


TOO SMALL TO FAIL:
Protecting Canadian Communities from Floods


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INTACT CENTRE
ON CLIMATE ADAPTATION

UNIVERSITY OF WATERLOO

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ABOUT THE INTACT CENTRE ON CLIMATE ADAPTATION (Intact Centre)

The Intact Centre on Climate Adaptation (Intact Centre) is an applied research centre at the University of Waterloo. Working with homeowners, communities, governments and businesses, the Intact Centre's primary purpose is to mobilize practical and cost-effective means of de-risking Canada from climate change and extreme weather events. The Intact Centre was founded in 2015 with a gift from Intact Financial Corporation, Canada's largest property and casualty insurer.
For additional information, visit: www.intactcentreclimateadaptation.ca.

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ACKNOWLEDGEMENTS

The Intact Centre on Climate Adaptation thanks Intact Financial Corporation for their funding support.

DISCLAIMER

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EXECUTIVE SUMMARY

Under the direction of the **Climate Change Adaptation Project** (CCAP – overseen by the Intact Centre on Climate Adaptation), 11 flood risk mitigation projects were implemented across Canada between 2012 and 2017. The purpose of the initiative – and by extension this report – was to identify and assess practical actions that communities and organizations (i.e. municipal governments, non-governmental organizations, conservation authorities) could engage to limit flood risk at a local or community scale.

As illustrated in Figure 1, the projects were grouped into the following categories: **Empowering Landowners; Rain Gardens, Bioretention Systems, and Permeable Pavement;** and **Restoration of Banks and Shorelines**. While the two projects under the Empowering Landowners category were educational, the projects under the other two categories involved the application of flood risk mitigation measures.

The eleven projects revealed broadly applicable lessons – highlighted throughout this report – that may contribute to greater efficiency applied to the execution of similar future projects.

Figure 1: Flood risk mitigation projects implemented across Canada, 2012 to 2017

EMPOWERING LANDOWNERS

Across Canada Workshop Series: Showcasing British Columbia's "Water Balance Model Express for Landowners"

In 2014, the **Partnership for Water Sustainability in BC** led the Across Canada Workshop Series on Adapting to a Changing Climate, showcasing British Columbia's WBM Express in Calgary, Toronto, Ottawa, Montreal, and Halifax.

RAIN Home Visit Program

In 2014, **Green Calgary** (a local partner of Green Communities Canada (GCC)) led the RAIN Home Visit Program in Calgary, Alberta, where 100 home visits were completed by certified RAIN guides as part of a larger campaign across Canada.

RAIN GARDENS, BIORETENTION SYSTEMS, AND PERMEABLE PAVEMENT

Leaders for Clean Water - Community Resilience Campaign

Between 2012 and 2015, **Credit Valley Conservation (CVC)** led the implementation of three LID demonstration projects: one in Caledon, Ontario and two in Mississauga, Ontario. All projects were executed with a high degree of community involvement.

Green Alley of Saint-Leonard

In 2015, **Nature-Action Quebec (NAQ)** led the implementation of a green alley project in the borough of Saint-Leonard in Montreal, Quebec, reducing impervious surfaces in the urban environment and creating a plantation zone for gardening.

Depave Paradise

Between 2013 and 2015, **Green Communities Canada (GCC)** led six Depave projects – five in Ontario (North Bay, Kingston, Otttawa, Peterborough, and Mississauga) and one in Alberta (Calgary). These were part of a larger campaign involving 30 projects done between 2012-2017.

City of Beloeil Dionis–Désilets Retention Basin

From 2014 to 2016, **Nature-Action Quebec (NAQ)** planted trees and shrubs in the Dionis-Désilets retention basin, which manages stormwater runoff from the recently developed Les Bourgs de la Capitale district of the City of Beloeil.

Bioretention System for Flood Risk Mitigation

In 2016, **Toronto and Region Conservation Authority (TRCA)** led the installation of a bioretention system at the Kortright Centre in Woodbridge, Ontario.

RESTORATION OF BANKS AND SHORELINES

Alfred Kuehne Natural Channel Design Project: Pre- and Post-Restoration Stream Monitoring

From 2012 to 2013, **Toronto and Region Conservation Authority (TRCA)** led the restoration of a 500-metre section of Spring Creek in Alfred Kuehne Park in Brampton, Ontario. Pre-restoration and post-restoration monitoring conducted.

Living Shorelines: Climate Change Adaptation Along Urban Coasts

In 2015, **Ecology Action Centre (EAC)** led the Living Shorelines restoration project at Saint Mary's Boat Club (SMBC) in Halifax, Nova Scotia.

Seymour Estuary Restoration Project

In 2015, **Adaptation to Climate Change Team (ACT) supported** the implementation of the Seymour Estuary Restoration Project in British Columbia.

Spring Creek Channel Restoration Project

Since 2012, **Toronto and Region Conservation Authority (TRCA)** has been leading the design of the Spring Creek Channel Restoration Project in Brampton, Ontario, with implementation expected to take place in 2019.

As most of the projects involved actual implementation of flood risk mitigation measures, the findings are presented in the context of a project lifecycle (Figure 2). While the Empowering Landowners projects were educational, key insights from these projects are still included.

A comprehensive analysis of the projects revealed two key success drivers that are often important throughout the entire project lifecycle:

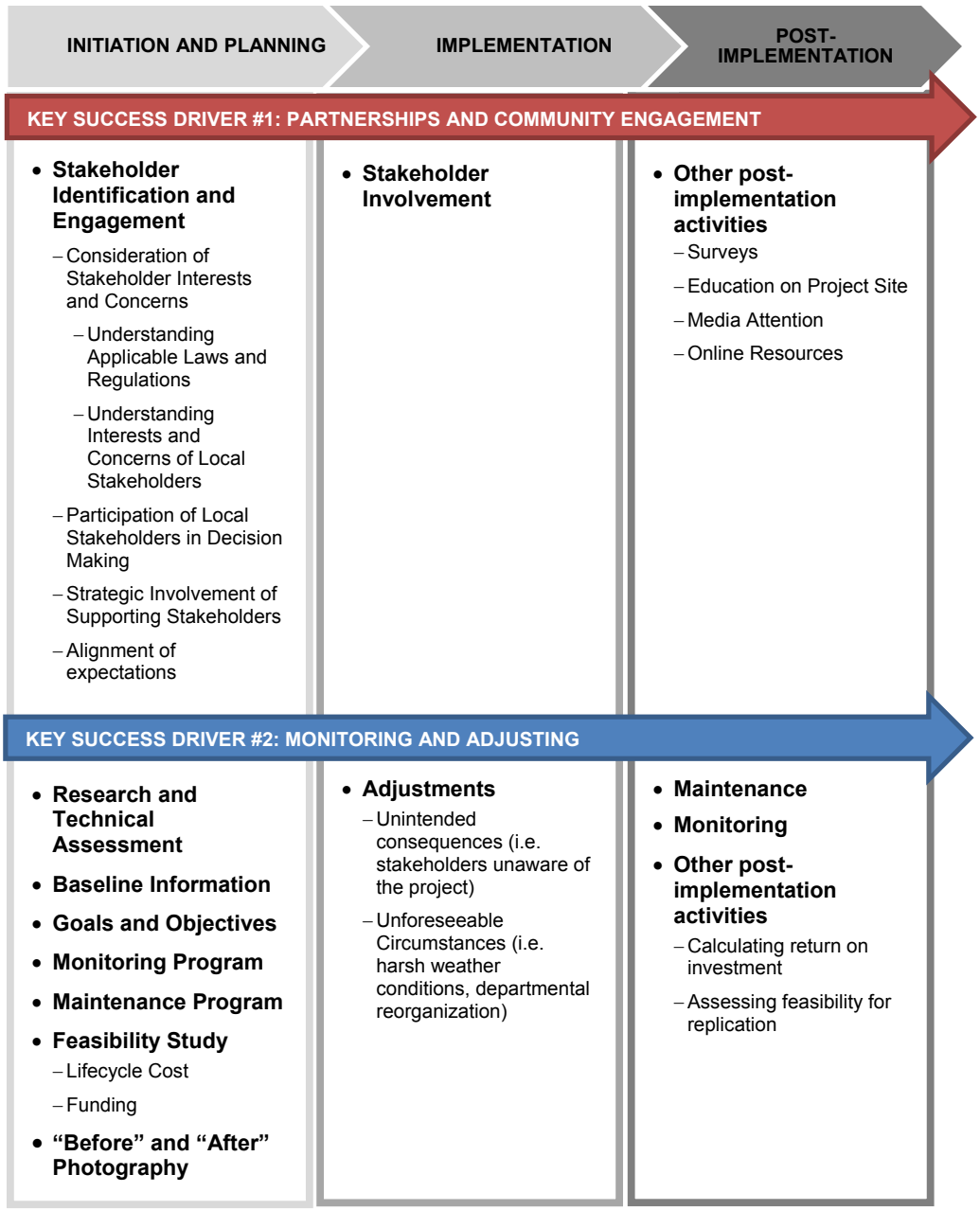
- **Partnerships and Community Engagement**

  Partnerships and community engagement can significantly contribute to the success of a project. There are many ways in which a partner can add value to a project, such as through providing scientific expertise or having a significant level of influence and leadership in a community. Engaging local stakeholders is critical, as they are the ones who are directly impacted by floods in an area. Continual engagement of stakeholders can result in greater widespread support, which could last well beyond the first few years following a project's implementation.

- **Monitoring and Adjusting**

  Monitoring and adjusting are critical to the success of a project. Systematic collection of data can provide insight on changes in conditions of a project area, indicating progress towards achieving the goals and objectives. If monitoring results indicate deviations from the predicted path of a project, timely adjustments should be made.

Figure 2: Summary of Key Findings Across the Flood Risk Mitigation Project Lifecycle



Not only are the two success drivers important throughout an entire project lifecycle, they are very often interdependent. The interdependency is particularly evident in projects that involve stakeholders in monitoring activities. In such cases, the stronger the relationship with the stakeholder, the more effective the monitoring program will be.

Whether empowering landowners to better understand flood risk, implementing bioretention measures and permeable pavement, or restoring banks and shorelines, all eleven projects demonstrated collaborative approaches to tackling the negative impacts of flooding at a local scale.

Accordingly, this report presents tangible examples of flood risk mitigation initiatives that have local utility and that can be replicated in communities across the country. If a combination of local initiatives were deployed on scale, the additive benefits could materially reduce the costs of flooding at the provincial or federal level.

DEFINITIONS[1]

Coastal Flooding: flooding associated with a defined shoreline along an ocean. Can occur due to a combination of high tides, storm surges, waves, rising sea levels.

Ecological Restoration: a process which seeks to recover degraded, damaged, or destroyed ecosystems.

Flood Mitigation: a sustained action taken to reduce or eliminate long-term risk to people and property from flood hazards and their effects. Mitigation distinguishes actions that have a long-term impact from those that are more closely associated with preparedness for, immediate response to, and short-term recovery from specific events.

Flood Protection: any combination of structural and non-structural additions, changes, or adjustments to structures, which reduce or eliminate risk of flood damage to real estate or improved real property, water and sanitation facilities, or structures with their contents.

Flood Risk: flood risk is a combination of the likelihood of occurrence of a flood event (flood frequency) and the social or economic consequences of that event when it occurs (through exposure to the flood hazard).

Floodplain: an area adjacent to a lake, river or coast, which can be expected to be regularly inundated or covered with water.

Hydraulic Analysis: an engineering analysis of flow scenarios carried out to provide estimates of the water surface elevations and velocity for selected recurrence intervals.

Hydrologic Analysis: estimation of flood magnitudes as a function of precipitation.

Infiltration (Sewer): the water entering a sewer system, including building sewers, from the ground through defective pipes, pipe joints, connections or manhole walls.

Lake Flooding: flooding associated with a defined land area along a lake. Can occur due to a combination of high water levels, waves, and storm surges.

Low Impact Development (LID): a of set of stormwater management design strategies which seek to mitigate the impacts of increased runoff and related pollution.

Overland Flooding: flooding that occurs when runoff water flows from the streets onto properties causing flood damages. It can happen anywhere in the community, independent of an overflowing water body.

Permeable Pavement: a pavement design in which uniformly graded stones are spread across a pervious paving material, used for managing stormwater.

Rain Garden (or Bioretention System): a system which captures and treats stormwater runoff through a combination of soil and plant material. Engineering filter media may be used to enhance the treatment function.

Regulatory Flood: the defined flood event used to delineate areas prone to flooding for the purposes of regulating land use. The minimum regulatory flood criteria standard in Canada is the 100-year return period flood, which is the peak flood flow with a one percent chance of occurring in any given year. Some regions, provinces, and territories implement standards that are more stringent.

Riverine Flooding: excess of stream flow in a watercourse, such that land outside the normal banks is submerged or inundated. Can be caused by extreme rainfall or snowmelt, or physical conditions (such as ice jams and undersized watercourse crossings) associated with a watercourse.

Runoff: the amount of water deriving from precipitation/ snowmelt, not otherwise evapotranspirated or stored, that flows across the landscape.

Sanitary sewer: part of the public sewage works for the transmission of sanitary sewage (includes human and industrial waste, and septic waste, but not stormwater).

Storm sewer: a sewer, the purpose of which is to carry stormwater (including surface and rainwater, melted snow and ice) and water in underground pipes and foundation drains.

Storm surge: the increase in coastal water levels above predicted astronomical tide levels (i.e. tidal anomaly) resulting from a range of location-dependent factors including low atmospheric pressure, wind and wave set-up and astronomical tidal waves, together with any other factors that increase tidal water levels.

Stormwater: rain, melting snow and ice that washes off driveways, parking lots, roads, yards, rooftops, and other surfaces.

Stormwater Management: the planning, design and implementation of systems that mitigate and control the impacts of man-made changes to runoff and other components of the hydrologic cycle. Stormwater management is better known as “rainwater management” in much of the world.

Flooding on the Toronto Islands. Photo taken on May 27, 2017.

1 INTRODUCTION

Flooding is a challenge of financial and social concern affecting a growing sector of the Canadian population. Multiple factors affect flood risk, such as a general increase in population density in urban and sub-urban centres, the loss of natural landscape impacting all provinces, growth in the impermeability of primarily city landscapes, all of which can be coupled with more intense and longer lasting storms driven by a changing climate. Despite the foreboding picture these factors paint, there are nonetheless many practical actions that may be deployed to mitigate flood risk.

The purpose of this report is threefold:

1. To outline the imperative for flood risk reduction in Canada;
2. To provide examples of practical flood risk mitigation initiatives that can be deployed in communities across the country; and
3. To highlight key factors that can influence the success of flood risk mitigation efforts.

Section 1 describes the rising financial costs and causes of flooding in Canada and presents key actions to limit flood risk

Section 2 profiles eleven flood risk mitigation projects that were implemented across Canada between 2012 and 2017, under the auspices of the Climate Change Adaptation Project

Section 3 highlights factors that can influence the success of flood risk mitigation efforts, based on findings of the mitigation projects, and

Section 4 presents summary remarks.

In February 2018, residents along the Grand River in Brantford, Ontario were forced to leave their homes. Flooding resulted from an ice jam upstream of Parkhill Dam.[2]

Photo courtesy of Aaron Vincent Elkaim / The Canadian Press

FLOODING: A COMPLEX PROBLEM

Every year, on average, Canada faces economic losses of over $1.2 billion due to flooding.[3] However, this dollar value alone does not illustrate the many ways in which Canadians are challenged by flooding. Considering different perspectives as well as the causes of flooding can help in the interpretation of this complex problem.

PERSPECTIVES OF KEY STAKEHOLDERS

HOMEOWNERS

Canadian homeowners have and will likely continue to face impacts due to flooding. Property damage, loss of personal belongings, and impacts to physical health (i.e. mould-related) and mental health (i.e. post-traumatic stress disorder, anxiety, and depression[4]) are amongst the many ways in which flooding can affect a homeowner. Not only are these impacts often devastating, they can be exacerbated by the economic, social, and health conditions of those affected, leaving already vulnerable people at a greater disadvantage.[5] People may also be forced to temporarily or permanently leave their homes.

In 2017, the U.S. Federal Emergency Management Agency reported that just one inch of water in a 2,500 square foot home can cause over $25,000 in flood damage[6] – an equivalent level of impact could be problematic for Canadian homeowners, as follows:

- ***Living Paycheque to Paycheque***
  In 2017, the Canadian Payroll Association reported that almost half of working Canadians are living paycheque to paycheque and one in four would not be able to "scrap together $2000 if an emergency arose next month."[7]
- ***Households at 'Very High Risk'***
  In 2016, a flood model supported by the Insurance Bureau of Canada indicated that 1.8 million Canadian households are at 'very high risk'.[8] While this figure represents 10% of Canadian households, another 20% are deemed to be at 'high risk.' [9]
- ***Limited Flood Insurance***
  Growing flood risk results in substantial increases to premiums. In cases where risk is excessive (i.e. households deemed at 'very high risk' or those experiencing repeated basement flooding), flood insurance coverage may be reduced or withdrawn altogether. Every year, Canadian homeowners bear approximately $600 million of uninsurable losses from flooding.[10]

MORTGAGE MARKET

As residential savings rates remain low and more households are subject to debilitating uninsured flood damage, mortgage holders may be faced with more flood-induced mortgage defaults.

INSURERS

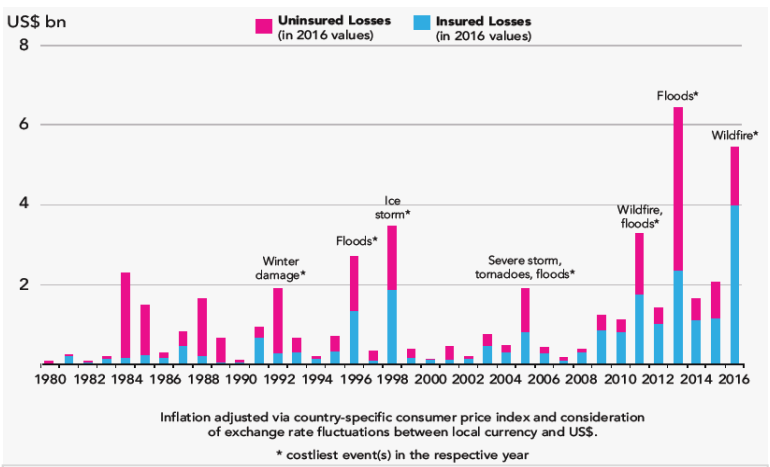
Property and Casualty insurers play an important role in absorbing the financial burden of natural disasters in Canada.

When a disaster results in insured losses totalling $25 million or more, these losses are deemed catastrophic.[11]

Relative to this definition, Figure 3 shows:

- **There has been a dramatic rise in catastrophic losses in the last decade in Canada**
  While insurable payouts averaged $400 million per year over the period of 1980 to 2008, for the last eight of nine years leading up to and including 2017, insurance payouts exceeded $1 billion in Canada.
- **The insurance gap in Canada is significant**
  Canadians have faced substantial uninsured losses, especially from the floods of 2013.

Figure 3: Catastrophic Losses in Canada in US$ billions, 1980 to 2016



Source: Munich Re, Geo Risks Research, NatCatSERVICE. As of February 2017.

CASE STUDY — **Southern Alberta Floods and Toronto Flood of 2013**

Losses from the 2013 floods illustrate the insurance gap

Although the year 2013 did not have the highest catastrophic insured losses, Canadians were faced with the highest uninsured losses in this year following two major flooding events. In June 2013, Southern Alberta was inundated by flood waters; three people lost their lives and over a hundred thousand people were forced to leave their homes.[12] A few weeks later, Toronto experienced severe flooding, which resulted in over 4,700 people submitting complaints regarding basement flooding.[13]

FEDERAL GOVERNMENT

Canada's federal government plays an important role in alleviating the financial impacts of natural disasters by providing compensation through the Disaster Financial Assistance Arrangements (DFAA) program.

Since the program's inception in 1970, several notable trends have occurred. There has been an increase in the number of natural disasters for which provinces and territories required assistance under DFAA[14] (Figure 4). Total compensation for disaster relief from 2009 to 2015 was greater than that of the previous 39 fiscal years combined.[15] Of DFAA's total estimated weather-related payouts, 75 percent are attributable to flooding.[16]

Although the federal government plays a critical role in providing compensation for flood damage, provinces and municipalities can also provide relief funding.

LEGAL IMPLICATIONS

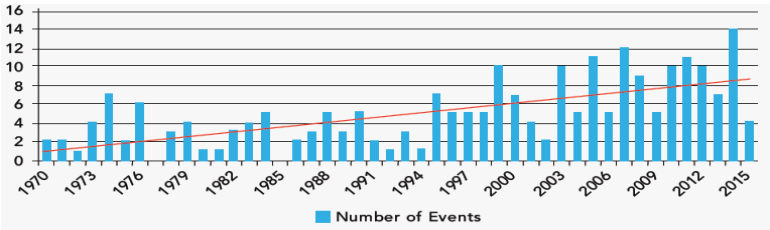
Flood-related lawsuits are on the rise across Canada[17] and they can involve homeowners, developers, local governments, conservation authorities, First Nations and Indigenous peoples, provinces, as well as private businesses.

Below are some recent examples:

- Anderson et al v Manitoba et al, 2017 MBCA 14 (CanLII) (ongoing)
- Wight v Peel Insurance, 2016 ONSC 6904 (CanLII)
- Muskoka Class Action, 2016 (ongoing)

Details on these cases and other cases are provided in Appendix A.

Figure 4: Number of Natural Disasters in Canada for which Provinces and Territories Required Disaster Financial Assistance Arrangements, 1970 to 2015



Source: Public Safety Canada. 2017.

PROVINCIAL / TERRITORIAL GOVERNMENTS

Canadian provinces and territories are responsible for submitting claims to the DFAA program, as the federal government does not deal with individual claimants within the jurisdictions.[18]

Provinces and territories have required and will likely continue to require federal assistance through DFAA to recover from natural disasters. However, if people are unaware of new changes in the availability of flood insurance, there may be serious implications.

As stated by Public Safety Canada in their Guidelines for the DFAA, the following category is ineligible under the program:

> **Costs of restoring or replacing items that were insured or insurable. Under the DFAA, insurable means that insurance coverage for a specific hazard for the individual, family, small business owner or farmer was available in the area at reasonable cost. Reasonable cost and availability are determined jointly by the province and the Public Safety Canada RD, with professional advice as required (e.g., Insurance Bureau of Canada, regional insurance broker)[19]**

With Canada's flood insurance landscape in a state of flux, provinces and territories may enforce similar rules relative to their own programs. In 2016, Emergency Management British Columbia warned residents about expected changes to the availability of overland flood insurance, emphasizing a rule under their Disaster Financial Assistance (DFA) program:

> **If a flooding disaster occurs and DFA is authorized for a disaster event, an applicant who could reasonably and readily have purchased overland flood insurance would NOT be eligible for DFA.[20]**

Although rules may vary from program to program[21], all levels of government should work together to ensure shared understanding.

LOCAL GOVERNMENTS

In Canada, flood risk mitigation is typically a responsibility of local governments. They review/approve new developments and maintain stormwater management systems.[22] Local governments can leverage land-use regulations to guide development away from high flood risk areas and can encourage the adoption of flood-resilient residential community design standards. A combination of these efforts can help reduce lawsuits, if a local government can demonstrate actions were taken consistent with what courts might deem as an appropriate standard of care.

Local government inaction to address flood risk may have serious financial implications. Credit rating agencies are beginning to examine climate change risks and potential impacts on ratings of tradeable assets, including municipal bonds. Insurers are also taking these matters more seriously, which has been recognized by the Association of Municipalities of Ontario (AMO):

> **The insurance premiums paid by municipalities reflect the legal reality that municipalities are 'deep pocket' defendants, often targeted for litigation because the law has established such a low threshold of responsibility. Just a fraction of fault can cost a municipality millions of dollars. The premiums charged by insurance companies, non-profit insurance reciprocals and pools reflect, in part, this legal risk. [23]**

While the substantial and rising economic costs of flooding illustrate the imperative for flood risk reduction in Canada, the factors that are causing the flooding in the first place further demonstrate the urgency to act now. It is important to note that it is not one factor alone that affects flood risk but rather a combination of factors.

UNDERSTANDING FLOOD RISK

Flooding can affect urban, rural or coastal communities. Flooding events can be broadly categorized as sewer backup or overland, with several sub-types under the latter category (Table 1).

Table 1: Types of Flooding

CATEGORY	TYPE(S) OF FLOODING
Sewer Backup	**Sewer backup flooding** occurs when an excess volume of flow backs up through sewer pipes into a building.
Overland	**Overland flooding** occurs when water flows across land and enters a building. It can happen anywhere in a community, independent of an overflowing water body. Overland flooding can be caused by one or a combination of the following flood types: ▪ **Pluvial flooding:** occurs when stormwater cannot be drained properly due to overburdened stormwater infrastructure or frozen ground over a natural drainage system. ▪ **Riverine flooding:** occurs when there is an excess of steam flow in a watercourse such that adjacent land is submerged or inundated. Riverine flooding can be caused by extreme rainfall or snowmelt, or physical conditions (such as ice jams and undersized watercourse crossings) associated with a watercourse. ▪ **Lake flooding:** occurs when a defined land area along a lake is flooded due to high water levels, waves, or storm surges. ▪ **Coastal flooding:** occurs when a defined land area along an ocean is flooded due to high tides, storm surges, waves, or rising sea levels.

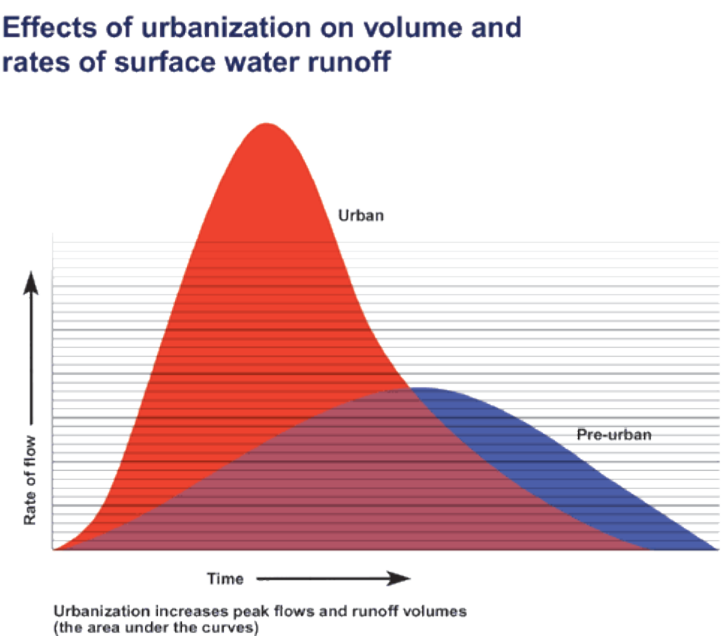
There are many factors that contribute to flood risk:

- ***Increased urbanization***

  There is a strong link between urbanization and flooding. Increased urbanization results in more impervious surfaces, decreasing the absorption capacity of the ground. Less permeability leads to an increase in the volume and rate of surface water runoff, as shown in Figure 5.[24]

  As over 80% of Canadians live in urban areas,[25] flood risk is an issue of significant concern across the country. Densely populated areas, especially those concentrated with high value assets, may be faced with substantial losses when a flood hits.

Figure 5: Effects of urbanization on flow volume and rate of surface water runoff



Source: Government of Canada. 2013.

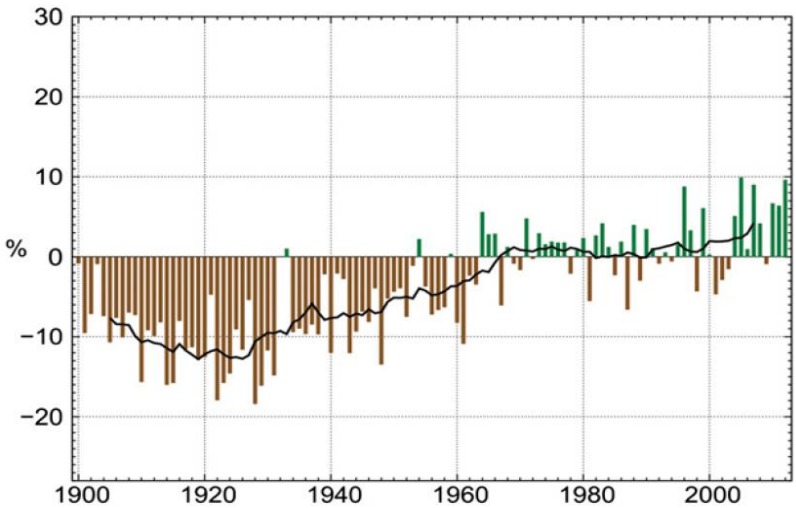
Note: Originally adapted from Drainage Manual, Roads and Transportation Association of Canada, 1982.

- ***Climate Change***

  The Intergovernmental Panel on Climate Change (IPCC) projects substantial warming and increased frequency of heavy precipitation events globally in the 21st century.[26] In line with this projection but specific to Canada, findings of Vincent et al. demonstrate an increasing trend in annual total precipitation in southern Canada from 1900 to 2012, with the latter 50 years showing significantly higher than average rainfall (Figure 6).[27]

  While changes in climate have been attributed to atmospheric and oceanic oscillations, these factors alone do not explain observed trends.[28] The changes have also been attributed to elevations in atmospheric greenhouse gas emissions through anthropogenic forcing, prompting global commitments and action in emissions reduction. However, according to the International Energy Association, "while countries are generally on track to achieve many of the targets set in their Paris Agreement pledges to reduce global warming, this is not nearly enough to limit warming to less than 2°C."[29]

Figure 6: Change in Annual Precipitation in Southern Canada, 1900-2012

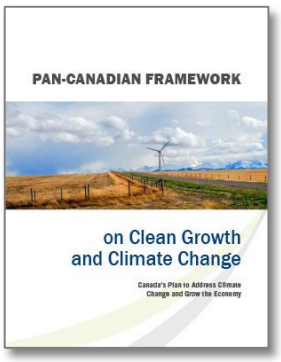


Source: Vincent et al. 2015.

Regardless of global commitments to reduce emissions, the fact remains that climate change has happened, is happening, and will continue to happen; the associated extreme weather catastrophes, such as floods, will ensue.

1.1 CANADA'S ACTION TO ADDRESS FLOOD RISK

Recognizing the pressing need to adapt to a changing climate, the Government of Canada established the Pan-Canadian Framework on Clean Growth and Climate Change. Chapter four of the framework is entirely dedicated to climate adaptation and improving Canada's climate resiliency. Specifically, the Government of Canada made commitments to invest in infrastructure that strengthens resilience and to develop climate-resilient codes and standards:



> **Federal, provincial, and territorial governments will work collaboratively to integrate climate resilience into building design guides and codes. The development of revised national building codes for residential, institutional, commercial, and industrial facilities and guidance for the design and rehabilitation of climate-resilient public infrastructure by 2020 will be supported by federal investments.[30]**

The National Research Council of Canada (NRC), which sets "model codes" for buildings, announced its commitment to update most of its codes to reflect climate change and extreme weather impacts. The NRC also funded the development of a Guideline on Flood Proofing and Flood Prevention Measures to Protect Basement Flooding by the Canadian Standards Association Group (CSA Group).[31] This is one of six projects launched by CSA Group to incorporate climate change into standards development processes. These include the development of climate change adaptation solutions within the framework of the Canadian Electrical Codes 1, 2 and 3, climate change adaptation provisions for the Canadian Highway Bridge Design Code and creation of new standards for green infrastructure to support flood mitigation and surface water protection.[32] Concurrently, the Standards Council of Canada (SCC) identified existing standards referenced in National Model Construction Codes, Provincial and Territorial Regulations and Master Building Specification that require updating to include climate change considerations.

In addition to the actions to address flood risk nationally, locally focused projects deployed en masse have the potential to mitigate an otherwise debilitating and pervasive Pan-Canadian risk. The following section profiles examples of locally deployed flood risk initiatives.

2 FLOOD RISK MITIGATION PROJECTS

Under the direction of the Climate Change Adaptation Project (CCAP), 11 project proposals were selected from 75 submissions made by conservation authorities and non-governmental organizations from across the country. These 11 project proposals were chosen based on how well they aligned with the mandate of the CCAP initiative, which was to showcase practical adaptation solutions that could be replicated in communities across Canada to limit flood risk at a local level.

The projects were implemented between 2012 and 2017, and they were grouped into the following categories:

EMPOWERING LANDOWNERS

A landowner can more effectively reduce flood risk on their property if they are equipped with the right knowledge and tools. Specific to residential properties, there are 50 potential ways that water might enter a home and cause flood damage;[33] thus deciding which actions are most appropriate is critical.

Two projects were focused on educating and empowering landowners:

1) Across Canada Workshop Series: Showcasing British Columbia's "Water Balance Model Express for Landowners"
2) RAIN Home Visit Program

RAIN GARDENS, BIORETENTION SYSTEMS, AND PERMEABLE PAVEMENT

Rain gardens, bioretention systems, and permeable pavement can be effective in reducing flood risk.

- Rain gardens and bioretention systems capture and treat stormwater runoff through a combination of soil and plant material.[34] Not only do these projects vary in scale, they can either replace impervious surfaces or they can be incorporated into existing green space (with 30% higher absorbency relative to a patch of grass[35]). Engineered filter media may be used to enhance the treatment function.
- Permeable pavement is a pavement design in which uniformly graded stones are spread across a pervious paving material.[36]

Five projects were focused on implementing rain gardens, bioretention systems or permeable pavement:

1) Leaders for Clean Water - Community Resilience Campaign
2) Green Alley of Saint-Leonard
3) Depave Paradise
4) City of Beloeil Dionis–Désilets Retention Basin
5) Bioretention System for Flood Risk Mitigation

RESTORATION OF BANKS AND SHORELINES

Ecological restoration seeks to recover degraded, damaged, or destroyed ecosystems.[37] Protecting and restoring banks and shorelines from erosion is important in reducing flood risk. The rate of erosion is dependent on both natural and anthropogenic processes, such as riverine sediment supply and shoreline protection respectively.[38] Planting native species in erosion-prone areas can help in stabilizing the soil[39], lowering the rate of erosion and limiting flood risk.

Four projects were focused on restoration activities:

1) Alfred Kuehne Natural Channel Design Project: Pre- and Post-Restoration Stream Monitoring
2) Living Shorelines: Climate Change Adaptation Along Urban Coasts
3) Seymour Estuary Restoration Project
4) Spring Creek Channel Restoration Project

Whether empowering landowners to better understand flood risk, implementing bioretention measures and permeable pavement, or restoring banks and shorelines, all eleven projects demonstrated collaborative approaches to tackling the negative impacts of flooding at a local level. While the two projects under the Empowering Landowners category were educational, the projects under the other two categories involved actual implementation of flood risk mitigation measures.

The implementation of these projects revealed factors that influence the success of flood risk mitigation efforts, which are outlined in Section 3 of the report.

2.1 Across Canada Workshop Series: Showcasing British Columbia's "Water Balance Model Express for Landowners"

Background

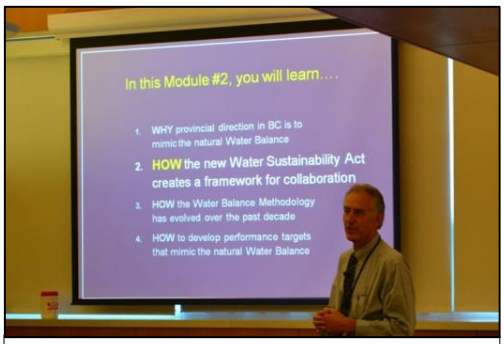
In 2002, the Province of British Columbia adopted the Water Balance Methodology, a performance target approach for managing rainwater runoff.[40] Operationalizing this methodology, several online tools have been developed through inter-governmental collaboration and funding. These tools as well as other resources are available on the website of the Partnership for Water Sustainability in BC.

Project Description

In 2014, the Partnership for Water Sustainability in BC led the Across Canada Workshop Series on Adapting to a Changing Climate. There were five workshops, one in each of the following cities: Calgary, Toronto, Ottawa, Montreal, and Halifax. A total of 266 people participated, of which 90% were members of local government.

The series showcased British Columbia's Water Balance Model Express for Landowners (WBM Express), an online tool that helps landowners identify what actions can be taken to address water flow on their property, ultimately making a property more resilient to flooding. Two other tools were presented: 1) the Drainage Infrastructure Screening Tool for assessing impacts of land use densification and climate change on piped systems, and 2) the Irrigation Scheduling Calculator for improving water use.

British Columbia's collaborative and science-based approach to protecting and restoring watershed health could be replicated in communities across the country.



Ted van der Gulik presenting at Calgary Workshop

"Climate change adaptation is about water. Long-term success in building community resiliency will depend on whether and how well we are able to mimic the Natural Water Balance."

- Ted van der Gulik, President of the Partnership for Water Sustainability in BC

LOCATIONS
- Calgary, Alberta
- Toronto, Ontario
- Ottawa, Ontario
- Montreal, Quebec
- Halifax, Nova Scotia

PROJECT START
2014

PROJECT GOAL
✓ Inspire water practitioners across Canada to replicate and/or adopt British Columbia's collaborative and science-based approach to protecting and restoring watershed health

PROJECT HIGHLIGHT
- WBM Express for Landowners
(*more details on page 28)*

LEADING ORGANIZATION
- Partnership for Water Sustainability in BC

HOST ORGANIZATIONS
- Alberta Low Impact Development Partnership
- Toronto Regional Conservation Authority
- Rideau Valley Conservation Authority
- Réseau Environnement
- Ecology Action Centre

Calgary Workshop

Toronto Workshop

Ottawa Workshop

Jim Dumont, Partnership's Engineering Applications Authority, presenting at Montreal Workshop

Halifax Workshop

2.2 RAIN Home Visit Program

Background

Developed by Green Communities Canada (GCC) with technical assistance from the Institute for Catastrophic Loss Reduction (ICLR), the RAIN Home Visit Program helps homeowners understand and solve stormwater issues on their properties. More specifically, it helps them prevent water damage caused by basement infiltration or sanitary sewer system backups. The program also addresses water conservation through rainwater harvesting and can bring aesthetic benefits to a property through implementation of a rain garden. These actions may contribute to the community's environmental priorities, such as securing groundwater recharge and preventing stormwater pollution.

In 2012, REEP Green Solutions led the first home visits in Kitchener-Waterloo, Ontario. Program delivery has continued in Kitchener-Waterloo (by REEP with city funding) and has expanded into Hamilton, Ontario (by Green Venture with funding from Natural Resources Canada) as well as into Calgary, Alberta (by Green Calgary, with funding from Intact Financial Corporation). To date, GCC and its local partners have completed 651 RAIN home visits across Canada.

Project Description

In 2014, Green Calgary led the RAIN Home Visit Program in Calgary. The project was aimed at empowering Calgary homeowners in taking action to de-risk their properties from flooding.

One hundred home visits were completed by certified RAIN guides. Not only did the RAIN guides bring advanced technical knowledge, they have been trained as the "ideal homeowner" in order to effectively engage people in the identification of property-specific problem areas as well as in the planning and prioritization of appropriate actions.

LOCATION
Calgary, Alberta

PROJECT START
2014

PROJECT GOAL
- ✓ Help homeowners understand stormwater issues on their properties and take appropriate action

PROJECT STATUS
Complete

PROJECT HIGHLIGHTS
- Addressing gaps in knowledge *(details on page 33)*
- Survey *(details on page 36)*

LEADING ORGANIZATION
- Green Calgary, a local partner of Green Communities Canada (GCC)

In November 2014, the homeowners were invited to participate in an online survey. There were 38 respondents and the results showed:

- 91% of homeowners visited would recommend the service to other homeowners;
- 87% of homeowners visited could correctly identify things they could do to reduce risk of basement infiltration;
- 77% responded that they had already passed the knowledge they learned during the visit to others (average eight other people per homeowner visited). This suggests a multiplier effect that for every 100 homeowners visited more than 600 homeowners are reached with key messages;
- 69% remembered they needed to re-grade around the foundation to ensure water runs away from the house;
- 60% remembered that they should redirect downspouts 2.4m (8') away and downslope; and
- 57% of homeowners visited reported needing professional help in implementing recommendations. 32% said they had contracted service providers. Half of these (6 people) spent less than $500. 17% of these (2 people) spent more than $5000. One re-graded an area paved with concrete and the other re-graded and installed a permeable patio.

RAIN Home Visit, where RAIN guide is touring a property with the homeowner and discussing problems and opportunities

2.3 Leaders for Clean Water - Community Resilience Campaign

Background

Between 2012 and 2015, Credit Valley Conservation (CVC) led the implementation of three low impact development (LID) demonstration projects. Whether creating rain gardens or implementing permeable driveways and boulevard bio-retention units, all projects were executed with a high degree of community involvement.

Project Descriptions

Alton Public School

In September 2014, a rain garden project was launched at Alton Public School in Caledon, Ontario. CVC worked with students of Alton Public School to design and construct the garden, using input from the Alton Design Charrette. Not only did the collaborative design approach provide students with educational opportunities, it allowed them to form a deeper connection and sense of ownership with the rain garden.

Kenollie Public School

In June 2015, the Kenollie Public School rain garden project was launched, engaging students, teachers, and sponsors. As Peel District School Board had identified Kenollie Public School as a location that experiences chronic drainage and winter ice issues, a rain garden was constructed. CVC has described the rain garden as "part of an outdoor classroom", as it is an educational resource for students and teachers. Monitoring equipment was installed allowing the school to assess the amount of water the garden can retain. The monitoring program started in 2016 and will run until 2019.

Lakeview

Completed in August 2012, the Lakeview project involved upgrading older residential roads with permeable paver driveways and boulevard bioretention units. Although the LID features are intended to mimic natural processes, regular inspection and maintenance is required, which in this case is a responsibility of the local residents. Through hosting an event, CVC educated property owners on how to properly maintain the permeable driveways and boulevard bioretention units.

Intact volunteers working on the rain garden

"Our Grade 6 students were interested in building a rain garden because they were concerned about shrinking monarch butterfly populations. Through this vision, we have developed a unique relationship with CVC resulting in the most beautiful rain garden."

- Jennifer El Refaie, Principal of Kenollie Public School

LOCATIONS
Caledon, Ontario
Mississauga, Ontario

PROJECT START
2012

PROJECT GOAL
- ✓ Promote and increase uptake of LID practices within Alton Village
- ✓ Educate local community

PROJECT STATUS
Ongoing

PROJECT HIGHLIGHTS
- Services of Ecosystems Recovery Inc. *(details on page 27)*
- Stakeholder involvement in implementation *(details on page 31)*
- Educating stakeholders on proper maintenance *(details on page 33)*
- Online resources *(details on page 36)*

LEADING ORGANIZATION
- Credit Valley Conservation (CVC)

OTHER ORGANIZATIONS INVOLVED
- Alton Public School
- Kenollie Public School
- City of Mississauga

The City of Mississauga councillor Jim Tovey talking to residents about the environmental benefits of the LID practices implemented in the Lakeview neighbourhood

2.4 Green Alley of Saint-Leonard

Background

Dating back to pre-20th century, alleyways have played an important role in the lives of people living in Montreal, Quebec.[41] Starting as routes between farmlands then turning into social spaces for merchants to trade and children to play, the alleyways still bring people together.

Recognizing a deficiency in green space, the Ruelles Vertes (or Green Alleys) program was developed. With the city first providing funding in 1997, the government and community groups have worked together on this initiative, converting over 250 blocks of alleys across 19 boroughs into green space.[42]

LOCATION
Montreal, Québec

PROJECT START
2015

PROJECT GOAL
- ✓ Slow down water runoff
- ✓ Lower temperature of air and surfaces

PROJECT STATUS
Complete

PROJECT HIGHLIGHTS
- Survey *(details on page 36)*

LEADING ORGANIZATION
- Nature-Action Québec (NAQ)

Project Description

In 2015, Nature-Action Québec (NAQ) led the implementation of a green alley project in the borough of Saint-Leonard, reducing impervious surfaces and creating a plantation zone for gardening. As Saint-Leonard has a high population density and a low tree canopy index, it has encountered some problems with stormwater accumulation and discharge of sewage. The project was aimed at addressing these issues, creating the first green alley of the borough.

Project Stages

Initiation and Planning

Using a heat map developed by the Institut national de santé publique du Québec, the site was selected. The project was designed to lower air and surface temperatures and to reduce flood risk through implementation of the following measures:

• replacing impervious asphalt in the middle of the alley with paving stone and applying new asphalt strips on the sides to help slow down water runoff and enhance water infiltration

• planting and maintaining urban green areas to help lower temperature of air and surfaces

Implementation

From May to August 2015, the Saint-Leonard Green Alley project was implemented.

Post-Implementation

In October 2015, people living in the neighbourhood of the Saint-Leonard's Green Alley were invited to participate in a survey. The survey results indicated that people were happy with the project.

Following the project's completion in 2016, a 2-year maintenance and monitoring program began. Led by Écoquartier Saint-Leonard, a local organization managed by NAQ, the program measures the alley's cleanliness level, car circulation, the proportion of surviving plants, and the number of citizens involved.

Pre-implementation photo of site

Setting the permeable layer

Paving stone walkway

Laying down the soil

Kids planting

Finished garden

2.5 Depave Paradise

Background

In 2012, Green Communities Canada (GCC) started Depave Paradise, a project aimed at removing impervious paved surfaces and planting native shrubs and trees in their place.[43]

The initiative was inspired by the success of Depave, an organization based in Portland, Oregon. Since 2007, Depave has replaced more than 60,000 square feet of paved surfaces.[44]

Volunteer depavers in actions

LOCATIONS
- North Bay, Ontario
- Kingston, Ontario
- Ottawa, Ontario
- Peterborough, Ontario
- Mississauga, Ontario
- Calgary, Alberta

PROJECT START
2013

PROJECT GOAL
✓ Reduce impervious surface

PROJECT STATUS
Complete

PROJECT HIGHLIGHTS
- Lessons learned in Initiation and Planning *(details on pages 26-27)*
- Media attention *(details on page 36)*

LEADING ORGANIZATION
- Green Communities Canada (GCC)

LOCAL ORGANIZATIONS
- Greening Nipissing
- Hearthmakers Energy Cooperative
- Ecology Ottawa
- Peterborough GreenUP
- Ecosource
- Green Calgary

Project Description

Between 2012 and 2017, GCC led 30 Depave projects, including the following below in Ontario and Alberta with CCAP between 2013 and 2015:

	Site Location	Local Organizer	Area Depaved (Square Metres)
1	North Bay, Ontario – city property across from City Hall	Greening Nipissing	49
2	Kingston, Ontario – Rideau Heights Public School	Hearthmakers Energy Cooperative	96
3	Ottawa, Ontario – Kitchissippi United Church	Ecology Ottawa	102
4	Peterborough, Ontario – Brock Street Mission	Peterborough GreenUP	62
5	Mississauga, Ontario – Russet Homes Cooperative	Ecosource	172
6	Calgary, Alberta – Twin Views Communal Garden	Green Calgary	171

While one Depave Paradise site alone may reduce the impervious cover of a city by only a marginal amount, the additive benefits of the projects may be significant. Not only have the projects helped in reducing stormwater pollution, decreasing runoff rates, and increasing plant biodiversity, they have engaged communities in understanding problems affecting the water cycle and inspired them to take action.

Volunteers from Intact Insurance take part in a planting event in Ottawa in September 2014

Volunteers performing maintenance work in the rain in Peterborough in June 2015

Depave Paradise project in Calgary

Volunteer depavers in action

2.6 City of Beloeil Dionis-Désilets Retention Basin

Background

The Dionis-Désilets retention basin manages stormwater runoff from the Bourgs de la Capitale, a recently developed neighbourhood in Beloeil, Quebec. The retention basin was a flat, empty space impacted by invasive plant species.

Project Description

Initiation and Planning

The project was initiated to increase water retention capacity, improve water quality, limit the growth of invasive plant species, and improve basin aesthetics. The design process involved developing plans and getting them approved by the district.

Pre-planting maintenance work was performed to remove invasive plant species.

The retention basin prior to implementation

Implementation

Between August 2014 and June 2016, planting activities were completed. Initially, shrubs were only planted on the slopes as that area was not included the city's planned excavation work. In 2015, herbaceous plants and grasses were planted in the lower level of the basin.

In total, over 50 trees, 1,600 shrubs, and 20,000 herbaceous plants were planted on the site.

Planting

Post-Implementation

A three-year integrated maintenance and monitoring program was approved by Beloeil (2016–2018). The program includes three to four site visits per year, where both maintenance (i.e. weeding) and monitoring activities (i.e. measuring temperature) are completed.

The community is now enjoying this small park for both educational and recreational purposes.

Retention basin transformation

Maintenance work

LOCATION
Beloeil, Québec

PROJECT START
2014

PROJECT GOAL
- ✓ Increase water retention capacity
- ✓ Improve water quality
- ✓ Limit the growth of invasive plant species
- ✓ Improve basin aesthetics

PROJECT STATUS
Complete

PROJECT HIGHLIGHTS
- Maintenance *(details on page 29)*
- "Before" and "After" photography *(details on page 30)*
- Post-Implementation Maintenance and Monitoring *(details on page 34)*
- Informative boards on site *(details on page 36)*
- Calculating ROI and assessing feasibility *(details on page 37)*

LEADING ORGANIZATION
- Nature-Action Quebec (NAQ)

OTHER ORGANIZATIONS INVOLVED
- City of Beloeil

2.7 Bioretention System for Flood Risk Mitigation

Project Description

In late spring of 2016, the Toronto and Region Conservation Authority (TRCA) led the installation of a bioretention system at the Kortright Centre in Woodbridge, Ontario. The system replaced a degraded roadside ditch along the visitor's parking lot. Unlike conventional curb and gutter drainage systems that simply convey runoff directly to receiving waters, the bioretention system was designed to reduce flow volumes, holding back runoff and draining at rates similar to that in natural landscapes.

Bioretention system at the Kortright Centre visitor parking lot

LOCATION
Woodbridge, Ontario

PROJECT START
2016

PROJECT GOAL
- ✓ Reduce flow volumes
- ✓ Remove phosphorus from stormwater

PROJECT STATUS
Complete

PROJECT HIGHLIGHTS
- Geotechnical assessments, collecting baseline data *(details on page 28)*
- 2-year post-implementation monitoring program *(details on page 35)*

LEADING ORGANIZATION
- Toronto and Region Conservation Authority (TRCA)

OTHER ORGANIZATIONS INVOLVED
- Ontario Ministry of the Environment, Conservation and Parks

Draining an area of approximately 1,150 m^2, the system allows for a surface ponding depth of 200 mm with sufficient storage to fully capture the 25-mm event without overflowing. When water levels rise above the ponding depth, flows are conveyed through an overflow pipe directly to the outlet of the system where water drains across a splash pad and energy dissipater into a natural forested area on the banks of the Humber River.

The bioretention system was designed to maintain predevelopment hydrologic regime, providing the storage, infiltration and detention functions required to attenuate the impacts of flooding on the built infrastructure. The system was also designed to capture and remove phosphorous from the stormwater runoff using engineered filter media.

Following installation, a two year performance monitoring program was conducted, which included measurements of outflow temperature, water quality and flow volumes both at the outlet of the bioretention cell and at a neighbouring asphalt control site. Relative to the control, results from the monitoring program showed over 70% lower runoff volumes, 80% lower peak flows, and the two sections of the bioretention cell with engineered filter media had effluent concentrations of phosphorus that were 68% less than that of the section with standard filter media.

2.8 Alfred Kuehne Natural Channel Design Project: Pre- and Post-Restoration Stream Monitoring

Project Description

From 2012 to 2013, the Alfred Kuehne Natural Channel Design Project was implemented to restore a 500-metre section of Spring Creek in the City of Brampton's Alfred Kuehne Park. The area was selected for restoration due to the negative impacts from stormwater runoff in this highly urbanized location.

Failing concrete channel in pre-restoration stage

LOCATION
Brampton, Ontario

PROJECT START
2012

PROJECT GOAL
- ✓ Reduce in flow velocity
- ✓ Improve natural sediment transport
- ✓ Improve fish and benthic macro invertebrate habitat
- ✓ Improve vegetation richness

PROJECT STATUS
Complete

PROJECT HIGHLIGHT
- Post-implementation monitoring assessments *(details on page 35)*

PARTNERS
- Toronto and Region Conservation Authority (TRCA)
- City of Brampton
- Peel Region

Project Stages

Initiation and Planning

In 2010, the Toronto and Region Conservation Authority (TRCA) collected baseline data and established measurable ecological indicators to effectively evaluate success in the post-restoration stage. Following the Ontario Stream Assessment Protocol (OSAP), TRCA collected general site information as well as data on physical habitat, water chemistry, and fish community sampling. Benthic macro invertebrates were sampled in conjunction with the OSAP data collection process, using the Ontario Benthos Biomonitoring Network (OBBN) protocol.

Implementation

Restoration began in 2012. Meanders and riffle-pool sequences with vortex rock weirs were added to reduce the energy required for water flow, increase overall habitat complexity and promote natural sediment transport. The project also aimed to improve fish and benthic macro invertebrate habitat, enhancing the integrity of the trophic structure. Multiple wetlands were created adjacent to the stream to improve water and sediment retention. Streambanks were stabilized using hardened natural substrate, embedded/pinned logs, and bioengineering techniques.

Restoration process

Post-Implementation

Following project completion in 2013, TRCA led a five-year post-restoration monitoring initiative to determine how effective the implemented measures were at changing the hydrologic conditions and, consequently, at enhancing the retention of sediment. The results from monitoring for three years (based on data collected in 2013, 2014 and 2015) showed reductions in flow velocity, increases in habitat quality and cover, and increases in fish, benthic macroinvertebrate and aquatic vegetation richness, relative to the pre-restoration conditions.

Post-restoration

2.9 Living Shorelines: Climate Change Adaptation Along Urban Coasts

Project Description

In 2015, Ecology Action Centre (EAC) led the implementation of the Living Shorelines restoration project at Saint Mary's Boat Club (SMBC) in Halifax, Nova Scotia in collaboration with Helping Nature Heal. The project was aimed at addressing the dual risks of flooding and erosion while also enhancing habitat for native species and improving water quality.

Volunteers participating in restoration activities

LOCATION
Halifax, Nova Scotia

PROJECT START
2015

PROJECT GOAL
- ✓ Address dual risks of flooding and erosion from a combination of stormwater runoff and ocean storm surges
- ✓ Enhance wildlife habitat
- ✓ Improve water quality

PROJECT STATUS
Complete

PROJECT HIGHLIGHTS
- Stakeholder engagement throughout entire project *(details on page 25)*
- Monitoring programs *(details on page 29)*
- Key lessons learned *(details on page 32)*

LEADING ORGANIZATION
- Ecology Action Centre (EAC)

OTHER ORGANIZATIONS INVOLVED
- Helping Nature Heal
- Halifax Regional Municipality
- Saint Mary's University
- Dalhousie University
- Bird Studies Canada

Project Stages

Initiation and Planning

The site was chosen based on the presence of significant coastal erosion, most of which was on the upland embankment and was caused by both overland stormwater runoff and ocean waves from the Northwest Arm. In addition, SMBC (owned by the City of Halifax) is often used by schools and universities for educational and recreational purposes, making it an ideal demonstration site in terms of opportunities for community engagement.

Prior to restoration, three workshops were held, educating community members on ecology-based climate adaptation approaches while also seeking their input on the project plan and selection of plants.

Implementation

In May 2015, about 70 people joined in the implementation of the project, following the Living Shorelines approach and building a rain garden.

Intact volunteers participating in restoration activities

Post-Implementation

In partnership with Saint Mary's University and Dalhousie University as well as Bird Studies Canada, volunteer-based monitoring programs were developed to track changes in erosion patterns and in habitat use by bird species.

Rain Garden

Shoreline work

Large view of site

2.10 Seymour Estuary Restoration Project

Background

In 2012, Habitat Conservation Trust Foundation started the Burrard Inlet Restoration Pilot Program. The program was aimed at mitigating the damage caused by the 2007 Burnaby oil spill, which affected approximately 1,200 metres of the shoreline.[45] Investing court-awarded funds, several projects were implemented, one of which was the Seymour Estuary Restoration Project.

Although the spill did cause significant damage to the estuary's fish and wildlife,[46] the estuary was in a vulnerable position to begin with. According to a 2013 report of the Gwa'sala-'Nakwaxda'xw First Nation and Government of British Columbia,

> **"the entire estuary is ranked as having very high shoreline sensitivity to sea level rise, due to the susceptibility of the estuarine sediments to erosion. Substantial re-arrangement of intertidal habitats and loss of trees along the shoreline can be expected as high sea levels and storm events coincide."[47]**

Project Description

In 2015, the Adaptation to Climate Change Team (ACT) supported the implementation of the Seymour Estuary Restoration Project. The project was designed to address the following issues: 1) Sensitivity to Sea Level Rise and Coastal Storm Surge, 2) Shoreline Erosion, and 3) Habitat Degradation.

Project Stages

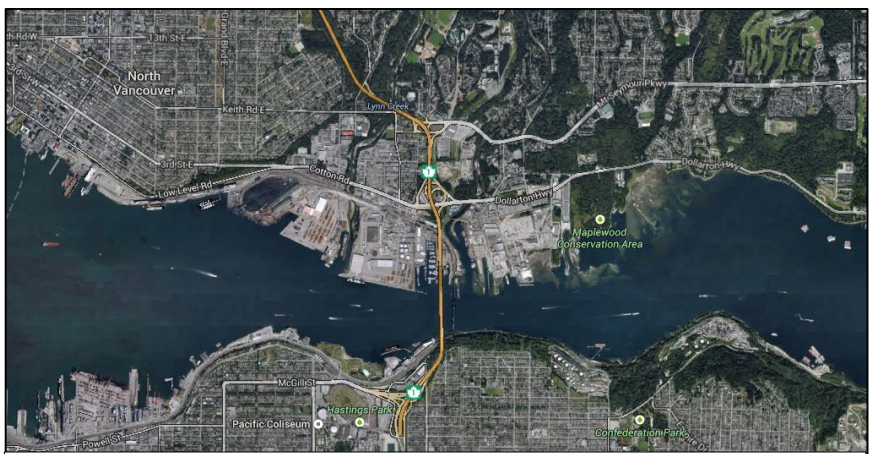
Initiation and Planning

The project was designed to improve the resilience of the entire estuary. Planned activities included:

- contouring and reinforcement of a previously denuded shipping area,
- reintroduction of intertidal and riparian zone vegetation, and
- the restoration of habitat conditions for salmon and other species.

Implementation

In March 2015, project implementation began with a bank stabilization workshop that involved BCIT and SFU students . The project stablized an actively eroding bank about 70 metres long with a combination of rock, wood, and bioengineered materials. There were 8,250 plugs of seven native seagrass species planted in the intertidal zone, and 1,000 specimens of 16 species of grasses, shrubs, and trees in the riparian zone. After the removal of invasive species was complete, logs were installed to provide structure.



Seymour Estuary

Post-Implementation

Following the completion of the Seymour Estuary restoration project in 2015, an ongoing monitoring program has been designed to be conducted in upcoming years to assess the conditions of the ecosystem.

LOCATION
British Columbia

PROJECT START
2015

PROJECT GOAL
- ✓ Improve resilience of the entire estuary
- ✓ Improve habitat for animals and plants

PROJECT STATUS
Complete

PROJECT HIGHLIGHTS
- Stakeholder involvement in implementation *(details on page 32)*

SUPPORTING ORGANIZATION
- Adaptation to Climate Change Team (ACT)

OTHER ORGANIZATIONS INVOLVED
- British Columbia Institute of Technology
- Simon Fraser University

2.11 Spring Creek Channel Restoration Project

Background

Spring Creek is a sub-watershed of the Etobicoke Creek, located in the Brampton, Ontario. The watercourse of the creek does not flow in a natural path. The watercourse has been both straightened and engineered using concrete as part of past efforts to address flooding. [48] Not only can this approach result in erosion, it can significantly damage the overall health of the creek.[49]

Project Description

Since 2012, Toronto and Region Conservation Authority (TRCA) has been leading the design of the Spring Creek Channel Restoration Project. While the project aims to reduce the risks of flooding and erosion, it will also improve channel habitat.

Reconnecting the creek back to the floodplain will assist in dissipating the stress to the channel during high flows, allowing it to spill into associated wetlands with the added benefit of a healthier riparian corridor and terrestrial habitats. The natural channel design approach develops a functional, self-sustaining stream system that provides valuable hydraulic (water transport), geomorphic (sediment erosion and transport) and ecological functions.

The project plan includes the following actions:

- The removal of approximately 500 to 800 meters of the impervious concrete channel;
- The restoration of 12,000 square meters of adjacent valley lands;
- The creation of floodplain wetlands alongside the site to help manage local water quality and quantity during high flows; and
- The naturalization of the riparian zone throughout the project site.

LOCATION
Brampton, Ontario

PROJECT START
2012

PROJECT GOAL
- ✓ Reduce flooding
- ✓ Reduce erosion

PROJECT STATUS
Awaiting approval of the environmental assessment

PROJECT HIGHLIGHTS
- Lessons learned in Initiation and Planning *(details on page 26)*

PARTNERS
- Toronto and Region Conservation Authority (TRCA)
- Peel Region

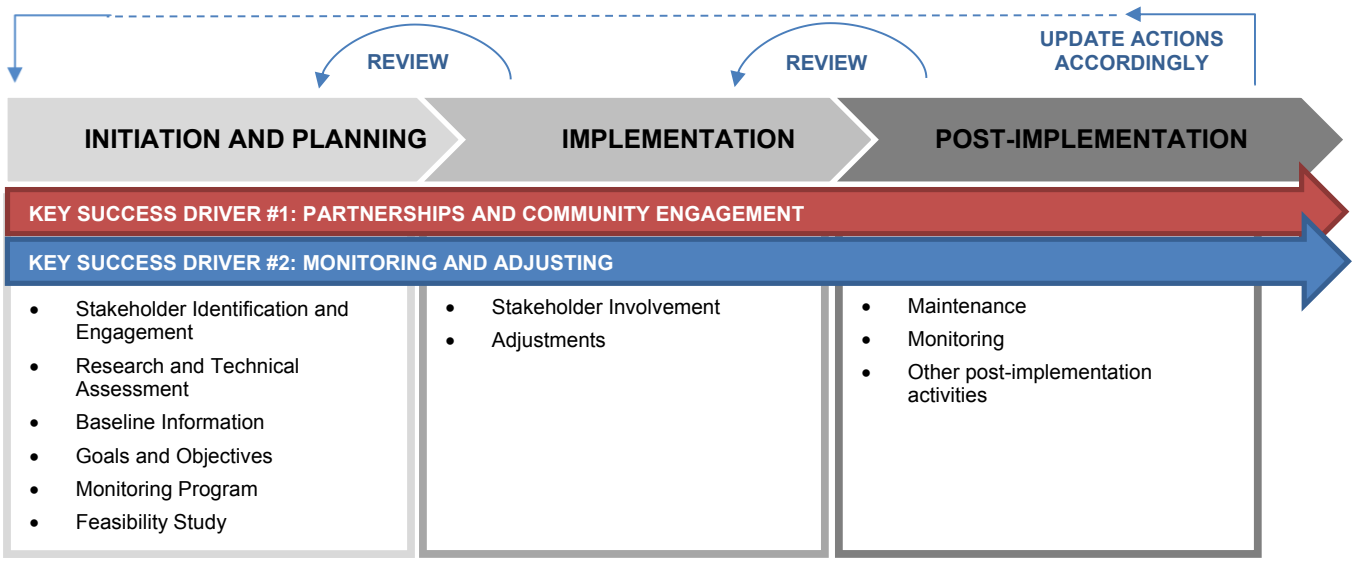
Since the TRCA must conduct its remedial flood and erosion control projects in accordance with the Environmental Assessment Act (EAA), the project is currently awaiting approval of the environmental assessment. Implementation is expected to begin in 2019.

Spring Creek

3 KEY CONSIDERATIONS FOR THE SUCCESSFUL COMPLETION OF FLOOD RISK MITIGATION PROJECTS

The eleven projects revealed broadly applicable factors that can influence the success of flood risk mitigation efforts. Although it can be difficult to determine the full extent to which risk has been reduced until multiple significant precipitation events occur, taking into consideration the best practices and lessons learned of these projects can ensure future ones are executed smoothly.

Figure 7: Flood Risk Management Project Framework



As the majority of the projects involved actual implementation of flood risk mitigation measures, the findings are presented in the context of a project lifecycle (Figure 7). While the Empowering Landowners projects were educational, key insights from these projects are included in the assessment below.

A comprehensive analysis of the projects revealed two key success drivers that often are important throughout the entire project lifecycle:

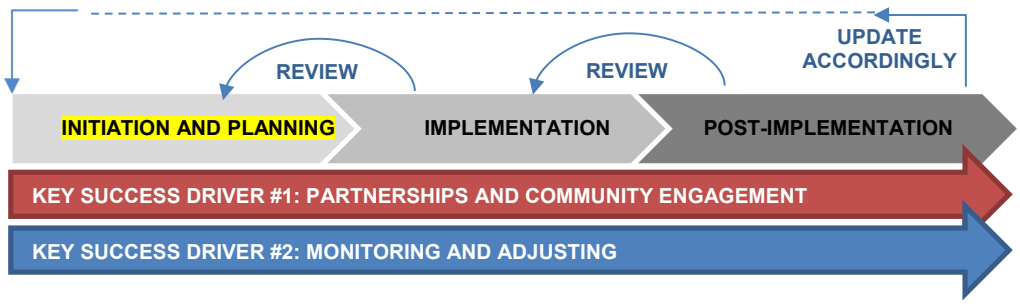
- **Partnerships and Community Engagement**
  Partnerships and community engagement can significantly contribute to the success of a project. There are many ways in which a partner could add value to a project, such as through providing scientific expertise or having a significant level of influence and leadership in a community. Engaging local stakeholders is critical as they are the ones who are directly impacted by floods in the area. Continual engagement of stakeholders can result in greater widespread support, which could last well beyond the first few years following a project's implementation.

BEST PRACTICE	KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT
	PROJECT: **Living Shorelines: Climate Change Adaptation Along Urban Coasts**
Effective engagement of key stakeholders (i.e. municipal and provincial government staff and elected officials, marine contractors, coastal property owners, politically engaged citizens, experts and students from St Mary's University and Dalhousie University) in site selection, project design, and implementation, helped to develop a comprehensive restoration strategy and inspired confidence in the local communities.	

- **Monitoring and Adjusting**
  Monitoring and adjusting are critical to the success of a project. Systematic collection of data can provide insight on changes in conditions of a project area, indicating progress towards achieving the goals and objectives. If monitoring results indicate deviations from the predicted path of a project, timely adjustments should be made.

The following subsections of the report outline best practices and lessons learned under each of the three stages of a flood risk mitigation project.

3.1 INITIATION AND PLANNING



The value of careful preparation and planning cannot be underestimated for a flood risk mitigation project of any scale. A variety of solutions exist for addressing flood risk. However, many factors must be considered when deciding on the best approach for a particular site. Prohibitive baseline conditions, budgetary limitations, and permitting challenges are amongst the many factors that could make a project unsuitable for implementation.

Key findings relating to the Initiation and Planning Stage are outlined below relative to seven themes:

1) Stakeholder Identification and Engagement
2) Research and Technical Assessment
3) Baseline information
4) Goals and Objectives
5) Maintenance and Monitoring Program
6) Feasibility Study
7) "Before" and "After" Photography

3.1.1 Stakeholder Identification and Engagement

Effective identification and engagement of stakeholders can be critical to the success of a flood risk mitigation project. Stakeholders can affect or be affected by a project in both a positive or negative way. Stakeholders can be local or non-local. In terms of stakeholders in supportive roles, level of involvement may vary. Depending on the type of project and the needs to the project team, stakeholders may include residents, schools, universities, government (local and other levels), conservation authorities, local businesses, utility companies, insurance companies, and industry associations. The following points should be considered when identifying and engaging stakeholders:

- **Consideration of Stakeholder Interests and Concerns**
  Understanding how different stakeholder groups could affect or be affected by a project is a critical first step in the identification of stakeholders.

➔ **Different Levels of Government**
Through conducting research and communicating with government authorities, a project team should understand what needs to be done to be in compliance with applicable laws and regulations. Projects that may impact existing physical and ecological conditions are often subject to regulatory review by federal or provincial / territorial authorities. To avoid delays and additional costs, a project team should determine early on whether any permits are required. If permits are required, the team should estimate the time and effort needed to complete the permit applications. Both the Depave Paradise project and the Spring Creek Channel Restoration project were faced with challenges regarding compliance to laws and regulations.

LESSON LEARNED
KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT
PROJECT: **Depave Paradise**

In Calgary, the project received initial positive support from the city that gave permission to use a city-owned park as a site for the Depave Paradise project. However, the original project did not identify the need for relatively expensive soil testing.. The project was designed to include food gardens. The testing requirements delayed the project beyond the feasible timeline and caused the local site re-design to include only non-edible plants, although upon further investigation there was no evidence of soil contamination.

LESSON LEARNED
KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT
PROJECT: **Spring Creek Channel Restoration**

The site of a proposed project or its potential area of influence was considered to be environmentally sensitive and meeting Environmental Assessment regulatory requirements led to delays of the project.

➔ **Local Stakeholders**
Local stakeholders (i.e. residents, schools, government, community groups) play a vital role in a flood risk mitigation project as they are directly impacted by flooding in the area. Understanding their perceptions of flood risk and incorporating their interests and concerns in the design and implementation of a project is critical.

- **Participation of Local Stakeholders in Decision Making**

  Not only is it important to understand and incorporate the interests and concerns of local stakeholders, having them participate in decision making can be beneficial. When local stakeholders participate in decision-making regarding targets, goals and required actions, they are more likely to dedicate their time to the project. Active and continual engagement can help to ensure that support goes well beyond the few first years following a project's implementation.

- **Strategic Involvement of Supporting Stakeholders**

  In considering potential partnerships and who to engage in the project, a project team should think about what areas they may be lacking knowledge and skills and how different stakeholders could help in addressing those gaps. Some stakeholders may have a significant level of influence and leadership in the community while others may have solid scientific knowledge and expertise. The Leaders for Clean Water - Community Resilience Campaign project is one that benefitted from the scientific expertise of a partnering organization.

CASE STUDY

KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
Leaders for Clean Water - Community Resilience Campaign

CVC staff retained the services of Ecosystems Recovery Inc. (ERI) to evaluate potential project sites for the Kenollie Public School rain garden project. CVC staff, ERI, and school staff toured the school's property and identified three potential locations for the rain garden. A number of factors were considered, including the current use of space, public visibility, student access, and site constraints. Once a location was confirmed, ERI conducted a geotechnical investigation of the site, and incorporated required changes into the rain garden design.

Involving a variety of stakeholders can be helpful in both securing widespread support as well as in cutting costs and avoiding delays in project implementation. However, effective stakeholder engagement requires strong communication and coordination strategies to build and maintain strong relationships throughout the project lifecycle, especially when several parties are involved.

- **Alignment of Expectations**

  Throughout the project lifecycle, especially at early stages, a project team should ensure continual alignment of expectations with supporting stakeholders. Developing a solid communication strategy early on can help in ensuring everyone is on the same page. Misalignment of expectations may lead to delays in project planning and implementation, which was a key lesson learned from the Depave Paradise project.

LESSON LEARNED

KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
Depave Paradise

Site selection proved to be a more time-consuming process than anticipated. Although there was a great deal of interest, in several of the communities initial site selections fell through or caused inordinate delays. To secure an appropriate project site, local member organizations need a lead time of several months in order to put out a call for potential sites, assess the sites and decide which approaches best meet the criteria, as well as to develop partnerships, and align expectations.

3.1.2 Research and Technical Assessment

Whether done by the project team or a partnering organization, conducting research and assessing the conditions of a site(s) under consideration can be critical to the success of a project. Although the process may be time-consuming, especially when many organizations are involved (as was the case in the Depave Paradise project), the information gathered can be helpful in both identifying opportunities and limiting the potential of an unsuccessful project.

The following are amongst many available tools and resources that can be used, separately or in combination, to assess site-specific conditions:

- **GIS software**

  Geographic Information System (GIS) software is used for storing, manipulating, and analyzing geographic data. Although GIS software can be quite expensive, free geospatial data is often available on many government websites. Natural Resources Canada provides free elevation and topographic data through their GeoGratis platform.[50]

- **Partnership for Water Sustainability in BC – Water Balance Tools**

  The Partnership for Water Sustainability in British Columbia has many online tools for assessing site-specific conditions which are available for free or available through a free trial. Whether a project team is interested in setting watershed-specific performance targets or a homeowner would like to learn about water flow on their property, there are tools for various types of projects which may be helpful at different stages of a project lifecycle.

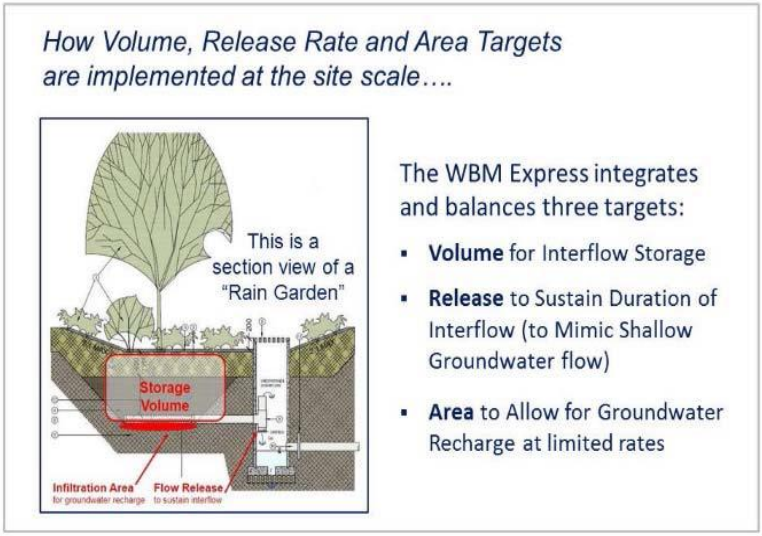
Showcased in the Across Canada Workshop Series, the Water Balance Model Express for Landowners (WBM Express) tool helps landowners identify what actions can be taken to address water flow on their property. Through the slowing, sinking, and spreading of rainwater, homeowners can achieve "water balance", making their property more resilient to flooding.

CASE STUDY

KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING

PROJECT:
Across Canada Workshop Series: Showcasing British Columbia's "Water Balance Model Express for Landowners"

Three target values are used to populate the web-based WBM Express decision support tool. The algorithms within the calculator engine integrate and balance the targets. The calculator engine outputs a weighted score on how well proposed site measures (such as rain gardens) would achieve the watershed targets.



After making an informed decision on the selection of a site, a project team can begin planning and design. Tools and resources that help in site selection may also be useful in project design, particularly in collection of baseline information which is necessary for effective monitoring.

3.1.3 Baseline Information

A project team should not begin design and implementation of a project without baseline information.

> **Note:**
> Many of the flood risk mitigation projects were initiated as a response to existing local problems for which baseline information was already gathered.

Whether the data is collected manually on-site (as was the case for the Bioretention System for Flood Risk Mitigation project) or is obtained from external sources, baseline information should accurately reflect pre-development conditions. In cases where a project team is unable to collect sufficient data for baseline analysis, they can refer to previously completed projects in which similar issues were resolved.

CASE STUDY

KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING

PROJECT:
Bioretention System for Flood Risk Mitigation

Geotechnical investigations were performed to characterize the native soil, water table elevation, and subsurface geological conditions beneath the parking lot (a development site). Selected samples of soil were analyzed to determine water content and grain size. The borehole data showed native soil conditions below the existing pavement structure to consist primarily of silt to silty clay soils underlain by clayey silt till material at 1.8 to 2.4 m below the surface.

Clay content in the samples ranged between 7 and 30%. The hydraulic conductivity of silty clay till materials typically ranges between 10-4 and 10-6 cm/s. The water table beneath the parking lot and across the Kortright property lies several meters below the surface.

Baseline information serves many purposes:

- ✓ Supports permit applications
- ✓ Informs the planning, development, and implementation of monitoring programs
- ✓ Provides a basis for setting goals and objectives

Once baseline information is collected, a project team can then use the data to set goals and objectives and to develop a monitoring program.

3.1.4 Goals and Objectives

After identifying stakeholders, conducting research, and gathering baseline data, a project team is ready to set goals and objectives. Involving stakeholders in this process can be very helpful, both informatively through different perspectives and in ensuring shared understanding. After coming to an agreement on what a project intends to achieve, a project team should define a set of actions that must be completed to reach the desired results. There may be several potential solutions that could work in achieving established goals and objectives, in which each solution should be carefully evaluated. After establishing what a project intends to achieve and through what actions, indicators for assessing progress should be established.

3.1.5 Monitoring Program

Developing a robust monitoring program with explicitly defined indicators is critical to effectively evaluating a project. A monitoring program plan should include a detailed schedule of what indicators are to be measured, when, and for how long throughout the project lifecycle. Indicators should be scientifically-based, measurable, and statistically valid. Involving key stakeholders in development of the program can be very helpful in obtaining support, as was demonstrated in the Living Shorelines project.

CASE STUDY

KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
Living Shorelines: Climate Change Adaptation Along Urban Coasts

In partnerships with local universities, including St. Mary's and Dalhousie universities, volunteer-based monitoring programs were developed to track changes in erosion patterns and in-habitat use by bird species. A coastal research team at Saint Mary's University helped to develop the erosion-monitoring program to be carried out from spring to autumn, and remains engaged as university researches process the data.

Bird Studies Canada and a bird research team developed the bird-monitoring program in conjunction. The data is collected by EAC volunteers using the Bird Area Survey Datasheet, and subsequently compiled and analyzed by university researchers. Area surveys are to be completed at the Saint Mary's Boat Club every three weeks beginning in early May.

3.1.6 Maintenance Program

Maintenance work can be critical to the success of a project; thus, a program plan similar to that for monitoring should be created. Maintenance work may begin prior to implementation, as was the case for the City of Beloeil Dionis-Désilets Retention Basin project

CASE STUDY

KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING

PROJECT:
City of Beloeil Dionis-Désilets Retention Basin

Pre-planting maintenance: Weed control was conducted from the beginning of the project in 2014. Removal of invasive exotic species such as common reed was scheduled for once a month, from May to October. Planting took place between August 2014 and June 2016.

3.1.7 Feasibility Study

Prior to implementation, a project should be evaluated in terms of its technical, legal, and economic feasibility. Although technical and legal aspects are often addressed in the early stages of planning (i.e. in site selection), it is important to re-evaluate a project based on these factors once project design is complete. Similarly, economic feasibility should be considered and assessed both during initiation and in evaluating project design.

When evaluating the economic feasibility of potential project designs, the following factors should be considered:

- **Lifecycle Cost**
  Conducting a lifecycle cost assessment is a critical step in evaluating project design. Not only does a project team need to consider the costs of construction in their assessment, they must also include estimated costs of annual maintenance and monitoring programs.

  The project's intended lifespan should be considered when assessing costs. Many flood risk mitigation projects require long-term maintenance and monitoring programs which sometimes are not feasible due to financial constraints. Volunteers can significantly reduce the financial burden of ongoing maintenance and monitoring. With this approach, responsibilities regarding monitoring and maintenance should be established early to avoid problems following project implementation.

  Although costs may be estimated based on those of previously completed projects, a project team should exercise caution when taking this approach as there are many underlying factors that could affect costs. While costs of materials, equipment, and labour may vary by location (i.e. region or province/territory), other factors such as design characteristics (i.e. length, depth, and width of a bioretention system) and site-specific baseline conditions (i.e. results of soil survey) may also affect costs. As documentation of previous completed projects may exclude important details affecting cost, the data should be carefully assessed before it is used for future cost estimation.

- **Funding**
  Consistent, realistic, and auditable cost estimates provide a basis for establishing project budgets, which are needed to support the allocation of funding. To secure funding effectively, a project team should create a detailed plan of how funds will be used.

3.1.8 "Before" and "After" Photography

Taking both pre-implementation and post-implementation photos can be very helpful in evaluating project success. Depending on how long implementation will take, it may be helpful to take photos during project construction as well.

In taking these "before" and "after" photos, it is critical to establish reference points to allow for more effective comparison. Reference points may include trees, houses, power lines, etc.

In the City of Beloeil Dionis-Désilets Retention Basin project, "before" and "after" photos were taken as shown below:

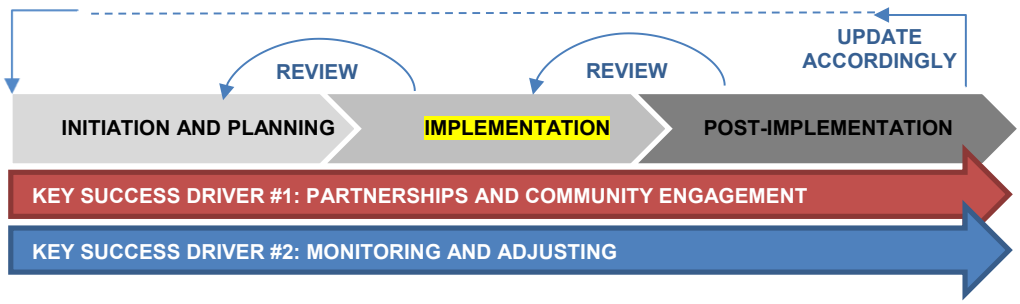
CASE STUDY

KEY SUCCESS DRIVER #2:
MONITORING AND ADJUSTING

PROJECT:
City of Beloeil Dionis-Désilets Retention Basin

BEFORE	AFTER
	
	
	

3.2 IMPLEMENTATION



Following careful planning and design evaluation, a project is ready to be executed. Generally, the better a project has been planned, the more smoothly it will be implemented. However, a project team could be faced with circumstances outside of their control that could affect the implementation and operation of the project. Having effective communication strategies in place while maintaining strong relationships with key stakeholders can significantly help a project team in facing these unforeseeable circumstances. While implementation may seem quite straightforward and far less time-consuming than planning for most projects, there are many factors that should be considered to ensure smooth execution.

Key findings relating to the Implementation Stage are outlined below through the following two themes:

1) Stakeholder Involvement
2) Adjustments

3.2.1 Stakeholder Involvement

Making the best use of implementation tools and resources can help a project team in achieving their goals and objectives effectively and efficiently. A project team can exercise creativity in finding ways to engage key stakeholders in the implementation process, even if they are not directly involved in construction activities. In the Leaders for Clean Water – Community Resilience Campaign project, Alton Public School students painted logs which were incorporated into a frame. Not only did the activity contribute to the aesthetics of the project, it also allowed students to develop a sense of connection and ownership with the rain garden.

The construction stage usually receives substantial public attention as community members often volunteer their time. Well developed construction plans can help market projects, raising awareness in nearby communities.

CASE STUDY

KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
Leaders for Clean Water - Community Resilience Campaign

The Alton Park rain garden was constructed in September 2014 using design input from the Alton Design Charrette. In an effort to continue engaging students in environmental education, CVC worked with the school to create art pieces for the garden made from reclaimed materials. This project was designed to help students form a deeper connection and sense of ownership with the rain garden. Students and staff each painted a log and these pieces were incorporated into a frame built with reclaimed barn wood. Four sculptures were created out of the painted logs. They were revealed at a ceremony attended by the entire school including the superintendent and trustee, CVC staff, and members of the community. At this ceremony, students were shown how the rain garden collects water and infiltrates it through the garden and back into the ground.

Alton Public School students celebrate completion of the rain garden

The Seymour Estuary Restoration Project is another project which benefitted from the participation of local stakeholders during implementation. Not only did they involve British Columbia Institute of Technology (BCIT) and Simon Fraser University (SFU) students through holding a bank stabilization workshop, restoration work involving the planting of native species was completed through a community-based planting event.

CASE STUDY

KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT: Seymour Estuary Restoration Project

In March 2015, project construction began with a bank stabilization workshop for BCIT and SFU students and involved stabilizing an actively eroding bank about 70 metres long with a combination of rock, wood, and bioengineering. The approach used semi-natural techniques to stop erosion of the bank; reduce the amount and quantity of dredging required by the local shipbuilder to maintain draught for ships, which causes erosion due to over-steepening; create cover habitat for aquatic species (mostly juvenile salmonids); and keep the access road to the estuary location intact.

The stabilization work was followed by rehabilitation of the mouth of the estuary through habitat restoration achieved through flattening of the area and placement of large logs brought in to provide grounding for habitat, with native plants installed in June 2015 in a community-based planting event.

Although involving key stakeholders and engaging with wider audiences is important during implementation, a project team should be prepared to deal with potential challenges.

3.2.2 Adjustments

Sometimes even the most comprehensive project plans may have gaps which might only become evident during (or after) implementation. In such cases, appropriate action must be taken to address the issues.

Below are two examples of situations that would require adjustments to a project plan, both based on lessons learned from the Living Shorelines: Climate Change Adaptation Along Urban Coasts project:

- **Unintended consequences of actions of stakeholders unaware of the project**
  A project may be negatively affected by people who were not aware of it. Whether these people were missed in stakeholder identification or they are new members of a stakeholder group who were just not informed, it is important to address the problem as early as possible. Fostering ongoing relationships with such stakeholder groups can help prevent unintentional consequences.

- **Unforeseeable Circumstances**
  No matter how well a project has been planned, there can be unforeseeable circumstances that could cause delays in implementation. For instance, harsh weather conditions and a partner's departmental re-organization could negatively affect both the level of stakeholder engagement and support provided. Careful scheduling and ongoing communication with supporting organizations can help effectively carry out project construction, keeping it on time and on budget.

The stronger the communication with stakeholders, the sooner these unintended and unforeseeable challenges can be identified and addressed.

LESSON LEARNED

KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING

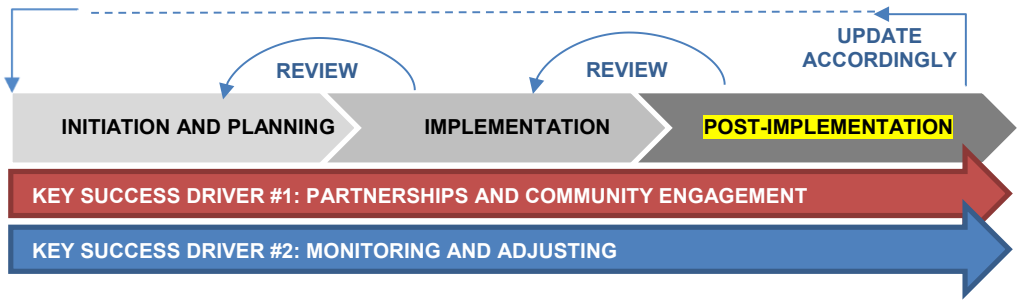
PROJECT: Living Shorelines: Climate Change Adaptation Along Urban Coasts

- Communication with grounds keeping contractors who do maintenance of property (lawn mowing, etc.) is important as the success of the living shoreline depends on its ability to grow wild and not be mowed or trimmed as a typical garden would. This communication challenge is caused by the many degrees of separation between the EAC project coordinator and the individuals who do the lawn care at the site. Fostering an ongoing relationship with the lawn care workers is important to ensuring the health and growth of the living shoreline and is an ongoing task for the project coordinator. Contractors are frequently changed every year, so it is often required to re-establish relationships.

- Working with the Halifax Regional Municipality was challenging due to the departmental reorganization occurring during this project. In 2014, the city had agreed to the project and had done much of the necessary groundwork, but when staff changes occurred, much of that groundwork needed to be repeated so the new employees were up to date. As many employees were new to their positions or their department, it was difficult to bring them on board with this project and to cultivate enthusiasm and interest. The completion and implementation of the interpretive signage and the maintenance of the site took a considerable amount of time and effort.

- The harsh winter weather caused the rescheduling of workshops several times, which made ensuring participation of key stakeholders and engaged citizens difficult.

3.3 POST-IMPLEMENTATION



The long-term success of a flood risk mitigation project very often depends on adequate maintenance and monitoring activities following the project's implementation. Depending on the type of project, maintenance and monitoring may begin several weeks or even months after construction. If members of the local community are responsible for these activities and the leading organization is interested in receiving updates regarding progress and any issues, there should be a solid communication strategy in place. For instance, if members of the local community are responsible for maintenance and monitoring work and local priorities shift, a project may be left with little or no support. The volunteer involvement of local stakeholders may be a cost-effective approach but may require some extra work in checking if monitoring and maintenance activities are taking place and whether they are being carried out properly. Without the proper maintenance and monitoring, a project may be less successful at reducing flood risk.

In addition to maintenance and monitoring of the project site, there are several other post-implementation activities that can take place. With reference to the 'Partnerships and Community Engagement' key success driver, a project team may engage in activities that educate and inspire others to take on similar projects. With reference to the 'Monitoring and Adjusting' key success driver, a project team may be interested in evaluating success in terms of the return on investment (ROI), which could inform adjustments that need to be made for future projects.

Key findings relating to the Post-Implementation Stage are outlined below through the following three themes:

1) Maintenance;
2) Monitoring; and
3) Other Post-Implementation Activities.

3.3.1 Maintenance

Following project construction, ongoing maintenance activities should take place to ensure the implemented measures are (or will be) successful in meeting the project's goals and objectives.

Those responsible for conducting maintenance activities should be equipped with the necessary knowledge and tools required to do the work properly. Any potential deficiencies in knowledge should be addressed early and there are many ways in which this can be done. For example, the Leaders for Clean Water – Community Resilience Campaign project held an event to educate property owners on how to maintain permeable driveways.

Although the RAIN Home Visit Program project did not follow a typical project lifecycle, the project team was able to identify resources which stakeholders were missing to implement adaptation measures. A similar approach could be taken when communicating with people involved in maintenance activities, gauging their level of readiness.

CASE STUDY	KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT PROJECT: **Leaders for Clean Water - Community Resilience Campaign**
To ensure that property owners know how to properly maintain the permeable driveways and boulevard bioretention units, CVC coordinated an event to engage and educate residents, welcoming 15 interested homeowners to "Ask a Designer Night".	

CASE STUDY	KEY SUCCESS DRIVER #1: PARTNERSHIPS AND COMMUNITY ENGAGEMENT PROJECT: **RAIN Home Visit Program**
Homeowners surveyed during the project reported needing a list of qualified contractors who can do important landscaping work like re-grading and increasing permeable areas.	

Some projects may combine maintenance and monitoring activities. The City of Beloeil Dionis-Désilets Retention Basin project is an example of a project that carried out maintenance and monitoring activities at the same time.

CASE STUDY	KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING
	PROJECT: **City of Beloeil Dionis-Désilets Retention Basin**

A three-year maintenance program was approved by the City of Beloeil (2016–2018). The maintenance program includes three to four visits to the site per year between May and October. Maintenance work consists of weeding plant beds, pruning shrubs and trees, controlling of exotic invasive plants, and adding chipped wood in planted areas. The temperature at various spots in the project location is recorded on each visit. The methodology for these records is described below.

To measure the project's impact on the heat island phenomena, temperatures at the site, taken during each site maintenance visit, will be recorded over a two-year period (2017–2018).

3.3.2 Monitoring

While monitoring and adjusting is critical throughout the entire project lifecycle, monitoring in the post-implementation stage is especially important. The City of Beloeil Dionis-Désilets Retention Basin project, Bioretention System for Flood Risk Mitigation project, and Alfred Kuehne Natural Channel Design project all had robust monitoring programs:

CASE STUDY	KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING
	PROJECT: **City of Beloeil Dionis-Désilets Retention Basin**

The methodology will be to take the temperature at nine locations on the site using an infrared thermometer. The recording sites were determined using various criteria that can affect temperature, such as soil height, soil humidity, and shade level. At the end of 2017, we had made three temperature recordings; three or four further recordings will be performed in 2018. It should be noted that the basin's water retention capacity and water quality have not been measured with scientific instruments; however, we perform site visits to ensure that retention capacity is sufficient, that the basin does not leak, and that plants and soil are still filtering water adequately.

Thus far, the temperature records show that:

- the warmest location is point 1, while the coolest location is point 3. We can therefore deduce that temperatures increase as a function of altitude.
- the temperature difference between the street (point 1) and all the other points in the basin (points 2 to 9) varies from 12.4 to 32.2 degrees Celsius, for an average of 7.1 degrees. We can therefore say that the higher the soil's mineral content, the more temperatures increase.
- In general, temperature increases as a function of soil humidity: the higher the soil humidity, the lower the temperature.

CASE STUDY

KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING

PROJECT:
Bioretention System for Flood Risk Mitigation

The 2-year monitoring program assessing water retention and stormwater control was developed to include the following measurements:

- precipitation;
- flow rates and volumes; and
- water quality, temperature, and water level.

A tipping bucket rain gauge installed within 500 m of the study site will be used to monitor precipitation. Outflow rates, volumes, and water quality will be monitored in a surface sampling hut installed down gradient of the site. Tipping bucket flow meters will record data every 5 minutes and flow restrictors will be used to ensure the outflow rates do not exceed the equipment maximum flow rate threshold (60L/min).

Tipping bucket flow meters and automatic water samplers installed in monitoring hut

ISCO portable water samplers will collect samples over the duration of each event. Discrete samples collected at 15-minute intervals will be weighted according to flow, and combined to form volume weighted composites, from which event mean concentrations can be determined. Influent sample concentrations will be determined from flow weighted samples collected from the asphalt control section. Samples will be submitted to the Ontario Ministry of the Environment, Conservation and Parks Laboratory in Etobicoke for analysis following MOECP lab preparation and submission protocols. The variables that will be analyzed are based on typical stormwater runoff contaminants in runoff from both parking lots and urban centres.

Results of the monitoring project will be assessed in relation to the original design objectives and targets for the project. The monitoring data will also be used to calibrate a hydrologic model that will be used to assess performance of the system during flood flow conditions (5-100 year events).

CASE STUDY

KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING

PROJECT:
Alfred Kuehne Natural Channel Design Project: Pre- and Post-Restoration Stream Monitoring

Following the stream realignment project completion, the following assessments were also conducted:

- Rapid Geomorphic Assessment to evaluate pre- and post-restoration channel stability;
- Photographic Documentation to document the status of the channel form, riparian vegetation, bank erosion, and the functionality of bioengineering features;
- Channel Geometry to evaluate changes in sinuosity;
- Surficial Geology;
- Bank Erosion Assessment.

During geomorphic assessments, photographs were taken to document the status of the channel form, riparian vegetation, bank erosion, and the functionality of bioengineering features. Photographs that have been taken at designated cross sections, so that they may be replicated in later years to monitor changes in stream and bank conditions. A few examples of photographs taken in 2014 and 2015 are provided at right.

2014	2015
	
	

Analysis of the data collected during the first three years of monitoring showed reductions in flow velocity, increases in habitat quality and cover, and resultant increases in fish, benthic macroinvertebrate, and aquatic vegetation richness, relative to the pre-restoration conditions. Increasing degrees of aggradation and bank instability following project completion were also observed.

3.3.3 Other Post-Implementation Activities

In addition to monitoring and maintenance, there are other post-implementation activities which a project team could engage in:

- **Surveys**

  Surveys can be used to gain useful insight from stakeholders, either from those responsible for maintenance and monitoring activities or those who may be directly impacted by the project. Through conducting a survey, the RAIN Home Visit Program found that the time when a survey is sent is important. In the Green Alley of Saint-Leonard project, a survey was conducted which showed that the initiative has improved the quality of life of people in the neighbourhood.

CASE STUDY

KEY SUCCESS DRIVER #1:
PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
RAIN Home Visit Program

The survey conducted in November 2014 indicated that the timeframe for follow-up (within a few short months) with homeowners was too soon to adequately gauge their actions on recommended priorities. However, results did show that 91% of survey respondents would recommend the service to other homeowners

CASE STUDY

KEY SUCCESS DRIVER #1:
PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
Green Alley of Saint-Leonard

In October of 2015, a survey was conducted in the neighbourhood of the green alley. It showed that people were generally very happy with the results and indicated that this initiative greatly improved the quality of life in their neighbourhood.

- **Education on Project Site**

  To further educate members of the local community, a project team may create informative boards and put them on site, which was a plan set out in the City of Beloeil Dionis–Désilets Retention Basin project. Informative boards may include information on the implemented flood risk mitigation measures as well as details on the historical significance of the site.

CASE STUDY

KEY SUCCESS DRIVER #1:
PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
City of Beloeil Dionis–Désilets Retention Basin

In order to inform nearby citizens about the project, two informative boards will be designed and put up at the top of the retention basin:

- The first panel outlines the life of Dionis Désilets, (1863-1964), a self-taught master cabinet-maker, builder, manufacturer and architect who designed many of the most beautiful churches of Quebec and whose working and production shops were located on the site;
- The second interpretive sign will give information about the retention basin functions and the indigenous species that were planted according to each basin level.

- **Media Attention**

  To attract attention to a project, various forms of media may be used, such as news papers, radio, television, Facebook, and Twitter. The Depave Paradise project is one project that received considerable media attention. Hosting local events can help attract attention and can be effective in terms of bringing together a variety of stakeholders.

CASE STUDY

KEY SUCCESS DRIVER #1:
PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
Depave Paradise

Depave Paradise local events attracted attention in their home communities, and were also flooded with attention in June of 2014 thanks to a press release put out by the Climate Change Adaptation Project. Here are some of the best examples of Depave Paradise media:

- CBC Radio as It Happens, June 4, 2014, interview with Clara Blakelock at GCC;
- The Toronto Star “Pilot project to rip up asphalt to protect cities from floods”, June 4, 2014;
- CBC Ottawa Morning, “Green Communities Canada unpaves and plants green” about Ottawa’s Depave Paradise project.

- **Online Resources**

  Project documentation may be made publicly available to help people interested in replicating similar projects, which was done in the Leaders for Clean Water - Community Resilience Campaign project. Documentation may include step-by-step descriptions of planning and implementation activities and may also include photos.

CASE STUDY

KEY SUCCESS DRIVER #1:
PARTNERSHIPS AND COMMUNITY ENGAGEMENT

PROJECT:
Leaders for Clean Water - Community Resilience Campaign

Alton was a pilot project intended to demonstrate how to develop and execute an LID marketing strategy in a small municipality. The goal is to replicate similar projects across the Credit River watershed. The steps of this project have been well documented through case studies and formalized in CVC’s Grey to Green Residential Retrofit Guide. It has also helped to inform the development of CVC’s Grey to Green: Residential Lands Guide. These resources are available through CVC’s website and will help other municipalities and conservation authorities looking to develop similar projects.

- **Calculating return on investment (ROI)**
  Calculating the return on investment is a very important post-implementation activity. Although sometimes it may be difficult to quantify the monetary value of ecosystem services, a project team can estimate such value based on previously completed studies. This was done in the City of Beloeil Dionis-Désilets Retention Basin project.

CASE STUDY

KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING

PROJECT:
City of Beloeil Dionis-Désilets Retention Basin

According to Environment Canada,[1] floods cost Canadians millions of dollars in property damage, lost production and wages, and trade deficits.

For Quebec alone, federal payments related to floods have totalled $301,179,846 since 1970. According to the Insurance Bureau of Canada, Canadian insurance companies pay out over $1.3 billion annually in indemnities due to flooding.[2]

Urban heat islands also have significant economic consequences. First, energy demands in affected areas are extremely high (e.g., air conditioning). Trees help keep the sun off building walls and windows in summer; they also block winds during winter, which reduces heating costs. It is estimated that a mature tree can take up as much as 450 liters of water from the soil and release it through evapotranspiration; the cooling effect of this cycle is equivalent to five air conditioners running for 20 hours per day. In one Montréal borough, it is estimated that trees can save up to $0.28 per year per tree in electricity costs.[3] Urban heat islands also impact health and mortality rates.

In the Dionis-Désilets retention basin, there are 25 buildings directly adjacent to the site. The project's total cost was $178,200, for a per-building average cost of $7,128. Given all the benefits mentioned above, we assume that the return on investment is positive, even though we cannot quantify it.

[1] https://ec.gc.ca/eau-water/default.asp?lang=Fr&n=02A71110-1#dammage
[2] Protégez-vous; http://www.protegez-vous.ca/maison-et-environnement/inondation-degatdeaudebordement-etes-vous-couvert.html
[3] Université de Sherbrooke; https://www.usherbrooke.ca/environnement/fileadmin/sites/environnement/documents/Essais_2013/Belanger-Michaud_H__2013-02-20_.pdf

- **Assessing feasibility for replication**
  Considering a project's ROI as well as constraining factors which may not have been captured in the ROI calculation, a project team can determine whether it would make sense to replicate the project in other areas. This was done in the City of Beloeil Dionis-Désilets Retention Basin project.

CASE STUDY

KEY SUCCESS DRIVER #2: MONITORING AND ADJUSTING

PROJECT:
City of Beloeil Dionis-Désilets Retention Basin

The project could easily be reproduced at other sites in Québec. The fact that the basin had already been built considerably reduced project costs and complexity, but it also presented several landscaping constraints. We therefore recommend integrating horticultural landscaping into basin construction plans in order to maximize the potential for greening. And indeed, the inclusion of retention basins in new housing developments in Québec presents a huge opportunity for creating green spaces and building a sense of local ownership.

4 CONCLUSION

This report presents tangible examples of practical flood risk mitigation projects that can be deployed in communities across Canada. Based on key findings of these projects, the report describes numerous factors that can influence the success of local flood risk mitigation efforts, each factor being specific to a stage of the project lifecycle (Initiation and Planning, Implementation, and Post-Implementation). In particular, the report highlights two characteristics common to all successfully deployed projects: **1) Partnerships and Community Engagement**, and **2) Monitoring and Adjusting**. Not only are the success drivers important throughout an entire project lifecycle, they are frequently interdependent. Stronger relationships with key stakeholders often lead to more effective monitoring and adjusting, ultimately increasing the likelihood of successful flood risk reduction.

Whether empowering landowners to better understand flood risk, implementing bioretention measures and permeable pavement, or restoring banks and shorelines, all eleven projects demonstrated collaborative approaches to reducing flood risk which can be easily replicated – thus they are scalable – in communities across the country. If future projects are deployed on scale, the additive benefits could materially reduce the costs of flooding at the provincial and federal level.

> **"Climate systems, like economic systems, are complicated: the forces at work can interact in unforeseen ways, so there are some significant unknowns. But these unknowns are all the more reason to act, especially if they imply even a small risk of a truly catastrophic outcome."[51]**
>
> -Timothy Lane, Deputy Governor of the Bank of Canada, 2017

APPENDIX A: EXAMPLES OF STORMWATER MANAGEMENT AND FLOOD-RELATED LAWSUITS IN CANADA

CASE NAME (YEAR)	DESCRIPTION (damages, cost and settlement amounts included where identified)	DEFENDANTS
Anderson et al v Manitoba et al, 2017 MBCA 14 (CanLII) (ongoing) **Manitoba**	A $950 M class action lawsuit was brought forward by 4,000 residents of four First Nations following severe flooding in the spring of 2011. A flood resulted in damage to property and the evacuation of many people from their homes. Plaintiffs brought claims of negligence, nuisance and breach of treaty rights, alleging that the Government of Manitoba contributed to the flooding through its operation of flood control measures and water control works that affected the water levels around the four First Nations. The class action lawsuit was certified in January 2017 and is moving forward.	Province, Manitoba Association of Native Fire Fighters Inc.
Wight v Peel Insurance, 2016 ONSC 6904 (CanLII) **Ontario**	A plaintiff sued their insurance company in contract for denying her coverage after a section of a nearby dam burst on a neighbour's property, causing a flash flood and damage to the plaintiff's home. The insurer initially denied the plaintiff's claim, but in a decision on the plaintiff's motion for summary judgment, the court found that the dam was a "water management system" and that the plaintiff's policy provided coverage for the accidental escape of water from a sewer or drain.	Insurance company
Muskoka Class Action, 2016 (ongoing) **Ontario**	A $900 M class action was launched by Muskoka residents, cottage owners and business owners against the Province of Ontario after damages were caused by flooding and high water levels. Plaintiffs allege that the Ministry of Natural Resources was negligent for failure to draw down the water levels and/or effectively manage the water levels. The claim is ongoing.	Province
Cerra et al. v. The Corporation of the City of Thunder Bay, 2012 (ongoing) **Ontario**	Floods in May 2012 resulted in severe damage in Thunder Bay. Plaintiffs allege negligence in repair, inspection and maintenance of the water pollution control plant, as well as lack of diligent operation and supervision at the time of the flood (including an allegation that alarms were ignored). The $300M claim is ongoing. The court certified action on consent in 2013.	Municipality
Vancouver Public Library Lawsuit, 2012 (ongoing) **British Columbia**	The City of Vancouver sued the developer, construction company, professional services/ design consulting firm and contractor company for damage caused by an October 2010 flood at the Kensington branch of Vancouver Public Library. The City claims that the catch basins were not constructed in accordance with the construction design details prepared by the civil engineer, that defendants were aware the library entrance was prone to flooding, and that defendants failed to take action even after the plaintiff notified them of the issue. This action is ongoing.	Developer, construction company, professional services/design consulting firm, contractor company
Maple Ridge Class Action. 2010 (ongoing) **British Columbia**	Fifteen households filed a class action lawsuit against a developer and contractor, two engineering firms, and the City of Maple Ridge after a 2010 flood. Plaintiffs allege that defendants were negligent, arguing construction failure, faulty workmanship and design, failure to inspect basements for leaks and failure to repair leaks as requested. Plaintiffs also argue that the houses were not waterproofed to code, despite the municipality's inspection, review and issuance of permits. The trial was scheduled to begin in 2016. The claim is ongoing.	Municipality, developer, contractor, engineering firms
Panza et al v. The Corporation of the City of Mississauga et al., 2012 **Ontario**	Upper and lower tier municipalities, the province and the conservation authority were all named as defendants in a negligence claim related to systemic flooding over several years in the Lisgar area of Mississauga. The $200M action was withdrawn before trial. However, this case shows the potential for systemic flooding to give rise to class action lawsuits.	Province, municipality, conservation authority
Dankiewicz v. Sullivan, 2011 ONSC 3485 (CanLII) **Ontario**	A property owner sued her neighbour, alleging negligence and nuisance after her neighbour's alteration of land caused a reversal of drainage flow and subsequent flooding. The court held that the flooding resulting from the defendant neighbour's actions constituted a nuisance. The court awarded the plaintiff $5,000 in recognition of the distress, inconvenience and interference with her enjoyment of her land, caused by the flooding, as well as $4,257 for replacement trees, a sump pump installation and other expenses related to the damage in her yard.	Homeowner
Dicaire v. Chambly, 2008 (QueCA) **Quebec**	The Quebec Court of Appeal dismissed a class action by owners of 1,723 homes that flooded in 1997 when sewers backed up following heavy rains. The court ruled that the sewers were designed, as provincial guidelines required; to cope with a "5-year storm," and the town was not obliged to do more. However, the court noted that current design standards might not protect municipalities in future lawsuits, in light of "recent climate phenomena" and other scientific advances.	Municipality
Lissack v Toronto, 2008 OJ No 5563 **Ontario**	The City of Toronto's storm sewer backed up following a heavy storm and flooded the plaintiff's basement. The plaintiff brought an action in negligence for damages against the city. The court found that the city breached its duty of care by failing to maintain and improve stormwater management systems.	Municipality
McLaren v. Stratford (City), 2005 CanLII 19801 **Ontario**	A major flood in the City of Stratford after severe rainfall in 2002 left many with sewage in their basement. Plaintiffs claimed negligence in design, construction operation and maintenance of the system. The class was certified by the court in 2005, and the case was settled in 2010, eight years after the flood. Stratford settled for $7.7M after already spending $1.3M in emergency relief and costly improvements to its system thereafter.	Municipality
Ingles v Tutkaluk Construction Ltd., 2000 1 SCR 298, 2000 SCC 12 **Ontario**	The appellant hired a contractor to renovate his basement. The required building permit was not obtained prior to construction. The inspector relied on the contractor's assurances that the underpinnings were properly constructed, without properly verifying this information, except for an examination of the concrete. The appellant began to experience flooding and hired another contractor, who determined that the underpinnings were completely inadequate and failed to meet the standard prescribed in the Building Code Act. The appellant sued the first contractor for a contractual breach and the city for negligence. Even though the owner consented to the construction without a permit, the City was also found negligent for failing to conduct an adequate inspection and ended up paying $185,000 in costs and rewards.	Municipality, contractor
Oosthoek v. Thunder Bay (1996) 1996 CanLII 1530 (ONCA) **Ontario**	After a storm in Thunder Bay, multiple homeowners' basements flooded. The plaintiffs brought an action alleging that the city knew of problems and acted negligently. The City was found liable for the flooding caused by the overloaded combined sewers. The city's negligence was based on its failure to enforce the by-law it passed requiring downspout disconnection from the sewage system.	Municipality

Source: Adapted from Zizzo Strategy. Legal Risks and Requirements to Address Flood Resilience. Prepared for the Intact Centre on Climate Adaptation. April 2017.

ENDNOTES

[1] Federation of Canadian Municipalities and National Research Council. National Guide to Sustainable Municipal Infrastructure: Stormwater Management Planning. 2004; Federation of Canadian Municipalities and National Research Council. National Guide to Sustainable Municipal Infrastructure: Infiltration / Inflow Control / Reduction for Wastewater Collection Systems. 2003.; Natural Resources Canada and Public Safety Canada. Federal Floodplain Mapping Framework. 2017.; City of London. Drainage By-Law. 2011.; Society for Ecological Restoration. International Standards for the Practice of Ecological Restoration. 2016.; Credit Valley Conservation &Toronto and Region Conservation Authority. Low Impact Development Stormwater Management Planning and Design Guide. 2010.; The Friends of the Greenbelt Foundation. "Green Infrastructure Types – Rain Garden and Bioretention." 2017.

[2] David Rider. "'Water is the new fire,' says the Insurance Bureau of Canada". *Toronto Star.* March 5, 2018. https://www.thestar.com/news/canada/2018/03/05/water-is-the-new-fire-says-the-insurance-bureau-of-canada-as-researchers-point-to-development-as-major-cause-of-basement-flooding.html

[3] SwissRe Canada. The Road to Flood Resilience in Canada. 2016. http://media.swissre.com/documents/The_road_to_flood_resilience_in_Canada.pdf

[4] Jessica E. Lamond, Joesph D. Rotimi, and David G. Proverbs. "An exploration of factors affecting the long term psychological impact and deterioration of mental health in flooded households." *Environmental Research* 140 (July 2015): 325-334. http://dx.doi.org/10.1016/j.envres.2015.04.008

[5] Paul O'Hare and Iain White. "Beyond 'just' flood risk management: the potential for—and limits to—alleviating flood disadvantage." *Regional Environmental Change* 18, no. 2 (September 2017): 385-396. https://doi.org/10.1007/s10113-017-1216-3

[6] United States Federal Emergency Management Agency. "Estimated Flood Loss Potential". 2017. https://www.fema.gov/media-library-data/1499290622913-0bcd74f47bf20aa94998a5a920837710/Flood_Loss_Estimations_2017.pdf

[7] Canadian Payroll Association. "Despite some economic gains, most employed Canadians continue to fall short of meeting their retirement savings goals." September 6, 2017. http://www.payroll.ca/PDF/News/2017/NPW/CPA_NPW_Survey_-_national_news_release_-_2017_FINA

[8] Greg Meckbach. "New IBC flood model shows 1.8 million Canadian households at 'very high risk'." *Canadian Underwriter.* February 2, 2016. http://www.canadianunderwriter.ca/insurance/new-ibc-flood-model-shows-1-8-million-canadian-households-at-very-highrisk-1004006457/

[9] Ibid.

[10] SwissRe Canada. The Road to Flood Resilience in Canada. 2016. http://media.swissre.com/documents/The_road_to_flood_resilience_in_Canada.pdf

[11] Insurance Bureau of Canada. Facts of the Property and Casualty Insurance Industry in Canada 2017. 2017. http://assets.ibc.ca/Documents/Facts%20Book/Facts_Book/2017/Fact-Book-2017.pdf

[12] SwissRe Canada. The Road to Flood Resilience in Canada. 2016. http://media.swissre.com/documents/The_road_to_flood_resilience_in_Canada.pdf

[13] City of Toronto. Staff Report: Follow-up on the July 8, 2013 Storm Event. 2013. https://www.toronto.ca/legdocs/mmis/2013/ex/bgrd/backgroundfile-62645.pdf

[14] Public Safety Canada. 2016-2017 Evaluation of the Disaster Financial Assistance Arrangements – Final Report. 2017. https://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/vltn-dsstr-fnncl-ssstnc-2016-17/vltn-dsstr-fnncl-ssstnc-2016-17-en.pdf

[15] Office of the Auditor General of Canada. Reports of the Commissioner of the Environment and Sustainable Development – Report 2: Mitigating the Impacts of Severe Weather. 2016. http://www.oag-bvg.gc.ca/internet/docs/parl_cesd_201605_02_e.pdf

[16] Parliamentary Budget Officer of Canada. Estimate of the Average Annual Cost for Disaster Financial Assistance Arrangements due to Weather Events. 2016. http://www.pbo-dpb.gc.ca/web/default/files/Documents/Reports/2016/DFAA/DFAA_EN.pdf

[17] Zizzo Strategy. Legal Risks and Requirements to Address Flood Resilience (Prepared for the Intact Centre on Climate Adaptation). 2017.

[18] Ibid.

[19] Public Safety Canada. Guidelines for the Disaster Financial Assistance Arrangements. 2007. https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/rcvr-dsstrs/gdlns-dsstr-ssstnc/gdlns-dsstr-ssstnc-eng.pdf

[20] Emergency Management British Columbia. "Disaster Financial Assistance (DFA) and Residential Flood Insurance." May 4, 2016. https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/embc/dfa/residential_flood_insurance.pdf

[21] Parliamentary Budget Officer of Canada. Estimate of the Average Annual Cost for Disaster Financial Assistance Arrangements due to Weather Events. 2016. http://www.pbo-dpb.gc.ca/web/default/files/Documents/Reports/2016/DFAA/DFAA_EN.pdf

[22] Daniella Dávila Aquije. "Paying for Stormwater Management: What Are the Options?" *IMFG Perspectives*. 2016. http://munkschool.utoronto.ca/imfg/uploads/342/imfg_perspectives_no12_stormwater_daniella_davilaaquije_apr26_2016.pdf

[23] Association of Municipalities of Ontario. AMO's 2011 Municipal Insurance Survey Results: Managing the Cost of Risk. 2011. https://www.amo.on.ca/AMO-PDFs/Reports/2011/2011ManagingtheCostofRisk.aspx

[24] Government of Canada. "Reducing Flood Damage." 2013. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/reducing-flood-damage.html

[25] Statistics Canada. "Canada goes urban." 2017. http://www.statcan.gc.ca/pub/11-630-x/11-630-x2015004-eng.htm

[26] Intergovernmental Panel on Climate Change. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. 2012. https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

[27] Lucie Vincent et al. "Observed Trends in Canada's Climate and Influence of Low-Frequency Variability Modes." *Journal of Climate* 28, no. 11 (June 2015): 4545-4560. https://doi.org/10.1175/JCLI-D-14-00697.1

[28] Ibid.

[29] International Energy Association. World Energy Outlook 2016. 2016. Accessed at: https://www.iea.org/publications/freepublications/publication/WorldEnergyOutlook2016ExecutiveSummaryEnglish.pdf

[30] Government of Canada. Pan-Canadian Framework on Clean Growth and Climate Change. 2016. https://www.canada.ca/content/dam/themes/environment/documents/weather1/20170125-en.pdf

[31] Canadian Standards Association Group. "Guideline on Flood Proofing and Flood Prevention Measures to Protect Basement Flooding." February 2, 2017. https://www.scc.ca/en/standards/notices-of-intent/csa/guideline-flood-proofing-and-flood-prevention-measures-protect-basement-flooding

[32] Canadian Standards Association Group. "CSA Group Launches Initiative to Incorporate Climate Change Adaptation into Seven Canadian Infrastructure Projects." April 28, 2017. http://www.csagroup.org/news_or_press/csa-group-launches-initiative-to-incorporate-climate-change-adaptation-into-seven-canadian-infrastructure-projects/

[33] Intact Centre on Climate Adaptation. Disaster Risk Reduction Applied to Canadian Residential Housing: Interim Report on the Home Flood Protection Program. 2017. http://www.intactcentreclimateadaptation.ca/wp-content/uploads/2017/12/HFPP-Interim-Report-Dec-2017-FINAL.pdf

[34] The Friends of the Greenbelt Foundation. "Green Infrastructure Types – Rain Garden and Bioretention." August 22, 2017. http://www.greenbelt.ca/gi_rain_garden_and_bioretention

[35] Toronto and Region Conservation Authority. "Rain Gardens." 2016. https://trca.ca/wp-content/uploads/2016/10/2138-STEW-Rain-Gardens.pdf

[36] Credit Valley Conservation & Toronto and Region Conservation Authority. Low Impact Development Stormwater Management Planning and Design Guide. 2010. https://cvc.ca/wp-content/uploads/2014/04/LID-SWM-Guide-v1.0_2010_1_no-appendices.pdf

[37] Society for Ecological Restoration. International Standards for the Practice of Ecological Restoration. 2016. http://c.ymcdn.com/sites/www.ser.org/resource/resmgr/custompages/publications/ser_publications/SER_Standards_English.pdf

[38] Government of Canada. Canada's Marine Coasts in a Changing Climate. 2017. http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/files/pdf/NRCAN_fullBook%20%20accessible.pdf

[39] Credit Valley Conservation. "Your Land & Water – Bank Erosion." https://cvc.ca/your-land-water/countryside-stewardship/stewardship-resource-centre/your-wetlands-streams-and-ponds/bank-erosion/

[40] The Partnership for Water Sustainability in BC. "Primer on Water Balance Methodology for Protecting Watershed Health." 2014. http://waterbucket.ca/wp-content/uploads/2012/05/Primer-on-Water-Balance-Methodology-for-Protecting-Watershed-Health_February-2014.pdf

[41] Lynn Freehill-Maye. "Montreal's Green Alleyways Take Visitors Backstage." *The New York Times.* October 27, 2016. https://www.nytimes.com/2016/10/30/travel/montreal-green-alleyways-take-visitors-backstage.html

[42] Ibid.

[43] Green Communities Canada. "Depaving "liberates the soil"." June 5, 2012. http://greencommunitiescanada.org/depaving-liberates-the-soil-2/

[44] Ibid.

[45] Habitat Conservation Trust Foundation. "Burrard Inlet Restoration Pilot Program." 2018. http://hctf.ca/what-we-do/projects-weve-funded/birpp/

[46] Habitat Conservation Trust Foundation. "Rewilding Burrard Inlet." August 24, 2015. http://www.hctf.ca/communications/blog/entry/rewilding-burrard-inlet

[47] Gwa'sala-'Nakwaxda'xw First Nation and Government of British Columbia. Wawaƛ/Seymour Estuary Conservancy Management Plan. 2013. http://www.env.gov.bc.ca/bcparks/explore/cnsrvncy/seymour_estuary/wawah-seymour-estuary-mp.pdf

[48] Region of Peel. Site Summary – Dixie-Steeles. 2011. http://www.peelregion.ca/planning-maps/NAI/site_summaries/Dixie_-_Steeles.pdf

[49] Toronto and Region Conservation Authority. Authority Meeting #2/14. 2014. http://www.trca.on.ca/dotAsset/184900.pdf

[50] Natural Resources Canada. "Free Data – GeoGrats." 2018. http://www.nrcan.gc.ca/earth-sciences/geography/topographic-information/free-data-geogratis/11042

[51] Bank of Canada. "Thermometer Rising—Climate Change and Canada's Economic Future." March 2, 2017. https://www.bankofcanada.ca/2017/03/thermometer-rising-climate-change-canada-economic-future/

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