DEVELOPING AN INTEGRATED RISK MANAGEMENT FRAMEWORK TO SUPPORT “ONE WATER” IN MUNICIPALITIES

Prepared by:

[Logos of the collaborating institutions]
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1 Introduction

Canadian municipalities are facing challenges from continued growth, climate change, aging infrastructure, and the increasingly limited ability of receiving waterways to absorb the impact of stormwater runoff and pollution. While many municipalities have water and wastewater asset management plans, stormwater infrastructure has largely been overlooked despite its impact on water and wastewater infrastructure.

Over the last decade, many municipalities have begun to recognize the importance of addressing water systems and their management using an integrated and holistic “One Water” approach. This approach allows municipalities, water managers, and regulators to better coordinate the development and management of water, land, and related resources in a sustainable and equitable manner. They also encourage decisions and investments that will achieve the best results and returns for public health, the economy, and the environment.

To support municipalities as they make the move to integrated water management and water sustainability planning, the University of Guelph in partnership with Credit Valley Conservation (CVC), McMaster University and Dalhousie University conducted a project in 2014-2015 to identify and remove some of the barriers that prevent municipalities from adopting a “One Water” approach. This report is the end result of that project. It will outline the risks and drivers related to water systems that municipalities are facing, demonstrate effective risk management tools and strategies, and discuss the need for an integrated risk management framework.

To help organize the layout of information in this report, a framework has been developed that illustrates the basic components municipalities need to consider when aiming for a One Water approach.

Figure 1 shows the components of the proposed framework, which includes sections on legislation and governance, the watershed approach, asset management practices, integrated risk assessment, innovative green infrastructure technology, and integrated financial planning.
Figure 1: The components of an integrated framework. Source: CVC
2 What is One Water?

In the natural hydrologic cycle, the majority of precipitation is subject to evapotranspiration and infiltration, with a small amount turning into runoff. However the opposite is happening in urbanized areas because of several factors, including large, impermeable surfaces. Evapotranspiration and infiltration are reduced while runoff volumes increase. This is altering the natural water balance and creating a shift towards urban water balance.

At the same time, human consumption of water is impacting the hydrologic cycle. Infrastructure that delivers potable water and discharges wastewater discharges are all part of urban water balance and must also be incorporated into the new water cycle.

One Water is an integrated water management approach that incorporates and mimics the natural hydrologic cycle. It looks at drinking water, wastewater and stormwater holistically, at a watershed scale. Figure 2 illustrates how we can combine the natural and urban water cycles to think of them as One Water.

Figure 2: The “One Water” approach. Source: Healthy Waterways.

To adopt an integrated approach, municipalities need to look at water management from a watershed perspective and consider the watershed as an asset. In doing so, municipalities can begin to see the many layers of complexity that influence water management. Figure 3 illustrates different water systems from the watershed perspective.
2.1 Complexities and interactions
A watershed perspective can help municipalities better understand how different water systems interact (see Figure 3). Within a watershed, different water infrastructures such as drinking water, wastewater and stormwater systems each have unique functionality, and they also influence one another. For example, in some municipalities, storm and sanitary sewers are combined, which can lead to combined sewer overflows (CSO’s) during large rainfall events.

However water, wastewater and stormwater are for the most part handled as separate services. Waste water is managed through individual or communal sanitary system. It is gathered and piped to a wastewater treatment plant where it is treated and discharged to the receiving waterway. Stormwater management systems are designed to collect rainfall runoff from urban watersheds and discharge the water into the nearest adjacent waterway or to end-of-pipe facilities (e.g. stormwater management ponds). Drinking water is treated at a water treatment plant and then distributed to the end users. In rural areas single homes may have private or communal wells.
Figure 4 illustrates the interactions between different infrastructures, in several different scenarios. The One Water approach recognizes that these systems are interrelated.

Relying on groundwater - With increased impervious area, population growth and changing climatic conditions, there is less infiltration to replenish groundwater supplies and base flow to the receiving stream. This impacts water supply.

Living close to the lake - Urban runoff can impact surface water quality and require more treatment at the drinking water treatment plant (DWTP) to achieve required standards, which could translate to increased costs.
Assimilative capacity - With decreasing base flow due to increased urbanization and population growth, it can become more difficult to achieve assimilative capacity targets for the wastewater treatment plant (WWTP), which could translate to expensive upgrades and/or receiving water impairment.

Combined sewer overflows and cross-connections - Heavy rainfall events can overwhelm combined sewer systems resulting in bypass of untreated wastewater and pollution of the receiving waterways. Downstream communities that rely on the receiving waterway as a source of drinking water may need to spend more to treat the water to potable standards.

Figure 4: Some of the different ways that infrastructures interact with each other. Source: CVC

Many municipalities that were once completely groundwater-based have reached maximum allowable growth based on existing water supply. In order to grow, these municipalities need to find alternative sources of water.
One solution is to stop managing water infrastructure systems and urban watersheds as mutually exclusive systems. For example, water is treated to potable standards, but then used for tasks that do not require portable water, such as irrigating lawns. Stormwater is a great alternative for irrigation, however it is often considered wastewater, and we take great strides to convey it efficiently from the land where it falls. Grey (or traditional) infrastructure solutions tend to be the status quo, but there are many proven benefits to using green (or soft) infrastructure solutions. Table 1 introduces new ways of thinking about different water systems that support the shift to a One Water approach.
Table 1: Changing approaches to different topics. Source: Adapted from EPRI, 2010.

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<th>New Paradigm</th>
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<td>Water use</td>
<td>Multiple use – Use household grey water for irrigation.</td>
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<tr>
<td>Water quality (supplied)</td>
<td>Apply “right water for right use” – Treat water to a level of water quality suitable for its intended use. Ex. We don’t need to use potable water for irrigation purposes or to flush toilets.</td>
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<td>Wastewater</td>
<td>“Close the loop” – Recover valuable resources (reclaimed water, nutrients, carbon, metals and biosolids) from “waste” water for beneficial uses such as potable water offsets, fertilizers, and generating power.</td>
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<tr>
<td>Stormwater</td>
<td>Harvest stormwater for water supply, irrigation, and/or infiltration benefits.</td>
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<tr>
<td>Increase system capacity</td>
<td>Implement cost-effective, demand-side, green infrastructure before increasing grey infrastructure.</td>
</tr>
<tr>
<td>Type of water infrastructure</td>
<td>Integrate the natural capacities of soil and vegetation (green infrastructure) to capture, infiltrate and treat water with grey infrastructure.</td>
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<tr>
<td>Centralized infrastructure</td>
<td>Multiple decentralized small water treatment and distribution systems combining local needs and the triple bottom line.</td>
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<tr>
<td>Complex design</td>
<td>Require new infrastructure design technologies and strategies to address today’s complex water problems.</td>
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<tr>
<td>Infrastructure integration</td>
<td>“Water is water” – Integrate infrastructure and management of all types of water regionally.</td>
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<td>Public involvement</td>
<td>Engage stakeholders in the decision-making system from the beginning.</td>
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<tr>
<td>Monitoring and maintenance</td>
<td>Move smart systems out to end users to provide real-time feedback regarding energy use and water use rates to build understanding, modify behavior for higher efficiencies, and notify for maintenance.</td>
</tr>
<tr>
<td>Cost-benefit analyses</td>
<td>Develop an understanding of the full cost and benefits of infrastructure, including externalities.</td>
</tr>
<tr>
<td>Water Balance</td>
<td>Understand the hydrologic needs of the local natural heritage system (i.e. maintain the water balance).</td>
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3 Identifying the Risks

Understanding how municipal water infrastructure systems are connected—including drinking water treatment and distribution, wastewater conveyance and treatment, stormwater management and combined sewers systems—is the first step in moving towards the One Water approach. The next step is to identifying the risks associated with water management. By identifying these risks, municipalities can start to develop solutions within an integrated water management framework.

Three key risks have been identified that challenge municipalities ability to manage water. They are:

1. Water infrastructure
2. Climate Change
3. Increased population grown and urbanization

3.1 Water infrastructure risks

Most of North America’s water and wastewater infrastructure was built during the post-World War II era of rapid economic growth. This infrastructure is approaching, or has already reached, the end of its design life. A recent estimate reveals that replacing Canada’s aging infrastructure to maintain current levels of service now and in the future would require a total investment of $87 billion. That’s an average of $6,488 per household (FCM 2012).

The two main reasons water and wastewater infrastructure can fail to carry out its intended function safely and effectively include:

1) **Physical degradation with age leading to structural failure.** Physical degradation of buried assets, for example, can lead to structural failure of linear assets resulting in leakage from pressurized pipes, external ingress to non-pressurized pipes, and ultimately, complete failure.
2) **Out-dated design capacity.** Changes in demand patterns can result from increased water and wastewater conveyance demands due to population growth.

3.1.1 Key drivers

There are six key drivers of risk related to aging infrastructure: insufficient funding, lack of up-to-date asset condition information, increased exfiltration, increased infiltration/inflows (I/I), physical degradation, and the potential for catastrophic pipe bursts.

1. **Insufficient funding:** Insufficient or unsustainable funding for infrastructure projects leads to inconsistent asset condition characterization and maintenance. Key implications of insufficient funding include limited asset inspection, irregular structural maintenance, irregular cleaning, and the

Many Canadian municipalities lack any condition information on their buried assets and 33% rely on expert opinion, not comprehensive visual inspection, when developing maintenance plans (FCM 2012).
inability to effectively budget for rehabilitation and growth. All classes of municipal water assets were determined to be at risk as a result of the inability to develop strategic maintenance plans in the absence of asset condition information. The potential impacts of inconsistent structural maintenance include, but are not limited to, catastrophic failure and flooding, extensive and costly repairs, and threats to public health and safety. Inadequate funding also affects the ability to plan for long-term growth and rehabilitation.

2. **Lack of asset condition information:** Asset condition information allows municipalities to locate and quantify the severity of threats to buried assets, avoid critical failures, and develop prioritized maintenance plans. Without this information, it is very difficult to budget for rehabilitation and growth, and the risk of failures looms. Organizations such as the American Society of Civil Engineers have identified that the performance of infrastructure is critical in maintaining a strong economy.

3. **Increased exfiltration from buried infrastructure:** Partially compromised pipe walls pose increased risks to buried conveyance systems. In these scenarios, water can still be conveyed, but contaminants can travel through the breaks and cause health and safety issues. Exfiltration is an issue for both pressure-driven water distribution systems and gravity-driven wastewater and stormwater systems. It is estimated that up to 30% of treated water entering Canadian distribution networks is lost through leaks in pipe walls. Exfiltration also causes a threat in wastewater conveyance, since contaminants may penetrate to groundwater. A recent study in Guelph, Ontario found 90% of the city’s 22 drinking water wells contained at least one sewage-derived contaminant and 45% of the wells exhibited human enteric viruses derived from sewage exfiltration (Allen 2013). Furthermore, the Center for Disease Control attributed 57 cases of waterborne disease outbreaks to cross-connections between drinking water and wastewater conveyance from 1981-1988 (EPA 2001).

4. **Increased infiltration and inflows from buried infrastructure:** Infiltration to wastewater conveyance systems during wet weather events results in increased water treatment requirements, elevated treatment plant operating costs and often results in sewer overflows. More than 75,000 sanitary sewer leaks occur annually across the United States, resulting in the release of several billions of gallons of untreated wastewater to surface water (EPA 2014).

5. **Causes of physical degradation:** Other age-based deterioration processes identified through the research, include internal scaling in pipes, tree root intrusion and damages incurred during excavation for future developments. Scaling in distribution pipes can contribute to an increase in biofilm growth of 600-620% for copper and 85-90% for PVC pipes. This growth can increase pipe degradation, as well as pose threats for public health (Fox & Abbaszadegan 2013). An estimated $33 million in unnecessary damage is caused to buried infrastructure though new developments planned around existing infrastructure (Federation of Northern Ontario Municipalities 2014).

6. **Catastrophic pipe bursts:** According to some research, the act of increasing pressure in distribution networks to compensate for pipe leaks can cause long-term failure rates to rise from 1 to 6 breaks per 100km/year as pressure is increased from 105 to 123 psi in aging
networks (Ambrose et al. 2010). Failure in distribution systems poses the risk of damage to surrounding infrastructure and property, as well as a loss of considerable volumes of potable water and potential exposure threats to water consumers due to ingress of ambient water into the water distribution system.

3.2 Risks from Climate Change

Severe weather is likely to become one of the greatest reasons for higher costs in the future delivery of water services and managing infrastructure (OECD 2006). Precipitation, evaporation and runoff patterns are changing, resulting in uncertainty about the security of water supply, the quality of drinking water, flood management in urban environments and the long-term health of natural ecosystems (CWN 2014).

Researchers have observed changes in rainfall intensities and their significance. From analysis of 13 rain gauges across Ontario, researchers observed an increased frequency of design storm events. In the Waterloo Region, they concluded that storm intensities for both five-year and two-year return period have increased for durations shorter than two hours (Vasiljevic et al. 2012).

Researchers at MIT and Princeton University have reported further evidence of changes in precipitation patterns and increases in storm intensities using predictive climate models. Through the simulation of tens of thousands of storm events under different climate conditions, researchers concluded that climate change could result in powerful tropical storms making landfall more frequently. Today’s “500-year floods” could occur once every 25 to 240 years (MIT 2012). Furthermore, extreme events are often cascading in nature where, instead of one dominant event, localities are dealing with multiple occurrences and types of extreme events, many of which are more severe than in preceding decades (WERF 2013). Combinations of extreme events are very challenging from an operations perspective, as during times of crisis, all systems are pushed to their maximum capacity, flexibility and capability, often leading to startling discoveries of weaknesses and limitations that were not previously anticipated or understood (WRF 2014).

3.2.1 Key drivers

This section reviews eight key risk drivers to municipal water systems resulting from impacts of a changing climate, including variation in historical precipitation patterns, changes in water/air temperatures, permafrost recession, changing snowmelt conditions, sea level rise, ineffectiveness of climate sensitive design tools, and lack of treatment/conveyance infrastructure resilience.

1) Increase in rainfall intensity: Changes in runoff quantity and quality as a result of varying precipitation can lead to elevated risk in municipal water systems. For instance, precipitation can transport organic contaminants and suspended solids from agricultural areas, which may result in adverse effects to surface water supply uptake and existing stormwater management facilities. Increases in high-intensity precipitation events are believed to increase the likelihood of waterborne disease outbreaks by a factor of two (Health Canada 2005). This projection is consistent with findings from Curriero et al. (2001), who determined 51% of waterborne disease outbreaks in the United States between 1948 and 1994 were preceded by precipitation events above the 90th percentile ($P = 0.002$) and 68% by events above the 80th percentile ($P = 0.001$). Increases in soil water content resulting from increased precipitation can result in heightened inflow and infiltration ($I/I$) to buried infrastructure, possibly leading to sewer back-up in homes. Basement flooding has become a significant issue in Canada, and is now the leading reason for
insurance payouts, surpassing fire, at an estimated value of $1.7 billion annually (IBC 2012). Finally, increased precipitation may cause flood damage to infrastructure.

2) **Increased water temperature:** Elevated temperatures, in addition to increased nutrient loading, may result in the augmented occurrence of algal blooms. Changes to surface water temperature can also result in the migration of invasive species into previously uninhabitable ecosystems. For example, zebra mussels have obstructed flow in water distribution systems in the United Kingdom, requiring increases in pressure to overcome the augmented friction (BBC 2014). Increased water temperature in distribution systems may also lead to accelerated contaminant regrowth, while increased temperatures in wastewater flows can result in heightened production of hydrogen sulphide gas, which is corrosive to pipes and toxic to humans (CSIRO 1988).

3) **Increased air temperature:** Increases in ambient air temperature has implications for all municipal water sectors but, perhaps most importantly, for drinking water infrastructure. Increased evaporation rates have the potential to diminish surface water sources as a result of heightened evapotranspiration. Current projections state rates could increase by as much as 8-15% from current levels as a result of climate change (Zhang & Lemckert 2012).

4) **Melting permafrost:** As a result of a warming climate, permafrost temperatures have increased considerably across the globe over the course of the last 20-30 years (Romanovsky et al. 2007). Loss of permafrost poses risk to buried infrastructure designed for frozen subsurface conditions. Changing underground conditions can impact the structural integrity of treatment plants, dams, reservoirs and pipes designed for frozen ground strength (Nunavut Climate Change Centre, 2015). In 2006 the community of Dawson City, Yukon was required to increase its water and sewer maintenance budget of $340,000 to a total of $1 million to manage the impacts of melting permafrost (Beacom 2006).

5) **Changing snowmelt conditions:** Climate change has resulted in rapid spring thaws as well an increased occurrence of mid-winter snowmelts (Columbia Basin Trust 2011). Changes in melt conditions pose additional risk to stormwater conveyance and management systems. In addition to variations in runoff quality, mid-winter thaws increase mobilization of road salt, potentially further impacting water supply sources.

6) **Sea level rise:** Projected sea level rise resulting from melting polar ice caps and thermal expansion of ocean depths poses risks to infrastructure in many low-lying urban areas (UCSUSA 2013). In addition to flood-related damage to infrastructure, salt water intrusion to coastal groundwater has been identified as a potential risk for many communities.

7) **Ineffectiveness of climate-sensitive design tools:** Changes in precipitation patterns, surface cover, topography, and water use pose substantial risk to municipal water systems, especially due to possible damage as a result of urban flooding. A lack of current and accurate information, such as intensity-duration-frequency (IDF) curves that reflect true precipitation trends, can put
municipalities at risk when they are design new stormwater management systems. As well, the average Ontario floodplain map is 22 years old. More than 80% of these maps are outdated and do not reflect the reality of increasing extreme weather in urban environments (ECO, 2014).

8) **Lack of treatment plant resilience:** Increasing demand is placing stress on existing infrastructure and requiring municipalities to make significant investments to upgrade the capacity of treatment facilities. During wet weather events that overwhelm existing infrastructure, municipalities are sometimes forced to discharge untreated wastewater directly to surface water, especially via combined sewer overflows. Large investments to treatment plants can reduce risk to public health and ecosystems associated with these discharges.

### 3.3 Population growth and increased urbanization

Almost 90% of Canada’s total population growth since 2001 has occurred in Canada’s 33 census metropolitan areas (Statistics Canada 2008). This issue translates into an increasing rate of urbanization in municipalities and in turn, watersheds. Growth in both of these areas means municipalities will have to ensure that the water, wastewater, and stormwater infrastructure meets the expected level of service. Changes in land use associated with urbanization can affect flooding patterns and impact in several ways. For instance, drainage networks can increase runoff to streams from rainfall and snowmelt, thereby increasing the peak discharge, volume and frequency of floods (USGS 2014).

#### 3.3.1 Key drivers

This section reviews five key sources of risk to municipal water systems that result from the impacts of population growth and increasing urbanization, including population growth, increased demand on undersized linear infrastructure, contamination as a result of urbanization, changes in surface cover, and implications associated with industrialization.

1) **Population growth:** Population growth poses several risks to all municipal water infrastructures. These risks stem from a higher demand for potable water, higher wastewater treatment requirements, and the impacts to stormwater management from changing land cover resulting from urban sprawl. Water demand in Canada has been increasing continually in conjunction with population growth – from 1972 to 1996 Canada’s cumulative water extraction increased from 24 to 45 million cubic metres per year, a total increase of 90% (Environment Canada 2013). In regard to changing surface cover from natural to urban land, studies have shown an 11 to 19 fold increase in stormwater runoff occurred while infiltration rates decreased from natural levels by 11% to 100% (Harbor 1994). These issues contribute both to flood risk as well as risks associated with reduced groundwater recharge. On a related note, an investment of $3.4 billion will be required to meet regulatory standards for wastewater by 2020 (FCM 2015). Providing food for a growing population also poses risks to water sources as increased consumption can result in pollutant loading through agricultural runoff, as well as more water requirements for crop irrigation

2) **Undersized linear infrastructure:** Growing demand on an aging linear network is another driver of risk to water systems, as linear networks were designed for smaller flows. This increases the likelihood of failure to perform their intended function. In regard to drinking water, as more
customers are added to a distribution network, increased pipe velocities may accelerate pipe
degradation rates, thereby increasing the frequency of pipe breaks (Public Works 2012). In the
United States, an investment of $298 billion will be required over the next 20 years to expand
and repair sewage conveyance systems and minimize the occurrence of combined sewer
overflows and separated sewer overflows resulting from increased conveyance demands and to
mitigate inflow and infiltration (ASCE 2013). As a result of changing surface cover, an increase in
wet weather flows will require stormwater management systems to be retrofitted to increase
capacity. A recent drainage study in Waterloo, Ontario projected a 25% to 50% increases in
stormwater flows as a result of further development (City of Waterloo 2005).

3) **Contamination due to urbanization:** To ensure sufficient treatment of increasing wastewater
volumes, municipalities will have to increase plant capacity or make existing systems more
efficient. Facilities in Calgary have been continually upgraded from 213,600 cubic meters per day
in 1954 to the current capacity of 500,000 cubic meters while still meeting discharge regulations
(City of Calgary 2015). Contaminants of emerging concern (CECs) such as pharmaceuticals are an
additional source of risk in urban environments since conventional wastewater treatment plants
are not designed to remove these materials. A surface water study found that 80% of 139
streams sampled across 30 U.S. states contained a wide range of CECs, believed to be from
residential, agricultural and industrial sources (Kolpin et al. 2002).

4) **Changes in land use:** Whenever we make changes to naturally occurring surface cover, we must
consider risk to municipal water systems, especially stormwater management systems. The
potential impacts of changes to surface cover include both higher runoff volumes and peak
runoff rates for a given storm event. These impacts are a direct result of reduced infiltration
capacity and improved stormwater conveyance, respectively. Potential impacts to receiving
water channels include increased erosion and sediment loading that could pose a flood risk to
downstream communities. Additionally, large areas of dark surface cover (roads, parking lots,
roofs, etc.), are increasing temperatures of urban runoff higher than what is found under
natural conditions. Changes in temperature may also have adverse effects on downstream
groundwater feed ecosystems.

5) **Industrialization:** Increased industrial activities drive risk for water systems due to the high
demand on water sources as well as the unique characteristics of contaminants in discharge
water. Canada’s three largest industrial water consumers (thermal electric power,
manufacturing and mining) use 30.6 billion gallons annually, accounting for a substantial portion
of the country’s total water intake (Statistics Canada 2009). Sources of water contamination
include industrial runoff as well as contaminants of emerging concern that are not removed by
traditional wastewater treatment facilities.

This section is a summary of research carried out by University of Guelph. For more information
please see Appendix A.
The Water Utility Risk Integration Matrix
The Water Utility Risk Integration Matrix developed by the University of Guelph is an interactive PDF that illustrates the interconnectedness of drinking water, wastewater and stormwater systems and the risks associated with managing them in isolation. Getting a view of the whole picture can help municipalities better visualize their integrated approach to risk management.

The matrix contains three sections that discuss risks associated with aging infrastructure, climate change, and urbanization and population growth. Figure 5 is a sample excerpts from the matrix to demonstrate the general organization of information within the tool. Throughout the matrix, users can find links to external resources, such as literature, guidance tools, and case studies that supplement information within the document.

Figure 5: Sample excerpts from the Water Utility Risk Integration Matrix, demonstrating the approach to information organization. Source: Utility Matrix, Richard Harvey
4 Legislation and Governance
The next step in moving towards a One Water approach is to identify tools that can help manage the risks identified in Chapter 3. Legislation and Governance is one of these tools.

The legal and governance framework for water management involves many actors across several jurisdictional boundaries, including federal, provincial, municipal and regulatory agencies. The distribution and overlap of responsibility often makes it difficult for municipalities to facilitate coordination and integration. Jurisdictional boundaries of legislative authority, combined with the dynamic, trans-boundary nature of water, can make risk management through integrated water management a challenge.

4.1 Legal responsibilities and different levels of government
Responsibility is divided among different levels of government, distributing powers among the federal, provincial, territorial, municipal governments as well as conservation authorities in some provinces. Under Canadian constitutional law, both federal and provincial governments have jurisdiction over environmental issues, including water management (*Constitution Act* (UK) 1867).

Table 2 highlights some responsibilities shared amongst the different levels of government, from an Ontario perspective.
<table>
<thead>
<tr>
<th>Federal</th>
<th>Provincial</th>
<th>Municipalities</th>
<th>Conservation Authorities</th>
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<tr>
<td>The federal government has jurisdiction over fisheries (Fisheries Act 1985), navigation (Navigational Protection Act 1999), federal lands (Canadian Environmental Protection Act 1985), and international relations, which includes boundary waters shared by the United States (International Boundary Waters Treaty Act 1985).</td>
<td>The Constitution Act grants provincial governments jurisdiction over water management (Constitution Act 1867). Provincial powers related to water resource management include public lands, municipal institutions, local works and undertakings, non-renewable resources, property and civil rights, and shared jurisdiction over agriculture (Constitution Act 1867). To facilitate water management, provincial governments rely on numerous government departments and agencies and create policies, legislation, and programs (de Loe 2008). Provincial legislative powers include, but are not limited to: flow regulation; authorization of water use development; water supply; pollution control; and thermal and hydroelectric power development. (Environment Canada 2015).</td>
<td>Municipalities are generally responsible for local administration and operation of water management services. Municipalities are empowered by provincial legislation that sets out municipal jurisdiction and responsibilities with respect to certain matters, such as the Municipal Act in Ontario. Generally, municipalities have authority to create by-laws and protocols to regulate water services within their territory (Municipal Act 2001) and are also involved in land-use and water systems planning. Water management at the municipal level often involves cooperation with fellow municipalities (especially in jurisdictions where there are two-tier municipality structures) and the Province (Municipal Act 2001).</td>
<td></td>
</tr>
<tr>
<td>In Ontario, conservation authorities are another public body responsible for water management. Generally, conservation authorities have watershed-based jurisdiction (Municipal Act 2001). The Conservation Authorities Act (Conservation Ontario Natural Champions 2013) grants conservation authorities broad powers with respect to water management, including the ability to make regulations restricting and regulating the use of water in or from water bodies within their jurisdiction subject to the approval of the provincial Minister (Conservation Authorities Act 1990).</td>
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4.1.1 Barriers to integration and legal responsibilities across departments

Within levels of government, water management involves multiple ministries. Each has its own overlapping mandates, priorities and accountabilities, which complicates the planning and implementation of integrated water management. For instance, within the federal government alone, more than 20 departments and agencies are responsible for various aspects of water management (Environment Canada 2015).

The existence of various departments encourages specialization that often results in departments acting in isolation, poor information-sharing practices, and confusion about roles, responsibilities, and authority (Morris 2014).

This isolation presents difficulties when actors are faced with complex, interrelated problems (Morris 2014). Although individual departments may understand the risks to their specific infrastructure, they do not often look at how these systems and risks interact with the other infrastructure systems. For example, building a larger stormwater pipe may be a simple solution for increasing capacity to deal with more extreme weather events, but it might also put downstream areas at more risk of flooding and erosion. It may also increase the levels of contamination from non-point source pollutants and pose risks to downstream source water protection, which would require more energy and/or expensive technologies to treat water to the required standards.

Conventional tools and strategies do not tend to support an integrated approach. Water managers need new educational tools that can support the implementation of an integrated approach. One such example is the Great Lakes Commission’s project to raise awareness among municipal officials about the financial and economic benefits of integrated water management. Supported by the Great Lakes Protection Fund, the project involves working with municipalities to help them evaluate how they could reduce environmental impacts and financial costs by better integrating the three water systems.

The various departments involved in water management may also have conflicting mandates and priorities, and a lack of clear guidance as to which priorities should take precedence. The numerous statutes relating to water management can make the legal framework complex and cumbersome. The patchwork of legislation is often unclear about how statutes relate to others. It is a huge administrative and operational challenge for those responsible for water management to be familiar with all the related legislation and regulation (Merrit and Gore 2002). For example, in a paper commissioned for the Walkerton Inquiry, authors found that the complex framework of legislation compromised the province of Ontario’s ability to provide comprehensive drinking water services (Merrit and Gore 2002). Further, the multiple sources of legislation can lead to regulatory fragmentation, which can prevent the implementation of more expansive regulations that would better protect ecosystems, watersheds, water resources, and human health (Craig 2008).
4.1.2 The roles of other actors

*Administrative agencies*
While governmental bodies take leadership, numerous administrative agencies and non-governmental actors play a significant role in water resource management. For instance, the Ontario Clean Water Agency ("OCWA") is a Provincial Crown Agency that services municipalities, First Nations communities, institutions and businesses providing water, wastewater and stormwater management and infrastructure. Given the integral role of OCWA and other administrative agencies, they should be actively involved in any attempts to integrate water management.

*Professional Associations*
Professional associations can also play a key role in water management. Many can administer professional certificate programs, facilitate knowledge-sharing amongst professionals, advise on policy matters, and provide technical support (BCWWA 2015). Likewise, industry organizations can play a key role in advocacy and public education (BCWWA 2015). The agricultural, oil and gas, manufacturing, and forestry sectors, among others, impact water resources significantly and their activities can impact water quality (Fraser Basin Council 2015). They are also important stakeholders in risk management as they often rely on water as a business input (Fraser Basin Council 2015). Environmental non-governmental organizations and watershed conservation groups can also play an important role in community outreach, advocacy, environmental monitoring, and restoration as they advocate for the protection of water resources, the environment, and public health. Lastly, academic institutions may play a key role in water management by conducting relevant research to inform decisions and educate professionals and policy makers.

*The public*
Due to the “dramatic changes that water governance has undergone in Canada over the past decade,” governments are seeking greater involvement of citizens in decisions about water management (Hill). For instance, Alberta’s Water for Life Strategy uses a “shared governance model” and adopts an overall watershed management approach, which involves a multi-stakeholder partnership of government, industry, and non-government organizations (Alberta Water Council 2013). The strategy is one of the main vehicles for coordinating water management in Alberta and acts as a roadmap for government and its partners when taking actions related to water quality and quantity and environmental concerns (Alberta Water Council 2013). Similarly, Nova Scotia’s Drinking Water Strategy works with stakeholders to develop watershed management plans and nutrient management plans. Lastly, in Ontario, the Environmental Bill of Rights affords interested parties participation rights (Environmental Bill of Rights 1993) and appeal rights (Hill 2013) in the development and approval of water related legislation, standards, licenses and authorizations.
4.1.3 Legal management of a trans-boundary resource

Water’s dynamic, trans-boundary nature exacerbates this legislative complexity. While water crosses borders, legislation generally applies to a specific jurisdiction. This misalignment has the potential to aggravate disputes over the use and protection of water resources between political jurisdictions and undermine the effectiveness of one jurisdiction’s water management legislation (Alberta Water Council 2013). Along the same vein, regulators have difficulty capturing non-point source pollution, such as runoff from municipalities and farms (often from diffuse effluent sources), in legislation, which can make it difficult and expensive to implement effective control mechanisms (Alberta Water Council 2013). Additionally, local governments are often responsible for implementing regulations addressing non-point source pollution, but coordination and incentives amongst local governments can be difficult (Environmental Bill of Rights 1993).

Figure 6 depicts a fictitious example of how different guidelines and criteria that apply to different municipalities across a watershed can also create barriers for a coordinated management of resources to reduce risk. Harmonization of the various guidelines and criteria across the different municipalities would help to ensure that a consistent approach is taken when managing water systems. For example, municipalities in the upper part of the watershed need to understand the drivers and risks that threaten their infrastructure and how their activities put downstream municipalities at risk. With increased imperviousness, headwater municipalities need to ensure that adequate groundwater recharge occurs and groundwater supplies are maintained to reduce the risk of not being able to meet the demand for drinking water. If they do not maintain the water balance, downstream municipalities may be at risk of not being able to meet assimilative capacity targets due to reduced base flow.
Figure 6: Varying guidelines and standards across different municipalities within a watershed. Source: CVC

The challenge of water management integration is not new. In fact, the federal government attempted to address the need for coordination with respect to water in 1987 through the Federal Water Policy. It was created to address the management of water resources by facilitating a supportive federal government that enabled the different agencies and departments, other orders of government and industry to fulfill their responsibilities (Environmental Bill of Rights 1993). However, the policy was never implemented and is of limited relevance today (Eckstein and Hardberger 2008). The Canadian Council of Ministers of the Environment, an intergovernmental forum comprised of environmental ministers from federal, provincial, and territorial governments, has a mandate to develop national strategies, norms, and guidelines for water supply and sanitation and attempts to ensure integration across various bodies (Mandelker 1989). Lastly, the federal government, along with the Federal-Provincial-Territorial Committee on Drinking Water, has developed Guidelines for Canadian Drinking Water Quality; however, these guidelines are neither binding nor enforceable and only Nova Scotia and Alberta have fully adopted them (Mandelker 1989).
4.1.4 Legal issues associated with stormwater management

Since the legal risks associated with water and wastewater systems are well established, they are more or less understood. However, this is not the case for legal risks associated with stormwater management.

With increasing weather extremes, water damage has become the leading cause of property damage and insurance claims (KPMG, 2014). Class action lawsuits over basement flooding and damage due to sewer back-up; basement damage due to storm sewer blockage caused by heavy rainfall and property damage due to severe rainstorms causing flooding are becoming more widespread. Find more information in Appendix B.

Municipalities face many challenges with regard to stormwater management. Stormwater infrastructure has evolved considerably since the 1970s, but many older neighbourhoods still need retrofits to protect homes and businesses from the impacts of wet weather. Changes in weather conditions add further strain on municipal sewer systems as they are unable to cope with more intensive storms. Some of the challenges facing municipalities today include (Zizzo, Allan and Kocherga 2014):

- Lack of dedicated funding
- Lack of information on guidance
- Lack of pressure from leaders and decision makers to prioritize stormwater management
- Lack of authority to go beyond management standards
- Lack of understanding of legal obligations
- No prescribed “level of service” for stormwater systems

There are a growing number of related class action lawsuits against municipalities (Zizzo, Allan and Kocherga 2014). These lawsuits often focus on the municipal failure to mitigate risk and prevent damage.

Class action lawsuits are significant financial threats to municipalities and have already resulted in settlements related to flooding. One example is the precedent setting class action lawsuit brought forth by residents of the City of Stratford against the City of Stratford for flooding resulting from July 28, 2002. The mediated settlement provided compensation totalling $7.7 million for more than 800 home owners (Zizzo, Allan and Kocherga 2014).

The insurance industry

The Intergovernmental Panel on Climate Change (IPCC) has predicted that insurance companies may be forced to withdraw coverage in the casualty and property insurance sectors or face bankruptcy as a result extreme weather damage (IPCC 2012).

Canada is the only G8 country that does not have homeowners insurance for overland flood damage (Sandink 2013); however, flood insurance covers losses associated with sanitary sewer back-ups. As municipalities further investigate damages, they are beginning to better
understand how storm sewers and sanitary sewer systems can impact one another. For instance, in older neighbourhoods, the building codes that existed during their development may have allowed for cross connections between storm and sanitary sewers. With extreme weather events, storm sewer systems can be at risk of surcharging, making it easier for excess water to enter the sanitary sewer system, bringing it over capacity. When that happens, water can back up into basements.

Another scenario that poses significant risk is in older neighbourhoods where overland flow routes for the major system have been altered resulting in more water ponding on the streets. This scenario poses a significant risk to the sanitary systems, since water can enter through manhole lids. This contributes a larger volume of water entering the sanitary system, potentially increasing risk of sanitary sewer back, as well as flows entering the wastewater treatment plants. Aside from increased liability concerns, these larger volumes can result in higher treatment costs; and worse, it could contribute to bypasses that send untreated sewage into receiving watercourses.

The IPCC (2012) has stated that the insurance industry cannot bear the financial losses associated with climate change alone. If neighbourhoods are deemed “high-risk” areas they may no longer be eligible for insurance protection or the premiums may become cost prohibitive and the public could turn to government to recuperate losses through class action lawsuits.

4.2 Governance
As previously stated, governments are now seeking greater involvement of citizens in decision-making for managing risk to municipal water systems (Environment Canada 2015). To support citizen engagement, emerging trends show that governments have a growing reliance on economic instruments, partnerships, multi-stakeholder councils, and shared and collaborative governance.

Despite these trends, governments have retained their role as central actors. Generally, this creates a situation in which delegated responsibility does not correspond with decision-making authority. To ensure legislative fragmentation does not lead to governmental paralysis, a networking governance structure is imperative within the Canadian water sector.

4.2.1 Networked governance structure
A networked governance structure is a collaborative approach that includes multiple stakeholders that have decision-making authority. Properly structured, networked governance can address the challenge of jurisdictional and legislative fragmentation in the Canadian water sector. The authors of this chapter proposed that the steering or controlling of such a network is best achieved through a conservation authority model, as it exists in Ontario, operating at a watershed level. This model reflects the imperative for integrated water management across municipal boundaries, as well as for the adoption of the watershed as the de facto unit for water management and governance for municipal water systems. Water is a flowing resource that cannot be managed at a fixed jurisdictional scale. The watershed scale enables downstream and
upstream municipalities and other stakeholders to collaborate and come to agreements about efficient and effective solutions that mitigate risk.

4.2.2 Municipal decision making
Municipalities are responsible for implementing legislation and delivering services. At this level, lack of a holistic decision-making body further exacerbates fragmentation. Most current municipalities have planning departments managing land use and community development, while sewer, stormwater, and drinking water systems are handled by other departments. This dispersed management results in a complex patchwork of actors and policies that generally do not take the cumulative effects of managing land and water in silos into consideration.

In Canada, a single-tiered municipality or a two-tiered municipality can be responsible for water management. In a two-tiered municipality, the regional municipalities often coordinate area-wide service delivery to all local municipalities. Legislation assigns responsibilities to either upper-tier or lower-tier municipality. Both municipalities may provide these services exclusively or non-exclusively within their geographical boundaries. Regional municipalities are responsible exclusively for water production, treatment and storage; and non-exclusively for the collection of stormwater and other drainage from land.

Upper-tier and lower-tier municipalities must work collectively to manage risk by developing integrated water management solutions. To achieve a seamless integration between upper and lower-tier municipalities, governance structure and frameworks need to be revised and updated to incorporate policies that allow local governments to integrate their initiatives with federal and provincial plans. Find more on this subject in Appendix C.

In 2014, CVC, University of Guelph, McMaster University and Dalhousie University coordinated a National Consultation Workshop to solicit feedback about different approaches to water management. 75 representatives from municipalities, provincial ministries, post-secondary institutions, conservation authorities and consulting firms participated. Graphs seen throughout this report are based on participant responses from the workshop.
4.2.3 An inter-jurisdictional approach to managing risks

Ecological boundaries—such as watersheds and subwatersheds—underline the importance of governance systems that coordinate decisions across political boundaries.

Figure 7 shows that most National Consultation Workshop participants supported the involvement of conservation authorities or watershed planners, municipalities, and the province in decision-making processes for integrated inter-jurisdictional approaches to water management.

Question: What governance structures and/or policy reforms could improve the integration of inter-jurisdictional water management? What would the decision maker complement look like?

Figure 7: Recommendations on decision making governance structure based on 2014 National Consultation Workshop. Source: CVC

4.2.4 Components of successful network governance

As part of an effective network governance structure, the One Water approach can help address hierarchical institutional arrangements, while adaptive management (AM) can assist with addressing the need to make decisions in an environment of uncertainty. The One Water approach provides a governance platform which allows for multiple-actor decision-making processes at watershed scales, while AM enables decision making in the face of uncertainty where policy is shaped through continuous feedback loops that create systematic experimentation and learning.

With a network governance structure, municipalities and stakeholders are still able to fulfill their water resource responsibilities with the added benefit of being able to have an integrative approach to problem solving. Networked governance can leverage distributed capacities brought by different actors who can contribute their unique skills and resources to generate creative, collaborative, and complete solutions. However, network governance structure may be
limited in effectiveness by hierarchical institutional arrangements and decision-making amidst an environment of uncertainty.

Many parties representing several interests can make solving challenges a complex process. However, as Figure 8 demonstrates, the 2014 National Consultation Workshop participants consistently identified public consultation, shared discourse, and mutual understanding as high priorities for effective governance with many stakeholders. Without these components, participants noted, leadership, resources, and other attributes would make networked governance less successful.

Question: What are the components of the proposed model governance structure?

![Pie chart showing components of successful network governance]

**Figure 8: Components of successful network governance. Source: CVC**

As Figure 9 shows, participants from the 2014 National Consultation Workshop also prioritized the following three options for better-integrated water management:

- Creating a municipal water utility to operate all water systems under one roof
- Coordinating municipal water plans and projects
- Jointly advocating for provincial policy and regulatory changes to reduce legal barriers.
4.3 Recommendations
The first step for the federal government is to revive the 1987 Federal Water Policy to support interprovincial integrated water management. One example of a related success is the Canada-wide Strategy for the Management of Municipal Wastewater Effluent, an initiative of the Canadian Council of Ministers of the Environment (Cook, C.L. 2011). Institutions such as CCME and the Federation of Canadian Municipalities are instrumental in developing and championing overarching policy frameworks.

At the provincial level, policy frameworks already exist and can form the building blocks for coordinating and integrating framework across the province. Within provinces, to address overlapping legislation and conflicting departmental mandates, legislation should clearly state priorities. For instance, in Quebec, the Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains under the Environmental Quality Act, invites communities to prepare and submit watershed management plans but explicitly states that the provisions of the Forest Act take precedence over such plans (Hill,xxxx). Similarly, under Ontario’s Clean Water Act, drinking water receives privileged protection over other uses or regulations.¹

The examples discussed above are attempts to ensure integration; however none of the past or current attempts led to efficient and effective integrated water management.

Overcoming the challenges presented by existing legislation and the jurisdictional fragmentation of responsibility is best overcome by a networked governance structure where all those with

¹ Hill at p. 325.
decision making authority are involved in making informed decisions on a scale appropriate to
the dynamic, trans-boundary nature of water – a watershed scale. It is proposed that the
steering or controlling of such a network is best achieved through a Conservation Authority
model, as it exists in Ontario, operating at a watershed level. This reflects the imperative for the
water sector to integrate across municipal boundaries and for the adoption of the watershed as
the de facto unit for water management and governance for municipal water systems.

This section is a summary of research carried out by University of Toronto & Laura Zizzo Allan
Demarco. For more information, review Appendix B and Appendix K.
Watershed planning is another tool available to municipalities looking to manage their risk when transitioning towards a One Water approach to water management.

Municipalities across Canada recognize the value of watershed planning. In Ontario, for instance, where the *Conservation Authority Act* has been in place for more than 60 years, watershed planning is a fundamental tool that informs land-use planning.

Today, watershed planning has taken two very distinctive paths. Conservation authorities and similar organizations have participated in traditional watershed/subwatershed planning that focuses on improving and maintaining environmental health. Developers and municipalities have focused on a subwatershed planning process that focuses more on development. The differences between these two approaches are significant. Where traditional subwatershed planning has focused on the fundamentals of managing cumulative effects, increasing natural cover, and managing stressors, development-driven subwatershed planning has focused on determining servicing needs and understanding development constraints.

Municipalities use additional planning strategies, including servicing and settlement plans, master plans, and community improvement plans. These types of land-use planning tools are limited by municipal boundaries but play an important role in how water, wastewater, and stormwater management systems are serviced.

As the Legislation and Governance section discusses, watershed and subwatershed boundaries introduce an optimal approach for integrated water management. In fact, respondents from the
2014 National Consultation Workshop agree that integrated water management must involve conservation authorities (or watershed planners), municipalities and the province in the decision-making process, and they should plan based on the biophysical context of the area (see Figure 10 below).

Consultations completed with stakeholders during the 2014 National Consultation Workshop showed a growing concern that traditional land-use planning often results in costly and difficult remedial actions and often lacks consideration for environmental capacity. Integrating watershed and subwatershed planning with municipal master planning process can help to bring environmental concerns to the forefront.

**Question:** Based on the watershed planning process presented, could your municipality implement this proposed approach?

![Figure 10: Support from practitioners on the watershed planning process. Source: CVC](image)

**5.1 Proposed next steps for watershed planning**

Watershed and subwatershed planning tools provide essential information on ecological attributes and functions within a watershed. Incorporating this information into the municipal master planning process can help municipalities’ better address environmental impacts from urbanization and make more informed decisions.

The following section outlines an approach that Canadian practitioners at the 2014 National Consultation Workshop supported as one of the best means of integrating municipal and watershed planning. This efficient approach provides a bridge from traditional approaches and offers consistency in the planning process.
5.1.1 Watershed and subwatershed plans

Typically, watershed management plans are environmental planning documents developed on a watershed basis (> 1,000 km²) that characterize major environmental features and functions of a river watershed or lake basin. They also propose management strategies and implementation activities. Watershed management plans include strategies focused on environmental and land use issues at a watershed scale. These strategies are often linked to municipal official plans, which set out the objectives and policies that are used to guide development. Ideally, official plans should contain goals and targets that align with broader watershed management strategies. Similarly, subwatershed management plans are documents that define environmental features and functions at a finer scale than watershed plans, typically 50 to 200 km².

While watershed plans provide watershed-wide policy and directives that aim to provide guidance to upper-tier and lower-tier municipalities, subwatershed plans provide further detail to address local environmental issues to guide lower-tier municipalities.

The watershed planning process is an adaptive management approach to land use planning and as such is an on-going planning process. Monitoring to test assumptions and assess how well management solutions are working is important and fundamental to the process. Monitoring results can be used to update and refine management solutions in the future and also feed into master planning process.

The goals and objectives developed for the subwatershed will influence the choices that municipalities and agencies make about the area. Study findings also allow the public to share input and track progress.

5.1.2 The municipal master planning approach

Municipalities prepare several master plans for infrastructure, including master servicing (water and wastewater) and drainage (stormwater). Master plans are usually developed in conjunction with land-use plans and policies such as strategic plans. They guide and support official plan reviews, development charge bylaw reviews, growth-related planning strategies, the preparation of capital works and operating budgets, and the final design of the preferred solutions.

Master plans generally follow a study process with multiple phases and are similar to the watershed/subwatershed planning process. This is usually conducted through the Class EA process that has 5 phases:

1. Identify problem opportunity
2. Identify reasonable alternative solution

CVC is currently developing a guide for completing an integrated stormwater master plan to be released in 2016.
3. Identify alternative methods of implementation for preferred solution
4. Compile all relevant study into an environmental study report
5. Implementation and monitoring.

Master plans are completed within municipal boundaries and typically do not integrate water, wastewater and stormwater. This is likely due to the division of responsibilities between upper tier and lower tier municipalities. They also do not typically include the capacity of the receiving system to withstand the cumulative impacts of changes to land use. Traditional master plans do not take into account the issues that may be occurring outside of the municipal boundaries as part of the planning process, and typically they do not consider watershed targets. However, these traditional practices are slowly changing, as more municipalities are starting to look at the needs of the watershed during the planning process.

5.1.3 Sustainability Plan
Conservation authorities typically carry out watershed and subwatershed management plans, while municipalities undertake master plans. As outlined earlier in the section, watershed and subwatershed studies focus on aspects within the geographic boundaries of a watercourse drainage area. Master Plans focus on performance and capacity municipal infrastructure within a municipal boundary, such as sewer infrastructure. The master plans that result from this approach tend to be centred on infrastructure, consisting primarily of storm and combined sewer systems, and end-of-pipe facilities. The 2014 National Consultation Workshop revealed that municipalities are focused primarily on managing tablelands. Often the watercourse is outside the responsibility of the municipalities.

Sustainability plans are the proposed approach to develop an integrated management framework for municipal water systems including drinking water, wastewater and stormwater systems. As shown in both Figure 11 and Appendix D, the integrated plan combines the watershed/subwatershed plans with the municipal master plans for drinking water, wastewater and stormwater.

To assist with successful sustainability plan delivery, stakeholders, practitioners and survey participants from the National Consultation Workshop have identified the need to develop targets specific to in-stream needs that municipalities can adopt to dictate servicing needs. The majority (81%) of the 2014 National Consultation Workshop participants agree or strongly agree that watershed targets can help establish infrastructure targets (see Figure 11 below). As well, practitioners identified the need to re-define stormwater as a resource to improve its management. In the same respect, practitioners identified the need to begin using the right water for the right needs. For example, many resources go into making water potable, but a significant amount of that water is used for flushing toilets, which does not require treated water.
Question: Can setting up watershed targets assist in setting infrastructure targets?

![Pie chart showing responses to the question:]

- **Strongly Agree**: 45%
- **Agree**: 36%
- **Maybe**: 3%
- **Disagree**: 2%
- **Strongly Disagree**: 14%

Figure 11: National Consultation Workshop respondents agree that watershed targets could inform infrastructure targets. Source: CVC

### 5.2 Recommendations
Feedback from the National Consultation Workshop indicated that watershed targets should include both water quality and water quantity, reflect the capacity of the natural environment, and consider climate change. Many municipalities set targets for stormwater that include flow and water quality. However, they often neglect setting targets for the natural environment and natural-based practices such as green infrastructure, stream naturalization, or enhanced natural heritage systems. Targets should be set in collaboration between conservation authorities/watershed planners and municipalities.

Despite the challenge of doing so, participants agreed that the Province should set and enforce targets.

This section is a summary of research carried out by Credit Valley Conservation Authority. More information can be found in Appendix D.
Asset management plans (AMPs) are the third tool in developing a One Water approach. AMP’s are intended to provide the basis for lowering infrastructure renewal costs, extending asset life, and ensuring funding for sustained growth by identifying efficiency gains, cost avoidance and cost effectiveness. A standardized overview of asset management (ISO 55000), provides guidance regarding establishment, implementation, maintenance and improvement was developed in 2014 (see The Woodhouse Partnership Ltd. 2014). However, standards for asset management are not currently enforced in Canada. Appendix E contains additional information regarding advanced asset management pertaining to water, wastewater and stormwater infrastructure. While the desired strategies and data for AMP are available, implementation is challenging. A large amount of data is needed to properly characterize the risks to infrastructure performance.

The overarching goal of all AMPs is to maintain an acceptable Level of Service (LoS) at the lowest life-cycle cost while concurrently operating with an acceptable level of risk. The framework for implementation of an AMP is based on five core issues:

1. Current state of assets
2. Level of service
3. Critical assets
4. Minimum life-cycle cost
5. Long-term funding plan

One of the most challenging of these issues is the determination of current asset state. Data are needed to characterize the condition of an asset and allow assessment of risk. Condition assessments to characterize risk typically consist of four stages (Sangster, 2010):
1. Information review and the identification of knowledge gaps
2. Evaluation of consequence/risk of failure
3. Evaluation of options for asset inspection
4. Definition of current asset condition

This chapter provides an overview of some of the issues of risk implementation of AMP’s. More details are provided in Appendix E.

6.1 Condition assessment and defining the level of service
The Province of Ontario requires any municipality seeking provincial capital funding to provide a detailed AMP indicating how any proposed project falls within it. However, development of an accurate and comprehensive AMP requires detailed data pertaining to water, wastewater and stormwater infrastructure, which many municipalities do not have. A 2012 survey of 346 Canadian municipalities demonstrated a substantial need for improved data assembly. Specifically, the survey indicated 41% of municipalities had no data on the condition of their water distribution pipes; 48% had no data on water transmission pipe condition; 33% had no data on their wastewater linear assets; and 53% had no data on their stormwater linear assets (CIRC 2012). Many municipalities use purely age-based assumptions of asset condition. This lack of available information on the current condition of infrastructure poses a significant barrier to system integration.
Question: What do you consider to be the top three barriers to implementing advanced asset management practices in Canada?

Figure 12: National Consultation Workshop participants identify barriers to implementing an advanced asset management practice in Canada. Source: CVC

Figure 12 shows feedback from the 2014 National Consultation Workshop and indicates the top three barriers to implementing an advanced asset management practice in Canada:

- Lack of adequate data required for analysis and planning;
- Difficulty developing useful service-level measures and targets; and
- Complexity, effort and cost of implication.

Age-based rate of deterioration curves are less accurate than information that can be attained from emerging technologies such modular robotic inspection, electromagnetic inspection or parameter-based procedures using data mining such as those described in Harvey & McBean (2014; 2014a). However, these more advanced methods of asset assessment are typically perceived as having high associated costs and cost uncertainty. The cost of localized assessment and rehabilitation is on average only 5% of the cost associated with complete replacement (Steffens et al. 2012). Basing rehabilitation and replacement decisions solely on infrastructure
age may result in the misallocation of funds to replace assets that have useful life remaining. An improved basis for risk characterization has considerable merit.

The most common type of defect in water distribution systems is pipe leakage due to structural damage or faulty connections. More than 8% of water mains in North America are beyond their useful life (Folkman 2012). Pipe failure results in an array of consequences, including increased operation and maintenance costs; decreased hydraulic capacity; contaminant ingress; potable water egress; and damage to surrounding infrastructure. Seventy percent of respondents in the first Canadian Municipal Infrastructure Survey indicated that reducing leakage and leaks, and improving water quality are critical or very critical (CATT 2014). Leaks from large-diameter water transmission pipelines make up less than 5% of the total number of leaks in a system, yet account for more than 50% of the total water being lost due to leaks. Therefore, municipalities tend to focus leak detection and condition inspection on the largest diameter pipes in their system. For detailed information, please refer to Appendix B.

Determining the condition of linear sewer assets typically buried underground is more difficult due to the fact that these assets are “out-of-sight and out-of-mind.” Municipalities commonly employ closed-circuit television (CCTV) to evaluate the interior condition of sewer pipes. Although CCTV technologies provide valuable information, they are expensive and time-consuming. As a result, only small sections of the overall system are evaluated and significant portions of assets remain uninspected, generating unknown risk. Additionally, CCTV technologies often miss defects that are hidden from the field-of-view by obstructions and are incapable of imaging below the water line.

Compounding the issues associated with asset management and condition inspection are the influences of urbanization and climate change. Urbanization and corresponding land developments result in decreased groundwater infiltration and increased demands on stormwater conveyance. In addition, increased population density places greater demands on both water and wastewater infrastructure. Determining the level of risk requires the determination of the required level of service and the identification of critical assets (key stages in implementing effective AMPs); and is predicated on estimations of future conditions. Level of service is typically developed based on financial, environmental, and community/organizational objectives. Quality, capacity, reliability, and cost are all issues that must be considered when managing risk. However, it is difficult to formulate precise levels of service due to changing climate and its effects on water, wastewater, and stormwater infrastructure.

6.2 Tools for integration
This section describes some of the tools that may assist municipalities in achieving effective integration:

**Identifying key drivers of risk**
Clearly, there are many risks associated with municipal water. In response, it is necessary to look at the key drivers creating these risks. This will help to focus on how to manage these risks. The
The top drivers of risk, as identified in Chapter 3, are population growth and urbanization; aging infrastructure; and climate change. Survey respondents from the National Consultation Workshop not only identified the above as the drivers of highest priority, but also expressed the need for an integrated approach to the management of these risks. For instance, higher intensity storms as a result of a changing climate must be considered in tandem with changing surface cover when designing stormwater management systems.

Creating effective data sharing
Data sharing is a key to attaining integration. It can be achieved by improving communication between various municipal departments/employees which rely on, and update, similar information. Geographic Information Systems (GIS) are now being widely implemented, allowing for efficient sharing of asset information (condition, capacity, location, etc.) between different divisions of city employees. An effective GIS platform provides an enormous advantage in terms of information availability and is key to understanding the magnitude of risks. GIS improves access to a wide range of information which allows water managers and regulators to better coordinate the development and management of water, land and related data sources, and avoid the ‘pillar’ mentality of assembly of information.

Improved asset management software
Software programs for asset management of buried infrastructure have made enormous gains in recent years, providing improved mechanisms to understand the current infrastructure risks that exist in a community. Thirty-one percent of all municipalities in Canada currently rely strictly on expert opinion when evaluating asset condition (determined based on age, estimated degradation, and observed failures), with no visual or structural inspection (FCM 2012). Without available information, the extent of risk cannot be established (Harvey et al. 2014; Harvey and McBean 2014(a); Ahn et al. 2005). Lack of maintaining assets and absence of data to allow for effective prioritization initiatives under constraints of limited budgets indicates there is limited ability to respond/prioritize to manage the risks in the assets (Harvey and McBean 2014(b)(c)(d)).

Assembly of information using tablets and software
Efficient mechanisms of information assembly and uploading are not being used to the extent that is needed. The use of tablets or any other portable communication technologies allows municipal workers to remotely search and update central information storage to ensure municipalities have the most accurate knowledge about conditions of assets. Having the public report infrastructure failures via Twitter or other social media is another option.

Directed focus on information available online
Being able to effectively identify key documents on the Internet is essential to understand how various governments (municipal, provincial, federal) are proceeding with asset management planning. Access to the most effective strategies to help municipalities understand risks and to integrate the management of these risks into day-to-day activities is essential. A specific tool –
The Water Utility Risk Integration Matrix, described in Chapter 3, provides direction to specific types of references to the technical literature.

**Collaboration, partnership, policy options and constraints and legal implications**
Understanding constraints, implications, opportunities and pitfalls are essential in gaining an understanding of how to integrate risk management. Hard data is required, as informed decisions cannot be made on instinct and educated guesses alone. High costs and duplication of data collection can be avoided by municipalities working together and collaborating to gather asset management data.

### 6.3 Adapting to Climate Change
As described in previous chapters, increasing temperatures and growing intensity of precipitation are elevating risks to water, wastewater, and stormwater infrastructure. Elevated temperature increases domestic water consumption patterns, and consequently increases the demand for potable water and distribution capacity, and larger quantities of sewage (See Appendix F). More intensive rainfall events lead to larger volumes of stormwater runoff, and increase the risk of water backup into basements. Early snowmelt in conjunction with heavy rainfall may result in increased risk of catastrophic flooding, which results in death and injury, damage to roads and buried infrastructure, contamination of source waters, and municipal service disruption.

Aging municipal infrastructure exasperates the risks driven by climate change and urbanization. In neighbourhoods with combined sewers, a cracked sanitary sewer pipe will release more hazardous material when flow is at a maximum. A clogged storm sewer is more likely to overflow when conveying stormwater at full capacity. Climate change and urbanization influence required levels of service and therefore necessitate the implementation of advanced asset management.

Many municipalities within Canada have communicated their concern with regard to flood risk and the need for access to regional and local climate projections. In Figure 13, results from 2014 National Consultation Workshop show that municipalities need guidance on updating floodplain maps and intensity-duration-frequency (IDF) curves, as well as toolboxes for evaluating adaptation strategies.

**Question:** In which of the following areas associated with climate change would further research and guidance assist your municipality in infrastructure planning? Choose your top three priorities in order.
General Circulation Models (GCMs) and related tools have been developed in the scientific community to provide essential data about future climatic conditions (e.g. annual and monthly averaged temperature, precipitation). The interpretation of climate model outputs and use of this data for municipal infrastructure planning and management typically requires professional expertise in meteorology, statistics, modeling, and analyses. These requirements pose huge challenges for municipalities.

The Water Utility Risk Integration Matrix (Appendix A) introduces basic knowledge of climate projections, covering the tools and techniques of GCMs, downscaling, and scenarios resulting from climate change. This knowledge can help municipalities to collect and make use of climate projections from databases provided by a variety of organizations.

It is important to understand that GCMs are only accurate with regard to the assumed emission scenario, and all climate projections have considerable uncertainties in their projections. Improved understanding of the uncertainties present within these estimates and variations between models and scenarios is necessary to produce defensible solutions in municipal infrastructure planning and management.
Identification of vulnerable components in municipal stormwater systems usually involves the use of IDF curves and floodplain maps. IDF curves serve as a medium between historical rainfall records and the design of minor stormwater drainage systems (e.g. roof leaders, foundation drainage, gutters and underground pipe systems). IDF curves are statistical characterizations of historical rainfall records and reflect the rainfall intensities that can be expected with a given possibility of occurrence, for different rainfall durations. Floodplain maps delineate areas that will be submerged during high river flows.

IDF curves and floodplain maps are likely to change under changing climate conditions. Case studies have demonstrated increased rainfall intensities (Amec 2012; Finnis 2012; Jakob and Lambert 2009; Ouranos 2008; Srivastav et al. 2014) and increases in high flow and flood extent (Turkkan et al. 2011; Laforce et al. 2011). Using updated IDF curves and floodplain maps, possible failures in municipal infrastructure can be identified and actions can be taken to reduce consequence and/or probability of failure.

To update IDF curves for future climate, rainfall records are simulated utilizing GCM projections, and then statistically analyzed to produce future IDF curves. An alternative approach is to predict statistical parameters directly from GCM projections, using regression or other techniques.

In addition to rainfall records, delineation of floodplain maps requires information such as snowpack regimes of snowmelt, rainfall runoff relationships, time of concentration, river routing, and river morphology, which are all subject to change. Hence risk, in accordance with climate and land-use changes. Therefore, updating floodplain maps requires projections of both future climates and land-use evolution.

**Appendix F** provides case studies showing data and models applied to update IDF curves and floodplains, covering municipalities from British Columbia to Atlantic Canada.

Updated IDF curves and floodplain maps are based on climate change projections, which are uniquely applicable to specific greenhouse gas emissions scenarios. Therefore, multiple emission scenarios based upon different models with multiple runs are recommended. All model outputs must be considered as equally possible future conditions.

An enormous amount of guidance and information is available online to help municipalities implement strategies to adapt to changing climate. **Appendix E** provides a list of useful resources and tools relevant to Canadian users that help municipalities in finding solutions pertinent to their local management and philosophy.

Climate change adaptation strategies need to be evaluated under the framework of integrated risk management. The risks driven by climate change pose cascading effects on all water infrastructures, such as pollution intrusion to groundwater that is under the direct influence of surface water during high flows, water borne diseases outbreaks, backup of sewage into homes,
etc. The Water Utility Risk Integration Matrix summarizes a comprehensive analysis of drivers and risks between infrastructures.

This section is a summary of research carried out by University of Guelph. For more information see Appendix E.
7 Integrated Risk Assessment

Integrated risk management is the next tool that can help us determine the complex risks that threaten current water infrastructure. The complexity of these risks is expected to impact a municipality’s ability to meet the required levels of service for all water, wastewater, and stormwater services to varying degrees. Municipalities will need to understand how their infrastructure is vulnerable to climate change, aging, and population growth. Identifying the components of infrastructure within a system that are highly vulnerable to these risks enables municipalities to develop cost-effective engineering, operations, and policy solutions (e.g. see Tran et al. 2008). To ensure sustainable future delivery of water services, municipalities will need to participate in risk assessments that reflect a watershed scale approach. This will help municipalities to understand how to integrate risk management.

Infrastructure provides a vital service to society and its safety, reliability and economic viability are extremely important. The financial consequences of asset failure and loss of service due to repairs, insurance claims, and disruption is costly and the financial liability is potentially substantial. The example in Figure 14 illustrates the costs associated with a failure of water infrastructure on Finch Avenue in Toronto. The cost to replace the failed culvert was less than 1% of the total costs associated with that culvert’s failure. Further insights into the case for fixing leaks are provided in Centre for Neighbourhood Technologies (2013).
7.1 Barriers and challenges
In Ontario, the Ministry of Economic Development, Employment and Infrastructure’s Building Together: Guide for Municipal Asset Management Plans highlights the management of risk as part of an asset management strategy. It requires the evaluation of an asset based on its potential risks through comparative analysis. Risks of each asset are scored based on both quantitative and qualitative measures. Similar guidelines across other provinces can promote a sustainable adaptation mechanism for risk vulnerabilities.

The lack of research on reducing risk failure to stormwater assets is another barrier to integration. Figure 15 indicates the response on research barriers from participants at the National Consultation Workshop.

Question: In the future, which infrastructure will require the most research to reduce the risk of failure due to climate change, aging infrastructure and/or urbanization?
Considering risk at the watershed scale provides a holistic approach to stormwater management and interacting assets. For example, the City of Calgary completed a risk assessment in 2011 that identified forest fires as a threat. With climate change causing drier temperatures, forest fires will be a factor to consider, as well as their potential impact to source water quality. This highlights the need to incorporate the interdependency of the ecosystem into the holistic approach to risk assessment.

While many municipalities can recognize the importance of risk assessments, conducted them can come with its own set of challenges. Figure 16 shows feedback from the participants at the National Consultation Workshop on the barriers that municipalities face in conducting risk assessments.

**Question:** What do you consider the top 3 barriers to conducting a risk assessment of the infrastructure in your municipality/organization?

![Bar chart showing the top 3 barriers to conducting a risk assessment.](image)

**Figure 16: Barriers inhibiting completion of risk assessment. Source: CVC**

The responses in Figure 16 indicate that significant shifts required addressing risk and vulnerability faced by municipalities.

The Canadian Infrastructure Report Card (CIRC) from 2012 indicates that most water infrastructure is in fairly good condition. However, these data are merely snapshots of the conditions of the assets. The CIRC also found that asset management is, and will continue to be, a critical activity to maintain and improve levels of service under the financial constraints that
municipal governments experience. As a result, the Report Card partners issued an Asset Management Primer in September 2013. In the context of risk management, the Primer indicates:

“Understanding and managing the risks associated with the failure of an asset is a key element in many AMPS. The risks in municipal infrastructure are impacted by the physical condition of the asset and the social, economic and environmental consequences that would occur if the asset fails to provide the service for which it was designed.” (Canadian Infrastructure Report Card- Asset Management Primer 2014)

A sound asset management plan can establish the exposure and sensitivity of infrastructure to threats.

### 7.2 Risk management framework

Once you know the physical condition of your water, wastewater and stormwater assets, it is important to then understand the vulnerability of the infrastructure to risks such as climate change. It is also important to understand how the different infrastructures can impact each other. Risk management framework can help to accomplish this.

ISO 31000 (see Figure 17) is a risk management framework that provides principles and process for managing risk. It can help organizations increase the likelihood of achieving objectives, improve the identification of opportunities and threats, and effectively allocate and use resources for risk treatment.

![ISO 31000 Risk Management](https://example.com/iso31000.png)

**Figure 17: ISO 31000 Risk Management. Source: ISO**
7.3 Tools for assessing the vulnerability of water infrastructure

There are many tools that can help municipalities further assess the risks and vulnerability of their water infrastructure. Each tool is unique and addresses a range of risk-associated concerns. This section will focus on some of the most useful tools available for assessing risk and vulnerability.

7.3.1 ICLEI Changing Climate, Changing Communities Framework

The International council of Local Environment Initiatives (ICLEI) has developed a milestone framework - Changing Climate, Changing Communities - to guide local government practitioners through a process of initiation, research, planning, implementation and monitoring for climate adaptation planning. This five-step process (see Figure 18) is supported by an online interactive tool, Building Adaptive and Resilient Communities (BARC), which is designed to assist communities in adapting to the impacts of climate change through the development of a Municipal Climate Change Adaptation Plan. This process can be applied at various levels within a community or municipality:

- At the single sector or department level
- For a municipal operations plan covering all departments
- For a community wide plan with multi-stakeholder, community involvement
- Community driven for a vulnerable sector within a municipality (e.g., residents from a flooded area)

Figure 18: ICLEI’s five-step milestone framework. Source: ICLEI, 2011.
The Atlantic Climate Adaptation Solutions Association produced a guidance document and workbook called *7 Steps to Assess Climate Change Vulnerability in Your Community*, which is an example of the ICLEI framework being applied.

1. Identify the types of climate and weather-related issues that have affected your community;
2. Locate where these issues have occurred or could occur in your community;
3. Assess what infrastructure has been or will be impacted;
4. Identify the residents who have been or will be most affected as well as those who can provide assistance in the community;
5. Assess which economic sectors have been or will be most impacted by the issues;
6. Identify how the natural environment has been or will be affected; and
7. Determine the best ways to address the issues identified.

The workbook produced for Newfoundland for example, includes climate (current, future predictions) information as well as expected trends and impacts from, for example, precipitation (intensity, frequency), temperature (average, extremes) and sea-level rise.

### 7.3.2 Residential Basement Flooding Vulnerability Assessment Tool-Municipal Risk Assessment Tool (MRAT)


MRAT focuses on basement flooding risks, and more specifically on mapping areas vulnerable to flooding within a city. The tool collects data from municipal infrastructure (inventory and condition), land use, current and future climate, and insurance claims. Using the traditional definition of risk, a formula considers the probability of climate events occurring in addition to the exposure and vulnerability. The formula produces a result indicating the susceptibility of infrastructure failure.
7.3.3 Engineers Canada- Public Infrastructure Engineering Vulnerability Committee Protocol

Engineers Canada, with support from Natural Resources Canada (NRCan) created the Public Infrastructure Engineering Vulnerability Committee (PIEVC) in 2005 to address engineering concerns in regards to infrastructure risk related to climate change impacts. In 2008, PIEVC created a protocol to guide engineers working with other professionals to assess the vulnerability of infrastructure and develop adaptation solutions. The protocol helps assess vulnerabilities in several related areas, such as planning, operations and maintenance of infrastructure.

The protocol is a five-step process that systematically reviews historical climate information and projects the nature, severity, and probability of future climate changes and events. It also establishes the adaptive capacity of an individual infrastructure as determined by its design, operation and maintenance. It includes an estimate of the severity of climate impacts on the components of the infrastructure (i.e. deterioration, damage or destruction) to identify higher risk components and the nature of the threat from climate change impacts. This information can be used to make informed engineering judgement on which components require adaptation, as well as how to adapt them (design adjustments, changes in operation or maintenance).
Engineers Canada has completed the initial development and testing of a Triple Bottom Line Decision Support Module, an extension of the PIEVC protocol. This tool evaluates adaption recommendations from the protocol using analysis that includes social, environmental and economic factors. This module is an additional tool to complement the protocol (as seen in Figure 20).

Feedback from participants at the National Consultation Workshop suggests that very few municipalities have used the tools from ICLEI, IBC, and PIEVC for risk assessment. This highlights the need to promote these tools and raise awareness about the importance of risk assessment. There are several tools and methodologies to assess risk that are not explored in this chapter. Figure 27 shows other risk assessment tools and methodologies, as well as their capabilities.

Review of Tools for Assessing the Vulnerability of Watersheds

A report to the Canadian Council of Ministers of the Environment (CCME) Nelitz et al. (2013) provides examples of when vulnerability assessments are useful, including:

- Providing insight into the actions needed to prevent loss of life, damages, or disasters.
• Understanding vulnerability as a prerequisite for developing adaptation policies that promote equitable and sustainable development.
• Anticipating where impacts may be greatest at a Canada-wide scale, setting priorities for regional assessment of climate change impacts and adaptation strategies, and monitoring climate change effects.
• Understanding the economic costs to communities and infrastructure due to extreme weather events (for example the costs from extreme weather events in Canada from 1996-2006 were greater than for all previous years on record combined).
• Developing policies and adaptation plans for vulnerable areas, sectors, groups, etc. as well as reducing climate change risk.

The authors use the standard definition of risk in describing the vulnerability of watersheds, which comprises, as illustrated in the figure below:

• Potential impact: exposure (to the hazard) and sensitivity (of the element to the hazard)
• Adaptive capacity

![Diagram of Watershed Vulnerability Assessments](image.png)

Figure 21: Elements of Watershed Vulnerability Assessments (after Neiltz et al., 2013)

The location and timing of a vulnerability assessment will be affected by the availability of sufficient expertise, time, and financial resources. It was also found that indicators are used in some form in most vulnerability assessments.

Throughout the literature, indices and indicators are often synonymously called themes, components, or sub-indices (index) and proxies (indicators). In their review, Nelitz et al. (2013) define an indicator as a single measure of a characteristic (e.g., water temperature), the units of which can be described by a particular metric (e.g., annual maximum temperature). An index is defined as a composite, or aggregate, measure of several indicators or indices. These terms are used even though they may not be consistent with the language of the original studies. They provide key considerations when identifying and selecting indicators, which include:

• Appropriateness and relevance to dimension of interest;
• Transparency (not too complicated, should be repeatable);
• Feasibility (considering cost of data collection and time availability); and
• Size and composition of each indicator (absolute vs. relative values, areal measure, etc.).

The tools in the report were selected to be representative of a broad range of water resource issues, data needs, and technical capabilities. They are varied and range from indicator-based approaches to sophisticated hydrological models that calculate exposure to flood events under future projections of climate change. They also range from qualitative to quantitative approaches that address a broad range of characteristics of social-ecological systems.

Figure 22: Capabilities and focus of relevant tools and reports. Source: WINA Report - When the Bough Breaks; Nov, 2014.

7.4 Sustainability Rating Tools
Sustainability rating tools allow municipalities to compare infrastructure solutions to see which ones offer the largest benefit. In general, sustainability rating tools include climate change risks to infrastructure and buildings as part the assessment. Some provide very basic methodologies on how to assess risks associated with natural hazards, including those from extreme weather. The International Federation of Consulting Engineers (FIDIC) produced the Sustainable Infrastructure: Rating and Certification Tools report in 2012 which summarizes an extensive international survey of these types of tools. The summary table is reproduced hereafter for convenience. In the Canadian infrastructure context, two rating tools seem to offer the greatest potential and are discussed in greater detail below: Envision (from the USA) and ISCA (from Australia) (FDIC 2012).
7.4.1 Envision™ Sustainable Infrastructure Rating System

Envision™ is the product of a joint collaboration between Harvard University and the U.S.-based Institute for Sustainable Infrastructure (ISI). It provides a framework for evaluating and rating the community, environmental and economic benefits of all types and sizes of infrastructure projects (ISI 2015). The tool evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle. Envision™ has assessment tools that can be used for infrastructure projects of all types, sizes, complexities, and locations. These tools include:

1) Checklists:
   - An educational tool that helps the user become familiar with the sustainability aspects of infrastructure project design. It can be used as a stand-alone assessment to quickly compare project alternatives or to prepare for a more detailed assessment.
   - Structured as a series of Yes/No questions based on the Envision™ rating system. It is organized into five categories and 14 subcategories.

2) Rating system:
   - Used by the project team to self-assess the project, or for a third-party, objective review.
   - Includes a guidance manual and scoring system.

An economic optimization tool, construction and O&M phase credits, and other stages of the Envision™ rating system are currently under development.

7.4.2 Infrastructure Sustainability Council of Australia (ISCA)

The ISCA rating scheme (see http://www.isca.org.au/ for details) was developed and administered by the Infrastructure Sustainability Council of Australia (ISCA). It is a rating scheme for evaluating sustainability across design, construction and operation of infrastructure. The ISCA rating scheme can be used to inform and assess most types of infrastructure including:

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<td>Bike paths and sidewalks</td>
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7.5 Recommendations

There are currently no case studies that highlight an integrated approach to risk management for all three water infrastructures at the watershed scale. Further work is needed to develop
case studies that highlight upper-tier and lower-tier collaboration in order to understand infrastructure vulnerabilities caused by climate change at a watershed scale.

Case studies should demonstrate how upper and lower-tier municipalities could collaborate on applying the protocol to identify adaptation recommendations that reduce climate impacts and mitigate risk for all three water infrastructures. These recommendations could take the form of integrating adaption measures into reconstruction or retrofitting projects that look at both grey and green infrastructure solutions. Or adaptation could be making changes in operation and maintenance practices that will extend the life of the assets. Further, recommendations can include identifying what adjustments to codes, standards, and practices are needed to account for future climate conditions. Through adaptation municipalities can lower the severity of climate change impacts.

While all the tools reviewed here provide valuable information for engineers, asset managers and decision-makers, the PIEVC Protocol has the engineering depth and breadth of application to help communities large and small adapt to a changing climate. The methodologies developed for risk assessments and climate change adaptation planning in the United States, Europe and Australia are all valuable, but may not be as affordable and timely as the PIEVC Protocol in engaging engineers who must work closely with other professionals to support the planning, operation, maintenance, management and use the infrastructure to benefit society. The results of a PIEVC Protocol assessment inform decision-makers to a level that is adequate to develop cost-effective recommendations that adapt the highest risk components to improve their resilience to climate impacts in ways other assessment tools may not. The use of the PIEVC Protocol in Canada has provided the opportunity to make recommendations concerning the review of selected infrastructure codes, standards and related instruments (CSRI) in light of the changing climate.

Finally, it is important to note that most, if not all methodologies for the assessment of infrastructure vulnerability to climate change, including those presented here, fit the general ISO 31000 Risk Management principles and framework. In the medium to long-term, compliance of all these methodologies with ISO 31000 would be a desirable outcome.

This section is a summary of research carried out in collaboration with Credit Valley Conservation Authority and Guy Felio from Engineers Canada. For more information, please refer to Appendix J.
Innovative green infrastructure technologies are practices that can be implemented using the one water approach. Currently, most municipalities make decisions about water resources separately from land-use planning. In fact, decisions on water, wastewater, and stormwater servicing are often made from the perspective of exclusive systems. While there has been progress in better managing water and wastewater assets at the municipal level, the integration of water, wastewater and stormwater has not been widely adopted. In fact, while most municipalities have established water and wastewater asset management plans, they have often overlooked stormwater infrastructure, even though poor management in this area could pose risks for water and wastewater infrastructure, not to mention liabilities for municipalities. As discussed in earlier chapters, aging infrastructure and climate change impacts exacerbate these risks.

8.1 Stormwater risks and impacts linked to drinking water and wastewater systems
This section highlights some of the potential risks associated with stormwater, its management, and its links to drinking water and wastewater systems.

In many areas, development and urbanization are changing pre-development surface conditions to predominantly impermeable surfaces, reducing the available areas for stormwater to infiltrate. From drinking water and wastewater perspectives, the effects of these reductions can include (after Konrad & Booth 2005):

- Reductions in the available community surface drinking water supply systems (e.g. reservoirs, lakes)
- Reductions in groundwater availability within drinking water wells
- Reductions in receiving water wastewater assimilative capacities due to streamflow reductions
- Loss of aquatic habitat due to streamflow reductions resulting in damages to overall ecosystem health.

Additionally, the transport of pollutants in urbanized catchments represents a concern for downstream environments, as well as drinking and wastewater systems. Common stormwater contaminants found in developed and developing watersheds include (after Klein 1979; Hamel et al. 2013; Wenger et al. 2009; WSA 2014):

- Total suspended solids (TSS)
- Nutrients (i.e. nitrogen, phosphorus)
- Organic pollutants (e.g., pesticides, hydrocarbons)
- Rubber and automotive fluids
- Particulate matter
- Trace metals (e.g., zinc, copper, lead)

Ultimately, the transport of these and other pollutants may result in eutrophication, fish kills, pollutant bioaccumulation in the food chain, and pathogen contamination leading to loss of recreational areas (US EPA 2003). These receiving water impacts also have the potential to affect risk and management of drinking and wastewater systems, including:

- Additional treatment requirements within drinking water systems as a result of reduced surface water quality
- Reduced assimilative capacity of receiving waterbodies, resulting in greater wastewater treatment requirements prior to discharge.

Conventional stormwater management approaches can also lead to additional receiving water concerns. Studies suggest that even minimal additions of impervious surfaces within a watershed have consequences for stream health (Klein 1979; Tillinghast 2012). Urbanized streams have been reported to have several differing characteristics when compared against non-developed watercourses, including ‘flashier’ responses to rainfall events, increased variability in flow rates, reduced base flows, and increased frequency of higher discharge events (Klein 1979; Konrad & Booth 2005). These differences lead to several consequences: high discharge velocities within receiving water environments causing significant downstream erosion and scour and mobilization of additional sediment, destruction of downstream fisheries habitats and ecosystems, and others.

Lastly, the increases in runoff flows and volumes due to urbanization of catchments and the use of conventional stormwater management techniques lead to additional inflows in combined sewer systems. These additional inflows have impacts on both receiving water environments and wastewater management systems, including:
8.2 Stormwater management approaches and risks

Stormwater management in both rural and urban developments has been a key responsibility of Canadian municipalities for more than 100 years. Over time, many municipalities have moved from combined sewer systems to dedicated stormwater management infrastructure, though several older municipalities across Canada (including Toronto) still have legacy combined systems. For systems both new and old, risk - as defined by the design considerations related to both probability of input phenomena and consequences to these inputs - is still the main concern in the design and implementation of any engineered stormwater management system. This section outlines conventional and green infrastructure stormwater management approaches.

8.2.1 Conventional stormwater management

The traditional approach for mitigating risks associated with stormwater management has been to minimize consequences to persons and property driven by significant, low-probability design storm rainfall events. By taking this approach, municipalities can address the consequences related to the rainfall events with the highest levels of catastrophic risks to people and property. However, the design of these systems do not often take into consideration the risks associated with frequent storm events that have to be handled throughout the year, which, if managed ineffectively, can create other issues.

Updated stormwater management and design guidelines prepared by some municipalities in Canada have shifted to address both quantity and quality concerns. That being said, these documents typically rely on design criteria related to the management of extreme precipitation events using a dual drainage stormwater management approach consisting of piped infrastructure in conjunction with overland flow management. The majority of stormwater systems in service in Canada are based on conventional stormwater approaches, which are focused on mitigating a single aspect of stormwater-related risk: peak flow management. However, municipal guidelines are beginning to incorporate additional considerations and criteria related to stormwater quality. For example, the City of Calgary has adopted criteria relating to TSS reductions, with additional criteria potentially forthcoming (City of Calgary 2011).

By incorporating water quality considerations into stormwater management requirements, updated stormwater guidance documents can support environmental protection and minimize impacts associated with impervious surfaces and pollutant sources. However, conventional stormwater approaches still prefer to collect and convey (rather than store and infiltrate); which means that pre-development hydrology is still affected by post-development, adding to potential risk.
There are also benefits of conventional stormwater systems. Stormwater professionals and contractors have collective experience in the design, implementation, and construction of these systems. There are extensive design guidelines based on years of experience, and these systems have been in place and successful in reducing risks from extreme precipitation events for several decades. Contractors are comfortable with construction techniques and requirements associated with these projects. Their experience and knowledge helps provide thorough checks against designs during the construction phase (Olorunkiya et al. 2012).

8.2.2 Green Infrastructure approaches and designs

Green Infrastructure are stormwater management systems and features in developed areas that emphasize drainage and conveyance characteristics that mimic pre-development conditions.

Although green infrastructure has been defined separately by different levels of government, academia, developers, and others, the following key points are relevant:

- Identification of stormwater as a resource rather than nuisance
- Maintaining natural hydrologic regimes
- Implementing infiltration-based stormwater management and source control features
- Minimizing site disturbances.

Strategies that use the same core concepts have been referred to by different names in other studies, such as low impact development (LID’s), best management practices (BMPs), source control practices (SCPs), sustainable urban drainage systems (SEPA 2014), and environmentally sensitive design (US EPA 2010). Many of these other definitions either share some overlap with the key concepts of the definition of green infrastructure given above, or represent components of the LID approach.

Some of the common LID features and designs for managing stormwater runoff include:

- Reduction of impervious surfaces through reduction of lane widths, the use of alternative construction materials (e.g., permeable pavement), and greening of minor traffic areas (e.g., residential back lanes)
- Implementation of infiltration-promoting bioretention and biofiltration areas, such as rain gardens, vegetative swales, and street runoff collection features (e.g., curb cuts to depressed traffic medians)
- Lot-scale stormwater management features, such as infiltration galleries and rain barrels
- Sub-dividing watersheds into smaller subcatchments with smaller and more distributed stormwater management features
- Reducing disturbances in new developments, keeping existing forests and vegetation.

Green infrastructure features can be implemented on a large scale at a site development level with a more integrated approach, but also as supplemental features to existing stormwater management systems. More information about specific green infrastructure features can be

The benefits of green infrastructure are well described in several documents published by both governments as well as in academia, such as US EPA (2012), City of Edmonton (2011), and ICF Marbek (2012). In general, green infrastructure features have been shown to reduce overland flows and stormwater quantity, improve stormwater quality, and benefit the health of downstream receiving waterbodies.

The following outlines the benefits of LID with a specific focus on issues within integrated water systems (e.g., drinking and wastewater):

**Stormwater quality and quantity:** As an approach that includes features and planning with a focus on the promotion of infiltration, the reduction of stormwater runoff generated by frequent storm events is a significant benefit of green infrastructure implementation. By storing and infiltrating these frequent storm events, a large percentage of the annually-generated runoff can be managed close to its source, reducing the burden on pre-existing, aging conveyance infrastructure. Although green infrastructure features are not intended to replace engineered flood-control structures designed for extreme weather events (US EPA, 2007), these design features help to reduce the severity of less extreme flood events due to the distributed conveyance methods used in many integrated water management programs. Additional benefits associated with increased infiltration of precipitation include maintenance of base flow levels in urbanizing streams, as well as a potential reduction in particulate loading associated with bed scour (Finkenbine et al. 2000).

One of the most significant improvements to stormwater quality as a result of green infrastructure practices relates to the corresponding reduction in stormwater quantities. Better infiltration correlates to a decrease in the amount of overland flow, resulting in decreased opportunity for pollutants to be collected and transported to receiving waters (US EPA 2007). Studies have also shown a reduction in common stormwater pollutant loadings in stormwater collected after exiting vegetative swales, permeable pavement areas, and other LID features (US EPA 2007). These and other water quality benefits allow a reduction in risk to downstream environments and potentially provide benefit in the protection of drinking water sources.

There are many other positive impacts to stormwater quality and quantity associated with green infrastructure, including increased groundwater recharge, pollution abatement, and greater availability of water to terrestrial flora and fauna within the watershed.

**Ecosystem health:** Green infrastructure practices have been shown to minimize negative impacts to stream health, and also to be potentially applicable in retrofits and redevelopments in heavily urbanized watersheds (Bernhardt and Palmer 2007).
8.2.2.1 Risks and Challenges for Green Infrastructure Implementation

Green infrastructure designs and concepts have been studied extensively for approximately 15 years. While conservation groups, academia, and other invested stakeholders have produced a significant amount of information and research relating to the benefits of proper implementation of green infrastructure features into stormwater management system designs, Canadian municipalities have been slow to adopt these approaches and technologies. Several potential barriers to the selection, design, and implementation of green infrastructure features have been identified in literature (CWAA 2011; Olorunkiya et al 2012, Primeau et al 2009; etc.), and generally include:

- Approvals and regulations not suited to implementing new technologies
- Minimal incentives for developers, from both lack of information and awareness in general public and minimal government pressure
- Risk associated with long-term maintenance requirements, including defining responsible parties
- Lack of supporting information in design guidelines to aid designers and streamline approvals;
- Construction and design inexperience
- Minimal municipal resources available for proper research/promotion of best LID features
- Lack of case studies to demonstrate successful tools.

Through an analysis of the survey results from the 2014 National Consultation Workshop, the barriers identified were generally consistent with the previous list. More information can be found in the whitepaper Low Impact Development within Integrated Water Management Systems: Barriers, Opportunities and Risks (Dalhousie University 2015) (Appendix F). The same report includes case studies about how green infrastructure fits within integrated water management systems.

8.2.2.2 Case studies about LID implementation

There are many opportunities green infrastructure features on a smaller scale in both retrofit and renewal projects. Retrofitting systems to incorporate green infrastructure features can allow for improvements to stormwater quality and reductions in stormwater runoff quantity. This can reduce risks in integrated water management systems.

Appendix M summarizes several examples of smaller green infrastructure implementation projects across Canada and North America, including the approaches, lessons, and considerations for risk. In these cases, green infrastructure features are implemented to supplement existing conventional drainage networks and systems.

Notable online resources with additional case study information include:

- Stormwater Case Studies website (US EPA 2014b)
Information about feature sizing is becoming more available through documents published by government agencies in both Canada and the United States (CVC & TRCA 2010; City of Edmonton 2011). As practitioners further develop their experience with particular features, they are publishing comprehensive guides (e.g., bioretention features, WI DNR 2014). With this experience come additional examples of typical green infrastructure design drawings and specifications (City of Portland 2008).

Effective green infrastructure implementation takes into account site-specific conditions and considerations. As such, it is difficult to recommend one solution for all design scenarios. Lessons and knowledge shared through additional case studies will lend to the collective growth in the field.

**8.3 Recommendations**

A more consistent Canada wide approach to promoting alternative stormwater management approaches would encourage more effective discussion, collaboration, and implementation of green infrastructure technologies. Additional demonstration projects focused on mitigating concerns related to long-term maintenance, the effects of road salt and de-icing chemicals on features and effects of green infrastructure on infiltration and inflows to sanitary systems will help in mitigating uncertainties. As the knowledge base grows, practitioners should continue to develop design support information, and make efforts to promote these features within the previously existing municipal stormwater guidelines.

This section is a summary of research carried in collaboration with Credit Valley Conservation Authority and Dalhousie University. For more information visit Appendix G and H.
Integrated financial planning is the last tool within the one water framework. With an asset management plan prepared for water, wastewater and stormwater infrastructure, municipalities can develop a long-term capital budget to tackle future replacement needs and an operating budget to deal with critical maintenance that will help ensure infrastructure achieves or exceeds the anticipated useful life and level of service. With an integrated financial plan, municipalities can combine the physical inventories of the infrastructure into one database to forecast when the assets will reach the end of their service life. At that stage, municipalities can prepare cost estimates to replace the infrastructure or apply new technologies to optimize infrastructure, thus delaying the need for full replacement and deferring cost.

A detailed life-cycle cost analysis can accompany replacement decisions by highlighting the full range of direct and indirect costs and benefits, as well as support full-cost pricing. This is an important change that needs to occur to support an integrated risk management approach.

With asset management plans in place, small, medium, and large municipalities can optimize decision making and reduce environmental, social, and economic risks. Using a sound financial model, municipalities can tackle the infrastructure deficit to implement the recommendations of the asset management plan. Municipalities will have a long-term capital budget to tackle future replacement needs and an operating budget to deal with critical maintenance.

Figure 23 illustrates how the full cost and benefits of infrastructure solutions including externalities could be considered when comparing grey and green retrofit solutions for a municipal road retrofit.
This chapter will highlight current approaches, tools, and strategies along with potential barriers to integrated financial planning. This includes approaches and methods on how to develop an integrated long-term capital budget and operating budget forecast which implements the asset management plan/strategy, considering the overall impact on service levels and rate payers.

9.1 Legislation that supports integrated financial planning

Since the Walkerton Inquiry, Ontario has adopted several pieces of legislation in an effort to support full-cost pricing, including the goal of implementing long-term asset management principles. The following proposed and interim legislation attempts to better define financial plans:

- Sustainable Water and Sewage Systems Act (SWSSA) - enacted but no Regulations, subsequently repealed
- O.Reg. 453/07- under Safe Drinking Water Act
- Water Opportunities Act - enacted but no Regulations
- Public Sector Accounting Board Reporting (PSAB)

9.1.1 Sustainable Water and Sewage System Act

Many people considered the Sustainable Water and Sewage System Act (SWSSA), passed in 2002, a good starting point for legislation. The intent of the Act was to introduce municipalities to undertaking a full-cost pricing assessment of water and wastewater services as a means of reducing the risk of increasing infrastructure deficit. However, the act was repealed in December 2012.
The definition of full-cost pricing for drinking water was defined as “source protection, operating costs, financing costs, renewal and replacement costs and improvement costs associated with extracting, treating or distributing water to the public and such other costs which may be specified by regulation” (SWSSA 2002). A similar definition was also created for wastewater systems that carried that same meaning.

Under SWSSA, two reports were required:

**Full Cost Service Report:** The full cost service report required an inventory of all the physical infrastructure including an infrastructure management plan and identification of costs of providing the service(s). This supported an integrated approach by requiring municipalities to identify all of the costs associated with delivering the service. Municipalities would eventually need to look at the cost of renewing and updating infrastructure, and optimizing infrastructure through the use of new technologies among other things.

The National Consultation Workshop revealed that many stakeholders believed SWSSA was a step in the right direction. They felt that if regulations were developed they would have supported the development of more complete and integrated financial plans.

**Cost Recovery Plan Report:** The second report would have outlined how the municipality intended to pay for the full costs of providing the service. This would include the capital costs, operating costs, future growth and the costs of utilizing new technologies to achieve the required level of service.

The preparation of these reports would have required the different municipal departments (i.e. engineering, finance, etc.) to collaborate thus ensuring good integration. Although this legislation was enacted, no regulations were ever created to fully implement it.

### 9.1.2 Ontario Regulation 453/07 (O. Reg 453/07)

In 2007, O.Reg 453/07 was passed by the Ministry of the Environment and Climate Change, requiring the preparation of financial plans for water systems under the *Safe Drinking Water Act*. This was intended as an interim legislation so that municipalities could be licensed to run the water system until regulations for SWSSA came into effect.

The regulation only pertained to drinking water and didn’t include wastewater and stormwater. These regulations only required municipalities to report on a financial statement basis with annual projections and did not embrace a forward looking approach. Financial statements typically take an accounting approach and follow a Public Sector Accounting Board (PSAB) reporting format.

O.Reg 453/7 was not as comprehensive as SWSSA because it didn’t look at the assets, new technologies, growth, impacts on rates, etc. Furthermore, the regulations only required a financial statement which tends to look backwards and not forward.
9.1.3 Public Sector Accounting Board Reporting

In 2009, municipalities began to move towards the Public Sector Accounting Board (PSAB) reporting. Municipalities started to integrate financial information such as the value of the assets, amortization, and depreciation to show the full financial picture. This ensured that municipalities developed more detailed records of their infrastructure assets. However, it recorded costs at a historic value. For example, the cost to build water mains 40 years ago is probably 10% of the cost of building them today. Once infrastructure reaches its useful life, the financial books do not accurately reflect the true replacement cost. It is very important that municipalities consider the true cost of replacing the infrastructure assets.

Figure 24 illustrates the different financial approaches currently in use across Ontario. PSAB and O.Reg 453/07 support the preparation of financial statements that use a backward-looking approach. SWSSA, on the other hand, would have required municipalities to look at the replacement of the future value of the asset.

<table>
<thead>
<tr>
<th>PAST EXPENDITURES</th>
<th>FUTURE EXPENDITURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSAB O. Reg. 453/07</td>
<td>Municipal Assets</td>
</tr>
<tr>
<td></td>
<td>- roads</td>
</tr>
<tr>
<td></td>
<td>- water</td>
</tr>
<tr>
<td></td>
<td>- wastewater</td>
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<tr>
<td></td>
<td>- stormwater</td>
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<tr>
<td></td>
<td>- recreation</td>
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<tr>
<td></td>
<td>- public works</td>
</tr>
<tr>
<td></td>
<td>- library</td>
</tr>
<tr>
<td></td>
<td>- etc</td>
</tr>
</tbody>
</table>

Figure 24: Comparison of different financial approaches. Source: XX

9.1.4 Water Opportunities Act

In 2010, the government passed the Water Opportunities Act. The act was introduced to foster innovative water, wastewater, and stormwater technologies, services, and practices. This act also has
provisions for the preparation of integrated financial plans. This is a forward-looking approach to improve the overall provision of services, embracement of new technologies, better environmental protection, and assessment of risks that could impact future delivery of services (i.e. climate change). The key drivers impacting today’s municipalities (aging infrastructure, climate change, and population growth) must be factored into asset management plans so the financial plan can reflect the costs of dealing with the associated risks.

### 9.2 Elements of a Financial Plan
The 2012 CIRC indicates that of the 346 surveyed municipalities, only 4.5% use complete and reliable assessment data when evaluating stormwater system capacity. Many municipalities use age-based assumptions of condition when assessing the current state of infrastructure assets which presents a significant amount of risk (see Appendix A).

Without an understanding of the physical condition of stormwater infrastructure, it is difficult to prepare a comprehensive financial plan that is also integrated with other water infrastructures. Figure 25 illustrates the typical elements of a financial plan for drinking water infrastructure. The process looks similar for wastewater infrastructure.

Two additional boxes (light blue) highlight how financial plans also need to include a risk assessment and consideration of how new technologies can optimize infrastructure performance. Through a life-cycle cost analysis, municipalities could compare different infrastructure options and technologies to understand how to deliver service at the lowest life-cycle cost in order to understand the influence decisions have on both capital and operating budgets. Water and wastewater typically require a 10 years cycle of budgets, while many small municipalities complete a one-year budget. Integrated lifecycle costing is necessary to ensure that all assets have a comprehensive financial plan.
9.2.1 Financing options

Stormwater funding mechanisms are currently in use across Canada and are important for securing a dedicated funding source for municipalities to achieve the required level of service for stormwater management.

Table 3 outlines the different funding mechanisms in use across Canada for funding stormwater infrastructure.

<table>
<thead>
<tr>
<th>Type of Charge</th>
<th>Basis for Calculation</th>
<th>Ease of Calculation</th>
<th>Equity</th>
<th>Administration</th>
<th>Public Understanding</th>
<th>Revenue Stability</th>
<th>Revenue Stability Benefit</th>
<th>Economic Development Benefit</th>
<th>Other comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property Taxes</td>
<td>Assessment</td>
<td>Easy</td>
<td>Low</td>
<td>Easy</td>
<td>Easy</td>
<td>High</td>
<td>Medium</td>
<td>Tax bill</td>
<td></td>
</tr>
<tr>
<td>Flat Rate per Property</td>
<td>Per lot</td>
<td>Easy</td>
<td>Low</td>
<td>Easy</td>
<td>Easy</td>
<td>High</td>
<td>High</td>
<td>Tax or rate bill</td>
<td>May be varied between residential and non-residential to reflect differences</td>
</tr>
<tr>
<td>Size of Property</td>
<td>Area of Property</td>
<td>Medium</td>
<td>Medium</td>
<td>Easy</td>
<td>Easy</td>
<td>High</td>
<td>Medium</td>
<td>Tax or rate bill</td>
<td>Often gaps in Assessment Data – need to supplement with GIS or site visit</td>
</tr>
<tr>
<td>Utility Rate</td>
<td>Water Meter Readings</td>
<td>Easy</td>
<td>Medium</td>
<td>Easy</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Rate bill</td>
<td></td>
</tr>
<tr>
<td>Run-Off Coefficient</td>
<td>Area and Use of Property</td>
<td>Difficult</td>
<td>High</td>
<td>Medium</td>
<td>Difficult</td>
<td>High</td>
<td>Low</td>
<td>Tax or rate bill</td>
<td></td>
</tr>
<tr>
<td>Impervious Area of All Properties</td>
<td>Measured Impervious Area</td>
<td>Difficult</td>
<td>High</td>
<td>High level of maintenance</td>
<td>Difficult</td>
<td>High</td>
<td>Low</td>
<td>Tax or rate bill</td>
<td>Need to monitor building permits and update data – need detailed review every few years</td>
</tr>
</tbody>
</table>
Funding for asset management plans can come from a variety of sources. The Federation of Canadian Municipalities outlines a variety of different options for finding funds to finance infrastructure renewal, including:

- Property tax
- Income tax
- Retail sales tax
- Land transfer tax
- Fuel tax
- Development charges
- Parking fees
- Hotel and accommodation fees
- Municipal financing authorities (CUPE 2014)

9.3 Potential barriers to integrated financial plans

**Governance**

Service easements for water, sanitary, and stormwater system within roads can cause challenges in integrating services between upper and lower-tier municipalities. Integrated financial plans would improve coordination between upper and lower-tier municipalities in terms of timing of construction (i.e. when services need to be repaired or replaced). Lack of funding adds to the complexity of challenges in terms of affordability for service.

**Appendix I** highlights examples of how water services are handled across different jurisdictions. For example, water could be split between treatment and distribution similar to Region of Waterloo and City of Waterloo. Lower-tier municipalities tend to work independently on storm drainage projects.

**Legislation**

In Ontario, there is legislation for water and some emphasis on wastewater. However, there is very little legislation for stormwater. Usually legislation is focused on target and performance but does not have any direct requirement for asset management or financial matters. It is also focused on individual service and there is no legislation enforcing integrated financial planning.

**Cost and affordability**
Incorporating new technologies, building infrastructure resiliency, and increasing service performance requires additional budget. Newer technology may influence legislation, but implementation could be costly. Municipalities have invested a lot of money in water and wastewater. In communities with older infrastructure, the cost of replacement is very high. This makes adding newer technology challenging, especially when municipalities consider population growth, climate change, and aging infrastructure.

Other matters to consider include historic approaches that tend to be generic and not specific to areas and regions. Municipalities need to consider climate, population, and economic variation between different regions.

Eventually, integrated planning could become a requirement for provincial infrastructure funding. For example, the Water Opportunities Act (regulations pending) could require municipalities to prepare a sustainability plan in order to get access to provincial funding.

*Green Infrastructure Lifecycle Costs*

Information about infrastructure lifecycle costs is needed to support the preparation of integrated financial plans. To support life-cycle costing methods for comparing solutions (i.e. grey versus green infrastructure), it is important that practitioners have access to life-cycle costing data to make informed decisions. Monitoring demonstration projects such as one water projects and collecting data on performance, operation and maintenance costs will support decisions at both the municipal and provincial level. Decisions that can be made with fewer assumptions reduce risk and uncertainty and make the life-cycle costing approaches easier to apply to non-traditional infrastructure projects (i.e. green infrastructure).

### 9.4 Recommendations

Figure 26 highlights the different things to consider when preparing an integrated financial plan. In general, financial plans should reflect an understanding of how infrastructure optimization can be performed between the three infrastructure systems. For example, how can improved stormwater management impact downstream assimilative capacity for a wastewater treatment facility? Is it more cost effective to retrofit existing urban areas with green infrastructure or upgrade the WWTP facility to achieve stricter targets? In general, integrated financial plans should consider:

- The costs associated with dealing with risks that may interfere with current and future delivery of municipal water services, including climate change;
- Cost efficiencies and added value that can be achieved through collaborative planning within and between municipalities;
- Take into account cost comparisons (based on the entire life cycle) for conventional and innovative infrastructures, technologies and practices that promote efficient water use and reduce adverse impacts on water resources (e.g. green infrastructure, LID);
• Reflect the cost to properly integrate provincial and municipal plans and policies, land use planning and infrastructure planning;
• Costs needed to building capacity and resiliency in water, stormwater and wastewater management.

The social/economic and environmental return on investment (ROI) is a term that is not often reflected in financial plans and statements and provides a indication of how effective an organization uses its capital and other resources to create value for the community. The challenging part to calculating the ROI, is quantifying the financial benefits for public health, the economy and the environment.

Making the paradigm shift to a “one water approach” would require developing a financial plan that can answer questions such as:

• What are the “deferred or avoided capital expenditures” of taking a green infrastructure approach over a gray infrastructure approach? What are the savings in operation and maintenance costs?
• How can innovative water management approaches “extend the lifespan of existing conventional infrastructure”?

The ROI can help develop integrated financial plans that demonstrate an understanding of the full cost and benefits of infrastructure, including externalities. For example,

• How applying the “right water for right use “can reduce water treatment costs;
• How the recovery of valuable resources (reclaimed water, nutrients, carbon, metals and biosolids) from “wastewater” can offset potable water costs, fertilizers, and generating power;
• The value of harvesting stormwater for water supply, irrigation, and/or infiltration benefits;
• Demonstrating how multiple decentralized small water treatment and distribution systems combining local needs and the triple bottom line;
• How new infrastructure design technologies and strategies to address today's complex water problems.

Integrated financial plans are also an excellent to help justify budgets/investment, better focus on priorities and understand the risks/consequences of alternative investment decision.
10 Recommendations and Conclusions

When considering the full range of key drivers, associated risk and examining the various risk management practices being applied to management of municipal water systems, it becomes apparent that an integrated water management framework for municipalities is necessary to address these complex and interconnected risks. The One Water approach allow municipalities, water managers and regulators to better coordinate the development and management of water, land, and related resources in a sustainable and equitable manner and better coordinate decisions and investments for the most effective results.

This document examines a proposed integrated framework through the lens of three main drivers of risk: aging infrastructure, climate change, and a growing population. The project team found that municipalities are beginning to understand and respond to these drivers and that integrated approaches, while slow to be adopted in Canada, are on the rise.

This chapter summarizes the components of the One Water framework, and provides the next steps government, conservation authorities, and academia need to consider to integrate the One Water approach.

10.1 Legislation and governance

There is substantial legislation and governance structure that provides barrier for municipalities to adapt an integrated approach to risk management. Among many steps that stakeholders can take towards an integrated approach, the proposed structure with the highest potential should include a ‘networked governance structure’ where all those with decision-making authority are involved in making informed decisions on a scale appropriate to the dynamic, transboundary nature of water. One such example proposed in this phase of the research includes a Conservation Authority (watershed planner/district) model, as it exists in Ontario, operating at a watershed scale.

Next Steps:

An initial step is for the Federal government to coordinate interprovincial integration of water management by reviving the 1987 Federal Water Policy. At a provincial level, significant infrastructure in the form of policy frameworks already exist and are the building blocks that can be evolved into coordinating and integrating framework across provinces. Within provinces, to address overlapping legislation and conflicting departmental mandates requires clear statement of priorities within the legislation itself.

10.2 Integrated Watershed Planning

Integrated Watershed Management is managing human activities and natural resources in an area defined by watershed boundaries aiming to protect and manage all natural resources and their functions today and into the future. Integrated water management, also termed ‘one water’, is an approach imbedded in the practice of integrated watershed management that
plans, manages, protects and conserves the urban and rural water cycle within the context of watershed boundaries. Today’s water management issues need to be addressed through a more integrated and holistic approach starting at the watershed scale.

10.3 Asset management
There is a wide range of practices currently being carried out by municipalities. Some key tools that offer the strongest potential for allowing for a more comprehensive consideration of risk include:

- Data sharing options;
- Improved asset management software;
- Assembly of information using software/tablets;
- Directed focus on information on the internet;
- Collaborations and partnerships.

Next Steps:

- The importance of keeping floodplain maps up to date;
- Improved methods of understanding the changing integrity of buried, linear assets;
- Access to regional and local climate information, and strategies for proactively managing floodplains and flood protection, including strengthening communication between upstream/downstream communities;
- Implementing and maintaining asset management programs;
- Updating Intensity-Duration-Frequency (IDF) curves including adjustments to reflect projected climate change conditions;
- Initiate pilot projects to demonstrate how upper and lower tier municipalities could integrate their asset management plans for water, wastewater and stormwater infrastructure;
- Development of a “Green Infrastructure Asset Management Planning” guide to help fill this gap;

10.4 Integrated risk assessments
The Water Utility Risk Integration Matrix highlights the key drivers, methodologies, and approaches to manage risks relevant to Canadian water infrastructure. The complexity of risks and drivers is expected to impact the municipality’s ability to meet the required levels of service for stormwater, wastewater and water services. Municipalities need to understand the vulnerability of infrastructure to climate change, population growth aging infrastructure, and the array of additional drivers that impact the ability to manage the risks. Identifying the components of infrastructure within a system that are highly vulnerable to these drivers enables municipalities to develop cost-effective engineering, operations and policy solutions. In order to ensure sustainable future delivery of municipal water services, municipalities need to participate in risk assessment methodologies at a watershed scale, to understand integration of
the different infrastructure systems. Based on the tools explored in Chapter 5, the PIEVC protocol holds the most potential for an integrated risk assessment of all three water systems.

Next Steps:

Develop a case study that highlights upper tier-lower tier collaboration to understand infrastructure vulnerabilities to climate change at a watershed scale. This case study should look at both grey and green infrastructure solutions. Step 4 of PIEVC Protocol- “Engineering Analysis” provides the opportunity to incorporate a more detailed analysis, and should be considered for further analysis of the interaction of the three municipal water systems.

10.5 Integrated financial planning
Preparation of integrated asset management plans is a critical step towards developing a long term capital budget to address future replacement needs and to ensure an operating budget able to deal with ongoing maintenance issues. Financial plans would incorporate findings from integrated risk assessments and the application of new technologies to optimize infrastructure, thus identifying opportunities to delay full replacement and deferring cost, where appropriate and feasible.

A detailed lifecycle cost analysis would accompany replacement decisions, highlighting the full range of direct and indirect costs and benefits and support full cost pricing. With asset management plans in place, small, medium and large municipalities are able to optimize decision-making. Municipalities are better able to address infrastructure deficits, based on a sound financial plan to implement the recommendations of the asset management plan.

In order to develop integrated and holistic financial plans, municipalities should perform the lifecycle cost analysis method when evaluating infrastructure solutions (e.g. grey vs green infrastructure). The lifecycle analysis will require looking towards the future when preparing a financial plan.

Next Steps:

- There is a need for green infrastructure life cycle costing information in order to perform a Lifecycle Costing analysis;
- Performance assessment data can be used to evaluate how different options achieve defined levels of service through performance indicators and targets;
- Develop case studies that quantify, for example, the ability of different green infrastructure treatment trains to meet or exceed specific performance objectives, level of service requirements and secondary benefits;
- Support decisions regarding green infrastructure investment and long term maintenance and operation (i.e. requiring fewer assumptions, thereby reducing doubt, uncertainty and risk);
- Transferability- Gather data which is needed to simulate watershed responses to widespread implementation of integrated infrastructure solutions;
• Financial plans need to reflect how infrastructure optimization can be performed between the three infrastructure systems;
• Develop case studies to highlight how lower and upper tier municipalities can develop an integrated financial plan that assesses the full cost recovery for meeting the required level of service for the three systems together.

10.6 Innovative green infrastructure technologies
Green infrastructure is the stormwater management practice with the strongest potential to allow for a more integrated consideration of risk and a tool to support more holistic approaches to municipal water management. To realize implementation of green infrastructure across Canada, more effort must be put into technical assessment, understanding of construction costs and O&M costs, including establishing responsibility for these costs, performance monitoring and knowledge transfer and translation. As well, development of new stormwater regulations and policies, continued development of updated design guidance and support documents, incentivizing lot-level green infrastructure adoption, and promoting green infrastructure synergy within different levels and departments of government will assist in promoting the adoption of green infrastructure approaches and features.

Next Steps:
• Technical assessment of LID through planning and design of demonstration projects
• Construction of LID projects to ensure proper construction and inspection prior to assumption;
• Performance assessment of LID projects to understand performance in different geographic regions;
• Knowledge transfer and translation through the development of guides, factsheets, case studies and sharing lessons learned to promote wide scale adoption;
• Incentive strategies;
• Increased government synergy;
• Implementation of pollution prevention practices in combination;
• Implement demonstration projects that can be the source of long-term performance data that can be used to develop tools like guidance documents or models to effectively plan, design and manage infrastructure to reduce risk;
• Track long term maintenance and operation costs to support infrastructure investment decisions;
• Gather data required to simulate watershed responses to widespread implementation of integrated infrastructure solutions and build a robust dataset for long-term assessment. Municipalities can use this information to develop rebates on development charges and credits on municipal stormwater rates. This helps strengthen the business case for implementing new and innovative technologies if there are potential savings to the end user.
- Quantify the ability of different green infrastructure treatment trains to meet or exceed direct benefits, including meeting specific performance objectives, level of service requirements and secondary benefits.

**Concluding statement**

Integrated water management has been described as a concept that is easy to talk about but difficult to implement. Municipalities across Canada are struggling to address a myriad of issues from aging infrastructure to insufficient funding and required to do more with less and at the same time use its capital and resources to create value for the community. The term “infra-stretch” says it all!

To prevent the further degradation of surface waters and damage to property and infrastructure from erosion, flooding and impaired water quality, multi-functional infrastructure solutions that embrace the “one water” approach are more important than ever. As described in earlier chapters of this report, municipalities, watershed managers and water utilities need to embrace changes or shifts that will yield integrated cost-effective solutions to address the environmental, social and economic issues facing today’s generation of water management practitioners.

These changes need to be at the top of mind so that today’s standard practices pertaining to infrastructure upgrades and improvements can change. Many opportunities currently exist for the implementation of novel water management infrastructure approaches that can be supported by a broad range of stakeholders using a science based approach towards creating more sustainable communities across Canada.
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