INTEGRATED RISK MANAGEMENT FOR MUNICIPAL WATER SYSTEMS IN CANADA THROUGH INTERJURISDICTIONAL ECOSYSTEM MANAGEMENT USING COSERVATION AUTHORITIES

Submitted to Dr. Gail Krantzberg

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To my daughter Langa and son Ndumiso, for not asking why I could not visit them more often

...I will never forget...

Abstract

This paper examines the risks and likely opportunities related to municipal water systems from a health and regulatory perspective especially after focussing events like Walkerton Tragedy that helped push risks facing municipal water systems into the public agenda thereby requiring policy responses. It is widely acknowledged that risks to municipal water systems are rarely confined to a single municipal jurisdiction but emanate from other jurisdictions. This creates the imperative for integrated risk management through the adoption of watersheds as de facto units for water management and governance of municipal water systems. A watershed approach enables downstream and upstream municipalities and other stakeholders to collaborate and come up with creative solutions to health and regulatory risks.

These collaborative approaches imply that multiple stakeholders are involved and this necessitates the introduction of a networked form of governance. Networked governance is properly disposed to addressing the problem of jurisdictional fragmentation within the Canadian water sector. It is proposed that the steering or controlling of such networks is better achieved through Conservation Authorities that are already in existence in Ontario and are operating at a watershed level. But a multi-stakeholder approach introduces problem complexity where stakeholder interests might be entrenched. An efficacy frontier will be used to examine how these complexities are resolved through trade-offs. Applications of a reformed governance model for Canadian applications are discussed.

An Urban Water Management Transitions Framework developed in Australia will be used to show that the most optimal way to address health and regulatory risk is for municipal water systems to transition to what are called water cycle and water sensitive cities that focus on demand rather than supply side factors. This transition allows for sustainable water approaches which address cultural and historically embedded values that are then expressed in current municipal water system infrastructure. There is now

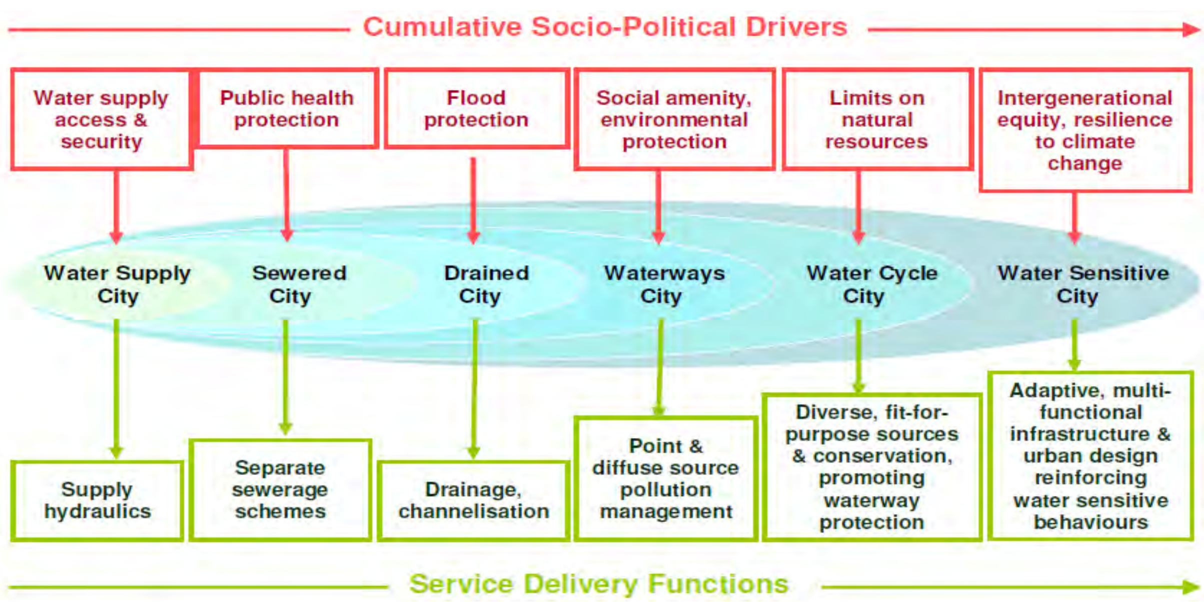
a convergence on the fact that impediments to the adoption of sustainable water practices lie in the social rather than the technical domain. This framework tackles the challenges emanating from these hydro-social contracts.

1. 0 Literature review

1.1 Historical evolution of municipal water systems

The Urban Water Management Transitions Framework Brown et al. (2008) Figure 1 presents a "typology of six city states" and identifies the ideological and technological contexts that the city states evolve through as they develop towards sustainable water conditions, which in this case is the Water Sensitive City. These city states can be taken to be representative of the evolution of municipal water systems. For the purposes of this paper, the term urban water system is synonymous with municipal water systems.

Figure 1: Urban Water Management Transitions Framework



Brown et al. (2008)

The framework is presented as a benchmarking tool to provide a vision for municipal water systems that pinpoints the requisite attributes of a sustainable and hence integrated system capable of handling risks faced by municipal water systems. Each city state is differentiated by the services provided by the municipal water system which is a function of the dominant social and political drivers (reflecting shifts in the normative and regulative dimension) and the service functions (representing the cognitive responses). Brown et al. (2008) labels these as the hydro-social contracts manifesting themselves in "three dimensions of institutional context" namely; the cultural-cognitive, normative and, regulative. These dimensions express themselves through institutional arrangements and regulatory frameworks that are physically presented as municipal water infrastructure. They are therefore mutually reinforcing such that reforming one pillar without the other two is not effective. What is common from the first three states is the normative perception of water as a limitless resource and the environment as benign where storm and sewer water can be conveyed into receiving water bodies and the dominance of engineered technical solutions to water problems. This paradigm was challenged by the emergence of environmentalism in the 1960s and recently reinforced by extreme events of drought and flooding, causing municipal systems to start transitioning to sustainable states.

1.2 Transitioning to the water-sensitive city

According to Ferguson et al. (2013)**,** municipal water systems deliver societal needs like water resources, sanitation, and flood protection through "traditional technocratic approaches" characterized by centralized water supply, sewage and drainage infrastructure. There is a growing recognition that municipal water systems are "socio-ecological" systems that encapsulate both complexity and uncertainty. The key to delivering societal needs under such conditions is for municipal water systems to adopt "adaptive paradigms" that capture complexity, uncertainty, and builds adaptive capacity through "flexibility, diversity, and redundancy". Such a paradigm is provided by transitioning to "water-sensitive" cities. According to Dobbie et al. (2014), developing to a water sustainable state such as the 'water-cycle city' (or water-sensitive cities) requires "shared, diversified risk management, which acknowledges the subjective risk perceptions of all stakeholders including water practitioners".

The water systems of the water-cycle city incorporate sustainability through its ability to provide water from multiple sources like rainwater, recycled wastewater, stormwater, sewage and seawater. It is an integrated system that reduces discharge to waterways and simultaneously promotes ground water recharge **(ibid).** The water-sensitive city on the other hand recognizes the concept of intergenerational equity where the needs of today should not compromise those of future generations as defined in United Nations (1987). Transitioning as already alluded to in Brown et al. (2008) is possible only in the context of shifting all the three dimensions of institutional context.

1.3 Dimensions of institutional context

Ferguson et al. (2013) provides empirical evidence of the institutional context that enabled the city of Melbourne to transition towards a "hybrid of centralised and decentralised infrastructure." Fundamental changes occurred in the "cultural-cognitive, normative and regulative dimensions of Melbourne's water system". Whilst drought was a fundamental driver in Melbourne's achievement, Ferguson et al. (2013) provides lesions on how others can create "enabling social conditions for more integrated approaches to water servicing in their own institutional contexts, without having to experience a crisis" before taking action **(ibid).** Table 1 is a summary of levers that can be applied to shift the three dimensions of the institutional context.

1.4 Manipulating change levers

Table 1: Shifting the dimensions of institutional context

DIMENSIONS	LEVERS TO EFFECT CHANGE
Cultural-cognitive	Scenario planning for future conditions/surprises; development of context-based evidence through mechanisms supporting knowledge building and sharing; local demonstrations to build practical experience
Normative	Visioning processes involving policy makers, water practitioners, and community members; active political lobbying; implementation structures and processes that support co-governance approaches
Regulative	Strategic planning processes to develop shared problem definitions and cross-boundary partnerships; mobilising government incentives to support desired outcomes, mechanisms for transparent evaluation of costs and benefits in a business case development; establishment of conditions that provide market certainty for investments in innovative solutions

Adapted from Ferguson et al. (2013)

1.5 Cultivating local enthusiasm

Floyd et al. (2014), states that cultivating “local enthusiasm” effectively drives participation in water governance than mandated approaches as it generates “autonomous motivation” which in turn drives the shifts in dominant institutional regimes. A case in point is where it can lead to the deconstruction of infinite water supply perceptions. In such a scenario, communities voluntarily invest in household infrastructure like rainwater harvesting tanks and the use of grey water for garden irrigation. Enthusiasm thus develops “social infrastructure” which in turn eases pressure on physical infrastructure.

2.0 Problem definition

2.1 Aging infrastructure and infrastructure deficit

Most of the water and wastewater infrastructure under the jurisdiction of municipalities is up for replacement as it was constructed in the 1950s and 1970s Rupert (2010), Mirza (2007)**.** A 2009-2010 survey of municipalities on drinking water systems, wastewater, and storm water networks revealed that 15% of drinking water infrastructure, 40% of wastewater infrastructure and 13% of stormwater management systems were rated “fair”, “poor” or “very poor” Federation of Canadian Municipalities (2011)**.** To repair, maintain, and upgrade this infrastructure, Mirza (2007) indicates that it will require capital expenditures of about a $100 billion dollars as shown in Table 2

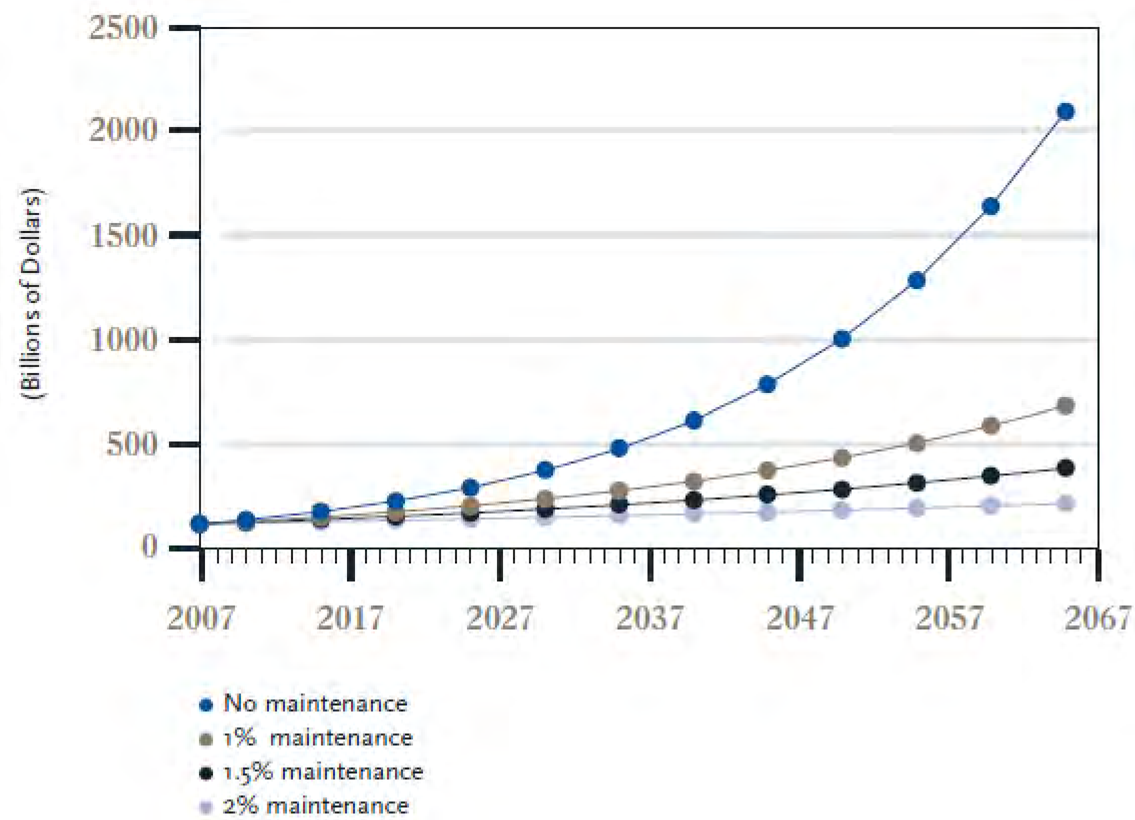
Table 2: Required infrastructure costs Mirza (2007)

Replacement Costs	$billions
Drinking Water Infrastructure	25.9
Waste Water Infrastructure	39.0
Stormwater Systems	15.8
Total	80.7
Upgrading of Wastewater Plants	20
Combined Total	100.7

2.2 Deferred maintenance

This is one of the main causes of the deterioration of municipal infrastructure as shown by the four levels of maintenance in Figure 2.

Figure 2: Effects of deferred maintenance on infrastructure deficit



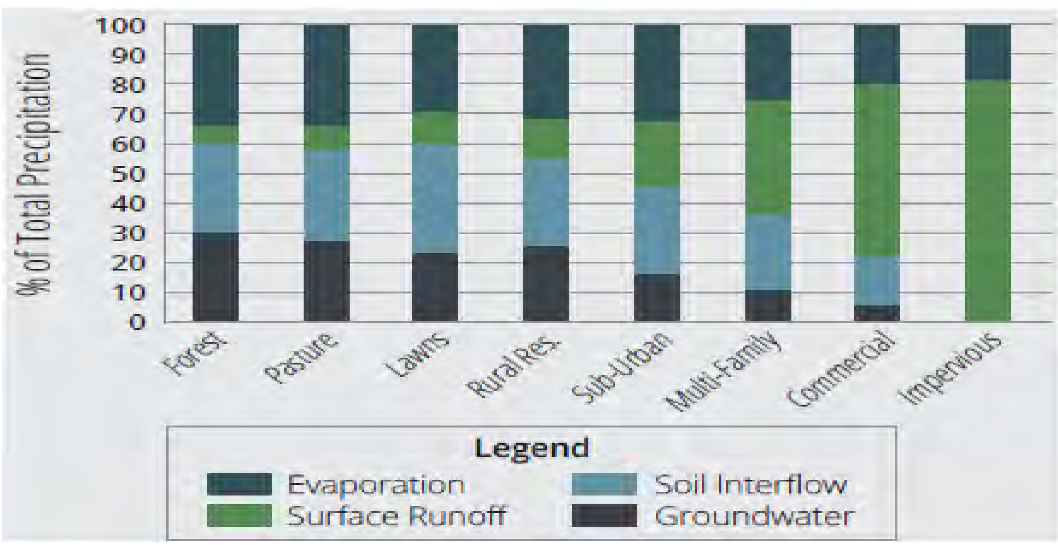
Mirza (2007)

Under conditions of no/deferred maintenance, the municipal infrastructure deficit will grow to about $2 trillion by 2065 **(ibid).** According to Vander Ploeg (2011)**,** aging infrastructure creates two problems of leakage and elevated contamination risks. About 13% of municipal water is wasted through leakages and the contamination risks are raising costs of water treatment **(ibid)**

2.3 The built-up landscape

The built up landscape in urban areas is increasingly dominated by surfaces that are impervious due widespread use of asphalt, roofs, and concrete. As a result most of the rainfall no longer infiltrates into the soil but is rapidly conveyed by municipal stormwater systems to receiving water bodies as stated by Schreier (2012), **P**orter-Bopp et al. (2011), Norman et al. (2010) and Aquafor Beech Limited (2006)**.** According to CVC and TRCA (2010)**,** the hydrological cycle is significantly altered resulting in severe impacts to water quality, flooding risk and human health. Appendix A shows the net effect of these impacts. Also refer to Figure 3 showing the increase in surface runoff as a function of land use change.

Figure 3: Land use impacts on the distribution of precipitation within the hydrological cycle



Schreier (2012)

Porter-Bopp et al. (2011) identifies three core problems linked to traditional stormwater management which are a "legacy of old stormwater management practices as also borne out by Brown et al. (2008). They are:

1. Urban design creates a perceived "problem" of runoff when it ignores the water cycle by replacing the natural landscape

2. The paradigm that rainwater poses a risk and must be conveyed from the landscape
3. Fragmentation in the roles and responsibilities with respect to watersheds between government levels and the absence of integration between land use and water planning within municipalities

These core problems are at the centre of the current predicament faced by municipal water systems and the resultant threats to human health and well being and they are more institutional rather than technical.

2.4 Combined sewer systems

Many Canadian municipalities depend on combined sewers "through which storm drains connect to sanitary sewer lines and discharge into water bodies when line capacity is exceeded. In Ontario, there are 107 combined sewer systems found in 89 municipalities spread across the province Binstock (2011)**. D**ocumented evidence of combined sewer overflows and bypasses was carried out by MacDonald et al. (2009) as shown in Tables 3 and 4.

Table 3: Sewage bypasses and combined sewer overflows (2006-2007)

Sewage releases	2006	2007
Total reported sewage releases	1,544	1,243
Total releases reported to be due to wet weather	1,256	849
Releases reported to include combined sewer overflows	376	701
Releases that included bypasses	1,061	1,089

MacDonald et al. (2009)

Table 4: Sewage bypasses by volume (2006-2007)

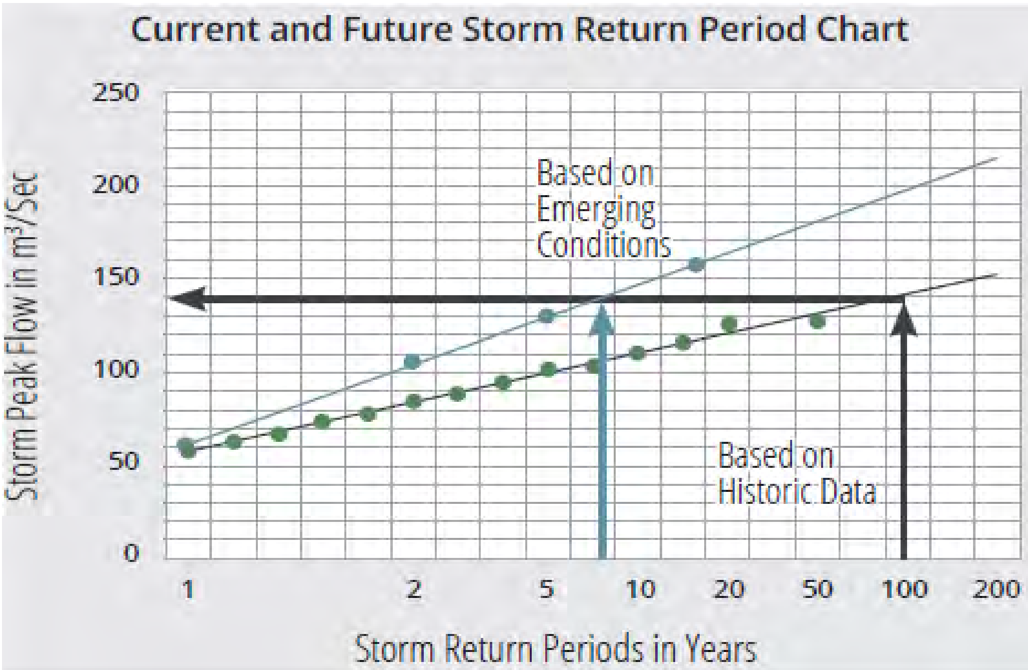
Watershed	Total Primary By-pass (Litres)	Total Secondary By-pass (Litres)	Total Sewage By-passes (Litres) [6]	Total Sewage Flow (Litres)
2006 Bypasses				
Lake Huron	1,313,048,000	168,765,000	1,536,366,000	166,644,113,000
Lake Erie	3,700,941,000	1,136,131,000	4,837,072,000	244,561,923,000
Lake Ontario	5,436,818,000	6,089,267,000	11,526,450,000	1,009,788,541,000
Lake Superior	346,000	57,511,000	57,857,000	23,716,153,000
St. Lawrence River	14,861,000	0	25,071,000	62,284,041,000
Ottawa River	4,817,000	75,263,000	81,235,000	180,238,612,000
Nelson River/Hudson Bay/James Bay[7]	311,969,000	1,089,000	373,880,000	110,538,079,000
Total	10,782,800,000	7,528,026,000	18,437,931,000	1,797,771,462,000
2007 Bypasses				
Lake Huron	394,813,000	134,050,000	536,698,000	135,444,622,000
Lake Erie	3,106,146,000	211,654,000	3,317,800,000	183,779,635,000
Lake Ontario	977,821,000	2,337,513,000	3,315,334,000	767,885,268,000
Lake Superior	0	231,466,000	231,466,000	22,239,380,000
St. Lawrence River	0	0	700,000	54,268,990,000
Ottawa River	3,574,000	549,252,000	552,826,000	161,119,933,000
Nelson River /Hudson Bay/ James Bay	408,711,000	0	408,711,000	20,970,689,000
Total	4,891,065,000	3,463,935,000	8,363,535,000	1,345,708,517,000

MacDonald et al. (2009)

2.5 Climate change

Climate change is churning out extreme events that are capable of disrupting municipal water systems whose components include “drinking water supply, wastewater conveyance and treatment, and stormwater management” Beller-Simms et al. (2014).Traditional planning for municipal water systems is based on the concept of “stationarity”. It is the “notion that seasonal weather and long-term climate conditions fluctuate within a fixed envelope of relative certainty” Sandford (2011) such that “the statistical properties of climate variables in future periods will be similar to past periods” Means III et al. (2010). In the water resources sector, this certainty is delineated by a 100 year period of observations of climate phenomena Beller-Simms et al. (2014). According to Schreier (2012) Figure 4 is a “historic and emerging storm flow return period” due to elevated climate change and increase in impervious surfaces. Storm events that occur once in a 100 years are more likely to occur every 7 years **(ibid)**.

Figure 4: Historic and emerging stormflow return period due to increased variability and impervious surfaces



Schreier (2012)

2.6 Risk of lawsuits

According to IBC (2014)**,** severe weather damages resulting from climate change have overtaken fire damage to become the dominant cause of property insurance. In 2013 alone floods in Toronto and Alberta reached historic proportions of $3.2 billion compared to an average of about $400 million per annum for a period of 25 years between 1983 and 2008. Table 5 is a list of some of the lawsuits resulting from wet weather events.

Table 5: Risk of lawsuits

Lawsuit	Court & Case #	Reason
Port Alberni(City) v. Moyer	B.C. Supreme Court [1999] B.C.J. No. 423	Basement flooding due to sewer back-up
Carson v. Gloucester (City)	Ontario Supreme Court of Justice [2000] O.J. No. 3863	Basement flooding – drainage ditch nearby flooded due to thaw and heavy rainfall
Clemmens v. Kenora (Town)	Ontario Supreme Court of Justice [1999] 6 M.P.L.R. (3d) 59	Sewer back-up due broken pipe
McLaren v. Stratford (City)	Ontario Supreme Court of Justice [2004] 50 C.P.C. (5th) 310	Property damage due to severe rainstorm causing flooding with both sewage and storm water
Tock v. St. John's Metropolitan Area Board,	[1989] 2 S.C.R. 1181	Basement damage due to storm sewer blockage caused by heavy rainfall
Oosthoek v. Thunder Bay (City)	Ontario Court of Appeal 30 O.R. (3d) 323	Basement flooding due to back-up caused by combined sewers and from burst, leaking or corroded cast iron watermains after heavy rainstorm

Adapted from Campbell et al. (2007)

3.0 The solution

3.1 LID technologies integrated at watershed scale

Low Impact Development (LID) stormwater management practices include rain water harvesting, green roofs, bioretention, permeable pavement, soakaways and swales. See (Appendix B for a description of these technologies). CVC and TRCA (2010) adapted the United States Environmental Protection Agency (USEPA) definition of LID and this will be used *in toto: Low impact development (LID) is a storm water management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible. LID comprises a set of site design strategies that minimize runoff and distributed, small scale structural practices that mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration,* *harvesting, filtration and detention of stormwater. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows.*

LID technologies "capture, retain, and treat" stormwater before it reaches municipal sewer systems and thus decreases pressure on sewers, decreasing the need for capital investments Binstock (2011). Table 6 below shows the benefits of LID technologies as applied to different scales from property to the watershed scale

Table 6: Innovative approaches to reduce stormwater runoff

PROPERTY SCALE	NEIGHBORHOOD SCALE	WATERSHED SCALE
Rainwater harvesting from roofs and impervious surfaces for re-use during dry periods	Minimize the size of roads, parking lots and impervious surfaces	Create large, continuous riparian buffer zones along streams and lakes
Green roofs to reduce and delay runoff	Create infiltration swales to direct road and impervious surface runoff into swales	Diversify stream channels into meandering and side stream systems (naturalize drainage)
Improve soil conditions to maximize infiltration and water storage	Create and incorporate wetlands into neighborhoods	Build wetlands and detention systems in the buffer zones
Minimize imperious surface and soil compaction	Provide temporary water storage in the form of ponds and detention systems	Select appropriate topographic areas for deliberate temporary water storage
Plant trees to reduce runoff where possible		Enforce land use zoning in the floodplain

Schreier (2012)

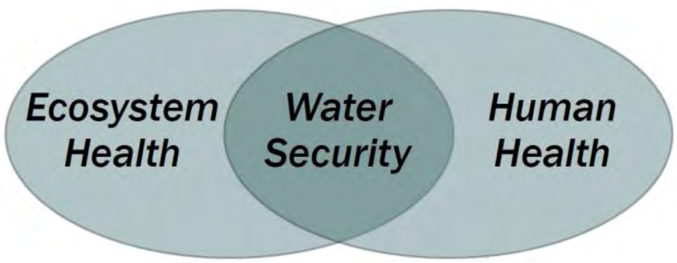
3.2 The watershed scale as an integrating mechanism

There is an increasing recognition that water should be managed on a watershed basis Zubrycki et al. (2011). Some of this impetus comes from the human and ecosystem health imperative and the triple bottom line perspectives.

3.3 The human and ecosystem health imperative

The Canadian Water Network prefers a definition of water security as "sustainable access, on a watershed basis, to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health" Zubrycki et al. (2011). This definition has an inherent implication of ecosystem health of both humans and other species as best served at the watershed level **(ibid).** Cities exist inside watersheds and their water is viewed from competing perspectives from both upstream and downstream actors including inter-alia, industrial, residential, and agricultural. One view is that of water as a "commercial asset" and the other is that of water as an "inherently shared social asset" **Norman et al. (2010).** Also, there are five dimensions to water security, namely; water resources, ecosystem health, human health, infrastructure, and governance and water security is at the interface of ecological and human health **(ibid),** as shown in Figure 5.

Figure 5: Water security - Ecological health and Human health



Norman et al. (2010)

Water is a "flow resource" and thus cannot be managed at "fixed jurisdictional scales"

Parkes et al. (2010) also links health and well-being to watersheds and concludes that "integrated governance of watersheds" is fundamental to health and well-being.

3.4 The Triple Bottom Line approach

According to Conservation Ontario (2010) employing the watershed as a managing unit is a pre-requisite for an integrated approach to water sustainability. Integrated watershed management is defined as "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." The watershed management is necessary because of the link between ecology, economy, and society hence it drives the triple bottom line approach as in Appendix C. de Loë et al. (2010) suggests that effective source water protection is accomplished when it is integrated with other strategies especially water and land use management**.** This task is best accomplished when source water protection is viewed as a "component of integrated watershed management" (IWM) and IWM is the most applicable frame that addresses the triple bottom line of economic, social and environmental issues that are water related **(ibid)**

3.5 The case for Conservation Authorities (CAs)

Once the argument is made that human health and well being is best protected at the watershed level, a supportable conclusion is that Conservation Authorities are suited to carry this task.

Porter-Bopp et al. (2011) makes a valid case for Conservation Authorities or similar bodies. As already proved, there is fragmentation over freshwater decisions where there is not a single authority responsible for the whole hydrological cycle. Since land and water are part of the entire natural system, decisions on these entities should be integrated rather than the current system where land use and community development are handled by the Planning department, whereas different departments deal with sewer and stormwater which also impact drinking water systems. Such a siloed approach results in a "complex patchwork of actors and legislation" without regard to cumulative effects as also acknowledged by Chilima et al. (2013)**.** Collaborative planning should be done across municipal jurisdictions where a coordinating mechanism in the form of a Conservation Authority is used. While they play a coordinating role, municipalities sharing the same watershed can also share LID implementation costs (**ibid).** In any case, according to Robins (2007)**,** Canada has in place, the building blocks of what can become country-wide Conservation Authorities as shown in Table 7 below together with the momentum to integrate LID technologies within municipal jurisdictions Credit Valley Conservation (2014) as shown in Table 8.

Table 7: Canada-wide building blocks for CAs

Alberta	8 Watershed Planning and Advisory Councils (WPACs Established under the government's Water for Life Strategy
British Columbia	Fraser Basin Council
Manitoba	18 Conservation Districts (CDs)
Ontario	36 Conservation Authorities (CAs)
Quebec	33 Watershed Organizations (WOs)
Territories	4 Land and Water Boards (Northwest Territories) 1 Planning Commission and 1 Water Board (Nunavut) 3 Regional Land Use Planning Commissions, 9 Renewable Resource Councils, and 1 Water Board (Yukon)

Robins (2007)

Table 8: Momentum to integrate LID technologies

Water Opportunities & Water Conservation Act (2010)	Municipalities are required to develop sustainable water, stormwater, and waste water plans
Great Lakes Protection Strategy (2012	Guides efforts to protect the Great Lakes and Ontario's role in the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem – supports green infrastructure, LID, and stormwater management
Climate Ready: Ontario's Adaptation Strategy and Action Plan	Identifies a need for increased resilience of municipal stormwater systems in light of climate change
Places to Grow	Encourages municipalities to implement and support stormwater management actions as part of development and intensification
Provincial Policy Statement (PPS) (2012)	Includes new policies for planning for stormwater management and encourages consideration of LID earlier in land use planning decisions
Ministry of Municipal Affairs: Municipal Planning and Financial Tools for Economic Development Handbook (2011)	Provides a Sustainability Checklist for land use planning which identifies groundwater recharge, reduced stormwater runoff, and water recovery and LID as an element of site plan control
Ministry of Infrastructure's plan: Building Together Jobs and Prosperity for all Ontarians	Acknowledges the impact of climate change on stormwater infrastructure and the need to reduce demand through by promoting conservation and use of green infrastructure

Credit Valley Conservation (2014)

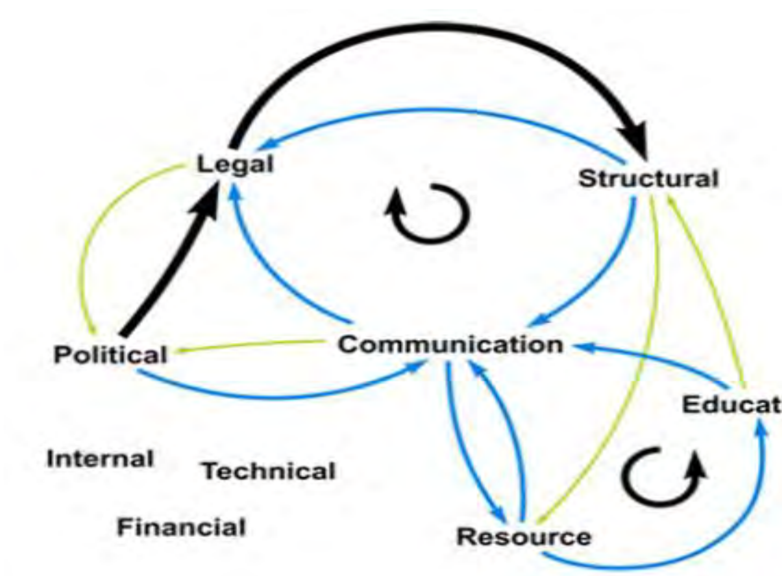
4.0 Barriers to LID uptake

Although the technology and expertise were in existence, barriers to sustainable water supply were located in the social and political domain. Understanding such barriers must precede strategies designed to overcome them Floyd et al. (2014)**.**

4.1 Barrier types and barrier interactions

Winz et al. (2014) in the Project Twin Streams (PTS) Catchment case study carried out in Auckland, New Zealand, provides empirical evidence on how barriers interact to form "barrier interaction networks" as shown in Figure 6.

Figure 6: Barrier interaction networks



Arrow	Interaction strength
Thick black	≥ 90%
Medium blue	70 – 89%
Thin green	60 – 69%

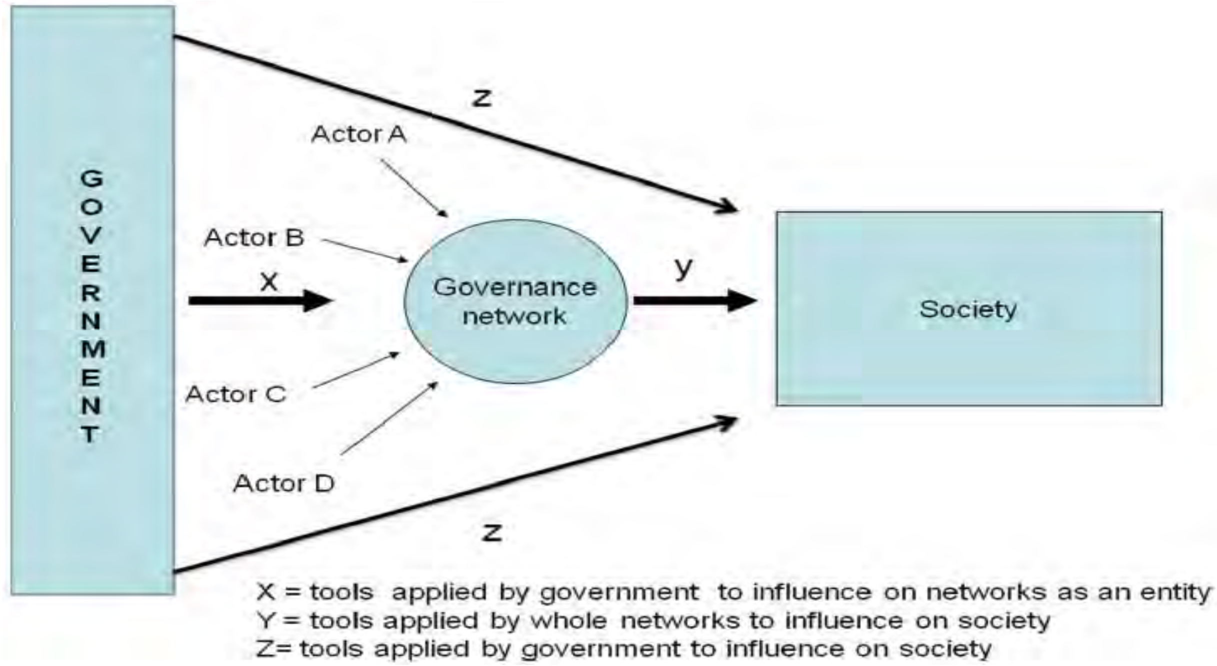
Winz et al. (2014)

The empirical data from the case study shows barriers to the uptake and implementation of LID technologies is located within the social (institutional and logistical) domain rather than the technical one. These barriers interact with each other and form 'barrier interaction networks' as shown by the arrows. During this interaction process, they reinforce each other, creating feedback loops that lead to "systemic complexity". Moreover, there is a 'causal network' where some barriers act as the driving force to other barriers (this is shown by the direction of the arrows). The former are accorded some ‘barrier driving power’ and the later, ‘barrier dependence’ power. As a result of the insight of barrier potency, implementation policies should be directed initially at tackling barriers with driving power rather than dependent barriers. This generates self-reinforcing change as a leverage strategy can be built on this phenomenon to effect change with reduced effort. Appendix D shows details of how the calculations were arrived at.

5.0 Governance at watershed scale

Literature review has shown that urban water management issues are best described as wicked problems landing themselves to high levels of complexity, uncertainty and multi-actor involvement Patterson et al. (2013)**,** Cook et al. (2013)**.** On the other hand, Salamon (2002) sees a “new approach to public problem solving” that places emphasis on the centrality of collaborative approaches to allow for multi-actor involvement of which the government is one of the actors. The most appropriate form for this governance is Networked Governance shown in Figure 7 below. The question is how central authorities fulfill their mandates in such structures. Vabo and Røiseland (2012) addresses the challenges faced by public leaders arising from new governance set-ups (networks) where government is just one of many stakeholders, thus rendering hierarchical approaches problematic. An empirical assessment of whether “classic and generic analytical framework to tools of government” such as the NATO-scheme **(ibid)** is relevant in hierarchical contexts would be applicable in network relations. The conclusion is that, the NATO-scheme remains relevant to networked governance. NATO stands for the tools available to governments to influence networks to achieve public goals. These are nodality (where governments have influence by virtue of being at the centre of the network). Authority refers to the legislative and regulative powers of governments while Treasure are the financial incentives or disincentives that they can apply to steer networks. Organisation is the administrative capacity the government has to deliver services on its own.

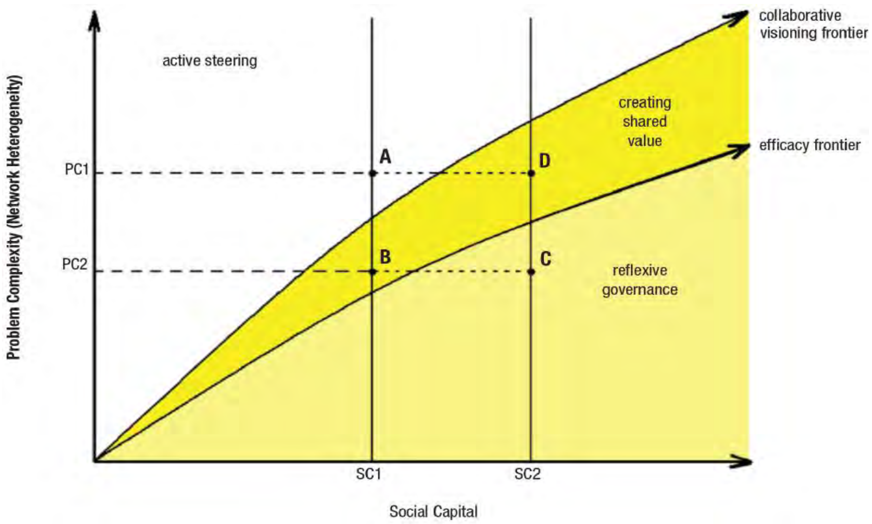
Figure 7: Tools of government applied at different levels



Vabo and Røiseland (2012)

According to Huppé et al., (2012), networked governance is a "decentralized integrative form of problem solving". Networked governance can leverage "distributed capacities" brought by different actors who can deploy their unique skills and resources to generate creative, collaborative, and complex solutions. Collaborative efforts are not guaranteed to succeed especially where social capital is deficient amongst stakeholders more so because the efficacy of network governance is a function of problem complexity and social capital. This creates an "efficacy paradox" (Figure 8), which determines how far centralized authorities get involved in controlling (active steering) the networks. Where there is a balance between problem complexity and social capital, the networks can steer themselves with little top-down involvement. Table 9 summarizes the trade-offs between active and self-steering.

Figure 8: The Frontiers of Networked Governance



Huppé et al., (2012)

Table 9: Summary of trade-off between active and self-steering

Problem	Applicable tools
A: Insufficient social capital, inefficacy of collaborative processes	Network management (policy & knowledge networks) Active steering Centralized problem solving
B: Social capital lies outside efficacy frontier but within collaborative visioning frontier	Possibility of creating shared value Use collaborative visioning processes Adaptive governance and transition management – hybrid models between active steering and self-steering approaches Modulated by centralized governance authorities
C: Same level of complexity as in B but higher levels of social capital	Networked governance processes Governance network has some capacity for self-steering Decentralized power Modulators partly distributed outside of centralized governance authorities High investment of resources required to maintain this capacity
D: Complexity level as B Higher Social capital, not sufficient for networked governance, capacity for self-steering as in C	Employ collaborative visioning processes as in B Modulators partly distributed outside of centralized governance authorities High investment of resources required to maintain this capacity

Huppé et al., (2012)

de Loë and Murray (2012) details a bottom-up study carried out by the Water Policy and Governance Group at the University of Waterloo with findings that are pertinent to the Canadian environment. From a historical perspective, Canada followed a top-down approach where governments were central actors in decision making. Emerging trends show growing reliance on economic instruments, partnerships, multi-stakeholder councils, and shared and collaborative governance. Despite this trend, governments have retained their role as central actors because these roles are constitutionally determined Sandford (2011)**.** Such a scenario has created a situation where delegated responsibility does not include corresponding decision-making authority and it is imperative to accept that authority for decision making should be located within the Provincial and Federal governments as a *fait accompli.* Doing otherwise compromises the concept of legitimacy and accountability. Both de Loë and Murray (2012) and Sandford (2011) suggest a workaround exists in addressing implementation problems arising from collaborative approaches. A policy framework that aids collaborative processes should be put in place so that a "safety net" is provided in case collaborative processes fail. (This is great for dealing with political risk). Memorandums of Understanding (MOUs) which provide clarity to "the purpose of collaboration and how outcomes would be implemented by governments and other actors" are an alternative to policy frameworks. Governance should be coordinated across Canadian provinces and this can be done through the Council of the Federation and the Canadian Council of Ministers of the Environment Sandford (2011).

Governance around watersheds raises the problem of legitimacy which in this respect has two perspectives, one with regards to "legislated legitimacy" and the other, "social legitimacy." Elected representatives bring legislated legitimacy to the decision-making process. But there is also an imperative to bring social legitimacy to the decision-making process in watershed governance which is fraught with complexity and fragmentation. Incorporating multiple stakeholders is a means to building this legitimacy de Loë and Murray (2012)

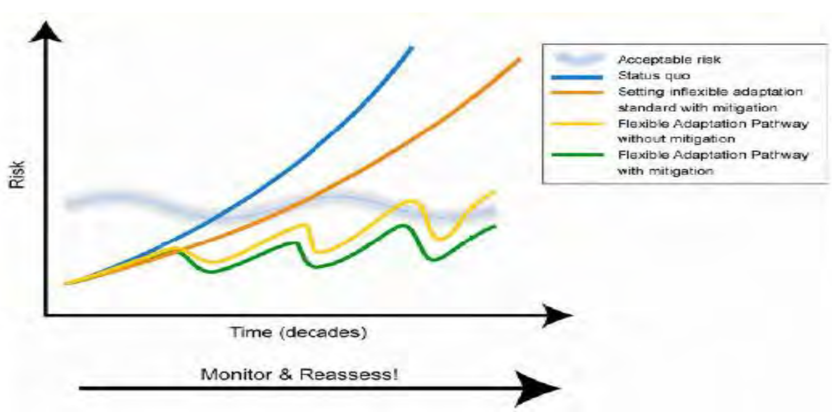
Some of the problems of watershed-scale governance are attributable to a misalignment between watershed boundaries and those of decision makers. A policy framework that supports governance at the watershed scale with delineated roles and responsibilities, entrenched decision making and implementation duties, and developed through consultative processes brings legislated and social legitimacy to watershed-scale governance.

6.0 Risk Management- Climate and Political risk

6.1 Establishing acceptable risk

Managing climate risk entails the integration of top-down (leadership directed) and bottom-up (grassroots) approaches NASA (2013)**.** Leadership focuses on policy coordination while the grassroots focus on "site specific, locally-led initiatives". Best available science is continuously evolving, creating an imperative to allow for the evolution of site-specific adaptation **(ibid).** Both NASA (2013) and Beller-Simms et al. (2014) suggest a paradigm that encourages the adoption of "flexible adaptation pathways" such that "a continuous, dynamic consideration of risk tolerances and corresponding policies" is provided Beller-Simms et al. (2014)**.** Such flexible adaptation pathways are established within the bounds of "Acceptable Risk" Figure 9 refers.

Figure 9: Flexible adaptation pathways



Beller-Simms et al. (2014)

The levels of acceptable risk are defined this level becomes the "target threshold" **(ibid)**. Communities are not locked into long-term strategies as a result of imperfect information but they can adapt as accurate information becomes available. This implies that site specific information should be provided to local communities bringing into play the role of local universities and research institutions **(ibid)** and effectively combining science and policy. Ferguson et al. (2013) encourages the recognition that societal values are not permanent as they evolve through "contextual drivers like resource limitations, environmental impacts, and socio-economic conditions." Since these factors cannot be controlled, it follows that the underlying integrating structure and relationship is not fixed, but must incorporate flexibility to enable adaptation when new conditions arise. Municipal water systems cannot be protected from all forms of risk. This implies that these systems should be enabled with in-built resilience capabilities to confront future extremes and surprises. Some of the strategies for embedding resilience into municipal water systems include "diverse portfolio of water sources" and "smart integrated and connected water grids that allow self-sufficiency and fit-for-purpose water to meet demands" **(ibid).** This goes a long way in aiding communities establish acceptable risk.

6.2 Scenario planning

Developing acceptable risk levels is indispensible from scenario planning. Rankin-Gouthro and Krantzberg (2011) employ a planning technique of scenario building as a means of describing different future scenarios and related outcomes. By examining the fundamental "what can happen if..." question, the approach acts as a driver enabling disparate stakeholders in "setting the foundation for desired policy and management outcomes". Ferguson et al. (2013) refers to "explorative scenario techniques" that focus on the long-term so that municipal water systems are not "locked into current generations of technology". Also as per Rankin-Gouthro and Krantzberg (2011) scenarios facilitate the creation of a common language that can be used by different expert groups. An example is where science and policy domains approach issues from different perspectives with scientists from a resource perspective whilst policy makers start with “social consequences of resource decisions”. “Actor-focussed scenarios are based on group participation with an emphasis on the actors involved, their relationship to the environment and their interpretation of events **(ibid).**

According to Means III et al. (2010) for municipality water systems to address the risks posed by climate change, a transition from conventional planning assuming climate stationarity to “uncertainty-based planning” is required. Scenario-based planning is ideal for such a transition to occur. Such transitions imply transitioning from classic decision analysis approaches where occurrences are assigned probabilities to a situation where all scenarios are treated as likely to occur. Adaptation strategies for each scenario are developed and it is prudent to adopt those strategies that have “near term actions that are common to all or most scenarios.” This is the essence of “No Regrets or Low Regrets strategies” which are “robust across multiple outcomes.” Such strategies have the advantage of reducing risk from climate change at the same time they address other co-beneficial objectives IPCC (2012) of municipal water systems. Because climate change impacts are already being felt by municipal water systems, a sense of urgency is created which originates from the fact that municipal infrastructure is long lasting and hence the necessity to include climate change in early design and operations decisions. Investing early in No and Low Regrets becomes imperative. Projects fitting in this are:

- Water efficiency
- Treating water to be “fit for purpose” where non-portable supplies, reuse, recycled water projects and programs to stretch portable supplies **(ibid)**

6.3 The precautionary principle

In the case of Canada Ltee (Spraytech, Societe d’arrosage) v. Hudson (Town), 2001 SCC 40 the Supreme Court of Canada endorsed the precautionary principle, “the idea that policy makers should act to protect human health and the environment even in the face of uncertainty” Pralle (2006)**.** Political risk can be handled through this principle since it provides some legal basis for potentially risky undertakings like LID projects which may fail on implementation.

6.4 Piloting

Morrison et al. (2012) raises the importance of a “strategic but incremental process of piloting” so that evaluations and comparisons of watershed-based public health initiatives can be tested for viability. Farrelly and Davis (2009) use the term demonstration projects and assert that they act as “bounded experiments, trialling the application of structural innovations, such as technology, infrastructure, or science…” These piloting projects are critical in providing new insights into how technologies contribute to the enhancement of existing practices. Through piloting, communities build on others’ experiences and they fill existing knowledge gaps including pitfalls. Because of low political risks, lessons learnt under safe conditions can significantly help in the uptake of LID technologies. According to Binstock (2011), barriers uptake of LID technologies and can be addressed through creation of substantial performance database of the various LID technologies. The study conducted a jurisdictional review which indicated that implementation barriers will be overcome through alleviation of risk faced by municipalities. This is possible through funding pilot projects across provinces to generate performance data that is regionally specific.

6.5 Opportunities

Canada is the world’s “largest repository of fresh water” and this resource can be leveraged for economic opportunities including “development of fresh water technology Rankin-Gouthro and Krantzberg (2011) as **Henderson and Parker (2012),** also states that Canada’s water treatment technology sector has international acclaim. According to (Federation of Canadian Municipalities 2011)**,** the global green economy is estimated to be in excess of US$4 trillion whist the Canadian sustainability market is projected to grow from $2 billion in 2010 to $4 billion by 2014. Henderson and Parker (2012) asserts that current infrastructure can be upgraded to meet current demand, but future demand will require water infrastructure to shift away from "large-scale centralised engineering projects to small-scale technologies and practises..." that can be deployed in households. Wastewater treatment and reuse, rain harvesting, and LID technologies such as urban wetlands that slow stormwater runoff and filter pollutants. These solutions create green jobs in areas like plumbing, manufacturing, and urban design and planning. Crane (2013) discusses "Growth path to 2050" where an additional two billion people, are a "game-changing new wave of consumers" and its implications on demand for clean water and sanitation. Demand for municipal water will rise by 80 billion cubic metres by 2025 from 190 billion cubic metres, a 40% increase from current levels **(ibid)**. A significant growth will be in the world's "Emerging 440 Cities" which will need access to advice on infrastructure planning and implementation. The global market is large and expanding currently stands at US500 billion per annum and is poised to reach US$1 trillion per annum. Canada should indeed develop its water technology potential in terms of LID and take advantage of this huge emerging market.

7.0 Conclusion

Municipal water systems have evolved through history driven by socio-political paradigms that led to unsustainable path dependences that disregarded the hydrologic cycle. Urban development created high levels of impervious surfaces that dramatically altered the hydrologic cycle by increasing the proportion of surface runoff flowing into stormwater systems into receiving water bodies and conveying pollutants into drinking water systems. The result has been threats to human health and well being of Canadians creating the imperative for effective responses to these threats. Climate change is compounding these negative impacts thereby compelling municipal water systems to transition to sustainable practices like integrating risk management through LID technologies applied at watershed scales, across municipal jurisdictions, and across sectors that although they are outside the purview of municipal water systems; they play a significant role in impacting these systems. Although the solutions are technically feasible, barriers to implementation are located in the institutional domain which can be enabled through collaborative and multi-actor approaches.

8.0 Recommendations

This research provides background information on integrating risk faced by municipality water systems

Municipalities provide direct services to their communities and it is necessary that actionable information be provided. It is therefore recommended that the next phase on this research be based on practical data gathered from a watershed wide case study especially from working primarily with a conservation authority and a sample of municipalities on the downstream and upstream of a watershed. Such an approach should be designed to produce actionable information that will be presented in the form of briefing notes dealing with different components like an agreed upon governance structure, how the LID technologies can be implemented across municipal jurisdictions and the financing thereof. Overall, the research should lead to the production of a Cabinet Submission which will form the basis for pushing the Provincial and Federal levels to commit to a watershed approach involving Conservation Authorities or similar bodies.

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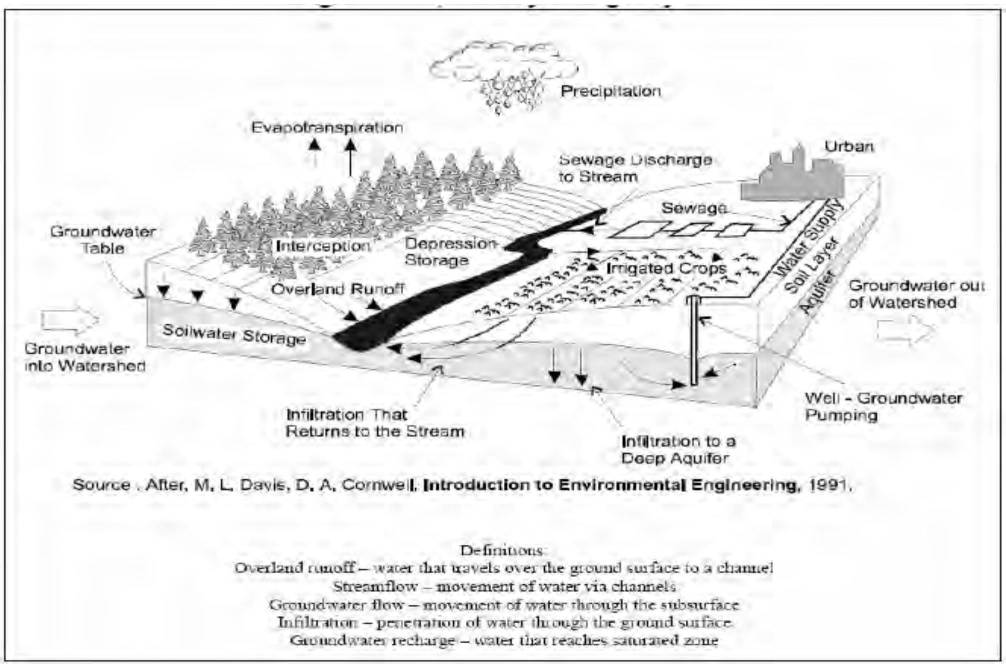
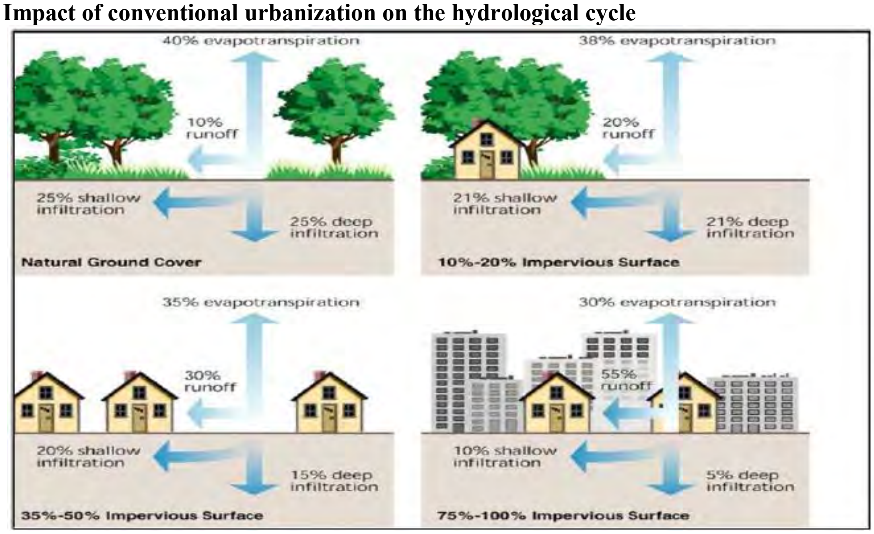
Appendix A: The hydrologic cycle



CVC and TRCA (2010)

Land urbanization changes the precipitation proportion infiltrating into the ground, and evaporates into the atmosphere to enter drainage features as runoff because of land use change

Impact of conventional urbanization on the hydrological cycle



CVC and TRCA (2010)

Dramatic alterations precipitation flow pathways. There is a 3 to five times the increase of reaching streams instead of recharging aquifers.

Ecosystem responses to urbanization

Results of Increased Imperviousness	Resulting Impacts					
	Flooding and Altered Stream Flows	Habitat Loss	Erosion and Sedimentation	Channel Widening	Streambed Alteration	Water Quality
Increased Flow Volume	✓	✓	✓	✓	✓	✓
Increased Peak Flow	✓	✓	✓	✓	✓	✓
Increased Peak Duration	✓	✓	✓	✓	✓	✓
Increased Stream Temperature		✓				✓
Decreased Base Flow	✓	✓				✓
Sediment Loading Changes	✓	✓	✓	✓	✓	✓

CVC and TRCA (2010)

The cascading effects of imperviousness in the absence of effective stormwater management

Major sources of common stormwater pollutants

Common Constituents	Major Sources Related to Urban Land Use
Sediment and Particulates	Construction, winter road sanding, vehicle emissions, pavement wear
Hydrocarbons (PAH's)	Spills, leaks, dumping, vehicle emissions, asphalt breakdown, wood preservatives
Pathogens (Bacteria, Viruses)	Illicit connection of septic systems to storm sewers, poor housekeeping (animal feces, bird feces from rooftops)
Chloride, Sodium, Calcium	De-icing salt applications
Cyanide	Anti-caking agent in de-icing salts and sand / salt mixtures
Nutrients (N, P)	Illicit connection of septic systems to storm sewers, detergents (car washing), lawn fertilizers
Cadmium	Tire wear, insecticides, wood preservatives
Zinc	Galvanized building materials, tire wear, motor oil, grease
Lead	Motor oil, lubricants, batteries, bearing wear, paint, vehicle exhaust
Copper	Wear of moving engine parts, metal plating, fungicides and insecticides
Manganese	Wear of moving engine parts
Nickel	Vehicle exhaust, lubricants, metal plating, wear of moving parts
Chromium	Metal plating, wear of moving parts
Iron	Steel structures, rusting automobile bodies
PCBs	Leaks from electrical transformers, spraying of highway right of ways, catalyst in tire construction

CVC and TRCA (2010)

Appendix B: LID Technologies

Rain Harvesting: Conserves portable water & reduces stormwater run-off Municipal water consumption reduced by about 55% Landscape irrigation, toilet flushing Cost saving – delayed expansion of municipal water treatment & distribution systems, lower energy for treating & pumping, lower water bills	
Green Roofs: Reduction of urban heat island effects, green space for passive recreation	
Downspout Disconnections: Directing flow to pervious areas and prevents stormwater directly entering stormwater system	
Bioretention: Rain garden, Stormwater filter and infiltration Temporarily stores, treats, and infiltrates runoff	
Bioretention: Curb extension	
Bioretention: Rights-of-way (ROW), Traffic Islands & Medians	

Appendix B: Permeable Pavement types

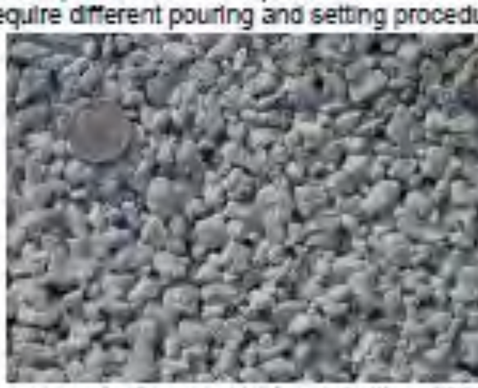
Permeable interlocking concrete pavers (block pavers): Concrete pavers are designed with gaps between them that allow stormwater to infiltrate into the aggregate reservoir. The gaps are approximately 10% of the surface area and are filled with small stone.

Permeable paver parking lot in Mississauga, ON (Source: CVC)

Plastic or concrete grid systems are concrete or durable plastic grids filled with gravel or a pervious planting mix for grass or low ground cover. The grids provide support for vehicles or foot traffic while preventing compaction and rutting of the fill material. Grid systems are appropriate for applications such as walkways, overflow parking, firelanes, maintenance and utility acccess lanes, or driveways.

Residential driveway (Source: R. Bannerman); Plastic grid filled with gravel (Source: Gravelpave®)

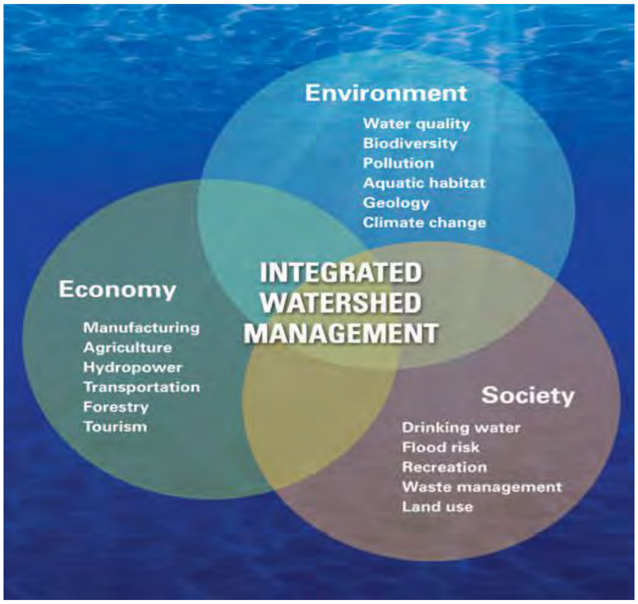
Pervious Concrete and Porous Asphalt have pavement mixes with reduced or no fines which creates stable void spaces. The void spaces allow stormwater to drain through to the underlying stone reservoir. They require different pouring and setting procedures than their impervious versions.



Pervious concrete(Source: Hunt and Collins, 2008); Porous asphalt parking lot (Source: University of New Hampshire Stormwater Center)

CVC and TRCA (2010)

Appendix C: Triple Bottom Line for watersheds



Conservation Ontario, 2012

Appendix D: Barrier strength calculations

The PTS comprises of an upper and lower catchment areas where the later consists of native forest regeneration and semi-pastoral land use whilst the former contains low-medium density residential areas together with commercial land use. This is a case study of an environmental restoration and stormwater management project whose aim was to strengthen communities by reconnecting residents with their local environment. Forty-five barriers were identified and grouped into 11 categories shown in Table 1. A pair-wise comparison between the individual barriers was done to determine the influence strengths between barrier categories which was calculated as a percentage and ranked as shown in

%	Rank	Category Pair	%	Rank	Category Pair	%	Rank	Category Pair
100	1	Political to Legal	55	18.5	Internal to Education	35	35	Financial to Political
92	2	Legal to Structural	55	18.5	Resource to Structural	34	36	Internal to Resource
83	3	Communication to Legal	54	20	Internal to Political	33	37	Resource to Legal
81	4	Structural to Communication	53	21	Political to Internal	30	39.5	Education to Resource
80	5.5	Communication to Resource	50	23	Communication to Structural	30	39.5	Resource to Financial
80	5.5	Resource to Education	50	23	Education to Political	30	39.5	Resource to Internal
75	7.5	Education to Communication	50	23	Technical to Structural	30	39.5	Political to Financial
75	7.5	Political to Communication	47	25	Legal to Resource	29	42	Financial to Internal
70	9	Resource to Communication	45	26	Political to Structural	25	45	Structural to Financial
67	10	Structural to Legal	44	27.5	Resource to Political	25	45	Internal to Financial
65	11	Communication to Political	44	27.5	Political to Resource	25	45	Structural to Political
63	12	Education to Structural	43	29	Internal to Communication	25	45	Financial to Legal
60	13.5	Legal to Political	42	30	Legal to Communication	25	45	Legal to Financial
60	13.5	Structural to Resource	40	31	Political to Education	20	48	Financial to Resource
57	15.5	Education to Internal	39	32	Communication to Internal	0	50	Internal to Physical
57	15.5	Technical to Internal	38	33.5	Financial to Structural	0	50	Structural to Physical
56	17	Communication to Education	38	33.5	Structural to Education	0	50	Education to Legal

(Winz et al. 2014)

Normalizes % of barrier interactions between two categories:

= Existing interactions/All possible interactions

e.g. Financial = 4
Political = 5

There are 20 possible interactions in one direction

Only 7/20 are considered

Interaction strength = 35%