictional scan, and multi-criteria analysis, were used to produce and analyze four potential policy options. This study recommends a policy bundle consisting of legislation for Conservation Authorities and a Environmental Impact Bond.

Keywords: nature-based solutions; extreme weather flooding; climate adaptation; barriers to implementation; environmental policy; British Columbia

Dedication

To all the individuals working tirelessly in the environment and climate change field; your commitment to finding sustainable solutions, advocating for policy change, and raising awareness is an inspiration to us all. Your work is not easy, and as a global community, we owe you our gratitude and support. Let us continue to work together towards a cleaner, healthier, and more sustainable future.

Acknowledgements

I want to thank my supervisor, Dr. Alaz Munzur, for her time, guidance, and support, especially in challenging moments. Without your help, this would not have been possible. I also want to thank Dr. Mohsen Javdani for their thoughtful questions and comments as an Examiner. Your perspectives were valuable and I appreciated your interest in my research.

Thank you to my parents who have unconditionally supported me throughout my master's program. Additionally, thank you for encouraging me to pursue my passion for change in the field of environmental and climate policy. Your support and encouragement mean the world to me.

I want to give a big shout-out to the friends that have supported me to do my best throughout this program and the capstone process. You all have been there through the good and hard times, in which I cannot express the endless gratitude I have for all of you. I specifically want to thank the seventh-floor girlies (you know who you are) for the long nights/weekends, endless laughs, and meaningfully suffering that we endured together. More so, I am immensely thankful for M.H, C.B, S.B, and A.T for the support, encouragement, friendship, and love.

Table of Contents

List of Tables

List of Figures

List of Acronyms

NbS	Nature-based Solutions
BC	British Columbia
EIB	Environmental Impact Bond
ICSP	Integrated Community Sustainability Plan
IUCN	International Union for Conservation of Nature
FEMA	Federal Emergency Management Agency
ECCC	Environment and Climate Change Canada
SFU	Simon Fraser University
MNAI	Municipal Natural Asset Initiative
FRB	Forest Resiliency Bond
PESP	Payment for Environmental Services Program
PWS	Payment for Watershed Service
DOEE	Department of Energy and Environment
SRC	Stormwater Retention Credit
ARDM	Adaptation, Resilience, and Disaster Mitigation

Executive Summary

Nature-based solutions (NbS) offer a significant yet under-utilized opportunity to address flooding resulting from extreme weather events in British Columbia (BC). BC's flood management policies are fragmented across various levels of government and local authorities, and its climate adaptation strategy lacks specific details and actionable measures for the implementation of NbS. Despite the numerous benefits of NbS, several barriers continue to impede their widespread adoption in BC. Thus, the policy problem that this study is addressing is that there are too many barriers associated with the implementation of NbS for flooding due to extreme weather. By identifying and addressing these barriers, the study seeks to promote the adoption of NbS and create a more resilient and sustainable future for BC.

The results of the literature review and seven expert interviews conducted for this study have identified specific barriers to the adoption of NbS that are unique to BC. These barriers include the need for proof of concept and funding opportunities, as well as issues related to institutional fragmentation. Given that these barriers are interrelated, this study focused on reducing the barrier of proof of concept and funding. A jurisdictional scan revealed feasible options in Ontario, Prince Edward Island, and Washington, DC, which could be adjusted to fit BC's context. Four policy options were then evaluated against five criteria and measure to identify key trade offs to determine the most effective policy at reducing barriers related to implementing NbS.

To overcome the obstacles associated with implementing NbS and to promote their widespread adoption, it is recommended that BC adopts a policy bundle consisting of Conservation authorities and a Environmental Impact Bond (EIB). This policy bundle is the most effective way to advance the number of pilot projects for NbS and provide necessary funding for their successful implementation. The policies are designed to be targeted at a watershed level, resulting in a high-performance impact that can significantly reduce flood risks from extreme weather events. The proposed policy options have the potential to equip BC with the necessary tools to build resilient infrastructure that can withstand the challenges posed by climate change.

Chapter 1.

Introduction

BC is particularly vulnerable to coastal, riverine, and urban flooding, which affects infrastructure, services, ecosystems, and human health (Ministry of Environment and Climate Change Strategy, 2019 & Gifford et al., 2022). In November 2021, record-breaking precipitation caused floods, landslides, several mortalities, and closed highways, putting the province in a State of Emergency. Over 20,000 people evacuated their homes, and businesses, farms, and livestock were heavily impacted (Schmunk, 2021). The estimated damages caused by the extreme weather event are between $450 million and $515 million (Insurance Bureau of Canada, 2022). Thus, BC needs to take adequate adaptation measures to reduce the risk and impacts of flooding due to extreme weather.

The 2021 extreme weather flooding in BC revealed the inadequacy of current flood management and adaptation strategies, highlighting the need for more resilient infrastructure. One solution is the implementation of nature-based solutions (NbS), which offer a holistic approach to climate adaptation. NbS can prevent flooding and increase storage capacity by absorbing 90% of precipitation when restoring riparian buffers (Luedke, 2019). NbS also provide benefits like improved water quality, enhanced biodiversity, and improved human health (Diaz et al., 2019; Shaw et al., 2020), making them effective against climate risks like flooding caused by extreme weather.

NbS provide multiple benefits, but there are barriers to their implementation in BC. BC has not set targets or legislation to enforce NbS as a preventative measure for climate change impacts. The globally recognized barriers of proof of concept, funding, and institutional fragmentation are hindering BC's adoption of NbS. Thus, to advance the utilization of NbS, the policy problem being address in this study is that there are too many barriers associated with the implementation of NbS for flooding due to extreme weather.

This study aims to identify and overcome barriers to implementing NbS for extreme weather-related flooding in BC. It uses qualitative research to evaluate policy options and provide recommendations. The importance of understanding NbS and policy

gaps are discussed in chapters two and three, while chapter five reports on interview findings, and chapter six provides a jurisdictional scan of best practices for NbS. Chapters seven and eight present a policy framework and four potential policy options. The remaining chapters evaluate and analyze those options, make recommendations, and provide a implementation plan. Overall, the goal of the study is to facilitate greater adoption of NbS and build resilience against climate change in BC.

Chapter 2.

Background

2.1. Flood Risk in British Columbia

The BC Climate Action Secretariat, in collaboration with ICF Climate Center, developed a risk assessment framework for evaluating the likelihood of 15 climate risks in BC by 2050 (Ministry of Environment and Climate Change Strategy, 2019). This framework prioritizes adaptation responses by the provincial government by assessing the consequences of each event (Ministry of Environment and Climate Change Strategy, 2019). The assessment outlines the potential health, social, environmental, and economic impacts of each event. It is the first framework of its kind in Canada to examine climate risks at a provincial level (Ministry of Environment and Climate Change Strategy, 2019). In 2019, the province conducted a preliminary Strategic Climate Risk Assessment of BC, which was the first phase in understanding the impacts of climate change (Ministry of Environment and Climate Change Strategy, 2019).

2.1.1. Moderate Flooding

BC experiences moderate flooding events every year that are caused by the frequency and magnitude of extreme rainfall events (Ministry of Environment and Climate Change Strategy, 2019). The consequences associated with moderate flooding are drastic to communities. A single moderate flooding event, has the potential to cost the provincial government an estimated $375 million (Ministry of Environment and Climate Change Strategy, 2019). The economic loss is even greater. The loss of economic productivity due to moderate flooding will depend on the location but it has the potential to range from $10 million to $99 million because of the impact on businesses, tourism, agriculture, etc. (Ministry of Environment and Climate Change Strategy, 2019). According to the Ministry of Environment and Climate Change Strategy (2019), flooding can severely disrupt the daily routines of individuals and society, causing lasting effects on essential services that could extend for several weeks or even months.

2.1.2. Riverine Flooding

The Risk Assessment Framework analyzed the provincial trend for riverine flooding to be a low likelihood but labeled it as a high-consequence event (Ministry of Environment and Climate Change Strategy, 2019). Climate change could make a one in 500-year Fraser River flood up to five times more likely to happen by 2050, affecting more than 30% of BC's population (Ministry of Environment and Climate Change Strategy, 2019). The estimated total cost to the provincial government for such a flood is estimated to range from $375 million to $750 million (Ministry of Environment and Climate Change Strategy, 2019). Thus, if BC does not adapt with preventative measures, riverine flooding will happen at an unprecedented level.

2.2. Understanding Nature-Based Solutions

NbS is an umbrella term for a variety of ecosystem-based approaches to address climate mitigation and adaptation while preserving biodiversity and promoting societal benefits (Vouk et al., 2021 & IUCN, 2020). The International Union for Conservation of Nature (IUCN) defined NbS as actions aimed at protecting, managing, and restoring ecosystems for human well-being and biodiversity (IUCN, 2020). The IUCN also established a Global Standard to highlight NbS's potential in mitigating flood risks (IUCN, 2020). NbS offer flexibility and opportunities for learning, which is crucial when addressing complexity and uncertainty in the context of climate change (Molnar et al. 2021). The goal of NbS is to increase the resiliency of cities and communities in the face of climate change. NbS is evolving and there is growing recognition and acceptance of NbS within Canada and BC.

2.2.1. Nature-Based Solutions for Riverine Flooding

Riverine flooding also known as fluvial flooding, occurs when water levels in a river rise and overflow onto surrounding banks and neighboring lands (Buttle et al., 2016; Moudrak, Feltmate, 2019). Riverine flooding is predominately driven by prolonged and intense rainfall events and/or spring snowmelt (Buttle et al., 2016; Moudrak, Feltman, 2019). NbS to reduce riverine flooding due to extreme weather include multiple different techniques to increase water storage capacity or absorption, which Table 1 provides greater detail on (Vouk et al., 2021; ACT, 2020). The preservation of

floodplains and river systems is broadly accepted as the most effective and efficient technique to reduce to risk of floods as it is viewed as cost-efficient (ICF, 2018; Voudrak et al., 2021).

Table 1. Types of NbS for Riverine Flooding

Type	Definition	Outcome
Floodplains and river systems	Preservation and restoration of natural floodplains and river systems to ensure room for floodwaters.	Reduces the peak flood flows and river levels, while providing room for natural river processes and increasing storage capacity in a floodplain.
Wetlands	Preserving, restoring, or creating wetlands for the absorption of floodwaters.	Reduces peak flood flows and river levels, while increasing storage capacity and infiltration within floodplains.
Two-stage channel	The creation of a wider floodplain bench on the upper main channel of a river that flows water when capacity is exceeded.	Increases flood flow capacity while mimicking natural floodplain and channel processes.
Relief Channel	Constructing, restoring, or mimicking additional river channels to divert floodwaters.	Increases the capacity and flow of floodwaters.
Vegetation	Planting/restoring various woodlands and vegetation on the riverbanks to create riparian buffers.	Reduce and regulates water flow in channels and floodplains, while improving infiltration and riverbank stabilization.

(Vouk et al. 2021& ICF, 2018)

2.3. The Value and Limitations of Nature-Based Solutions

The benefits of NbS as an adaptation technique for riverine flooding from extreme weather are numerous. NbS offer a wide range of benefits including climate-resilient infrastructure for communities, reducing greenhouse gas emissions, and being cost-efficient (Drever et al., 2021 & Diaz et al., 2019). NbS are estimated to provide 37% of climate change mitigation by 2030 and is an opportunity for Canada and BC to reach

their emissions reduction goals (Drever et al., 2021 & Diaz et al., 2019). The Municipal Natural Asset Initiative (MNAI) found that using NbS in infrastructure systems can save between $0.2 to $414 million compared to traditional engineered solutions (Feltmate, 2020). The capital value that NbS offer to society is still unknown, but the MNAI has quantified the value of certain natural assets for flood resilience (Mondar, 2020). The assessment found that NbS offer significant value to society (Moudrak & Feltmate, 2020, Vouk et al., 2021):

- Naturally occurring ponds in Gibsons can provide a value of $3.5 million to $4 million in stormwater services;
- Widening and naturalizing 1,292 metres of the riverbanks in Courtenay, BC, would provide a value of $2.4 million of protection from flood damages;
- A restored and engineered wetland in Manitoba was found to provide a value of $3.7 million for reducing floods and improving water quality;
- A seven-kilometer riverbank in Ontario provides a value of $18.9 million dollars for increased stormwater flow.

It is important to note that it is a prominent challenge in the literature on NbS on how to quantify the cost-benefit analysis of NbS, which is what makes engineered solutions more appealing (Vouk et al, 2021). Overall, the direct benefit of NbS for riverine flooding is to reduce the negative consequence that occurs when flooding happens while simultaneously providing resilience against climate change events.

Most of the co-benefits that NbS provide are related to ecosystem services such as support, culture, provisions, and regulation. Table 2 provides a better perspective of the co-benefits for each of the categories. These co-benefits have the potential to advance the implementation of NbS (Drever et al., 2021).

Table 2. Ecosystem Service Benefits of NbS

Supporting	Cultural	Provisions	Regulation

Imporves biodiversity Habitat creation Soil formation Pollination	Recreation Tourism Stewardship Education Preservation of heritage and cultural assets.	Clean air Clean water Green growth & job creation Improves community liveability	Carbon sequestration & storage Flood and erosion risk management Climate resilience Human health

(Source: Vouk et al., 2021; Shaw et al., 2020; Moudrak & Feltmate, 2020)

NbS can help mitigate riverine flooding caused by extreme weather by providing numerous benefits and co-benefits to communities. To increase public support for NbS, it's important to communicate their benefits and definition clearly, highlighting their connection to local government priorities (Shaw et al., 2020). This will dispel misunderstandings and increase understanding, resulting in wider use of NbS (Shaw et al., 2020).

However, there are some limitations to using and implemenitng NbS. One limitation is that depending on the scale of NbS they can cross jurisdictional boundaries. When using NbS on a watershed scale level, it requires joint decision-making across multiple local, regional, or ministries (Seddon et al., 2020). Additionally, it fosters communication challenges, political considerations, as well as legal barriers. Thus, a lack of policy coherence can lead to inaction due to the difference in priorities, interests, and values amongst departments and jurisdictions (Seddon et al., 2020). Moreso, NbS may not always be the appropriate solutions for flooding as it may not be feasbile to implement in an area, making them site specific (Kabisch et al., 2016). Another limitation associated with NbS is the insufficient knowledge and understanding surrounding their effectiveness, cost, and value (Nelson et al., 2020). The limited data and knowledge available on NbS reinforce the idea that they are not an effectiveness solution for adaptation and flooding (Kabisch et al., 2016 &Sarabi et al 2019). The unknowns and limitations attached to implementing NbS make them a less appealing approach to flooding and climate resiliency in general.

2.4. Gray Infrastructure Versus Nature-Based Solutions

NbS have been found to provide a more holistic approach to flooding when compared to gray infrastructure, which includes seawalls, dikes, culverts, and pumping stations (Marriot, 2020; Federal Emergency Management Act (FEMA), 2021). Unlike gray engineered solutions, which offer a specific action under specific conditions, NbS can provide climate resilience against climate impacts and offer long-term benefits (FEMA, 2021). Although gray infrastructure can provide immediate and direct relief, it has a limited lifespan, requires constant maintenance, and significant capital costs to construct (Marriot, 2020). The benefits of NbS have been shown to outweigh the cost of implementation and maintenance for flood risk reduction compared to gray infrastructure (Marriot, 2020). However, NbS may have a longer implementation time frame before the benefits are seen, and their effectiveness may be more difficult to evaluate compared to gray infrastructure. Overall, both options have their pros and cons that need to be considered when looking for solutions to extreme weather flooding.

Chapter 3.

Policy Landscape in BC For Flooding and NbS

3.1. Integrated Flood Hazard Management

The government of BC has developed an Integrated Flood Hazard Management plan with the goal to reduce the impacts of flooding on individuals, communities, and infrastructure (Government of BC, n.d a). The Integrated Flood Hazard Management is a collaborative approach that involves multiple stakeholders as well as several legislative acts to govern flood management between provincial and local governments (Government of BC, n.d.a). Under the Integrated Flood Hazard Management, it includes Flood Hazard Area Land Use Management Guidelines, floodplain maps, Dike Maintenance Act, and a River Forecast Centre.

BC provides a Flood Hazard Area Land Use Management Guidelines to aid local governments in decisions regarding development approvals in potential flood hazard areas to “reduce or prevent injury, human trauma and loss of life, and to minimize property damage during flooding events” (Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2018, p.5). Incorporating flood risk management into land-use planning and urban planning is viewed as a key requirement for reducing the impacts of flooding (Government of BC, n.d. a). The guidelines set out by the province, give local governments the authority to develop flood hazard area bylaws, grant flood hazard area land development exemptions, and establish the requirements for subdivisions in flood prone areas (Government of BC, n.d.a). Furthermore, experience has shown that land-use management and flood proofing in areas that are susceptible to flooding is the most practical and cost-efficient way to reduce the effect of flooding on individuals and their property (Government of BC, n.d.a).

BC provides floodplain maps to inform the public on areas that experience periodic flooding from nearby waters (Government of BC, n.d.a; Government of BC, 2022). The purpose of floodplain maps is to identify and relay information regarding the areas that are most susceptible to flooding and the minimum elevation for flood proofing (Government of BC, 2022). This provides individuals with the ability to make informed decisions about their property choices. Local governments are responsible for

understanding the risk of flooding in their areas and making the appropriate land-use decisions based on the information they have (Government of BC, n.d. a). BC created historical floodplain maps between 1987 and 1998 for the seven regions of BC (Government of BC, n.d.e). However, the provincial government cannot confirm if the information is accurate as some maps have been updated or replaced by local governments and authorities, thus users should reach out to their respective local governments (Government of BC, n.d.e).

One of BC's flood protection mechanisms is gray-engineered solutions including dikes, seawalls, culverts, and/or pumping stations. BC has developed a Dike Maintenance Act, defining dikes as an "embankment, wall, fill piling, pump, gate, flood box, pipe, sluice, culvert, canal, ditch, drain, or anything that is constructed, assembled or installed to prevent flooding" (Dike Management Act, R.S.B.C 1996, c95, p. 1). There are over 200 regulated dikes in all of BC providing up to 1100 kilometres of protection on vulnerable lands susceptible to flood risks (Government of BC, n.d.b). Likewise, the Lower Mainland is dependent on the reliability of 600 kilometers of dikes, 400 flood boxes, and 100 pump stations to prevent flooding events (Government of BC, n.d. b). The provincial government is responsible for the legislation surrounding dikes, however BC administered the Dike Safety Program, giving local governments and authorities the responsible for operating maintaining, constructing, and upgrading dikes and other physical flood protection infrastructure (Floodwise, n.d). Overall, dikes are one of many flood protection infrastructures under the Integrated Flood Hazard Management that BC uses frequently to address flood risks.

The government of BC provides a River Forecast Centre that not only forecasts river and stream flows but also assesses flood risks, analyzes snowpack, and evaluates seasonal water supply (Government of BC, n.d.d). Additionally, it provides maps and warnings to inform the public about current and upcoming streamflow conditions (Government of BC, n.d.d). BC specifically provides an interactive map that provides further information about flood warnings and advisories for flood risks. The interactive map provides three types of notifications: high streamflow advisory, flood watch and flood warning (Government of BC, n.d.d). The purpose of the map is intended to alert the public to potential flood risk, in order that they can properly prepare for a flooding event.

3.1.1. Limitations to BC’s Flood Management

There are numerous limitations within BC’s current flood management that lack effective action against climate and flood risks. Currently, BC's flood management primarily relies on reactive policies and planned relocation, instead of implementing preventive measures, resulting in a lack of NbS being utilized for flood resiliency. Specifically, within BC’s flood management there are two main limitations such as disjointed roles and responsibilities and the aging diking system.

The first limitation is that BC’s flood management is disjointed due to multiple agencies and organizations being responsible for different aspects of flood management. This leads to fragmentation amongst levels of agencies, which can lead to inconsistencies in approaches and responses to flooding. The disjointed flood policies create a lack of coordination and effectiveness for flood management in the province (Auditor General of BC, 2018). The sole responsibility falls on local governments who are not properly equipped to handle climate issues on their own (Auditor General of BC, 2018). Without adequate support a majority of local governments do not have the technical capacity to manage flood risks (Auditor General of BC, 2018). Additionally, local governments cited that the disjointed approach fosters a lack of leadership and guidance from the provincial government on flood management. This limits financial support, reliable data, knowledge, and effective policies (Auditor General of BC, 2018). Thus, it creates limitations due to the increase complexity for greater collaboration and alignment in policy decisions.

Secondly, the current diking system is aging and without proper monitoring, it will eventually not withstand the increasing flood risks (Auditor General of BC, 2018). Dikes only provide protection from a predetermined level of flooding and are subject to weaken or fail over time due to erosion. Currently, there are over 100 flood protections mechanisms in BC that are not actively maintained by a diking authority (Government of BC, n.d.c). Many of these dikes were built out of emergency conditions and do not meet the provincial standards for dikes (Government of BC, n.d.c). It is noted by the provincial government that the construction of dikes as a flood reduction measure is not a cost-efficient strategy to control all flood risks, (Government of BC, n.d.b; Delcan Corporations, 2012). Overall, the aging diking system in British Columbia poses a significant risk to the province's flood protection.

3.1.2. Nature-Based Solutions in BC

NbS are an underutilized opportunity within BC as there is no policy, standards, or regulations for using NbS. Thus, NbS are rarely seen in provincial commitments against climate change. Throughout BC's flood management and Climate Adaptation there is a lack of acknowledgement towards using nature as a means to reduce climate risk and flood risks. BC's Climate Preparedness and Adaptation Strategy outlines a wide range of actions for 2022-2025 to address the impact of climate change (Government of BC, 2022). The strategy refers to broad actions and investments and lacks concrete plans to implement such adaptation measures (Auditor General of BC, 2018). The strategy is intended to strengthen BC's capacity to respond and handle sudden events such as wildfires, heatwaves, and even flooding while encouraging resilience (Government of BC, 2022). However, there is a lack of concreate actions regarding the use of NbS.

In terms of NbS, one of the six guiding principles of the strategy is to "promote Nature-Based Solutions to Enhance Community Resilience. Nature-based solutions are actions that can protect, sustainably manage and restore ecosystems in ways that benefit people as well as biodiversity and ecosystem functions" (Government of BC, 2022, p.13). Throughout the strategy, it briefly mentions utilizing and investing more in natural assets but states no concrete actions or plans to do so. The strategy highlights using natural assets to create resilient species and ecosystems while providing services to communities and reducing greenhouse gas emissions (Government of BC, 2022). It is crucial for BC to explore climate adaptation through a nature-based lens to mitigate the risk of flooding due to extreme weather.

3.2. Barriers to the Implementing NbS in BC

While NbS are growing in awareness as a means to reduce the risk of riverine flooding, there are still multiple barriers that affect the uptake and implementation of NbS. The barriers that BC encounter when implementing NbS are also globally recognized barriers that all jurisdictions are challenged with. Thus, the barriers discussed below will make reference to the context in BC for using NbS. Given the scope of the study, only two main barriers will be the focus for reduction including proof of concept and financial constraints, which were identified by existing literature to be

important in advancing the uptake of NbS. Additional barriers are discussed in Appendix A, which consists of knowledge gaps and uncertainties, institutional fragmentation, and policy and regulation. Altogether, the barriers presented are intertwined with each other and add a level of complexity when addressing them.

3.2.1. Proof of Concept

A main barrier to advancing the implementation of NbS is establishing a proof of concept that NbS are a effective solution to climate adaptation. One contributing factor to this barrier is path dependency. Path dependency constrains decision-makers to align with past experiences and the path that is least resistant to change (Sarabi et al., 2019). The path dependency of BC's decision-making for flood management has a history of relying on gray-engineered infrastructure which inhibits the growth of NbS. Changing the mindset of stakeholders will also be challenging as NbS are perceived as uncertain (Vouk et al., 2021). The effectiveness of NbS is not always known. There is already a growing acceptance within Canada of NbS as well as the evolution that NbS is a useful tool to mitigate flooding. Other opportunities that BC could consider is education and outreach to gain support for NbS (Vouk et al., 2021). Additionally, the lack of technical guidance, monitoring, and performance metrics intersects with perceptions as it makes it confusing and unclear of how to go about the use of NbS (Ershad Sarabi et al., 2019 & Vouk et al., 2021). Having established these measures will help boost confidence and understanding of how NbS intend to work and will reduce uncertainties. Ultimately this intersects with the barrier of regulation/policy and institutional fragmentation and create an abundance of compounding factors that make it challenging to establish an evidence base of NbS..

3.2.2. Financial Constraints

The BC government lacks specific funding opportunities to facilitate the implementation of NbS (Sarabi et al., 2019). Traditionally, natural assets and NbS have not been categorized as capital assets like traditional approaches, which is the fundamental reasoning to why it makes it difficult to obtain funding (Moudrak and Feltmate, 2020). Projects such as NbS that require capital spending’s such as maintenance or adaptive management are often categorized as de-incentivizing projects and funding agencies will be less likely to invest (Vouk et al., 2021). A major reason

behind this is that with NbS, the co-benefits are only realized in the long term and many funding schemes tend to be short-term (Sarabi et al., 2019). Furthermore, local governments have limited resources and rely heavily upon provincial governments to financially back their projects. In general, the lack of financial opportunities relates to the accessibility of resources available for local governments to utilize. This highlights a critical need for the exploration of finances and economic opportunities elsewhere such as private investments. An opportunity to increase funding and financial support for NbS is to recognize NbS in adaptive infrastructure programs and explore innovative insurance for the risk associated with NbS (Vouk et al., 2021). Therefore, a lack of dedicated funding envelopes for nature-based projects in BC is impeding their uptake.

Chapter 4.

Methodology

This study utilized a combination of qualitative research methods, including a comprehensive literature review, semi-structured interviews with experts in the field, a scan of nature-based policies across different jurisdictions, and a Multi-Criteria Analysis to evaluate policy options.

4.1. Literature Review

To gain an understanding of the history and context of NbS, its barriers and benefits, and the debate against gray-engineered solutions, a thorough literature review was conducted. The literature review also consisted of a policy scan of BC's flood management, climate adaptation strategy, and NbS. A range of sources including Google's search engine, Google Scholar, government websites, and Simon Fraser University's (SFU) online library were utilized to find relevant information. The gathered data was sourced from a variety of materials including peer-reviewed literature, news articles, published reports, government reports, and documents from environmental and climate non-governmental organizations.

4.2. Expert Interviews

Seven experts in NbS and climate adaptation, including representatives from environmental non-governmental organizations, NbS project workers, and academic experts, were interviewed via Zoom from November to December 2022. The objective was to understand the barriers in BC and the feasibility of different approaches to implementing NbS for flood risk reduction. The interviews revealed six themes: perceptions of NbS, strengths, barriers, hybrid models, Indigenous engagement, and policy options.

4.3. Jurisdictional Scan

Upon reviewing relevant literature and information gathered from interviews on NbS, key jurisdictions were selected for deeper exploration of their policies and implementation techniques for NbS. The selection of case studies was based on similarities in the use of NbS, including the barriers to implementation and experiences with flooding due to extreme weather. Information on the policies in each jurisdiction was obtained from government websites and literature sources, including Google Scholar and SFU's online library.

4.4. Multi-Criteria Analysis

To determine the most effective policy for reducing barriers to the implementation of NbS, a Multi-Criteria Analysis (MCA) was conducted. Five criteria were identified to evaluate the policy options: effectiveness, administrative complexity, development, cost, and stakeholder acceptance. The criteria were weighted based on information obtained from a literature review, expert interviews, and a jurisdictional scan. Each policy option was rated as either good, moderate, or poor for each criterion, with a maximum possible score of 15 for each policy. The policy option with the highest score will be recommended as the most suitable option.

4.5. Limitations

One of the limitations of this study is the narrow scope of representation in the interviews due to time constraints. The majority of interviewees came from non-governmental organizations with a favorable perspective on NbS, leading to potential bias. Furthermore, there were no interviews with government representatives to assess the feasibility of policy options. This lack of diverse representation could result in oversimplified conclusions and may not accurately reflect the consensus on advancing NbS. A more extensive outreach to a broader range of stakeholders could provide a clearer and more representative picture.

Chapter 5.

Interview Findings

The purpose of conducting seven expert interviews with researchers and specialists in the field of NbS and climate adaptation was to gain a deeper understanding of the barriers to implementing NbS in BC and to assess the viability of potential policy options. The analysis of these interviews revealed six key themes, which are presented in the following section.

5.1. Perceptions of Nature-Based Solutions

At the start of each interview, participants were asked to provide their initial thoughts upon hearing the term "NbS." Consistently, participants identified NbS as a way to address environmental and climate challenges by utilizing natural assets or natural infrastructure:

“Solutions that employ natural ecosystems or natural functions to provide solutions to environmental challenges, specifically in the realm of climate change, either reducing emissions or offsetting emissions.”

“In a broad sense, I see NbS as any time your using our natural systems or ecosystem assets to mitigate climate change [to] protect biodiversity [and] environmental objectives”

For some, NbS include the incorporation of green infrastructure:

“We think of nature-based solutions as a combination of green and natural assets and green infrastructure as strategies to advance ecosystem health and services.”

Furthermore, participants cited NbS as a way for Canada and provinces to achieve its biodiversity, conservation, and Paris Agreement goals:

“Can’t reach biodiversity goals and net-zero goals without incorporating nature into it.”

This implies that NbS is a broad concept, where individuals have different perceptions of what it means to use NbS. This suggest that the definition of NbS is not clear or

universally understood as also seen from the literature review. The lack of a clear definition creates challenges for planning and implementing NbS. Additionally, the diverse perceptions imply that NbS should be approached holistically rather than for addressing specific environmental challenges such as flooding.

5.2. Strengths

A consistent theme among participants was the multiple co-benefits that NbS provide. Participants discussed the advantages of NbS in terms of the various benefits they offer to communities and governments. They highlighted the wide range of services that NbS can offer and the potential to leverage these solutions for a variety of purposes:

"We receive a lot of infrastructure and non-infrastructure services from nature, and we tend to really not acknowledge this in our decision-making."

"This is your business case, centering it around services and the fact that [nature] has no capital costs and lower operating costs. I think the evidence base speaks for itself."

Framing NbS as service delivery reaffirms the importance of utilizing them as multi-solving solutions. Participants acknowledged the appeal of these co-benefits, but also noted that measuring their effects can be challenging. This highlights the need for a comprehensive approach to advancing NbS implementation, focusing on both the infrastructure and ecosystem services they offer and the benefits they provide.

Another leverage point for utilizing NbS is that they are a cost-efficient mechanism to address climate adaptation. There was a consensus from participants that NbS are more cost-efficient compared to gray infrastructure:

"[NbS] can perform the same or better function than engineered and sometimes less upfront cost, less long-term cost, and often less maintenance."

Therefore, to advance the implementation of NbS as a cost-effective means of adaptation to extreme weather events and climate change, a holistic lens should be applied that focuses on both the infrastructure and ecosystem services they provide and highlights their benefits.

5.3. Barriers

When participants were asked if BC or other provinces were effectively utilizing NbS for flooding due to extreme weather, there was a broad consensus that they were not. Participants were then able to identify multiple barriers that governments confront when trying to understand and implement NbS. Significant barriers that were identified are a lack of guidance and standards, funding, and uncertainties regarding NbS. Specifically, in BC, there is a strong lack of provincial guidance in regard to infrastructure management or ecosystem management for NBS:

"you will not find in any piece of legislation that the province is responsible, any driver or push to consider nature and the services it provides"

"In the BC adaptation [strategy] there is not much guidance, targets, goals, or funding for [nature-based solutions].

"[BC's] Dike Management Act specifically says you cannot consider or cannot have natural components to it."

This implies that there is limited support or resources provided by the provincial government for the implementation of NbS. This lack of support and resources creates confusion on how NbS should be implemented. Additionally, there are specific policies as mentioned by participants that are exacerbating the issue by creating barriers that prevent the integration of NbS into flood management strategies.

Another major barrier identified consistently by participants is the need for funding and where to get it:

"Local government couldn't figure out where to put NbS funding. Whether it goes into infrastructure, planning, or municipal budgets. Should it be in the capital plan? Who should be responsible for NbS in terms of what departments."

There is a remarkable amount of confusion about who is responsible for planning and implementing NbS and where to source the funding for projects. Within BC there is not enough funding available to facilitate implementing projects that have a focus on using nature. Having a lack of provincial standards for NbS interconnects with why there

is a gap in funding. Therefore, NbS cannot be implemented if there is no funding to support such projects.

Participants raised the concern that NbS are not being utilized because of the uncertainties related to nature-based activities:

“There are perceived uncertainties that engineers and policymakers have that make them resistance to adopting nature-based solutions.”

“I worked as a consultant in an engineering company and many engineers are uncomfortable with the perceived increased risk from using NbS.”

One aspect that relates to the barrier of uncertainty is path dependency for using the gray infrastructure. This reaffirms what was found in the literature review, that individuals perceive NbS to be ineffective due to historical reliance on decisions that involved the use of gray infrastructure to address flooding (Sarabi et al., 2019). Individuals seem to be more comfortable with the use of gray engineered solutions rather than nature due to their unpredictable performance. It is also important to mention that all the barriers mentioned in this section are interconnected and influence why there is this lack of evidence base in BC. In return, a lack of evidence-based projects makes individuals skeptical of the effectiveness of NbS. In conclusion, many of the barriers identified in the literature review overlap with the specific barriers that BC and other provinces in Canada are confronting when implementing NbS.

5.4. Hybrid Model

When participants were asked to compare the effectiveness of NbS and gray infrastructure in addressing flooding caused by extreme weather, they consistently noted the benefits of a hybrid approach. This is because the appropriate solution is context-dependent:

“I think it’s always a hybrid [approach] and the amount of nature-based solutions vary from context to context.”

“Well, I think that you know that nature-based solutions are not necessarily appropriate in all locations.”

“I think there is room for both and there is probably a need for both.”

A hybrid model can incorporate the strengths of both NbS and gray infrastructure to effectively address the specific challenges presented in each situation. It may not always be feasible to use NbS to mitigate flooding. Thus, NbS and gray infrastructure both have a role to play when addressing the issue of extreme weather flooding. Moreso, NbS should be integrated into the planning process for flood control:

“The order of analysis should shift. I think first you should think about how [can] natural infrastructure and natural systems provide infrastructure solutions and that would be your priority choice. Only when you can’t figure out how they would work well enough then you look to engineered solutions as a complement to that. It’s like a decision tree when it comes to flooding with your analysis of nature-based solutions first and then go into gray and engineered.”

This implies that the conventional method of addressing flooding should be revised to prioritize the consideration of NbS. Then, gray infrastructure can be evaluated to complement any performance gaps in NbS. Therefore, adopting this hybrid approach could lead to greater adoption and integration of NbS into flood mitigation and more sustainable infrastructure solutions.

5.5. Indigenous Engagement

A consistent theme that participants raised was the need to engage with Indigenous Peoples and communities when implementing NbS. Engaging with Indigenous communities offers perspectives and knowledge about the land and its value when wanting to implement NbS:

“I haven’t had extensive experience working with Indigenous groups on nature-based solutions, but from the limited experience, I do see increased use and reconnecting with nature as a tool for reconciliation. [Nature is great for] collaborating and reconciliation with Indigenous [Peoples] because [of their] value system. I can’t generalize but the viewpoints presented to me is that [Indigenous Peoples] value is that nature comes first, whereas in our society money comes first.”

This implies that Indigenous communities bring a unique local and regional perspective that may be overlooked by provincial governments or external organizations. This perspective allows Indigenous Peoples to re-establish their connection to the land through their traditions and cultural practices, which have been disrupted by colonization. The lack of inclusion of Indigenous knowledge and practices in NbS highlights the need for better engagement and collaboration. In order to effectively integrate NbS, Indigenous perspectives, knowledge, and practices must be considered. Therefore, Indigenous Peoples and communities offer insightful perspectives on how to utilize NbS and how they can be implemented in a meaningful way with the land.

5.6. Policy Options

Multiple policy options were raised during the interviews on how to alleviate the barriers associated with implementing NbS. This section highlights a few ideas for potential policies such as mainstreaming NbS into different policy avenues, creating a knowledge platform, regulations, and financial support. When participants were asked about incorporating NbS into land-use management, disaster risk reduction, or forest management, they alluded that NbS need to be implemented across all sectors.

“It all needs to be integrated together. It’s not just one thing and that’s where the government is currently failing.”

“From a policy perspective, the policy [for climate adaptation] is all over the map. We have flood maps, natural asset management plans, and urban strategies. They all exist in isolation.”

Again, this emphasizes the importance of taking a holistic approach as NbS are better utilized when they are not implemented in one department for one specific issue. There is an emphasis on having a wide-scale approach to the implementation of NbS. A holistic approach to implementation implies opportunities to create synergies between departments and to come to a common understanding for the use of nature in solving society’s issues. Although, participants deemed one area of implementation of NbS to be more important than others:

“I think a fundamental is to have organization at the watershed scale … British Columbia doesn’t have a solid watershed management system. So, I would say that is a fundamental building block.”

Thus, participants believe that NbS at the watershed level is the most efficient and effective way to address flooding due to extreme weather along with other water-related issues:

“Nature-based solutions have to be implemented at the watershed scale and if not its hard to tell its effectiveness.”

Therefore, NbS should be universally implemented across governmental departments, with an emphasis on the watershed scale in order to address flooding due tot extreme weather.

Another potential policy option that was proposed to participants is for the government to create a knowledge platform where best lessons and case studies could be shared amongst different levels of governments and organizations. Participants had mixed concerns about a knowledge platform:

“A knowledge-sharing platform cannot be looked at in isolation and it’s not the most important thing.”

“I don’t know what people in this age go to a platform … There’s so many resources there, so much work, and keeping it up to date [would be a challenge] and unless it is… up to date, it’s not useful”

This highlights that a knowledge platform would not be the most important intervention in advancing NbS as there are many technical concerns regarding upkeep. More so it may not get used by many individuals as there are other tools for finding information. Thus, a knowledge platform does not address the barriers to advancing the implementation of NbS and will not be used as a potential policy option for this study.

When participants were asked if they would support or oppose a regulation for natural asset management as a policy option, the majority of participants were supportive:

“[NbS offer] regulatory efficiency. It is easier to create a regulatory system that allows [implementation of NbS] to be done quickly. Natural infrastructure is quite often easier to permit and easier to regulate than an engineered solution.”

Whereas others said it depends on what the regulation is intended to do

“It depends. Ontario has O Reg. 588/17 [which is] basically around asset management, but it’s a big scramble and it’s not done well.”

Overall participants were able to identify potential avenues for regulating NbS such as regulating the standardization of natural asset inventories:

“Inventories are kind of the first step and they're not the same as natural asset management. It only really tells you, these are the natural assets in your jurisdiction. It tells you a bit about the condition they're in and about the risks that they face.”

Thus, inventories can provide baseline information about natural assets, which can be used to inform further management decisions. Creating inventories of natural assets allows for the realization of their value and potentially how to incorporate it into provincial or national public accounting standards. It can be assumed that inventories would help identify what NbS can and can’t do as well as where they are appropriate to be used. Additionally, participants raised the idea of mandating natural assets into financial statements. This would also help achieve dedicated funding for implementing projects if a portion of government budgets were allocated to NbS:

“The District of West Vancouver has pioneered best practices in this area of funding by insisting $1.5 million of their capital budget go towards nature-based solutions.”

Furthermore, to address the barrier of lack of funding, participants consistently highlighted the need to incentivize local governments to start utilizing NbS:

“One thing [governments] can do is to have dedicated funding envelopes because municipalities aren’t considering natural infrastructure in the same way and with as much ease as they consider engineered. I think having dedicated infrastructure funds that are for nature-based solutions will cause municipalities to educate themselves on those solutions in order to apply for those funds.”

Another way to increase financial security with NbS is to incentivize public-private investments using green bonds. One participant identified a particular case study:

“DC Waters [developed an] environmental impact bond to overcome the uncertainties around the effectiveness of green infrastructure for stormwater management.”

Having proper financial mechanisms attached to NbS makes them more appealing and an affordable option. Aside from some hesitancy from participants, they were able to identify multiple instances where regulations can be beneficial. This affirms that regulations can be one the strongest methods to advance the implementation of NbS as long as there are financial resources tied to it.

Chapter 6.

Jurisdictional Scan

To focus on NbS implementation for flooding caused by extreme weather events in British Columbia, specific case studies were analyzed due to the limited availability of comprehensive policies globally and challenges in obtaining information on implementation. The interview findings also informed case studies as they had brought to light potential solutions. Thus, case studies were selected on the basis of their relationship to NbS. The selected case studies offer diverse insight into implementation strategies that can be customized to reduce the barrier and increase NbS adoption. Additional case studies that are relevant to this study can be found in Appendix B.

6.1. Ontario

Ontario is the first in Canada to regulate asset management planning at a municipal level. Ontario enacted O.Reg. 588/17, Asset Management Planning for Municipal Infrastructure in January 2018, under the 2015 *Infrastructure for Jobs and Prosperity Act* (MNAI, 2019). The regulation was created due to the province recognizing that municipalities are encountering similar issues with existing infrastructure degrading quicker than it is being replaced or repaired (MNAI, 2019). The regulation requires municipalities to perform inventories, values, and integrate green infrastructure, which includes natural infrastructure and natural assets into their asset management planning (MNAI, n.d). Ultimately this would help promote NbS by identifying opportunities where NbS would be the most effective or where to implement protection and restoration efforts. It will be useful for informing decision-making processes about land-use management. Additionally it allows for natural and green infrastructure to be evaluated and monitored, which can provide valuable information on the performance of nature-based solutions. The regulation requires that all municipalities have a strategic asset management policy in place by July 2019, an asset management plan for core infrastructure by July 2022 and other municipal infrastructure by July 2025 (MNAI, n.d). Core assets are defined as supporting the delivery of services such as roads, bridges, culverts, water, wastewater, and stormwater, while non-core assets are defined as other assets supporting city services (MNAI, 2019). Under the regulation the Strategic Asset

Management Plan will be updated every five years (Campbell, 2019). The O.Reg 588/17 allowed municipalities to gain valuable information of their infrastructure assets and allows them to act accordingly.

Additionally, Ontario has established Conservation Ontario, a non-profit association that represents Ontario's 36 Conservation Authorities (Conservation Ontario: Natural Champions, n.d). The Conservation Authorities were established in the 1940's by municipalities and the province to respond to flooding and erosion problems in Ontario and were later legislated under the Conservation Act in 1946 (Conservation Ontario: Natural Champions, n.d). Conservation Authorities are a community-based watershed management agency with the mandate "to undertake watershed-based programs to protect people and property from flooding, and other natural hazards, and to conserve natural resources for economic, social and environmental benefits" (Conservation Ontario: Natural Champion, n.d).

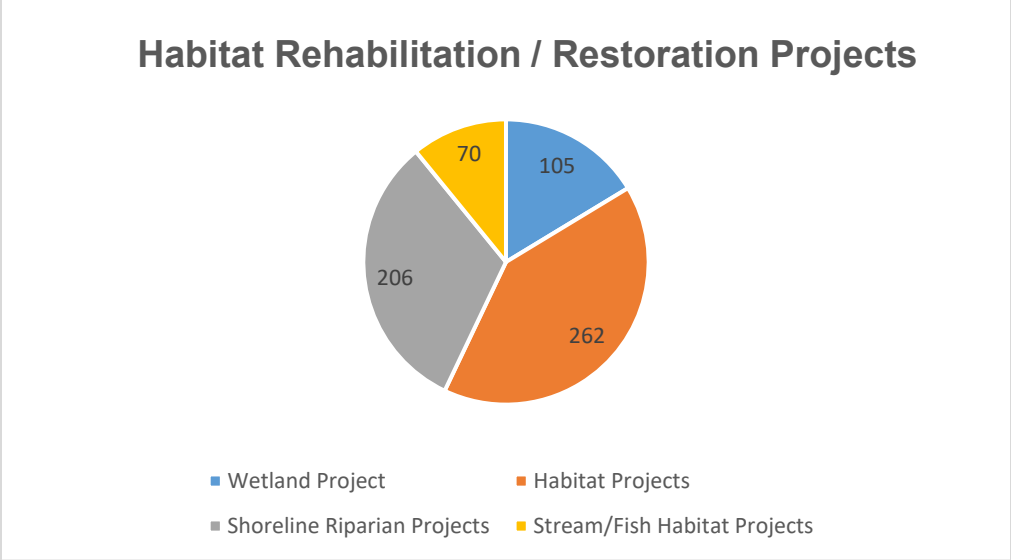
Conservation Authorities provide science-based advice and services for integrated watershed management where they are responsible for managing human activities and natural resources on a watershed basis (Conservation Ontario: Natural Champions, 2019). Conservation Authorities take into consideration environmental, economic, and human needs and interests (Conservation Ontario: Natural Champions, 2019). Conservation Authorities provide a wide range of responsibilities that fall under watershed management objectives such as protecting people and property from flooding, safe drinking water with source water protection, urban and rural stewardship for clean and sustainable water resources, monitoring and report on the health of Ontario's water and land resources, connecting people with nature and helping keep Ontarians healthy, and environmental education (Conservation Ontario: Natural Champions, 2019). Additionally, a core part of their work is grounded in protecting, restoring, and managing natural resources.

Under their responsibilities for urban and rural stewardship for clean and sustainable water resources, they identify and target areas for stormwater management and green infrastructure projects (Conservation Ontario: Natural Champions, 2019). Under this responsibility, they also provide landowners with financial and technical assistance to carry out rehabilitation and restoration projects for wetland, shorelines, streams, and habitats (Conservation Ontario: Natural Champions, 2019).

Another main function of Conservation Authorities is to protect people and property from flooding. Conservation Authorities have partnered with the province and municipalities to monitor potential flooding, issue warnings to municipalities, manage $3.8 billion of flood control and prevention infrastructure (damns, dikes, channels, etc.) (Conservation Ontario: Natural Champions, 2019). Other services include protecting substantial ecosystems such as wetlands and forest to help prevent flooding (Conservation Ontario: Natural Champions, 2019).

The Conservation Authorities perform projects that involve NbS. They implement activities such as planting trees, agricultural stewardship, rural water quality projects, green infrastructure and habitat restoration to improve watershed health and build resilience (Conservation Ontario, 2019a). Figure 1 below demonstrates a breakdown of the types of projects.

Figure 1. Types of Projects for Habitat Rehabilitation and Restoration Projects.



(Source: Conservation Ontario, 2019a).

Conservation Ontario has partnered with 17 Conservation Authorities to implement 53 Nature-based Solutions (NbS) projects from 2021 to 2024, which will be funded by the Nature Smart Climate Solutions Fund for Place-based Actions (Conservation Ontario: Natural Campions n.d.a). These projects will take place on conservation authority-owned or managed lands as well as private lands (Conservation Ontario: Natural Champions, n.d.a). The goal of this program is to deliver multiple nature-based solutions including protection and restoration of wetlands, grasslands, and

riparian areas, as well as enhanced land management practices that will enhance carbon sequestration (Conservation Ontario: Natural Champions, n.d.a).

6.2. Prince Edward Island

The City of Charlottetown was the first to create a natural asset inventory as part of a national movement with the MNAI to aid municipalities in understanding the importance of natural assets and leveraging them in decision-making processes (City of Charlottetown, n.d). The MNAI defines the term “municipal natural assets” as:

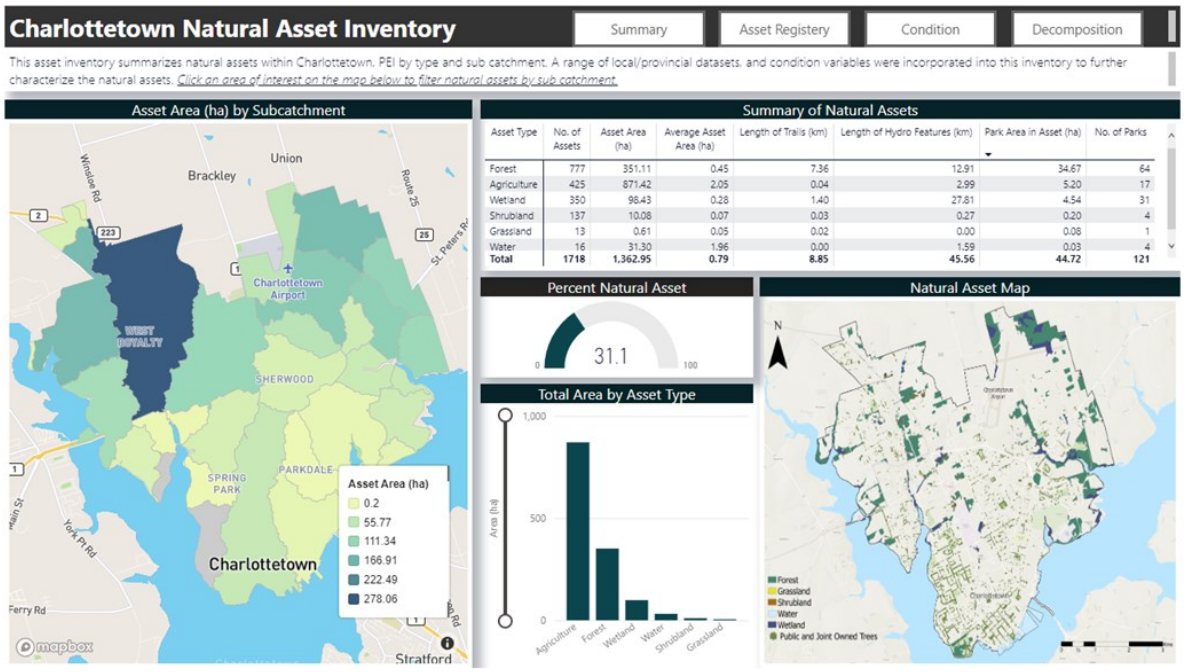
“the stock of natural resources or ecosystems that is relied upon, managed, or could be managed by a municipality, regional district, or other form of local government for the sustainable provision of one or more municipal services”

- MNAI, 2021 & MNAI, 2017

Thus, a natural asset inventory contains a variety of information regarding the location, types, extent of natural assets, and the condition they are in (Eyquem et al., 2022 & MNAI, 2021). Charlottetown has already identified nature as an important theme in their Integrated Community Sustainability Plan (ICSP) such as riparian zone health assessments, reforestation projects, woodland inventories, and a street tree inventory (MNAI, 2021). Establishing a natural asset inventory is the first step for providing a municipal natural asset management, which advance the recognition of natural assets in decision making processes about infrastructure (MNAI, 2017).

MNAI helped Charlottetown developed an online dashboard that has publicly available information that provides graphical representation of natural asset data (City of Charlottetown, n.d). Additionally, the online dashboard allows user to navigate, organize, and analyze specific natural assets (City of Charlottetown, n.d). Currently there are 1,719 individual natural assets that are registered under the dashboard and are divided into agricultural lands, forests, grassland, shrubland, water, wetland (City of Charlottetown, n.d). Figure 1 below provides a sample of what the online dashboard looks like. The dashboard is categorized into four sections including summary, asset registry, condition, and decomposition.

Figure 2. Charlottetown Natural Asset Inventory: Summary Page



(Source: City of Charlottetown, n.d)

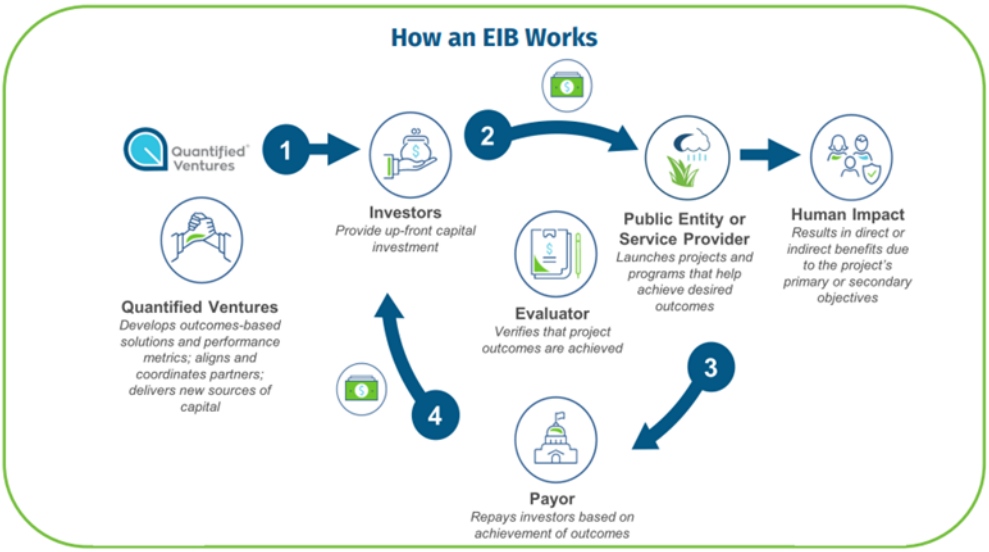
6.3. Washington, DC

In 2016, the Department of Energy and Environment (DOEE) established a program and marketplace where individuals can generate and sell Stormwater Retention Credits (SRC) to earn profits for projects that reduce stormwater runoff by installing green infrastructure (DC Government, n.d; Green Finance Institute, n.d). Green infrastructure for runoff can include planting trees, green roofs, rain gardens, restoring wetlands, and bioretention installations (Friedrich, 2016). How the SRC works is that when developers that want to meet their stormwater reduction obligations, they can buy the credits directly from sellers, which generate the credits by implementing voluntary green infrastructure for runoff (Green Finance Institute, n.d). Projects are required to retain a minimum of 50% of the water anticipated from a 0.8 to 1-2-inch storm (Bassi et al., 2017). SRC have a one-year lifespan begins after its use (Bassi et al., 2017). The DOEE manages the program by determining the rules as well as tracking the

compliance of regulated sites and SRC-generating sites (DC Government, n,d; Bassi et al., 2017). The DOEE reduces transaction costs when participants join the program because they provide sample contracts and financial return calculators (Bassi et al., 2017). The program demonstrates how SRC market can provide financial assistance and returns for voluntary implementation of green infrastructure (Parker, 2014).

Additionally, DC was the first city to issue a $25 million Environmental Impact Bond (EIB) in 2016 to attract private funds for green infrastructure projects (Bassi et al., 2017). The EIB is a 30-year tax-exempt municipal bond with a mandatory tender after five years (Bassi et al., 2017). DC Water issued the bond to investors Goldman Sachs Urban Investment Group and Calvert Impact Capital for the purpose of capturing and infiltrating runoff that would overflow in Rock Creek (DC Water, n.d & Lindsay, 2021). The model for EIB allowed DC Water to share a portion of the financial risk that is associated with green infrastructure when trying to implement and upscale projects (Lindsay, 2021). How the EIB works is that DC Water paid the cost of constructing the green infrastructure, but the performance risks and benefits for managing stormwater runoff are shared amongst DC Water and the investors. Therefore, the outcome payment on the EIB is based on the success of the project, which follows in-depth documentation of pre and post construction performance monitoring (DC Water, n.d). Figure 3 below gives a better idea of the process of using an EIB.

Figure 3. How an EIB Works.



(Source: Quantified Ventures, n.d.a).

Quantified Ventures was the one to establish outcome-based performance metrics to determine if a project achieved the initial goal and intent (Quantified Ventures, n.d.a). The function of Quantified Ventures was to be the intermediary finance transaction for the investors (Quantified Venture, n.d.). If the project performed as expected there would be no payment due, while, if the project underperformed the investors had to make a risk share payment to DC Water of $3.3 million (Quantified Ventures, n.d.a). Lastly, if projects overperformed DC Water would have to make a payment of $3.3 million to the investors, which meant that green infrastructure could be build a lower cost than expected (Quantified Ventures, n.d.a). In spring 2021, DC Water made the mandatory tender and fully repaid the EIB along with a strong evaluation of the projects outcomes that confirmed effectiveness of green infrastructure (Lindsay, 2021). Overall, the success of the project performed as expected which means no outcome payment is due to the investors and no penalties were needed (DC Water, n.d).

Chapter 7.

Policy Evaluation Framework

A Multi-Criteria Analysis is conducted to evaluate the trade-offs of potential policy options to address the problem issue of there being too many barriers associated with implementing NbS for flooding caused by extreme weather. This chapter outlines five criteria and five measures. Table 3 below summarizes how each policy option will be evaluated against the criteria and relevant measures.

Table 3. Policy Criteria and Measure Summary.

Criteria	Definition	Measure	Rating
Effectiveness	The extent to which the policy reduces the number and severity of barriers to adoption.	Significantly reduces the severity of barriers	Good (3)
		Moderately reduces the severity of barriers	Moderate (2)
		Minimally reduces the severity of barriers	Poor (1)
Administrative Complexity	Ease of implementation	A low degree of complexity for implementation	Good (3)
		A moderate degree of complexity for implementation	Moderate (2)
		A high degree of complexity for implementation	Poor (1)
Development	The extent to which a policy promotes regional economic development.	Significantly promotes development in a community	Good (3)
		Moderately promotes development in a community	Moderate (2)
		Minimally promotes development in a community	Poor (1)
Cost	The initial cost to the provincial or local government	Low initial cost to the provincial government	Good (3)

	to establish and administer policy.	Moderate cost to the provincial government	Moderate (2)
		High costs to the provincial government	Poor (1)
Stakeholder Acceptance	The level of acceptability for mainstreaming the implementation process of NbS among the public and the government.	High acceptability for implementing NbS	Good (3)
		Moderate acceptability for implementing NbS	Moderate (2)
		Low acceptability for implementing NbS	Poor (1)

7.1. Key Objective: Effectiveness

This research aims to evaluate the effectiveness of policies by addressing the barriers to implementation of NbS for extreme weather flooding. The effectiveness of a policy will be measured by the extent to which it reduces the main barriers, namely funding and proof of concept, and the severity of their reduction. Additionally, effectiveness is looking at whether the policy option will facilitate nature-based activities for flood control. This would include reducing flood flows or increasing water storage capacity. Policies aimed at facilitating flood control measures through NbS can simultaneously reduce barriers to the adoption of NbS. These two objectives are closely interconnected, and reducing barriers can lead to a greater uptake of nature-based activities for extreme weather flooding. Policies that effectively address both barriers will receive a good rating, while those that neglect to address either proof of concept or financial barriers will receive a poor rating.

7.2. Administrative Complexity

Administrative complexity evaluates the varying degrees of complexity required to implement the proposed policies. Factors that influence a low degree of complexity are a policy that requires few changes to existing policies or programs, and no new policy developments. Factors such as creating a new policy or program, multiple

stakeholders, and a long implementation period will all increase the complexity of implementation. Thus, a policy with a low degree of administrative complexity will be rated good, while a moderate degree of complexity earns a moderate rating, and a high degree of complexity earns a poor rating.

7.3. Development

Development evaluates the extent that a proposed policy will promote regional economic development. Factors that affect this criterion are employment opportunities and the added value or benefits a community will receive. Added value or benefits refers to increased green space, community activities like gardening or recreation, sustainable infrastructure, and improved ecosystem services. A policy that significantly improves development in a community will earn a rating of good, while moderate improvements in development will receive a rating of moderate, and minimal development receives a rating of poor.

7.4. Cost

The consideration of cost would assess the initial cost to provincial or local governments for establishing and administering the policy. This is measured in dollars when possible. Similar programs in other jurisdictions are used to estimate what the cost would be in BC. Policies that have a low initial cost to the government will earn a rating of good, while moderate costs earn a rating of moderate, and high costs earn a rating of poor.

7.5. Stakeholder Acceptance

To advance the implementation of NbS, there needs to be acceptance of the development and use of natural assets. Depending on the type of implementation strategy used, there could be varying levels of acceptability amongst the public, NbS experts, and the government. Additional public stakeholders include private landowners, industry associations, and non-governmental organizations. Factors that affect this criterion include the policy's usability, the program's permanence, and the level of engagement amongst stakeholders. Policies that are expected to be highly acceptable to stakeholders will earn a rating of high, while policies that are moderately acceptable will

earn a rating of moderate, and policies that have a low acceptability will earn a rating of poor.

Chapter 8.

Policy Options to Reduce the Barriers of Implementation for Nature-based Solutions

Four policies were derived from research on reducing the barriers for NbS implementation and mitigating flooding caused by extreme weather. These policies target the use of nature-based solutions at the watershed level in BC to advance the adoption of NbS and improve flood management.

8.1. Policy Option 1: Mandate Municipalities to Perform Natural Asset Inventories

For BC to increase the adoption of NbS, the first step is to identify and evaluate the current conditions of natural assets and natural infrastructure at the local level. Similar to Ontario's regulation (O.Reg 588/17) and PEI's inventory of natural assets, this policy option combines the two, requiring the BC government to legislate an *Infrastructure Asset Management Planning Act*. The reason it is mandated at a municipal level is that the majority of NbS that are already happening in BC, are constructed at the local government level as it is easier to implement. The *Act* would be developed under the Ministry of Transportation and Infrastructure, requiring municipalities to conduct inventories and values of their municipal infrastructure assets, which would inform how they develop and manage those assets moving forward (MNAI, n.d). It is important to highlight that municipal infrastructure assets include natural assets as well as green infrastructure. Under the *Act* one main specific requirement will be that municipalities create an online dashboard for natural assets where they provide information on the location, types, extent of natural assets as well as the condition they are in (Eyquem et al., 2022). Municipalities will have to develop an asset management plan for natural assets by 2028-2029 depending on the size and capacity of municipalities. Municipalities can work with Asset Management BC or MNAI to develop their natural asset strategy. Under the *Act,* management plans will be updated every ten years while inventories are to be updated every five years. Overall, this policy option is intended to increase the use and understanding surrounding natural asset management.

The goal of this policy is to increase the awareness and proof of concept of NbS through a natural asset inventory. A natural asset inventory takes stock of all the different natural assets in an area. The inventories are used as a tool to collect, organize, and analyze information on the location, condition, and value of natural assets such as forests, wetlands, waterways, and other ecosystems (MNAI, 2019 & Eyquem et al., 2022). The inventory can be used to identify the current state of natural assets, including their quality, extent, and potential, and to inform decisions related to their management (MNAI, 2017 & MNAI, 2021). Developing an inventory of natural assets can provide a starting point to introduce NbS into decision-making processes as it identifies and analyzes opportunities for where nature-based projects could be located. Essentially this would bolster proof of concept for NbS. Inventories can also display the value of natural assets, along with their benefits, which raises awareness and support for integrating NbS into those areas. The *Act* also makes it mandatory for municipalities to show how they will plan and manage natural assets by developing a strategic asset management policy, which could involve specific plans for NbS (MNAI, 2021). The inventories offer valuable baseline information for various departments and enhance understanding of how natural assets are interconnected with new developments, which may provide opportunities to integrate NbS into land-use management (MNAI, 2021).This policy option recognizes the value of natural assets in managing and adapting to climate change impacts by requiring municipalities to assess the vulnerabilities of aging infrastructure and increase the use of natural and green infrastructure (MNAI, 2019). Thus, natural assets and NbS are interconnected and are a key role in climate change planning for adaptation and resiliency (MNAI, 2019).

8.2. Policy Option 2: Provincial Government Legislates Conservation Authorities

The current provincial approach to mitigating flood risks is a piecemeal of policies at best and lacks concrete measures to include NbS as a mean for prevention and protection. Inspired by Ontario's Conservation Authorities, this option requires BC to legislate a *Conservation Authority Act*, under the Ministry of Water, Land, and Resource Stewardship. This *Act* requires the creation of Conservation Authorities to manage community-based watersheds activities in BC while also being able to administer a NbS lens. Conservation Authorities are a legal entity of the government that work at arm's

length to provide a multitude of watershed services including flood protection, clean and sustainable water resources, restoration, safe drinking water, and environmental education (Conservation Ontario: Natural Champions, n.d). Multiple interview participants along with evidence from case studies, exemplified that NbS are best utilized and effective when implemented at a watershed level. An integrated watershed management approach through Conservation Authorities protects natural assets while building resiliency within ecosystems.

The goal of this policy is to increase the use of NbS for flooding due to extreme weather as it is evident by Ontario, that it is feasible for Conservation Authorities to achieve this goal. Not only will this policy address the proof of concept of NbS in BC, but it provides relief in terms of funding projects as Conservation Authorities outsource financial funds from a variety of stakeholders. The programs that Conservation Authorities provide will improve and protect BC's watersheds, which involves reducing the risk of flooding and erosion by using NbS, while also providing additional services related to watershed management. Under the *Act,* Conservation Authorities are empowered to regulate development and activities in or beside rivers or stream valleys, lakes, and inland lake shorelines, watercourses, hazardous land, and wetlands (Conservation Ontario: Natural Champions, n.d.c). Furthermore, Conservation Authorities work with provincial and municipalities to deliver expertise and evidence-based science to programs and projects while alleviate capacity issues for local governments (Conservation Ontario: Natural Champions, n.d).

8.3. Policy Option 3: Environmental Impact Bond

One of the most influential barriers to advancing the implementation of NbS is having the financial capacity to make it happen. Through BC's current Adaptation, Resilience and Disaster Mitigation (ARDM) program, the BC government would integrate a $25 million Environmental Impact Bond specifically for implementing NbS for riverine flooding and urban flooding. A $25 million EIB was determined as it was mirrored off of Washington's case study, but more so, it would be a third of the ARDM program funding as they supply an estimated $81.865 million (Government of BC, n.d.g). When combining the funding for individual communities and multiple communities it provides $30 million in total, making a $25 million EIB a middle ground (Government of BC, n.d.g). Thus, the $25 EIB ensures that communities will receive sufficient funds to

develop NbS for riverine flooding. This program would be under the responsibility of the Ministry of Transportation and Infrastructure with the EIB being applied at the watershed level. The reason for integrating it into the ARDM program is because it is a fund for flood mitigation infrastructure projects. This policy option would be modelled off of DC's EIB, meaning that the BC government would need to hire a third party to establish outcome-based performance metrics to determine the success of the project. The creation of a nature-based EIB will advance flood resilience as projects will provide restoration of riverbanks and floodplains, planting vegetation, and providing channel relief.

The goal of this policy option is to advance the implementation of NbS by alleviating financial constraints by investing in public-private relationships. This policy option is specifically tailored to NbS and flooding due to extreme weather. An Environmental Impact Bond would serve the same purpose as the ARDM, but only for increasing natural capacity with the intent of reducing or negating the effects of flooding (Government of BC, n.d.f). Overall, this policy will reduce the effects of riverine flooding and advance NbS adoption by utilizing a cost-efficient mechanism.

8.4. Policy Option 4: Nature-Based Credits

The last policy option is also aimed at reducing the financial barriers of implementing NbS through developing a nature-based credit market under the BC's Green Infrastructure program. This is also under the responsibility of the Ministry of Transportation and Infrastructure. The nature-based credit scheme mirrors DC SRC in that credits are used to address flooding and stormwater runoff due to extreme weather. This policy option is targeted specifically at private landowners who will voluntarily restoring or managing riverbanks and floodplains (Bassi et al., 2017). This policy option can be applied more broadly and allow for green infrastructure projects to catch stormwater like the DC stormwater retention program. Similar to DC, nature-based projects or green infrastructure will have to retain up to 50% of rainfall during a storm of 0.8 to1-2 inches of water (Bassi et al., 2017). In terms of restoration project, they will have to meet a criterion of holding a certain amount of flood water for projects consisting of widening riverbanks or floodplains. Overall, this fourth policy options provides a greater opportunity to advance the implementation of NbS on private property as the cost for constructing the projects are reduced.

Chapter 9.

Policy Analysis

This chapter provides an evaluation of the Multi-Criteria Analysis for each of the proposed policy options in chapter eight. The literature review, interview data, and case studies are used to inform each score. Table 4 offers a summary of the analysis.

Table 4. Summary of Policy Analysis.

Objective	Mandate Municipalities to Perform Natural Asset Inventories	Legislate Conservation Authorities	Environmental Impact Bond	Nature-Based Credits
Effectiveness	1	3	3	2
Administrative Complexity	1	1.5	1	1
Cost	2.5	2	2	2
Development	1.5	3	2	1
Stakeholder Acceptance	2.5	2	3	2
Total	8.5	11.5	11	8

9.1. Mandate Municipalities to Perform Natural Asset Inventories

9.1.1. Effectiveness

Natural asset inventories are given a poor rating as they do reduce some barriers associated with NbS but not necessarily the implementation challenges. This policy option increases the proof of concept for NbS as it grows awareness and knowledge of the location and potential value that natural asset can offer in terms of ecosystem services. The data that is gathered has the potential to inform flood mitigation decisions but still does not increase implementation of NbS. This policy option is only an initial assessment of the condition that natural assets are in rather than a means to addressing flooding. Even though the inventory is evaluating natural assets, the inventory does not implement NbS techniques such as restoration, protection, or widening floodplains. Therefore, this policy lacks the ability to perform NbS for flooding due to extreme weather. Overall, natural asset inventories are more for filling the gaps rather than addressing the main barriers to implementing NbS.

9.1.2. Administrative Complexity

Developing and maintaining a natural asset inventory can be administratively complex for municipalities as there are multiple components to this policy option. Depending on the size and capacity of municipalities, developing natural asset inventories can be challenging due to hiring experts, setting up an online dashboard, and developing a natural asset management strategy. An inventory is a long-term commitment where the dashboard will need to be updated every five years to ensure accurate data. However, it is important to note that once the dashboard and systems of evaluations are established there will be less burden when performing updates. Thus, this policy option rates poor for administrative ease.

9.1.3. Development

There is the opportunity that conducting natural asset inventories can provide job opportunities for local communities in terms of ecosystem restoration, park and forest management, as well as construction for green infrastructure. There is also the

opportunity to hire local companies to help aid in conducting inventories. Overall, this policy option rates low to moderate for promoting regional economic development.

9.1.4. Cost

The cost to provincial governments would inherently be low as they are mandating municipalities to perform natural asset inventories. Thus, the cost of conducting analysis of natural asset can be expensive due to the administrative duties tied to the policy, especially if local governments do not have the funds. It could be challenging for local governments to justify their budget to reflect natural assets, however this policy could help leverage natural asset management into departmental conversations. For example, the City of Saskatoon performed an inventory of two natural assets to place a value on them, which costed an estimated $125,000 through a grant (Yobb, n.d). One opportunity is that the BC government could fund grants to complete this work. Therefore, this policy option would be rated as moderate to high in terms of cost.

9.1.5. Stakeholder Acceptance

It is expected that there would be high stakeholder acceptance for the BC government to mandate local governments to perform natural assets inventories. There is already an estimated 35 towns and municipalities in BC that are conducting inventories and/or putting a value on natural assets, thus support would be high (Eyquem et al., 2022). For example, the Town of Gibson's, Town of Comox, City of Colwood, City of Courtenay, City of Grand Forks have all engaged in activities that support natural assets. The BC government would be acceptive to this policy as it only involves an enforcement of the mandate; however, some local governments may have push back due to capacity and financial issues of the policy. It is assumed that industry associations would be moderately supportive for this policy option as it could serve as a tool for land-use planning with developmental projects. Additionally, based off interview participants, non-governmental organizations in the conservation and environmental field would be support of this as they alluded it's a first step to incorporating NbS into decision-making processes. Lastly, this policy option would not necessarily affect private land-owners as it is assessing public natural assets. Therefore, stakeholder acceptance for this policy options ranks as moderate to high.

9.2. Legislate Conservation Authorities

9.2.1. Effectiveness

Conservation Authorities address flooding and other water related issues at the watershed scale using both NbS and other adaptation strategies. Ontario's Conservation Authorities have prevented over $150 million in flood damages per year (Conservation Ontario: Natural Champions, 2019; Conservation Ontario, 2022a). Furthermore, Ontario's Conservation Authorities have restored or rehabilitation over 400 hectares of land for flood control and this includes 1,123kms of streams (Conservation Ontario, 2019a). It is estimated that each year Conservation Authorities plant two million trees with roughly 1,859 landowners (Conservation Ontario: Natural Champions, 2019). In terms of habitat rehabilitation and restoration projects, Ontario's Conservation Authorities have engaged with 321 landowners that have resulted in over 643 projects (Conservation Ontario: Natural Champions, 2019). It is important to note that the work that Conservation Authorities do may not have immediate effects as they are long-term focused for results, especially with NbS as the environment takes time to adapt to changes (Ontario, 2010).

Legislating Conservation Authorities reduce multiple barriers to implementing NbS as well as alleviating the challenges surrounding BC's current flood management. The main barriers that are reduced in terms of NbS is proof of concept, financial, and technical expertise. As exhibit by Ontario, Conservation Authorities provide local and technical expertise to all levels of government (Conservation Ontario: Natural Champions, 2019). Additionally, Ontario's Conservation Authorities are the second biggest landowners in that province that own, protect, and restore an estimated 150,000 hectares of combined forests, wetlands, cultural sites, recreational lands, (Conservation Ontario, 2019a). Having an entity that works with that amount of land has the opportunity to implement multiple NbS. For example, Ontario's Conservation Authorities set the goal of completing 53 NbS from 2021 to 2024 (Conservation Ontario: Natural Champions n.d.a).

Conservation Authorities leverage funding for nature-based activities through partnerships, which elevates issues of securing funding for implementation. Ontario's Conservation Authorities have received funding for NbS from municipalities who provide

31% funding, the province providing 24%, others providing 21%, and the federal government providing 7% (Conservation Ontario, 2019a). Although, it is important to note that of those projects 40% were agriculture rather than targeted at flood control (Conservation Ontario, 2019a). Overall, Conservation Authorities rates high for reducing the main barriers to implementing NbS as well as additional ones surrounding issues to flooding.

In addition, Ontario's Conservation Authorities have created an interactive story map of the 10 out 53 projects that have been implemented thus far specifically under their Natural Climate Solutions (Conservation Ontario: Natural Champions, n.d.a). There have been 41 projects identified for restoration, five projects targeted at enhanced land management, and seven projected targeted at land securement (Conservation Ontario: Natural Champions, n.d.a). Supplementary project details and achievements to date include 1,686 hectares with enhanced land management practices applied, 95 hectares of land restored, and 175 hectares of land secured for conservation (Conservation Ontario: Natural Champions, n.d.a). Overall, Conservation Authorities offer a multitude of ways that NbS can be implemented, and it is evident from Ontario's case that they have succeeded in implementing NbS specifically for riverine flooding.

However, one major limitation of Conservation Authorities is the possibility of overlapping mandates and fragmentation of responsibilities amongst agencies. Ontario's Conservation Authorities have a fragmented legislative structure that is lacking a provincial water management strategy (O'Connor, 2002). Thus, an integrated management approach entails the collaborative efforts of multiple agencies and stakeholders who continuously rely on informal local networks to coordinate activities (Wrote, 2017). This also contributes to how different Conservation Authorities in their jurisdiction have different programs depending on their capacity and size. Overall, this could result in a lack of transparency and overlapping mandates, which could impact the ability to implement effective conservation policies.

9.2.2. Administrative Complexity

Conservation Authorities are less complex due to their streamlining of planning as well as the reduction of red tape with conservation processes (Conservation Ontario: Natural Champions, 2022). Furthermore, Conservation Authorities take on a role that

allows the provincial government to take a back seat. However, it is important to note that Conservation Authorities are a highly collaborative entity which will require multiple engagements with local communities, which can be time consuming. Additionally, this policy option requires legislating a new act rather than integrating it into an existing policy or program. Due to the multitude of services that Conservation Authorities provide, it could be demanding and administratively complex yet that onus would not be on the provincial or local government. Thus, this policy option rates a poor to moderate for administrative complexity.

9.2.3. Development

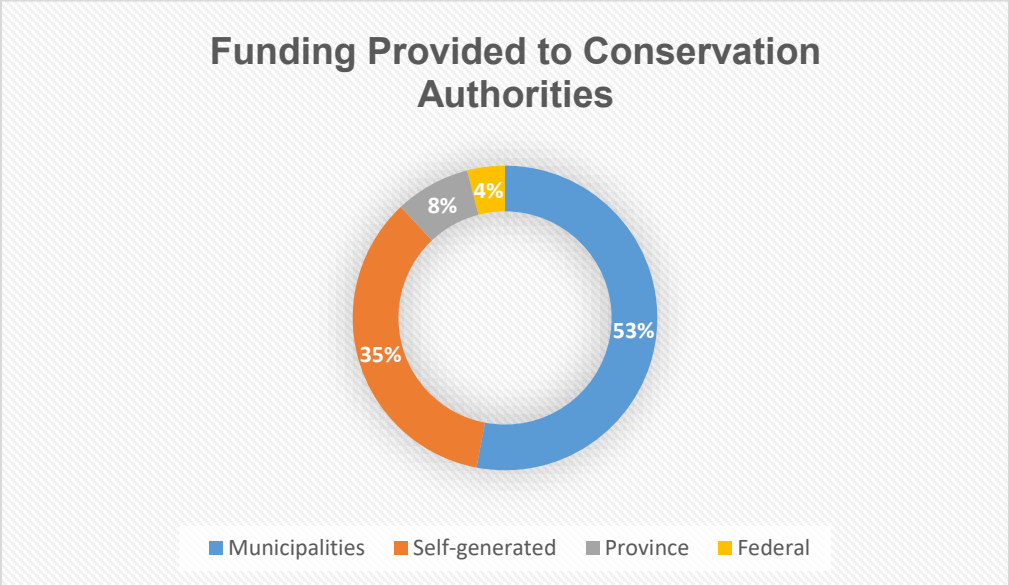
Conservation Authorities provide a variety of opportunities to engage and collaborate with communities. Conservation Authorities provide opportunities for individuals to connect with nature through their programs (Conservation Ontario: Natural Champions, 2019). They work closely with municipalities, the province, the federal government, landowners, and a variety of groups and agencies to be able to deliver and address community-based needs related to maintaining a healthy watershed (Conservation Ontario: Natural Champions, 2019). This highlights the importance of relationship building with partners. Conservation areas that are provided by the Conservation Authorities act as living classrooms for roughly 3,000 schools (Conservation Ontario, 2022a). Furthermore, this policy would contribute to local tourism economies due to an estimated 8-10 million individuals visiting conservation areas for recreational activities (Conservation Ontario, 2022a). Overall, Conservation Authorities deliver multiple benefits to communities, giving this policy option a rating of good for promoting regional economic development.

9.2.4. Cost

Conservation Authorities are cost efficient as they leverage any additional funds from partnership to expand their investments (Conservation Ontario: Natural Champions, 2022). Ontario's Conservation Authorities are primary funded through municipal support and self-generated funds through with additional support from the province's mandated programs such as natural hazards and drinking water source protection (Conservation Ontario: Natural Champions, 2019). For example, in 2017, Ontario's Conservation Authorities received a total of $375 million in revenues (Conservation Ontario: Natural

Champions, n.d). Figure 4 below provides a greater breakdown of where the funds came from. Overall, Conservation Authorities provide approximately $390 million annually in programs and services (Conservation Ontario, 2019a). However, many conservation authorities in Ontario reported that the cost of implementation actions through watershed plans was significant and time-consuming (Ontario, 2010). Additionally, funding cuts throughout the years have caused financial issues for Ontario's Conservation Authorities. The provincial government only provides funding directly for structural approaches to natural hazard management, particularly flooding (Mitchell et al., 2021). Thus, all other programs that are operated by Conservation Authorities are funded through municipalities as the provincial government deemed them as local interest (Mitchell et al., 2021). Therefore, Conservation Authorities receive a moderate rating for cost to the government as the outsource funds from multiple avenues.

Figure 4. Breakdown of Funding for Conservation Authorities



(Source: Conservation Ontario: Natural Champions, n.d).

9.2.5. Stakeholder Acceptance

One of the many benefits of Conservation Authorities is that they engage with local governments and communities. Thus, we can assume that local residents, private landowners, and municipalities would rate high for stakeholder acceptance due to educational, recreational activities and partnerships that Conservation Authorities provide. All programs are targeted at local interests. More so, the public would be likely

to accept Conservation Authorities as they provide connection to nature and environmental education. It is expected that the government would be accepting of Conservation Authorities as they offer province-wide delivery and alleviate some administrative burdens for the province; however, it may be challenging to legislate.

Additionally, Conservation Authorities are subjected to political pressures and can encounter challenges in maintaining their independence and autonomy, which may impact their ability to make informed decisions and implement policies (Mitchell et al., 2021). Depending on which political party is in power it could have an impact on whether Conservation Authorities get legislated. For instance, the Ontario Premier and the Conservative government have been working to narrow the scope of Conservation Authorities as they are limiting developmental projects and impacting a number of broader provincial goals and objectives (Mitchell et al., 2021). This also means that industry associations would probably oppose this option as it favours conservation over development by putting restrictions on where projects can be implemented. Overall, this policy option would receive a moderate acceptance for Conservation Authorities across all stakeholders.

9.2.6. Cost

The initial cost to the provincial government will be expensive as it is a $25 million bond, but there is the opportunity that some of that money will come back if projects do not achieve the goal. The EIB is a pay-for-success model where it allowed the risk of the project to be transferred away from government payers to outside investors, which minimizes the impact on taxpayer funds (Quantified Ventures, n.d.a). Investors are the ones who bear the upfront risk, and the government will only have to pay when results are successful. Although, it is important to note that if the project is unsuccessful there could be penalties on the investors (Quantified Ventures, n.d.a). Thus, this policy option scores a moderate rating in terms of cost to governments.

9.3. Environmental Impact Bond

9.3.1. Effectiveness

An EIB receives a score of good as it is increasing an evidence base of nature-based projects and reducing financial constraints. An EIB serves as a potential model for authorities to leverage private capital to finance uncertainty in regard to NbS and flooding due to extreme weather. An EIB is a cost share risk, which is based off a pay for success model. Each investor and authority share the financial risk and if the project succeeds neither must pay. Having the opportunity to share the risk when investing in NbS will ultimately allow for more pilot projects in BC, increasing the evidence base of NbS being effective at combating riverine flooding. However, there is the chance that if a NbS does not achieve the goal of reducing flood risks, investors will have to pay back a small amount. Additionally, in the case of DC's EIB, when projects underperform, it leaves an option to evaluate the effectiveness and viability of green infrastructure, which could potentially deter the option of NbS (Quantified Ventures, n.d.a).

The Rock Creek project in Washington, DC, was able to construct 77 green infrastructure practices from the EIB (DC Water, n.d). The green infrastructure from the projects have the ability to capture an estimated 650,000 gallons of water annually (Quantified Ventures, n.d). The Rock Creek projects created an estimated 20 arcs of green infrastructure that included two new green infrastructure parks and landscaped retention facilities (DC Water, n.d). The projects that DC Water undertook achieved the goals set out in 2016 and reduced runoff in Rock Creek by approximately 20% over five years (Quantified Ventures, n.d & Lindsay, 2021). Thus, tailoring the EIB to NbS has a high chance for increasing storage capacity for flooding through using nature as similar programs have succeed.

9.3.2. Administrative Complexity

BC's EIB would be less administratively complex as it is integrated into the ARDM program. Thus, BC would already be familiar with the application process for green infrastructure based off previous experience. This policy option requires extensive collaboration between the public-private sphere in order to establish performance outcomes. Furthermore, the performance outcomes require rigorous measurements

before, during, and after a project to see if the project achieved its objective (Goldman Sachs et al., n.d). The rigorous documentation could cause issues related to staff capacity and time constraint. Even though there is the opportunity for an EIB to improve transparency to local ratepayers by having to predict, measure, and publicly report the environmental impacts of NbS, it does not change that it is an extensive process (World Economic Forum, n.d). Thus, this policy option scores a rating of high for administrative complexity.

9.3.3. Development

The EIB will deliver access to new green spaces within the region and has potential to encourage job opportunities for locals in green infrastructure or NbS. DC Water's EIB created a green infrastructure workforce certification where they train and certify residents to construct, inspect, and maintain green infrastructure facilities (Quantified Ventures, n.d, & Goldman Sachs et al., n.d). DC Water ended up hiring over 100 candidates that were trained for green infrastructure jobs for the Rock Creek project and set a goal of having 51% of new jobs created by green infrastructure be certified by local residents (Goldman Sachs et al, n.d). BC could set up a similar program in lieu of the EIB to help boost green jobs and economic development. Overall, this policy option rates as moderate as it has the opportunity to build training and jobs in green infrastructure and NbS.

9.3.4. Stakeholder Acceptance

Stakeholder acceptance for an EIB would receive a score of good as it is a financial incentive for encouraging private-public investments. The provincial government may be hesitant at first due to it requiring a major upfront investment, but the risk is not all on government as it is a cost-sharing policy. Industries and corporations would be in favour of an EIB as it allows them to invest in NbS and restoration work alongside developmental projects. It would help promote sustainable development in the long-term. Local government would be supportive as multiple or individual communities could apply for the EIB and use it to foster projects across their jurisdictions. Given the scope of this policy option it is not applicable to private residential landowners. The public and other stakeholders would be highly accepting as it gives them an opportunity

to be involved NbS to solve flooding issues. Overall, an EIB fosters collaborative partnerships, which helps it receive a good score for stakeholder acceptance.

9.4. Nature-Based Credits

9.4.1. Effectiveness

Developing a crediting scheme for NbS and green infrastructure will reduce the implementation barrier of funding. The credit market for NbS allows developers to avoid high cost when utilizing the credits (District Stormwater LLC, n.d). DC's SRC program had over 660 transactions between 2014 and 2019 at an average price of $2.40 Canadian per credit (Marshall, 2020). Although, this policy is only targeted at reducing financial burdens for private property owners and will potential not have widespread application of NbS. Having green infrastructure included in the credit scheme could also hinder NbS implementation as green infrastructure is a concept that is more understood. Additionally, there is the potential for BC to introduce a price ceiling for the NbS credits to further reduce financial uncertainty. DC's program introduced a Price and Lock Program, which was a $11.5 million fund to purchase SRCs from eligible credit generators that were looking to sell the credits to the district at fixed prices (no author, 2019 & Beck et al., 2019). The purpose of this was to give property owners the chance to sell their credits to local water authorities or the government if their project was not eligible or failed (Beck et al., 2019 & no author, 2019). Overall, NbS credits receive a score of moderate in terms of reducing the barriers associated with implementing NbS for flooding due to extreme weather.

Furthermore, this policy is intended to fund both NbS projects and green infrastructure for flooding and runoff retention from extreme weather. DC's SRC program estimated that it would alleviate seven gallons of runoff annually in the first phase (Beck et al., 2019). Furthermore, 13 to 15 precent of the projects under DC's SRC met a portion of their retention volume offsite and that as of June 2020 there was over 20 acres of green infrastructure retrofits that have occurred (Marshall, 2020). DC's SRC program has resulted in a ten-fold increase in the number of stormwater retention projects developed each year (no author, 2019). If landowners chose to do restoration or planting vegetation it may take a long time before NbS can fully store enough water.

9.4.2. Administrative Complexity

Developing a credit trading scheme is a complex system to establish, let alone adding in NbS. This policy option would be created under BC's Green Infrastructure program but would require a new creation of a crediting scheme. BC would have to develop a database for tracking and tracing the credits as well as reporting the program's outcome, which can be administratively taxing and time-consuming. However, DC's SRCs program only needed six staff, three of whom were full-time (Marshall, 2020). For DC's SRCs to be fully operational, it took over two years, and following implementation further investment was required for the credit market to be functional (Marshall, 2020). Furthermore, DC's SRC required extensive and ongoing stakeholder engagement, which is to be expected in the case of BC. Stakeholder outreach was for the purpose of working out the design of the credit market and political buy-in (Marshall, 2020). Under DC's SRCs, regulatory requirements are immediate met for the site and liability transfers away from site manger to the offsite credit seller, meaning less regulatory responsibility for the site manager (District Stormwater LLC, n.d). Overall, this policy option ranks as poor in terms of administrative complexity due to the varying levels for execution.

9.4.3. Development

NbS credits do not provide regional economic development to a community as it is solely based on private property. The only benefit from this policy option would be in terms of the landowner's property value increasing. Additionally, property space is maximized by reducing the amount of required gray infrastructure for onsite retention for stormwater catchments (District Stormwater LLC, n.d). However, NbS do provide a magnitude of co-benefits in terms of improving air and water quality for communities but that is challenging to quantify for the scope of this study. Thus, this policy option receives a score or poor for improving regional economic development.

9.4.4. Cost

All maintenance and operation of green infrastructure projects or NbS under this program would be the responsibility of private landowners and not the government (Marshall, 2020). This would require less cost to the government in terms of having to

maintain NbS or green infrastructure. Although, there could be additional upfront costs to the government to establish a new market and to get it operational. Thus, the cost to government would be rated as moderate as there is the upfront cost for establishing the program but less lifecycle costs.

9.4.5. Stakeholder Acceptance

Stakeholder acceptance would be rated as moderate as BC and private landowners would perceive the program as a positive. The provincial government would be in favor of this program as it requires less work and implementation from them as private landowners will be responsible for the construction, maintenance, and lifecycle of the nature-based activities or green infrastructure. By focusing on both NbS and green infrastructure it has greater appeal to landowners. Having the option to sell credits back to water agencies when the project is not feasible to implement is an additional aspect that is attractive to private landowners. Although, uptake of the program may be slow because some landowners who are skeptical of the effectiveness of NbS will probably not volunteer. Given the scope of the project, there is uncertainty around how it would impact non-governmental organizations and industry associations, therefore it receives a moderate score in terms of stakeholder acceptance.

Chapter 10.

Recommendation and Implementation

Given the analysis outlined in chapter nine this study recommends a policy bundle of legislating Conservation Authorities and developing an EIB for NbS. There is no single solution that will address all the barriers associated with implementing NbS for flooding due to extreme weather. Thus, these two policy options will have the highest probability of increasing adoption of NbS by reducing the main barriers such as funding and proof of concept.

In the short time, the BC Government should implement an EIB as it is an integration into an existing program (the ARDM program). This should allow for a semi-quick uptake of the policy. The main goal of an EIB is to reduce financial constraints involved when developing and implementing NbS. The EIB is specifically tailored to utilize NbS for flooding caused by extreme weather, with a main reason of it being able to increase flooding capacity. However, while an EIB receives a moderate score for development and cost, the policy fulfils the purpose of reducing the barrier associated with implementation, especially in terms of funding as it is an incentive for public-private investments.

Meanwhile, Conservation Authorities can be legislated simultaneously with an EIB, although it will have a longer implementation period until it is fully operational due to the transition of responsibilities and powers. It is important to note that the long-term benefits for legislating Conservation Authorities outweigh the upfront administrative burdens. Conservation Authorities may be moderate in terms of upfront costs to the government, but they outsource their funds from multiple stakeholders, allowing financial relief. Where Conservation Authorities are implemented at the watershed scale, they are the best suited to address flooding as well as NbS, which is why their performance impact for nature-based activities will be high. Conservation Authorities are effective at reducing the implementation barriers of funding and creating an evidence-base for NbS in BC, which was the main objective of the study.

Although mandating municipalities to perform natural asset inventories is rated as a low policy, it should be considered in tandem with the other recommendations.

Natural asset inventories are important in identifying how and where to implement NbS. Integrating natural assets into decision-making processes for climate adaptation and infrastructure services was emphasized in interviews, making natural asset inventories useful to bridge the gap in developing nature-based policies. Thus, conducting natural asset inventories should be considered as a means to bridge the gap in developing nature-based policies across departments.

Chapter 11.

Considerations

The use of NbS for flood management during extreme weather events should be evaluated carefully on a case-by-case basis. As the interview results suggest, NbS may not be suitable for all situations and gray infrastructure may be required to address the gaps. The context of the area, whether it be urban or rural, has a significant impact on the feasibility and success of NbS. A combination of NbS and gray infrastructure has the potential to deliver a strong performance against flood risks. Hence, a blended approach could be more appropriate in some situations.

Involving Indigenous Peoples in the development and implementation of NbS is important as it presents a unique opportunity for collaboration, healing, and knowledge sharing. NbS are connected to Indigenous cultural practices and relationship with the land, making it an opportunity to showcase Indigenous leadership and traditional conservation techniques. The government of BC should prioritize seeking out Indigenous partnership to effectively implement NbS and address climate change. Engaging and consulting with Indigenous communities is essential in determining the best way to utilize and implement NbS

The 2023 Watershed Security Strategy presents an opportunity to incorporate NbS into watershed management through Conservation Authorities. The strategy's outcomes align with those of Conservation Authorities, such as safe drinking water, healthy ecosystems, and reduced flood risks (Ministry of Environment and Climate Change Strategy, 2022). Despite limited mentions of NbS in the strategy, during stakeholder consultation, there were 12 submissions supporting NbS, calling for provincial support, leadership, education, and funding (Ministry of Land, Water, and Resource Stewardship, 2022). By implementing Conservation Authorities into the strategy, it could improve watershed management and increase NbS adoption.

Earlier in 2022 the MNAI and Environment and Climate Change Canada signed an agreement with the CSA Group to develop a new National Standard for Canada on natural asset inventories (MNAI, n.d). This methodology could have policy implications

that support the decision to mandate municipalities to perform inventories of natural infrastructure assets and incentive the BC government.

Chapter 12.

Conclusion

Despite the numerous advantages of incorporating NbS into climate adaptation for addressing the impacts of extreme weather flooding, their usage remains limited. This is primarily due to the perception that NbS are complex and pose many barriers to implementation, leading the BC government to prefer traditional flood management strategies. However, BC's current flood policies, which focus on reactive measures, temporary displacement, and gray infrastructure, fall short in addressing the issue of extreme weather-related flooding. NbS offer a proactive approach to flood management. Therefore, to improve the implementation of NbS and effectively address the challenges of extreme weather flooding, it is necessary to address these barriers and increase the utilization of NbS in BC.

This study aimed to identify the main challenges for implementing NbS in BC, with proof of concept and funding being the key barriers to reduce. The study analyzed different implementation strategies and determined a policy bundle of Conservation Authorities and a EIB to be the most effective in addressing these barriers and reducing the risks of extreme weather flooding. The study's findings emphasize the importance of considering a combination of policies, as no single policy can address all the challenges associated with the implementation of NbS. It is essential to overcome these implementation barriers to promote a resilient future and advance NbS adoption in BC.

References

Auditor General of British Columbia (2018). Managing Climate Change Risks: An Independent Audit. Office of the Auditor General of B.C., Victoria, British Columbia. https://www.bcauditor.com/sites/default/files/publications/reports/Climate_Change_FINAL_0.pdf

Alvarez, J. (n.d). “The Forest Resilience Bond: A Tangible Solution to the Wildfire Crisis”. National Forest Foundation. https://www.nationalforests.org/blog/the-forest-resilience-bond

Andrade Silva, A. R., & Ribeiro, F. L. (2016). Payment for Watershed Services: It’s Possible, but for which Conservation Policy on Fresh Water and Ecosystem Services?.

Bassi, A., Cuéllar, A., Pallaske, G., & Wuennenberg, L. (2017). Stormwater markets: Concepts and applications. International Institute for Sustainable Development. https://www.iisd.org/system/files/publications/stormwater-markets-concepts-applications.pdf

Beck, M. W., Pfliegner, K., Quast, O., & Stadtmüller, D. (2019). Ecosystem-based adaptation and insurance: success, challenges and opportunities. InsuResilience Secretariat, Bonn, Germany. https://www.anticipation-hub.org/Documents/Case_Studies/Ecosystem-based-Adaptation-and-Insurance.pdf

Blue Forest. (n.d. a) “The Yuba Project”. Blue Forest Conservation. https://www.blueforest.org/the-yuba-project

Blue Forest Conservation. (2017). Fighting fire with finance: A roadmap for collective action. Trust for Conservation Innovation/Private Capital for Public Good, 1-102.

Blue Forest Conservation and Convergence: Blending Global Finance. (2020). “Case study: The Forest Resilience Bond (FRB)”. https://assets.ctfassets.net/4cgqlwde6qy0/3oQyq8vM4lnMi0seO2b5dd/59bd96505808514328f379ef2673a83e/Convergence_FRB_Final_Final_Draft_.pdf

Blue Forest Conservation. (2020). “The Forest Resilience Bond: Annual Impact Report 2020”. https://static1.squarespace.com/static/5e9a1c0d4e0c2e67582026f2/t/607f3dc65d59974ec8ee074c/1618951648454/BFC+Yuba+Impact+Report+2020.pdf

Buttle J. et al., (2016) "Flood Processes in Canada: Regional and Special Aspects," Can. Water Resour. Journal, vol. 41, no. 1-2, pp. 7–30.

Campbell (Shultz), Jenna. (2019). "The Successful Implementation of O. Reg. 588/17: Organizational Factors that Contribute to the Success of Asset Management Planning for Municipal Infrastructure in Small Ontario Municipalities". MPA Major Research Papers. 224. https://ir.lib.uwo.ca/lgp-mrps/224

City of Charlottetown. (n.d). “Municipal Natural Asset Inventory.” https://www.charlottetown.ca/environment___sustainability/nature/municipal_natural_asset_inventory

Conservation Ontario: Natural Champions. (n.d.). “About Conservation Authorities”. Conservation Ontario: Natural Champions. https://conservationontario.ca/conservation-authorities/about-conservation-authorities

Conservation Ontario: Natural Champions. (n.d.a). “Nature-based climate solutions”. Conservation Ontario: Natural Champions. https://conservationontario.ca/policy-priorities/climate-change/nature-based-climate-solutions

Conservation Ontario: Natural Champions. (n.d.c). “Conservation Authorities Act: Section 28 Regulations.” Conservation Ontario: Natural Champions. https://conservationontario.ca/conservation-authorities/planning-and-regulations/conservation-authorities-act-section-28-regulations

Conservation Ontario: Natural Champions. (2019). “Fact Sheet”. Conservation Ontario: Natural Champions. file:///C:/Users/mkl34/Downloads/CO_Fact_Sheet_Sept_2019.pdf

Conservation Ontario. (2019 a). “Conservation Authorities: Partners for a more Resilient Ontario”. *Conservation Ontario: Natural Champions.* file:///C:/Users/mkl34/Downloads/CO_Resilient_Ontario_2021_FINAL.pdf

Conservation Ontario: Natural Champions. (2022). “Re-Imagining nature: valuable partners for a more resilient Ontario”. file:///C:/Users/mkl34/Downloads/PP_CO_Re-Imagining_Nature_2022-03-18.pdf

Conservation Ontario. (2022a). “Conservation Authorities Are Important Partners for a Resilient Ontario: 2022 https://conservationontario.ca/fileadmin/pdf/policy-priorities_section/PP_Pre-Election_Discussion_Paper_REVISED_Feb_22_2022__003_.pdf

Curry, C.L., Islam, S.U., Zwiers, F.W. and Déry, S.J. (2019). Atmospheric rivers increase future flood risk in western Canada’s largest Pacific river. Geophysical Research Letters, 46(3), 1651–1661. Retrieved from https://doi.org/10.1029/2018GL080720

DC Government. (n.d). “Stormwater Retention Credit Trading Program”. *Department of Energy and Environment*. https://doee.dc.gov/src

DC Water. (n.d). “FACT SHEET: DC Water Environmental Impact Bond Results-Successful”. https://dcwater.com/sites/default/files/finance/eib-factsheet.pdf

District Stormwater LLC. (n.d). “Buy Credits.” *District Stormwater LLC* https://www.districtstormwater.com/buy-credits

Díaz, S. M., Settele, J., Brondízio, E., Ngo, H., Guèze, M., Agard, J., ... & Zayas, C. (2019). The global assessment report on biodiversity and ecosystem services: Summary for policy makers.

Drever, C. R., Cook-Patton, S. C., Akhter, F., Badiou, P. H., Chmura, G. L., Davidson, S. J., ... & Kurz, W. A. (2021). Natural climate solutions for Canada. Science Advances, 7(23), eabd6034.

Dyke Management Act. (R.S.B.C 1996, c95). Retrieved from the BC Laws website. https://www.bclaws.gov.bc.ca/civix/document/id/consol20/consol20/00_96095_01#section1

Ecoagriculture. (2011). "Payments for watershed services in the United States. https://ecoagriculture.org/wp-content/uploads/2015/08/Payments-for-EcoServices-Brief.pdf

Eyquem, J. L, Church, B. Brooke, R and Molnar, M. (2022). Getting Nature on the Balance Sheet: Recognizing the Financial Value of Natural Assets in a Changing Climate. Intact Centre on Climate Adaptation, University of Waterloo. https://static1.squarespace.com/static/60a50c60a83ef84c78cb1413/t/633dedf0ae874a5a4661f77c/1665002994265/GETTING+NATURE+ON+THE+BALANCE+SHEET.pdf

Federal Emergency Management Agency (FEMA). 2020. Building Community Resilience with Nature-Based Solutions: A Guide for Local Communities. Washington, DC: Federal Emergency Management Agency. https://www.fema.gov/sites/default/files/documents/fema_riskmap-nature-based-solutions-guide_2021.pdf

Floodwise. (n.d). "Flood Management Responsibilities: Who Does What?" Floodwise. https://floodwise.ca/flood-101/who-does-what/

Fraser Basin Council. (2022). "Metro Vancouver Flood Resilience Task Force. Lower Mainland Flood Management Strategy." Fraser Basin Council. http://www.metrovancouver.org/boards/FloodResiliency/FRTF_2022-Feb-23_PPT.pdf

Friedrich, K. (2016). “Stormwater Credits in D.C. Could Provide a Blueprint for Other Cities”. *Conservation Finance Network.* https://www.conservationfinancenetwork.org/2016/06/06/stormwater-credits-in-dc-could-provide-blueprint-for-other-cities

Friends of the Verde River. (n.d). "Payments for Watershed Services". https://verderiver.org/payments-for-watershed-services/

Goldman Sachs, DC Water, and Calvert Foundation. (n.d). “Fact Sheet: DC Water Environmental Impact Bond.” https://www.goldmansachs.com/media-relations/press-releases/current/dc-water-environmental-impact-bond-fact-sheet.pdf

Government of British Columbia. (n.d. a). Flood Hazard Land Use Management. *Government of British Columbia.* https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/integrated-flood-hazard-management/flood-hazard-land-use-management

Government of British Columbia. (n.d. b). Dike Management. Government of British Columbia. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/integrated-flood-hazard-management/dike-management

Government of British Columbia. (n.d. c). Flood Protection Structures in B.C. Government of British Columbia. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/integrated-flood-hazard-management/dike-management/flood-protection-structures

Government of British Columbia. (n.d.d). "River Forecast Centre." https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/river-forecast-centre

Government of British Columbia. (n.d.e). "Floodplain Maps by Region." Government of British Columbia. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/integrated-flood-hazard-management/flood-hazard-land-use-management/floodplain-mapping/floodplain-maps-by-region

Government of British Columbia. (n.d.f). “Adaptation, resilience and disaster mitigation program.” British Columbia Government. https://www2.gov.bc.ca/gov/content/safety/emergency-management/local-emergency-programs/financial/ardmp

Government of British Columbia. (n.d.g). "Adaptation, resilience and disaster mitigation program." Government of BC. https://www2.gov.bc.ca/gov/content/safety/emergency-management/local-emergency-programs/financial/ardmp

Government of British Columbia, (2022). Climate Preparedness and Adaptation Strategy | Actions for 2022-2025. https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/cpas.pdf

Green Finance Institute. (n.d). “DC Stormwater Retention Credit Trading Programme”. https://www.greenfinanceinstitute.co.uk/gfihive/case-studies/stormwater-retention-credit-trading-programme/

ICF, (2018) Best Practices and Resources on Climate Resilient Natural Infrastructure, Canadian Council of Ministers of the Environment. Available: https://www.preventionweb.net/files/64196_naturalinfrastructurereporten1.pdf

International Union for Conservation of Nature (ICUN). (2020) The IUCN Global Standard for Nature-based Solutions: A User-Friendly Framework for the Verification, Design and Scaling Up of NbS, Gland, Switzerland: IUCN. https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf

Insurance Bureau of Canada (2022). Severe Weather in 2021 Caused $2.1 Billion in Insured Damage. Retrieved March 2022, from http://www.ibc.ca/on/resources/media-centre/media-releases/severe-weather-in-2021-caused-2-1-billion-in-insured-damage

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., ... & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society, 21(2).

Lindsay, Q. (2021). “DC Water’s Pioneering Environmental Impact Bond a Success”. Quantified Ventures. https://www.quantifiedventures.com/dc-water-eib-results

Luedke, H. (2019). "Fact Sheet | Nature as Resilient Infrastructure - An Overview of Nature-Based Solutions." Environmental and Energy Study Institute. https://www.eesi.org/papers/view/fact-sheet-nature-as-resilient-infrastructure-an-overview-of-nature-based-solutions

Malavasi, E. O., & Kellenberg, J. (2002, March). Program of payments for ecological services in Costa Rica. In Building Assets for People and Nature: International Expert Meeting on Forest Landscape Restoration, Heredia, Costa Rica (Vol. 27, pp. 1-7).

Marshall, S. (2020). Exploring Opportunities and Challenges Associated with Managing Rainwater From Private Properties in the Public Realm: Alternate Compliance Mechanism for Private Realm Rainwater Management.” UBC Sustainability. https://sustain.ubc.ca/sites/default/files/2020-55_Managing%20Rainwater%20from%20Private%20Properties_Marshall.pdf

Ministry of Environment and Climate Change Strategy (2019). Preliminary Strategic Climate Risk Assessment for British Columbia. Report prepared for the Government of British Columbia, Victoria, BC. Accessible at: https://www2.gov.bc.ca/gov/content/environment/climate-change/adaptation/riskassessment

Ministry of Environment and Climate Change Strategy. (2022). “Watershed Security Strategy and Fund: Discussion Paper.” Government of British Columbia.

Ministry of Land, Water, Resource Stewardship. (2022). Watershed Security Strategy and Fund Discussion Paper: What We Heard.” Government of British Columbia.

Mitchell, B., Shrubsole, D., & Watson, N. (2021). Ontario conservation authorities–end, evolve, interlude or epiphany?. Canadian Water Resources Journal/Revue canadienne des ressources hydriques, 46(3), 139-152. https://www.tandfonline.com/doi/epdf/10.1080/07011784.2021.1930585?needAccess=true&role=button

Municipal Natural Asset Initiative. (n.d) “Resource to help navigate and implement O. Reg. 588/17.” Municipal Natural Asset Initiative.

Municipal Natural Assets Initiative (MNAI). (n.d). “Natural Asset Inventories Standard Now Out for Public Review.” https://mnai.ca/natural-asset-inventories-standard-now-out-for-public-review/#:~:text=A%20natural%20asset%20inventory%20contains,full%20natural%20asset%20management%20process

Municipal Natural Assets Initiative (MNAI). (2017). “Defining and Scoping Municipal Natural Assets.” Municipal Natural Asset initiative. https://mnai.ca/media/2018/02/finaldesignedsept18mnai.pdf

MNAI. 2019. “Advancing and Integrating Municipal Natural Asset Management through Asset Management Planning in Ontario.” https://mnai.ca/media/2020/01/MNAI_MNAPOntario.pdf

Municipal Natural Assets Initiative (MNAI). (2021). Toward natural asset management in the City of Charlottetown, Prince Edward Island. Summary of inventory results and implications. https://mnai.ca/media/2021/11/MNAI-Inventory-Cluster-Charlottetown-report-102.pdf

Molnar, M. (2020). Healthy ecosystems can reduce community infrastructure costs. David Suzuki Foundation. https://davidsuzuki.org/expert-article/healthy-ecosystems-reduce-community-infrastructure-costs/

Molnar, M., Olmstead, P., Mitchell, M., Raudsepp-Hearne, C. and Anielski, M. (2021): Ecosystem Services; Chapter 5 in Canada in a Changing Climate: National Issues Report, (eds.) F.J. Warren and N. Lulham; Government of Canada, Ottawa, Ontario.

Moudrak, N., & Feltmate, D. B. (2019). Weathering the storm: Developing a Canadian standard for flood-resilient existing communities. Intact Centre on Climate Adaptation, University of Waterloo.

Moudrak, N. and Feltmate, B. (2020). “Under One Umbrella: Practical Approaches for Reducing Flood Risks in Canada.” Intact Centre on Climate Adaptation, University of Waterloo.

Nelson, D. R., Bledsoe, B. P., Ferreira, S., & Nibbelink, N. P. (2020). Challenges to realizing the potential of nature-based solutions. Current Opinion in Environmental Sustainability, 45, 49-55. https://reader.elsevier.com/reader/sd/pii/S1877343520300750?token=39D056E1C9153F0E47B34D9E7FF75C4AC25A0EB364512314DE7542664E6D30BCA3F8

2EFB08F55B9B20567392AD019DCD&originRegion=us-east-1&originCreation=20230401234841

No author. (2019). " Stormwater Credit Trading: Lessons from Washington D.C." *Metropolitan Planning Council.* https://www.metroplanning.org/news/8671/Stormwater-Credit-Trading-Lessons-from-Washington-D-C

O'Connor, D. R. (2002). Report on the walkerton inquiry: A strategy for safe drinking water Part 2. Toronto: Queen's Printer.

Ontario, C. (2010). Overview of integrated watershed management in Ontario. Conservation Ontario. https://conservationontario.ca/fileadmin/pdf/policy-priorities_section/IWM_OverviewIWM_PP.pdf

Oulahen, G., Klein, Y., Mortsch, L., O'Connell, E. and Harford, D. (2018). Barriers and Drivers of Planning for Climate Change Adaptation across Three Levels of Government in Canada. Planning Theory and Practice, 19(3), 405–421. Retrieved June 2021, from https://doi.org/10.1080/14649357.2018.1481993

Parker, J. (2014). "Stormwater Retention Credit Trading Program". Autocase. https://autocase.com/stormwaterretentioncredittradingprogram/

Quantified Ventures. (n.d). "DC Water: First Ever Environmental Impact Bond". https://www.quantifiedventures.com/dc-water/

Quantified Ventures. (n.d.a). "Case Study: DC Water." https://static1.squarespace.com/static/5d5b210885b4ce0001663c25/t/5e136b61f2afef61e95e7472/1578331001269/DC+Water+Case+Study_Quantified+Ventures

Sarabi, S., Q. Han, G.,Romme, B. de Vries, & L. Wendling. (2019). Key enablers and barriers to the uptake and implementation of nature-based solutions in urban settings: a review. Resources8, 121. https://doi.org/10.3390/resources8030121

Schmunk, R. (2021). Historic flooding in southern B.C., by the numbers. CBC News. Retrieved January 2022, from https://www.cbc.ca/news/canada/british–columbia/flooding–mudslides–bc–by–the–numbers-1.6252453

Seddon, N., Chausson, A., Berry, P., Girardin, C. A., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B, 375(1794), 20190120.

Seddon N, Smith A, Smith P, Key I, Chausson A, et al. (2021). Getting the message right on nature-based solutions to climate change. Glob. Change Biol. 27(8):1518–46

Shaw, A., Harford, D., Tolsma, K., Basnayake, H. (2020). "Accounting for Natural Assets in Local Government: A Low Carbon Resilience Approach" Simon Fraser University, Adaptation to Climate Change Team.

Voskamp, I., de Luca,C.,Polo-Ballinas,M.,Hulsman,H.,& Brolsma, R.(2021). Nature-based solutions tools for planning urban climate adaptation: state of the art. Sustainability,13, 6381. https://doi.org/10.3390/su13116381

Vouk, I., Pilechi, V., Provan, M., & Enda, M. (2021). Nature-Based Solutions for Coastal and Riverine Flood and Erosion Risk Management. Canadian Standards Association. Accessed at: https://www. csagroup. org/wp-content/uploads/CSA-Group-Research-Nature-Based-Solutions-for-Coastal-and-Riverine-Flood-and-Erosion-Risk-Management. pdf, 82.

Wamsler. C., Wickenberg, B., Hanson, H., Olsson, J., Stalhammar, S., Bjorn, H., Falack, H., Gerell, D., Oskarsson, T., Simonsson, E., Torffvit, F., Zelmerlow, F. (2020). Environmental and climate policy integration: targeted strategies for overcoming barriers to nature-based solutions and climate change adaptation. Journal of Cleaner Production,247, 119154. https://doi.org/10.1016/j.jclepro.2019.119154

Watershed Markets (n.d). "Mexico-National PSAH Programme". International Institute for Environment and Development. https://watershedmarkets.org/casestudies/Mexico_National_PSAH_eng.html

World Economic Forum. (n.d). “Case Study. DC Water’s Environmental Impact Bond.” *World Economic Forum.* https://www3.weforum.org/docs/WEF_Urban_Transformation_Case_Study_DC_Water_2022.pdf

Worte, C. (2017). Integrated watershed management and Ontario’s conservation authorities. International Journal of Water Resources Development, 33(3), 360-374.

Yobb, T. (n.d). “Measuring the value of natural assets.” Green Municipal Fund. https://greenmunicipalfund.ca/case-studies/measuring-value-natural-assets

Appendix A.

Additional Barriers to NbS Implementation

Institutional Fragmentation

Institutional fragmentation refers to the challenges of coordination among levels of governments, stakeholders, organizations, and policies (reference). The differentiated responsibilities across levels of government and organizations make it difficult to coordinate as they have their own vision, legal framework, or procedures (Ershad Sarabi et al., 2019). Departmental mandates and structures of government hinder the recognition of the overarching benefits of NBS and impede proper assignment of ownership and financial stability for nature-based projects (Sarabi et al., 2019). This essentially leads to confusion about who is responsible for leading the project, funding, and maintenance. There are also limited opportunities and roles for multi-disciplinary and multi-sectoral communication and collaboration (Vouk et al., 2021). Furthermore, the need for multi-disciplinary expertise could be considered as expensive for small-scale projects (Vouk et al., 2021).

Additionally, there is a shortage of skilled NbS practitioners within Canada (ICF, 2018). The capacity of each level of government is also a barrier as small local communities do not have the staff to implement such nature-based projects alone. This leaves the question of how stakeholders and the public can be involved in the long-term planning and administration of NbS (Kabisch et al., 2016). Allowing inclusivity on NbS will increase the understanding of local preferences and capabilities. Producing an overall framework and guidance for the implementation of NbS at a provincial level will allow municipalities and organizations to have the same understanding and process across the board.

Regulation and Policy

Within BC, there is a lack of regulation and policy for NbS. The regulations and policies vary across jurisdictions and BC currently does not have a provincial regulatory framework for NbS. The majority of regulations and policies within BC are geared to

engineered structures such as the dikes. A shortage of streamlined processes and synergies between different levels of government can prevent the adoption of NBS (Ershad Sarabi et al., 2019). Having a whole system thinking for NbS has the potential to create a paradigm shift in flood risk management practice and governance (Vouk et al., 2021). An overarching theme in this barrier is the lack of guidance and standards at the provincial or national level on implementing NbS (Sarabi et al., 2020). There is no supportive framework or polices for local government to implement nature-based projects. It is proven that the lack of institutional and financial mechanisms is rooted in the lack of knowledge about design and technical guidelines to implement NbS (Raška et al., 2022). At the provincial level in BC there is a lack of institutional capacity to oversee and strategically implement NbS, while local municipalities also struggle due to limited sources of expertise, funding, and staffing (ICF, 2018).

Knowledge Gaps

There are multiple knowledge gaps and uncertainties associated with NbS such as creation, implementation, effectiveness, and management of nature (Ershad Sarabi et al., 2019). In terms of effectiveness, there are uncertainties about when the project will exhibit the trade-offs and multiple benefits as NbS are a long-term solution (Kabisch et al., 2016). It is unclear which approaches will be most effective in the long-term to mitigate the risk of flooding and further data collection and sharing is needed to close the gap on lack of knowledge (Kabisch et al., 2016). Within this category, there is a lack of professional expertise and resources. Key players lack the technical and multi-sectoral expertise needed to design and implement NBS in municipal planning (Walsmer et al., 2020). The knowledge gap associated with NbS filters down to the public as many individuals are not exposed to NbS or have the opportunity to learn about them (Voskamp et al., 2020). Thus, a lack of knowledge decreases the level of participation from stakeholders and perceived effectiveness of NbS.

Appendix B.

Additional Case Studies

California, United States of America

California is known for having unnaturally dense forest, which are a primary concern for exposing communities to heightened wildfire risk, degraded water supplies as well as other climate vulnerabilities (Blue Forest Conservation and Convergence: Blending Global Finance, 2020). Currently, there is an estimated six to nine million arcs of forest land that need restoration activities to reduce those risks (Blue Forest Conservation and Convergence: Blending Global Finance, 2020).

With public funds being limited due to focusing on fire suppression rather than prevention, the Forest Service signed an agreement with Blue Forest Conservation in 2018 to share the commitment to landscape-scale restoration by utilizing a Forest Resilience Bond (FRB) (Blue Forest Conservation, n.d.a). A FRB is a public-private partnership that allows private capital to finance forest restoration activities to reduce wildfire risk while simultaneously delivering environmental and social co-benefits (Blue Forest Conservation, 2017). How the FRB works is that funding comes from four investors, with three beneficiaries providing funding at contracted rates to reimburse the investors as restoration activities are completed by an implementation partner (Blue Forest Conservation, 2020 and Alvarez, n.d). The FRB allows for private capital to play an influential role in public land management while also reducing the financial gap when performing restoration duties.

Later that year Blue Forest Conservation launched a pilot project through the FRB called the Yuba Project (Blue Forest Conservation, 2017 and Convergence: Blending Global Finance, 2020). The Yuba Project is a 14,545-acre project in the North Yuba River Watershed of Tahoe National Forest where the FRB will perform 7,114 acres of restoration to protect a 15,000-acre area (Blue Forest Conservation, 2017; Convergence: Blending Global Finance, 2020; Blue Forest Conservation, n.d. a). After two completed field sessions of restoration work in 2019 and 2020, the Yuba Project is 50% complete and is on track for completion as originally planned (Blue Forest

Conservation, 2020). Additionally, investors have been paid off according to their contracts (Blue Forest Conservation, 2020).

Costa Rica

One of the most common approaches in Costa Rica for the conservation and restoration of forest ecosystems is the promotion of sustainable practices for ecological services (Ferraro and Simpson, 2000). Thus, Costa Rica developed the Payments for Environmental Services Program (PESP), which is where private landowners receive direct payments for the ecological service that their lands produce only when they adopt sustainable land use and forest management techniques (Malavasi, Kellenberg, 2002).

PESP can be defined as “voluntary transactions between service users and service providers that are conditional on agreed rules of natural resource management for generating off-site services” (Friends of the Verde River, n.d). The purpose of PESP is to incentive the conservation of ecosystem services “to protect the primary forest, allow the secondary forest to flourish, and promote forest plantations to meet industrial demands for lumber and paper products” (Malavasi, Kellenberg, 2002, p.3-4). There is a multitude of structures and methods for PESP such as direct public payments or private payments for services provided, or they can also come in the form of a tax incentive or certificate program (Friends of the Verde River, n.d). The PESP goals fro Costa Rica are met through site-specific contracts with small and medium-sized farmers or landowners where they present a sustainable forest management plan certified by a licensed forester and carry out their conservation or sustainable forest management activities (Malavasi & Kellenberg, 2002). There are three different contract options that are available, as summarized in the table A1 below.

Table A1. Summary of the Different Contracts for PESP

Contract Type	Summary	Percentage of Contracts
Forest Conservation Easement	Target areas of conservation for vegetation cover in primary and secondary forests over 5 years at a rate of US$210 per hectare that is disbursed over 5 years.	85%

Sustainable Forest Management	Landowners commit to maintain forested areas for a period of 15 years at a rate of US$327 per hectare disbursed over five years.	9%
Reforestation	Landowners commit to maintaining reforested areas over a period of 15 to 20 years at a rate of US$537 per hectare disbursed over five years.	6%

(Source: Malavasi, Kellenberg, 2002)

Mexico, United States of America

Similar to Costa Rica, Mexico has initiated a national PESP investing earmarked water use fees into the conservation of forest cover in priority areas for the enhancement of hydrological resources (Watershed Markets, n.d). Mexico's National Payment for Environmental Services has been ongoing since 2003 and active as of 2011 (Watershed Markets, n.d). Mexico developed a Payment for Watershed Service (PWS). A PWS is a subset of PESP where landowners or land managers are offered cash payments or other benefits if they adopt a variety of mechanisms for watershed protection that can result in improved or sustained watershed services (Ecoagriculture. 2011 & Andrade, Ribeiro, 2016). For example, landowners can manage water quality and quantity by restoring forests, protecting wetlands, or increasing flood water storage (Ecosgriculutral, 2011). Then these watershed services are purchased by service beneficiaries, including water utilities or government agencies (Ecoagriculture. 2011 & Andrade, Ribeiro, 2016).