WET INFRASTRUCTURE:

Building Blue and Green

A series of research based handbooks designed to offer accessible and practical information about blue-green infrastructure approaches.

Setting the Context

Governance

Best and Next Practices

Activation Plan

Developed At:

Ryerson University

School of Urban and Regional Planning

WET INFRASTRUCTURE:

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A series of research based handbooks designed to offer accessible and practical information about blue-green infrastructure approaches.

Handbook 1:

Setting the Context

A Primer of Key Concepts on Stormwater Management in Toronto, Ontario

WET INFRASTRUCTURE Building Blue and Green developed at:

Ryerson University

School of Urban and Regional Planning

In accordance with course requirements for

Master of Planning, Studio, Fall 2016.

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WET INFRASTRUCTURE: Building Blue and Green is a series of accessible informational handbooks about blue-green infrastructure and the opportunities for the City of Toronto. The intended use of this series is to educate and inform stakeholders on the design, monitoring, maintenance, and policy considerations for urban stormwater management. Urban stormwater refers to rainfall and snowmelt which falls on the built environment and infiltrates, evaporates or runs off into storm sewers, streams and lakes.[25]

As a part of this project, the team conducted site visits and best practice interviews with stormwater professionals in the Netherlands in October 2016. The Dutch are internationally recognized as world leaders in both hard-surface control-based engineering and soft-surface adaptive design approaches to flood management. With the majority of their economy situated at or below sea level, the Dutch have pioneered innovative stormwater solutions and established global benchmarks for engineering technology. This series draws from current stormwater management practices and related governance structures in the Netherlands, and grounds them in the Toronto context through a governance analysis and professional communications with involved stakeholders.

This project was undertaken by graduate students from the Ryerson University School of Urban and Regional Planning, under the academic guidance of Professor Nina-Marie Lister.


Grant Mason, 2016

WHY THIS? *Stormwater management is incredibly complex.*

Today, the majority of the world's population lives in an urban delta – an area at the mouth of a river, where land and water meet. Toronto is both a riverfront and lakefront city, and this holds particular planning and design challenges and opportunities for effective stormwater management. Blue-green infrastructure is an emerging set of design technologies, based on ecological functions, using landscape treatments to help meet today's stormwater management needs.

Stormwater management is closely connected to the various components of the urban environment: from transportation to waterfront development. Critical alignment between the policies and legislation, and the actions and interests of stakeholders at various scales - from homeowners to developers, regional governments to Aboriginal communities - is pivotal to effective and resilient stormwater management.

WHY US? *We are a multidisciplinary group.*

Our diverse academic and professional experiences, coupled with the professional communication and field research we have conducted during this study, provides us with a unique and extensive understanding of how problems are faced by various stakeholders involved with urban stormwater management.

WHY NOW? *The time to act is now.*

The increasing frequency and severity of storm events are linked to climate change, causing significant economic, social, and ecological impacts on Torontonians. Three major storms, between 2013 and 2016 alone, have resulted in over two billion dollars in damage. Adaptive and innovative approaches to stormwater management are imperative to building a resilient and sustainable future. A contemporary approach to climate resilience includes blue and green infrastructure.

Grant Mason, 2017

HOW SHOULD THIS BOOK BE USED?

Setting the Context- A Primer of Key Concepts on Stormwater Management in Toronto, Ontario, is the first handbook of the four part series. Intended for use by stakeholders from all backgrounds and disciplines, from homeowners, to development professionals, and municipal staff, this primer aims to develop a shared vocabulary among readers and to provide a foundational understanding of blue-green infrastructure. This handbook will illustrate the current status of stormwater management in Toronto - highlighting both the historical and current approaches, as well as breaking-down the key terms, concepts, and strategies.

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Grant Mason, 2017

On July 8, 2013, Toronto experienced more rainfall during a two-hour period than is normally recorded over the course of a month. The storm produced between 90-126 mm of rain, overburdening the current stormwater management system, causing dangerous flash flooding throughout the city.[5]

Power Outages

Affected approximately 300,000 residents.[5]

Basement Flooding

More than 4,700 calls from residents reported flooded basements by August 8, 2013.

Most Expensive Disaster for the Province of Ontario

Over $850 million worth of damage on insured properties.[5]

Disrupted Public Transit Services

GO Train in the Don Valley, carrying 1,400 passengers, was stranded for more than seven hours.[9] TTC subways, Union Station, and flights were also disrupted during the flood event.

This storm was critically important for reopening the municipal conversation on deteriorating infrastructure, outdated design standards, the lack of natural infiltration systems, and the city's mangement for controlling stormwater.[5] **Flooding is one of the most damaging natural disasters in the world, causing average annual losses over $40 billion.**[19] If cities do not take action, these damages are likely to increase over time as urban growth and climate change continues to put pressure on aging stormwater infrastructure.[24] Approaching climate change planning in a proactive rather than reactive manner requires both building and governing for resilience. As defined by Lister (2015),

> *"Resilience refers generally to the ability of an ecosystem to withstand and absorb change to prevailing environmental conditions; in an empirical sense, resilience is the amount of change or disruption an ecosystem can absorb and, following these change events, return to a recognizable steady state in which the system retains most of its structures, functions and feedbacks."* [21 p.14]

Grant Mason, 2017

Toronto is a vulnerable city. The city is directly located within the largest surface freshwater system in the world - impacted by the Gulf of Mexico, Atlantic Ocean, and Arctic air masses - as well as containing 2.8 million residents from a broad spectrum of socio-economic backgrounds. As such, Toronto is a complex urban settlement that is increasingly vulnerable to the impacts of severe weather events.[23] This vulnerability is further amplified by our past approaches in engineering and urban development which have fundamentally altered and compromised our hydrological systems.

In response to the flood risks exacerbated by climate change, Toronto has strategically invested in infrastructure and adopted new policies to encourage innovative approaches to stormwater management. Currently, the City of Toronto uses multiple flood design standards to define risk thresholds for vulnerable floodplains. These standards are 1) Hurricane Hazel of 1954, and 2) the 100 year flood.[28]

As climate change increases the frequency and severity of extreme weather events, these standards, established through benchmarking against past events, may become inadequate. Effective, forward-looking standards must consider future climate projections.[22]

Toronto reveals a complex urban settlement that is increasingly vulnerable to the impacts of severe weather events.

A house built in a 100-year floodplain has a 1% chance of flooding during any given year, but has a 26% chance of flooding during a 30-year term (a typical period for a mortgage). This means that a new owner has a one in four chance of experiencing flooding during this period. In contrast, major developments and critical infrastructure in the Netherlands are constructed to 10,000 year flood standards.

DELTA CITY

1750

Myrvold, 1997

Originally settled by the Iroquois, the area of present-day Toronto was established on the mouth of multiple natural delta systems: the Don River, Humber River, and the Rouge River.

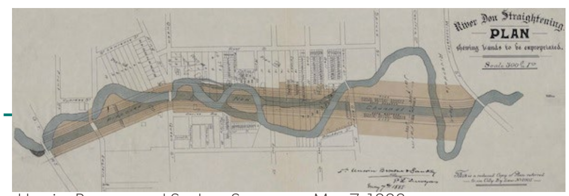
1870

“City builders...spoke ambivalently of nature: it was exalted, feared, and considered outside the bounds of human control.”

-Desfor & Bonnell [20]

The meandering and shallow Lower Don River was considered a menace to public health. Agricultural and industrial practices have changed the river’s hydrology through deforestation and water diversion, as well as the disposal of waste and sewage into the water system.

1880



Unwin, Browne and Sankey, Surveyors. May 7, 1888.

Politicians move forward with the Don Improvement Plan to alter, widen, deepen, and straighten the Lower Don River. This is intended to improve public health and create new urban forms that would serve the city’s rapid urbanization interests.

1902

Despite the economic benefits of new industrial lands, chronic problems including flooding, ice jams, and pollution continued. An ice jam near the Don’s mouth resulted in significant flooding along the lower river; blocking transportation corridors and causing severe property damage.

1912

City of Toronto Archives, Series 376, File 4, Item 47

The Harbour Commission undertook a $25 million project to modify 800 hectares of solid land, wetland, and water; primarily by lakefilling Ashbridge’s Bay to create a new industrial centre for the city. This endeavour, which required the intricate understanding of biophysical and socio-ecological dynamics, resulted in newly constructed land for both political and economic gain.

1922

The lower Don River was significantly modified from its original morphology, including the newly-constructed Keating Channel, created to divert water from the new industrial land.

1954

Hurricane Hazel struck Toronto, leaving 4.000 people homeless, killing 81 people, and resulting in $137,552,400 [1954 dollar figure] of damage. Vast stretches of land were acquired by the present-day Toronto and Region Conservation Authority (TRCA) for flood control.

National Weather Service, 1954)

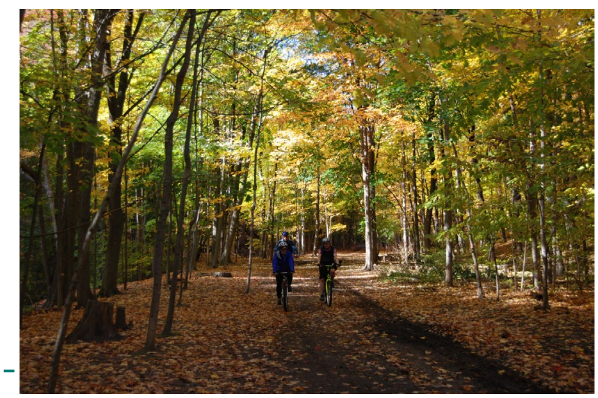
1991

The 'Bring Back the Don' movement, grounded in values of sustainability and healthy urban ecosystems, pushed for restoration and re-naturalization of the Don Valley. This shift in thought surrounding natural water systems sparked new dialogue and later, an international design competition to reimagine the problematic waterfront into a revitalized and accessible space.

2016

Recognized as Toronto's most celebrated and defining public treasure, the ravines that flow towards Lake Ontario are the most dominant physiographic feature of the city's original landscape. To prioritize their protection, the city has embarked on the Ravine Strategy, a plan to guide "management, use, enhancement, and protection" of the water systems.[17]

As the original delta system, Don River, and various lost rivers of the city have been hydrologically compromised by our urbanization goals, the ravines offer an opportunity to learn from past mistakes, and move forward with the consideration and protection of natural systems throughout the City of Toronto.



Toronto Bike Tours, 2015.

This timeline was informed by Gene Desfor and Jennifer Bonnell's chapter: Planning Nature and the City: Toronto's Lower Don River and Port Lands within "Urban Explorations: Environmental Histories of the Toronto Region."

RAVINE CITY

TRCA, 2016.

The City of Toronto is encompassed within **nine watersheds,** all of which drain into Lake Ontario.[29]

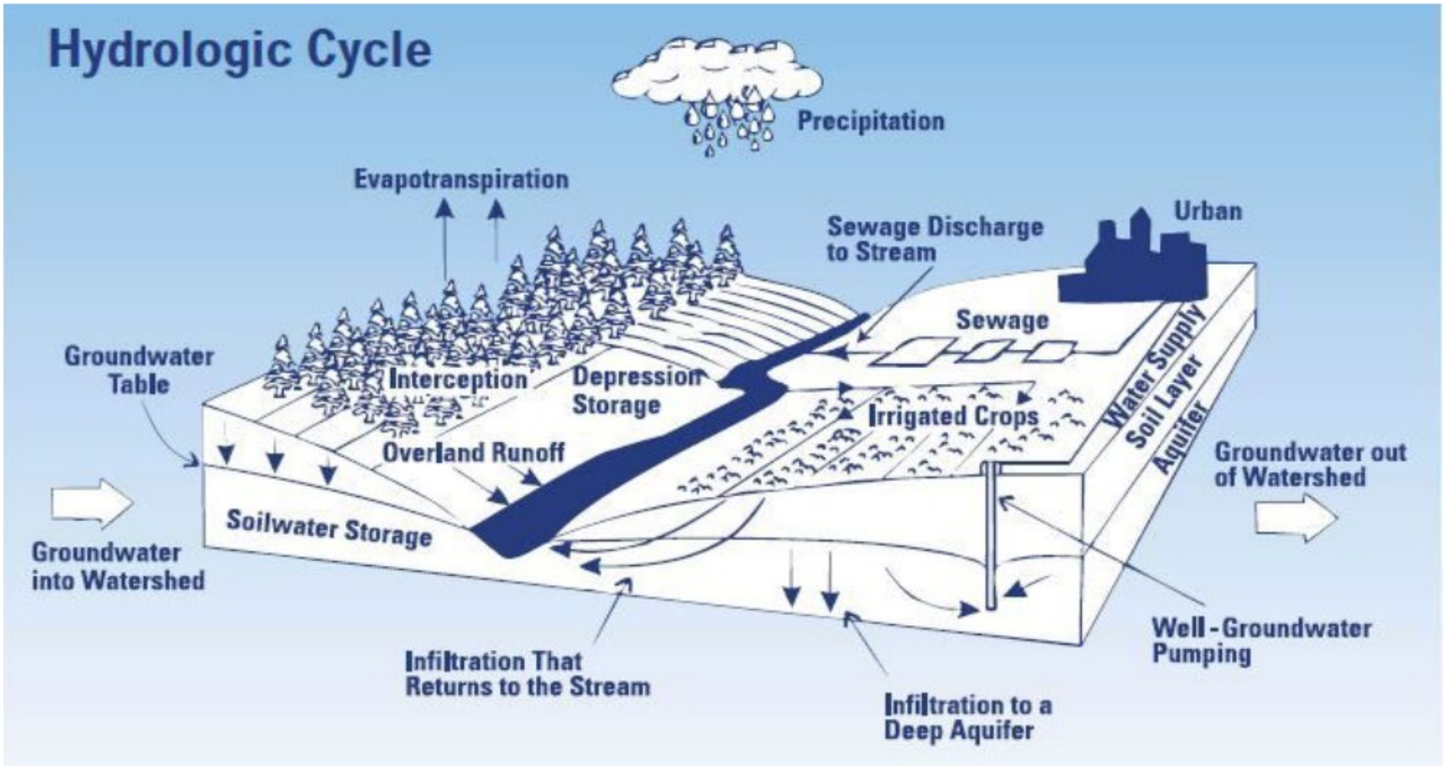
Since watersheds are **not bound by municipal political boundaries,** they are monitored and managed by watershed-level Conservation Authorities.[29]

For more information on the legal authority and creation of Conservation Authorities, refer to the handbook ***Governance - A Review of Toronto's Stormwater Management Structure***

WATERSHED AND HYDROLOGICAL CYCLE

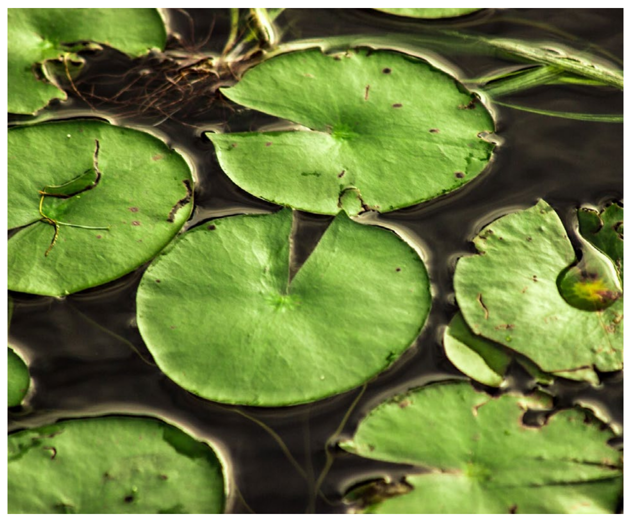
In urban areas, the high percentage of impermeable surface cover, as well as river channel straightening, reduces opportunities for natural infiltration and produces high levels of runoff and rapid flood peaks.[26]

These interventions have fundamentally changed how stormwater is discharged into our natural streams and wetlands, leading to increases in flooding, water pollution, and loss of habitat.[26]



After et al. 1991

Understanding the hydrological system is essential for recognizing how effective stormwater management practices can intervene and support natural cycles. Decreases in infiltration within urban areas contributes to reduced soil moisture and groundwater recharge, leading to loss of vegetation and aquatic life.[24]


Grant Mason, 2016.

Furthermore, impermeable surface cover causes more rapid evapotranspiration, providing fewer opportunities for stormwater to be absorbed into the natural groundwater table. The water balance is comprised of hydrological features that require natural replenishment (such as aquifers, streams, wetlands, etc) which are impacted by infiltration, evapotranspiration, and runoff due to urban development.[30]

Home drainange and causes of basement flooding, Toronto Water, n.d.

GREY INFRASTRUCTURE AND THE DIFFERENT TYPES OF WATER

3,930 km of sanitary sewers transport wastewater in Toronto, collected from building drains, toilets, and sinks. This wastewater from residences and businesses flows to treatment plants where it is cleaned before being released into Lake Ontario.

4,954 km of storm sewers capture rainwater or snowmelt from residential and commercial properties in Toronto and conveys it to nearby watercourses or the lake.

Grey Infrastructure: conventional piped drainage and water treatment systems.

1,511 km of combined sewers transport both wastewater and stormwater together in the same pipes. While combined sewers are no longer built, they can be found in old parts of the city. During normal conditions, combined sewers carry all contents to treatment plants.

However, during major rainfall events, the volume of water may exceed the system's capacity, causing some of the water to overflow untreated into the lake. This is called a combined sewer overflow (CSO).

Toronto Water is the agency in charge of constructing and operating all potable water, stormwater, and sanitary sewer systems in the city. It is funded through a user charge, which is calculated based on each property's consumption of potable water.[11] In effect, property owners currently pay higher potable water fees to subsidize the construction and maintenance of public stormwater infrastructure.

To address a budget shortfall and to create incentives for property owners to better manage stormwater on-site, the City of Toronto has considered reducing potable water rates while establishing a separate, dedicated stormwater charge. The initiative was intended to incentivise property owners to reduce their impact on stormwater systems by assessing a stormwater fee by property based on surface stormwater runoff volumes. As of May, 2017, Toronto City Council has chosen not to proceeded with the stormwater charge.

GREY INFRASTRUCTURE LIMITATIONS

Local Flooding

During major storms, the carrying capacity of the underground storm sewer system is exceeded. This results in excess water flowing along streets, open channels, and walkways. While a certain amount of pooling or overland flow can be temporarily inconvenient, it is preferable when compared with the potential flooding of private property.

The negative impacts of local flooding are magnified when stormwater enters and overwhelms the sanitary sewer system. When this happens, black water, the highly contaminated discharge from household toilets and kitchens, can back up into basements and low lying areas, causing extensive property damage.[13]

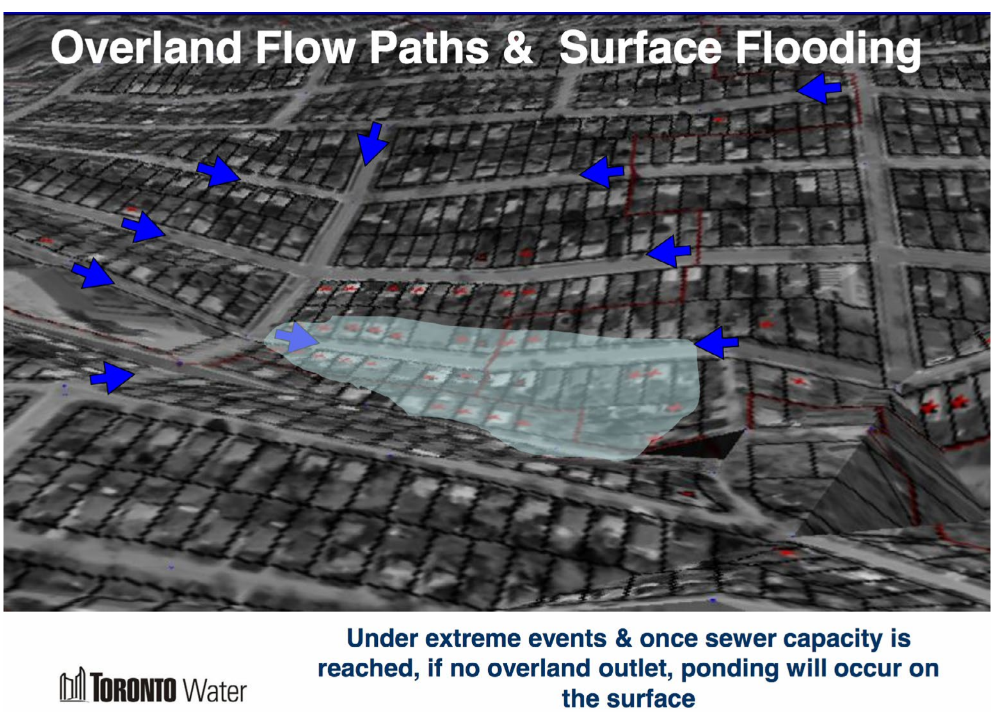
Capacity

For most parts of the city, stormwater infrastructure has been sized based on the historical maximum rainfall that would typically occur every 2-5 years.[8]

Increasing urban development and impervious surfaces, combined with increasingly extreme weather and aging infrastructure, have put a strain on these systems.

As a part of the *Wet Weather Flow Master Plan*, the City of Toronto has developed a basement flooding prevention program.[18]

Learn more about it **here.**



LIMITATIONS CONTINUED

System Flooding

Higher flows, caused by heavy rains, can induce erosion and flooding in urban streams; damaging habitat, property, and infrastructure. Certain areas along Toronto's rivers, such as the Lower Don Lands, are within a floodplain and are prone to inundation during major storms.[34]

Cost

Grey infrastructure systems require technical engineering, continual maintenance, and often costly upgrades in order to meet the increased demands of our growing city.

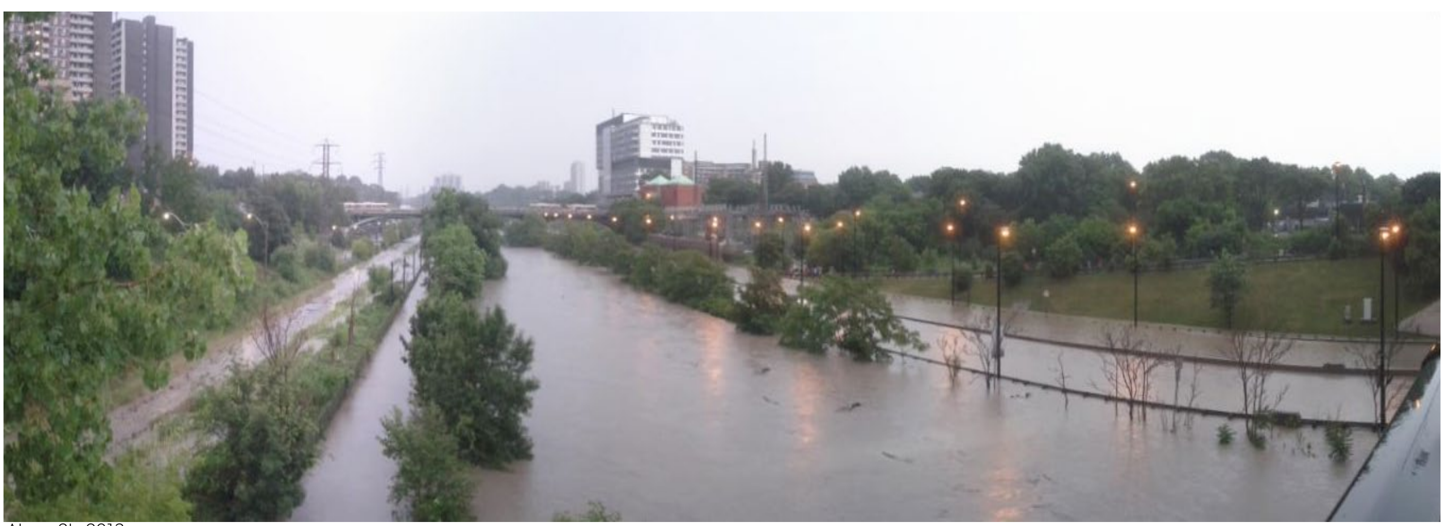
Toronto Water's 2016-2026 10 year capital budget includes $4.73B for wastewater treatment & collection and $2.79B for Stormwater Management.[11]

Water Quality

When rain falls on impermeable surfaces such as roofs, streets, and parking lots, the runoff carries trash, salt, oils, and heavy metals from the urban landscape into natural systems.[33] This adversely impacts the habitats of many downstream aquatic species.[24]

In areas with combined sewer systems, storm events which overwhelm the system result in highly polluted black water entering the natural environment.[9]

Water quality issues also affect the livability of areas around rivers and their confluences with Lake Ontario, restricting opportunities for recreational uses such as swimming and boating.[13]



Alaney2k, 2013.

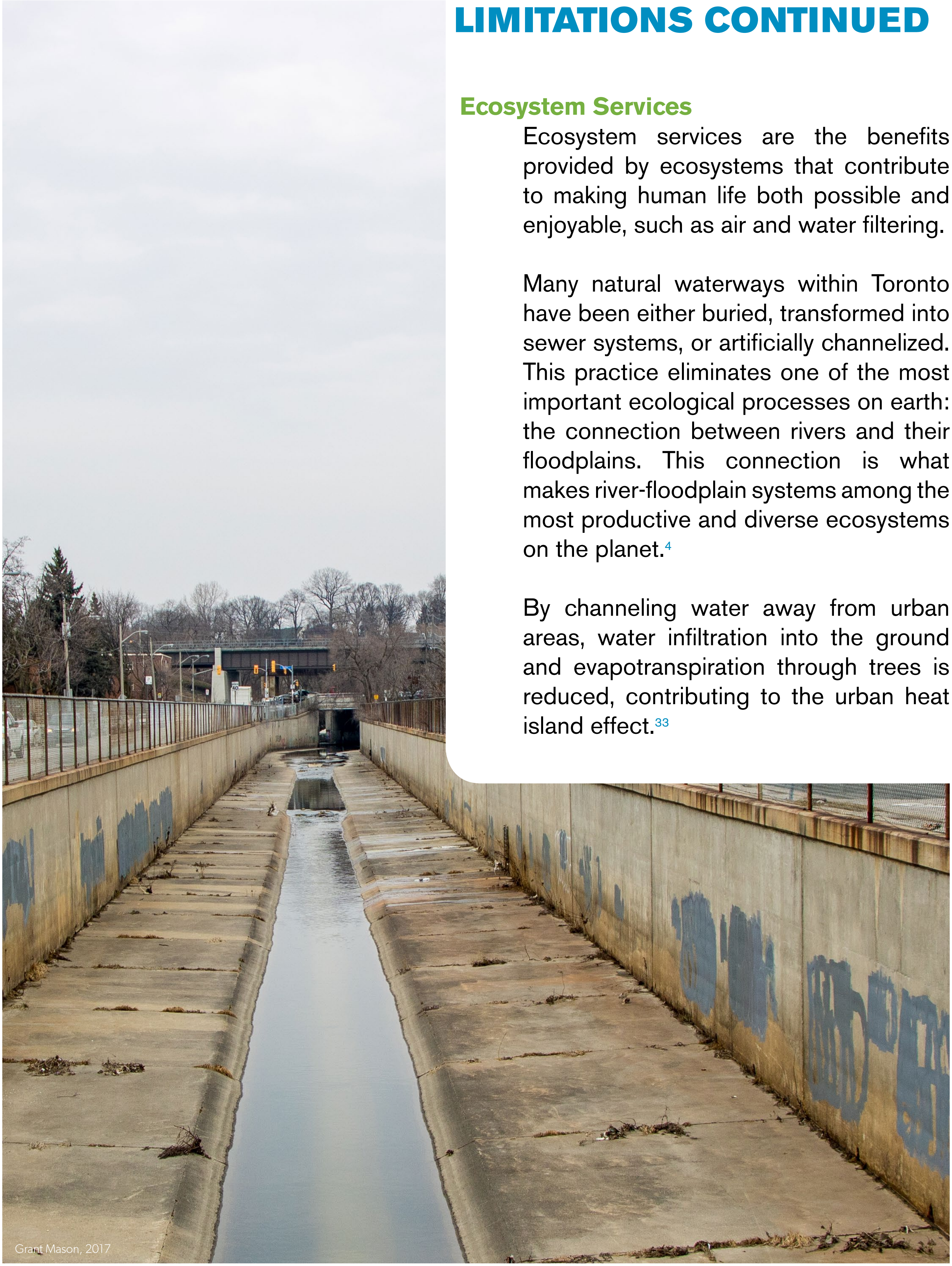
LIMITATIONS CONTINUED

Ecosystem Services

Ecosystem services are the benefits provided by ecosystems that contribute to making human life both possible and enjoyable, such as air and water filtering.

Many natural waterways within Toronto have been either buried, transformed into sewer systems, or artificially channelized. This practice eliminates one of the most important ecological processes on earth: the connection between rivers and their floodplains. This connection is what makes river-floodplain systems among the most productive and diverse ecosystems on the planet.[4]

By channeling water away from urban areas, water infiltration into the ground and evapotranspiration through trees is reduced, contributing to the urban heat island effect.[33]



Grant Mason, 2017

BLUE-GREEN INFRASTRUCTURE

Given the challenges of maintaining and expanding grey infrastructure, amidst increasing frequency and severity of storm events, many cities are exploring opportunities to complement traditional pipe and sewer systems with blue-green infrastructure approaches.

Landscape-based design interventions can help achieve improved water quality, and reduce rapid fluctuations in stormwater flows by slowing, holding, cooling, and cleaning stormwater near where it falls.

Blue-green infrastructure solutions should be considered as components that work together in an interconnected "Treatment Train" process, as described by the TRCA in their Stormwater Management Criteria document. The treatment train hierarchy, consists of three main components -

1) source control,
2) conveyance control, and
3) end-of-pipe control,

These will be discussed later in this handbook.

Many industries and professions are involved in the stormwater management process, each with their respective terminology with overlapping definitions. To establish a common understanding across stakeholders, the various terms are explained in the following overview:

Green Infrastructure:

The City of Toronto's Official Plan defines green infrastructure as natural and human-made elements that provide ecological and hydrological functions and processes. Green infrastructure may include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs. This term is commonly used within the landscape architecture profession and is referenced in most of Toronto's stormwater management documents. The broad definition of Green Infrastructure largely overlaps with "Low Impact Development"[32] and "Blue-Green Infrastructure".[27]

Low Impact Development:

Commonly used within the development industry, the engineering profession and in policy documents, Low Impact Development (LID) is a term used to describe the overall design philosophy of managing runoff close to the source. LID is alternately referred to as better site design, sustainable urban drainage systems, water sensitive urban design, or stormwater source control.[32]

Blue Infrastructure:

The term "Blue Infrastructure" is rarely used by itself in North American academic literature and policy documents. When referred to within the context of "Blue and Green Infrastructure", "Blue Infrastructure" describes the landscaped elements of stormwater management designed to contain or convey water.

Blue-Green Infrastructure:

For the purposes of this project, all types of infrastructure that combine natural and human-made elements to slow, hold, and clean stormwater will be referred to as "Blue-Green Infrastructure". While this definition partially overlaps with the term "Green Infrastructure", "Blue-Green Infrastructure" more accurately describes how this type of infrastructure serves not only as greenery or for aesthetic purposes, but provides vital hydrological functions.

FUNCTIONS OF BLUE-GREEN INFRASTRUCTURE

Slowing

Blue-green infrastructure can mitigate the risk of flash flooding by reducing rapid stormwater runoff through retainment and absorption. Landscaped, gentle slopes can retain water, rather than allowing it to run off and cause property damage.[33]

Holding/Recycling

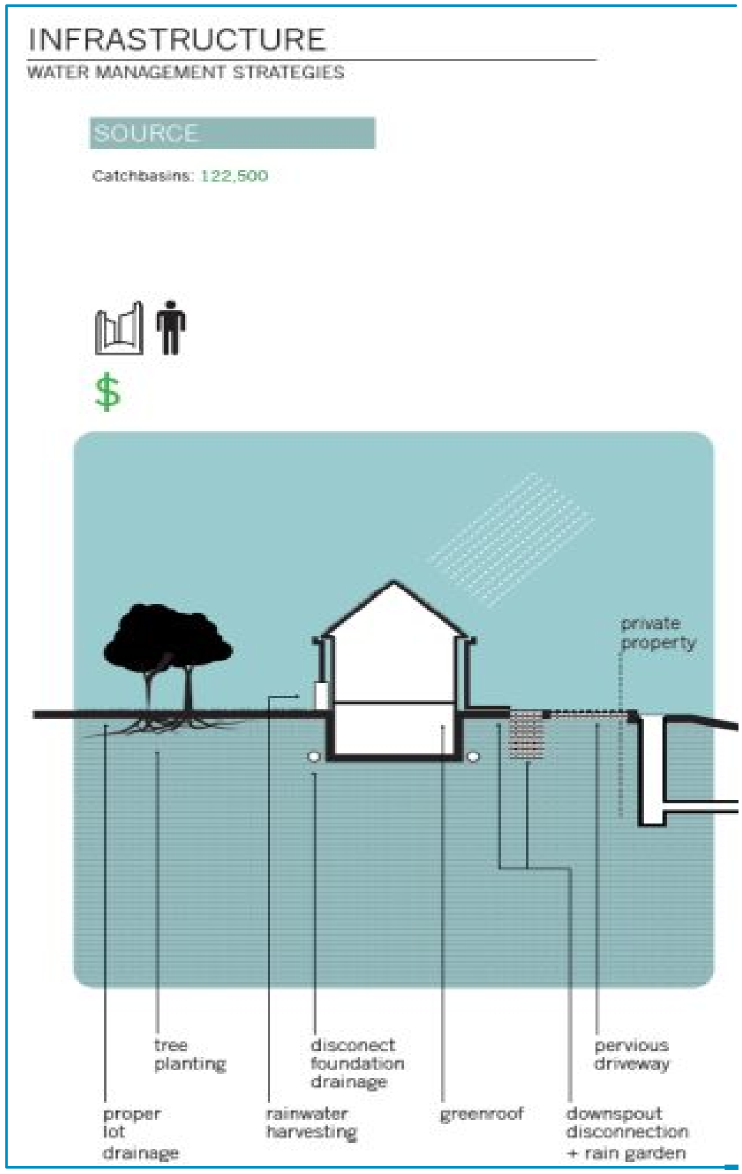
Urban stormwater collected in rainwater harvesting systems can be used for outdoor irrigation to significantly reduce municipal water demand. Further, retained stormwater can be purposely infiltrated into the soil to recharge groundwater tables.[33]

Cooling

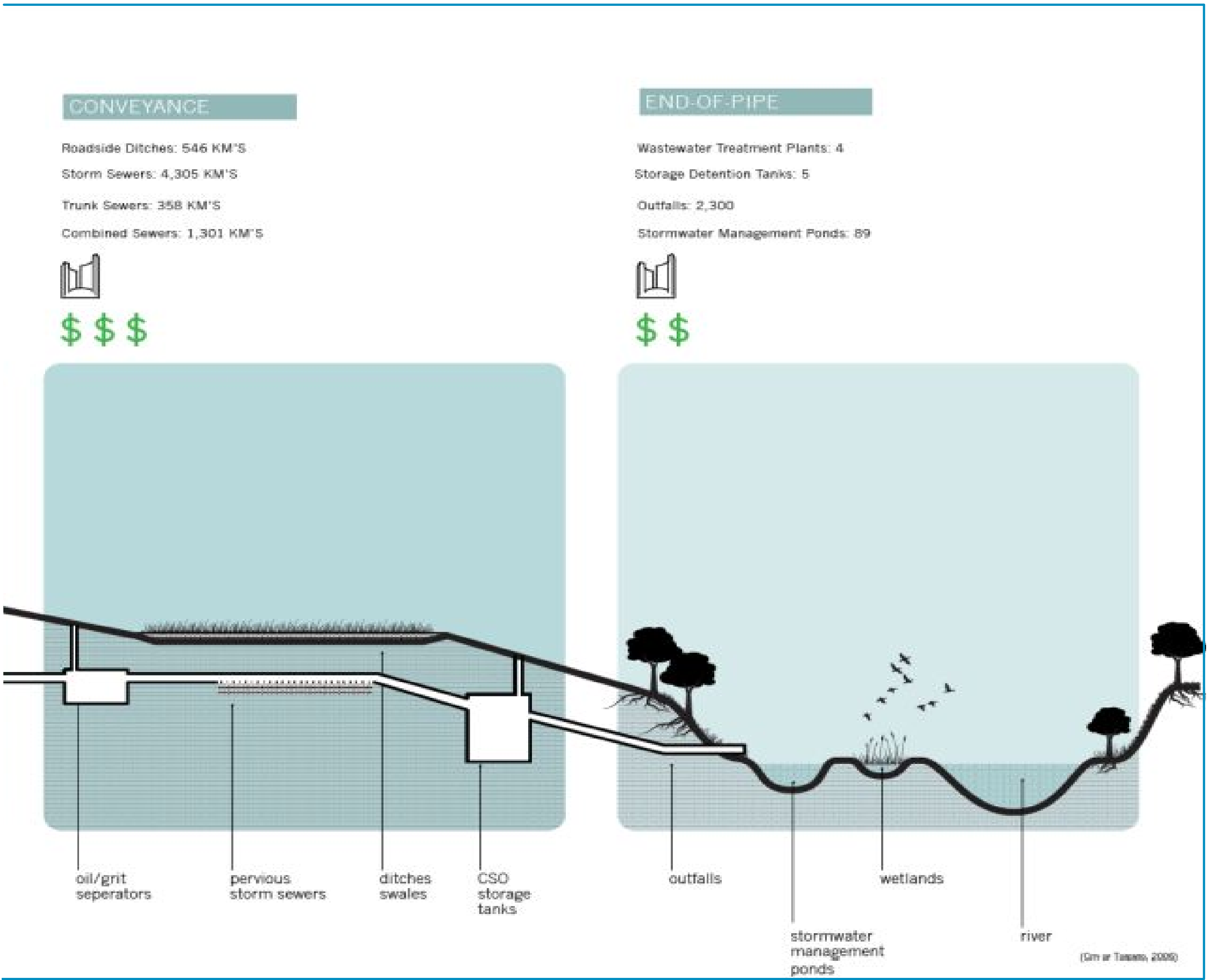
Blue-green infrastructure effectively absorbs and reduces the temperature of urban stormwater that has fallen and drained on top of heated impermeable surface cover. It accomplishes this by shading and minimizing the amount of water exposed to the air. Without cooling, warm stormwater has the potential to disrupt native species and coldwater fisheries.[24]

Cleaning

Urban stormwater runoff can collect contaminants including oil, metals, pesticides, and waste, and transfer them to streams or groundwater. Blue-green infrastructure reduces untreated stormwater discharge in natural water systems through retainment; naturally cleaning the water before it is released or recycled.[33]



Bishop et al., 2014 Studio,University of Toronto.



Blue-green infrastructure solutions should be considered as components that work together in an interconnected "Treatment Train" process.

The treatment train hierarchy, consisting of three main components - source control, conveyance control, and end-of-pipe control.

TREATMENT TRAIN: AT SOURCE

Managing rainwater where it falls reduces the amount of treatment needed further downstream. Source controls occur at the lot level and therefore **can be implemented by residents, property owners, and developers.**

Urban Tree Cover

Grant Mason, 2017

Mature deciduous trees can intercept 10% to 20% of the annual precipitation that falls on them.[32]

In addition to providing shade cover and temperature regulation, mature deciduous trees can intercept 10% to 20% of the annual precipitation that falls on them, while coniferous trees will intercept 15% to 40%.[32] As of 2010, Toronto had an estimated tree cover of 27% and has a goal of reaching 40% over the next 40-50 years, as stipulated in the Urban Forestry Strategic Plan.[10]

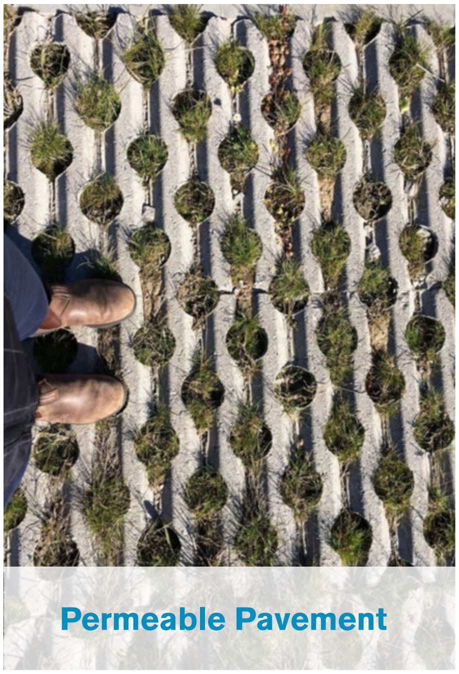
Toronto was the first city in North America to enact a bylaw to require the inclusion of green roofs on new developments.

Green Roofs

Ryerson Urban Farm, 2015

Green roofs are building roofs covered with vegetation that provides stormwater runoff, building energy, and air quality benefits.[14] Toronto was the first city in North America to enact a bylaw to require the inclusion of green roofs on new developments through the Toronto Green Standard.

AT SOURCE CONTINUED



Permeable Pavement

Cate Flanagan, 2016

In parking areas and driveways, the use of permeable pavement allows for a portion of rainfall to infiltrate into the ground instead of flowing into storm sewer systems.

Rain Barrels

Benoit Rochon, 2011

As an alternative to directing downspouts to ground surface, rainwater can be directed into rain barrels that temporarily hold and store water for non-potable uses.

Downspout Disconnection

US EPA, n.d.

Historically, rainwater from roofs was drained through downspouts connected to the storm-sewer system, contributing to the system's overload during heavy rainfall. In 2007, the City of Toronto enacted a bylaw making it mandatory for property owners to disconnect their downspouts. Directing rainwater to flow over land, particularly over gardens or other permeable surfaces, reduces the amount of stormwater that must be handled by downstream grey infrastructure systems.[7]

Today, source control measures are required within the development approval process, under guidelines set through the Toronto Green Building Standard. In the future, source control measures for city streets will be informed by the Toronto Green Streets Technical Guidelines, currently under development.

See Table 1 of Toronto's ***Wet Weather Flow Management Guidelines*** for a complete list of source control options.

TREATMENT TRAIN: DURING CONVEYANCE

Rainwater that has not infiltrated into surfaces during the source control step becomes runoff. **This water flows into the underground sewers** which are part of the treatment train, called conveyance control. Conveyance control methods can include blue-green infrastructure components to further slow, hold, and clean stormwater as it passes into the final stage of the treatment train; the end-of-pipe solution which is explained in detail further in this handbook.

Bioswales

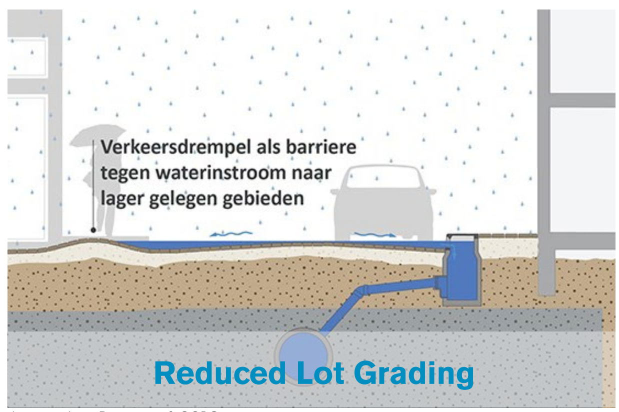
Watershed Council, n.d.

Bioswales are vegetative ditches designed to treat a specified amount of stormwater runoff from large, impervious surfaces such as parking lots and roadways. By using specifically engineered soil mixes and vegetation, bioswales absorb runoff when it begins to rain. Once saturated, they continue to filter water as it passes through before entering the sewer system.[32]

By using specialized and engineered soil mixes and vegetation, bioswales absorb runoff and filter water as it passes through.

Blue-green infrastructure projects exist across the City of Toronto, however their effectiveness is lacking recognition and appreciation. One of the key features of bioswales is their capability of filtering dissolved solids that grey infrastructure cannot. Demonstrating this to the public, through visualization at the site, would foster a recognition that beautiful, naturalized spaces can be very effective and create hybrid infrastructure.

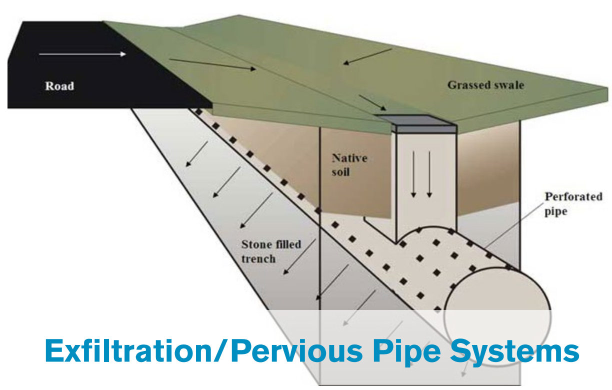
Adjusting grading to slow the conveyance of water in non-critical areas (away from buildings) can help reduce peak loads on stormwater systems.[3]



Reduced Lot Grading

Amsterdam Rainproof, 2016

Pervious piping systems allow for the infiltration of water into the surrounding soil as it travels through the underground piping system.[32]



Exfiltration/Pervious Pipe Systems

Sustainable Technologies, n.d.

Learn more about community engagement and awareness strategies in *Setting the Context*

TREATMENT TRAIN: END OF PIPE

The final component of the treatment train is end-of-pipe control. While some older areas within Toronto lack end-of-pipe controls and discharge stormwater directly into streams and Lake Ontario, the use of stormwater storage and treatment facilities prior to discharge has become prevalent in the past decades.

Stormwater Retention Ponds

Chris Yuen, 2016

Wet ponds are designed to collect and store runoff, allowing sand, silt, and other solids to settle to the bottom prior to the water being released into creeks and rivers downstream. Over time, the functionality of these ponds are adversely impacted by sediment buildup and must be dredged and re-habilitated. The maintenance needs of these ponds can be minimized by pre-treating stormwater and removing sediment through source and conveyance controls upstream of the ponds.

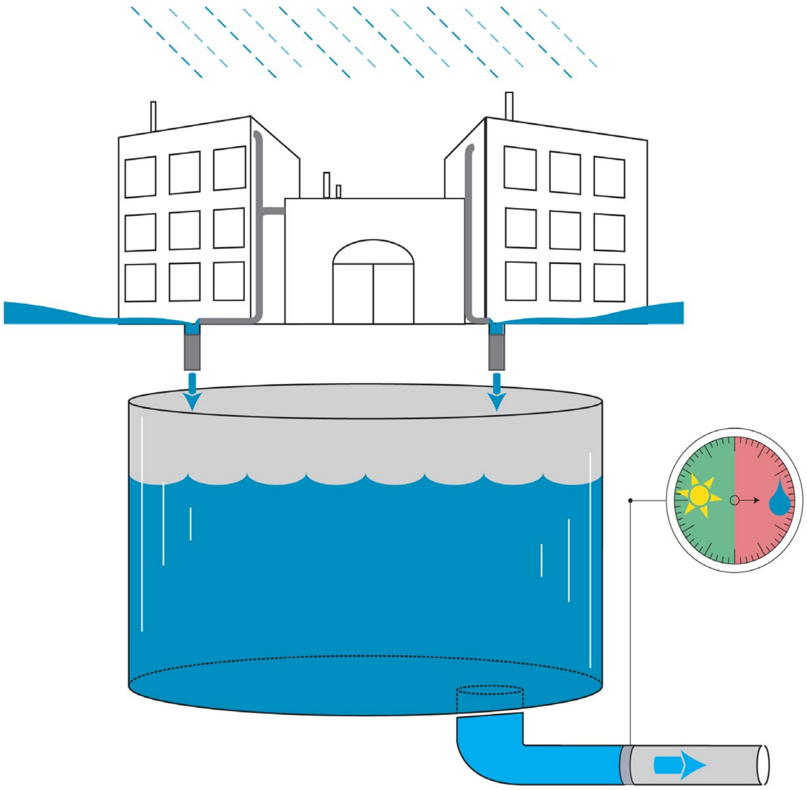
Constructed Wetlands

City of Toronto, n.d.

Constructed wetlands provide storage capacity similar to stormwater management ponds, but adds natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality.[33]

End-of-pipe controls have received increased attention and implementation in the past decades.[22]

END OF PIPE CONTINUED



Grant Mason, 2017

Holding Tanks

In areas serviced by combined sewer systems, holding tanks can be used to prevent combined sewer overflows during heavy rain. The use of detention tanks at Toronto's Eastern Beaches has significantly improved water quality and reduced the number of days the beaches have been declared unsafe for swimming.[16] While holding tanks may not be considered blue-green infrastructure per se, these storage facilities can be integrated into parkland or buried under road right-of-way,[12] and thus act as a hybrid of blue-green and grey infrastructure.

Of the three categories within the Treatment Train, end-of-pipe controls have received the most attention and implementation in the past decades. To encourage a more integrated approach to stormwater management that considers at source, conveyance and end-of-pipe solutions, the Sustainable Technologies Evaluation Program, led by the TRCA, is currently developing an LID Treatment Train Tool.

This **web-based tool will help** developers, consultants, municipalities, and landowners **quantify the incremental benefits of each blue-green infrastructure component** to implement better stormwater management practices.[31]

BENEFITS OF BLUE-GREEN INFRASTRUCTURE

As described in the treatment train concept, blue-green infrastructure works to incrementally slow, hold, and clean stormwater near its source. Blue-green infrastructure creates opportunities for cost savings by reducing the need for maintaining, operating, and expanding grey infrastructure as the city continues to grow.

A 2002 study found that seniors with nearby parks and tree-lined streets showed improved lifespan over a 5-year period.[28]

Improved Air Quality

A 2008 study of green roofs in the City of Portland, Oregon found that one 40,000 sq.ft green roof would remove 1,600 pounds of pollutant from the air every year and would yield $3,024 annually in saved health care costs.[2]

Multi-Functionality

Blue-green infrastructure can be multi-functional, combining elements such as recreational opportunities, ecological functions and stormwater management. This is especially important within the context of spatial and budgetary constraints in urban environments.

Increased Property Value

Homes located nearby naturalistic spaces are valued 8% to 20% higher than comparable properties.[35]

Water Square, Rotterdamn
Public recreation space designed to fill with water during periods of rain.

Grant Mason, 2016

BENEFITS OF BLUE-GREEN INFRASTRUCTURE CONTINUED

Grant Mason, 2016

Livability and Population Health

Blue-green infrastructure has been proven to improve community connections, perceptions of well-being and neighbourhood satisfaction. A 2002 study found that seniors with nearby parks and tree-lined streets showed improved lifespan over a 5-year period.[28]

Reduced Urban Heat Island Effect

Vegetation growing on blue-green infrastructure cools the surrounding air through evapotranspiration by absorbing water through their roots and releasing it back into the air. A 2006 study in the City of Philadelphia found that 196 heat-related fatalities could be avoided over a forty year period through the use of blue-green infrastructure.[6]

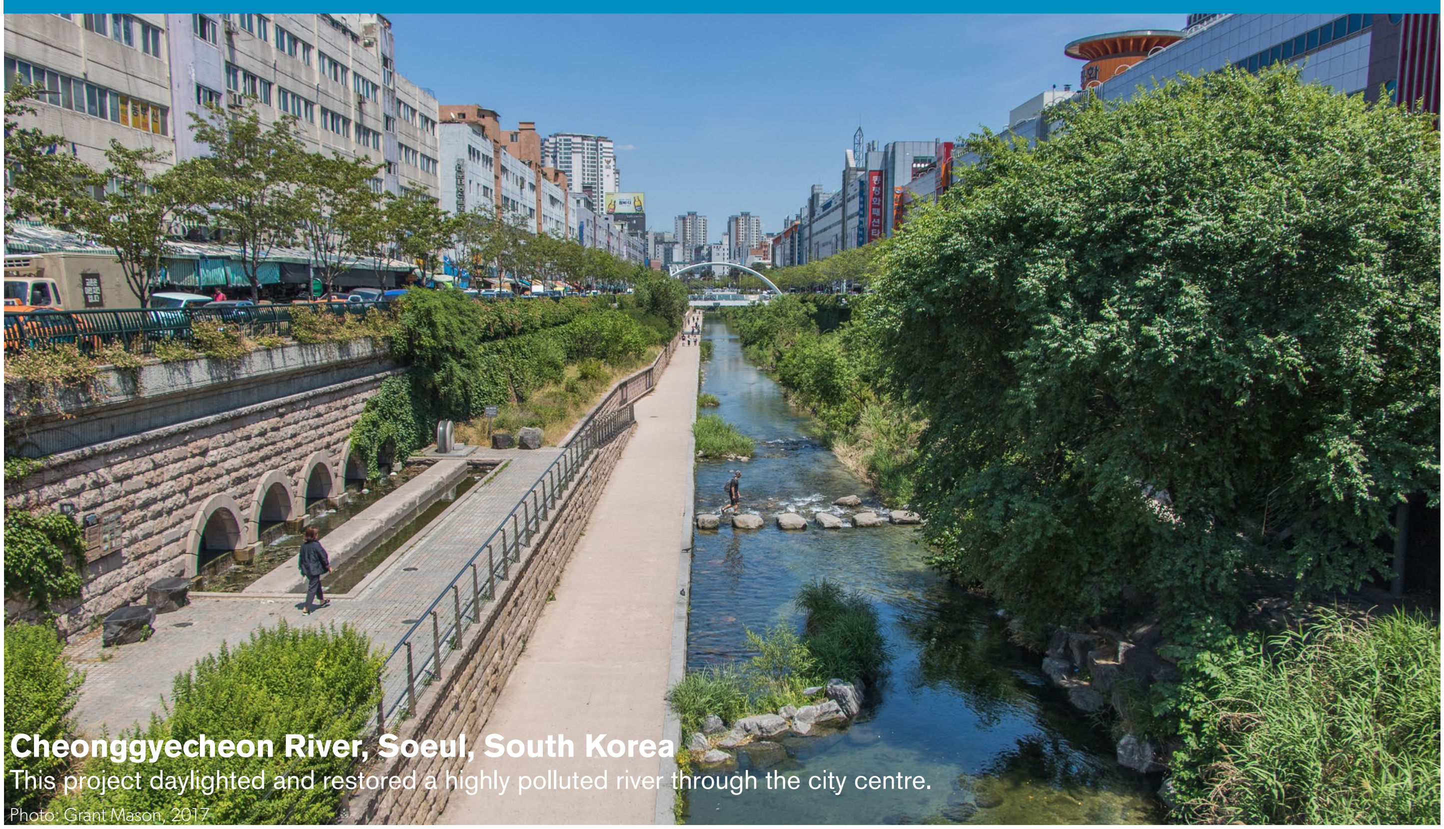
Habitat and Wildlife

Rain gardens and other vegetated infiltration features have been found to perform best when planted with native species. These natural features offer habitats for both resident and migratory species.

MOVING FORWARD

Despite facing increasing vulnerabilities from the impacts of climate change, Toronto is in many ways a progressive leader in stormwater and flood risk management. From long-term plans such as the Wet Weather Flow Master Plan, to performance measures such as the Toronto Green Standard, to policy such as the basement flooding prevention program, Toronto has made significant progress over the past decade. However, there is much more to be done in terms of stormwater management and implementation of blue-green infrastructure in order to be prepared for the impacts from climate change.

Blue-green infrastructure offers a myriad of benefits and tangible solutions to reduce flood risk in Toronto. Ranging from resident maintained rain gardens to large-scale stormwater ponds, blue-green infrastructure harnesses the power of natural systems in an integrated stormwater system. Stakeholders must work together to determine and implement the best solutions for managing urban stormwater in Toronto; reducing vulnerability, protecting the watershed, and contributing to the health and livability of our diverse community.



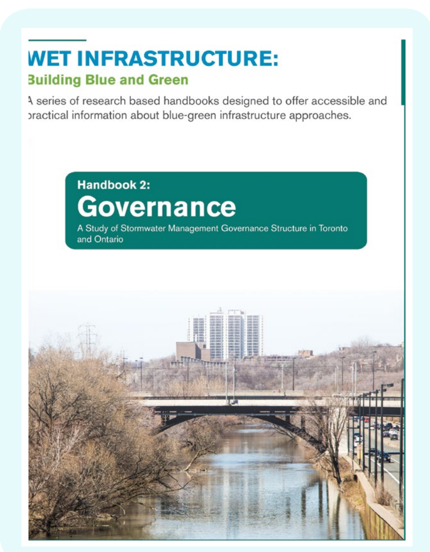
Cheonggyecheon River, Soeul, South Korea

This project daylighted and restored a highly polluted river through the city centre.

Photo: Grant Mason, 2017

To learn more about future opportunities for stormwater management in Toronto, please refer to the other parts of this handbook series:

Nextvoyage, nd.



WET INFRASTRUCTURE:
Building Blue and Green
A series of research based handbooks designed to offer accessible and practical information about blue-green infrastructure approaches.

Handbook 2:
Governance
A Study of Stormwater Management Governance Structure in Toronto and Ontario

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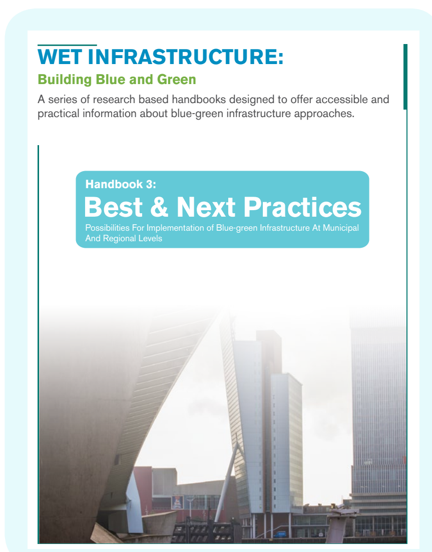

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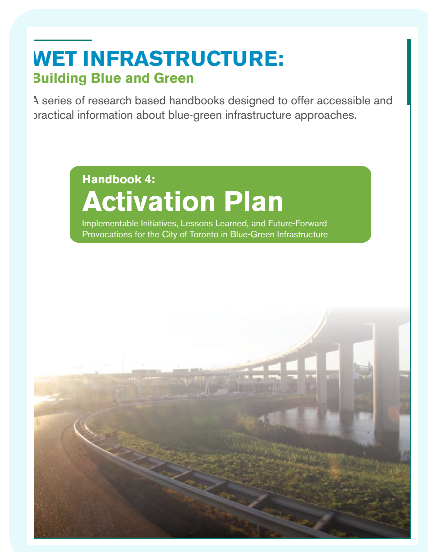
Handbook 3:
Best & Next Practices
Possibilities For Implementation of Blue-green Infrastructure At Municipal And Regional Levels

Best and Next Practices
International Opportunities and Approaches in Stormwater Management



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Handbook 4:
Activation Plan
Implementable Initiatives, Lessons Learned, and Future-Forward Provocations for the City of Toronto in Blue-Green Infrastructure

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