NATURAL INFRASTRUCTURE IN A CHANGING CLIMATE

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We tend to notice infrastructure when something goes wrong. Delayed trains, power outages, and water contamination make us aware of how much we rely on the physical structures that provide services to our communities. Unfortunately, flooded buildings and train tracks, increased potholes from freeze-thaw cycles, and downed power lines from severe storms are just some of the many impacts a changing climate can have on infrastructure.

Climate change threatens the effectiveness and lifespan of the critical infrastructure systems that we use to travel, power our homes, and keep us safe and healthy. Adapting human-engineered or grey infrastructure (like bridges and culverts) to withstand extreme weather events is critical to making our communities more climate-resilient. In Canada, it has been estimated that it will cost $5.3 billion per year to adapt our infrastructure to be resilient to the impacts of climate change. However, the costs of not adapting our infrastructure will be even higher. As an example of just one extreme weather event in a single municipality: a record rainfall event in Toronto on July 8th, 2013 caused severe flooding, resulting in more than $850 million in insured property losses. This event cost the municipal government over $70 million. Studies show that the return-on-investment for climate-resilient infrastructure is 6:1, which means that for every dollar invested in adaptation measures, $6 is saved in future damages.[1]

Municipalities are starting to acknowledge that harnessing the resiliency of natural systems is a key part of preparing for climate change. Natural or green infrastructure are terms that are increasingly being used to describe ecosystems and built forms that use natural processes to provide essential infrastructural services. Natural elements like tree roots, healthy soils, and wetlands provide functions that can reduce or mitigate the impacts of climate change or other natural hazards, such as those wrought by significant rainfall events, ice storms, and heat waves. Ecological processes within natural or naturalized areas prevent and mitigate floods, erosion and landslides, moderate the urban heat island effect, and purify our groundwater.

Additionally, natural infrastructure provides environmental, economic, and social benefits not typically produced by grey infrastructure. For instance, trees in cities provide cleaner air by removing pollutants, offer cooling benefits by providing shade, and improve health and wellbeing by providing greenspace for residents. The Regional Municipality of York (York Region) estimates that it would cost $12 billion to replace their 29 million trees, which provide millions of dollars worth of services annually to residents.[2] In some instances, these co-benefits can make natural infrastructure a more cost-efficient and cost-effective measure against the impacts of a changing climate, when used alongside grey infrastructure, than can be achieved using grey infrastructure alone.[3]

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1 IBC and FCM, 2020
2 York Region Forestry, 2017
3 ICF, 2018

Green and natural infrastructure are assets that should be invested in and managed alongside their grey counterparts. Like all assets, natural infrastructure needs to be managed appropriately. To achieve this, communities need to inventory their existing natural assets and determine a desired level of service required from them. In the same way we need to know how much transportation capacity we have and need, we also need to understand how much woodland we have and need. The actions needed to maintain healthy and functioning natural infrastructure – like restoration and management – should be planned for and consistently funded. Some examples of climate adaptation needs, as well as a comparison of grey vs green infrastructure solutions, are outlined in the table below.

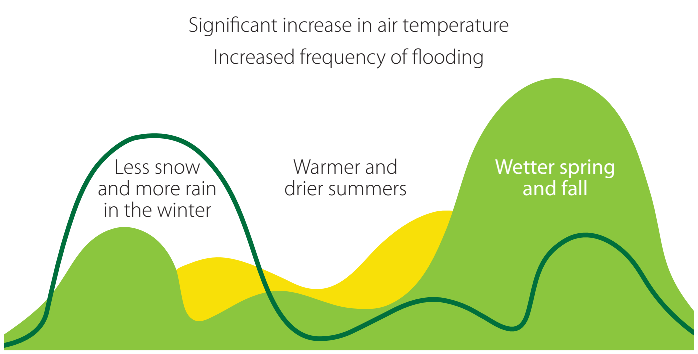
CLIMATE CHANGE ADAPTION NEED	ENGINEERED/GREY SOLUTION	GREEN OR NATURAL INFRASTRUCTURE SOLUTION	EXAMPLE OF INVESTMENT NEEDED
More extreme heat days	Cooling centres, air conditioning, shade structures	Street trees provide cooling for pedestrians, as well as shade for grey infrastructure like roads, extending the lifespan of the roads.[4]	Street trees that are stressed do not function well and provide less shading service. Investing in proactive tree management like watering and mulching is needed.
Drought	Water holding tanks and irrigation systems for agriculture	When integrated properly into agricultural landscapes, trees can buffer the impact of water stress on crop performance.[5]	Investment is needed to support farmers and rural landowners in appropriately utilizing agroforestry and tree row practices.
Flooding	Dams	Wetlands function like sponges and can often store and slowly release water.[6]	While wetlands can help adapt to changes in water levels, they are also at risk because of these changes. Investments in monitoring and restoration are needed.

It is worth noting that many of the adaptation services that green or natural infrastructure provide cannot be replaced by engineered or grey solutions. For example, there are known mental health and social risks associated with climate change (see the Greenbelt Foundation's *Mental Health in Changing Climate* series of reports). The restorative and recreational services of Ontario's natural infrastructure, like that found in the Greenbelt, provide important mental health benefits. Lakes, forests, wetlands and similar natural features have no grey infrastructure equivalent (Trees Ontario, 2010).

Our water infrastructure in the Greater Golden Horseshoe (GGH) needs investment in order to adapt to climate change. This paper explains some of the challenges in municipal water management and lays out innovative ways of bringing the contributions of nature back into our communities, including how individuals can help.

4 Center for Urban Forest Research USDA, 2020
5 Nasielski, et al., 2015
6 US EPA, 2002

MUNICIPAL WATER INFRASTRUCTURE IN A CHANGING CLIMATE



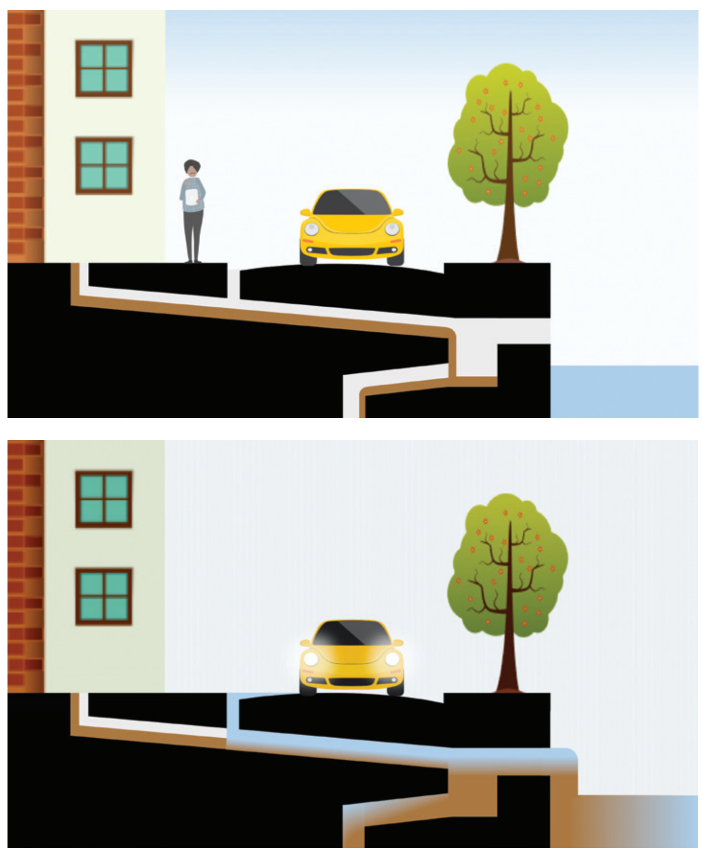
Likely climate change impacts to stormwater systems in Ontario

Water management infrastructure like sewers, culverts, and storm drains, collects and treats rainwater and snow melt that runs off the surface of urban areas, protecting aquatic ecosystems and drinking water. With climate change, it is anticipated the GGH region will experience a range of changes to rainfall and snowfall patterns, in addition to higher overall temperatures. In the summer, it is expected that we will have longer dry periods interspersed with rain arriving in more intense storms (see figure to the left). This will create water management challenges both when we have too much water, and when we have too little. These challenges will put additional stress on already aging municipal water infrastructure that is also facing pressure from increased urbanization.

MUNICIPAL WATER INFRASTRUCTURE IN THE GREATER GOLDEN HORSESHOE

The way rainwater moves through urban and suburban landscapes, like those found in the GGH, is very different from the way it would move in a natural area. Rainstorms deliver varying depths of rainwater, with the shallowest storms of less than 5 mm being most common. In 2020, we would expect a storm of 20 mm maybe once or twice per year. A storm of 20 mm falling on a typical forest would cause no runoff as all the water would either be trapped on leaf surfaces or would soak into the soil. Only 50% of the same stormwater would be trapped on the urban landscape, and the rest of the water would run into sewers (Jen Hill, personal communication, 2020). This is because buildings, which are typically smooth, flat, and planar surfaces, have far less surface area than the leaves and bark in forests, not to mention that much soil is covered by asphalt and concrete (Pope & Treitz, Leaf Area Index (LAI) Estimation in Boreal Mixedwood Forest, 2013). The impermeability of urban surfaces is a contributing factor to urban flooding.

Some of the earliest sewers in the GGH were constructed around the mid-1800s.[7] Most of these sewers were built to accommodate the sewage from homes, industrial processes, and excess stormwater from the streets. These sewers are called combined sewers because of this combination of sources. While wastewater from homes and industry is produced at a relatively predictable and stable rate, stormwater can arrive in huge volumes very quickly. When this happens, the combined sewer may overflow through emergency outlets into our rivers or lakes—an alarmingly common occurrence. This does not even take into consideration the more intense storms anticipated as climate change progresses. For example, in the City of Toronto, sewage overflows happen often from spring to fall (Lake Ontario Waterkeeper, 2020). These overflow events can cause significant contamination of water with bacteria and other pollutants that affect our beaches, fishing, and wildlife. In 2017 in Ontario, 21 million cubic meters (that's 21 billion litres) of sewage entered natural water courses through combined sewer overflows (Statistics Canada, 2020). Modern sewers do not overflow in the same way. Unfortunately, many urban areas still rely on old-fashioned sewer systems; replacing old sewer systems is a complex and expensive job that is ongoing in the GGH.

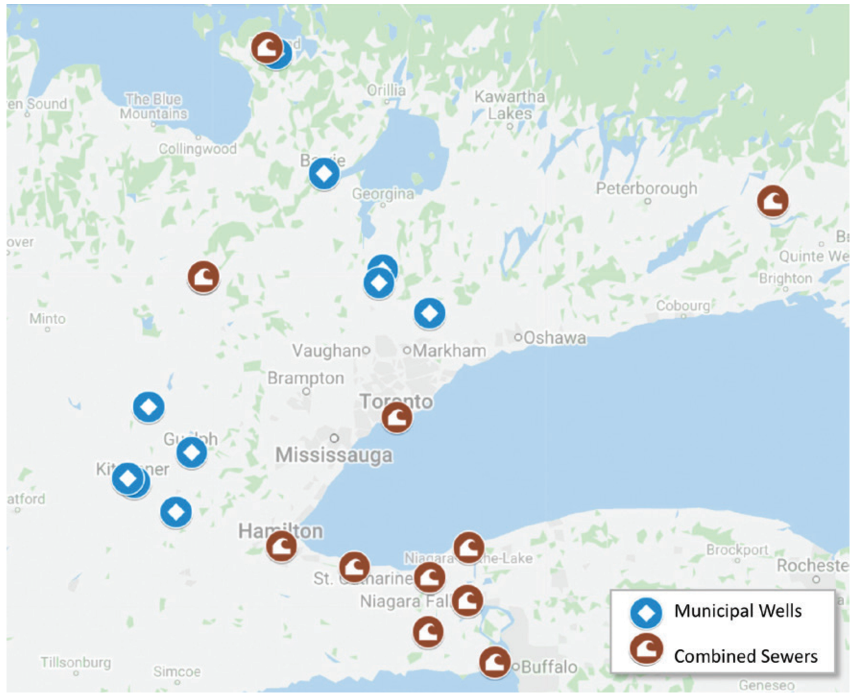


Combined sewer on a dry day (top) and combined sewer overflowing during intense rainstorm (bottom)

7 Brace, 1995:23(2)

Table 1: Example places with combined sewers and/or municipal wells

Combined Sewers	Municipal Wells
Fort Erie	Barrie
Grimsby	Cambridge
Hamilton	East Gwillimbury
Niagara-on-the-Lake	Elora
Niagara Falls	Guelph
Penetanguishene	Kitchener
Shelburne	Midland
St. Catherines	Newmarket
Toronto	Shelburne
Trent Hills	Waterloo
Welland	Whitchurch-Stouffville



The GGH's early urbanized areas were established along Lake Ontario for easy access to freshwater. Many of the towns and cities established further from the lake rely on municipal wells to provide clean freshwater. These wells are dug to a depth where the surrounding soil is completely saturated with water; this saturated soil is called an aquifer. Aquifers can be small or large, but none contain infinite quantities of water. The water in many aquifers comes from surface water, which has permeated down through the soil, either locally or somewhere nearby where the ground is more *permeable*.

Urbanization causes a significant increase in runoff from rainstorms compared to forests

GREEN INFRASTRUCTURE refers to the natural vegetative systems and green technologies that collectively provide society with a multitude of economic, environmental, and social benefits.

LOW IMPACT DEVELOPMENT (LID) absorbs and holds stormwater, helping reduce the amount of runoff entering sewers during rain events. By absorbing rain where it falls, LID decreases the amount of untreated runoff that is discharged into water bodies from combined sewer system overflow events.

In addition to increasing the volume of runoff from rainstorms, urbanization adds pollutants and heat to the runoff water. Chemical pollutants and increased water temperature are both very damaging to our local aquatic ecosystems.

New (Old) Ways of Stormwater Management

In addition to building separated sewers, many municipalities and communities are using a range of techniques to manage excess stormwater before it even reaches the sewers. This provides resiliency to the overall sewer system, both for areas where increased urbanization is producing too much stormwater runoff, and for all areas given an uncertain climate. These 21st century techniques are often called 'low impact development' (LID) or sometimes 'green infrastructure'. But they are not new ideas; some are very ancient, such as rainwater harvesting, soakaway pits, and tree planting.

EXAMPLES OF LID AND GREEN INFRASTRUCTURE

Rainwater Harvesting

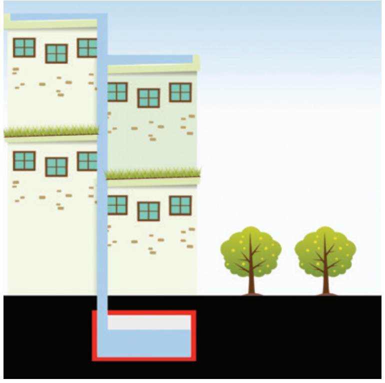
Utilizing rainwater is a practice that is rapidly increasing in popularity in dense urban areas throughout North America. Large storage cisterns can help reduce flood risks. Using rainwater can reduce energy requirements otherwise needed to disinfect freshwater and reduce overall demand for municipal well water. Because it takes a lot of energy to make harvested rainwater suitable for direct human consumption, the most popular uses include landscape irrigation and toilet flushing.

In a changing climate, rainwater harvesting can add resiliency to developments by offsetting potable water demand during times of drought. For year-round use, cisterns need to be protected from freezing conditions by being in basements or buried below ground.

Underground rainwater cistern being installed[8]

Vegetated roofs

Vegetated or "Green" roofs, which incorporate low-growing plants, are often only 10-15 cm deeper than a non-vegetated roof. Green roofs are most often found on new developments but are sometimes added to existing buildings. The water storage capacity of vegetated roofs is modest. However, they can be installed in very dense urban areas. Irrigating the plants on these roofs with harvested rainwater can help to reduce the urban heat island effect through evaporation of the irrigated water. Additional co-benefits of vegetated roofs include amenity value (i.e. reduced air conditioning bills for residents) and ecological value for small urban animal species.



Schematic of rainwater harvesting (plus vegetated roofs)

Soakaways

Underground soakaway systems are a very old technology, pre-dating sewer systems in Ontario. These systems are designed to hold a large volume of water that is slowly allowed to infiltrate into soil. Soakaways help control stormwater runoff from intense rain events. Compared to rainwater harvesting, this type of system can offer the benefit of returning water to the aquifer.

Soakaway type systems include: dry wells, infiltration trenches, infiltration chambers, and infiltration crates. Historically, soakaway systems have been made from brick, rocks or even animal horns[9]! Modern soakaways are often made from reinforced plastic, which allows much large structures to be constructed and hold much more water within them.

Because this type of system is underground, most members of the public would never know it was there. Soakaways are commonly installed under parking lots, sports fields or other landscaped spaces.

In areas where municipal wells are used, it is important not only to return water to the aquifer, but to ensure that the water being returned is not polluted. De-icing salt is one significant source of pollution found in water that runs off roads, parking areas, and sidewalks. It is a best practice to prioritise collecting rainwater from rooftops to infiltrate into the ground.

Underground infiltration crates being installed[10]

8 Mississippi Watershed Management Organization, 2018
9 Richardson, 2008
10 Abeyasekere, 2012

Bioretention and Rain Gardens

Bioretention features are becoming popular in some public spaces. These usually (but not always) have decorative plantings with flowering species. Key features include: a slightly hollowed out shape compared to traditional landscaped areas, an inlet or some way that rainwater would enter the feature, and quite often some pipework, a grate or other piece of drainage infrastructure may be seen.

Like soakaways, bioretention features store excess stormwater so that it can slowly infiltrate the soil. Like vegetated roofs, the planting helps to moderate local temperatures, traps particulate air pollution, adds to urban ecology, and provides amenity to our streets and parks.

Some residents may construct a rain garden in their yard. This is a similar structure without a direct connection to the municipal sewer. Unlike a rain barrel, a rain garden does not require emptying between rainstorm events. This makes rain gardens a good strategy for homeowners who want a passive stormwater management system.

Schematic illustration of how a bioretention or rain garden would permit water to infiltrate (left) Bioretention feature designed to capture roadway stormwater runoff in Kingston, Jen Hill (right)

Tree Pits

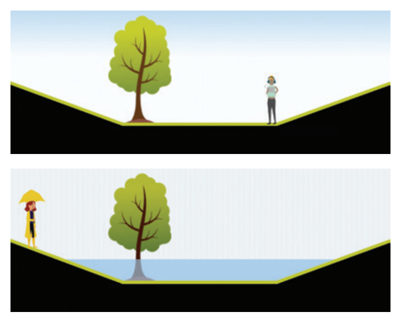
In addition to the benefits offered by other vegetation, trees provide important shade and structure to our built landscapes. With that said, it can be challenging to support trees in reaching maturity in streets, plazas, parking lots and similar landscapes with dry, compacted soil and high levels of pollution. Climate change predictions indicate that many familiar species of trees in the GGH will find it increasingly difficult to survive the warmer, drier temperatures and intermittent but extreme summer storms.

There are new techniques available that help urban trees grow large and more resilient. Planting trees with their roots in a reservoir of sandy soil, connected to the street drains, helps the roots retain water during storms and permits the tree to access more water for a longer period.

Tree cell schematic (left). Underground tree cells, in York Region (right)

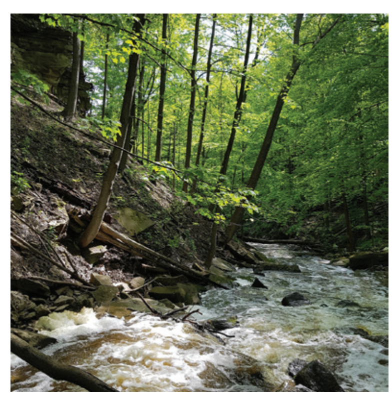
Dry Ponds

This is another very old technique, which can be used to add green space to our urban landscape, and help reduce flooding. Nuisance flooding can be reduced by designing parks and large public spaces to deliberately flood during an extreme weather event. There are many examples of these throughout the GGH; new installations are most common in large developments, including parks.



Ecological Conservation and Restoration (Natural Infrastructure)

Protecting and enhancing natural assets like wetlands and forests can help reduce flood risks and improve water quality to communities downstream. When natural assets, like those found throughout the Greenbelt, are properly stewarded, they become more valuable over time. In contrast, grey infrastructure loses value as it ages.



FEDERAL FUNDING FOR GREEN INFRASTRUCTURE IN YORK REGION

In 2019, York Region was approved for $10 million in funding through Infrastructure Canada's Disaster Mitigation and Adaptation Fund in order to implement a natural infrastructure project. This fund typically contributes to grey infrastructure projects such as building water, transportation, and energy infrastructure. In contrast, York Region's project is one of the first examples of this fund specifically investing in natural infrastructure. Approval of this project symbolizes an important recognition of the services natural infrastructure provides. It also indicates that there is a growing awareness that proper natural asset management can help Canadian municipalities adapt to and mitigate climate change.

York Region is home to 1.11 million people, most of whom live in densely populated urban areas in the southern and central parts of the Region. Greenspace also makes up a large portion of York Region and includes important natural features like the Oak Ridges Moraine. The Moraine plays a critical role in the prevention of urban flooding and in the protection of southern Ontario's freshwater source. Properly valuing and managing natural areas, like the Oak Ridges Moraine, ensures they continue to provide the services that residents have come to rely on.

York Region's project will focus on planting over 400,000 trees and shrubs over eight years with a total project cost of $25 million. One component of the project is to strategically acquire 100 hectares of land and reforest the area by planting over 200,000 trees. This will help to offset the urban heat-island effect and mitigate downstream flooding events by intercepting, storing, and slowing the flow of water. The Region is working with the local conservation authorities to identify high priority areas across the Region for these afforestation efforts.

Another component of the project focuses on planting over 200,000 trees and shrubs in urban areas. According to the i-Tree Eco model, trees in York Region prevent over 6.5 million cubic metres of stormwater runoff per year at a value of $15 million in stormwater management to our urban centres. Planting natural spaces within these urban areas will also help manage stormwater and mitigate more localized flooding.

In addition to showing leadership by investing in new natural infrastructure, York Region is also recognized as a leader in managing their green infrastructure as assets. In 2017, York Region published an asset management plan that looked at the state of their natural assets, as well as the level of service and investment needed to maintain them. In addition to the valuable information that came from this plan, it also resulted in securing additional capital funding at $500,000 per year.

ACTION YOU CAN TAKE

Community and Municipal Action

- **Advocate** for dedicated natural infrastructure funding from higher levels of government.
- **Incorporate** natural infrastructure solutions into community design and retrofits as much as possible.
- **Educate** your community on the benefits natural infrastructure can provide and the investments needed to prepare for the changing climate.
- **Reduce** stress on our water resources and natural infrastructure by using less road salt in the winter.
- **Support** Ontario's Greenbelt and its range of unique ecosystems or "natural assets" that provide infrastructural services to communities in the GGH. This includes the important role of the Oak Ridges Moraine and the Niagara Escarpment in protecting our water resources.
- **Follow** the footsteps of leading municipalities in the Greenbelt, like York Region, which is addressing key infrastructural needs by planting over 400,000 trees and shrubs over eight years with a total project cost of $25 million. $10 million has been provided to this project from Infrastructure Canada's Disaster Mitigation and Adaptation Fund to implement this natural infrastructure project.

Individual Action

- **Let the rain in** by removing pavement or sealed surfaces on your property. (See Rain Community Solutions)
- **Plant** a tree or install a rain garden. (See your local Conservation Authority)
- **Volunteer** to help keep natural areas or street trees healthy. (See LEAF's Adopt a Street Tree)
- **Speak up** and let your municipal and provincial representatives know you support natural infrastructure solutions to climate change. (See MPP Contacts)
- **Share** this report with government officials and staff in your municipality.
- **Take care** of the trees and other natural infrastructure on your property to make them more resilient to severe storms and other extreme weather.

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