Prairie Climate Centre

Building a Climate-Resilient City: Water supply and sanitation systems

KEY MESSAGES:

- Building and maintaining a water supply system resilient to climate shocks requires “multi-barrier” methods that strengthen all infrastructure components.
- Redundancy in water supply should be a policy priority with the flexibility to shift between surface and groundwater options.
- Highly decentralized water supply and sanitation options are now feasible; they provide resilience and complement centralized systems.
- Water conservation and green infrastructure options for stormwater management are proven approaches for reducing climate risks.

In recent decades, Alberta has experienced significant changes in its climate as well as its economy, population and environment. Mean annual temperatures are increasing and projected to continue to rise in the coming decades—potentially by 2.0°C by the 2030s and 4.0°C by the 2060s (compared to the 1990s)—should the current rate of global greenhouse gas emissions remain unchanged. Total average annual precipitation is also projected to increase, but this change will vary between seasons; precipitation levels are likely to increase more in the winter and decline in the summer.[1] While these shifts in average climate conditions are significant, the more profound risk of climate change lies in the expected increase in climate variability and extreme weather events such as longer heat waves and more frequent heavy rainstorms. Should global greenhouse gas emission rates decline, the change in Alberta’s climate will be less severe but still significant.

These climatic changes carry with them many implications for urban centres in Alberta, including the cities of Calgary and Edmonton. Although all infrastructure systems will be affected, water supply and sanitation will be especially affected by direct impacts within municipal boundaries and by impacts in the upstream watersheds that provide source water. Long-term drought may deplete potable water availability; severe flooding or other climate shocks (e.g., tornados) may damage water and/or wastewater treatment plants, and blackout events may mean insufficient backup power to operate plants.

In response, there is a need to build the resilience of cities so that they are better able to withstand anticipated and unanticipated shocks and stresses. A resilient city is one in which its institutions, communities, businesses and individuals have the capacity to function and are able to "survive, adapt and grow" in response to any kind of sudden short disruption that they may experience. Such cities integrate the qualities of flexibility, redundancy, robustness, resourcefulness, reflectiveness, inclusiveness and integration into all aspects of city functions (see Box 1). These qualities of resilience are considered essential to preventing the breakdown or failure of a system and enabling it to take action in a timely manner.[2]

This paper examines ways to build resilience in the water supply and sanitation system as a contribution to urban resilience building. Its purpose is to highlight areas of best practice for developing a more resilient water supply and sanitation system. In addition, it will demonstrate the significance of the system's interconnectedness and dependence on other infrastructure systems, such as transportation and energy, and provide concrete recommendations to be considered for implementation within Calgary and Edmonton. It is one of a series of papers prepared by the Prairie Climate Centre to provide the public and government officials with an overview of the means by which to build cities that are resilient to the impacts of climate change, drawing on lived experience and best practices.

Envisioning a Resilient Water Supply and Sanitation System

Just as foundational infrastructure, such as water supply and sanitation systems, is essential for the functioning of both daily and vital services to communities, it is also essential that water supply and sanitation infrastructure be protected against failure and maintained despite climatic disruptions. Building more robust networks, integrating redundancies and encouraging resourcefulness into these sectors can assist in reducing the myriad of impacts incurred when these systems are offline. There are many ways of building resilient cities, some of which are illustrated through interventions that enhance the qualities of robustness, redundancy and resourcefulness.

Building Robustness

A climate-robust water supply and sanitation system draws upon multi-barrier water protection principles—essentially an integrated system of procedures, processes and tools that prevent or reduce the contamination of drinking water from source to tap. Investing in the ecological integrity of water supply sources and their watersheds is an increasingly important component of the multi-barrier approach.

Through the 20th century, water supply and sanitation—like energy systems—have become ever more centralized and reliant on key water and wastewater treatment plants. A basic resilience strategy means hardening these infrastructure nodes to climate impacts. The ascendant 21st century technologies allow higher levels of service decentralization, the resilience benefits of which will be explored in subsequent sections.

In 2011 Associated Engineering Calgary (AEC) reported[4] climate change impacts on Calgary's water supply system using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol developed by Engineers Canada. Their key engineering recommendations focused on hardened mechanical components, controls and crucially multiply-redundant power systems as the most critical elements, foreshadowing the vulnerabilities exposed in the 2013 flood. AEC's other major climate impact insight was increased vulnerability to forest fire in source watersheds, which would result in much decreased source water quality (sedimentation, turbidity) and potentially excessive demand on water treatment plants. Advanced fire suppression, ecological watershed management and water conservation were noted as no-regrets mitigation actions.

BOX 1. QUALITIES OF A RESILIENT CITY[3]

Reflective: People and institutions reflect and learn from past experiences and leverage this learning to inform future decision making.

Robustness: Urban physical assets are designed, constructed and maintained in anticipation of high-impact climate events.

Redundancy: Spare capacity is built into the system to account for disruptions and surges in demand. It also involves multiple ways of fulfilling a need or function.

Flexible: Refers to the willingness and ability to adopt alternative strategies in response to changing circumstances or sudden crises. This can be achieved through new knowledge and technologies.

Resourcefulness: Citizens and institutions are aware of climate risks, able to adapt to shocks and stresses and can quickly respond to a changing environment.

Inclusive: Inclusive processes emphasize the need for broad consultation and many views to create a sense of shared ownership or a joint vision to build city resilience.

Integrated: Integrated processes bring together and align city systems to promote consistency in decision making and investments. Exchange of information between components of the system enables them to function collectively and respond rapidly.

Promoting Redundancy

The principle of redundancy for water supply and sanitation is best understood as the capability of subsystems to source water and treat wastewater in the event that key nodes in the network are disrupted. Water supply system redundancy includes source water supply diversity. For example, Regina has the flexibility to source potable water from a network of groundwater wells when its surface water source (Buffalo Pound Lake) is impaired, which happens during severe climate events, typically when high temperatures impair water quality or during drought episodes.

Calgary and Edmonton have no such redundancy in their source water supply. Edmonton is wholly reliant on flows in the North Saskatchewan River, which, according to paleo-climatic analysis, has had episodes of zero flow in past centuries. Calgary has slightly more redundancy as its water is sourced from both the Bow and Elbow watersheds; however, because of their proximity, they have highly correlated climatological risk: drought in one means drought in the other. Conjunctive surface/groundwater development has long been advocated for Alberta's rational development for semi-arid Western cities generally—the benefits of which are clearly demonstrated by Regina—and should be re-examined as a source of climate resiliency.[5, 6]

Redundancy in the sanitation sector is strongly related to the adoption of modular, decentralized wastewater treatment technologies, an extremely active cleantech sector globally and in Canada. Decentralized wastewater treatment reduces public safety risk in the event that centralized wastewater treatment plants are forced offline from a climate shock. They are recognized by the U.S. Environmental Protection Agency as a viable alternative, particularly in new subdivisions and industrial parks.[7]

BOX 2. THE CREDIT VALLEY CONSERVATION AUTHORITY'S LOW-IMPACT DEVELOPMENT MODEL[9]

The Credit Valley Conservation Authority (CVC) protects and manages the Credit Valley watershed. The Credit River rises above the Niagara Escarpment and meets Lake Ontario at Port Credit, now part of Mississauga. The CVC was founded in 1954 when the Credit watershed was mostly rural, but becoming ever more developed and enveloped by suburban sprawl within the municipal boundaries of Mississauga and Brampton. By 2020, the Credit watershed is projected to be 40 per cent developed based on currently approved plans. Because urbanization and suburbanization disrupts natural watershed function, the Credit watershed does not retain rainfall efficiently and runoff volumes are much higher than they would be if the watershed were undeveloped.

The CVC is a Canadian leader in low-impact development (LID) to mitigate stormwater runoff, reducing flood risk and pollution loads. The CVC invokes climate change as a key reason for their continued commitment to LID. After six years of constructing and monitoring LID practices for water quantity and quality results, the CVC reports annual runoff volumes have reduced by up to 80 per cent. There has also been an 80 per cent decrease in suspended solids, an 80 per cent reduction in phosphorus loadings, heavy metal loading reductions from 50 to 90 per cent and, very impressively from a climate adaptation perspective, a cooling effect on water filtered by LID systems of more than 5°C.

CVC success with LID practices and systems—primarily on public land—have led neighbouring Ontario municipalities Toronto and Peel to also incorporate LID into new infrastructure design standards along roadways, parks, and within public and institutional spaces. CVC also recognizes that to achieve the full benefit of LID, the practices must be extended to private land through regulatory and economic instruments. In 2016 Mississauga began levying a residential stormwater fee based on the amount of impervious surface on each property as determined by aerial imagery and mapping software, with the broad intent of bringing LID principles to privately owned land within the Credit Valley watershed.

The range of new wastewater technologies is truly impressive, including drop-in small footprint and energy-efficient secondary treatment replacement reactors for conventional wastewater plants. Existing installations serve 50,000 to 1 million people.[8] Cities could opt for multiple small reactors within the footprint of existing plants or deploy spatially distributed systems with network redundancy to re-route waste flows from city quadrants that have been disrupted from climate shock.

Highly decentralized wastewater treatment to the individual household is also possible and should be examined for retrofit and new build contexts. The recently commercialized Dutch DeSaH concept (Decentralized Sanitation and Re-use) integrates gray water (shower, bathtub, sink) re-use for flushing with separated black water (toilet, kitchen) waste treatment via fermentation and biogas production with sludge returned as agricultural fertilizer. The DeSaH concept demonstrates extreme redundancy by applying water, energy and nutrient cycling principles.

Encouraging Resourcefulness

Resourcefulness is the intelligent use of existing resources by empowered citizens and government. In the water and sanitation sector, it typically involves the creative re-use and retention of water to minimize the utilization of conventional infrastructure, and some degree of autonomy from the water and sewerage networks in the event of system malfunction.

A basic example is rooftop rainwater harvesting using cisterns for potable water supply, an ancient technology still practiced widely: many Canadian provinces and U.S. states allow it, and the U.S. Virgin Islands and Bermuda require it for all new residential construction. Cisterns are ubiquitous in rural Canada and on the B.C. coastal islands. In 2012 the Canadian Standards Association (CSA) released a new standard (b126) covering residential cistern design and installation. Residential, neighborhood and industrial park water retention practice can also ease the loading on sewerage systems—especially combined sewer overflow—from extreme precipitation events.[10] Rainwater harvesting, green roofs and downspout disconnection are all consistent with this principle. Very simple technologies like backflow valves to prevent basement flooding should be required in new construction at this point, as is the case in Edmonton.

At the municipal and watershed levels, the LID concept applies resourcefulness principles at larger scales, incorporating elements such as bio-retention, vegetated filter strips, permeable pavement and grassed swales, all integrated into the spatial design and management of subdivisions and watersheds. LID objectives are typically to maximize the retention of runoff, nutrients and suspended solids—essentially designing highly permeable landscapes that permit ecological systems to replace the key functions of conventional infrastructure.

At the institutional scale, resourcefulness manifests as larger-scale watershed management that can reduce dependence on or defer/reduce investment in conventional infrastructure by investing in enhanced ecosystem function. Examples include water quality trading systems, which allow municipalities to purchase improved water supply and/or quality from surrounding watersheds rather than invest in treatment plants. Water supply examples include New York City, U.S.A and Lima, Peru; water quality examples include Chesapeake Bay, U.S.A. and the Murray-Darling Basin, Australia.[11]

Recommendations

Strategic

- Perhaps the foremost strategic decision cities face is the degree to which they choose an ecosystem-based perspective to source water protection and develop the relationships with upstream and downstream watershed management agencies and municipal governments. Support for green infrastructure ("natural vegetative systems and green technologies that replicate the functions of ecosystems and provide society with a multitude of benefits") for source water protection, water quality treatment and climate adaptation generally will not be widely adopted unless managers and the public are broadly aware of ecosystem service concepts and applications. Well-designed ecosystem service approaches create a rural-urban relationship that can foster mutually beneficial green infrastructure investments.
- Conduct leading-edge climate impacts analysis on source watersheds using stochastic hydrology based on multi-model global circulation models. Such an exercise will help managers understand the range of future hydro-climatologic risk and advocate more clearly for infrastructure investment including green infrastructure options.
- Conduct risk management scenario planning exercises for managers that consider the joint effects of simultaneous flooding and power outages and drought and power outages as a second phase of the source watershed climate impact analysis.
- Conduct a scoping study on decentralized water supply and wastewater treatment with respect to emerging technologies, economic development opportunities for cleantech leadership and the benefit of increased climate resilience. Consider the 2013 flood as a benchmark scenario and examine how decentralized treatment systems could have reduced vulnerabilities.
- Develop position papers regarding water-use efficiency and decentralized water treatment as forms of cleantech innovation and as distinctive attributes of the investment value proposition worthy of demonstration at residential, industrial and subdivision scales.

Regulatory/Administrative

- Conduct a review of the infrastructural and institutional mechanisms that would permit reallocation of existing water supply in crisis situations (such as from industrial to residential), including a review of the regulatory vulnerabilities associated with First In Time First In Right (FITFIR) water allocation system in the context of hydrologic drought.
- Review the regulatory context for decentralized water supply and wastewater treatment facilities (cisterns, grey water recycling, and decentralized water and wastewater treatment). Identify regulatory obstacles to innovative applications of decentralized water technologies and develop a municipal strategy for creating water technology innovation testbeds.

Economic Instruments

- Review tariff structures for residential and industrial water supply and consider alternative tariff structures for consistency with social justice, equity and conservation objectives.
- Analyze water-use efficiency among industrial and residential consumers; review the international state-of-the-art standard for industrial water-use efficiency and consider incentives for water conservation and for encouraging redundant supply—such as the ability to switch to groundwater.
- Conduct a feasibility analysis of water trading systems for industrial consumers in order to drive down demand. Include a review of international precedents for water supply trading.
- Review the North American experience with stormwater levies (Mississauga) and stormwater retention credits (Washington, D.C.), as well as rebates based on xeriscaping, to establish potential large-scale green infrastructure systems for urban stormwater management.

Voluntary/Community Linkages

- Develop public education materials for a "water smart" culture, with household-level conservation and low-impact development such as permeable surface materials for paved areas, rainwater collection systems and bioswales.
- Promote citizen science in the educational system for water and hydrology, including crowd-sourced monitoring of precipitation, temperature, streamflow and water quality to augment official data gathering to introduce water stewardship and climate change concepts to school-age children.

References

[1] Projections based on data generated by the Pacific Climate Impacts Consortium. The average of 12 models over a 30-year time period were used for the time frames of 2021 to 2050 (the 2030s) and 2051 to 2080 (the 2060s) against a baseline of 1981 to 2010 (the 1990s) using a business-as-usual greenhouse gas emissions scenario (Representative Concentration Pathway 8.5). Further information is available through climate profiles created by the Prairie Climate Centre for Calgary and Edmonton.

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[3] Ibid.

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[8] One such example of modular wastewater treatment solutions is the Nereda Wastewater Treatment plant in Rio di Janeiro. See: https://www.royalhaskoningdhv.com/nereda

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The Prairie Climate Centre is a collaboration of the University of Winnipeg and the International Institute for Sustainable Development established to advance practical climate change solutions for the Canadian Prairies. The centre's mandate is to translate climate science into knowledge products, frameworks and decision-making tools that will help local governments, the private sector, civil society organizations and other practitioners implement adaptation measures.

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