CITIES ADAPT WITH CLIMATE RESILIENT INFRASTRUCTURE

CELEBRATING LOCAL LEADERSHIP

by Sophie Guilbault, Esther Lambert, Paul Kovacs, Darrel Kwong and David Lapp, eds.

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Across Canada, different types of public infrastructure are impacted by a wide range of climate hazards. This includes heatwaves, ice storms, severe wind, extreme rainfall, hailstorms, coastal flooding, and wildfires. Each year, municipal buildings, transportation systems, water supply and wastewater treatment systems, and many other types of public infrastructure are affected by severe weather events in communities across the country. As Canadian municipalities continue to be threatened and impacted by these events, most communities are rethinking the way they design and manage municipal infrastructure to ensure their long-term durability and performance under current and future climate conditions.

Most public infrastructure in Canada was designed many years ago using construction codes and standards that were based on historical climate data in planning for extreme weather conditions. Recently, however, communities have observed firsthand that these construction norms often result in assets that cannot properly withstand current climate extremes, which puts them at even greater risk under future climate predictions. Furthermore, according to the federation of Canadian municipalities (FCM), nearly 60% of public infrastructure in Canada is built and maintained by municipalities. The increased risk faced by infrastructure across all provinces and territories has led several municipalities to consider the current and future resilience of their infrastructure, when faced with rehabilitating or building new assets.

Extreme weather and climate events are expected to be more frequent in the future in our changing climate. As demonstrated in the cases featured in this report, many municipalities have showcased leadership in enhancing the climate resiliency of their infrastructure by planning with future climate conditions in mind, assessing the state of their assets, monitoring, performing regular maintenance, and investing in structural changes. The role of municipalities in developing and implementing local solutions and tailoring broad strategies to suit the local context is especially important. While there is still much more to be done to narrow the infrastructure gap in a national context of aging infrastructure, this report celebrates the many Canadian communities that have demonstrated their ability to adapt and plan ahead as they work to design and rehabilitate their local infrastructure.

Previous Cities Adapt publications celebrated the actions taken by municipalities to adapt to specific natural hazards including extreme rainfall, extreme heat, and severe wildfires. Frequently this includes efforts to build back stronger and to implement risk reduction initiatives. Many case studies in the previous reports presented adaptation
actions focused on community engagements, incentive programs and changes in local regulations. Adding to the body of knowledge from previous Cities Adapt reports, this edition focuses specifically on the actions taken by municipalities to ensure the climate resilience of their infrastructure against multiple hazards. More specifically, it highlights the efforts of communities in better understanding the risks faced by their infrastructure and the methods used to rehabilitate and design new infrastructure based on future climate conditions. In addition, it also focuses on various funding mechanisms used by communities to secure investments in public infrastructure.

As Canada’s leading disaster research institute, the Institute for Catastrophic Loss Reduction (ICLR) continues to support municipalities in their efforts to improve the climate resilience of their infrastructure. Affiliated with Western University and supported by its 120-member insurers, ICLR has worked to support municipal climate resilience for 25 years. The Institute is a pioneer in leading and promoting disaster risk reduction research and outreach with municipal support that includes ICLR’s Resilience in Recovery program and ICLR’s Showcase Homes program.

The case studies presented in the report are a testament to the importance of municipal action based on the four priority areas identified in the Sendai Framework.
for Disaster Risk Reduction, published by the United Nations to offer guidance on reducing the risk of loss and damage from seismic and climate disasters. The cases presented here cover a wide cross-section of infrastructure types including sewer systems, treatment facilities, buildings, roads and related infrastructure such as culverts, bridges and coastal infrastructure. As stated in the Framework, the resilience of new and existing critical infrastructure is instrumental in achieving enhanced preparedness at the community level.

The four priorities of the Sendai Framework are:

• Understanding disaster risk
• Strengthening disaster risk governance
• Investing in disaster risk reduction
• Building back better in recovery

The adaptation actions taken by the 20 local governments presented in this report align with the Sendai Framework’s recommendations. The local leadership showcased in this report is inspirational and presents tangible examples of what communities can achieve and what should be built upon into the future. Most case studies presented have had great success by establishing successful partnerships and collaborations with provincial, federal, and territorial governments, as well as the private sector.

This publication presents cases from eight provinces and one territory, featuring communities ranging from under 3 km² to over 5,000 km². It includes both urban and rural communities as well as various scales of infrastructure. Yet, from this diverse group, each community has taken strong action to reduce their vulnerability and improve the climate resilience of various infrastructure assets.

While many communities continue to experience the devastating impacts of aging infrastructure destroyed by more frequent extreme climate and weather events, the 20 communities presented in this report prove that a lot can be done to ensure greater resilience of public infrastructure. Municipal adoption of best practices like the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol has helped communities to understand the state of their assets and provides recommendations on concrete actions to be taken to improve resilience. The benefits of taking action extend way beyond the avoided damage to the infrastructure itself and include the broader social, natural, and economic environment.
LESSONS LEARNED
Local actions to reduce climate risks faced by public infrastructure

By Esther Lambert and Sophie Guilbault

Source: City of Surrey
The 20 case studies discussed here demonstrate that many local leaders are taking concrete actions towards ensuring the climate resilience of their municipal infrastructure. Moreover, the Sendai priorities for action can be applied at the infrastructure level to build lasting climate resilience. Local leaders have identified infrastructure vulnerabilities and considered how these might change with a changing climate.

In Canada, there has been a gradual shift towards ensuring a more resilient public infrastructure. This shift has often been triggered in response to severe weather events; other times by proactive planning for the long-term performance of municipal assets, in which future changes in climate conditions are implicated. However, these case studies suggest that most communities tend to implement more focused actions after experiencing extreme weather events in or near their vicinities that have resulted in extensive damage and disruption of community services. Targeted actions also tend to be taken after conducting a vulnerability assessment for infrastructure such as the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol, which considers climate data in determining the level of risk expected for a given type of infrastructure. Extreme weather such as ice storms and heavy rainfall in Toronto and flooding after the remnants of Hurricane Katrina in Welland triggered these communities to further understand the risks faced by their aging assets and undertake targeted actions.

Some municipalities had policies and programs in place prior to catastrophic events, which provided strategic guidance for risk reduction actions. Climate change and asset management plans, policies and programs can provide strategic direction for infrastructure impacted by a wide range of climate events. The lessons learned from these 20 case studies are organized around the four priorities for action identified in the Sendai Framework for Disaster Risk Reduction.

**Understanding climate risks to infrastructure**

Actions taken to develop and implement policies, plans, and projects meant to ensure the climate resilience of infrastructure were often preceded by vulnerability and risk assessments like the PIEVC in order to understand specific risks faced by infrastructure. These assessments are frequently used by communities to better understand key vulnerabilities of their infrastructure and build strong funding requests to council or other funders. The City of Windsor is in a better position to receive external funding after having done some groundwork geared towards understanding the vulnerabilities of their stormwater infrastructure. Vernon also understood the value of studies that use risk and level of service assessments to guide upgrades to existing infrastructure as well as new developments. Climate risk and vulnerability studies were used to prioritize needs and to make decisions about resilient drainage infrastructure upgrades.

Victoriaville’s reservoir restoration project required an understanding of hydrological
changes within the Beaudet Reservoir for different climate scenarios to ensure a safe and reliable source of water for the community. In the case of the Regional Municipality of Torch River No.488, the aging bridge had been monitored and vulnerabilities had been identified. There needed to be thorough assessments of the climate risks for proposed changes to existing infrastructure and/or construction of new ones.

For Northern and remote communities like Norman Wells and Tuktuuyaqtuq that are facing some of the most rapid climate changes, carrying out vulnerability assessments and identifying mitigation options are particularly pressing. It often means hiring consultants with the technical skill to carry out such studies and suggesting creative ways of accessing materials to implement adaptation projects within time constraints. In cases where resources are limited, municipalities can engage other organizations and stakeholders to help identify and define their risk. As stated by Shawn Stuckey, Senior Administrative Officer for Tuktuuyaqtuq, “Engaging university research programs to understand the science behind the problems now and those expected with future climate is a step worth taking.”

It is important to remember that risks can change as communities develop. Factors such as population dynamics and land use needs are dynamic; hence, needs and vulnerabilities have to be revisited regularly. This is recommended as part of the PIEVC protocol. Assessing risks every 5-10 years is recommended, as better science and modelling becomes available. These investigations take time, and municipalities need to view time invested in understanding risk as time well spent.

Figure 2: The Rural Municipality of Torch River identified the vulnerabilities of one of its aging bridges. (Source: RM of Torch River No. 488)
Effective governance for climate resilient infrastructure

While municipalities hold primary responsibility for ensuring that their infrastructure can withstand future climate conditions, collaborating with other levels of government and the private sector often increases communities' ability to pursue and accomplish long-term investments in risk reduction and adaptation undertakings. Fragmented governance can interrupt effective leveraging of expertise and division of responsibilities, leaving municipalities isolated and ill positioned to advance their plans and strategies.

Multiple levels of government and other stakeholders are involved in the management and maintenance of infrastructure, and this was observed for all 20 cases, to varying degrees. Surrey’s local government worked closely with the private sector to replace its Serpentine Railway Bridge. The community benefited from sharing responsibilities, which made the project more manageable for all involved. Success is often dependent on proper coordination among partners and the identification of common objectives to work towards.

Victoria-by-the-Sea identified the need to work with all levels of government, non-governmental organizations, and the public over many years to replace its aging seawall. Identifying funding mechanisms and determining which partner would take on different responsibilities were crucial for a positive outcome. Partnerships are particularly important for smaller jurisdictions that lack the institutional capacity. Multi-stakeholder collaborations have proven to bring significant benefits to communities who have embarked on cross-jurisdictional initiatives.

Investing in climate resilient infrastructure

Research by the Institute for Catastrophic Loss Reduction finds that investments geared towards the climate resilience of public infrastructure leads to big savings for municipalities, frequently with benefits 5- to 10-fold greater than the cost as future damage is avoided or reduced. In addition to proper assessment of climate risk and effective governance, a prioritization strategy can help municipalities invest strategically. Determining which assets need immediate attention, especially in situations where resources are limited, can help in allocating budgets wisely. As municipalities are faced with competing priorities, understanding which initiatives will result in the most value for every dollar spent and greatest benefit to the social and environmental fabric of communities is instrumental. Welland was able to use the PIEVC protocol to prioritize interventions on its storm and wastewater systems.

Calgary also learned the importance of prioritizing and benefited from conducting in-depth studies that made it easier to attract funding under initiatives such as the Municipalities for Climate Innovation Program (MCIP) and to get the support of Council. Municipalities must plan to attract funding. The City of Surrey benefited from having a Coastal Flood Adaptation Strategy in place, which aligned with federal
funding requirements under the Disaster Mitigation and Adaptation Fund (DMAF). Many communities reported the importance of getting their councils on board before investing in climate resilient infrastructure and highlighted the importance of having completed studies and risk assessments to justify the investment needed for proposed projects.

Some municipalities were already making investments prior to using the PIEVC protocol or any other types of vulnerability assessment; however, the assessments helped to further confirm vulnerabilities and needs. It also created a model that can be applied system-wide and not only for individual projects. Ottawa has taken on this city-wide approach by adapting the PIEVC process and applying it more broadly.

Careful consideration of timing is important when putting an investment plan together. This becomes particularly crucial for indigenous communities reliant on infrastructure such as ice roads that are accessible for a limited time. Tuktuuyaqtuuq reported this important consideration after facing challenges associated with sourcing and transporting construction materials.

Improving preparedness and rebuilding stronger

While investing in upgrades to existing infrastructure is good, research shows that the economic benefit of ensuring new infrastructure is done right is even greater. In the
case of rebuilding, Toronto learned that a reconstruction plan was essential before moving forward after the collapse of its Finch Avenue culvert in 2005. Design changes in light of expected climate changes should be part of any reconstruction plan, as was done in Toronto and St. John’s.

When considering different design, it is important to include skilled resources as part of a multi-stakeholder team. The Siksika Nation learned that the involvement of stakeholders with specific knowledge and expertise was critical in determining their best path forward in recovery. An emergency response team is essential and should already be in place prior to adverse weather and climate events, and situating critical infrastructure away from hazard prone areas should be a part of the reconstruction approach.

Consideration of alternatives will ensure the best option is selected during the rebuild phase. The Rural Municipality of Torch River was faced with repairing its existing bridge or replacing it with culverts, and the latter proved more cost effective. After reconstruction, ongoing monitoring and assessment is essential so that changes can be made as the understanding of climate and risk changes.

The need to establish an understanding of resiliency was raised by the Saddle Lake Cree Nation. The project team, including the consultant, spent time to understand how different aspects of the community need to be considered in achieving resilience.
SECTION I

BETTER UNDERSTANDING DISASTER RISK

Understanding disaster risk: Disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics, and the environment. Such knowledge can be used for risk assessment, prevention, mitigation, preparedness, and response.

Source: UNDRR - Sendai Framework for Disaster Risk Reduction
NORMAN WELLS
Understanding riverbank erosion and its impact on local infrastructure

By Sophie Guilbault
THE SCIENCE

The way Canadian communities are affected by climate change varies greatly depending on location, with northern communities facing unique challenges. Climate change is happening more rapidly at higher latitudes than in other parts of the country, leaving northern communities with constantly evolving adaptation needs. Current and future climate patterns in the North are most visible through changes in sea ice, seasonal snow cover, glaciers and ice caps, permafrost, and river and lake ice. Changing climate conditions in Canada’s North are threatening the integrity of community infrastructure, including foundations, roads, water and wastewater facilities, pipelines, and traditional travel routes.

THE TRIGGER

The Town of Norman Wells is located in the Northwest Territories, on the shores of the Mackenzie River, approximately 680 km northwest of Yellowknife. Over time, local authorities started noticing increased erosion on the riverbank, threatening the stability of local roads and other infrastructure. Concerned with this situation worsening under our changing climate, the Town decided to request funding through the Climate Change in the North Program of Crown Indigenous Relations and Northern Affairs Canada in order to conduct a geotechnical investigation of the riverbank. The study conducted by a consulting firm allowed local leaders in Norman Wells to better understand the consequences of the erosion of the riverbank and the associated risk to local infrastructure moving forward. In addition to providing a vulnerability and risk assessment of the area, the report also looked at remediation alternatives to protect the existing riverbanks against future erosion and impacts from climate change.

THE APPROACH

The Town of Norman Wells hired Stantec Consulting to conduct the geotechnical field investigation with four main objectives in mind: evaluate the historic performance of the riverbank, review stratigraphic and permafrost information along the riverbank, estimate future potential permafrost degradation from climate change and its expected impact to the riverbank stability and adjacent infrastructure, and finally evaluate the riverbank stability impacts and improvement options.

The consulting firm responsible for the study identified various processes affecting the riverbanks. Firstly, the study reported that thaw settlement of roadways as a result of permafrost degradation could impact road infrastructure, more specifically as it relates to grades for land drainage ditches and culverts. Second, when looking at slope stability of the riverbank, the study identified key areas of concern that were also faced with greater erosion. Finally, the report noted that surface runoff erosion and gully formation was observed at several locations along the studied area caused by inadequate surface runoff management.

Beyond these observations, the study offered recommendations to implement climate change adaptation actions that would reduce the impact of these risks on
the Town of Norman Wells’ infrastructure. For instance, the consulting engineers recommended placing additional granular fill to fill areas of settlement and conduct regular topographic surveys to quantify levels of settlement. In terms of slope stability, the recommendations included the construction of stabilizing measures such as rockfill buttress to provide lateral support and increase soil strength along the riverbanks. Providing additional support in areas that are more significantly affected by slope stability would simultaneously help with the impact of erosion, given that the areas where riverbank erosion is of greatest concern generally coincide with areas identified at higher risk for slope stability. It is interesting to note that given challenges associated with accessing construction materials in northern and remote communities, it was suggested to the Town of Norman Wells to consider using meshed tires from the town’s landfill to help fill the areas of concern along the riverbanks.

The study also highlighted the need for the Town to pay close attention to municipal drainage as a strategy to reduce erosion and flooding risk. More specifically, the report specifies that the construction of armoured channels at the culvert outlets to direct water down the riverbank slope would be an effective way to mitigate erosion caused by surface runoff.
THE OUTCOME

The report that came out of the geotechnical investigation of the riverbank was well received by the Town’s Council. Since it was shared with the community in April 2020, Council supported the development and implementation of a comprehensive drainage plan to reduce erosion and flooding risk along 7 km of the Mackenzie River. In addition to the drainage work that was completed, several considerations were incorporated within Norman Wells’ community plan, including the restriction of any development that may adversely affect water quality and natural patterns, ground coverage, melting permafrost, and potential for erosion.

The study conducted by Stantec also allowed the community to better understand the risks faced by Mackenzie Drive, the road bordering the river, and remediation actions that needed to be taken to ensure its longevity. Given challenges around construction planning and access to materials in northern communities, Mr. Frank Pope, Mayor of the Town of Norman Wells, emphasized the importance of understanding risk faced by specific infrastructure and planning their rehabilitation to ensure they function over long periods of time. “In order to prolong the life of our roads and protect our coastline, it’s important to understand what adaptation actions need to be implemented. Proper understanding and planning can give you an additional 10 to 15 years on your roads when things are done properly,” said Mayor Pope.

A WORD FROM NORMAN WELLS

When asked what advice she would give to other northern communities interested in better understanding some of the climate risks facing their infrastructure, Cathy Clark, Senior Administrative Officer for the Town of Norman Wells, emphasized the need to push for a cultural shift in the North. “As northern communities are increasingly facing the impact of climate change, it is instrumental to not only inform but to educate community members on the risks faced by local infrastructure and the need to implement adaptation actions,” said Ms. Clark. Mayor Pope added that, while communication with community members was key to the implementation of successful adaptation initiatives, it is equally important to make sure the information communicated is delivered in a way that is easily understandable and avoids scientific engineering terms that might confuse people who do not work in the field.
WINDSOR
Involving residents in understanding future risk to develop a flood protection master plan

By Esther Lambert
**THE SCIENCE**

Windsor is expected to experience an increase in average precipitation in the coming decades, facing a heightened risk of loss and damage to infrastructure including sewer systems. Extreme precipitation has resulted in an overwhelming of city storm water infrastructure and widespread basement flooding, increasing households’ financial burden through property losses and reconstruction costs. The increasing financial impact of flooding events on the City of Windsor has been a big motivator for putting plans and policies in place to guide risk reduction actions. Developing plans and policies around adaptation action often involves studies to understand the impacts of climate change, risks, vulnerabilities, and priority issues.

While municipalities have a key role to play in reducing urban flood risk, actions taken on private property are essential to manage the inflow and infiltration of rainwater into municipal wastewater systems. Involving homeowners in the process of understanding risk and planning policies around adaptation can be a great way to increase engagement and risk reduction actions at the lot level to further support municipal adaptation actions.

**THE TRIGGER**

With a track record of recent extreme storms in 2010, 2011, 2014, 2016 and 2017, the City of Windsor acknowledged the importance of building climate resilience within local infrastructure and, for almost a decade, has been taking action towards adapting. The duration of those flood events was short (six hours); however, they were followed by extended aftermath effects. For the 2017 flood event, over 220 mm of rainfall was recorded – which exceeds that expected for a 1 in 100-year storm – flooding more than 6,200 basements. Flooding extended beyond Windsor to LaSalle, McGregor, Tecumseh, Amherstburg, and Lakeshore. Damage was estimated at over $175 million.

Frequent storm occurrences followed by increasing losses was an impetus to apply for funding for the completion of a Sewer and Flood Protection Master Plan, which provides guidance on improving all of the City’s sewer systems and overland drainage infrastructure. The storm events also led the City to rethink how it understands the impact of increasingly extreme storms on lake levels. In 2019, the East Riverside Flood Risk PIEVC assessment was conducted, confirming a new record high level in Lake St. Clair and the need to conduct an assessment of vulnerable regions along the Detroit River.

**THE APPROACH**

One of the first intentions of the City of Windsor was to understand the causes of basement, surface, and coastal flooding and the areas at risk. This was accomplished through the development of a Sewer and Coastal Flood Protection Master Plan, which was fully approved by City Council in July of 2020. City staff and consultants collaborated on this project over a two-year period to identify and prioritize rehabilitation projects. More specifically, the master plan identified improvements to
The City of Windsor has experienced flooding caused by severe rainfalls on many occasions and in various parts of the municipality. (Source: City of Windsor)

The City put together a technical team with representation from different departments, including Engineering, Operations, Pollution Control (which manages treatment plants and pumping stations), legal, building, and parks personnel. A stakeholder advisory committee consisting of 17 people was also established and included representatives from the community, environmental experts, and academics. They met seven times with the technical committee to provide advice and feedback to the project team as it evolved.

Ongoing public engagement and education activities throughout the development of the master plan included two public information sessions, public meetings attended by property owners, and the dissemination of three newsletters. There was also a website named “Weathering the Storm” where the public could follow the progress of the project. A special survey called “Partners for Action” was completed by 306 residents to understand their opinions on various aspects of the project. The public information sessions attracted homeowners, indigenous communities, and other interested members of the public. The City reported on its findings about flood risk in various locations and on its proposed solutions, which included projects that require cooperation from homeowners for effective implementation and those under the jurisdiction of the City such as projects concerning pump stations, sewers, stormwater management ponds, and treatment plants.

**THE OUTCOME**

The master plan identified four priorities and recommendations on how to tackle them. First, it suggested increasing downstream outlet capacity by an expansion of the Little River Pollution Control Plant to account for population growth. Second, the plan recommended implementing coastal flood protection actions to include
the construction of an earth berm along the northern or southern stretch of Riverside Drive East. Third, it suggested implementing source control and private property measures through public education campaigns, implementing low impact development (LID) features and updating the City’s development standards. Finally, the fourth priority was to improve sewer system conveyance and storage capacity. After the work was conducted to further understand flood risk and establish the master plan, the City is not in a position to work towards securing funding for specific risk-reduction actions.

The public education component of the master plan development revealed that homeowners do not understand certain aspects of the function of their homes; however, after looking at the website and participating in the information sessions, people gained a better understanding of how their drainage works and why it is important to maintain their sewage backflow preventer.

**A WORD FROM WINDSOR**

Anna Godo, Senior Engineer for the City of Windsor, stated that municipalities ought to take on a leading role in implementing plans meant to provide direction on improving the resilience of public infrastructure, so that public interests are taken into consideration. She spoke about the master plan with great pride, highlighting major accomplishments to include recommendations for the improvements of both private property and public infrastructure. Ms. Godo added, “If we can keep the water from getting into the system and encourage infiltration, as opposed to collection by the storm sewer system, this would be good for the City.”

She mentioned that it is also necessary to look at private property issues that reduce the size of public infrastructure. “The City is saying that we can facilitate the change needed, but in the vast majority of cases, it has to be the individual homeowners that make the changes,” says Karina Richters, Supervisor in the Environmental Sustainability and Climate Change Department, in agreement. Another important point emphasized by Ms. Richters was the need for municipalities to position themselves well to receive funding. “The municipality has to lead to develop a sewer master plan to provide the information needed for funding applications.” Furthermore, support from Council is crucial.
LAVAL
Understanding risk to support future adaptive actions

By Sophie Guilbault

Source: City of Laval
THE SCIENCE

Understanding climate risks faced by critical municipal infrastructure is instrumental in planning future rehabilitation initiatives and having data available when opportunities arise to secure funding. The PIEVC protocol was created in 2005 to allow for engineering assessment of the vulnerability of Canada’s public infrastructure to the impacts of current and future climate risks. The collaborative approach promoted by the PIEVC enables stakeholders from various lines of work to share their respective perspectives on key challenges and opportunities faced by infrastructure assets or systems, with the objective to gather a comprehensive picture of climate risks at play and their associated risk reduction recommendations.

THE TRIGGER

In 2011, the City of Laval was among the early adopters of the PIEVC protocol and used the PIEVC approach to further understand the vulnerabilities to climate change faced by the combined and partially separated sewers of the tribute Basin of the Belgrand overflow structure. At the time, funding had been made available through the Centre of Expertise and Research in Urban Infrastructure (Centre d’expertise et de recherche en infrastructures urbaines – CERIU) for municipalities to conduct PIEVC assessments of vulnerabilities to climate change and the City of Laval leveraged this opportunity to apply the protocol to the Belgrand overflow structure, which is a key component of the City’s stormwater system. This structure was designed to control overflow of rainwaters and constitutes a major component of the wastewater collection system in the La Pinière watershed, a 45 km² largely urbanized territory served by combined, pseudo-separate and pluvial sewers.

THE APPROACH

In an effort to further understand the various risks and vulnerabilities faced by the Belgrand overflow structure, the City of Laval partnered with consulting firm Genivar (now known as WSP) and Ouranos to gather the diverse expertise needed around the table. This involved recruiting the right stakeholders from various municipal departments including public works, engineering and environment to understand the infrastructure as a whole. Having the right stakeholders at the table during workshop sessions allowed the municipality and its partners to look at questions that went beyond the calculation of the infrastructure’s performance and touched on topics such as instrumentation, maintenance, controls management, and vulnerabilities induced by extreme heat and severe rainfalls.

One of the key findings of the study was the necessity to design new structures within the Belgrand overflow structure catchment area that would promote stormwater management at the source and reduce some of the pressure faced by the Belgrand overflow structure. Unfortunately, the lack of an overall master plan for the City’s water department did not allow the City to fund and undertake these initiatives. Fast forward several years, the PGDEP (Programme de soutien aux municipalités dans la mise en place d’infrastructures de gestion durable des
eaux de pluie à la source) funding program was created to support municipalities in the implementation of sustainable rainwater management at the source. In order to receive funding, the City of Laval had to present a project that would tackle adaptation to a climate risk and demonstrate technically how the proposed project would improve the performance of existing infrastructure. The PIEVC report highlighting the risks and vulnerabilities of the Belgrand overflow structure and opportunities to mitigate these risks was instrumental in supporting the proposal and contributed to a favourable decision from the funder.

Laval chose to focus initially on a pilot study to better understand the risk and test potential solutions. Sometimes communities find greater access to initial funding through smaller scale initial projects. If proven effective, successful pilot projects may help provide a strong foundation to secure funding for larger scale initiatives.

**THE OUTCOME**

The City of Laval received nearly $500,000 to build a pilot project of stormwater infiltration features built alongside municipal sidewalks within two different areas of the Belgrand catchment area. The first site was built within an industrial area and the second one in a residential neighbourhood, for a total of 34 stormwater infiltration features. The municipality partnered with researchers from INRS (Institut National de la Recherche Scientifique) to track and measure water quality and quantity following the construction of the infiltration features and evaluate how it impacted the Belgrand overflow structure. The monitoring period will soon end and will allow
the City to establish if the pilot project is worth being replicated on a larger scale, and what would be its optimal design.

The work undertaken by the City of Laval over the last decade highlights the importance for municipalities to understand their infrastructure risk, even when capital funding isn’t currently available to build or rehabilitate public infrastructure. “The PIEVC report on the Belgrand overflow structure was an important piece of the puzzle when submitting our proposal for the design of new stormwater infrastructure. It also demonstrated that we had done our due diligence to identify what actions could be taken to mitigate current and future risks,” said Martine Galarneau, engineer with the City of Laval.

A WORD FROM LAVAL

When asked what advice she would offer to other municipalities interested in deepening their understanding of their infrastructure vulnerabilities, Ms. Galarneau mentioned that she would highly recommend using the PIEVC protocol to get a comprehensive analysis. “The protocol allowed us to highlight specific risks and vulnerabilities that we may have otherwise missed without the multi-disciplinary approach that was used,” said Ms. Galarneau. She added that larger municipalities can have a tendency to work in silos within individual departments and the approach promoted by the protocol allowed to foster strong collaboration between various groups. The work that the City of Laval undertook to identify the specific challenges faced by the Belgrand overflow structure enabled the municipality to start planning for future projects and act quickly once capital funding became available.
VERNON
Multi-disciplinary stakeholders participation in a drainage infrastructure prioritization project

By Esther Lambert

Source: City of Vernon
THE SCIENCE

The climate resilience of a municipality’s drainage system is key in preventing flooding during and after excessive rainfall. Municipal infrastructure that is designed and maintained to withstand expected increases in rainfall can save a city millions of dollars of damage to private property and other public infrastructure. Understanding the impact of projected climate scenarios on environmental processes such as erosion and sedimentation that impact drainage systems is crucial.

The City of Vernon recognized the need to investigate the vulnerabilities of its drainage infrastructure and to determine the level of risk for different regions. Projected increases in the magnitude and frequency of rainfall, especially extreme events, present a high risk for the City's drainage infrastructure. Studies that use risk and level of service assessments to inform upgrades and new construction are essential.

THE TRIGGER

The City of Vernon’s recent flood events of 2017 and 2018 highlighted the importance of drainage in the long-term sustainability objectives of the City. There had also been more frequent drainage issues related to rainfall, which indicated a need to prioritize investments for different components of the municipal water management system and set sustainable funding levels for stormwater. As such, a more thorough analysis of drainage impacts related to new development projects, especially hillside developments, was required. The City was also preparing a Climate lens grant funding application for Infrastructure Canada. The Completion of a PIEVC assessment and Drainage Infrastructure Prioritization Plan and study satisfied a large component of the Climate Lens assessment requirement.

THE APPROACH

The first comprehensive study completed to assess the capacity of Vernon’s drainage infrastructure was the 2001 Master Drainage Plan. More recently, the Drainage Infrastructure Prioritization Plan was undertaken and aligns with the goals set out in City council’s strategic plan of 2019-2022, which presents the undertaking of drainage studies, risk and threat assessments, related bylaw amendments, and developing and implementing asset management plans as priorities for the municipality.

The project team worked with staff from the Utilities and Development Engineering Departments to understand existing and past drainage issues. They identified existing drainage, capacity, operational, and maintenance issues. Once overland flow routes were generated using LiDAR (a digital mapping tool), staff was instrumental in fact checking these flow routes and identifying overlooked culvert locations. Besides investigating overland flow routes, the City carried out a full-day risk assessment workshop with regional stakeholders including City staff (managers), mayor of Vernon, regional district, the British Columbia Government (Section Head, Public Safety & Protection), Ministry of Transportation, and Vernon’s Climate Action Committee. City
staff also participated in watershed tours and flood risk mapping and assessment workshops hosted by the Okanagan Nation Alliance and the Okanagan Basin Water Board, respectively.

Technical issues encountered in the generation of overland flow routes and catchment areas using very high-resolution LiDAR data were overcome by utilizing open-source GIS software packages. Incorporating culverts and piped infrastructure into the overland flow routes also proved challenging as these conduits had to be “burned” into the existing elevation surface, so engineering judgement had to be incorporated.

In brief, the City put together a team with the capacity to provide a comprehensive assessment of the risk and identify a broad range of possible solutions. The diverse nature of the team assembled was critical to the success of the initiative.

THE OUTCOME

Major climate-related risks and vulnerabilities were identified by the study. Projected increases in rainfall event magnitude and frequency, especially for more extreme events, present the highest risk for the City’s drainage infrastructure. The Upper British Columbia Express Company (BX) Creek and its drainage infrastructure was identified as the most vulnerable to projected climate change. Vulnerabilities include higher peak flow rates and increased sediment production, transportation, and deposition due to climate change. Overland and natural drainage courses, which

Figure 7: The City of Vernon’s most recent flood events of 2017 and 2018 highlighted the importance of drainage in the long-term sustainability objectives of the City. (Source: City of Vernon)
typically flow through existing development, are also highly vulnerable to climate change. The impacts correspond to increased runoff from more extreme rainfall events, and high runoff, erosion, and sediment conveyance after wildfires. Lower BX Creek and Vernon Creek (Upper and Lower) are vulnerable to projected changes in more extreme rainfall events. The analysis also revealed that existing capacity deficiencies will be exacerbated as climate conditions change. Projected increases in wildfire potential and severity also present significant risks in the form of increased runoff, erosion, and sediment transport.

Important Council resolutions were triggered by the Drainage Infrastructure Prioritization Plan. First, Council requested an investigation of high priority overland flow routes to develop a strategy to incorporate overland flow path improvement and protection projects into the year’s capital plan. This is reflected in the City’s capital funding envelope for citywide drainage improvements, which addresses drainage issues identified in the Drainage Infrastructure Prioritization Plan/Study. Second, Council directed administration to identify amendments to the City’s applicable bylaws to designate and protect overland flow routes as per Section 34 of the Community Charter and Section 744 of the Local Government Act.

A PIEVC assessment was conducted following the study, which confirmed that overland and natural drainage courses are highly vulnerable to climate change, with impacts corresponding to increased runoff from more extreme rainfall events, and high runoff, erosion, and sediment conveyance after wildfires.

A WORD FROM VERNON

Geoff Mulligan, Infrastructure Management Technician for the City of Vernon, stressed the need for municipalities to invest time in understanding their unique needs and vulnerabilities. He recommended starting with building a strong foundation of knowledge to include understanding the infrastructure (minor and major drainage systems), understanding geography and climate (present and future), and understanding the risk. “This can be achieved through plans, risk assessments and workshops that include a variety of stakeholders,” says Mr. Mulligan.

He further explained that this approach can be operationalized by “Making climate adaptation a part of the planning process by integrating climate vulnerability into a prioritization framework and using risk as a decision tool to make improvements to drainage infrastructure as well as to protect overland flow routes from development.” He also highlighted the value of developing useful tools such as mapping for decision-makers, including field staff, so that the data derived from these plans are accessible and usable.
VICTORIAVILLE
Reservoir restoration to ensure continuous water supply

By Sophie Guilbault

Source: City of Victoriaville Facebook Page
THE SCIENCE

Municipalities around the country rely on reservoirs for potable water. More frequent floods and droughts can reduce the reliability of a reservoir’s water supply. The amount of water available in reservoirs can also be impacted by sediment accumulation, which can worsen under increased erosion conditions upstream. Reservoir capacity can be significantly reduced over time when large volumes of accumulated sediments are left unattended. The hydrological implications of future climate conditions should be taken into account when designing, restoring, and planning the maintenance of water reservoirs.

THE TRIGGER

In 1977, the City of Victoriaville built the Beaudet Reservoir to ensure sufficient freshwater supply for its population and also to prepare for future drought conditions. Prior to that, the municipality was getting its supply directly from the Bulstrode River, but water flows were sometimes insufficient in the summertime. Once the Beaudet reservoir was built, the City noticed over time that it was losing 1% of its capacity annually. This situation highlighted the need to understand what was causing this phenomenon and then create a plan to ensure sufficient water supply for the community in the years to come.

The City of Victoriaville first started looking into the causes behind the water loss inside the reservoir over 20 years ago. Initial studies revealed that one of the main issues was the high amounts of sediments that had gradually filled the basin at the rate of approximately 16,000 m³ per year. These accumulations led to reduced water storage capacity, which was decreased by 41% between 1979 and 2018. The loss of average depth of the reservoir also led to an increase in water temperatures, which simultaneously increased the risk of cyanobacteria proliferation. This phenomenon, coupled with increased inputs of phosphates and nitrates coming from agricultural activities upstream and the loss of depth, created an environment prone to the proliferation of aquatic plants. The initial studies showed that if no mitigation actions were taken, the reservoir would gradually turn into a big swamp and would no longer be able to fulfill its primary role to provide sufficient drinking water to the population. The studies also highlighted current risks around water quality associated with the increased amounts of sediments. Recurring high-flow events in the Bulstrode River were responsible for increased erosion and transportation of sediments to the reservoir. Challenges around water quality were also expected to increase under future climate conditions and cause greater strain on water treatment systems if no action was taken.

THE APPROACH

The initial studies requested by the City of Victoriaville confirmed the need to take action to mitigate further degradation of the reservoir. City staff from various departments, consultants, and representatives from several provincial ministries started looking simultaneously into actions that could be taken around the reservoir as well as upstream to reduce the transportation of sediments. Different options
were compared from an environmental, cost, and benefits perspective, and the results showed that working upstream to reduce the transportation of sediments wouldn’t be as impactful given that most sediments came from natural erosion associated with the meandering character of the Bulstrode River.

The City and its various partners determined that, for optimal results, an initial dredge of the reservoir followed by recurrent dredging over time would provide the best outcome for the community. The targeted volume for the initial dredge was determined with a drought return period of 30 years while considering changes in topping flows under future climate conditions. While recurrent dredging can manage issues associated with water quantity, a separate plan needed to be implemented for water quality and for the disposal of sediments.

On the water quality front, it was decided that a separate water reservoir would be built adjacent to the current one to store clear raw water that can be used when water quality decreases in the main basin. The water will be pumped from the main reservoir into this additional storage basin under specific water conditions. This will allow the municipality to consistently maintain sufficient drinking water volumes for the population and ensure water is also available at all times for emergency use, such as firefighting needs.

The approach undertaken by Victoriaville also necessitated a plan for the disposal of accumulated sediments in the Beaudet reservoir. In order to manage the regular dredging process, the community decided to build a sediment dewatering plant next to the reservoir. The water collected at the plant will be returned into the reservoir and the dry sediments will first be used to fill a large hole where a public recreation
space will be created for community members. Once that hole is filled, sediments will be redirected to be used elsewhere in the community.

THE OUTCOME

The initial dredge as well as the construction process for the separate water reservoir and sediment dewatering plant started in the spring of 2021 and construction was expected to be completed in 2022. The dredging process will be conducted over an 11-week period annually for the next five years, followed by maintenance dredging beginning in 2028. Over 40 studies were completed prior to the construction to provide a greater understanding of the situation, including literature reviews, environmental impact assessments of specific adaptation solutions and feasibility studies.

The comprehensive approach followed by the City of Victoriaville will ensure the sustainability of the community’s freshwater supply under current and future climate conditions. The rapid deterioration of the Beaudet Reservoir posed a significant threat to the community but the process that was implemented to determine how the reservoir could become more sustainable and climate resilient will provide long-lasting results for the population.

A WORD FROM VICTORIAVILLE

When asked what advice he would give to other municipalities interested in pursuing similar initiatives, Joël Lambert, Associate Director of Engineering and Environment Services for the City of Victoriaville, highlighted the need to foster strong relationships between the various partners on large infrastructure projects to ensure successful outcomes. “It is imperative to work as a team, both internally and externally to make sure all departments and stakeholders are aligned on desired outcomes and deliverables. We found it was key in Victoriaville to build on a unifying goal that brought benefits to all parties involved,” said Mr. Lambert. He also emphasized the importance of investing time and resources to understand the current risks faced by the infrastructure that needs to be rehabilitated. “While it took a long time to get a comprehensive understanding of the situation we were dealing with and identifying the right adaptation solution for the community, it was key to do so to ensure public funds were invested in a way that would serve the population in the long run,” he added.
SECTION 2

STRENGTHENING DISASTER RISK GOVERNANCE

Strengthening disaster risk governance:
Disaster risk governance at the national, regional and global levels is very important for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It fosters collaboration and partnership.

Source: UNDRR - SENDAI Framework for Disaster Risk Reduction

Source: Adobe Stock photo
SURREY
Serpentine Railway Bridge replacement

By Esther Lambert

Source: City of Surrey
THE SCIENCE

Increasingly severe weather poses a threat to railway infrastructure, its users, and the surrounding environment. While railway bridges, like the Serpentine Railway Bridge in Surrey, are used primarily to facilitate the movement of people and goods, they may also form part of the overall flood control infrastructure system, which includes such features as spillways and dykes. As such, their proper functioning and ability to withstand climate change is crucial in ensuring transportation safety, reduced likelihood of flooding in surrounding regions, and protection of agriculture and other ecosystem services.

THE TRIGGER

Located in Surrey’s extensive floodplain, the railway bridge would often have to be shut down whenever significant rainfall was expected to cause flooding. The risk of infrastructure failure was high due to the age of the structure and increased flood occurrences. The replacement of the Serpentine Railway Bridge with a more climate-resilient crossing was planned to ensure the safe movement of approximately $190 million of freight typically transported along the railway annually. The new crossing also completes the City’s flood control system, which protects agricultural lands, homes, utility corridors, roads, and highways.

The decision by the City of Surrey to replace the Serpentine Railway Bridge was preceded by the implementation of an ambitious program in 1997, to address lowland flooding in the floodplains of the Serpentine and Nicomekl Rivers. The goal was to control flooding within these floodplains and to support and promote agricultural activities. This flood control drive resulted in improvements of the dyking system. Since then, the City has worked with regulators and partners to implement 17 drainage pump stations, 20 km of ditches, and to replace bridge crossings.

THE APPROACH

A study identified the Serpentine Railway Bridge, owned by the Southern Railway of British Columbia Ltd., as a bottleneck that was negatively impacting the City’s efforts at the long-term management of the floodplain. It was a 58-year-old timber railway bridge prone to damage and overtopping. The City used climate models based on future scenarios for sea-level rise and increased precipitation to determine the impact on the bridge, which justified the need for a bridge replacement.

As the asset owners, Southern Railway also had a major interest in the project, having experienced significant economic losses due to the washing out of railway assets. With funding from the federal government’s Disaster Mitigation and Adaptation Fund ($750,000) and Southern Railway of British Columbia ($1 million), the City was able to start bridge replacement work in 2019. It was the first of 13 coastal

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flood adaptation projects made possible through the Adaptation Fund and guided by Surrey’s Coastal Flood Adaptation Strategy.

A collaborative approach between the City of Surrey and Southern Railway was taken to address a problem that was affecting both. The design of the new crossing was based on climate modelling assuming one-meter sea-level rise by 2100, as recommended by the Province of British Columbia. Southern Railway led the development of the design, and the City consultant reviewed the design to ensure it met their standards. All this groundwork coupled with the Coastal Flood Adaptation Strategy as a guiding policy document enabled the City to develop a strong funding application. Residents were also engaged and informed of how construction activities would affect them. The new bridge was completed three months after shutting down the old bridge, resulting in a relatively short interruption of activity in the area.

One of the biggest challenges faced by the City was to get buy-in from Southern Railway in a timely fashion. Initially, the organization was also considering an alternative approach of repairing the existing bridge by replacing the damaged timber. Hence, the City needed to consider not only its interests but that of its private-sector partner, so that both their goals were being addressed.

**THE OUTCOME**

As the first completed project of 13 projects under the City’s DMAF program, this
Project highlights Surrey’s leading role in reducing flood risk in the province. The new design took into consideration the one-meter sea-level rise projection for 2100. Due to limits on slope angles for freight railway lines, the new crossing was built at the same elevation as the previous infrastructure, with a flood-safe design that allows it to be submerged during high water levels, while avoiding flooding of the railway itself. Concrete walls on both sides protect the track from flooding. The new design also discourages debris build up and includes a walkway to ensure the safety of workers. The redesign subsequently allowed the City to integrate and upgrade its surrounding dyking infrastructure and address the weak spot in its flood control system.

While long-term monitoring has not yet been done, debris accumulation is now non-existent, and there has been no interruptions of rail service since the construction was completed. Monitoring mechanisms have been put in place by the City to observe impacts of projected climate changes, while Southern Railway maintains the new crossing.

**A WORD FROM SURREY**

Upon reflecting on the best advice to give municipalities considering similar adaptation actions, Mr. Yonatan Yohannes, Utilities Manager, and Mr. Amir Shirazian, Project Engineer for the City of Surrey, noted the need for partners to collaborate very early in the planning process, even if all the fine details of the project have not yet been discerned. Mr. Yohannes stressed the importance of “looking at the bigger picture and involving all stakeholders in discussions about the science to support different project alternatives and the consequences of taking no action.” Ms. Tjaša Demšar, Sustainability Planner, further qualified this view by adding that municipalities ought to think outside the box about who potential partners could be, stating that, “A private company wouldn’t necessarily be the first partner a municipality would consider but, in our case, it was a great success.”

She also encouraged stakeholder engagement throughout the life of the project to ensure that residents are aware of how the project is expected to impact them. Finally, the importance of putting together a team of people passionate and determined about the project goals and qualified to get the work done was a major recommendation from Mr. Yohannes, which he believes could be one of the most crucial considerations for success.
MONTREAL
Rethinking urban parks to mitigate flood risk

By Sophie Guilbault

Source: City of Montreal
THE SCIENCE

In many cities across Canada, combined sewer systems have conventionally been used as the primary system to collect and transport rainwater during rainfall events. However, these systems have frequently been overwhelmed in communities when faced with severe rainfall events, resulting in basement flooding for thousands of homeowners. Many cities have started using land use planning tools as a way to increase natural absorption of rainwater into the ground and delay its transportation to the sewer system. Different types of low impact development (LID) strategies can be used to serve this purpose, such as stormwater management ponds and rain gardens. When properly designed, these green infrastructure projects allow the gathering of rainfall and surface water runoff, reducing the amount of water that needs to be transported by the municipal sewer system during peak flow periods.

THE TRIGGER

The City of Montreal has faced several extreme rainfall events in recent years, resulting in urban flooding incidents in numerous areas of the community. One particularly devastating event occurred in May 2012 and resulted in over 5,000 basement flooding claims. Faced with recurring extreme rainfall events and projections of these events increasing in frequency and intensity under future climate conditions, Montreal started reflecting on various strategies that could be used to reduce its urban flooding risk. One of the main conclusions that emerged from the City’s discussion was the need to look at alternative supportive actions that could be taken in parallel to the rehabilitation of the underground stormwater infrastructure. More specifically, City staff started reflecting on how Montreal could better live with water and use it as an opportunity to create unique and interesting outdoor spaces for the community.

THE APPROACH

Given the growing health concerns associated with neighbouring fires, as well as the A new approach took shape on the site of the former Outremont railyards. For decades, this place, by its location at the foot of Mount Royal and the Borough street grid, had been acting as a natural infiltration zone. The redevelopment of the railyards in a new dense neighbourhood by the City and University of Montreal, called “MIL Montréal,” offered a great opportunity to rethink traditional stormwater management. The development plan included a university campus of 300 000 m2, 1,300 dwelling units, local shops and four hectares of new urban parks. The planning of the new Pierre-Dansereau park came as an opportunity to incorporate green infrastructure to collect rainwater and delay its transportation to the sewer system, which tends to be overwhelmed by large amounts of water during severe precipitations. Beyond the implementation of innovative stormwater management practices, the design team also wanted to ensure that the new park would respond to the community’s needs and decided to invite the neighbourhood’s residents to participate in public consultation and codesign sessions at the very beginning of the design process. Once the needs of the community were clearly defined, the design team was able to develop a creative master plan for the future park that both aligned with the
community’s wishes and accounted for 627 m$^3$ of rainwater to be managed for future periods of heavy rain.

The team planned the Pierre-Dansereau park with the integration of natural infiltration and retention zones that could collect stormwater for small and large rainfall events with return periods ranging from three months to 50 years. The various infiltration zones designed within the park created interesting variations in elevation that were then used to create interesting multi-functional spaces that serve the community. For instance, a dry stream acting as a retention basin was integrated within the design and the space has become very popular among the neighbourhood’s children who use the area to play with rocks and vegetation.

**THE OUTCOME**

The initial planning in stormwater management in this new neighbourhood was based on the underground retention. This will ultimately be developed on the surface in order to reduce the ecological footprint of this major project, to limit construction costs and times, but also to raise citizens’ awareness of this major issue of stormwater management. The intervention designed by the City of Montreal’s team for the entire neighbourhood includes now a total of three parks with stormwater ponds, one rain garden and only one underground basin. “When the various municipal departments got together to plan the Pierre-Dansereau park, we understood the importance of planning stormwater management not only for the park itself but also

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**Figure 10:** The project team planned the Pierre-Dansereau park with the integration of natural infiltration and retention zones that could collect stormwater for small and large rainfall events. (Source: City of Montreal)
in the neighbouring streets in order to ensure that water runoffs would be properly directed to the stormwater ponds and rain garden,” mentioned Vincent Defeijt, the project engineer behind the project.

Beyond the advantages associated with better stormwater management, the design and construction of the Pierre-Dansereau park ended up being beneficial financially for the City. Alexandre Guilbaud, Urban Planning Advisor for the City of Montreal explained that “Designing a park that improved stormwater management capacity for the neighbouring areas allowed the City to mutualize its investment. Building new stormwater infrastructure independently from the construction of the park would have been more expensive for the municipality.’

**A WORD FROM MONTREAL**

The experience of the City of Montreal in designing and building the Pierre-Dansereau park has served as a precedent that has since been used for the design of several other parks within the City that will also incorporate stormwater management features to reduce the pressure of peak water flows in the sewer system during rainfall events. When asked what advice he would like to share with other municipalities interested in implementing similar projects, Rémi Haf, Planning Advisor for the Water Department of the City of Montreal, emphasized the multi-disciplinary nature required for this type of endeavour: “Multi-disciplinary teams must be collaborating and remain in constant dialogue from the initial conception to the completion of the project to ensure all aspects from the design to the stormwater management system are well integrated,” said Mr. Haf. “The City has relied on traditional stormwater management practices for many years, but we have noticed a big changeover in recent years. Our new approach to designing urban parks has increased in popularity and there is no doubt that the City will allocate more resources to this type of initiative to keep up with the increasing demand,” added Mr. Haf.
VICTORIA-BY-THE-SEA
Rebuilding the Village’s seawall

By Esther Lambert

Source: Village of Victoria-by-the-Sea Facebook page
THE SCIENCE

Coastal communities across Canada continue to face the threat of sea-level rise and storm surges that place coastlines and developments at risk from flooding and inundation. This trend is expected for most of Atlantic and Pacific Canada and is further exacerbated by a gradual decrease in sea ice, which protects the coastline during storm surges; otherwise, erosion occurs. The combination of a full moon and a high tide accompanied by onshore winds carried by storms constitutes a high risk for coastal flooding and erosion.

Seawalls can help to protect shorelines against coastal erosion and other processes, such as weathering and sediment transportation; however, their effectiveness is heightened when implemented together with other soft engineering approaches (example, wave-breaking reefs and sea hives) and green infrastructure. It is important to consider the types of materials and engineering design while taking other mitigating actions when planning to build or rebuild seawalls.

THE TRIGGER

Located along the south shore of Prince Edward Island between the larger communities of Charlottetown and Summerside, the Village of Victoria-by-the-Sea is a small community with a year-round population of 120, reaching the thousands in the summer months. Its economy is sustained by farming, fishing, and tourism. Being sheltered and located strategically, Victoria’s harbour was an important seaport from the late 1800s to the early 1900s, trading with the West Indies, Europe, and ports along the east coast.

The community’s aging cement seawall dated back to the 1960s. After the Lobster Hatchery Research Facility ended operations, there was no maintenance of the wall and it began to wash away gradually. Its deterioration continued as the community started to face sea-level rise, more intense and frequent winter storms, and extensive flooding along the coast during storm surges. During these storms, the water on the wharf is usually knee-deep. Residents’ basements along Water Street, as well as restaurants and businesses along the wharf, frequently get flooded. The lowest lift pump is about 40 feet from the ocean and, if breached, there would be a serious sewage problem. In addition to the above-mentioned issues, boats are also being severely damaged when flooding extends over the wharf. Lastly, pack ice has been decreasing, resulting in less protection for the coastline and nearby structures. The community knew there was a problem, given the history of extensive flooding, and actions needed to be taken to better protect the municipality and its residents.

THE APPROACH

Rebuilding the seawall using large granite boulders required collaboration from local, provincial, and federal levels of government, as well as the private sector and civil society over many years. It took approximately 10 years from planning to completion of the project. The municipality discussed and planned replacement of the wall for years before taking action. This included identifying funding, as Victoria-by-the-Sea was
unable to cover the entire cost of this large rehabilitation initiative. All jurisdictions provided funding and a private company imported the granite boulders from the mainland and lined them along the seawall. Some of the major actors included the local harbour authority, Emergency Measures Organization, and the Department of Fisheries and Oceans. The Village hired consulting engineers to design the new seawall, who looked at floodplain and sea-level rise maps to understand current and future risk. (UPEI Climate log has a tool that is used to visualize sea-level rise.) They also looked at sea-level rise analysis.

In planning this reconstruction, Victoria acknowledged that it would not solve all its coastal erosion and flooding problems, but it would be one step towards progressively adapting and attempting to stop further damage by using more resistant material in reconstruction.

As with other multi-jurisdictional infrastructure projects, there were a number of challenges. For instance, the Village had to buy privately owned land on the waterfront to complete the replacement of the seawall.

**THE OUTCOME**

Victoria’s shoreline is now better protected, which also provides some protection for homes and businesses on and near the coastline. The concrete wall has been replaced with a permeable granite boulder seawall. Having a stronger, more reliable seawall has given the community time to address other ongoing issues, such as water mains and septic tanks behind the seawall. The collaboration process has inspired conversations about how to adapt to long-term sea-level rise. For instance, there is some dialogue about whether developments may need to be relocated away from the shoreline or rebuilt on stilts. The community was also inspired to invest more time in forging
partnerships with organizations working in the area of climate and adaptation who can be long-term project partners. The Village formed a partnership with the University of Prince Edward Island Climate Lab to install a weather station on the wharf. Wind speed, temperature, and barometric pressure are recorded. The station also has a tide gauge. These readings add to ongoing data collection and help to identify climate trends.

A WORD FROM VICTORIA-BY-THE-SEA

Eric Gilbert, Municipal Councillor for Victoria-by-the-Sea, explained that planning and executing a project of this size has taught this small community about the process of getting large-scale rehabilitation initiatives done. He also emphasized that it has been a great learning experience about the process of interacting with different levels of government. He looks forward to working with other municipalities and organizations on pilot projects and highlighted the importance of forming strong partnerships so that the voice of smaller communities can be amplified. His advice to other small communities is to start taking action immediately, even if all resources have not been identified, as these projects take time. “These projects will likely take a long time, will be expensive and possibly unpopular with part of the population, but the key to success is to partner with other organizations facing similar issues and to start building relationships and having conversations with universities, not-for-profits, environmental groups, and other levels of government,” he said. He added that building relationships can help to build capacity through the sharing of information and resources.

Nevertheless, Mr. Gilbert reminded other communities that their small size also makes it relatively easy to identify all vulnerable groups and to assess the major climate risks. It also forces the municipality to use its limited resources efficiently.
TORONTO
Finch Avenue culvert reconstruction

By Esther Lambert
The City of Toronto learned a great deal about the importance of building infrastructure with future climate and weather in mind after the collapse of its Finch Avenue culvert following a few hours of intense rainfall in 2005. A reconstruction plan was developed that incorporated design changes backed by best practice and a culvert management system, which are helping to reduce the risk of flood damage and recovery costs for residents, businesses, and the environment.

As an essential component of municipal drainage systems, culverts serve the dual purpose of conveying water under a road and providing a crossing path for various vehicles, pedestrians, and cyclists. The Finch Avenue culvert, originally built with a corrugated steel pipe (CSP), was reconstructed with reinforced concrete pipes (RCPs) as RCP culverts are less prone to catastrophic failure. With an expected service life of 75 to 100 years, RCPs experience a more gradual failure, allowing sufficient time for repair before any sudden calamitous failure. They are a recommended option for many Canadian towns and cities, like Toronto, that are expecting an increase in extreme rainfall.

The Finch Avenue culvert collapse was caused by an extreme rainfall event on August 19, 2005, that brought a significant amount of rain over a short period of time. The existing corrugated steel culvert was undermined by water and debris accumulating behind it. Debris from the upstream stretch of Black Creek gathered downstream and blocked the culvert, resulting in a buildup of pressure and its eventual breach and collapse.

Reconstruction of the culvert and associated infrastructure cost the City millions of dollars and led to a road closure at Finch Avenue for over a year. This contributed to gridlock and added to congestion. The full extent of social and financial impacts to residents and businesses on adjacent routes were inestimable. The City’s bridge management group recommended the replacement of the steel pipe with a concrete one.

The reconstruction process was guided by three main elements. First, following consultations with the Toronto and Region Conservation Authority, the City of Toronto’s Engineering and Construction Services Division prioritized resiliency in the new culvert design, and conducted research to determine best practice. It decided on the more costly yet more climate-resilient concrete option. Second, the City changed design standards to reflect projected climate changes. The culvert was built to withstand 100-year storms as opposed to 50-year storms, which was the former standard. As such, one of the major considerations was the hydraulic capacity of the infrastructure for larger storm events. The chosen design also included additional features like spillways to allow water to vacate the road if over-topping occurred. Finally, during the time of the culvert collapse, the City’s Environment and Energy
Division was developing its climate change strategy, and there was a push to support climate change in asset management, which served as additional support for the climate-smart culvert design.

**THE OUTCOME**

The Finch Avenue culvert collapse and subsequent reconstruction brought to light some deficiencies within the City’s culvert design and management system and inspired key changes. Culverts were designed for 50-year storms, while current climate science supports design for 100-year storms. The new culvert takes that into consideration. Prior to the collapse, there was an absence of a comprehensive inspection system for culverts to include standardized procedures and inspections. To address this, after each major rainfall event, operations and maintenance personnel are dispatched to all the major culverts to inspect and to communicate the findings, as well as to address any deficiencies requiring immediate attention. In addition, the Transportation Services Division also developed an inventory management system for its many smaller culverts that are under three metres in width. Each culvert was rated, which allowed the development of a multi-year funding plan for inspections and rehabilitation. This system has helped prevent or avoid culvert failures, flooding, and potential losses.

*Figure 12: The Finch Avenue culvert collapse was caused by an extreme rainfall event on August 19, 2005, that brought a significant amount of rain over a short period of time. (Source: City of Toronto)*
The new system of operating has also opened lines of communication with other City departments such as the Parks, Forestry and Recreation Division responsible for maintaining vegetation of embankments, and the Toronto and Region Conservation Authority that does periodic inspections around the rivers. Internal training of staff on what to look for when inspecting culverts was also a major outcome. Furthermore, the need for a vulnerability assessment was recognized and the PIEVC protocol was applied to key culverts across the city, which revealed that many were underdesigned.

One of the major challenges faced by the City in implementing its approach to culvert rehabilitation and management had been in convincing Council of the devastating impacts that climate change can have on infrastructure and the need for an increase in budgets to address those challenges. Each City division considered their assets and how they were being impacted by climate change. This information was brought to Council who then recognized the importance of integrating resilience in all capital and maintenance plans for all City infrastructure, which allowed divisions to secure additional funding to upgrade their assets.

A WORD FROM TORONTO

Mr. Nazzareno Capano, Manager of Transportation Policy & Innovation in the Transportation Services Division, highly recommends that cities and communities assess the vulnerability of their infrastructure. He stated, “I would suggest undertaking climate change vulnerability assessments for major pieces of infrastructure as it will help identify potential risks and guide the development of programs and procedures to mitigate the future impacts of climate change.” With its ‘no-regrets’ approach to managing infrastructure, Toronto seems to be one of the leaders in that regard. Mr. Capano stressed the importance of putting in place whatever is needed now to prevent adverse impacts of climate change in the future, by first establishing where the priority is and by working with local conservation authorities for support. He also highlighted the need to get the support of Council by presenting a case for taking actions that will enhance the climate resilience of municipal infrastructure.
TROIS-RIVIÈRES

Governing with future risks in mind: ensuring the long-term supply of drinking water

By Sophie Guilbault
THE SCIENCE

While many public infrastructure operate independently, several are part of a broader system that needs to be considered as a whole to further understand future risks and vulnerabilities faced by a specific asset. When looking at critical infrastructure such as municipal drinking water infrastructure system, proper operation and long-term planning of the assets is key to avoid future severe disruptions. The framework presented in the PIEVC protocol is one of the methodologies that can be used by municipalities when looking at both independent infrastructure and systems composed of various assets. A deeper understanding of best practices to rehabilitate, maintain and invest in infrastructure also allows communities to integrate specific interventions within their long-term climate adaptation plans and policies.

THE TRIGGER

As the City of Trois-Rivières was planning the rehabilitation of its drinking water treatment plant to increase its capacity, the municipality started questioning whether or not it should maintain all of its drinking water supply sources. To answer that question, a deeper analysis of the drinking water supply and distribution system was instrumental to further understand the vulnerability to climate change faced by various components of the system such as treatment plants, aqueduct network, wells and water intake. Trois-Rivières decided to rely on the PIEVC protocol to better understand risks and vulnerabilities faced by the drinking water system and improve design and operation in the management of sudden and prolonged climatic events in the future.

The study conducted with the PIEVC protocol aligned with the sustainable development policies adopted by the municipality in March 2009, which has set the objectives to adapt to climate change and ensure the supply of quality drinking water for the current and future population as priorities.

THE APPROACH

The City of Trois-Rivières undertook the PIEVC assessment with the support of Ouranos and consulting firm WSP (known then as Genivar). At the time of the study, the City of Trois-Rivières was getting its raw drinking water from surface reservoirs as well as 57 groundwater wells. The water treatment plant that was collecting water from the Saint-Maurice river was about to be rehabilitated to increase its capacity to better serve the City and neighboring communities, with plans to have sufficient capacity to support 175,000 people (the area deserved by the reservoir currently counts 140,000 people).

In an effort to better understand how changing climate conditions would affect the drinking water system in Trois-Rivières and consequently, how the network should be approached and maintained in years to come, the project team identified a list of climate variables and infrastructure assets to be considered in the analysis. They worked alongside several municipal departments including water, engineering, environment, and land use planning in addition to technical staff that operating the
various infrastructure assets. Climate variables included variations in temperature, freeze/thaw cycles, ice storms, snow accumulations, severe winds, droughts and many others. The projected climate conditions prepared by Ouranos were then considered for each infrastructure asset involved in the analysis to understand what were the various vulnerabilities and risks on both individual assets and the system as a whole. The analysis was centered around the water demand and its evolution in usage over time, the quantity of water available at various sources, the quality of the water collected and methods to be used for water treatment.

One of the key findings of the PIEVC analysis was that several hydraulic infrastructure elements such as wells, reservoirs, water treatment systems and water intake were more sensitive to climate change, particularly under conditions such as high temperatures, periods of drought and heavy rains. With projected increase in extremely hot days, the rehabilitation of underground reservoirs was identified as a one of the key priorities for the City of Trois-Rivières.

THE OUTCOME

The recommendations coming out of the PIEVC analysis were able to guide the political decision-making process and the City decided to maintain underground water supply and rehabilitate its underground reservoirs. The analysis demonstrated

Figure 13: Residents of Trois-Rivières were invited to visit the new water treatment plant after its rehabilitation. (Source: City of Trois-Rivières)
that maintaining higher flexibility in water supply sources would be a great way to plan for future climate conditions and ensure access to drinking water if the St-Maurice River was not able to provide enough in the future. Since the publication of the PIEVC report, all reservoirs have been upgraded and the water treatment plant has been fully rehabilitated.

Rehabilitating water supply and treatment infrastructure is often very costly for municipalities. In Trois-Rivières, these investments were easier to justify given the pre-established plans that identified the preservation of drinking water supply and adaptation to current and future climate risks as priorities. The PIEVC protocol allowed the community to prioritize interventions to achieve the most impactful outcomes. In addition to the strong governance in place, municipal staff led several information campaigns, which included television and radio commercials as well as adds shared in various other media to ensure that residents were aware of the reasons behind the work that was taking place. This was particularly helpful during the rehabilitation of the water treatment plant when residents were asked to reduce their water usage at specific times.

A WORD FROM TROIS-RIVIÈRES

When asked what he would recommend to other municipalities looking at implementing a similar initiative in their communities, Julien St-Laurent, Head of the Environmental Department with the City of Trois-Rivières, highlighted the importance of strong multi-disciplinary collaboration within municipal departments as well as strong outreach and engagement strategies with the population. “In Trois-Rivières, we have ensured complete transparency with the population through the rehabilitation process to appease residents. This was instrumental in getting buy in from the community and get residents’ collaboration when reaching important milestones of the project”, said Mr. St-Laurent. Having a clear strategy in place and support from Council to invest in the drinking water system over an 8-year period was also key in ensuring the sustainable future of water supply in the City and its neighbouring communities.
INVESTING IN DISASTER RISK REDUCTION

Investing in disaster risk reduction: Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment.

Source: UNDRR - SENDAI Framework for Disaster Risk Reduction
OTTAWA
Graham Creek Stormwater Infrastructure Upgrades

By Esther Lambert

Source: City of Ottawa
THE SCIENCE

Stormwater infrastructure, such as culverts and storm sewer structures, slow the flow of water to reduce the risk of flooding during extreme rain events and act as a purification system to prevent contaminated water from entering waterways. Investing in upgrades to individual municipal infrastructure, especially aging ones, is important to ensure long-term performance. Also important is the value in understanding infrastructure vulnerability of multiple assets simultaneously and acting with entire systems in mind. Vulnerability assessment tools such as the PIEVC protocol, while they can be used to assess the climate vulnerability of individual types of infrastructure, can also be used to achieve a system-wide approach to asset management that requires multiple other actions alongside the protocol. The Graham Creek stormwater infrastructure upgrades were pursued within this systems-focused approach.

THE TRIGGER

Ottawa’s Graham Creek stormwater infrastructure includes a number of stormwater management structures along Graham Creek’s old alignment from West Hunt Club Road to the Ottawa River. Graham Creek traverses a mature, multi-component system through residential and specially designated areas and parks. Faced with infrastructural issues, such as the need to improve catch basins and neighbourhood drainage throughout the city, the City decided to understand asset vulnerability and to build staff capacity in implementing the PIEVC protocol within the existing asset management structure. Coincidentally, the Graham Creek Infrastructure project presented an opportunity to apply the PIEVC protocol to a specific project while applying it system-wide and taking other important actions such as developing climate projections and city-wide flood risk profiles and understanding how to implement upgrades. Approximately 530 m of culvert and other storm sewer structures were included in the Graham Creek stormwater infrastructure PIEVC assessment.

THE APPROACH

Prior to the Graham Creek PIEVC assessment and recommendations of 2017, the City of Ottawa had already implemented some of the recommended actions stated in the report. For decades, the City has been taking actions to understand its climate risk profile for buildings and sewers, so the PIEVC protocol was seen as a useful tool to add to their toolbox. The PIEVC protocol used alongside other risk analysis actions is meant to not only gain a deeper understanding of city-wide risks but to also become more proactive and adaptive in dealing with specific risks.

Some of the major PIEVC recommendations implemented for the Graham Creek stormwater infrastructure project were the installation of headwalls on the inlets of existing Graham Creek stormwater infrastructure, which are corrugated steel pipe culverts to improve their structural integrity and also minimize the risk of structural deformation and collapse while surcharged, and the installation of wingwalls at the inlets of the culverts to increase their hydraulic capacity. Trash racks were placed apart from the inlet of culverts to ensure that they do not reduce the ultimate hydraulic design capacity of the culverts. Culvert design changes considered, not only hydraulic
capacity, but also resiliency measures. For instance, the City based the design on “when” a design event is exceeded rather than “if” a design event is exceeded. The design capacity includes full functionality to the end of service life. Actions were also taken to consider operations and ongoing inspection and maintenance during design. Flexibility was incorporated into the design to enable upgrades before the end of service life, should the climate change assumptions and design parameters prove to be insufficient.

The City has had to make the transition from PIEVC design of standalone projects to PIEVC asset management by making some changes to the normal PIEVC matrix. It carried out hydraulic analyses, which is not strictly required by the PIEVC protocol. Multiple scenarios were simulated, which included stress tests much higher than the City’s standard stress test.

THE OUTCOME

The City is currently applying the lessons from the Graham Creek project to the current update of its sewer design guidelines, which will now include a culvert design guideline. After the Graham Creek project was completed, the City wrote up a report presenting guidance on how to apply the PIEVC protocol to entire systems. This new process includes the use of GIS and other high-level tools to screen out all culverts for various risk factors identified in the PIEVC assessment in order to create a table of risk factors. The municipality’s current plans are to apply this process 

Figure 14: Approximately 530 m of culvert and other storm sewer structures were included in the Graham Creek Storm Infrastructure PIEVC assessment. (Source: City of Ottawa)
city-wide. In the case of Ottawa, the use of the PIEVC will allow the City to make high-level decisions on priority infrastructure investments.

**A WORD FROM OTTAWA**

When asked about the usefulness of the PIEVC protocol and its ability to assist municipalities in understanding the vulnerability of their infrastructure, Hiran Sandanayake, senior engineer in the Department of Water Resources for the City of Ottawa, indicated that the PIEVC protocol can be successfully used beyond individual projects. “Applying PIEVC for a specific project at a specific time is just a piece of the bigger picture,” he said. Mr. Sandanayake appealed to municipalities to incorporate the PIEVC for a long-term approach to asset management. He mentioned that in Ottawa’s case, the PIEVC process is helping to corroborate and validate findings from other assessments and adaptation actions. The importance of revisiting adaptation actions as risks change and viewing the process as iterative was also highlighted. As Mr. Sandanayake continued to explain, “I will find the PIEVC process a success if, 10 years from now, I look back and see how we’ve been able to change and grow as new information becomes available.”
TUKTUUYAQTTUUQ
Road raising erosion mitigation project

By Esther Lambert
THE SCIENCE

Road raising may be part of an adaptation and resilience strategy in response to sea-level rise and coastal erosion for coastal communities across the country. Climate- and environment-related factors posing a threat to coastal communities include an increase in the duration of open-water season from June to September and May to October/November over the past 20 years. This has been attributed to higher temperatures over longer seasonal durations, resulting in coastline exposure to a higher frequency of storm surges and increased coastal erosion. Road raising, coupled with other regular, costly and logistically challenging maintenance of gravel roads and highways that are close to the coastline, may form part of a coastal erosion protection approach.

THE TRIGGER

Located on the shores of the Arctic Ocean east of the Mackenzie Delta, Tuktuyaqtuuq is an Inuvialuit Hamlet with a population of approximately 1,026 (2017) and accessible via the Inuvik Tuktuyaqtuuq Highway completed in 2017. Warmer temperatures have led to a doubling in the frequency of summer storms during open-water season from one to two per summer to three to four, combined with a change in the level of storm surge from 1.7 to 1.9 m. As such, the rate of erosion has increased from 1.8 to 2.5 m per year. Increased erosion has exposed the permafrost, leading to increased extent and depth of degradation, which undermines houses and roads located adjacent to the shoreline. Community consultations also brought to light these effects on the community and the huge economic impact of rehabilitation.

Although no formal risk assessment was undertaken the Modelling for Coastal Erosion report, completed for the community in 2018-19, documented current impacts and provided scenarios for erosion and permafrost degradation over the next 30 years, taking future climate into consideration. Adding to the scientific rationale behind taking risk reduction action, more than 10 local studies were conducted by universities and federal government departments. These examined a range of issues from measuring and characterizing permafrost depth, distribution of erosion, and historical trends, which contributed to the scientific evidence required in funding applications. A key trigger was the availability of funding from the Government of Northwest Territories and the federal government (Disaster Mitigation and Adaptation Fund – DMAF) coupled with successful proposals that have secured $12 million for the road raising project.

THE APPROACH

The Hamlet held community consultations to discuss the results of the Erosion Modelling Study and application of its recommendations. The policies of the Disaster Mitigation and Adaptation Fund program guided eligibility, implementation, and use of funds. Scientific experts and the consultants that completed the Modelling for Coastal Erosion report attended these meetings. In addition to the road raising project, more than 15 houses have been moved in response to erosion near the shoreline, funded
in part by the Government of the Northwest Territories.

From a technical standpoint, Tuktuuyaqtuuq is using a riprap design to cover the sides of the elevated roadway, which virtually eliminates erosion and protects the permafrost. Ground insulation is used to prevent moisture propagation and to separate the permafrost foundation from the gravel cover.

The Hamlet is managing to implement this project, but not without challenges. For example, road raising requires the installation of much larger (36 to 48 inch) culverts that require road transport (air transport is prohibitive) via the Yukon using ice roads on sections of the route that are available for a limited time. Hence, the timing of intended works is critical for materials supply and must inform planning. Planning and construction must consider longer timeframes for supply of materials and labour since the construction season is limited.

As with other northern communities, the Hamlet does not have engineers or planners on staff, so there is a reliance on other levels of government and consultants to provide guidance and funding for engineering and planning services. Furthermore, only two to three firms provide erosion mitigation services, hence impacting schedule and costs. The cost of travel and accommodation for trades people who must be flown in for a short construction season (two to three months) each year means that
high productivity during the construction period is crucial to ensure progress and completion of projects. The COVID-19 pandemic has resulted in an added layer of complexity as contractors are not as available as before. Overcoming these issues has required extensive logistics, supply, and personnel planning over multiple years and a commitment to include the community in decision-making.

THE OUTCOME

The road raising project is ongoing. About a third of the funding has been spent ($4 million out of $12 million total) to date. Improvement in road performance has been achieved and, in combination with diligent maintenance and related response to climate-related events, is helping to assure the continued viability of the roadway and its vital contribution to the community in its present location from the current and projected threat of sea-level rise and storm surges. In addition, there are now reduced maintenance and repair costs for the completed sections of the elevated road through reduced erosion and lower occurrence of other processes such as frost heave and pothole formation.

Local residents have greater awareness and support for the necessity of the adaptation measures and there has been strong collaboration with territorial and federal government departments for funding, staff, and expertise (both science- and engineering-related). Additionally, there is now a wider recognition of the challenges of implementing adaptation, including longer timelines, increased costs, and logistical challenges, which have helped to convince funding agencies to relax timelines and flow of funding from original plans.

A WORD FROM TUKTUUYAQTUUQ

Amidst the growing social and economic challenges faced by northern communities – challenges made increasingly more difficult by the COVID-19 pandemic and the changing climate – Shawn Stuckey, Senior Administrative Officer for Tuktuuyaqtuuq, believes that indigenous communities can still secure some success in protecting their infrastructure against climate change. He recommended a three-pronged approach that consists of securing funding, sourcing the right expertise, and ensuring planning that includes public engagement. He urged communities to seek scientific expertise and experience from fellow northern communities, territorial and federal government departments, especially Natural Resources Canada and the National Research Council, stating that this advice can often be obtained at no direct cost. He also encouraged, “Engaging university research programs to understand the science behind the problems now and those expected with future climate change and securing funding from federal programs such as the DMAF.”
MISSISSAUGA
Central Parkway low impact development (LID) project

By Darrel Kwong

Source: City of Mississauga
THE SCIENCE

The design and construction decisions behind Canada’s aging public infrastructure were based on climate trends that have now changed. In the past, the lack of government mandate to integrate climate resilience into infrastructure planning might have been attributed to insufficient climate science data; however, this is changing as asset management is becoming more of a necessity. Today, climate change has placed more strain on aging water, wastewater, and stormwater infrastructure in Ontario, resulting in extreme flooding. The City of Mississauga, located in the Golden Horseshoe region, is investing in low impact development (LID) projects to upgrade their stormwater infrastructure – actions consistent with their Climate Change Action Plan (CCAP). The Central Parkway LID road retrofit is a successful example of this. The City, in partnership with DeepRoot, TD Friends of the Environment Foundation, and Credit Valley Conservation (CVC), installed a bioretention system within the existing road median.

At the project site, Central Parkway had a paved concrete median, which would discharge stormwater flow directly into the storm sewer system. Through the modification of existing catch basins, runoff from the road is now directed to a bioretention system that incorporates Silva Cell technology for water quality and quantity treatment. The trees, shrubs, and bioretention soil within the system filter out nutrients and pollutants (e.g., total suspended solids, phosphorus, and nitrogen) as the water moves through the soil profile beneath the median surface. The vegetation and biomedia also retain and infiltrate some stormwater into the surrounding soil, thereby reducing the amount of stormwater entering municipal storm sewers within the Cooksville Creek Watershed and reducing peak flow levels in nearby catchment areas.

THE TRIGGER

The City of Mississauga’s Stormwater Program is focused on improving existing municipal stormwater infrastructure and enhancing stormwater management wherever effective and feasible. The Stormwater Assets and Programming Department is primarily funded through Stormwater Charge revenue. Stormwater projects, among others, support and are in alignment with the City’s CCAP as they build resiliency with green infrastructure and provide opportunities for better asset management – both identified actions in the CCAP. It was against this backdrop that a City Council resolution was passed in 2014, which paved the way for LIDs to be integrated with other projects in the City, such as the road rehabilitation program. The City also received a grant from TD Green Streets for implementing green infrastructure at Central Parkway.

THE APPROACH

LIDs have been formalized as a viable option to support the City’s stormwater management goals. Every year, the City reviews city-wide infrastructure projects for opportunities to integrate LID features. In undertaking LID projects, internal and external stakeholders are taken into consideration so that there is coordination with
planned construction projects.

The Central Parkway LID was retrofitted into existing infrastructure, which required the City to be creative and flexible with design, techniques, and solutions, and to think beyond traditional engineering design. A partnership was formed with CVC, which provided design and construction assistance and conducted performance monitoring and maintenance inspections.

Other project partners and stakeholders included municipal decision-makers, provincial and federal environmental agencies, engineering and planning professionals, academia, and watershed advocate groups. City staff managing the project collected input from other departments to include Parks & Forestry (in the initial stages of the design process), to receive recommendations on types of vegetation and soil most suitable for the median, and the Works Operations Department for facility maintenance over its lifecycle.

THE OUTCOME

The Central Parkway LID project has resulted in substantial water quality and quantity benefits. For instance, there was a 98% reduction in total suspended solids and a 94% reduction in total phosphorous in the treated stormwater from 2015 to
2017. Of the 115 monitored events, 31 produced outflow that resulted in a 95% total volume reduction of stormwater entering the municipal storm sewer system. The average peak flow reduction for all events was 97%. This project demonstrates how innovation can play a key role in driving climate resilience of infrastructure. The Silva Cell system had been specifically used for stormwater treatment for the first time in Mississauga. Additional benefits include encouraging tree growth and aesthetic design.

These results have been showcased through presentations, events, and site tours, helping educate numerous stakeholders on the benefits of LIDs. The great successes have led stormwater staff to continue to seek implementation of LIDs in other projects. The City’s partnership with CVC continues through monitoring LID performance to demonstrate the benefits to sub-watersheds within their jurisdiction.

Their partnership with CVC will persist to ensure the well-being of watersheds within their jurisdiction.

**A WORD FROM MISSISSAUGA**

Implementing LIDs requires various City departments and stakeholders to be on the same page. To ensure everyone has the same goal and a good understanding of the LIDs, Zain Zia, Storm Drainage Coordinator at the City of Mississauga, emphasized the importance of engaging colleagues in the planning stage. This initial conversation helps ensure all stakeholders are satisfied with what is being built, how it will function, and how it will be maintained. Scott Perry, Manager of the Stormwater Assets and Programming team at the City, stressed the need for champions who support these types of facilities. LID projects are integrated into the streetscape, requiring a collaborative approach with multiple stakeholders involved. As Mr. Perry remarked, “We need people to bring up creative solutions incorporated with a holistic approach. Without these champions, especially on the stormwater side, it would be a challenge.”

Mr. Perry also stressed the importance of the City’s Stormwater Assets and Programming Department in spearheading LID projects. He said, “Asset management is about who owns what and who’s responsible to maintain it. In the stormwater group, we’re taking ownership of these assets, we’re maintaining them, we’re paying for it, and we’re integrating it with the rest of our colleagues and partners in the right-of-way and we’re lucky to have a stormwater charge to support it.”
WELLAND
Improving the climate resilience of the city’s municipal stormwater system

By Esther Lambert

Source: City of Welland
THE SCIENCE

Projected changes in the frequency and severity of extreme storms in Ontario are expected to harm the province’s natural and built infrastructure. These impacts could have significant economic consequences unless the region’s infrastructure resilience improves. The City of Welland, 20 km west of Buffalo NY and home to a growing population of more than 50,000 residents, began incorporating climate resilience into municipal infrastructure planning with a 2012 study of the City’s storm and wastewater systems. Of special concern was Welland’s outdated combined sewer systems that conveyed both storm and wastewater through the same pipe. These systems were built in the early 1900s, with an initial planned lifespan of 50 to 100 years. Separate stormwater and sanitary systems have been municipal best practice for more than 60 years; nevertheless, many communities across Canada continue to operate and maintain old combined systems.

Increasing frequency and severity of extreme rainfall events due to climate change render such systems more vulnerable to combined sewer overflows as the wastewater volumes exceed the capacity of treatment plants. Combined sewer overflows, which often occur during extreme rainfall events, result in the release of partially treated sewage into streams and lakes. Moreover, extreme rainfall can overwhelm these systems resulting in untreated water backing up and flooding basements. This pollution seriously concerns municipalities and provinces. The Region of Niagara, like many other jurisdictions, no longer constructs combined sewers. Cities within the region like Welland have been working on upgrading wastewater treatment facilities, separating combined systems, and upgrading older sewer pipes and pumping stations, but this takes time and funds.

THE TRIGGER

Welland’s decision to improve its storm and wastewater infrastructure evolved over time. The City has been increasingly incorporating climate change into infrastructure policy and planning. Two major motivations accelerated its resilience efforts. First, in 2005, the remnants of Hurricane Katrina passed over southern Ontario, dropping 102 mm and 93.4 mm of rainfall at the Port Colborne and Welland weather stations, respectively, causing widespread basement flooding, particularly in areas with combined sewers.

Second, in 2011 and 2012, Welland conducted a Public Infrastructure Engineering Vulnerability Committee (PIEVC) assessment, which confirmed medium risk for infrastructure considering climate projections. The PIEVC analysts recommended updating Welland’s Intensity, Duration and Frequency curves (developed from 1963-era Buffalo, NY, weather) so stormwater management efforts reflect current climate for long-term planning. Welland began to work with the region to enhance its infrastructure’s climate resilience in several ways.
THE APPROACH

Welland considered its storm and wastewater systems in parallel and together. It sought to prioritize projects and initiatives that would enhance system resilience. After receiving the PIEVC report, the City decided to focus on the stormwater system. Looking at all infrastructure at once would have been overwhelming. Having so many neighbourhoods served by combined sewers presented challenges. Because the region is responsible for wastewater treatment and the City manages the collection of treated water, both the municipal and regional levels of government played a crucial role.

Storm design standards and Intensity, Duration and Frequency curves were updated. Developers were encouraged to incorporate a five-year, instead of the previous two-year, design standard by using curves updated to 2050. The likelihood of increased costs with the new design requests provoked developer resistance. Voluntary design standards were deemed unlikely to help. The City also invested in pilot studies such as the Dain City Flood Risk Assessment Study of 400-500 homes. These studies promoted infrastructure planning that considered impacts of future climate and looked beyond specific local areas. They were meant to alert developers to a bigger problem that would require implementing design features to help the broader community. Lastly, educating and engaging asset managers in climate-focused planning proved to be an effective approach that factored in logistical and operational issues crucial to infrastructure planning.
THE OUTCOME

The initial groundwork laid out in the approach set the stage for two major successes. First, Welland was successful in securing $12 million for a sewer separation project, including $8 million from provincial and federal governments. Phase four of that project was scheduled for completion in 2021 to considerably improve the 80-year-old infrastructure in much of the city. Further, every year, the City cost-shares with the Region to undertake sewer separation works.

Second, implementation efforts were scaled up through the development of plans such as the Corporate Climate Change Adaptation Plan and the Asset Management Plan, which provide strategic guidance. These also urge Council and asset managers to consider climate change in their plans. A recent update to Welland’s Asset Management Plan includes climate change considerations for inventory of all assets. Work already done on climate change risk will feed into that updated plan.

A WORD FROM WELLAND

The City’s success in implementing the PIEVC protocol recommendations, as well as other risk-reduction actions, is partly attributable to its ability to engage a wide cross-section of stakeholders to include consultants, representatives from the Region, academics, asset operators, and other experts to rally around particular policy, plans, and programs in support of more resilient public infrastructure. Marvin Ingebrigtsen, former Infrastructure Asset Manager for the City of Welland, mentioned the importance of Council support, indicating that one way to garner its support is to emphasize that many funding entities like the federal government require the incorporation of climate change considerations as a precondition for funding.

Of particular importance was the presence of a champion who had the passion for understanding the risks posed by climate change. Mr. Ingebrigtsen advocated for changes and initiatives informed by climate science. Also, leveraging the interest created by an extreme weather event to ensure those changes are realized was crucial. As indicated by Mr. Ingebrigtsen, “In 2018, we had a rain-on-snow event that resulted in a 100-year storm runoff event in the Dain City area and 30 basements were flooded. This helped to garner complete support from Council for the Dain City Flood Risk Study.”
RURAL MUNICIPALITY OF TORCH RIVER NO. 488
Investing in the rehabilitation of the 6th Mile Bridge

By Esther Lambert
THE SCIENCE

According to Canada’s Changing Climate Report, increases in winter and spring flows have been observed over the last several decades, placing bridges and other infrastructure at risk for flooding. Many rural bridges in Saskatchewan and across Canada are in bad structural condition and either are or will soon be under load restrictions. The repair or construction of rural bridges can pose many challenges to rural municipalities due to unfavourable weather, remote locations, and the lack of skilled contractors. Yet, it is a challenge that Torch River No. 488 has taken on as part of the province’s Prairie Resilience: A Made-in-Saskatchewan Climate Change Strategy.

It can take from one to three years to fix any rural bridge under load restriction. Traffic detours of an additional 10 km over a period of time can become a big irritant for community members in addition to increasing the community’s carbon footprint unnecessarily. The replacement of short-span aging bridges, like the 6th Mile Bridge in the Rural Municipality (RM) of Torch River No. 488, with culverts has become a common best practice in rural communities to minimize risks associated with spring flooding.

THE TRIGGER

Located on Township Road 532, the 6th Mile Bridge (6.0 m long and 7.3 m wide) served the tributary of Kelsey Lake situated north of Township Road 532, which channels water year round. The bridge conveyed much of the spring flow, which is expected to increase in the future. While the move to replace this bridge was not linked to a specific severe weather event, its deteriorating condition suggested an inability to withstand future weather and climate changes and necessitated a three-ton load restriction in 2017. As a result, residents and farmers had difficulty hauling their equipment, and carrying gravel from the nearby gravel pit became onerous and involved frequent detours to avoid this location. The lack of access to the bridge also reduced access to a nearby landfill that had to be regularly accessed. Council was also influenced to rehabilitate the 6th Mile Bridge with culverts because of a provincial target to increase the number of culverts that meet its flood standards.

THE APPROACH

Two alternative solutions were considered for the rehabilitation of the 6th Mile Bridge. The first was to repair the timber bridge, to extend its life. The second was to replace the bridge with two 2000 mm diameter culverts and to use financial resources from the Regional Municipality to fund the project. The Rural Municipality had completed a similar bridge replacement project in the past, so there was some knowledge and experience with this kind of project. The proposed size of the culverts was also aligned with the Provincial Climate Resilience Report, which recommended the minimum diameter of culverts on the provincial highway network be 900 mm.

Council held discussions with Councillors, the Reeve, the RM’S Administrator, a shop supervisor, and the project coordinator and decided on the second option. It was
concluded that option 1 would be too time consuming and costly for the size of the bridge and its estimated remaining life. In compliance with the Environmental Protection Act (2010), the Rural Municipality then submitted a Department of Fisheries and Oceans (DFO) review request and the DFO conducted its assessment and approved the commencement of work for the project. An Aquatic Habitat Protection Permit was also obtained from the Water Security Agency.

The Rural Municipality of Torch River’s decision to replace the short-span bridge with culverts was made on the following basis: First, it will remove the load restriction quicker than fixing the bridge, which will redirect the traffic to its original route. Second, Torch River was able to complete the design and permit requirements in-house. Third, the crew was also able to complete the installation by itself instead of tendering out, which saved a considerable amount of time. Fourth, it was a cost-effective and quick solution. Lastly, it ensured minimum disturbance to the creek and natural assets.

Torch River followed the Saskatchewan Ministry of Highways Hydraulic Manual and
Standard Specifications for Rural Municipalities to complete the pre-construction work. Construction of the culvert began in late August of 2019 to avoid the summer floods and after the long heatwaves and timely visits of the conservation officer. This involved the installation of a cofferdam, road closure, culvert installations, and restoration of embankments. The biggest challenge was in isolating the site and installing the cofferdam. Pumps and sand berms were used to install the cofferdam.

THE OUTCOME

The project was completed in 2019. A major outcome of this project is that traffic does not have to detour; and materials and goods can now be transported safely without the risk of failing infrastructure. Because the culvert has been built with expected climate change events in mind, it is now ready to face varying extreme weather and climate conditions such as increased precipitation, elevated lake levels, extreme storms, and other severe conditions.

This project also inspired the development of a strategy to replace the short-span bridges with culverts, which forms part of the community’s resilience measures against the small number of aging bridges. Torch River’s strategy can be adopted by other small rural communities facing similar challenges.

A WORD FROM THE RURAL MUNICIPALITY OF TORCH RIVER NO. 488

Samrat Hussain, Engineer with the Rural Municipality of Torch River stated that a replacement of the bridge with culverts has proven to be the best substitution for short-span bridges across the country. When asked to offer some words of advice to other municipalities facing similar challenges, he said that it is important to inspect all assets routinely. His reasoning for this approach is that it will allow the municipality to identify a list of assets that need attention. In voicing his opinion on the need for municipalities to assume control over projects and full responsibility for the upkeep of their infrastructure, he said, “The municipalities just cannot leave the structure out there to fight with climate without looking after them.” He also suggested incorporating the requirement for inspections and paying close attention to critical infrastructure in the asset management plan.
SECTION 4
BUILDING BACK BETTER IN RECOVERY

Build back better in recovery: The growth of disaster risk means there is a need to strengthen disaster preparedness for response, take action in anticipation of events, and ensure capacities are in place for effective response and recovery at all levels. The recovery, rehabilitation and reconstruction phase is a critical opportunity to build back better, including through integrating disaster risk reduction into development measures.

Source: UNDRR- SENDAI Framework for Disaster Risk Reduction

Source: City of St John’s
**ST JOHN’S**
Rehabilitation of a storm sewer to support current and future precipitation patterns

*By Sophie Guilbault*
THE SCIENCE

Several parts of the country are expected to experience an increase in the frequency and severity of weather extremes – particularly more frequent high-intensity rainfalls – as a result of climate change. This presents a challenge that may be most evident in the design, operations, and maintenance of infrastructure that aims to provide service to the public over a long period of time. As changes in precipitation patterns impact municipal stormwater infrastructure, it is crucial for municipalities to plan for the rehabilitation of storm sewers in a way that accounts for future rainfall projections, in order to reduce costly damage and potential harm to the population.

THE TRIGGER

St John’s is a coastal city that has been impacted by several severe storms including Tropical Storm Gabrielle (2001), Hurricane Igor (2010), and many other large rainfall events that resulted in urban flooding, which highlighted the need to upgrade the existing sewer system. The City prioritized its intervention on Kenmount Road, one of St John’s main commercial streets that connects the eastern and western parts of the community. The existing storm sewer system on Kenmount Road was deteriorating and did not have the capacity to handle severe rainfall events. During those storms, the system would become inundated and storm water would run down the street, flooding buildings and endangering motorists. The replacement of Kenmount Road’s storm sewer was prioritized based on a combination of considerations, including the existing sewer’s diameter that was no longer sufficient to accommodate very large flows, the amount of maintenance that was required as a result of the deterioration of the sewer, and the risk associated with some of the existing corrugated metal pipes that were severely corroded and had caused numerous sinkholes along the road over time.

THE APPROACH

When approaching the design of the new sewer for Kenmount Road, the engineering team made it a priority to plan the new infrastructure in a way that would ensure its performance under future climate conditions. To do this, the team used an XPSWMM model, a proven approach used by engineers and stormwater managers to improve the management of stormwater. The model allows the project engineers to simulate hydrology, hydraulics, and surface flooding for the entire catchment area surrounding the new sewer. This tool models interactions between flood waters and drainage systems for various elements, allowing for a complete understanding of risks and system performance. The information gathered through the modelling allowed the team to decide to plan the design of the new sewer based on a return period of 25 years. The new sewer ranges in size from 200% to 400% greater than the previous pipes that were in place.

Given that the sewer replacement project in St John’s was happening on a high-traffic route, the City planned the replacement process over a four-year period and invested a lot of resources to ensure proper communication with residents and local business owners to minimize the impact of construction on the population. Mark White, Manager of Construction Engineering for the City of St John’s, mentioned “One of
Figure 19: The new sewer ranges in size from 200% to 400% greater than the previous pipes that were in place. *(Source: City of St John’s)*

The biggest challenges was fitting the new storm system in Kenmount Road while maintaining traffic and access to businesses. However, while this was one of the most difficult aspects of the project, it was also one of the biggest successes. Traffic was always top of mind and, with proper planning, communication, and completion of specific tasks outside of peak time, we were able to successfully complete the work with minimal disruption.” The replacement of the Kenmount Road sewer was recently completed and despite a few large rainfall events, the street has been free of flooding.

**THE OUTCOME**

The replacement of the Kenmount Road sewer was a capital project for the City of St John’s that was made possible with contributions from both the provincial and federal government. The City estimated that incorporating future climate projections into the design of the new storm sewer increased initial costs by approximately 15-20%. These initial additional costs were not a concern for the municipality who anticipated that lifecycle savings would outweigh the additional capital cost. This investment also reduced operating and maintenance costs, damage claims, and premature asset replacement for the City. Most importantly, the sewer rehabilitation reduced flooding on Kenmount Road.
and adjacent properties. In addition, the inclusion of future rainfall projections into the design brought peace of mind to the municipality given the low likelihood that there would be any issues associated with this new infrastructure. “This allows us to keep moving forward and to address more of the many other infrastructure needs, rather than knowing that in the short-to-medium term we would have to re-assess the capacity due to changes in precipitation,” said Edmundo Fausto, Sustainability Coordinator, Public Works at the City of St John’s.

A WORD FROM ST JOHN’S

When asked about what advice he would give to other municipalities interested in making large infrastructure investments that incorporate future climate predictions in their design, Mark White highlighted the importance of prioritizing these projects based on the impact and future benefits to the community. “These projects take time and money to realize, and it is essential to understand the various risks and rehabilitation benefits associated with infrastructure replacement. There will never be a shortage of projects and the successful completion of impactful initiatives also means there are less things to worry about in the future,” said Mr. White. He also recommended researching opportunities for cost-shared funding for climate-resilient initiatives given the high cost associated with large projects like the Kenmount Road sewer rehabilitation. Finally, Mr. White and Mr. Fausto emphasized the importance of planning and strong communication from the very beginning of the design process to ensure alignment on priorities and deliverables, and to overcome challenges easily as they arise.
CALGARY
Investing in dam upgrades for future climate conditions

By Esther Lambert

Source: City of Calgary
THE SCIENCE

Dams are a vital type of water infrastructure that can provide multiple services to communities. Among some of their major functions are the provision of reservoirs for potable water, reduction in river flood flows during periods of heavy precipitation, and, in the case of Calgary, they are also part of the recreational landscape that attracts activities such as sailing, rowing, paddling, and cycling. Many dams, like Calgary’s Glenmore Dam built in the 1930s, are approaching the end of their lifecycle and need to be rehabilitated and upgraded so that the services they provide can be sustained for the enjoyment of future generations.

The City’s recent upgrades to the Glenmore Dam were implemented as part of a broader flood and drought resilience strategy. Rigorous scientific (e.g., hydrological) studies were undertaken and comprehensive options analyses were performed to determine an optimal infrastructure solution for water supply, flood protection, and dam safety. The result was that new flood gates were designed to meet these project goals.

THE TRIGGER

The Glenmore Dam and Reservoir, located on the Elbow River in southern Alberta, is a source of safe, reliable drinking water for Calgarians. It was constructed in 1933 as Calgary’s primary source of drinking water. Eighty years later, in 2013, a major flood occurred, which resulted in $2 billion in damages. Although not originally intended for flood resilience, the Glenmore Dam was invaluable during the flood as its operation reduced peak downstream flow by more than 40%. However, flood damage confirmed the need for lifecycle rehabilitation and an opportunity to improve operations to manage the variability of the Elbow River.

Following the flood, the City’s water utility commissioned an extensive review of flood mitigation and resilience options. The dam upgrade project fell on the heels of a significant analysis looking at the variability of the Elbow River and Calgary’s vulnerability to flood and drought. The study included a review of water supply over the next 70 years, which is part of Calgary’s potable water long range plan.

THE APPROACH

While plans for rehabilitation started before the flood, the design process took place between 2017 and 2018. Construction was completed in 2020 and, in 2021, final adjustments were made to the automation systems and control structures. The City secured part of the funding from the Alberta Community Resilience Program that was available for projects addressing flood resilience following the 2013 flood.

To accommodate a changing climate, the City’s approach is to pursue a suite of resilience measures that include upstream flow attenuation, community flood barriers, and flood-resilient land-use policy. Water Services executed the improvements to the Glenmore Dam, and other entities were charged with different measures; for instance, the Water Resources Business Unit commissioned the study that recommended a
suite of resilience measures. New flood gates on the dam crest were recommended to increase its storage volume to complement the function of the Province’s Springbank Off-stream storage reservoir project approved at the time and under construction today.

The operable gates can be raised to increase water supply through the dry winter when flows are low. For flood flows that could happen in the spring, the gates can be carefully raised in a manner that balances holding and releasing floodwaters. Its operation allows the City to respond to a diverse set of extreme weather and flooding events. Recognizing the recreation benefits of the infrastructure, there were also improvements to the pathway over the top of the dam through relocation of water and gas utility lines that allowed for more space for pathway users.

One of the greatest challenges in implementing this project was in developing the operational plan. This was an intricate process that involved operations staff, City experts, the consultant design team, and the contractor to meet high operational standards for the system.

THE OUTCOME

The operable steel gates built on the crest of the dam system double the storage volume available during a flood event. Analyses suggest this reduces the probability
of damage to downstream private and public property by about 50%. Drought vulnerability was also reduced tremendously now that the City has doubled storage capacity to make water available to citizens during periods of drought.

Calgary’s Leader of Watershed Analysis, Mr. Frank Frigo, indicated that the City is better equipped to respond to climate change through diverse resilience measures, operational flexibility, and improved situational intelligence for the Bow and Elbow River basins. The hydrological studies conducted to support this work addressed flood resilience and drought resilience, in addition to identifying design parameters for lifecycle improvements.

Climate change continues to be an important consideration to the City. As more climate studies are completed, Calgary will develop strategies for improved operation for flood and drought conditions. As such, Calgary has forged a partnership with Global Water Futures, providing an opportunity to conduct further analyses to better predict the behaviour of the Elbow River.

**A WORD FROM CALGARY**

The importance of stepping back and taking the time to develop a holistic plan around resilience was a key piece of advice offered by Mr. Frigo. He urged municipalities to identify their priorities early and to start working towards them, as funding or other opportunities may come at any time and communities must be ready. He also reflected on the value of having taken a holistic approach for their flood resilience program, which frustrated some citizens due to increased complexity and time, but ensured key elements were not overlooked. He said “We want to make sure we understand the right suite of things. Until you really have a sense of what the ingredients are for the resilience meal, you can’t buy the right groceries.”

Similar sentiments were echoed by Andrew Forsyth, Planning Engineer with the City. He stated “It can be tempting to take a level of service approach, but it is more prudent to apply a wider and more strategic lens to guide design. Adaptability for current and emerging trends is ever-more important today, and a holistic strategy will best serve citizens through the future.”
SELKIRK
Investing in a state-of-the-art wastewater treatment plant

By Darrel Kwong and Sophie Guilbault

Source: City of Selkirk Facebook page
THE SCIENCE

Public infrastructure that was built decades ago met construction and environmental standards of the past. However, as climate science advances and cities set climate resilience targets, some aging infrastructure no longer meet those targets or comply with new provincial regulations. Several public infrastructure were also designed to accommodate the needs of smaller local populations and must be rehabilitated to accommodate the needs of growing communities. As Canadian municipalities plan the construction or rehabilitation of their infrastructure, considerations for both future risks and needs are essential to ensure long-term performance and the highest possible return on investment. These concepts were at the core of the reflection of the City of Selkirk when the time came to rebuild their wastewater treatment plant (WWTP).

THE TRIGGER

The rehabilitation of Selkirk's wastewater treatment plant was triggered by new provincial regulations regarding the amount of effluent that could be released into Lake Winnipeg. To prevent further nutrification of the lake and resultant algae blooms, the provincial government limited the amount of nitrogen and phosphorus that wastewater treatment plants could release. The old wastewater treatment plant was 40 years old and did not meet these requirements. The City of Selkirk had also set the need to invest in safe and sustainable infrastructure as a priority in its 2014 Strategic Plan.

A complete redesign of the existing plant to meet the new provincial requirements was too costly to be considered by the municipality. However, the City of Selkirk was committed to “future-proof” its infrastructure and decided to work towards the planning, design, and construction of a new plant that would be more efficient, resilient, and could support future population growth.

THE APPROACH

In seeking to address its aging infrastructure and associated risk, the City of Selkirk constructed a new wastewater treatment plant that features a membrane-bioreactor treatment process. With two sets of membrane filtration cartridge units operating in the plant, each capable of handling six million litres of wastewater per day, the new facility can treat 12 million litres of sewage in total every day. This capacity is greater than Selkirk’s current need as it is designed to allow for future expansion with population growth. To increase capacity by 50%, the City will need to add a third cartridge costing about $1 million. The modular design of the plant allows for significant expansion if needed, which could easily accommodate future population growth without completely redesigning the infrastructure.

As part of its greenhouse gas reduction plan, the City has chosen to power its wastewater treatment plant using solar arrays. Furthermore, to avoid the carbon footprint involved in building a large structure, the City built a diversion system that directs large amounts of water to lagoons for temporary retainment during a peak event. Current provincial regulations require effluent to contain no more than
1 mg/L of phosphorus and 15 mg/L of nitrogen. With the wastewater treatment plant’s new technology in place, high-quality effluent is released into the Red River and Lake Winnipeg without increasing the risk of toxic algae blooms.

The need to follow new provincial regulatory requirements prompted Selkirk to hire a panel of experts for advice. Scientists and engineers were consulted to help assess different wastewater treatment options, and the membrane-bioreactor treatment process was selected because of its lower cost and higher effectiveness. To proactively consult with stakeholders, the City organized public hearings, broad community information sessions, reached out to the media, and released updates via social media. There was general acceptance by the public, but most residents were concerned about what the new WWTP would cost. Hence, a water conservation program was introduced to address their concerns. The program educates people about steps they can take to reduce water use in hopes of reducing their costs.

**THE OUTCOME**

In addition, to be more adapted to future needs and risks, one of the greatest achievements of the new WWTP is its contribution to fight climate change. The old plant contributed 60% of greenhouse gas emissions in the city, whereas the new plant...
is an emissions-free building. This can be attributed to the elimination of fossil fuel to power the plant, which uses electric heating and recovered waste heat from the wastewater. It also has the ability to accept solar energy as a power source, making it a significant improvement in a bid to decarbonize the city.

Furthermore, the new plant produces the highest effluent quality possible with today’s modern technology, safeguarding the biodiversity and water quality of the Red River and Lake Winnipeg. Even if provincial regulations were to change again soon, the new infrastructure could meet those requirements with small alterations at minimal cost.

To establish partnerships with academia and the private sector, a Centre of Excellence is included in the WWTP to provide space for innovation. The City is considering repurposing the 40-year-old plant for a wide variety of potential new uses, including possibly a fish farm or hydroponic garden, which could be supplied by Selkirk’s recycled water.

It is also important to note that the recently published climate change adaptation strategy (CCAS) was not in place when the municipality started building the new plant. Climate-sensitive decisions were made by a group of experts within the City who were determined to push for climate action and challenge the general tendency to be risk averse. It was not until 2019 that the City published its CCAS, which helped Selkirk integrate climate change into asset management planning. It has since encouraged policymakers to change their thinking behind how decisions are made and has ensured outcomes that align with climate resilience targets.

**A WORD FROM SELKIRK**

Achieving community resilience will require better decisions over long periods of time – longer than the careers of most senior decision-makers. Duane Nicol, Selkirk’s Chief Administrative Officer, remarked “Policymakers need to think about how to ensure the people after them will be empowered to make better decisions.” He mentioned one way to achieve this target is by modifying existing decision-making frameworks so that they are based on long-term targets and demonstrate the impact of different planning decisions so that appropriate steps can be taken. Additionally, it is essential to think in systems. Decision-making is not one event but a series of dozens or hundreds of asynchronous events that culminate into a conclusion. Changing the rules of those events would change their outcomes and, thus, change the decision. If the current municipal government is reluctant to consider future climate impacts and externalities, a paradigm change is needed. “Changing the pattern of thought in decision-making attracts young, skilled, creative talents. Their new way of thinking helps us improve,” Mr. Nicol said.
SADDLE LAKE CREE NATION
Rethinking road design following spring flooding

By Esther Lambert

Source: Saddle Lake Cree Nation
THE SCIENCE

As flooding and landslides continue to cut off roads and major highways across Canada, Alberta has not been spared. The June 2013 floods highlighted the susceptibility of the province to impacts of intense rainfall and unseasonable snowmelt – an occurrence that resulted in $6 billion in damages. With projected extreme events such as floods, intense storms and droughts, the Prairies are at considerable risk for damage to roads and related infrastructure.

The Saddle Lake Cree Nation located in central Alberta is one community that faces seasonal flooding of the same areas almost every year. Some of these roads were built in the 1970s on black dirt with improper ditching and road structure to include lack of crown, proper compaction, and adequate gravel structure. Rebuilding these roads with climate in mind is helping to build the resilience of the community that relies on these transportation networks for access to essential services such as water treatment and delivery to households. The Nation’s roads are being reconstructed on a properly designed and constructed foundation and at a higher grade for better drainage and stability. New culverts have and will continue to be installed with adequate sizing to handle future storm events that consider climate change impacts.

THE TRIGGER

The design and subsequent iterative reconstruction of the NE2, SW7, and NW2 roads was triggered after an intense spring melt in 2017, which rendered roads impassable, preventing the transportation of water to residents. The roads are flooded nearly every spring and when there isn’t overland flooding, the roads themselves become saturated from spring melt as they have improper drainage (lack of ditching and undersized, damaged, or missing culverts) and road structure (lack of crown, proper compaction, inadequate gravel structure). NE2 Road, in particular becomes so saturated that the road structure fails, which blocks transportation. This represents a huge risk to the Nation as it is the only road that connects the community’s water treatment plant. The Nation declared a state of emergency and worked with Urban Systems Ltd., their civil engineering consultant, to access funding available through Indigenous Services, Canada’s Emergency Management Assistance Program’s non-structural mitigation program (EMAP) all supported by the “Mandatory Enhancements” policy. This funded the design and included some mitigative efforts to address drainage repair works, namely the ditching and raising of the road structures.

THE APPROACH

Saddle Lake has taken a proactive approach to climate resiliency through several projects, including road improvements. Following the state of emergency declaration, the Nation took control. The initial response was to deliver water to households as most of the houses depend on cisterns, which got contaminated by flood waters. Afterwards, the Director of Public Works and climate specialists from Urban Systems established which resiliency projects were worth pursuing, given the needs of the community. Every year, Saddle Lake does a capital investment plan to manage
their assets, so the projects included as part of the plan are prioritized. The project manager with Saddle Lake was able to influence the Council to approve the road improvement projects. The public was also informed and engaged before and during the construction process.

Road improvement works are ongoing. While the rehabilitation efforts funded under the Emergency Management Assistance Program went a long way in keeping NE2 Road accessible all year round, it was evident that more significant improvements were required. Through other climate analysis, it also came to light that the road was at risk of flooding due to rising lake levels from climate change. To fully rehabilitate the road, over $5 million was needed. The Nation spent three years and worked with four different funding groups to gain enough funding to fully implement rehabilitation of the road.

**THE OUTCOME**

The improved road drainage design features are expected to withstand increased projected precipitation of almost 30% in the next 100 years, resulting in a more resilient road infrastructure. Beyond the higher performance achieved by the rehabilitation, the new road will ensure the continuous ability to deliver potable water to residents of Saddle Lake Cree Nation, as well as other critical services.

Figure 22: The improved road drainage design features are expected to withstand increased projected precipitation of almost 30% in the next 100 years, resulting in a more resilient road infrastructure. (Source: Saddle Lake Cree Nation)
The adjustments seek to address the risk of extreme events and the anticipated impact of climate change. The objective was to build a road system that is more resilient and better prepared for extreme hazards.

The full rehabilitation of NE2 Road is occurring in 2022. While the work pursued by Saddle Lake Cree Nation is considered a success story, it is important to highlight that the Nation had to pursue multiple levels of government for funding, demonstrating how significant the barrier to adequate capital dollars can be for First Nations’ communities.

**A WORD FROM SADDLE LAKE CREE NATION**

In responding to the question about useful advice for other communities interested in implementing similar projects, Ken Large, Director of Public Works and Housing for Saddle Lake, raised an important point, that every First Nations community is different and each will have to consider its unique mix of challenges and opportunities. However, many First Nations and other municipalities face some broad issues, including funding scarcity, challenges in convincing the Council to fund specific initiatives, and maintaining long-term support for projects. Commenting that, “It is important to know the budgets and finances and how to keep programs surviving,” Mr. Large underscored the value of identifying funding sources to keep projects going for the long term.

He attributed the Nation’s success with Council to well-developed proposals that secured external funding. Such proposals typically highlight the urgency and need for the project, aligning its goals with that of the funder. Oftentimes, external expertise is required to accomplish this. In the case of Saddle Lake, it was the community that worked with Urban Systems and the First Nations Technical Services Advisory Group Inc.
EDMONTON
Incorporating climate adaptation measures into the Quesnell Bridge design

By Sophie Guilbault

Source: City of Edmonton
THE SCIENCE

Infrastructure assets across Canada are aging and strained due in part to population growth and the expansion of our communities. Beyond the increased pressure put on Canadian municipal infrastructure as a result of higher population density, climate change effects often force high pressures or conditions on the infrastructure that it was not initially designed to support. As such, municipalities are frequently faced with high investments in maintenance and repair to ensure their infrastructure can continue to serve the community. Designing, building, and rehabilitating current infrastructure into climate-resilient ones has the potential to improve the reliability of service provision, increase asset life, and protect asset returns. As more investments are being made to design and build infrastructure in a way that anticipates and adapts to changing climate conditions, municipalities can expect to be faced with less costly retrofitting needs and a reduced risk of their infrastructure asset becoming prematurely obsolete.

THE TRIGGER

The Quesnell Bridge is one of nine roadway bridges crossing the North Saskatchewan River in the City of Edmonton. It was originally designed in 1968 as a five-lane structure to accommodate local traffic. However, since the bridge was originally built, Edmonton’s population has more than tripled, and traffic volume has increased considerably. In order to alleviate current traffic congestion on the Quesnell Bridge, the municipality decided to undertake a rehabilitation of the bridge to include two additional traffic lanes. The City of Edmonton wanted to ensure that the bridge would be retrofitted in a way that would ensure its structural performance over the next 50 years and, as such, decided to undertake a climate change vulnerability assessment under the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol to assist with the design process. The framework of the PIEVC protocol allows to define, evaluate, and prioritize information and relationships around the potential impacts of climate change on specific infrastructure.

THE APPROACH

The vulnerability assessment of the Quesnell Bridge followed the framework identified in the PIEVC protocol to define, evaluate, and prioritize information and relationships around the climate change impacts faced by the infrastructure being assessed in an effort to make recommendations around its rehabilitation. In order to define potential climate risks faced by the bridge over the next 50 years, a list of climate parameters of interest was created to further evaluate potential stressors on the structure, including future changes in temperature, precipitations, wind speed, ice, hail, and frost. For the bridge, the main risk revolved around greater temperature swings, which involve more movement of the bridge itself as materials expand and contract, as well as more extreme precipitation events that could lead to an increased flood risk.

In addition to the climate data collected in the nearby weather stations, the team conducting the assessment also considered future climate projections and potential
The City of Edmonton decided to conduct a PIEVC assessment of the Quesnel bridge prior to rehabilitating it in an effort to ensure its design would be adapted to current and future climate risks. (Source: City of Edmonton)

extreme weather events. The impact of the climate data collected by the assessment team was considered for all components of the bridge, including abutments, piers and approach slabs. The objective was to rebuild the bridge to anticipate current knowledge about the future climate anticipated over the lifetime of the bridge. This forward-looking approach was essential to ensuring optimal performance of the structure.

The analysis revealed that two infrastructure components were showing greater vulnerability to future climate risks: The first involved the wearing surface of the deck system. The second was the drainage system, which includes the deck drainage and the retention pond. Given that these components were being replaced during the rehabilitation, the team evaluated the potential of proposed alternatives for the replacement to improve the performance of the bridge and extend its useful operational life. Although failure of these components would not lead to catastrophic failure of the bridge, the ability of these components to have consistent performance could be compromised if not properly designed.

THE OUTCOME

The PIEVC assessment allowed the City of Edmonton staff to design the rehabilitation of the Quesnell Bridge in a manner that would ensure its structural performance over the next 50 years under changing climate conditions. Throughout the assessment
process, the hired consulting firm worked in partnership with City staff to ensure they had gathered field perspective to produce a comprehensive analysis.

The rehabilitation of the Quesnell Bridge was completed 10 years ago and there have not been any issues, neither has City staff identified any concerns with the structure since the completion of the construction, despite some extreme weather events such as extreme heat in the summer of 2021. While the bridge is on an annual maintenance cycle, there have not been any emergency issues or concerns raised by the building inspectors since the rehabilitation.

**A WORD FROM EDMONTON**

When asked what advice he would give to other municipalities looking at undertaking a similar project, Mark Scanlon, Bridges Supervisor with the City of Edmonton, emphasized the idea that investing in the proper rehabilitation of key municipal infrastructure can have immense environmental and financial benefits for communities. “I’m a strong believer that the most resilient and environmental structures are the ones in place, the more we can do to protect them, the more sustainable and less costly they will be over time,” said Mr. Scanlon. The investment made in Edmonton for the rehabilitation of the Quesnell Bridge was aligned with this philosophy and has only brought limited maintenance cost to the municipality since the project was completed.
BEST PRACTICES
A comprehensive local plan

By Sophie Guilbault, Paul Kovacs and Esther Lambert
In 2019, the Council of Canadian Academies published Canada’s Top Climate Change Risks, in which an expert panel of climate scientists identified the top 12 climate change risks where adaptation is urgently needed in Canada. Risks to physical infrastructure was identified at the top of this list. This includes addressing the threat of direct damage to homes, buildings, and critical infrastructure from heavy precipitation, high winds, and flooding.

Moreover, the expert panel also reported physical infrastructure as the climate risk with the greatest adaptation potential. That is to say, there is a greater consensus in the expert community about the actions proven to reduce the risk of loss and damage to physical infrastructure than for Canada’s other top climate risks. For example, there is agreement about what actions are needed to reduce and perhaps prevent most damage to municipal infrastructure.

In addition, studies by the Institute for Catastrophic Loss Reduction and others find that the additional cost to enhance the resilience of municipal infrastructure is fully offset by reduced risk of future damage. The benefits of investing in climate resilience typically exceed the cost by 5- to 10-fold.

Canadians know what to do, and the economics of action is favourable; however, communities continue to experience significant damage and destruction of municipal infrastructure as a result of extreme climate hazards.

The 2016 World Risk Report, jointly published by the Bündnis Entwicklung Hilft (Alliance Development Works) and the United Nations University, highlights the idea that when a hazard strikes, infrastructure performance can be a deciding factor in whether or not the situation becomes a disaster. Roads can, for instance, allow communities to evacuate and provide fast access to relief aid to affected communities; but if roads are destroyed, entire regions can become isolated and cut off from support.

The vast majority of Canada’s public buildings and infrastructure has been designed and built with the use of older building codes and construction standards that were based on historical climate data and can no longer withstand the extreme weather events we are increasingly witnessing. The case studies presented in this book demonstrate that a wide variety of infrastructure is at risk, including buildings, bridges, and water and wastewater systems, and that comprehensive actions need to be implemented in order to mitigate current and future risks of failure. Importantly, we celebrate the 20 cases here of municipal leadership to address this risk. Climate change will increase the frequency and severity of many extreme climate hazards, but we can prevent extreme events from becoming disasters by investing in climate-resilient public infrastructure and buildings.

Cities across the country have large infrastructure portfolios to look after. The value of these infrastructure is anchored in the services they provide. Comprehensive
management of public infrastructure by local government will result in fewer risks faced by the community and its residents. The Institute for Catastrophic Loss Reduction has identified four critical elements that should be included in a comprehensive strategy to maintain, rehabilitate, and design climate-resilient infrastructure:

- Understanding infrastructure vulnerabilities to climate risks;
- Creating asset management plans;
- Leveraging cross-sectoral collaborations;
- Growing local capacity for climate-resilient planning;

UNDERSTANDING INFRASTRUCTURE VULNERABILITIES TO CLIMATE RISKS

Policies, design, and construction practices for public infrastructure should be anchored in a strong understanding of climate risks faced by the specific asset and its broader infrastructure system when applicable. When evaluating the risk faced by an infrastructure, various elements need to be considered, such as current and future climate conditions, exposure, infrastructure vulnerability, capacity, maintenance needs, etc. The knowledge coming out of vulnerability assessments is instrumental in planning lasting design and rehabilitation needs and can assist municipalities in their long-term planning effort.

The Institute finds that communities should manage municipal infrastructure with a focus on performance over the lifetime of the asset. Assets should be designed and managed based on the climate expected in the future, not the weather experienced in the past. Climate models can provide specific climate forecasts for each community.

Various strategies can be used by municipalities to further their understanding of public infrastructure vulnerability. The PIEVC protocol was used by several Canadian municipalities, including eight case studies presented in this report, to review historical and future climate conditions and establish the adaptive capacity of a wide range of infrastructure assets. Indeed, more than 150 PIEVC assessments have been completed for a broad range of public infrastructure projects. To do so, the protocol promotes cross-sectoral collaborations to evaluate the infrastructure design, operation and maintenance to identify which components are at higher risk of specific climate threats.

The comprehensive assessment used under the PIEVC protocol allows communities to make informed decisions around budget planning, intervention prioritization, and long-term rehabilitation planning. The City of Laval used the PIEVC protocol to understand the vulnerabilities faced by a major overflow structure on the City’s territory. The vulnerability risk assessment allowed the municipality to have important knowledge available and a clear path forward when funding became available to
implement risk reduction actions that would reduce the demand faced by the infrastructure. Similarly, the City of Vernon used the PIEVC assessment to confirm previously suspected risks and, as a stepping stone, to conduct a broader analysis through the Climate Lens program of Infrastructure Canada.

The knowledge gathered through infrastructure vulnerability assessments is instrumental to support prevention and mitigation actions and to allow communities to plan their asset maintenance and rehabilitation in a sustainable way.

**CREATING ASSET MANAGEMENT PLANS**

Municipalities benefit from getting the most value of their public infrastructure with low maintenance and rehabilitation expenses. Asset management planning allows communities to establish long-term management plans that can inform decision-makers on priority investments.

Understanding the vulnerabilities of public infrastructure allows municipalities to establish long-term asset management plans over the lifecycles of a large asset portfolio. These management plans allow decision-makers to make informed decisions on priority investments and allocate resources wisely. Municipalities presented in this report have taken different approaches to asset management planning. The City of Ottawa used the PIEVC protocol alongside other risk analysis methods to gain a deeper understanding of infrastructure risk around the community and prioritize risk mitigation initiatives. The PIEVC process used by Ottawa also allows municipal staff to include new information that may emerge around climate risks and infrastructure components, ensuring that the asset management strategy evolves over time as new information emerges.

The City of Calgary's strategy was guided by a systems approach and operational plan that allows for flexibility and adaptability when considering ways to improve climate resilience of infrastructure. The Glenmore Dam rehabilitation was part of a comprehensive analysis that allowed the municipality to develop a holistic plan around flood mitigation and resilience. While this type of approach typically requires more time and resources during the analysis period, it ensures various components of key infrastructure are not overlooked and that the infrastructure system is considered as a whole.

Asset management plans allow communities to prepare for capital investment planning so that particular projects are given priority. Saddle Lake Cree Nation represents a great example of this approach. The community partnered with a consulting company to first establish which interventions were worth pursuing to increase climate resiliency of infrastructure assets given the needs of the community. Following this initial analysis, Saddle Lake has been reviewing annually which infrastructure investments will be prioritized.
LEVERAGING CROSS-SECTORAL COLLABORATIONS

As cities work to understand their infrastructure vulnerabilities and plan for their maintenance and rehabilitation, it is crucial to leverage the expertise and resources that come with cross-sectoral collaborations. Case studies presented in this report have highlighted the need to leverage cross-sectoral partnerships as a way to obtain a comprehensive analysis of risks faced by an infrastructure asset or system, but also to secure funding for infrastructure repair, construction, and maintenance.

When evaluating asset vulnerabilities, the PIEVC protocol favours multi-disciplinary and multi-stakeholder teams to provide thorough assessments. The project team can be customized to the specific needs of the community, but often includes engineers, climate scientists, representatives from the infrastructure owner (e.g., operators, risk managers, public works, etc.), as well as other stakeholders (e.g., emergency managers, planners, policymakers, etc.). Through participatory workshops, the various stakeholders get to exchange and engage in two-way dialogues to share their perspective and collective experience with the infrastructure being assessed. Those facilitated sessions allow for the exchange of both quantitative and qualitative data, enabling the project team to prepare a comprehensive analysis of vulnerabilities and options to repair, redesign, and maintain in the future. Cross-sectoral collaboration during infrastructure vulnerability analysis also allows for identification of any missing information, from local historic climate data to maintenance records and to clearly identify where an infrastructure is within its lifecycle. Early and ongoing stakeholder engagement enables for a clear project definition as well as a shared understanding around expectations and execution.

Public infrastructure is costly to build and maintain. Many communities presented in this report have benefited from external sources of funding from the federal and provincial governments through programs such as the Disaster Mitigation and Adaptation Fund (DMAF) from Infrastructure Canada, the Climate Change in the North Program of Crown and Indigenous Relations and Northern Affairs, the Alberta Community Resilience Program and the Indigenous Services Canada’s Emergency Management Assistance Non-Structural Mitigation program. Some communities have also benefited from non-governmental funding through programs like the Municipalities for Climate Innovation program (MCIP) from the Federation of Canadian Municipalities.

GROWING LOCAL CAPACITY FOR CLIMATE-RESILIENT PLANNING

Increasing local capacity to perform climate-resilient infrastructure planning and maintenance is key to ensuring the performance and longevity of public infrastructure across Canada. In this context, building local capacity refers to financial, human, and political resources.
From a financial standpoint, planning and securing resources for infrastructure maintenance and upgrades is key, particularly in the context of increased extreme weather events that can put a significant amount of stress on aging infrastructure. Local governments presented in this report have been successful at leveraging public spending to attract additional funding resources while ensuring that the infrastructure investment was consistent with a climate-resilient economy.

There is considerable value in educating and engaging municipal staff in climate-focused infrastructure planning. This was particularly well demonstrated in Welland where the engagement of asset managers proved to be effective in factoring in logistical and operational issues crucial to climate-resilient infrastructure management. Beyond the engagement of municipal staff, outreach and engagement of local communities is beneficial to achieve successful outcomes. This was demonstrated in Windsor, where frequent public engagement sessions, public meetings, and newsletters were used to encourage community ownership and responsibility for the project.

Human resources are not limited to staff and consultants involved in climate resilience planning, but also require the presence of strong political leadership. This report features several local champions who have successfully influenced and secured resources to ensure that infrastructure investments were done in a way that would be sustainable environmentally, socially, and economically for their communities. They have been leaders through a transformational change that involved rethinking how public infrastructure should be designed, given changing climate conditions.

Finally, it is important to note that all case studies presented in this report are strongly aligned with the Sendai Framework priorities for action. Communities have showcased their commitment to understanding their infrastructure risk through comprehensive vulnerability assessments, demonstrated strong disaster governance by making climate-resilient planning a local priority, secured significant resources to invest in disaster risk reduction, and committed to rebuilding infrastructure in ways that would optimize their performance under future climate conditions.

This report celebrates communities across Canada who are actively working to adapt their public buildings, sewer systems, water treatment facilities, bridges, roads, and other public infrastructure. Climate change is increasing the risk that more frequent and severe extreme weather events result in direct damage and failure in the performance of municipal infrastructure. Nevertheless, we find communities across Canada investing in climate resilience. Proven and affordable adaptation, like the examples reported here, demonstrate how communities can reduce and prevent the risk of loss and damage in a changing climate. More action is urgently needed, yet it is important to celebrate the leaders taking action now.
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Canada’s leading disaster research institute, the Institute for Catastrophic Loss Reduction (ICLR) was established with funding from the insurance industry in 1997 as an independent, not-for-profit research and outreach institute to champion disaster resilience in Canada. ICLR is an international centre of excellence affiliated with Western University. The Institute develops and champions evidence-based disaster safety solutions that can be implemented by homeowners, businesses and governments to enhance their disaster resilience.

Vision

Disaster-resilient Canadians, certain in their capacity to cope with and recover from flooding, wildfire, earthquakes, severe wind, hail and other natural hazards. Canadians prepared for extreme or catastrophic hazards will be confident in their capability to respond to any natural hazard. Their confidence is based on a sound understanding of risk, knowledge of effective risk reduction solutions and actions taken to reduce the impact of natural hazards.

Mission

Demonstrate objective and independent science through leadership by providing science and evidence-based disaster risk management knowledge. Support Canadians to become aware of actionable solutions that reduce the risk of loss of life, injury and property damage caused by flooding, wildfire, earthquakes, severe wind and hail. Support sustained actions by homeowners, businesses, governments and others that improve society’s capacity to adapt to, anticipate, mitigate, withstand and recover from natural hazards.
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