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Mandatory Downspout Disconnection

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Engineering ■ Operations ■ Pollution Control ■ Building	■ Building Adaptive Capacity ■ Delivery of Adaptation Options	■ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ■ Private

CONTEXT

Until recently, downspouts were connected directly to sewers (sanitary, combined or storm) in order to direct stormwater flow from rooftops to sewers as quickly as possible. However, due to the increasing extreme precipitation events and aging infrastructure this method of dealing with stormwater is no longer considered appropriate. Based on the Canadian Climate Change Scenarios Network model future precipitation projections are estimated at 2.2 % (by 2020) and up to 8.3 % (by 2080) over the baseline period of 1971 to 2000 (Environment Canada 2011). The average precipitation measured at the Windsor airport for this baseline period was 918.2 mm. It is important to note that during 2011, the City of Windsor received a record of 1568.2 mm of precipitation (Environment Canada 2012). To compound the issue, the 30 minute extreme rainfall events are expected to continue to increase in intensity by 5 % per decade until 2050 (Bruce et al., 2006).

ISSUE

Past practices encouraged the use of eaves troughs and downspouts to collect and divert rainwater from rooftops to sewers as quickly as possible. One of the major issues with this practice is how quickly the sewer systems can be overloaded by rainfall. If this rain water, ends up in the sanitary sewer the primary concern to a resident would be the increased risk of basement flooding. In addition to the increased risk of basement flooding, relatively clean rain water entering the sanitary sewer will end up being treated at a wastewater treatment facility. Similarly, rainwater entering the combined sewer system will either be treated at a wastewater treatment facility or discharged with sanitary sewage to the Detroit River with little to no treatment (combined sewer overflow).

Depending on the time and type of home construction, certain homes will be more at risk to basement flooding. Code and construction practices have evolved over time, and while the building code governs some aspects of construction, whether or not foundation drains are connected to a sanitary or storm sewer lateral, or to a sump system is almost independent of code.

***Table 1**: Code Considerations for New Home Drainage (Sanitary)*

Timeframe	Code Considerations for New Home Drainage
<1967	All plumbing in and around the house, including weepers, downspouts, and all sanitary fixtures could be connected into an internal combined system
1968-1992	Sanitary and storm drainage was required to be separated, but could then join together underneath the foundation and discharge via a single 'sanitary' lateral
1992-1995	Similar to that above, but code stipulated the separate pipes should be connected on the exterior of the building
1995	Separated sanitary and storm laterals required to the property line.
Today	No storm or groundwater drainage is permitted to be discharged to sanitary sewers

Source: (City of Kingston)

In general, any practice that directs storm drainage (roof and foundation drains) to the sanitary connection place that home, or adjacent homes at an increased risk of flooding.

Assuming an average annual precipitation of 918.2 mm (1971 -2000 average) disconnection of an average home with a roof area of 140 m2 would result in diversion of over 128,500 litres of stormwater from the sewer system each year. In reality, downspout disconnections usually can be done on about ¾ of a property's downspouts without resorting to more complex and costly disconnections.

Had downspouts been disconnected during the previous major flood events, then most of the basements that flooded would not have. A 10 % reduction in water volume heading to the sanitary sewer would greatly reduce instances of basement flooding (City of Windsor, 2012).

BENEFIT

The principle benefit of downspout disconnection is to minimize basement flooding. Downspouts that are connected to combined or sanitary sewer, contribute a significant volume of water at the peak of storm events. By disconnecting downspouts there is a delay of stormwater entering the system. This eases the pressure on the system at critical times and directly reduces the risk of basement flooding.

CO-BENEFITS

Disconnecting downspouts brings a number of additional economic and environmental benefits to the municipality and the homeowner by:

- Reducing the amount of storm water entering the sanitary and combined sewers thereby reducing the amount of combined flow requiring treatment;
- Reduces the amount of combined sewer overflows entering waterways without full treatment;
- Improved quality of storm water entering watercourses as storm water passing over roof tops pick up other contaminants; and
- Rainwater directed from the rooftops to rain barrels or cisterns can provide a source of water for gardens.

REDUCED QUANTITY OF STORMWATER BEING TREATED Stormwater entering the combined or sanitary sewer is carried to the City's wastewater treatment facilities for treatment. The presence of this flow creates an additional expense to the City of Windsor as electricity and chemical costs associated with treatment are dependent in large part based on the volume of water being pumped and treated. There is no easy method to quantify how much of the total flow was attributed combined sewer overflows, however, a conservative estimate of 10 % equates to $2.7 million a year to treat and dispose of rain water. Disconnection of downspouts will reduce but not eliminate the unnecessary treatment of rainwater at the wastewater treatment plants (City of Windsor, 2012).

REDUCTION OF COMBINED SEWER OVERFLOWS Combined sewer overflows (CSOs) are a release of storm and sanitary sewerage to a water course before full treatment has taken place. CSOs can happen at two different stages. First CSOs can happen along the sewer system. When the sewer system becomes overcharged with storm water the sewer may overflow to the Detroit River or other watercourse to minimize basement flooding. Unfortunately, the City of Windsor does not have flow monitoring on many of the CSO overflow sewer to quantify how much is occurring each year.

CSOs can also occur at the wastewater treatment plant. This occurs when the plant has reached capacity and wastewater must be directed to the Detroit River without being fully treated, in order to protect the infrastructure. This type of CSO is often referred to as a plant bypass. As a requirement of the Ministry of the Environment, plant bypasses are monitored and tracked. This information is also reported as an important Environmental Indicator under the Environmental Master Plan. The following table outlines the last five years of total plant by-passes.

Table 2. Total Waste Water Treatment By-Passes

Year	Total Precipitation (mm)	Total By-Pass (m^3)
2007	985.6	1,765,129
2008	1082.9	6,547,999
2009	947.6	1,901,200
2010	903.6	840,847
2011	1568.2	3,799,500

Disconnections of downspouts will reduce the amount of stormwater entering the sewers and the wastewater treatment facility thereby reducing the quantity of combined sewer overflows.

IMPROVED STORMWATER QUALITY Rain passing over roofs may also pick up other contaminates deposited on the roof by wind, animals, insects, or by the leaching and dissolving of roofing material. Downspout disconnection reduces the loading of such materials into sewers that eventually drain to the Detroit River.

WATER CONSERVATION Rain barrels and cisterns are low-cost storage devices that can be use to capture excess roof runoff and provide a source of water for gardens. Because residential irrigation can account for up to 40 per cent of domestic water consumption, water conservation methods such as rain barrels can be used to reduce the demand on the municipal water system, especially during the hot summer months (Ecojustice 2008).

BEST PRACTICES

Many municipalities in Canada and the United States have already begun to either impose voluntary or mandatory downspout disconnection policies. Some of these policies include incentives or no cost disconnection for residents that participate.

City of Kingston – Sewer Use By-law The sewer use by-law is very clear in its prohibition of extraneous water/flows to the collection system. Sections 3.8 to 3.11 under this by-law prohibits the connection of roof leader/down spouts, sump pumps, and weeping tiles to the sanitary or combined sewer system (City of Kingston 2008).

Recently, a report to the City of Kingston's Infrastructure and Transportation Policies Committee stated that a critical component to addressing the extraneous flow problem was enforcement of the By-law. The report recommends a more aggressive and proactive approach to by-law enforcement targeting all areas of the collection system, particularly the areas that have experienced flooding and those areas "upstream" of the noted areas (City of Kingston, 2011).

City of Toronto – Mandatory Downspout Disconnection In 2011, the City of Toronto approved a by-law making it mandatory for property owners to disconnect their downspouts. The by-law will come into effect across the city in three phases and is enforceable under Chapter 681 (Sewers) of the Toronto Municipal Code (City of Toronto, 2010). Exemptions may be permitted when it is not technically feasible or where a disconnection would create a hazardous condition.

A financial assistance program offers a reimbursement of the costs of labour and materials, up to a maximum of $500 for eligible low-income seniors or low-income persons with a disability.

City of Windsor – Downspout Disconnection For over a decade the City of Windsor has been encouraging voluntary downspout disconnection. More recently the City of Windsor has implemented mandatory downspout disconnection under Bylaw 26-2008, *A By-Law to Require Downspout Disconnection and to Regulate Stormwater Drainage* in areas that have experienced flooding. Under this bylaw the City Engineer would be authorized to disconnect roof leader downspouts from any municipal storm and/or combined sewer systems where conditions warrant. The bylaw also gives explicit authority to the City Engineer to disconnect downspouts and enforce disconnection of illegal taps to sanitary sewers (City of Windsor, 2008).

The first area requiring mandatory disconnection was the South Walkerville area bounded by Tecumseh Road East to the north, CPR tracks to the south, Walker Road to the east and Howard Avenue to the west. An earlier study of this area recommended a disconnection of 50 per cent of the downspouts in the area. Efforts to achieve a 50% disconnection rate with voluntary participation were not successful (City of Windsor, 2008).

The voluntary approach to downspout disconnection has not achieved more than 10 % disconnection.

CHALLENGES

The implementation a mandatory downspout disconnection in the City of Windsor may face challenges such as: education, funding, physical restrictions, and standing water complaints.

EDUCATION AND AWARENESS Lack of understanding with the public may lead to delays in achieving disconnection goals. A large portion of the general public does not have a thorough understanding of how the City's sewer system works or how their individual actions may contribute to the problem. This is especially true in areas that have previously not experienced basement flooding. However, it is important to address the issue proactively to minimize the risk of basement flooding.

Other issues that property owners have sighted is a perceived loss of an asset, particularly if the owners has taken other steps to flood-proof their home, and that disconnection is a strategy by the City to delay municipal infrastructure improvements.

FUNDING The City of Windsor currently offers a free downspout disconnection. Under the current tender for downspout disconnection, the cost for each individual downspout disconnection is $130 to $150.

At approximately 70,000 households, the cost to disconnect all downspouts in the City of Windsor could range anywhere from $5.25 million to $35 million. It is noted that some houses are already disconnected and not all downspouts can be disconnected due to physical restrictions. During, the 2012 capital budget City Council approved $2,000,000 in 2013, $400,000 in 2014, $220,000 in 2015 and $330,000 in 2016 for the expansion of the downspout disconnection program (City of Windsor, 2012).

PHYSICAL RESTRICTIONS Some property characteristics may prohibit the disconnection of some or all of the downspouts including:

1) The lot size should be sufficient to provide an area for the diverted runoff to infiltrate. Runoff should not pool significantly or run off onto a neighbouring property.
2) Property grading should be considered for downspout disconnection. A steep grade will promote runoff minimizing infiltration.
3) The proximity to nearby buildings needs to be considered as runoff reaching a building could cause foundation damage or basement flooding.
4) Some downspouts are located in areas that make disconnecting difficult, such as; into porches, driveways, patios or connected internally. Addition costs may be required to redirect the eave troughs to another location.

STANDING WATER COMPLAINTS Downspout disconnection may lead to increased standing water complaints (from water from the downspout accumulating on the homeowner's surrounding property). Statistics from the Building Department indicate that, on average, 150-200 property flooding/grading complaints are received annually. While complaints/investigations in this area may increase, the benefits of reducing the amount of stormwater entering into the sanitary sewer outweigh the risk of isolated backyard flooding.

SAFETY AND LEGAL CONCERNS A number of safety and legal concerns can arise with downspout disconnection. Safety concerns relate primarily to the threats posed by pooled runoff and ice formation on walkways in the winter months. Legal concerns may also arise with runoff onto neighbouring properties especially if such runoff causes damage to the foundation or basement flooding. These issues can be mitigated with proper planning surrounding downspout disconnections (CMHC, 2012).

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Mandatory Backwater Valves

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Engineering ■ Operations ■ Building	■ Building Adaptive Capacity ■ Delivery of Adaptation Options	■ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ■ Private

CONTEXT

Over the last decade, the City of Windsor has been facing more frequent and intense precipitation events. In some instances, stormwater entering the combined or sanitary sewers has overwhelmed the sewer system. When this occurs the water may backup into the basement. Observed rainfall trends show between a 4.5 to 5 % increase in the 30 minute extremes, while daily extremes increased by 7 % per decade from 1970 to 2000. To compound the issue, the 30 minute extreme rainfall events are expected to continue to increase in intensity by 5 % per decade until 2050 with a 3 % increase on the daily extremes (Bruce et al., 2006). One way to protect a basement from a sewer back-up is the installation of a backwater valve (backflow preventers).

ISSUE

Past practices encouraged the connection of downspouts to collect and divert rainwater from rooftops to sewers as quickly as possible. The connection of downspouts, the use the combined sewers (or cross-connections between foundation drains and sanitary sewer connections), the increase in intensity of rainfall events and aging infrastructure contribute to risk of sewer systems becoming overloaded during rainfall events. When this the primary concern to a resident is the increased risk of basement flooding.

Depending on the time and type of home construction, certain homes will be more at risk to basement flooding. See the appendix on downspout disconnection to determine if a home or neighbourhood may be at higher risk.

BENEFIT

The use of backwater valves may reduce the risk the basement flooding to an individual home by not allowing water to back-up into the home.

CO-BENEFITS

Proper installation of the backwater valve will require the disconnection of weeping tiles from the sanitary sewer. The redirection of stormwater from weeping tiles and downspouts into a sump pump that discharges to the ground will reduce the quantity of stormwater entering the sanitary or combined sewer. This action will produce many of the co-benefits described in the Appendix on downspout disconnection including the reduced quantity of stormwater being treated and the reduction of combined sewer overflows.

BEST PRACTICES

Many municipalities in Ontario administer a program packaged as a 'Preventative Plumbing Program', or similar, that has multiple components to it, for two pronged purpose;

i) To allow a homeowner to better isolate their home from flood sources; and
ii) To reduce extraneous flows to the sanitary sewer system.

Most programs offer anywhere from $1,000 - $5,000 (typically 50 – 100%) of total eligible costs to the home owner for works on the private-side that reduce the risk of flooding to the owner while also reducing stormwater flow to the sanitary sewer system. Most programs have elements for backflow prevention devices as well as foundation disconnection works (including sump installation) (City of Kingston, 2011).

City of Ottawa – 'Protective Plumbing Program' The Residential Protective Plumbing Program (RPPP) provides consultation and grant assistance services to City of Ottawa property owners who have experienced or live next door to a home that has experienced a backup of water caused by the overloading or blockage of city sewers.

The amount of a grant is governed by the City of Ottawa Protective Plumbing By-law 2005-209 and its amendments. The maximum amount of reimbursement allowed for protective plumbing grants is:

- 100 per cent of the cost of the work to a maximum of $4,000 (including taxes) where a basement or cellar experienced a backup resulting from the blockage or surcharging of a city sewer, or
- 50 per cent of the cost of the work to a maximum of $2,500 (including taxes) for a house that did not have a backup but is located in an area with a history of the blockage or surcharging of city sewers (City of Ottawa, 2010).

Effective April 4, 2011, the City of Ottawa has mandated the use of backwater valves on sanitary laterals for new home construction (City of Ottawa, 2010).

City of Toronto – Basement Flooding Protection Subsidy Program Financial assistance is provided for 80 % of eligible costs up to $3,200 based on activities completed including backwater protection, sump pump installation and foundation connection severance and capping (City of Toronto)

The Toronto City Council mandated the installation of backflow valves on sanitary laterals where there is a below grade living area in the City.

Financial Assistance Programs in Ontario City of Hamilton has a 'Protective Plumbing Program' that provides financial assistance of 100 % up to $2,000 plus financing of additional $2,000 loan to homeowners for backwater valve installation, sump pump installation (with backwater valve), CCTV inspection and downspout disconnection plus permits (City of Hamilton 2012).

City of St. Catharines provides financial assistance of 100 % up to $3,000 under a 'Flood Alleviation Program (FLAP) for homeowners who have documented recurring sanitary back-ups as a result of sewer surcharging (City of St. Catharines, 2012).

City of Peterborough administers a 'Sanitary Backflow Prevention Subsidy Program' which includes backwater valves, installation of a sump pit and pump required to disconnect foundation drains and/or storm water leaders from existing connections to the building sanitary sewer. The financial assistance is 100 % coverage up to $800 each, or 100% up to $1,800 for both backflow and sump (City of Peterborough, 2012).

City of London administers a 'Basement Flooding Grant Program' which funding of 75 % of the costs up to a maximum of $2,650 for foundation drain disconnection, $575 for backwater valves and $3,775 for construction of storm laterals (City of London 2009).

City of Greater Sudbury administers a 'Preventative Plumbing Subsidy' for 50 % of eligible costs to various maximums of $1,000 for backflow valves, $1,250 for sump construction or $2,250 for both (City of Greater Sudbury, 2012).

CHALLENGES

INSTALLATION The proper installation of a mainline backwater valve can be complicated. In an existing home, installation will require the breaking up of the concrete basement floor and cutting a section out of the sanitary sewer lateral. This will require the assistance of a licensed plumber (ICLR, 2009).

MAINTENANCE Like any other part of the home, backwater valves require periodic maintenance to ensure proper performance over time. An improperly maintained valve may fail during a flood event. Most mainline backwater valves come with a see-through top so that you can check to see if it is clogged with debris. The valve should be checked regularly to ensure that it will function properly when it is needed.

SUMP PUMP REQUIREMENT When installing a backwater valve, the installation of a sump-pump and sump-pit will also be required if weeping tiles are connected to the sanitary lateral. This is to allow foundation drains to continue to drain when the backwater valve is closed. Disconnecting the weeping tile from the sanitary lateral will also reduce water and sewage from backing up into the weeping tile, causing weeping tile blockage, odour issues and infiltration flooding into the home.

LIMITED USE OF WATER DURING INTENSE RAINFALLS During heavy rainfalls homeowners need to determine if the backwater valve is closed. When the backwater valve is closed, waste water generated in the home will not be able to exit the home and will backup through floor drains and plumbing fixture drains in your basement. If the valve is closed during a rainfall event flushing toilets, running dishwashers, washing machines, or running of taps is not recommended.

FUNDING In 2011, City Council approved the Basement Flooding Protection Subsidy Program (BFPSP) as a measure to assist Windsor homeowners to reduce the impact of flooding due to storm water. The program provides homeowners with a subsidy of up to $2,800 to install eligible plumbing components such as backwater valves and installation of new sump pumps and pits.

Assuming approval of capital funding requests for 2012 to 2016, approximately $1,750,000 will be available for the BFPSP. As of May 24, 2012 payments and projected payments total $896,447.75.

LIMITED PROTECTION Unlike the disconnection of downspouts, the use of backwater valves protects the individual home but does nothing to help with the impacts of adjacent residents. If one home is protected by a backwater valve but the adjacent home is not, basement flooding could be compounded in an adjacent unprotected home.

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Enhanced Sewer Maintenance and CCTV Program

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Engineering ■ Operations	■ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

The City of Windsor's sewer network consists of approximately 1,700 km of sewers including; 732 km of storm sewers, 675 km of sanitary sewers, 226 km of combined sewers and 24.5 km of over-under sewers. Currently the City of Windsor allocates approximately $1.3 million operating dollars towards a preventative sewer maintenance cleaning program which includes flushing and rodding of sewers, cleaning of catch basins and maintenance of municipal drains. This program assists in identifying issues with aging infrastructure and to clears blockage before issues arise. With an increase in annual precipitation predicted, as well as more intense storms it is important to maintain as much capacity within the sewer system as possible.

"A good preventive maintenance program is key to keeping a wastewater collection system in good repair. It helps preserve capital investment while preventing service interruptions and the excessive infiltration/inflow (I/I) and system failures that can result in Sanitary Sewer Overflows (SSOs). (US EPA)"

ISSUE

Currently, there are 18 employees in the sewer maintenance area who perform sewer maintenance on the City's 1,700 km of sewers. It takes approximately three years to complete one flushing cycle of the storm sewers, while it takes five years to complete a cycle on the sanitary and combined sewer system due to the volume and materials (heavy sedimentation, roots, grease, etc) associated with sanitary sewage. Sewer flushing involves forcing a heavy flow of water through the sewer line to remove floatables and some sand and grit. Flushing is most effective when used in combination with other mechanical operations such as rodding or bucket machine cleaning.

Rodding of sewers in areas of the City known for root infiltration occurs continuously and takes approximately 2.75 years to complete one cycle. Sewer rodding involves the use of an engine and drive unit to push rods with blades through the sewer. As the blades rotate, they break up grease deposits, cut roots and loosen debris. Rodding is most effective in lines up to 300mm (12 inches) in diameter.

Only 15 % of the entire 1,700 km of City sewers has been examined using closed circuit television (CCTV). Certified CCTV operators use video footage to record the type and location of defects along a sewer line. CCTV is an effective tool and common industry method for inspecting pipes/sewers. It provides visual data on leaks, location of connections, and sediment and debris accumulation. This information assists with prioritizing both capital replacements and short-term maintenance requirements (City of Windsor, 2012).

As the City's sewer infrastructure ages a loss of capacity can be expected. Unfortunately, this is occurring at a time when average annual precipitation and more importantly extreme rain events are increasing. Enhancing the preventative maintenance on the City's sewer system will help maintain or restore some of the lost capacity, minimizing the risk of basement flooding.

BENEFIT

Conducting routine sewer maintenance and CCTV inspections allows the City of Windsor to identify possible restrictions or blockages in sewer system. Flushing and rodding of the City sewer systems cleans debris and blockages from the sewer system reducing the risk of the sewer surcharging and backing up into basements.

CO-BENEFITS

PRIORITIZATION OF CAPITAL PROJECTS The use of CCTV along with sewer flushing and rodding allows the City of Windsor to determine the overall condition of the sewer as well as identify human induced issues (i.e. grease blockages). Based on the condition of the sewer, prioritization of capital replacement of sewers can be completed. In some cases the condition of the sewer may be acceptable but blockages are being created due to grease or other material being disposed of in the sewer. In these cases, public education may be needed and not costly sewer replacement.

BEST PRACTICES

A study performed by the American Society of Civil Engineers reports that the most important maintenance activities are cleaning and CCTV inspections.

A maintenance plan should include a strategy to prioritize the maintenance of pipes based on several of the following factors:

- Problems - Areas with a history of back-ups or blockages;
- Age - Older systems have a greater risk of deterioration;
- Pipe construction – non-reinforced concrete, brink, asbestos are all susceptible to corrosion;
- Pipe size/volume conveyed – pipes that carry larger volumes take precedence over pipes that carry a smaller volume; and
- Location – Pipes located on shallow slopes or in flood prone areas have a higher priority (US EPA, 1999)

Fairfax County, Virginia - The Fairfax County Sanitary Sewer System comprises over 3000 miles of sewer lines. Reorganization and streamlining of the sewer maintenance program, coupled with renewed emphasis on increasing productivity has resulted in very significant reductions in sewer backups and overflows.

The sewer maintenance program consists of visual inspections, scheduled sewer cleanings based on maintenance history, unscheduled cleanings as determined by visual or CCTV inspections, and follow-up practices to determine the cause of backups and overflows. Older areas of the sewer system are inspected every two years; whereas the inspection of relatively new areas may be completed in 3 to 4 years.

Sewer line cleaning is prioritized based on the age of pipe and the frequency of problems within it.

The cost per foot for maintaining the Fairfax system has decreased over the years because of streamlining and increased efficiency and productivity of the field staff (US EPA, 1999)

CHALLENGES

FUNDING Currently, the City of Windsor spends approximately $1.3 million in proactive maintenance. To decrease the maintenance cycle and complete the CCTV inspections on all City sewers additional staff and possibly addition equipment would be needed.

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Consideration of Additional Off-line Storage for Storm Water

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Engineering ■ Operations ■ Pollution Control	■ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Changes in annual precipitation have already been observed in the City of Windsor. Analysis of the precipitation data recorded at Windsor Airport shows that over time the average annual precipitation is increasing (1941-1970 – average 835.9 mm, 1971 – 2000 – average 918.2 mm) with the most precipitation ever recorded at Windsor Airport occurring in 2011 with 1568.2 mm. Based on the Canadian Climate Change Scenarios Network, future precipitation projections indicate further increases above the baseline period (1971 – 2000) of over 2 % by 2020 and up to 8.3 % by 2080. Increases in precipitation will lead to additional strain on the storm water infrastructure especially during extreme events. Some of these issues can and should be addressed through improvements of green infrastructure technologies such as green roofs, porous pavement, and rain gardens. However, the use of traditional grey infrastructure may still be beneficial and recommended in certain circumstances. Depending on the situation and location, construction of off-line storage can be achieved through traditional grey infrastructure such as additional pipes, or vaults, or through the use innovative green infrastructure technologies such as engineered wetlands or rain gardens.

ISSUE

As precipitation increases, especially the extreme rainfall events, the storm sewer system may become overwhelmed causing overland flooding of streets, parks etc. In combined sewer areas, storm water entering the system can lead to further issues such as combined sewer overflows and basement flooding.

Incorporation of additional off-line storage allows storm water to be retained and released at a specified flow rate that minimizes the risk of flooding. Off-line detention is placed outside of the natural watercourse or storm sewer system.

Since the storage is not within the conveyance system, water may be stored as long as desired to achieve the necessary improvement in water quality or peak-flow reduction.

Off-line storage of storm water can be achieved through several different methods including; storm water management ponds, constructed wetlands, and underground storage facilities.

Stormwater Management Ponds (SWMPs) are facilities designed to collect runoff from the local storm sewer system following either a rainfall or snowmelt event. SWMPs are designed to retain stormwater and then release it at a predetermined flow rate that minimizes the impact of downstream storm sewers. Properly designed SWMPs also provide the added benefit of improving storm water quality by removing certain pollutants. Unfortunately, SWMPs can require significant maintenance in the summer to remove aggressive growth of unwanted plant material, however, they may also add to the aesthetics of a community. Another consideration for SWMPs is that they attract waterfowl and therefore are not permitted in the vicinity of airports. The larger footprint associated with SWMPs limits their use in already developed neighbourhoods.

Constructed wetlands, also referred to as engineered wetlands, are similar in nature and purpose to storm water management ponds. That is, constructed wetlands normally maintain a permanent pool of water for contaminant removal, and they can be designed to include live storage for flood control and streambank erosion protection as well (Dayton & Knight Ltd, 1999). The difference between SWMPs and constructed wetlands is that constructed wetlands are shallow detention systems, which regularly fill and drain. Wetlands are typically extensively vegetated with emergent aquatic macrophytes, while the vegetation in a storm water management pond is limited to the edges of the pond. Several of the considerations mentioned under the SWMPs are also relevant to constructed wetlands.

Underground storage facilities are constructed facilities (pipes, vaults) that retain storm water runoff and release water at a predetermined rate similar to that of a SWMP. As these facilities are constructed underground they are often used in developed areas with limited space as a method to provide additional storm water capacity. However, these underground facilities do not provide the same level of storm water quality improvements as storm water management ponds or constructed wetlands.

BENEFIT

The use of off-line storage allows storm water to be retained and released at slower rates. This helps reduce the peak flows in the storm or combined sewers minimizing the risk of the sewers becoming overwhelmed causing flooding of roadways and basements.

CO-BENEFITS

IMPROVED STORMWATER QUALITY Off-line facilities, such as storm water management ponds and constructed wetlands can be designed to provide treatment of storm water and have proven effective in reducing total suspended solids, organic carbon, phosphorus, nitrogen, metals and bacteria (Dayton & Knight, 1999).

STORM WATER HARVESTING AND REUSE Over recent years, stormwater harvesting and reuse have emerged as a new field of sustainable water management. Harvesting and reusing stormwater offer both a potential alternative water supply for non-drinking uses and a means to further reduce stormwater pollution in our waterways. Stormwater harvesting complements other approaches to sustainable urban water management, including rainwater tanks, greywater systems and effluent reuse and demand management. Harvested stormwater has commonly been used for irrigating public parks and golf courses, and other non-potable uses are possible (Department of Environment and Conservation NSW, 2006).

REDUCTION OF COMBINED SEWER OVERFLOWS Off-line storage provides additional capacity and reduces the peak flow rate within the combined sewer system, thereby reducing the quantity of combined sewer overflows.

DEFERRED CAPITAL INVESTMENT Some municipalities are looking to include off-line storage in existing communities where the current sewer infrastructure is in good physical condition but capacity is an issue. The use of off-line storage can be used to provide the additional capacity needed to handle the heavier storm events, while the existing system is adequate to handle dry weather or routine storm events. Off-line storage provides an alternative to replacing kilometres of sewer lines that may be in good condition. Likewise, off-line storage may offer additional protection in communities that have aging infrastructure but the time line for complete replacement is significant.

BEST PRACTICES

The use of off-line storage is not a new concept to municipalities. The use of off-line storage is often used by land developers required to restrict storm flows to pre-development conditions. During the design of new developments, consideration is given to the location and type of off-line storage facilities that will enhance the neighbourhood.

The use of off-line storage is becoming more desirable with municipalities for use in existing communities. Changes in precipitation and aging infrastructure have contributed to an increase in storm water related issues such as basement flooding in many communities. Off-line storage can provide additional relief to a system constantly overwhelmed by storm water, while the municipality works to replace the aging infrastructure.

City of Toronto - The City of Toronto promotes a hierarchical approach for treating stormwater starting with source controls (ex. downspout disconnection), conveyance control (ex. sewer separation) and finally end of pipe controls (ex. off-line storage). The evaluation of alternative solutions for the management of storm water includes consideration for the natural environment, social/cultural environment, technical and economic. As part of the Scarborough Waterfront CSO/Storm water Outfalls Control Flood Protection Study several areas will include off-line storage. For example, the recommended solution for Sandown Park area includes the construction of an infiltration facility that will capture stormwater runoff and treat runoff prior to discharging back to the storm sewer. The storage facility will be located under Sandown Park.

Figure 1: During and after construction (City of Toronto, 2009)

CHALLENGES

PUBLIC PERCEPTION The use of off-line storage may be perceived by the public as the municipalities' way to prolong the replacement of deficient sewer infrastructure. However, the use of off-line storage may be the best way to minimize risk of flooding in the short-term while sewer reconstruction is taking place.

COORDINATION OF CAPITAL PROJECTS One of the benefits of using off-line storage, especially underground storage is that it can be incorporated within existing neighbourhoods often in park land. Ideally, the coordination of installation of underground storage should coincide with parks improvement projects.

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Increase Use of Flow Restrictors

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations ■ Pollution Control	■ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Catch basins located on local roadways quickly drain storm water from the road and into either the storm sewer or combined sewers. During wet weather, the capacity of combined sewer systems may become overloaded, causing overflows to receiving waters (combined sewer overflows), waste water treatment plant by-passes or basement flooding. Slowing storm water entering the combined sewer system delays and reduces the peak flow in the combined sewer system mitigating some of the risks noted above. One method to delay the influx of storm water is through the use of flow restrictors on catch basins along the combined sewer system. Since the 1970s observed trends show an 5 % per decade increase in the 30 minute extreme storms, a trend expected to continue until 2050 (Bruce, 2006). The City of Windsor has already been experiencing the impacts of these more intense storms on basement flooding and plant by-passes. The City of Windsor currently has 226 km of combined sewers and 24.5 km of over-under sewers.

ISSUE

Combined sewers were designed to carry both sanitary sewage and storm water runoff in a single pipe to a waste water treatment plant. Over-under sewers were designed with two pipes, a storm sewer above and a sanitary sewer below. Over-under sewers were believed to be cost-effective as only one trench was needed during construction and only one manhole was required to service both the sanitary and storm sewers while allowing separated flows. However, over time the manhole plates in the combined, over-under manholes have deteriorated allowing storm water to flow into the sanitary sewer below. The routine construction of combined sewers was ended in the 1950s while over-under sewers were constructed for several more years. For the purposes of this document, over-under sewers will be considered combined sewers.

As mentioned above, during wet weather periods, the capacity of the combined sewer system is often exceeded due to the influx of storm water into the system. The results of the inflow of stormwater may be combined sewer overflows to the Detroit River (untreated), waste water treatment plant by-passes (partially treated) or basement flooding. Reducing the speed, at which the storm water enters the system, delays and reduces the peak flows in the combined sewer system. Several technologies exist that assist municipalities in delay these peak flows including downspout disconnection (see appropriate appendix) and flow restrictions in catch basins.

BENEFIT

The use of flow restrictors in catch basins allows storm water to be temporarily stored on roadways and other overland flow routes. The storm water is retained on the surface and flows to the sewer system at a controlled rate, eliminating or reducing the chance that the system will overloaded.

Flow restriction works best in relatively flat areas where temporary ponding or detention of water on streets is acceptable (US EPA, 1999).

CO-BENEFITS

RELATIVELY INEXPENSIVE The use of flow restrictors is relatively inexpensive and easy implemented.

BEST PRACTICES

City of Winnipeg The Combined Sewer Overflow Management Study finalized for the City of Winnipeg outlines utilization of flow restrictors on catch basins to reduce the rate of inflow into the combined sewer system to improve hydraulics to achieve the required capacity for a one in five year 'design storm' (Wardrop Engineering, 2002).

City of Chicago, IL After a flood in 1997 caused hardship and property loss for some 35,000 residents, the City of Chicago formulated a two-pronged strategy; installing catch basin inlet restrictor valves and promoting downspout disconnection by homeowners. The City has installed 200,000 catch basin inlet restrictors ahead of schedule and under budget.

Near Chicago, the City of Evanston has installed a similar valve system that has helped reduce basement backup.

CHALLENGES

PUBLIC EDUCATION Public education is required to build support and address concerns that residents and elected officials may have regarding on-street storage.

MAINTAINING SAFE ROADWAYS The use of flow restrictors should be restricted to low volume, low speed residential roads. The storage of storm water on roadways may create safety concerns for vehicle and bicycle traffic using the roadways. Before the installation of flow restrictors on any roadway, consideration must be given to determine the potential for unsafe travel condition.

INCREASE MAINTENANCE Material such as leaves and litter that previously may have passed through the catch basin and into the combined sewer may now be caught up on the flow restrictor. Additional maintenance may be required to clean the catch basins of such debris. However, it is important to note that such material should not be entering the combined sewer system either, which may cause increased problems within the sewer system above and beyond that from being caught in the catch basin.

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Seal Manhole Covers

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations ■ Pollution Control	■ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Sewer manholes are installed approximately every 100 m along a sewer line. There are approximately 11,424 manholes located along the City's sanitary and combined sewers. These manholes provide access for maintenance and inspection of the sewer system. Leaking manholes can be a significant surface of inflow and infiltration. As the infrastructure ages, manhole risers may begin to deteriorate allowing storm water to infiltrate into the system, while vent and pick holes add another route for inflow into the system. Based on climate change projections, southern Ontario may see increases of 2 to 8 % in annual precipitation over the baseline period of 1971 to 2000 (CCCSN, 2011).

ISSUE

Extraneous flows of storm water into the sanitary or combined sewer systems is one of the main causes of basement flooding. During storm events, manholes located at low points within the roadway can account for 10 or more times the flow that a typical household would (UMA, 2005).

Storm water can penetrate through cracks in precast or brick manholes beneath the road or through the manhole covers. Each manhole has 2 or 4 small square openings to facilitate opening and allow for ventilation however, these holes also allow storm water infiltration, especially where storm water gathers.

The sealing of manhole covers can include: the replacement of existing covers with a new solid, gasketed cover; sealing of existing manhole covers through the installation of a gasket and plugging of the vent and pick holes; or through the installation of a manhole insert, which uses the existing cover in conjunction with a watertight insert that is installed under the cover to prevent entry of water into the manhole (NASSCO).

BENEFIT

Sealing manholes located at low points within roadways provides a quick and simple means to reduce unwanted flows within the sanitary or combined sewer system. Inflow and infiltration of storm water is one of the primary causes of basement flooding.

CO-BENEFITS

REDUCED QUANTITY OF STORMWATER BEING TREATED Storm water entering the combined or sanitary sewer is carried to the City's wastewater treatment facilities for treatment. The treatment of storm water creates an additional expense to the City of Windsor as electricity and chemical costs are dependent in large part on the volume of water being pumped and treated.

BEST PRACTICES

City of Peterborough Under the Flood Reduction Master Plan, it was recommended that the City of Peterborough begin immediately to develop a phased, well planned approached to reduce extraneous flows to the sanitary system (UMA, 2005). This includes identification of candidate manholes and physical installation of manhole inflow reduction measures (sealing of manhole covers).

City of Fairfield, OH - This bedroom community, a suburb of Cincinnati has been aggressive towards rehabilitation of manholes. The sewer system is relatively new, construction started in 1965 but by 1986, the City was seeing storm-related sewage overflows caused by inflow and infiltration. Sewer maintenance crews inspect approximately one fifth of the 4,500 manholes in the months of December and January when weather permits.

Depending on the condition of the manhole, risers may be re-grouted, or manhole covers replaced with gasketed, solid models in low lying areas of the roadway where storm water accumulates. Since the program started, the City's population has grown by nearly one-third, while average daily wastewater flow has declined by 200,000 gallons (Municipal Sewer & Water, 2011)

CHALLENGES

ENSURING ADEQUATE VENTILATION In addition to allowing for the manholes to be opened, the holes provide a means to ventilate the sewer system. By sealing the holes in the manholes ventilation is reduced. Care is required to ensure that enough ventilation exists to prevent the build up of gases within the system. Therefore, sealing of manholes covers should only be permitted on known low points along the roadway where storm water is known to accumulate. Manholes upstream and downstream should remain open.

RESEALING Manholes are opened routinely to conduct inspections and maintenance on the sewer system. Occasionally manholes may be opened to conduct sampling of spills to sewers. Once the seals are removed they would have to be replaced.

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Update IDF Curves

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Engineering ■ Operations	■ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

The design of municipal infrastructure (sewers, stormwater management ponds or detention basins, street curbs and gutters, catch basins, swales, and pumps. etc) is based on the use of local rainfall Intensity Duration Frequency (IDF) curves. The City of Windsor's current IDF curves were developed in the early to mid-1970s using historical rainfall data. The average annual precipitation in the City of Windsor has climbed from an average of 836 mm (1940-1970) to 918.2 mm for the period of 1971 to 2000. The total precipitation in a year does not affect the IDF curves, but focuses on a storm event's individual intensity and frequency over a duration (for example a 12 hour or 24 hour rainfall event). Since the 1970s (when the curves were last updated), observed rainfall trends show between a 4.5 to 5 % increase in the 30 minute extremes, while daily extremes have increased by 7 % per decade. To compound the issue, the 30 minute extreme rainfall events are expected to continue to increase in intensity by 5 % per decade until 2050 with a 3 % increase on the daily extremes (Bruce et al., 2006).

ISSUE

IDF curves are a set of guidelines which informs the design and implementation of everything from pipe size to pump strength and construction practices. For example, in Canada storm sewers are typically designed to carry a minimum of the 5-year storm from the area upstream of the sewer system.

Currently, IDF curves are typically developed by analyzing past rainfall events to determine standard expected return periods for certain rainfall events. Typically 2, 5, 10, 25, 50 and 100 year return periods are shown (as lines) as a set of IDF curves. For example the 5-year line on an IDF curve would represent rainfall events that have a statistical probability of occurring once every 5 years.

These curves are calculated under the assumption that past rainfall statistics continue to represent rainfall statistics into the future. As mentioned above, the IDF curves were last developed in the early to mid-1970s. More recent observed rainfall events appear to be changing in both frequency, duration and intensity. It is also unclear what data or methodologies were used by Environment Canada to develop the curves.

The City of Windsor has experienced extreme rainfall events exceeding the historic 1:50 year storm return rates in 2006, 2007, 2010 and 2011. The current changes in rainfall intensities emphasize the need to update the IDF curves.

Updating the IDF curves to consider climate change will allow the City of Windsor and developers to design sewer and pump infrastructure to deal with rainfall intensities expected into the near future.

BENEFIT

New IDF curves will contribute to the planning, design, and management of storm water infrastructure that can better handle current and future rainfall events. New developments or replacement sewer projects will benefit from the new IDF curves as the infrastructure will be designed to better handle the current increasing precipitation trend. Consideration for the possible increase in extreme rainfall events in the design of local infrastructure will reduce the risk of basement, property and road flooding. There will also be a reduction in the City's liability to future legal action against negligence, primarily due to property damage from flooding. Stormwater infrastructure that is designed with updated IDF curves that consider climate change may also increase the ability for the City's residents to maintain or augment flood protection insurance.

CO-BENEFITS

New developments may find the use of green infrastructure a more economical way to manage the possible increase in storm water management requirements and possibly enhance their properties. Using green infrastructure (green roofs, rain gardens, etc) has several co-benefits. Green infrastructure actions are highlighted in various appendices in this report.

BEST PRACTICES

In recent years, there has been more discussion revolving around how infrastructure will need to be designed with consideration to more recent observed climate as well as for future climate projections. The following quotes highlight concerns from different agencies for not considering the new precipitation patterns.

"due to the changing climate, future heavy rainfall and high/low-flow events could significantly increase in the 21st century... the [climate] change should be taken in consideration in adjusting engineering infrastructures design standards and developing adaptation strategies and policies" (Environment Canada, 2007)

"Climate change is exposing Canada's infrastructure to conditions it was not originally designed to withstand. This can reduce its useable lifespan and may expose Canadians to disruptions to their lives and daily routines, and increase risks to public health, safety, the environment and result in economic loss. Engineers have a professional responsibility to minimize such disruptions and reduce risks by designing, building and maintaining resilient infrastructure that can adapt to the impacts of a changing climate" (Engineers Canada, 2008)

"infrastructure designed using historical IDF values may be at greater risk of damage or failure. It is therefore important to understand how extreme precipitation and IDF values are changing in the current climate, and to take stock of our state of knowledge and uncertainties"… (Canadian Standards Association, 2010)

City of London In 2009, the City of London in collaboration with the University of Western Ontario undertook a study to update the city's rainfall IDF curves using more recent rainfall trends as well as consideration for climate change projections.

A comparison between the updated and the historical Environment Canada IDF curves shows a difference that ranges between 10.7 % and 34.9 % with an average value of approximately a 21 % increase (Simonovic, 2009). This difference is shown in Figure 1.

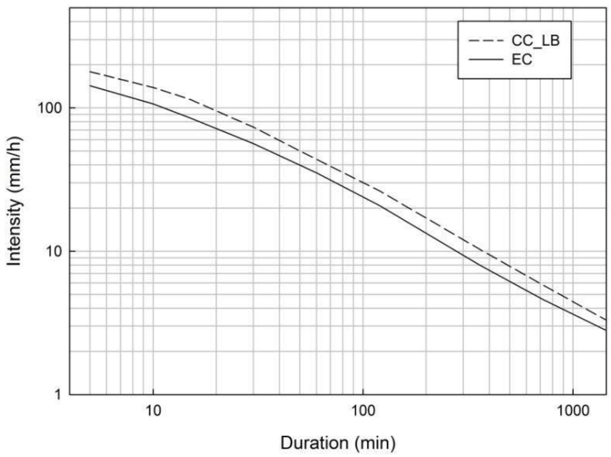

Figure 1: *Comparison of new (CC_LB) and old (EC) IDF Curves for the City of London*

Duration (min)

CHALLENGES

Until the new IDF curves are developed, the City of Windsor has no way to predict how the changes to the curves will affect infrastructure replacement or new development.

LACK OF RAIN FALL DATA Until recently the region has only been serviced by one environmental monitoring station, which is located at the City of Windsor airport. As observed with recent storms, localized down bursts are becoming more of the norm. These intense and compact storms may not be picked up at that one station. As such, numerous municipalities have begun investing in their own rain fall monitors. The City of Windsor currently has 14 rain gauges installed. These rain gauges were installed at the end of 2011 and early 2012 and therefore don't provide a significant amount of information for developing the curves.

FUNDING FOR NEW IDF CURVES Under the 2012 Capital Budget, the City of Windsor has committed $50,000 towards updating the IDF curves in partnership with the Essex Region Conservation Authority. ERCA's administration is coordinating the development and delivery of the IDF curves with participation from local municipalities. If ERCA is successful in getting all municipalities involved the City's share may be reduced (City of Windsor, 2012).

FUNDING OF FUTURE INFRASTRUCTURE PROJECTS If the updated curves indicate a change similar to that seen with the City of London, the City of Windsor should consider an increase in IDF curve design, which would increase the cost to construct storm water infrastructure with the required larger pipes and pumps. The alternative is to accept a lower level of service to the City residents and/or increased costs of future maintenance and replacement.

HISTORICAL INFRASTRUCTURE Designing for new or replacement infrastructure will require additional consideration of outlet capacity in existing infrastructure. Additional storage capacity may be needed to be provided in order to allow for discharge to existing infrastructure under the historical IDF curves.

CHANGES TO FLOODPLAIN MAPPING Depending on the changes to the IDF curves, additional research may be required to determine if local floodplain mapping is still acceptable.

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Flow Monitoring of Priority Sewers

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Engineering ■ Operations ■ Pollution Control	■ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

The City of Windsor's sewer network consists of approximately 1,700 km of sewers including; 732 km of storm sewers, 675 km of sanitary sewers, 226 km of combined sewers and 24.5 km of over-under sewers. This system was constructed over the better part of a century with several areas being inherited from preceding municipalities that were subsequently amalgamated and/or annexed by the City of Windsor including; the Town of Walkerville, Ford City, Town of Riverside, Sandwich East Township and Sandwich West Township. Each sewer system was designed and constructed to the standards of the respective municipality at the time. Many of these systems have never been studied in detail to determine how the system functions as a whole. Currently, flows to the sewer system are only monitored at pumping stations and the waste water treatment plants. Quantifying storm flows to the City's sanitary and combined sewer system is critical to developing a comprehensive storm and sanitary sewer master plan that will ultimately allow the City to prioritize capital investment in the sewer network and inclusion of green infrastructure projects. Flow monitoring will also provide key information for development of a proactive maintenance program to respond to concerns to minimize the risk of basement flooding.

ISSUE

During precipitation events, the City's sanitary and combined sewers often become overwhelmed with storm water. Storm water enters the sanitary or combined sewers through downspouts and foundation drains that are connected to the sanitary sewer, illegal connections, and infiltration into the collection system through leaking pipes and bad connections. Currently, limited data is available as to where the storm water is entering the system. Flow rates are currently only obtained at pumps along the sewer system or at the entry point of the waste water treatment plants. This limited information does little to determine where and how storm water is entering the system.

Without flow monitoring, the City is often left to respond to sewer issues after flooding has taken place. The use of on-going flow monitoring will allow the City to identify areas where the sewer system is surcharging during less intense rainfall events. Proactive inspection and maintenance of these areas will help to minimize the risk of basement flooding when more intense rainfall events occur.

BENEFIT

The greatest benefit of flow monitoring of the sewer system is to better understanding how the sewer system is operating especially under storm conditions. The flow monitors will allow quantification of flows that can lead to the identification of sources of extraneous flows (storm water entering sanitary sewers), blockages or restrictions due to tree roots, grease or collapsed pipes, etc. Once these problems are identified proactive maintenance can be completed to repair the issue and minimize the risk of basement flooding.

CO-BENEFITS

PRIORITIZATION OF CAPITAL PROJECTS Flow monitoring will allow the City of Windsor to better understand how the sewer system is operating; a priority list of sewer replacement projects can be coordinated. The results may indicate priority areas for the inclusion of green infrastructure solutions to reduce inflow and infiltration into the system.

OPTIMIZATION OF THE WASTE WATER TREATMENT PLANTS The more information that the waste water treatment plant operators have in regards to quantities of flow heading to the plant the better they will be able to control the process. In addition the need for expansion of the treatment plants can be delayed or eliminated due to the reduction of extraneous flows.

The use of flow monitoring and modelling can also be used to determine how peak flow rates at the waste water treatment plants will be affected by changes to the sewer system.

REDUCTION OF COMBINED SEWER OVERFLOWS The use of flow monitoring will help identify areas of the sanitary or combined system that are experiencing heavy inflows of storm water. This information can then be used to enhance programs in an area such as downspout disconnection, sewer relining, sealing of manhole covers, etc.

SOCIAL MARKETING The use of flow monitoring will allow the City of Windsor to monitor the levels in the sewer system. If the system is becoming overwhelmed due to storm flow, the City of Windsor can use social marketing or the media to get a warning out to residents to take precautions at home to minimize the risk or damage from basement flooding.

BEST PRACTICES

Many municipalities are now creating computerized models of their entire sewer system. The first step of this process is the installation of flow monitors in manholes throughout the system to monitor the flows and determine how the system is actually performing.

Region of Peel Twenty six alarmed real-time flow monitors, two real time rain gauges, and twelve other rain gauges (where data is collected monthly), have been installed in the sanitary sewer system in the Region of Peel as part of their inflow and infiltration strategy. The purpose of this strategy includes;

1. Identification and quantification of areas in the system that are significantly impacted by inflow and infiltration,
2. Generation of additional flow data for Peel's sanitary sewer model, and
3. Augmentation of Peel's operations "flood patrols" in areas with a history of basement flooding during rainstorms.

The flow monitors allow for real-time monitoring of how the sanitary sewer system is responding to rain events. The figure below shows how quickly the sanitary sewer is reacting to a rain event.

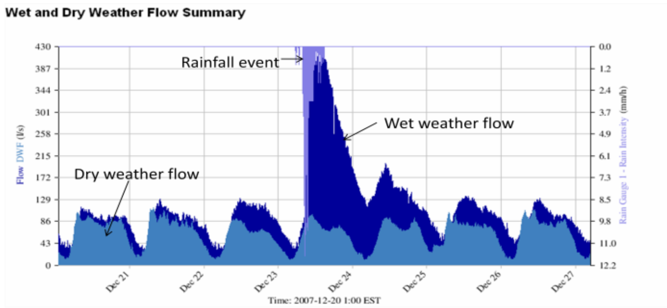

***Figure 1:** Comparison of dry and wet weather flows in a sanitary sewer.*

The Region of Peel's existing sanitary sewer system model is currently being upgraded into a dynamic hydraulic model that will support inflow and infiltration and storm response analysis. The flow monitors will include a real-time alarming capability that the Region will use in areas with a history of basement flooding (OCMBP, 2008).

City of Peterborough Since 2005, the City of Peterborough has monitored flows in their sanitary sewer system. Using the flow data obtained, a sewer modelling program was created that could predict where the system would surcharge during a particular size rain event. The model results showed that under a 1 in 25 year rain event there were 16 sewer "clusters" that would be highly susceptible to flooding.

Based on the results of the flow monitoring and modelling the main cause of high flooding in the sanitary sewer system was attributed to the inflow and infiltration of storm water. Using the information obtained from the flow modelling, the City of Peterborough has the information required to minimize the risk of flooding in these high risk areas. The alternatives presented to reduce the risk of basement flooding include:

- Reduction of inflow and infiltration (downspout disconnection, foundation drain disconnection, sealing of manholes, pipe rehabilitation, etc);
- Conveyance improvements such as pipe replacement, twinning of sewers;
- Adding storage capacity using off-line storage or storage tanks; and
- A hybrid solution of the above.

This study went one step farther into looking at how these alternatives would impact the flows at the waste water treatment plant. A hybrid solution or the reduction of inflow and infiltration had the biggest impact on reducing the peak flows at the waste water treatment plant, while doing nothing or adding conveyance capacity would lead to higher peak flows at the treatment plant (Cole Engineering, 2012).

City of Kingston A monitoring program has been in place for some time in the City of Kingston to document flows in the sanitary sewers. The data is analysed for the purposes of trying to identify the worst problem areas by looking at areas that show the biggest response to storm events as well as the areas that experience more infiltration during dry weather. Using this information the City of Kingston has been able to focus efforts on actions that reduce stormwater flow into the sanitary sewer (City of Kingston, 2011).

CHALLENGES

LACK OF EXPERIENCE Some municipalities have developed in-house experience once the computer modelling is completed. This includes engineers to perform the ongoing modelling, field technologists to install, clean and monitor the flow meters on a daily and weekly basis, and an analyst who reviews the data. Once the model is complete the City of Windsor will need to determine if the internal resources exist to keep the model updated on a continuous basis or have a consultant provide this ongoing service.

FUNDING The initial funding to hire a consultant to perform the flow monitoring and hydraulic modelling of the City's sewer system has been approved in the 2012 Capital Budget. This information will be used towards the development a Master Plan for storm and sanitary sewers. Ongoing funding will be required after the completion of the master plans to achieved continued benefit of flood forecasting and proactive maintenance.

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Undertake Public Education on Sewer Use, Waste Water Treatment

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Pollution Control ■ Operations ■ Building	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Educating homeowners about proper sewer use and waste water treatment is important to decrease water pollution, sewer overflows and basement flooding. Pollution Control at the City of Windsor already does this in many ways, including print advertisements, demonstrations and give-aways at Earth Day and at schools, as well as offering the Yellow Fish Road Program to youth organisations. The city also participates in the Children's Water Festival, where an activity is offered for kids to be "flushed down the toilet", and go through an obstacle course simulating a waste water treatment plant.

ISSUE

The improper use of sewers can range from illegally dumping oils, greases or paints into the storm or sanitary sewer, to simply disposing of food scraps down your kitchen sink. Both cause water pollution as well as the potential to block the sewer and cause a sewer back up or a pipe to burst. When contaminants or organic material ends up in the sanitary sewer, the waste water treatment plant has to work harder to clean the water. Sometimes, the waste water treatment plan is not able to clean certain contaminants out of the water before it goes into the Detroit River. An example of contaminants that are hard to remove from waste water is prescription drugs.

When contaminants or organic material are poured into a storm sewer, residents may think that they will go to the waste water treatment plant. In fact, they will go directly into the Detroit River. One great way the City of Windsor educates residents on this issue is by participating in the Yellow Fish Road program.

Figure 1: *A City of Windsor Activity Guide Advertisement.*

In addition, a greater understanding of the waste water treatment process may be beneficial to residents in order to stress the importance of allowing only toilet paper and human waste to be flushed down the toilet. Food scraps and other materials should not be allowed to enter kitchen drains, as this organic material places a strain on waste water treatment plant operations.

The improper use of some sewers in the City of Windsor may be a result of a lack of education amongst residents and business owners. It is important to increase the delivery of education as well as continue to monitor municipal drains to ensure that contaminated materials do not end up in either the sanitary or storm sewers.

Proper sewer use education aims to connect residents and businesses with their local water courses and increase their awareness of where contaminants go when they are poured down the drain. Education of these issues can occur using many different programs and media and need to involve various sectors of society including youth and new immigrants to Windsor.

BENEFIT

INCREASED AWARENESS OF LOCAL WATER QUALITY Through increased delivery of sewer use education, residents of Windsor will know more about how sewers work, where they lead to (the waste water treatment plant and/or the Detroit River), and what not to throw or pour down the drain. Highlighting the risk of basement flooding or contamination of the Detroit River brings this issue to a resident's local environment.

Connecting people with their local water body and drinking water source better ensures that they will protect this resource. Involving the youth is important in order to further educate the adults. As well, by giving youth the knowledge and tools now, they're more likely to become environmental stewards. Providing all information in multiple languages for targeted areas is crucial as in many countries, liquid waste and contaminants may be disposed of differently.

CO-BENEFITS

IMPROVED WATER QUALITY As the City of Windsor continues to delivery sewer use education, it is hoped that the behavioral patterns of residents will change to include the proper disposal of household wastes, organic material, oils and greases as well as any other contaminants. Proper disposal in a backyard composter, garbage, or the Hazardous Waste Depot will help to decrease the amount of contaminants reaching the waste water treatment plants and the Detroit River.

BEST PRACTICES

Many municipalities have included education as a key means of improving sewer use among residents and business owners.

City of Toronto – Toronto's *Wet Weather Flow Master Plan (WWFMP),* adopted in 2003, aims to reduce and ultimately eliminate the adverse impacts of wet weather flow, which is runoff generated when it rains or snows. The implementation plan describes education as the real key to the success of dealing with stormwater pollution. Their public education and outreach program includes various mass media campaign on reducing stormwater contaminants. This was mainly done using printed ads and billboards with messaging such as "Not Grate for the Lake" and "Where Does the Oil End Up" (City of Toronto, 2012).

Figure 2: *A sample advertisement from Toronto Water's stormwater education campaign.*

To build on these programs, the Wet Weather Flow Master Plan goes a step further by:

- Establishing a network of community and business partners to work together to prevent stormwater pollution;
- Promoting stormwater pollution prevention solutions;
- Developing social marketing programs that encourage Torontonians to adopt environmentally sound behaviour;
- Celebrating and rewarding our partners who help promote and contribute to pollution solutions.

Toronto also posts campaign advertisements on their YouTube channel. Here, Chuck and Vince promote the city's "We Want It" ad campaign for household hazardous waste disposal. Some of these videos have received over 45,000 views.

Figure 3: *City of Toronto YouTube video campaign example.*

Regarding their downspout disconnection campaign, the City of Toronto used billboards, bus shelter and bus advertisements as well as radio spots to encourage home owners to disconnect their downspouts.

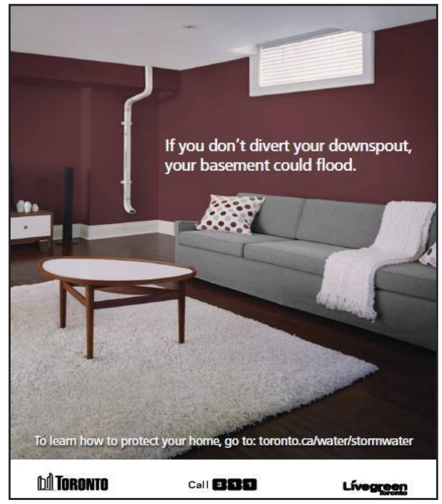

Figure 5: *City of Toronto billboard advertisement.*

City of London – London has recently released a great public education campaign around proper sewer use. The campaign consists of many brochures, some in up to seven languages. Short, simple videos have been created to show residents how to properly dispose of waste, and why it is important to not put anything into the toilet, sink, or storm sewer (City of London, 2012).

Figure 5: *City of London YouTube video campaign example.*

In addition, the city has created an interactive "Basement Flooding House" on their website where residents can click on various incorrect sewer use behaviors and learn about how to use sewers properly. This is a great hands-on way to teach sewer use education to residents of all ages.

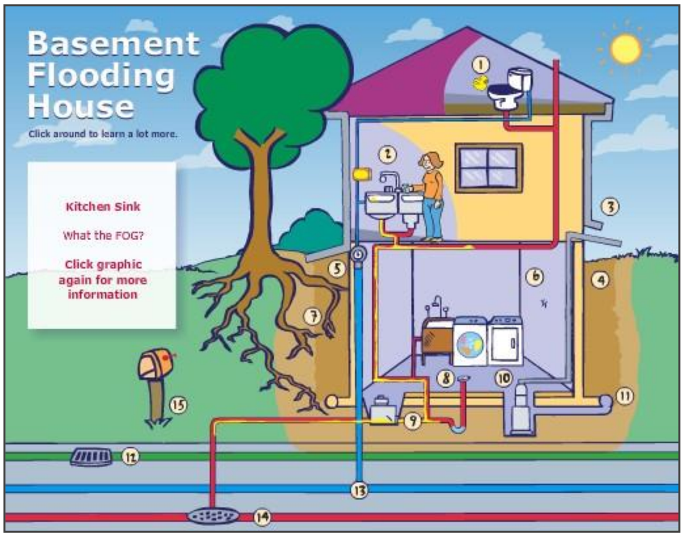

Figure 6: *City of London On-line education tool*

Finally, the City of London is targeting storm sewers in close proximity to city parks for education by installing stormwater grates with a permanent fish embedded in the design. Similar to the "Yellow Fish Road Program", this encourages residents to realise that what does down this drain heads straight to the river, untreated.

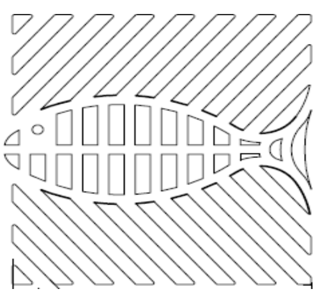

Figure 7: *City of London storm sewer grate with embedded fish design.*

CHALLENGES

LACK OF MEASURABLE RESULTS A lack of measurable results may be one reason why some municipalities have not invested time and resources into sewer use education. It is very difficult to measure the success of an education program involving sewer use as any improvements may be based on a number of factors. This may be a barrier for Council and administration as they allocate funds towards pollution control programs.

INSUFFICIENT FUNDING Educating residents through advertisement campaigns can become quite expensive. In order to attract a lot of attention, billboard, radio and printed advertisement are often necessary. Fortunately, as social media becomes more prevalent, municipalities are now able to spread their message in a more cost effective way. The videos created by the City of Toronto and the City of London are great examples of how this can be done. Although the use of social media is cost effective, any videos created will still have associated costs to the municipality.

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Targeted Educations towards Homeowners with Suspected Cross-Connections to Sanitary Sewer

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Engineering ■ Pollution Control ■ Operations	■ Building Adaptive Capacity ☐ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Educating all residents on the proper use of sewers, waste water treatment and stormwater issues is necessary to help decrease the quantity while improving the quality of water flowing to the waste water treatment plants and/or the Detroit River. However, due to certain characteristics such as proximity to the river, previous basement flooding issues or being serviced by a combined sewer, it may be beneficial to focus educational resources on a select group of residents. This way, the information provided will go to those individuals who have the most influence and ability to improve water quality and quantity. In previous years, the City of Windsor has targeted certain neighbourhoods when promoting their complementary downspout disconnection program. Targeted areas included those who had previous issues with basement flooding. In addition, the city has also targeted neighbourhoods that require mandatory downspout disconnection in order to decrease the strain on municipal infrastructure during a rain event.

ISSUE

During and after an intense rain event is when there is the most water flowing through municipal infrastructure. This water either travels through the storm sewer into the Detroit River or through the sanitary sewer to one of the waste water treatment plants. Many characteristics have an impact on the quantity and quality of water produced during a rain event. Most importantly are downspouts or weeping tiles that drain to sanitary or combined sewers, and contaminated stormwater runoff which enters the Detroit River in a Source Water Protection significant threat area. The proposed Essex Region Source Protection Plan includes education as a tool to help protect vulnerable areas (ERCA, 2012).

Ensuring residents with the issues mentioned above know about proper sewer use and stormwater management techniques have the potential to provide the greatest benefit to the system.

Providing all information in multiple languages is crucial as in many countries, liquid waste and contaminants may be disposed of differently. For this reason the City of Windsor has identified new immigrants as a target area for sewer use education.

In addition, businesses and restaurants may be targeted to educate owners on the consequences of pouring fats, oils and grease into the sewer.

BENEFIT

INCREASED WATER QUALITY AWARENESS IN VULNERABLE AREAS AND POPULATIONS Targeted sewer use education to residents of Windsor with the most impact on quality and quantity of sewage (i.e. combined sewer areas) should be encouraged to learn more about how sewers work, where they lead to (the waste water treatment plant and/or the Detroit River), and what not to throw down the drain. Highlighting the risk of basement flooding or contamination of the Detroit River brings this issue to a resident's local environment.

Understanding how these issues impact residents personally, such as basement flooding, ruptured pipes etc. may influence homeowners to use sewers properly.

CO-BENEFITS

COMPLIANCE WITH SOURCE WATER PROTECTION PLAN POLICY Under the Source Water Protection Plan Policy the City of Windsor will initiate and lead Education and Outreach activities when the Source Water Plan takes effect. The education and outreach will educate property owners within the sewershed areas of subject vulnerable areas where existing CSOs are significant threats, and where future stormwater management could be significant threats. The education and outreach is to promote downspout disconnection, use of rain barrels and rain gardens, and will provide information on what not to dispose of down the drain and the spills action centre in case of spills, and other such initiatives that assist in educating the property owners about combined sewer overflow, as well as stormwater management. The delivery of the education and outreach is targeted for completion in 2014 and will be continued as needed (ERCA, 2012).

IMPROVED WATER QUALITY As the City of Windsor continues to deliver targeted sewer use education, it is hoped that the behavioral patterns of residents will change to include the proper disposal of household wastes, organic material, oils and greases as well as any other contaminants. Proper disposal in a backyard composter, garbage, or the Hazardous Waste Depot will help to decrease the amount of contaminants reaching the waste water treatment plants and the Detroit River.

In addition, as more and more downspouts are disconnected and weeping tile issues resolved, water is diverted from waste water treatment facilities during a rain event. This decreases the frequency of combined sewer overflows, decreases the energy and costs required to treat water as well as decreases the strain on municipal infrastructure.

BEST PRACTICES

City of Toronto – Toronto has targeted specific areas or groups of people in order to increase the positive benefits of their campaign. For their mandatory downspout disconnection program, which is city wide and rolling out in stages, the City of Toronto produced both a widespread and a targeted campaign. Their widespread campaign included transit shelter advertisements, radio spots, digital boards and newspaper ads. These encouraged downspout disconnection but did not promote the "mandatory" component, as it is currently not mandatory for the whole city. For the target part of the campaign, to be repeated as more areas become mandatory, packages were delivered to homeowners stressing that the program is mandatory. Material was also made available at a number of public events in the affected areas. Inserts in water bills of affected residents were also used as an education tool (City of Toronto, 2012).

The City of Toronto is also concerned with cross connections. A cross connection is created when a household sanitary plumbing fixture is mistakenly connected to a storm drain, sending waste directly to a watercourse. Cross connections are responsible for polluting rivers with raw sewage and contributing to beach closings in the summer due to elevated E.coli (bacteria) levels. This problem can be created when homeowners renovate or install their own kitchens or bathrooms. In order to target this population, the City of Toronto ran advertisements in do-it-yourself magazines as well as ethnic newspapers.

Figure 1: *Targeted advertisement for homeowners.*

City of London – The City of London has undertaken targeted homeowner education, specifically in one area in London which has been susceptible to basement flooding in the past, largely due to weeping tiles sending stormwater to the sanitary sewer. To target this specific neighbourhood in London, dedicated letters were sent to residents describing the issues and the importance of downspout disconnections, sump pumps and backwater valves. A brochure on basement flooding was also provided, and information about an incentive program specific to their area. The incentive program provided 100% financial reimbursement for the installation of sump pumps, backwater valves, as well as disconnecting weeping tiles from the sanitary sewer. The incentive program produced interest from homeowners whose basements had flooded previously, however it is still challenging to involve homeowners who have not experienced basement flooding.

In addition, the City of London hosted two public open houses in the targeted area. These events helped increase resident interest and were deemed worthwhile events according to a City of London Wastewater and Drainage Engineer.

The Institute of Catastrophic Loss Reduction conducted a survey in the targeted London subdivision to gauge homeowner knowledge of basement flooding causes and sewer issues. Surveyors travelled door-to-door and mailed surveys to homeowners in the neighbourhood and received a 35% rate of return. This survey was a great way to gather information about homeowner knowledge and behaviour related to urban flood reduction and revealed many opportunities for both the City of London and insurers to increase homeowner knowledge and home-level action for urban flood reduction.

There were many interesting statistics found as a result of this survey. For example, one third of respondents did not know whether or not their home had a backwater valve. In addition, although the City of London had taken various measures to inform residents in the area of flood risk and city programs for flood risk reduction, many respondents reported that they had not read or received any City of London information on flooding and many respondents had not heard of the City's basement flood reduction subsidy program. Further, a considerable proportion of respondents who experienced sewer backup flooding and the majority of respondents who experienced clean water flooding did not report their flood experiences to the City.

Several respondents experienced flooding from sump pumps and open-ended responses indicated that residents were concerned about flood risks associated with sump pumps. If there is a similar perception in Windsor that sump systems lead to flooding, it may be difficult to encourage the use of sump systems as a means of flood reduction. Uptake of mitigative adjustments was relatively low, and very few respondents reported having installed sump pump systems or backwater valves on their own.

Though public meetings are an important part of effective public education and engagement, respondents preferred other means of information distribution, including handbooks and brochures mailed to homes and websites. A large proportion of respondents reported that they would like to receive information from City websites; however, only a small number of respondents had reported accessing the City's existing website.

More aggressive information distribution methods may be required to increase resident up-take of city information. While only a small proportion of residents reported having read City information about basement flooding, almost two thirds indicated that they would like to receive more information about basement flood reduction from the City.

An incremental approach to information distribution that takes advantage of strategic moments, including times when a flood event has made local news or when residents are purchasing new homes, may help increase uptake of City flood reduction education programs (Sandink, 2011).

CHALLENGES

LACK OF MEASURABLE RESULTS A lack of measurable results may be one reason why some municipalities have not invested time and resources into sewer use education initiatives, including targeted campaigns. It is very difficult to measure the success of an education program involving sewer use as any improvements to the system are hard to measure and may be based on a number of factors. This may be a barrier for Council and administration as they allocate funds towards pollution control programs.

INSUFFICIENT FUNDING Educating residents through targeted advertisement campaigns can become quite expensive. Targeted campaigns can be labour intensive if they involve door-to-door activity, individual mailings, or handouts in various languages.

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Use Social Media and Other Communication Tools to Warn Public

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Pollution Control ■ Operations ■ Communications ■ Building	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	■ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Communication is a critical tool for municipalities to engage their residents in local environmental issues. From education to updates and information, there has always been a constant flow of two-way communication between city residents and the City of Windsor. This is becoming more prevalent and accessible due to social media outlets such as Facebook, YouTube, Twitter and Flickr. These tools have changed the way municipal staff members communicate with residents. Individuals from generation Y (born from the 1980's to the 2000's) have come to expect this form of instant communication. However, recent research on the use of municipal social media is popular with all ages and demographics, the City of Windsor statistics are as follows: Ages 13 – 17, 1.9 %; Ages 18 – 24, 14.7 %; Ages 25 – 34, 15.4 %; Ages 35 – 44, 26.3 %; Ages 45 – 54, 19.4 %; Ages 55 – 64, 8.8 % and 65 +, 4.5%.

ISSUE

Social media use by Ontario's 444 municipalities has grown by more than 650% in the last two years (Redbrick Communications, 2012). The City of Windsor has joined this growing number in 2012, creating Facebook, YouTube, Flickr and Twitter accounts.

The most practical incentive for municipalities to invest in social media is the ability to transmit and disseminate information very quickly. It is therefore not surprising that fire departments and other emergency responders were among the first municipal service providers to embrace social media (Association of Municipalities of Ontario, 2011). For the same reason, the use of social media to communicate climate change related updates and information is very important. For example, as rainfall events become more intense, social media may be used as a tool to instantly inform many residents of the potential for basement flooding in certain areas of the city. In addition, social media may be used to issue Heat Alert and Smog Days.

Since the inception of the City's Facebook page in February 2012 there have been over 76,900 unique visitors and 536 "Likes" to the page.

BENEFIT

INSTANT COMMUNICATION By instantly informing residents of climate change impacts such as flooding and extreme heat, the City of Windsor will be able to update residents who are also using social media of the imposing threat and ask for assistance in order to adapt to the impact as soon as possible. This may include asking residents to stop flushing their toilets and reduce water use if there is an immediate threat of basement flooding. This will hopefully decrease the strain on our infrastructure as soon as possible, allowing the threat to be mitigated.

EASILY AUGMENTED BY 311 OR WEBSITE

The use of social media can be augmented by 311 or the website. As social media is meant to provide quick, short messages to the public, it may be necessary under certain circumstances for the public to be able to get additional information from sources such as 311 or the City's website.

BEST PRACTICES

As of April, 2012, 44% of Ontario municipalities are using social media (Redbrick Communications, 2012). It is difficult to determine if these municipalities are posting updates specifically related to climate change impacts, however, some examples can be found. The City of London has applied numerous measures to increase flood awareness, including social media sites Twitter and Facebook (Institute for Catastrophic Loss Reduction, 2011). As another example, the City of Guelph and the City of London both post Heat Alert information on their Facebook site.

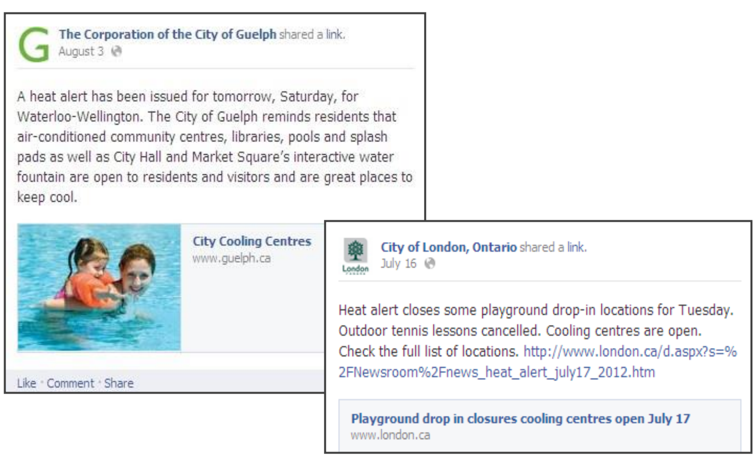

Figure 1: *Social Media examples from the City of Guelph and the City of London.*

Both city Facebook sites are thriving: Guelph's site is "liked" by nearly 3,000 residents, and London's site has 7,500 "likes".

It is in the best interest of the City of Windsor to inform as many residents as possible as quickly as possible about potential climate change impacts such as flooding and extreme heat. Considering the low cost and generally low time constraint required to post updates to social media, it is recommended that these type of updates be incorporated into our social media in order to adapt to climate change impacts as quickly and efficiently as possible.

CHALLENGES

Social media will never replace the need for other communication tools and sources. Many residents, especially senior citizens, are not likely to use social media websites to gather local information. For this reason, a well rounded approach to communication through mass media such as newspaper and radio is still necessary to reach as many residents as possible.

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Enhanced Maintenance and Inspection of Roads and Sidewalks during Snow or Extreme Weather Events

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations (Maintenance Division) ■ Risk Management	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Windsor's changing climate is expected to result in an increase in the frequency of severe storms, as well as an increase in the overall amount of precipitation. As a result, the severity and frequency of significant winter snow accumulation may increase. Increased frequency of freeze thaw cycles may also impair road conditions by initiating premature pavement deterioration, as well as increase the need for more frequent road salting (Natural Resources Canada, 2007).

Figure 1: *City of Windsor winter maintenance vehicles (OGRA, 2010)*

While Windsor is Canada's warmest city, it continues to receive an average of 44 cm of snow annually, which requires sophisticated winter maintenance operations in order to clear accumulation and improve traffic safety. Recently, the City of Windsor has improved the efficiency of its winter maintenance vehicles through incorporating the use of GPS devices. Large vehicles are equipped with one unit for vehicle locating and another for route guidance and salt spreading control. Data is continuously being gathered on the location of maintenance vehicles, their speed, how salt is being applied, and whether the plough is in use. This allows for greater efficiency and reduces over-salting while maintaining traffic safety. This system can also be used to assist in defending against damage claims by verifying the activities of winter maintenance operators against unwarranted accusations (Ontario Good Roads Association, 2010a).

Despite improvements from the GPS systems, the City's maintenance standards could be further improved. The City aims to maintain a balanced level of service in order to maintain efficiency within budgetary constraints. Costs of winter control maintenance totalled $3.27 million in 2011. The City's priority areas for road clearing include the E.C. Row Expressway, arterial and collector roads, Transit Windsor routes, and emergency routes. However, City maintenance standards require that secondary and residential roads only be cleared after 10 cm of snowfall. Furthermore, the City has limited resources to devote to sidewalk clearing. Sidewalks on and adjacent to City parks and facilities are given priority, while City by-law requires residential and commercial sidewalk areas to be cleared by adjacent property owners. Under *By-law 8544*, residents must clear their sidewalks within twelve hours, and commercial property owners must clear their sidewalks within four hours of snowfall (City of Windsor, 2012). In order to reduce the incidents of injury and the frequency and severity of claims made against the City of Windsor arising from snow and ice on sidewalks, it is recommended that the City devote more resources to winter maintenance for roads and sidewalks.

ISSUE

Municipalities are responsible for maintaining road and sidewalk conditions in a manner that maintains roadway safety. Snow and ice conditions directly impact public safety, transportation efficiency, the provision of City services, and have associated economic costs. In instances where roadway safety is not properly maintained, victims may seek compensation from municipalities for property damage or injury. Such cases may result in significant expenses being paid by the City to residents. As a result, it is important for the City to improve their winter maintenance operations in order to reduce the occurrence of an incident and their potential liability arising therefrom.

BENEFIT

The primary benefit of this adaptation action is to reduce the incidents of injury and liability arising from poor road and sidewalk inspection and maintenance practices. This will not only benefit the community, but will reduce the City's resulting legal expenses. Enhanced winter maintenance operations will also benefit the City by improving efficiency and reducing costs for winter control operations.

MUNICIPAL PRACTICES

The following programs represent other municipal practices in Ontario with respect to the winter maintenance of roads and sidewalks. These programs may be investigated to determine actions that may be taken to enhance the City of Windsor's program. However, based on case law, even these practices may not be sufficient to reduce liability.

City of London – Winter Maintenance Program

With a budget of approximately $11 million, the City of London's Winter Maintenance Program is extensive in order to manage the 220 cm of snow the region receives annually. Their equipment consists of approximately 24 sanders/salters, 62 ploughs, and 37 sidewalk units.

Over time, the City has adopted many different technologies and procedures to improve the effectiveness of their Winter Maintenance Program. For instance, the City developed a Salt Management Plan in 2001 in response to concerns about the environmental impacts of salt. This resulted in the innovative use of de-icing chemicals, which combine Geomelt (See Figure 2), a sugar-beet solution, with salt in order to reduce the total amount of salt applied to roads.

Figure 2: *Geomelt salt accelerator (Geomelt, 2012)*

In addition to the use of GPS systems in their winter maintenance vehicles, the City has installed five Road Weather Information System (RWIS) stations. RWIS stations use sensors below the pavement surface to predict icing conditions before they occur. This allows operators to take the appropriate actions in a timely manner to develop successful anti-icing responses.

The City of London has also continuously made significant investments in vehicle equipment and storage facilities. For example, in 2006 the City purchased nine high-efficiency spreaders which can be converted from summer to winter maintenance vehicles. These spreaders are equipped with GPS controls and infrared pavement thermometers, and effectively spread de-icing liquids, sand, and salt while completing ploughing. The City has also recently built salt storage buildings that minimize adverse environmental effects by better containing salt runoff (Ontario Good Roads Association, 2012b).

London's maintenance crews are responsible for clearing 3500 lane kilometres of road, as well as 1400 kilometres of sidewalk. Crews are responsible for clearing the roads and sidewalks designated within 62 different areas or "beats" (City of London, 2012). Clearing begins on primary and secondary roads after 5 cm of accumulation. Local street clearing does not begin until after 10 cm of accumulation, and the City requires these streets to be cleared within 24 hours. In order to maximize the efficiency of sidewalk ploughing, they are cleared after 8 cm of snow, and to snow-packed conditions (City of London, 2012).

City of Toronto –Winter Operations Program

Within the City of Toronto, 24-hour patrols check road conditions while staff members monitor pavement temperatures and weather forecasts. Similar to London, the City has four Road Weather Information System units to provide information on air and pavement temperatures. This data is used by staff in order to inform the initiation of salt spreading procedures. Monitoring of environmental conditions also occurs by the City's Water and Wastewater Division. A chloride monitoring program exists in order to determine the salt content in watercourses to avoid adverse environmental effects.

Prior to snowfall accumulation, the City sends out anti-icing trucks to apply brine (salt and water) mixture to hills and bridges before snowfall occurs, ensuring that safety is maintained in these high risk areas. The City of Toronto begins ploughing expressways after 2.5 cm of snow has fallen, and main roads after 5 cm. Main roads consist of those serviced by the TTC and emergency vehicles. Side street clearance begins after 8 cm, and the City aims to complete this service within 14-16 hours after the initial snowfall. In order to maximize the efficiency of road clearing while maintaining safety, the City also prioritizes winter service standards. For instance, expressways, arterial, and collector roads are cleared to bare pavement conditions. However, local roads and laneways only have to exhibit "safe and passable pavement" conditions (City of Toronto, 2004).

Sidewalk clearing begins after 8 cm of snow has fallen. The City aims to provide a residential sidewalk clearing service in areas where it is feasible. However, this service is not provided in some parts of the City, including the downtown core. In these areas, residents are responsible for clearing their sidewalks within twelve hours. However, seniors and/or disabled individuals are eligible to submit an application for City clearing services where necessary (City of Toronto, 2012).

City of Vaughan – Ploughing and Snow Removal The City of Vaughan's ploughing and road salting operations differ from Windsor's as they commence after periods of lighter snowfall. In Vaughan, road clearing operations commence after snow accumulation reaches 5 cm. However, primary roads are cleared prior to secondary roads. It is the goal of the City to complete primary road clearing and salting within four hours after a snow event, and secondary road clearing and salting within twelve hours.

The City clears primary sidewalks within eight hours, which include those along streets serviced by York Region Transit, as well as sidewalks adjacent to schools and places of worship. All other municipally owned sidewalks (secondary), including those in municipal parks are cleared after the primary sidewalks. Similarly to Windsor, a bylaw is in place requiring residents to clear the sidewalks in front of their properties. However, in periods of heavy snow the City will assist residents in clearing the snow from public sidewalks.

Similarly to Windsor, Vaughan utilizes GPS devices to control their winter maintenance operations. However, the City of Vaughan publishes a publically viewable live map on their website that residents can consult in order to determine which streets have received service (City of Vaughan, 2012).

York Region – De-Icing Strategies York region has adopted a number of de-icing strategies in order to improve winter maintenance in response to increasing climate variability. One strategy that it has adopted is the use of pre-treated rock salt. This salt is coated with the Geomelt solution in order to melt ice at colder temperatures and to reduce the quantity of salt used by 10%.

York Region has also implemented the use of four Road Weather Information Systems into their road maintenance operations. Their systems monitor the sub-surface temperature, ground temperature, salt concentrations, wind speed, and precipitation levels. The use of RWIS stations allows York Region to collect real time data to help staff understand, forecast, respond, and adapt their strategies to winter storm threats.

Like many other municipalities, York Region has also equipped their vehicles with GPS technology to obtain information on location and salt application rates.

CHALLENGES

COST The costs of road and sidewalk maintenance for a single winter storm event in Windsor currently total approximately $300,000 (City of Windsor, 2012). As improvements are made, it is inevitable that these costs will increase. Therefore, in order to ensure that improvements take place, the City will need to increase the operating budget for winter control activities. Additionally, the City of Windsor should continue to seek out innovative methods of road and sidewalk inspection and maintenance as well as methods of documenting these efforts, that maximize the efficiency of time and resource use in order to reduce operational and legal costs.

RESEARCH AND DEVELOPMENT Research undertaken by The Ontario Ministry of Transportation (MTO) has been crucial in the past to the development and pilot testing of new winter control technologies such as the RWIS stations and Geomelt. However, in recent history the MTO's role in research and development has become more subdued. This places an increasing responsibility on municipalities to undertake their own testing and pilot projects to enhance their winter maintenance programs.

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Development of a Green Roof Policy

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations ■ Forestry & Horticulture ■ Facilities ■ Planning	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ■ Private

CONTEXT

The impacts of climate change in Windsor are expected to result in increased precipitation, as well as extreme rainfall and heat events. This makes it imperative to utilize infrastructure such as green roofs to manage stormwater and the urban heat island effect (UHIE). Green roofs are contained vegetation areas situated on built structures. They consist of many components including: plants, a growing medium, drainage system, root barrier, insulation, waterproof membrane, and structural support (*Figure 1*). Green roofs are categorized as either intensive or extensive. Intensive green roofs have significant maintenance and cost requirements. They are generally planted with a wide variety of species including trees, shrubs, grasses, herbs, and mosses. Conversely, extensive roofs require less maintenance, and are limited to shallow depth plant species (Getter & Rowe, 2006).

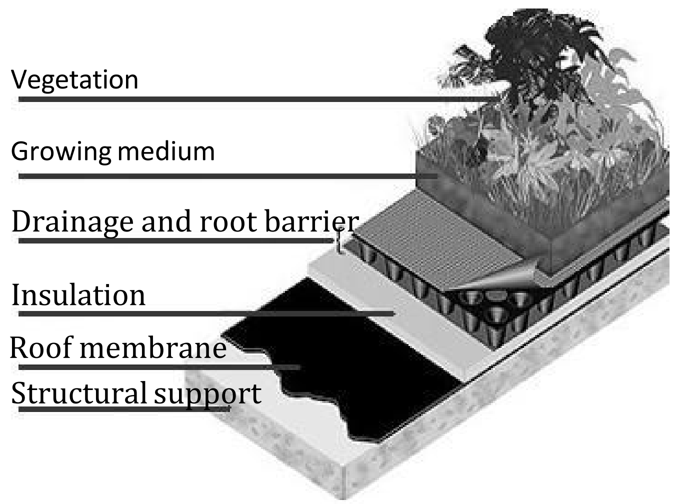

Figure 1: *Green roof structure (City of Toronto, 2006)*

Within Windsor, there are currently a number of private green roof developments situated on the Art Gallery of Windsor, Dr. David Suzuki Public School, St. Christopher Catholic School, the Glengarda Child and Family Services building, as well as the Faculty of Law and Engineering buildings at the University of Windsor. The City of Windsor has recently installed green roofs on the Ojibway Nature Centre, the Lou Romano Water Reclamation Plant, the WFCU Centre, the Bistro Restaurant and the new festival stage. Support for green roofs has been expressed in the Environmental Master Plan, which outlines a goal to install green roofs on five City facilities by 2011. The construction of green roofs is also recommended explicitly to achieve the objective of incorporating sustainable development practices in the design of neighbourhoods, homes, and businesses. One action plan suggests for the creation of a sustainable development guide, citing green roofs as a potential design feature. Additionally, green roofs are mentioned in order to complete the objective of reducing energy use by City operations by 15%, and will also help to attain the goal of preventing combined sewer overflows (CSO). To fulfill these objectives, it is recommended that the City of Windsor develops a green roof policy.

ISSUE

Urban areas consist predominantly of hard, nonporous surfaces which lead to significant runoff that periodically overburdens municipal stormwater management operations. Within these urban environments, approximately 50% of impervious surfaces are roofs (Oberndorfer *et al.,* 2007). Issues associated with urban runoff include: CSO into surface water bodies, the transport of pollutants, erosion, sedimentation, and flooding. The completion of the Lou Romano Water Reclamation expansion and construction of the Retention Treatment Basin will address some of these issues. However, CSOs and frequent flooding of basements, property, and roads remain ongoing issues. The development of a green roof policy is an important stormwater management strategy that will help to reduce these issues, and provide a number of additional co-benefits.

BENEFIT

The primary benefit of installing green roofs is to improve stormwater management by reducing the aforementioned risks associated with urban runoff. Precipitation is held within plant foliage, absorbed by roots, and stored in the drainage layer. This helps to reduce the rate of runoff, which minimizes the amount of water entering the sewer system during intense rainfall, decreasing the risk of CSO events. It is estimated that green roofs can delay stormwater runoff by 1.5-4 hours (Getter & Rowe, 2006).

Water is also used by plants and returned to the atmosphere via evapotranspiration, helping to reduce the volume of runoff overall. Studies have shown that green roofs can reduce building runoff by 60-79% depending on the intensiveness of the green roof. The reduction will vary depending on the plant species, root depth, membrane selection, roof slope, and rainfall intensity. In addition to decreasing the quantity of stormwater runoff, research has also demonstrated that green roofs have the ability to improve the quality of stormwater by selecting species that remove contaminants such as heavy metals and nutrients (Oberndorfer *et al.,* 2007).

CO-BENEFITS

REDUCED URBAN HEAT ISLAND EFFECT (UHIE)

The incorporation of green roofs into building design helps to reduce the UHIE by increasing albedo and evapotranspiration. Vegetation has a higher albedo than traditional roofing materials such as asphalt shingles, tiling, concrete, gravel, and corrugated roofing. As a result, vegetation helps to reflect a larger proportion of solar radiation, minimizing air temperatures. Additionally, plants initiate cooling by releasing water vapour into the atmosphere through evapotranspiration. A study examining the benefits of green roofs in Toronto found that if green roofs were installed on 50% of the roof surfaces in downtown Toronto, temperatures would be reduced by 0.1-0.8°C (Forkes, 2010).

AIR QUALITY Vegetation helps to improve air quality through the absorption of gaseous pollutants in stomata, and the interception of particulates by leaves. Through these processes pollutants such as NO_x, SO_2, O_3, CO, and particulates can be removed from the atmosphere, helping to improve regional air quality (Getter & Rowe, 2006).

ENERGY EFFICIENCY Green roofs help to improve the energy efficiency of buildings by dissipating solar radiation and by providing shading. These processes result in interior cooling, decreasing the need for air conditioning. Furthermore, vegetation helps to reduce heat transfer by improving insulation, minimizing energy demand (Oberndorfer *et al.,* 2007).

BEST PRACTICES

Municipalities in Canada and the United States have begun developing programs and policies that support the construction of green roofs in order to realize the aforementioned benefits. These initiatives include: green roof bylaws, tax abatements, credits, voluntary incentives, stormwater management guidelines, planning guidelines, and demonstration projects.

City of Toronto – Green Roof Bylaw The City of Toronto currently has approximately 36,517 m^2 of green roofs, due largely to their progressive green roof policies. Toronto's Green Roof Bylaw evolved from the creation of the Green Roof Strategy, which won the Federation of Canadian Municipalities' FCM-CH2MHill Sustainable Community Award for sustainable community development. This Strategy aimed to improve stormwater management, mitigate the UHIE, increase the energy efficiency of buildings, improve air quality, and increase green space (City of Toronto, 2006).

While the Green Roof Strategy encouraged green roof development, this was translated into a requirement through the creation of the Green Roof Bylaw under Section 108 of the City of Toronto Act. The Bylaw requires new institutional, commercial, and residential developments with a gross floor area greater than 2000m^2 to include green roofs. The exact requirements concerning green roof area vary depending on the size of the building, but range from 20-60%. With respect to industrial buildings, developers must build green roofs covering the lesser option of 10% roof space or 2000m^2. Detailed requirements regarding the construction and maintenance of green roofs can be found within the Toronto Green Roof Construction Standards (City of Toronto, 2009).

Financial assistance for building green roofs is provided by Livegreen Toronto's Eco-Roof Incentive Program. Green roof projects are eligible for funding of $50/$m^2$ to a maximum of $100,000. This funding is provided for existing buildings of any size, new buildings with a gross floor area less than 2000m^2, and new School Board buildings. To be eligible for funding green roofs must be designed to have vegetation coverage on 50% of a building's ground floor area, and fulfill the requirements of the Toronto Green Roof Construction Standards. Since 2009, the program has administered approximately $640,000 for green roof projects.

Figure 2: *Metro Central YMCA Green Roof in Toronto, ON*

City of Port Coquitlam – Green Roof Zoning Bylaw The City of Port Coquitlam was the first municipality in Canada to adopt a green roof policy. The Green Roof Zoning Bylaw mandates green roof installation on all developments of industrial and commercial buildings which are larger than 5000 m^2. The Bylaw was designed as a method to reduce stormwater runoff, to improve the thermal performance and reduce energy consumption in buildings, and to mitigate the UHIE (City of Port Coquitlam, 2006).

Milwaukee Metropolitan Sewerage District (MMSD) – Rooftops to Rivers
The MMSD incorporated the use of green infrastructure into their combined sewer overflow reduction strategy. As a result, capital funds are allocated to support projects aiming to build green roofs. The MMSD along with the Housing Authority of the City of Milwaukee has installed 5.6 acres of green roofs as of May 2011. MMSD also facilitates community workshops about the benefits of green roofs, funds pilot projects, and provides a matching-fund program that allocated $5 million in 2010-11 to support green roof development (Natural Resources Defense Council, 2011).

City of Chicago – Adding Green to Urban Design This plan presents a vision and implementation plan for sustainable urban design within Chicago. The document was designed to guide decision-making on the part of City Council and the Chicago Plan Commission regarding investment in development projects. The plan focuses on outdoor areas that are exposed to the environment including: landscaping, parking lots, sidewalks, parks, streets, building facades, and rooftops. It seeks to encourage design that optimizes water conservation, improves air quality, preserves green space, and improves quality of life. The plan outlines twenty-one action plans and includes information on related policies that exist to facilitate their implementation.

Figure 3: *Schwab Rehabilitation Hospital Green Roof in Chicago, IL*

One key concern of city officials is combined sewer overflows which can result in basement flooding, street flooding, and the release of untreated sewage into the Chicago River. The plan encourages the construction of green roofs as a solution to reduce the volume of stormwater runoff. It is also presented as a solution to mitigate the UHIE, as well as to improve the quantity of vegetated surfaces in the city. As an incentive for building green roofs, developers qualify for a floor area bonus that is calculated based on the size of the roof area. Also, the Green Roof Grant Program was initiated to provide grants up to $5000 for residential and commercial green roof developments. Thus far, the program has administered grants for 32 projects (City of Chicago, 2008).

City of Minneapolis – Stormwater Quantity Credit This credit is designed to encourage property owners to take part in stormwater management by reducing the quantity of stormwater that enters the sewer system. Currently, property owners are administered monthly stormwater utility charges. However, if any of the stormwater best management practices are implemented, which includes green roofs, property owners are eligible for a credit. If the green roof can handle a 10-year rain event, a 50% credit is administered, and if the roof can handle a 100-year rain event a 100% credit is administered (City of Minneapolis, 2011).

State of New York – Green Roof Property Tax Abatement Program This program provides building owners in New York State with a one-year tax abatement of $4.50 per square foot of green roof. A maximum abatement of $100,000 or the buildings tax liability can be provided, whichever value is less. Only cities with a population greater than 1,000,000 are eligible for the credit.

To ensure that the green roofs meet acceptable requirements for quality and maintenance, a number of compulsory elements must be met in order to receive the abatement. These requirements mandate that a minimum of 50% of the roof area must be covered with a green roof, 80% of the vegetation layer must be covered with plants, and a minimum of 2" of growing media must be present. Additionally, the design must include a waterproof membrane, a root barrier layer, an insulation layer, a drainage layer, and a growth medium. Finally, a maintenance plan must be included that requires: semi-annual inspection, plant replacement plans, monthly drainage inspections, and maintenance of the roof for a minimum of four years after the abatement is administered (City of New York, 2010).

City of Portland – Ecoroof Program This program was developed to expand stormwater management infrastructure in Portland, and to improve the health of the watershed. The City set a target to construct 43 acres of ecoroofs by 2013. It is also required that all new City-owned buildings incorporate an ecoroof that covers a minimum of 70% of the roof surface (Blackmer, 2005).

To facilitate this program, the City of Portland offers incentives and bonuses to encourage ecoroof development. The Ecoroof Incentive provides owners and developers with up to $5 per square foot of ecoroof. The total funding that is provided is based on an evaluation of the cost, size, ratio of ecoroof to total roof area, visibility, and innovation of the incentive application. An Ecoroof Floor Area Ratio (FAR) Bonus also provides developers with an incentive if they incorporate ecoroofs into their design. In addition, the City aids building owners in developing ecoroofs by providing technical assistance, resources, and conducting ecoroof tours to aid in ecoroof design.

CHALLENGES

COST In comparison to traditional roofs, green roofs have higher costs associated with their design, installation, and maintenance. While these high costs may dissuade building owners, it is important to note that the lifespan of green roofs exceeds traditional roofs, and there are financial returns in the long-term due to increased energy efficiency. Ecosystem services such as stormwater management also have financial values associated with them (Getter & Rowe, 2006).

KNOWLEDGE GAPS Building owners, developers, and municipal employees may lack knowledge regarding the benefits of green roofs, resulting in apprehension towards their construction. Quantifiable data on green roofs is also minimal, making it difficult to convey their importance to stakeholders in a cost-benefit analysis framework. However, demonstration projects and resources provided by non-governmental organizations such as Toronto-based Green Roofs for Healthy Cities may aid officials in understanding the value of green roofs (Getter & Rowe, 2006).

MAINTENANCE Upon initial construction and planting, green roofs must be adequately maintained to ensure that they are functional in the long-term. As a result, most green roof policies require submittal of detailed maintenance plans prior to their approval. It is also crucial to allocate appropriate funding and personnel to perform maintenance requirements due to changing environmental conditions that may impair plant growth. These conditions include: precipitation, intense sun and wind, urban air pollution, temperature, and invasive species proliferation (Currie & Bass, 2010).

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Develop Pilot Projects for the use of Porous Pavement on City Properties and Develop Guidelines for their use in Development

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Engineering ■ Planning ■ Pollution Control	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ■ Provincial ☐ Federal ☐ Private

CONTEXT

Within the City of Windsor, climate change is expected to result in increased precipitation as well as the increased frequency of extreme weather. Due to these potential trends, the City's stormwater management approaches and infrastructure may not be sufficient to handle significantly greater quantities of stormwater. The City's current approach to stormwater management utilizes grey infrastructure. When using a grey infrastructure approach, stormwater is transported quickly and directly along hard surfaces into a municipality's storm sewer system. Furthermore, stormwater issues are typically addressed through hard infrastructure improvement projects such as sewer upgrades, or downspout disconnection programs. However, by utilizing green infrastructure techniques such as porous pavement, cities can address issues related to stormwater quantity and quality.

Porous (permeable, pervious) pavement contains void spaces that allow precipitation and stormwater runoff to infiltrate, become stored within subsurface layers, and exfiltrated beneath the earth's surface (Scholz & Grabowiecki, 2007). A variety of material options exist to construct permeable pavement surfaces including: porous asphalt, porous concrete, concrete interlocking grid pavers, and turf pavers. The use of porous pavement reduces rates of stormwater runoff and improves runoff quality, helping to alleviate stress on stormwater management systems (City of Calgary, 2007). To achieve these benefits, it is recommended that the City of Windsor undertakes porous pavement demonstration projects, and develops construction guidelines for the use of porous pavement.

ISSUE

Urban development in cities creates increased runoff rates through the replacement of natural landscapes with hard, impervious surfaces. This leads to stormwater issues such as: increased rates of runoff, increased peak flow of stormwater, higher pollutant concentrations, combined sewer overflows (CSOs), and flooding (LaPaix & Freedman, 2010).

By utilizing porous pavement, these issues will be addressed by capitalizing on opportunities to capture, store, and treat stormwater using green infrastructure. Permeable pavement allows for the infiltration of water that is collected, filtered, and transferred to the groundwater system. Through facilitating runoff infiltration, permeable pavements may help to reduce localized flooding, to recharge groundwater, to filter pollutants and debris, and to reduce the volume and costs of treating stormwater.

BENEFIT

This adaptation action will most significantly improve stormwater management by reducing the quantity of runoff entering wastewater treatment plants. The use of porous pavement helps to reduce runoff rates by facilitating infiltration of stormwater below the pavement surface, and temporarily storing it in the subsurface layers. This reduces both the total volume and rate of runoff flow to wastewater treatment plants. Therefore, the risk of flooding, CSOs, and pollutant washout into nearby sewers and water bodies becomes decreased. This also helps to lessen the demand on Pollution Control facilities by reducing peak flow and the costs of treating stormwater (Ordonez & Duinker, 2012).

CO-BENEFITS

IMPROVED STORMWATER QUALITY Infiltration of stormwater through pavement also results in improved water quality. Improved stormwater quality occurs through the removal of pollutants of concern such as suspended solids, dissolved solids, nutrients, hydrocarbons, and heavy metals (Frazer, 2005).

A study completed by the City of Calgary found that the concentration of suspended solids in runoff from impervious pavement ranged between 30-300 mg/L, while their concentration in runoff from pervious surfaces ranged from 0-50 mg/L. Reductions in runoff pollutant concentrations result due to the presence of lower runoff volumes, as well as from the physical removal of contaminants within the structure of permeable pavement. Processes that result in pollutant removal include: runoff filtration, entrapment, sedimentation, and biodegradation as stormwater travels between the subsurface layers (City of Calgary, 2007).

BEST PRACTICES

The following initiatives are representative of best practices for undertaking porous pavement demonstration projects as well as for the development of municipal guidelines.

City of Chicago – Green Alley Project
The Green Alley Project was initiated in order to alleviate stormwater management challenges in Chicago. In the past, Chicago's extensive alley network has often experienced flooding due to poor grading and a lack of permeability. As an alternative to building expensive connections to Chicago's sewers, the utilization of permeable pavement was proposed. Originally beginning as a pilot project in 2006, the Green Alley Project has since evolved and resulted in the construction of approximately 200 permeable pavement alleys. The project sees that alleyways are retrofitted using permeable pavement as their scheduled maintenance is needed, rather than using traditional paving materials. The Green Alley Project also recognizes and encourages the adoption of other sustainable techniques such as using light-coloured materials to increase albedo, using recycled concrete, and planting rain gardens alongside alleyways (Daley & Bryne, 2010).

Figure 1: *Stormwater runoff before (above) and after (below) porous pavement alley construction (Daley & Bryne, 2010)*

City of Portland – Pervious Pavement Projects

The City of Portland has conducted various types of pervious pavement projects across the city and for surfaces experiencing various levels of vehicular traffic. Some of these projects received partial funding from the U.S. Environmental Protection Agency (EPA) who administered grants from 2002-2003 to support alternative stormwater management projects.

The first project undertaken in Portland was the Westmoreland Permeable Pavement Project, which evolved based on recommendations from a report on alternative paving materials that was submitted to council by the Sustainable Infrastructure Committee. This pilot project tested various types of permeable paving materials along three blocks of streets in order to evaluate cost and performance. This is unique, as the majority of permeable pavements projects have been completed for lower intensity surfaces such as parking lots, driveways, and alleys. The approaches tested included a roadway with permeable concrete blocks, and a combination of standard asphalt in the center lanes and permeable pavement in the curb lanes.

Another pilot test called the North Gay Avenue Project resulted in the City paving four blocks using different paving strategies. These strategies include: porous concrete curb-to-curb, a combination of standard and porous concrete, porous asphalt curb-to-curb, and a combination of standard and porous asphalt. The project found that using porous pavement reduced the frequency of CSOs, reduced basement flooding, and increased groundwater recharge rates (City of Portland, 2012).

The City of Portland also completed a demonstration project for a 5225 ft^2 parking lot at East Holladay Park. The cost of completing the project was approximately \$10.00/ft^2 in comparison to conventional asphalt which typically costs \$3.50-4.00/ft^2. The project resulted in complete onsite stormwater treatment and runoff infiltration. This was achieved by covering 100% of the surface with permeable pavers, and by landscaping areas adjacent to the parking lot to capture runoff (City of Portland, 2007).

Figure 2: Before (above) and after (below) East Holladay Park porous parking lot construction (City of Portland, 2007)

Ravinia Festival Parking Lot – Highland Park, IL The Ravinia Festival South Parking Lot was rebuilt using permeable pavement in order to reduce severe surface flooding issues which had occurred approximately 25 days per year. The owners of the parking lot had previously received numerous complaints regarding the inability to access the parking lot, as well as flooding in nearby yards, basements, and homes.

The frequency of such complaints was reduced to 0% upon completion of the project.

This project illustrates best practices for permeable pavement construction in areas with soils that have high clay contents. In most cases, the use of permeable pavement in areas with clay soils is discouraged. This is because soils with high clay content exhibit very low infiltration rates, minimizing the quantity and rate at which water can be absorbed into the ground. However, the builders of this project overcame this issue by constructing underground water detention areas beneath the permeable concrete block pavers. Up to 249,000 gallons of water can be stored in the detention area, and are then released slowly into the municipal storm sewer system (Landscape Architecture Foundation, 2011).

Ontario Ministry of Transportation – Pervious Concrete Pavement Standards

In 2009, the MTO publication *Road Talk,* reported positively on their first pervious concrete pavement project at a GO Transit commuter parking lot in Guelph, ON. In addition to the Guelph parking lot, two additional commuter lots have been paved with pervious concrete in Brampton and Barrie. In collaboration with the University of Waterloo and the University of Guelph, these lots were monitored to compare the rainfall quality to stormwater quality after filtration through the pavement.

As a result of these pilot projects, MTO developed the *Ontario Provincial Standard Specification* for pervious concrete construction. It is their hope that this specification will spur increases in the application of this technology across municipalities in Ontario. MTO recognizes that the use of pervious concrete has many environmental benefits such as: reducing runoff, minimizing the risk of flooding, increasing groundwater infiltration, and reducing the heat island effect (Ministry of Transportation, 2012).

Credit Valley Conservation Authority (CVC) – Elm Drive Green Street Pilot Project

Elm Drive is located within the Cooksville Creek Watershed in Mississauga, ON. Due to significant development in the area, a number of issues have arisen with respect to stormwater management. The region has experienced flooding and erosion due to high stormwater runoff rates. This has led to infrastructure problems such as bridge collapse in the area. Concerns were also raised about the contamination of Cooksville Creek which intercepts water directly from storm sewers that contains pollutants.

To mitigate these issues, a Green Street Pilot Project was proposed to enhance the ability to manage stormwater using green infrastructure. This project was aided by a $1 million dollar grant provided by the Provincial government to the CVC. The two techniques used in the project include permeable pavement lay-bys that were installed adjacent to bioretention planters to replace the traditional concrete sidewalks, and permeable parking lanes (Credit Valley Conservation Authority, 2010).

Figure 3: *Elm Drive Green Street Pilot Project (Credit Valley Conservation Authority, 2010)*

City of Calgary – Porous Pavement Demonstration Projects and Development Guidelines Increasing rates of urbanization in communities such as Calgary increase the flow, rate, volume, and amount of contamination in stormwater. Cities can mitigate these issues by fostering the development of demonstration projects that test sustainable and low impact technologies such as porous pavement (City of Calgary, 2009). The City has shown a commitment to developing these technical tools through projects such as the Water Centre, Currie Barracks, and Aurora Business Park's porous pavement parking lots.

Support for these projects was largely generated due to the City's creation of the Stormwater Source Control Practices Handbook in 2007. These practices are designed to encourage environmental stewardship with respect to stormwater management. Recommended practices include the development of: vegetated swales, absorbent landscapes, bioretention areas, rainwater harvesting, green roofs, and permeable pavement surfaces. The handbook serves as an aid for those designing and constructing permeable pavement systems by detailing the necessary technical specifics, design approaches, and construction guidelines (City of Calgary, 2007).

CHALLENGES

DURABILITY In comparison to impermeable pavement, porous pavements lacks durability as the void spaces may deteriorate due to air infiltration, oxidation, stripping, and shear stress. Concerns about the durability and longevity of porous pavement have rendered it suitable for only surfaces that receive light and infrequent usage. As a result, the use of porous pavement is commonly reserved for the following areas: driveways, road shoulders, parking lots, golf course paths, pedestrian paths, and bicycle trails (Scholz & Grabowiecki, 2007).

Clogging in older permeable pavements is often due to the presence of sand, either in the bedding layer or applied on the surface to improve wheel traction during the winter. Newer installations of permeable pavement use washed stone in the pavement openings and bedding layer because these resist breakdown into smaller particles with age, and the pore spaces are large enough to transmit fine particulate matter deeper into the coarser base layers, thereby reducing the potential for surface sealing. At a minimum, the base should be free of sand or other fine particles, and surfaces must be well protected from sediment transport during construction (University of Guelph, 2007).

MAINTENANCE The presence of void space may also lead to clogging of porous pavement, reducing the potential for water infiltration. This may result as sediments become trapped in the pores or as shear stress from vehicle weight causes the pores to collapse. If the void spaces become completely clogged, the pavement area would require complete replacement. To avoid this potentially costly issue, it is therefore necessary to develop maintenance regimes for street sweeping and pressure washing to clear debris from the void spaces (City of Calgary, 2007). The aim of maintenance, generally vacuum assisted sweeping and power washing, is to remove smaller particles that have accumulated in the surface voids (University of Guelph, 2012).

The University of Guelph tested various maintenance measures on seven permeable pavement parking lots. Infiltration rates were observed to increase after vacuuming and pressure washing treatments. Preliminary observations suggest that the most effective surface treatment is a two-part practice: dislodging compacted sediment followed by the permanent removal of sediment (University of Guelph, 2007).

SITE APPLICABILITY The ability to successfully use permeable pavement is dependent on characteristics such as climate and soil conditions. Within Windsor, the cold winter climate and high clay content of soils may pose some challenges with respect to the development of porous pavement projects. Conflicting reports exist regarding the impact that freeze-thaw cycles can have on the lifespan of porous pavements. Therefore, it is important for pilot projects to be carried out in order to better understand how porous pavement will function in local climatic conditions.

Typically, permeable pavement systems are not suitable for sites with soils that have a clay content >30%. However, as noted for the Ravinia Festival parking lot construction case study, structural modifications may be made in order to facilitate water infiltration and exfiltration. In situations where the clay content of soil is high, cost-benefit analysis should be carried out in order to assess if the additional construction modifications result in substantial stormwater management benefits (City of Calgary, 2007).

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Installation of Rain Gardens as a Pilot Project to Determine Effectiveness

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations ■ Parks and Facilities ■ Planning ■ Engineering	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ■ Private

CONTEXT

Stormwater runoff from roofs, driveways and other hard surfaces is typically directed towards the street and into the municipal storm sewer system. This stormwater runoff, which has picked up harmful substances such as road salt, heavy metals and oils, ends up in the Detroit River and subsequently Lake Erie, where it can harm water quality and aquatic habitat. Meanwhile, water used for lawns and gardens is drawn from the local drinking water supply.

One way to reduce runoff and better use stormwater while ensuring proper drainage is to install rain gardens, also called bioretention areas, throughout the City of Windsor. A rain garden is a bioretention garden that is built in a shallow depression and provides a simple yet effective method for controlling stormwater runoff. Strategically placed, rain gardens intercept and collect water from paved surfaces and allow it to infiltrate the soil rather than to run into storm sewers and then to the Detroit River. Rain gardens are built using a variety of soil types and vary in their size, and are commonly located adjacent to parking lots, sidewalks or road medians (Green Venture, 2012). Rain gardens can be used in various climates. For example, the same rain garden adjacent to a parking lot can be used to retain and filter rainfall runoff during warmer seasons and also to store snow during colder seasons (Ecojustice, 2008).

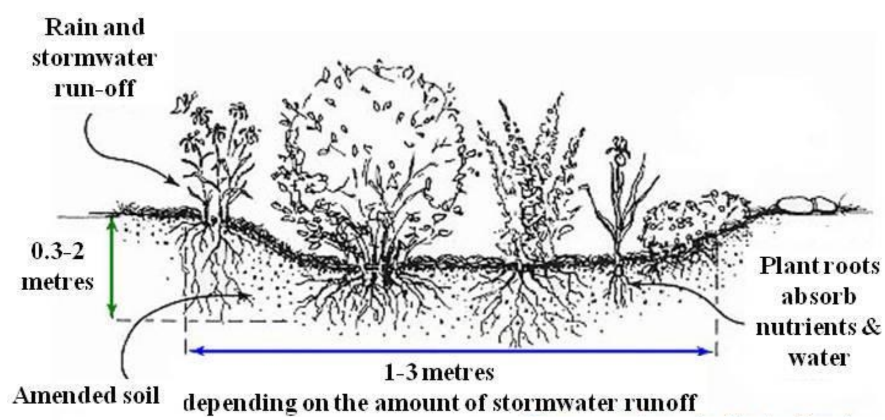

Figure 1: *Cross-section of a Rain Garden*

ISSUE

Traditional “grey” infrastructure aims to remove stormwater where it lands and transport it at high speeds and volumes to the nearest water body as soon as possible. This creates problems such as the transportation of pollutants, erosion and sedimentation. As demonstrated in the body of this plan, Windsor has seen an increase in intense rainfall events in recent years. This has lead to many combined sewer overflows, where wastewater treatment plants are unable to handle such a large volume of water, and subsequently, partially treated sewage is overflowed into the Detroit River. Instead of treating stormwater as something harmful that needs to be removed from city surfaces, we can begin to use green infrastructure to keep rainwater where it lands. This prevents it from becoming toxic stormwater entering our river and puts less strain on our grey infrastructure and waste water treatment facilities.

Managing stormwater runoff through traditional grey infrastructure costs Canadian taxpayers billions of dollars each year. For example, the City of Toronto estimates that over the next 25 years it will spend $1 billion on capital costs and $233 million on operating costs ($42 million per year) for the management of stormwater and waste water systems (Belanger, 2008). Grey infrastructure has to be continually maintained and improved upon as it breaks down over time. Using green infrastructure such as rain gardens is a way to limit the strain on traditional infrastructure and reduce contaminated stormwater from eroding soil and polluting waterways. In many cases, rain gardens are cost effective and generally maintenance free after two years (Green Infrastructure Ontario, 2011).

In addition to controlling stormwater runoff, rain gardens are often cost effective when incorporated into large re-development projects and major infrastructure improvements, and in addition will save the city money over the long term. A 2007 U.S Environmental Protection Agency study found that green infrastructure saved money for developers, property owners and communities, while also protecting and restoring water quality (US EPA, 2011). An analysis conducted by the City of Vancouver indicates that retrofitting green infrastructure into locations with existing conventional stormwater controls will cost only marginally more than rehabilitating the conventional system, but introducing green infrastructure into new developments will cost less (Natural Resources Defense Council, 2006). While green infrastructure may be more costly than conventional stormwater or CSO controls in certain instances, the added costs should be weighed against the enhanced stormwater control and other environmental benefits gained from their use.

BENEFIT

WATER QUALITY AND QUANTITY Through increasing capital for rain gardens in the City of Windsor, the primary benefit is to minimize the volume of contaminated stormwater entering our regional water bodies.

This will occur as rain gardens filter and act as a temporary reservoir for rain water falling in the City of Windsor. Rain water will be treated as the resource it is instead of turning it into contaminated stormwater as it travels over impermeable surfaces on its way to the Detroit River.

CO-BENEFITS

URBAN HEAT ISLAND EFFECT The construction of rain gardens throughout Windsor will provide much needed green space in our urban areas. Rain garden vegetation helps reduce the UHIE through evaporative cooling. Additionally, rain gardens will provide cooling by replacing current asphalt and concrete surfaces with natural vegetation able to decrease the amount of heat emitted from paved surfaces, creating more comfortable microclimates.

NATURALIZED HABITAT AND BIODIVERSITY Rain gardens are generally constructed using native plants as they are best suited to thrive in our local environment. This is a direct investment in biodiversity, a declared priority of both the provincial and national governments (Green Infrastructure Coalition, 2011). Natural areas cover in Windsor-Essex County has been calculated at 8.5% in 2012 by the Essex Region Conservation Authority. Promoting and encouraging investment in naturalized habitat is done by ERCA to protect the most biologically significant parts of our region, and to increase natural areas cover to 12% of the landscape (ERCA, 2012).

IMPROVED AESTHETICS AND PROPERTY VALUES Green space on or near buildings directly contributes to property values, thereby increasing local taxes. Numerous studies indicate that property value increases anywhere from 5 to 30 per cent depending on the size and type of green space, the type of housing and the distance from the green space (Tomalty and Komorowski, 2010). For example, the City of Windsor along with the Essex Region Conservation Authority have made great improvements to the waterfront to promote the use of green space and habitat restoration. The same goals can be achieved using rain gardens on municipal property.

BEST PRACTICES

There are many resources available to homeowners wanting to install a rain garden on their own property. The Canada Mortgage and Housing Corporation (www.cmhc-schl.gc.ca) provides detailed, step-by-step instructions on how to build a rain garden.

There are many resources in Windsor-Essex County for selecting and learning about native plants to grow in your rain garden. The Naturalized Habitat Network of Essex County & Windsor (www.naturalizedhabitat.org), the Essex Region Conservation Authority (www.erca.org) and the City of Windsor's Ojibway Nature Centre (www.ojibway.ca) are all great resources when looking for native plant information.

Some examples of places to purchase native plants include Native Trees & Plants in Amherstburg and Wheatley Woods Native Plants.

POLICIES AND GUIDELINES

There are many examples of policies and guidelines available for municipalities when they are considering incorporating green infrastructure such as rain gardens into their stormwater management initiatives. The University of Victoria published a guide in 2011 called "Peeling Back the Pavement: A Blueprint for Reinventing Rainwater Management in Canada's Communities". In addition, Ecojustice produced "Green Cities Great Lakes: using green infrastructure to reduce combined sewer overflows" in 2008, and in 2006 the Natural Resources Defence Council published "Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows".

Many forward thinking municipalities are incorporating green infrastructure such as rain gardens into their current stormwater management strategies, as well as providing incentives and information for homeowners who are interesting in installing their own rain garden.

City of Vancouver – Vancouver has established municipal programs and public funding for rain gardens as well as many other green infrastructure technologies. To address stormwater runoff from roadways, Vancouver has initiated a number of innovative street design projects as part of the city's Greenways

Program. One of these projects is the Crown Street redevelopment project.

Prior to the redevelopment project, stormwater runoff from Crown Street flowed untreated into two Vancouver creeks. Along with street narrowing and structurally supported grass, rain gardens were instrumental in the redesigned street, which will now retain 90% of the annual rainfall volume on site. Construction cost $707,000 in contrast to a conventional curb and gutter system costing approximately $364,000. However, eliminating the project-specific additional costs and consultant fees that would not be necessary of future projects, the cost would be brought down to be in line with conventional drainage systems (Natural Resources Defense Council, 2006).

Another interesting rain garden initiative in Vancouver is their Green Streets program. While being driven by aesthetics and community involvement, the function of many of the gardens is to absorb rain and prevent the movement of stormwater.

Green Streets gardens are planted in traffic circles and corner bulges and are constructed and planted by the City. Drought tolerant and native plants are used in the gardens. Once planted, the community who requested the garden is in charge of maintaining it. This program began in 1994 with only a couple of gardens and has now grown to include well over 350 Green Streets gardens cared for by volunteers (City of Vancouver, 2009).

Figure 2: *A City of Vancouver "Green Streets" garden*

City of Toronto – While the City of Toronto does not currently have a specific rain garden policy or program, the city is taking strides to encourage residents to convert typical lawn into native plant gardens. On the toronto.ca website are instructions on how to build water efficient gardens using a variety of native plants.

In addition, the Wet Weather Flow Management Policy (2003) identifies many green infrastructure technologies including rain gardens to help mitigate stormwater effects. This formulates a 25 year plan designed to reduce flooding and intense rainfall and impacts on streams and lake water. The suggested measures are currently voluntary for contractors.

In addition, the City of Toronto has released Draft Design Guidelines for 'Greening' Surface Parking Lots (2007). This document helps developers and designers of surface parking lots meet Official Plan policies and environmental performance targets of the Toronto Green Development Standard. The installation of rain gardens is incorporated into the proposed guidelines.

Municipality of Delta, BC – Delta's Engineering Department has been installing rain gardens in and around Delta roadways and at several elementary schools. These rain gardens are designed to intercept storm water and allow it to infiltrate the soil for absorption by plants.

Delta staff has also developed a complementary rain garden curriculum for Grade 4 and 5 students. This is a great way to connect students with their local watershed and help raise awareness as to how everyday actions may impact nearby watercourses. The rain garden allows students to experience caring for nature by maintaining the garden. The goal of this program is for all elementary schools to have a rain garden installed. The Town installs 1-2 new rain gardens each year (Corporation of Delta, 2012).

***City of Philadelphia* -** Green City, Clean Waters (2011) is Philadelphia's 25 year plan to protect and enhance their watersheds by managing stormwater with innovative green infrastructure. Over the past decade, the Philadelphia Water Department (PWD) has created, tested and implemented new strategies to promote the economic and social growth of the City and meet environmental, ecological and business goals.

The city has developed the 'Big Green Map' which displays various green infrastructure projects including rain gardens on an interactive map. Project locations, information and status are shown on the map. There are currently 42 rain gardens in the city.

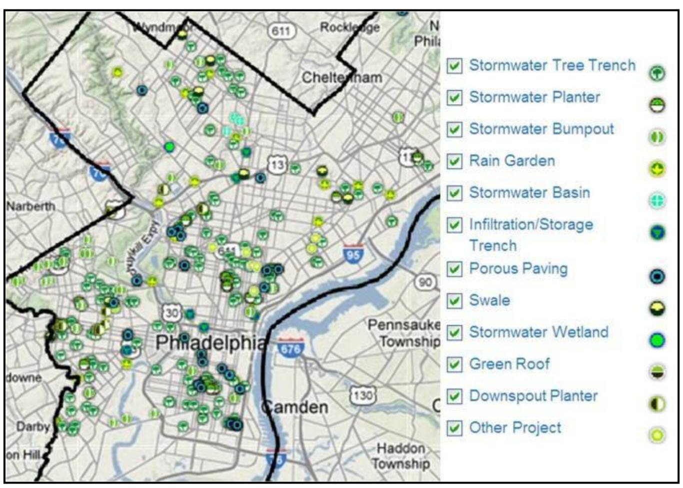

Figure 3: *Philadelphia's Big Green Map detailing green infrastructure projects.*

The PWD seeks to partner with community stakeholders across the city to develop green stormwater management projects. There is a place on the website where community members can learn about the community input process and submit a project suggestion.

Programs offered by the PWD include Green Streets, Green Schools, Green Public Facilities, Green Parking, Green Parks, Green Industry, Business, Commerce and Institutions, Green Alleys, Driveways and Walkways as well as Green Homes. The potential for rain garden design and construction is included in all of these programs.

There are currently 17 Green Streets projects in Philadelphia. These use a combination of vegetated and engineered strategies to manage rain or melting snow at its source. Green Street designs incorporate various green stormwater infrastructure tools, including rain gardens (City of Philadelphia, 2012).

In addition, the City of Philadelphia, through the Philadelphia Water Department and the Philadelphia Industrial Development Corporation has created the Stormwater Management Incentives Program to offer incentives and assistance to non-residential customers. These programs aim to stimulate investment in and utilization of stormwater best management practices, including the installation of rain gardens, which reduce a parcel's contribution of stormwater to the City's sewer and surrounding waterways. Five Million dollars is available through this grant program (City of Philadelphia, 2012).

***City of Portland* –** Portland encourages sustainable stormwater management through policy initiatives and has promoted funding and education for innovative stormwater management over the past decade. The city provides funding for sustainable stormwater management projects, including rain gardens or curb extensions, through various grants, matching-grant programs, and the Green Investment Fund, which is a $500,000 per year grant program to support innovative building practices in the private sector (Ecojustice, 2008).

The city has created a "How to Build a Rain Garden" video which is available on their website, as well as a document outlining how to build a rain garden. Once your rain garden has been built, residents can qualify for a discount on their stormwater utility fee through the Clean River Rewards Program (City of Portland, 2012). This program also offers free workshops by request for groups of ten or more where participants will learn about the stormwater discount program or about how to manage stormwater with rain gardens or other options.

Portland residents also have the option of registering in the city's Green Street Steward program. Green Streets are landscapes that transform street surfaces into living stormwater management facilities through the use of rain gardens. The city has produced a guide detailing simple activities residents can do to care for and maintain a Green Street. The rain gardens are installed by professional landscapers and the guide shows which maintenance tasks will be performed by professionals and which can be performed by local residents (City of Portland, 2012).

The five year goal of the Green Streets initiative is to construct 920 facilities, emphasizing partnerships with other city bureaus and agencies such as the Portland Water Bureau, the Portland Bureau of Transportation, and the Portland Development Commission. As of fall 2009, there were approximately 700 green street facilities in Portland that cumulatively manage an estimated 48 million gallons (182 million litres) of stormwater runoff a year. Of the 920 planned facilities, an estimate 573 (62%) will be located in the combined sewer area (Entrix Inc., 2010).

The City of Portland commissioned a report quantifying the benefits of green infrastructure, including rain gardens in 2010. Results show that rain gardens as part of the Green Streets program improves air quality by removing 0.04 lbs of PM_{10} per facility per year, has energy savings of 155+ kWh/facility, reduces CO_2 emissions by 0.3 metric tonnes/facility/year and has a positive effect on property values by 3-5% (Entrix Inc., 2010).

Town of Maplewood Minnesota - Maplewood installed their first rain garden to help manage stormwater in 1996. Today, their program has expanded to include over 620 rain gardens throughout the town, and over 60 rain gardens on city land.

During the spring of 2012, the town held "A Rain Garden for your Yard" series where classes were offered to design and build your own rain garden. There is also plenty of information available on their website for residents wanting to build their own rain garden.

The town encourages developers and businesses to consider rain gardens when determining how best to infiltrate runoff from their site. Many developers have created rain garden and these are highlighted on the town website. The site also boasts favourite places to see Maplewood Rain Gardens such as the Gladstone neighbourhood and City Hall (Town of Maplewood, 2012).

CHALLENGES

EDUCATION AND AWARENESS A lack of knowledge amongst municipal decision makers as well as the general public is a large barrier to installing rain gardens composed of native plants. This stems from a lack of knowledge of green infrastructure principles and benefits to the economic, social and environmental attributes of cities who implement them. Adopting green infrastructure such as rain gardens requires a holistic approach of the whole infrastructure system. It involves the need to look beyond treating stormwater as a waste product that has no value and that needs to be removed from property as soon as possible and in the fastest way possible.

Treating rain as a resource may be a difficult concept for municipal officials and city administration to understand and adopt. Although many cities are currently experiencing great success with rain garden implementation, pilot projects in Windsor are needed to demonstrate their effectiveness as well as co-environmental and social benefits to decision makers. Demonstration gardens may begin to change people's perspective on the value of rain gardens and naturalized habitat.

INSUFFICIENT PROVINCIAL GUIDANCE AND FUNDING Unfortunately there is no clear provincial mandate for green infrastructure in Ontario. There are many players in the field at all levels of government, and a high degree of fragmentation among and within jurisdictions. The result is a lack of provincial guidelines and weak linkages among ministries and a lack of public funding available (Green Infrastructure Ontario, 2011).

LACK OF INCENTIVE PROGRAMS The City of Windsor does not currently have a way to entice residents and business to install rain gardens and contain rainwater on their own property. The City of Portland provides a great example of an incentive program by offering residents a discount on their stormwater utility fee when they install their own rain garden. However, as the City of Windsor's sewer surcharge is tied directly to water use, an education program to show the benefits of retaining stormwater onsite to offset future watering requirements may be worthwhile. Municipal grant programs can also be made available through partnerships with other stakeholders to improve the quality of the Detroit River and minimize combined sewer overflows.

NATIVE PLANT AVAILABILITY FROM MUNICIPAL GREENHOUSES Although the City of Windsor grows native tree species in our greenhouses, we do not yet grow native wildflower or shrubs. Introducing native plants to city greenhouses would be extremely beneficial to the creation of a rain garden or Green Streets program. In some cases, funds needed to purchase native plants for rain gardens can be a barrier to their construction.

SALT SENSITIVITY Depending on the location of the rain garden, winter runoff may be impacted by road salting activities. For rain gardens located in public right-of-ways or parking lots that are frequently salted, consideration should be given towards plant species that are more salt tolerant.

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Improvement and Enhancement of Green Space

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Parks and Facilities ■ Forestry	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Windsor's changing climate is expected to result in warmer average temperatures as well as higher annual precipitation. The impact of climate change is seen as a significant threat to current stormwater infrastructure and management approaches. To mitigate adverse impacts, alternative methods that rely on ecological services and green infrastructure can be used to manage stormwater. One potential strategy is to improve and enhance the proportion of green space in Windsor. This may take place through the acquisition of new land, or by naturalizing existing open spaces under the City's jurisdiction. Naturalization is a planting method that involves minimal use of fertilizers, irrigation, and machinery. It improves the ecological integrity of urban areas by preserving native elements and requires minimal human interference (Ordonez & Duinker, 2012). In addition to the urban forest network and the Windsor Trail, there are approximately 2800 acres of green space distributed amongst 215 parks in Windsor. These parks include spaces designated as gardens, playgrounds, picnic areas, and sportsfields. The City also maintains naturalized areas surrounding municipal buildings such as the Ojibway Prairie Complex, as well as the native garden at the Lou Romano Water Reclamation Plant. However, by expanding and enhancing green space, greater stormwater management benefits may result.

ISSUE

Urban development and sprawl in Windsor have resulted in a landscape predominantly characterized by the replacement of vegetation with hard, impermeable surfaces. These new surfaces create stormwater management issues as a result of reduced permeability. These issues include: increased rates of runoff, increased peak flow of stormwater, higher pollutant concentrations, combined sewer overflows (CSOs), and flooding (LaPaix & Freedman, 2010).

In addition to the conversion of vegetated areas into impermeable areas, conventional landscaping of existing green space further contributes to stormwater issues. Conventional landscaping is associated with the use of high energy, chemical, and financial inputs to maintain well manicured green areas that lack native vegetation. Such restrictions on plant growth and diversity reduce the ability of plants to absorb and filter runoff. Also, the use of chemicals to maintain these areas may contaminate run-off.

This adaptation option also has the potential to influence community development. Enhancing green space by creating community gardens on vacant land will provide local food for residents and foster a sense of community while continuously providing climate change adaptation benefits.

To address these issues, the City of Windsor should designate new land as green space as well as naturalize existing open areas. These goals are in line with the Environmental Master Plan objective to manage stormwater run-off and to reduce CSO frequency (Gerber *et al.,* 2007).

BENEFIT

This adaptation action will most significantly improve stormwater management. On hard, paved surfaces, stormwater runoff is diverted quickly into the sewer system. Conversely, vegetated areas help to reduce the flow rate by temporarily storing runoff. As a result, the risk of flooding, CSOs, and pollutant washout into nearby sewers and water bodies becomes decreased. This also helps to lessen the demand on Pollution Control facilities by reducing peak flow (Ordonez & Duinker, 2012).

This adaptation option will also help to improve stormwater quality, as filtration by vegetation removes some pollutants. The shift to naturalization from conventional landscaping will also help to minimize pollutant concentrations by reducing the release of contaminants from the use of fertilizers, pesticides, and herbicides (Ingram, 2001).

CO-BENEFITS

URBAN HEAT ISLAND MITIGATION This adaptation option will also help to diminish the urban heat island effect (UHIE). Increased vegetative cover in green spaces increases rates of evapotranspiration as plants absorb water and release it into the atmosphere as vapour. Evaporative cooling can be increased through naturalization by increasing the plant surface area where evapotranspiration can occur. UHIE mitigation also results from vegetative shading which prevents the absorption of radiation by land. However, this effect is most pronounced when greening strategies are focused on tree planting, which results in significant canopy cover (Ingram, 2001).

REDUCED GREENHOUSE GAS EMISSIONS Vegetation removes atmospheric CO_2, a greenhouse gas (GHG), through sequestration and storage by plants. Improving and enhancing green space will increase the mass of CO_2 that is stored, as sequestration is proportional to overall plant biomass.

Furthermore, by naturalizing existing green spaces, the need for mechanical maintenance of these areas will reduced. Conventional landscaping largely depends on intensive maintenance regimes to preserve neat, well-manicured areas. This requires significant use of machinery that release gases such as: CO, CO_2, NO_X, and volatile organic compounds (VOCs), which contribute to the greenhouse effect. Therefore, CO_2 sequestration combined with reduced mechanical maintenance will help to diminish the greenhouse effect that contributes to climate change (Ordonez & Duinker, 2012).

POLLUTANT REMOVAL Similarly to GHG reductions, by increasing the amount of vegetated land cover in Windsor, rates of atmospheric pollutant absorption will increase. Absorption of air pollutants by vegetation occurs via uptake in leaf stomata and through the deposition of airborne particles on plant surfaces. Through these processes, plants can absorb pollutants such as O_3, NO_2, SO_2, CO, and particulate matter. Upon improving green space in Windsor, there will be a greater overall plant surface area in which pollutant removal can take place (Ingram, 2001).

WILDLIFE HABITAT Restoration of land into green space helps to re-establish traditional landscape functions that support wildlife populations. As a result, increased biodiversity in green areas will likely be found. Additionally, the creation and expansion of green space will help to improve habitat linkages by increasing connectivity to other natural areas. This helps to facilitate migration, maintain fecundity, maintain resilience to stochastic environmental events, and to maintain genetic diversity (Ordonez & Duinker, 2012).

BEST PRACTICES

The following municipal plans and programs represent best practices in North America with respect to the development and enhancement of green space.

City of Brampton – Valleys Re-naturalization Planting Program Created in 2002, this program is designed to restore native plant species within the City's valley lands that have lost vegetation due to previous agricultural and development practices. The goal of this program is to plant a total of 24,000 native trees, 200,000 native shrubs, and 100,000 native perennials over ten years. As of 2011, approximately 280 acres of valley land had been re-naturalized (City of Brampton, 2011).

City of Guelph – Community Gardens The City of Guelph offers a community garden program where interested community groups and residents can apply to start up a community garden on municipal property. The City will work with the community group to identify and assess viable sites that meet certain criteria in order to choose an appropriate site for the garden. A garden site will be prepared and submitted to the Community Engagement Coordinator who will circulate it to other City departments for their comments. Both the garden group and the site must include specific criteria determined by the City.

Once the site plan has been approved, the City and the community garden group will hold a consultation process with the neighbours near the potential site. The City often assists with site preparation and in-kind donations of mulch, gravel etc. Currently, there are two community gardens on municipal property (City of Guelph, 2012).

City of Richmond – Official Community Plan Within the subsection on Parks, Open Spaces, Trails and Greenways, the City outlines five objectives and associated policies to ensure that Richmond maintains its Garden City legacy. Objective 2 expresses a commitment to designing and maintaining parks, open spaces, trails and greenways in an "environmentally sustainable manner" (City of Richmond, 1999). As a result, the City plans to use environmentally friendly maintenance techniques that conserve resources, to retain natural trees and vegetation when developing new parks and open spaces, to relocate trees when their removal is necessary, and to facilitate public education about Richmond's natural features.

Additionally, the City aims to expand the open space network both on City-owned land areas as well as through private partnerships. In public areas, the municipality plans to maintain inventories of leftover parcels of land that can be easily integrated into the existing open space network. Furthermore, city officials are encouraging the development of "privately-owned publicly-accessible (POPA)" areas that can be integrated as naturalized green space (City of Richmond, 1999).

City of Waterloo – Partners in Parks Program The Partners in Parks Program provides opportunities for community involvement in stewardship activities aimed at expanding greenspace in the City of Waterloo. Projects residents can become involved with related to the greening of public lands include: planting native vegetation within parkland naturalization areas, planting garden beds, and planting vegetated buffers. One example of a successful project arising from this program is the re-naturalization of Roxton Park, as illustrated in *Figure 1* (City of Waterloo, 2007).

Figure 1: *Roxton park re-naturalization (City of Waterloo, 2007)*

City of Bellingham – Greenway Advisory Committee This committee was formed in order to identify, recommend, and develop projects that are eligible to receive Greenway Levy Funds. These funds are generated through a property tax levy that was designed to raise money for greening projects in Bellingham, Washington. Committee members advise City Council and staff regarding efforts to secure land rights for the development of open space, trails, and ponds. To date, approximately 21 projects have been developed as a result of the distribution of these funds (Green Infrastructure Foundation, 2009).

City of Chicago – The Lurie Garden at Millennium Park The initial master plan for the three acre Lurie Garden called for the use of predominantly turf and concrete paths to cover the top of an underground parking garage. However, these plans were modified in order to develop a garden and park space that would provide environmental benefits such as stormwater management, reduced irrigation, reduced chemical use, and increased biodiversity. The landscape plan was altered to incorporate the use of regional materials and to require minimal maintenance. The park was planted using perennials and woody plants of which 60% were Midwestern natives. As a result, irrigation needs were significantly reduced, and no insecticides, fungicides, and herbicides are used to maintain the area. In addition to the sustainable plant selection, all limestone was regionally sourced, and FSC-certified hardwood was used for seating and walking surfaces.

Estimates of the park's landscape performance benefits approximate that the park reduces stormwater runoff by 60%, reduces annual irrigation by 888,543 gallons, and sequesters 55 tonnes of carbon annually. In addition to these environmental benefits, the park serves as an educational site for Chicago residents, as staff members and volunteers provide workshops on residential native planting techniques (Landscape Architecture Foundation, 2010).

City of Milwaukee – Menomonee Valley Stormwater Park This stormwater park was created in response to environmental contamination and an economic recession in the Menomonee River Valley. In response to these concerns, the City initiated this project to redevelop the brownfield, to create jobs, and to attract businesses. The completion of the $20 million project resulted in the generation of naturalized areas to manage stormwater, trails, playing fields, and open areas. The combination of native plants, woodlands, restored riparian zones, and topography help to detain water, preventing issues related to excess stormwater runoff (Green Infrastructure Foundation, 2009).

***Figure 2:** Menomonee Valley Stormwater*

CHALLENGES

TRADITIONAL LANDSCAPE VALUES One of the primary barriers to increasing green space by naturalizing open areas is a preference amongst the public for conventional landscaping. Many individuals have aesthetic preferences for manicured areas, and see naturalized landscapes as unkempt, messy, and dangerous. Additionally, individuals may prefer to allocate open space areas for different uses such as recreation, rather than areas that can provide environmental benefits. Due to these factors, residents may be reluctant to support naturalization projects. Therefore, it remains critical to educate these individuals about the environmental costs of conventional landscaping and the benefits that natural landscaping provides (Ingram, 2001).

LACK OF TECHNICAL EXPERTISE A lack of knowledge amongst municipal employees on the benefits and complexities involved with creating natural landscapes may prevent the development of these projects. Education of key stakeholders about naturalization will likely help build political support. As well, it may be necessary to hire trained professionals such as consultants and landscape architects in order to guide project development regarding design, site selection, and plant selection (Ingram, 2001).

ARTIFICIAL TURF AND LANDSCAPING

There has been significant debate over the use of natural grass versus artificial turf in the development of sportsfields and outdoor play areas. There is no clear consensus regarding which grass application is best, and each option should be evaluated on a case by case basis (Jackson 2008; Simon, 2010).

ADVANTAGES

- Quick installation
- Withstands all-weather and heavy use
- Increased playing hours
- Reduced maintenance costs
- Reduced water consumption
- Reduced hydrocarbon emissions from machinery use

DISADVANTAGES

- Increased chance of sports injuries
- Concerns about the health effects of chemicals used to manufacture crumb rubber
- Loss of environmental services: stormwater management, CO_2 sequestration, pollutant removal, cooling via evapotranspiration, erosion control
- Hot spots – artificial fields can be up to 60°F warmer than natural grass fields

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Increase Tree Planting

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations - EMP ■ Parks and Facilities ■ Planning	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ■ Private

CONTEXT

Urban forests provide valuable environmental, social, and economic benefits to cities, and constitute the sum of woody biomass located within dense urban areas. The City of Windsor contains an urban forest network of approximately 70,000 trees located on streets, as well as 35,000 trees found within public areas and parks (Clean Air Partnership, 2012). Further natural areas that contribute to Windsor's tree coverage include the Ojibway Prairie Complex, and the Peche Island and Spring Garden Area of Natural and Scientific Interest (ANSI). Public tree coverage is also complemented by the existence of trees on private lands. Planting and tree maintenance remains the responsibility of the Forestry Division within the Parks and Facilities department. In addition to guidelines on tree management, mechanisms to ensure that trees are protected are outlined in the *Urban Forestry* document. Other policy provisions designed to preserve the urban forest network include *By-Law #231-2005 Natural Environment Areas* and *By-Law #135-2004*, which aims to protect trees on municipal property. The City also regularly invites the public and community partners such as *One Million Trees* to participate in greening efforts. Another important community group is the Essex Region Conservation Authority (ERCA), who have outlined a goal to increase the tree canopy in Windsor-Essex from approximately 8% to 12.5%.

ISSUE

Climate projections predict that the City of Windsor will be subject to changes regarding temperature, precipitation, extreme weather, and water level trends. To mitigate the wide range of potential impacts related to these trends (See Pg. 13) increasing tree coverage has been identified as a necessary adaptation action.

The primary goal of this adaptation option is to reduce negative effects of climate change that contribute to the Urban Heat Island Effect (UHIE). The UHIE is a concern in Windsor due to the regional climate, urbanization, and the potential for synergy with air pollution impacts. Risks related to the UHIE include: heat-related illness, mortality, increased frequency of extreme weather, air quality issues, and increased prevalence of water and food borne disease. The likelihood of occurrence of these impacts is heightened due to Windsor's demographics which include an increasing elderly population, a large number of people living with chronic diseases, a large low income population, and a significant number of private households. Currently, there is high industrial, commercial, and residential land use in Windsor in comparison to natural areas. As a result, increasing tree coverage in Windsor is necessary both to diminish the UHIE and to enhance the ecosystem services afforded by trees that help mitigate and adapt to climate change.

BENEFIT

The strategy to increase tree coverage in the City of Windsor is primarily designed to reduce the UHIE. Temperature reduction results due to evapotranspiration in plants which occurs as they absorb water and release it into the atmosphere as water vapour. During this process, energy from solar radiation is used and transformed by plants into latent heat rather than sensible heat, which cools the ambient air surrounding vegetation (Bowler *et al.,* 2010).

In addition to evapotranspiration, trees increase atmospheric cooling through shading. Tree canopies reflect shortwave solar radiation, which prevents the absorption of radiation by land and infrastructure below trees (Hamin & Gurran, 2009; Bowler *et al.,* 2010). This effect has been found to yield measurable differences in the temperature of features shaded by trees including buildings, parking lots, and sidewalks (Nowak & Dwyer, 2007).

The collective action of urban trees undergoing evapotranspiration and providing shade can result in reduction of the UHIE. This results in ambient air temperatures decreasing to values that more closely approximate those in the surrounding countryside and natural areas. Cooling will result in a reduction in the number of days where extreme heat alerts are issued, minimizing the previously mentioned risks related to the UHIE. A systematic review of seventy-four studies that measured air temperature changes in response to greening was completed, and determined that increasing tree coverage resulted in an average air temperature decrease of 0.94°C in urban environments (Bowler *et al.,* 2010).

CO-BENEFITS

In addition to the aforementioned benefit of minimizing the UHIE, multiple co-benefits result from increasing tree coverage that have positive ecological, social, and economic implications.

CARBON SEQUESTRATION While the primary benefit of this adaptation action is to diminish the UHIE, it also serves as a mitigation strategy with respect to climate change. The carbon sequestration ability of a natural area increases as the total biomass in an area increases. Therefore, the addition of biomass through tree planting efforts will result in an increase in the storage of CO_2 in trees, helping to reduce the greenhouse effect (Larsson, 2010). A study in the Town of Oakville determined that city trees resulted in the sequestration of approximately 22,000 tonnes of CO_2 annually (Clean Air Partnership, 2012).

ENERGY CONSERVATION The energy conservation benefits afforded by improved tree coverage result from urban shading, decreased winter wind speeds, and reductions in air temperatures (Nowak & Dwyer, 2007). Urban shading results in energy conservation by cooling urban infrastructure, minimizing the demand on air-conditioning systems. The benefits of shading are best realized by strategically planting trees on the eastern and western sides of buildings. Urban trees also aid in decreasing wind speeds in the winter, helping to reduce heating costs (Nowak & Dwyer, 2007).

A recent study also revealed that the energy consumption required for indoor cooling increases by approximately 4% for every 1°C increase in temperature (Millward & Sabir, 2011). Therefore, reductions in overall air temperature will further minimize demands on heating and cooling systems, leading to increased energy savings. Research completed in the City of North Vancouver using the Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM) revealed that the city's 5,414 trees were responsible for $6,514 in energy savings annually (Wong & Gordon, 2011).

AIR QUALITY The air quality in urban areas is influenced by: the total surface area of tree leaves, pollutant emissions, and meteorological conditions (Clean Air Partnership, 2012). Absorption of air pollutants by trees may occur via uptake in leaf stomata or through the absorption of airborne particles on plant surfaces (Nowak & Dwyer, 2007). Through these processes, plants have the ability to absorb pollutants such as O_3, NO_2, SO_2, CO, and particulate matter (Millward & Sabir, 2011). Quantification of air pollutant removal in the Town of Oakville revealed that trees absorbed 172 tonnes of pollutants yearly (Clean Air Partnership, 2012).

STORMWATER MANAGEMENT Improving tree coverage will lead to additional improvements in stormwater management. Trees help to reduce the flow of stormwater runoff, which reduces the risk of flooding and pollutant washout into nearby sewers and water bodies (Millward & Sabir, 2011). Furthermore, reduced stormwater runoff can lessen the demand on Pollution Control facilities by decreasing peak flow and the likelihood of combined sewer overflow (CSO) events. This can also result in cost savings for treatment plants by decreasing the total volume of water treated (Nowak & Dwyer, 2007).

BIODIVERSITY Increases in total tree coverage will correspond proportionately with increases in overall species abundance. Additionally, strategic planting and species selection can be undertaken to ensure that new trees are chosen that are native or ecologically significant to an area. Increases in tree cover have also been correlated with the enhancement of regional biodiversity (Nowak & Dwyer, 2007).

SOCIAL BENEFITS A number of social benefits to local populations have been linked to increased tree canopy in urban areas. These benefits have been demonstrated to contribute to improvements in social cohesion, well-being, and the psychological health of local populations (Millward & Sabir, 2011). These benefits include: enhanced aesthetic quality, noise reduction, reduced stress, and increased recreational opportunities (Nowak & Dwyer, 2007). Additionally, tree coverage has also been associated with increased willingness to pay to live in forested areas, higher property values, community empowerment, as well as improvements in neighbourhood desirability (Millward & Sabir, 2012).

BEST PRACTICES

The following section outlines best practices for the protection, maintenance, and planting of urban forests in order to achieve heightened tree coverage. These best practices were derived from plans, policies, and procedures that are currently in place within Canadian municipalities outlined within Clean Air Partnership's ***Urban Forestry Scan*** (Clean Air Partnership, 2012).

Town of Aurora – Boulevard Tree Planting This program engages local residents in tree maintenance by involving them in species selection and care of the Town's trees. Residents are responsible for watering, mulching, and monitoring boulevard trees. This minimizes the funding, time, resources, and personnel that the Town requires to maintain their tree network.

Town of Aurora – Private Tree By-law ***By-law #4474-03.D*** requires all residents and commercial landowners to apply for a permit in order to remove trees found on private property.

The permit system requires a replanting agreement to be established, and fees are administered when removal requests exceed the By-law's guidelines. A fee of $415.00 is required for the removal of more than five trees, plus $75.00 for additional trees to a maximum of $715.00. Individuals that violate the conditions of the by-law are subject to financial penalty.

City of Brampton – Woodlot Development Guidelines As outlined in Brampton's ***Official Plan*** all development proposals adjacent to the City's woodlots must be accompanied by a *Woodlot Management Plan.* Such plans must outline conservation and management actions necessary to protect against the destruction of woodlands. The plans must also include an assessment of significant vegetation in the woodlands and the identification of specific measures for their protection before, during, and after construction (City of Brampton, 2006).

Town of East Gwillimbury- Local Enhancement and Appreciation of Forests (LEAF) The Town is partnering with the community organization, LEAF, in order to address educational and engagement issues amongst residents. The program aims to increase appreciation for the value of forests through education, and encourages private tree planting through the DIY Backyard Planting Program.

Town of Halton Hills – Official Plan The ***Official Plan*** (Section C9) outlines multiple measures designed to protect the Town's trees and to promote increases in overall tree canopy. These measures include: management plans for trees impacted by development, requirements for the establishment of replanting programs when trees are lost due to a public work, commitments to tree planting in parking lots and along streets, and the establishment of tree planting programs along main roads and watercourses (Town of Halton Hills, 2008).

City of Hamilton – Street Tree Program This program enhances the urban forest landscape by providing a free tree planting service to homeowners. Homeowners are able to submit requests for trees on their City-owned road allowance. Standard lot applicants may plant a maximum of one tree, and corner lot applicants can plant a maximum of three trees.

Town of Markham – Trees for Tomorrow The Town of Markham formalized their tree planting goals through the creation of the ***Trees for Tomorrow***. The aim of the program was too plant 75,000 trees by 2010. The Town's achievements exceeded their initial goal by 50,000. The program also involves the establishment of the *Trees for Tomorrow Fund* to aid community organizations in tree planting efforts on public land. Additionally, the Town partnered with LEAF to provide planting services for homeowners at a cost between $80-$190. LEAF also became involved in community education through administering *Tree Tender* workshops to inform residents about the proper care of trees (Town of Markham, 2009).

City of Mississauga – Tree Inventory The City maintains an in-depth tree inventory that includes information on the species, diameter, mapping, and condition of their 250,000 trees. The maintenance of detailed records on their trees allows the City to strategically identify ongoing maintenance, removal, and planting needs.

Town of Oakville – Tree Protection During Construction
This procedure requires developers to pay a sum equal to the value of trees they eliminate during construction, or plant new trees that will provide a canopy cover equal to that provided by the removed trees.

Town of Oakville – Official Plan
Under section 10.3(b) of the ***Official Plan***, the Town states the objective to have no net loss of existing urban forests. To meet this requirement, all development projects must ensure that new trees are planted equal to the square metre of leaf area that is removed. This ensures that development does not result in disproportionate tree coverage due to differences between the leaf area of mature trees that are replaced by smaller trees (Town of Oakville, 2006).

Town of Richmond Hill – Development Guidelines The Town requires a detailed community landscaping plan to be submitted prior to granting approval for new subdivision developments. The plan must include provisions concerning: boulevard tree planting, entrance features, buffer planting zones, pedestrian walkways, and the maintenance of community connectivity. Developers must also plant and pay the Town's boulevard Tree Planting Fee.

City of Toronto – Every Tree Counts
The City completed this report to identify the value of Toronto's trees with respect to the ecological services they provide. When compared to other municipalities, this report is unique as it provides recommendations specifically concerning mortality prevention of existing trees. This is important as mature trees provide the greatest benefits in terms of ecological services, but can be vulnerable to mortality resulting from diseases and pests.

York Region – Greening Strategy
The Greening Strategy involves wider conservation goals of restoring habitats, increasing natural areas through land acquisition, and environmental education. In line with these goals are a number of projects related to the Region's goal to achieve 22.5% canopy cover. Efforts aimed at achieving this goal include: annual planting of 70,000 trees, acquisition of forest and conservation lands, a backyard tree planting program, large property planting for areas greater than 0.8 hectares, and the sale of low cost seedlings to residents.

City of London – Urban Forest Effects Model (UFORE) The ***UFORE*** project is a forest inventory project that assigns economic values to tree's environmental services. These values concern: carbon sequestration, pollutant removal, and energy savings. This project allowed City officials to better understand the economic value of trees, and formed the basis through which London will develop their *Urban Forest Strategy*. The project is also a useful decision-making tool, as the quantification of tree's economic benefits allows policy makers to see value in policies and plans that support increased coverage.

CHALLENGES

The implementation of best practices designed to increase tree coverage in the City of Windsor may be negatively impacted due to the following challenges regarding: education, funding, inventories, tree maintenance, and environmental stressors.

EDUCATION AND AWARENESS Lack of knowledge amongst City officials and the public may lead to delays in the establishment of progressive plans and policies. Professional, industry, and government groups may neglect to see the value in enhancing urban forests when they have competing development interests (Hamin & Gurran, 2009). These competing interests may lead to cases of land-use conflict in which existing trees are displaced by other urban forms and developments.

Also, lack of public knowledge regarding the value and maintenance necessary to grow trees may hinder private tree planting. Therefore, it is critical to invest in educational programs regarding tree maintenance in order to address the issues and concerns of homeowners. As a result of these awareness issues, it is important to educate stakeholders about the benefits trees provide to communities and the environment. Furthermore, tools such as ***UFORE*** remain useful to convey the ecological and social values of trees in monetary terms**.**

MAINTAINING INVENTORY DATA The establishment of policies concerning tree coverage necessitates the maintenance of accurate tree inventories. However, maintenance of these records can be difficult due to the large investments in financial, employee, and database resources needed to update them. Inventories will form the basis through which decisions are made requiring the strategic maintenance and planting of new trees. Additionally, recording data on the number and condition of trees can be used to measure performance towards tree canopy goals. Therefore, it is necessary for the City to allocate appropriate funding and personnel to ensure that accurate inventories are accessible.

TREE MAINTENANCE The ability of trees to reduce the impact of climate change is dependent on their health, maturity, and species diversity (Ligeti *et al.,* 2007). However, the ecological conditions found in urban environments are less conductive to healthy tree growth than those found in natural landscapes. These negative conditions include: constricted space to develop root systems, competition for light with urban structures, inadequate soil conditions, heightened soil salinity, and physical damage due to human interference (Clean Air Partnership, 2012). Due to these factors, urban trees often require comprehensive maintenance in comparison to trees in natural settings.

To ensure that healthy trees develop it is necessary for the City to improve their capacity for maintenance by allocating appropriate funding and personnel and by completing inventorying. Specifically, it is necessary to complete regular pruning, removal of damaged trees, invasive species management, and to plant trees suited to the growing conditions found in urban areas (Ligeti *et al.,* 2007).

FUNDING The implementation of best practices to increase tree coverage in Windsor will require the acquisition of long-term funding. Funding will be necessary to support programming, policy development, research, inventory updates, and ongoing maintenance. In addition to allocating the municipal budget to these activities, applications for external funding sources and the formation of community partnerships will aid in the attainment of necessary funds.

ENVIRONMENTAL STRESSORS In the future, new environmental stressors that adversely impact Windsor's total tree coverage may arise. It is important for the City to anticipate future sources of stress to tree health such as climate change, pests, disease, and invasive species. The potential for synergistic threats between these stressors should also be considered as they have the potential to severely degrade ecosystems. It remains important for the City to predict potential stressors and develop adaptive maintenance and planting regimes if they arise.

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Increase Capital for Shade Structures

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations - EMP ■ Parks and Facilities ■ Planning	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Climate change and its related impacts such as extreme heat have been identified in the City of Windsor as significant risks to human health. As the number of days exceeding 30°C are expected to increase in the future, it remains important to construct features such as shade structures to reduce heat-health vulnerability. Shade structures are natural and constructed features which prevent direct sunlight and ultraviolet radiation (UVR) from being absorbed and reflected by the earth. They are designed to prevent heat-related illnesses in communities by minimizing exposure to UVR and heat. Natural variation in the UVR result from changes in sun height, latitude, cloud cover, altitude, the ozone layer, and seasonality (Toronto Cancer Prevention Coalition, 2010). UVR intensity can also be modified by strategically locating shade structures on municipal properties. However, policies and guidelines regarding the construction of these features within outdoor spaces are not currently in place within the City of Windsor.

ISSUE

The conditions of outdoor environments can affect human health, making it critical to adopt measures to modify these environments to create healthy communities for residents and tourists (Boldemann *et al.,* 2006). Communities in Southern Ontario are currently exposed to the strongest UVR in Canada, putting citizens at risk of developing acute and chronic illnesses resulting from UVR exposure and heat. These conditions include: skin cancer, lip cancer, eye melanoma, eye cataracts, skin aging, heat-induced mortality, heat stress, and aggravation of chronic health conditions such as respiratory disease (Toronto Cancer Prevention Coalition, 2010). These issues are amplified with respect to vulnerable populations such as children, the elderly, and outdoor workers.

BENEFIT

Through increasing capital for shade structures in the City of Windsor, the primary benefit is to minimize the risk of Windsorites and tourists developing heat-related illnesses. This will occur as shading structures can be used to minimize direct and indirect exposure to solar radiation by providing physical protection.

In addition to protecting human health, the use of shade structures may help to reduce the Urban Heat Island Effect (UHIE). Natural shade structures include vegetation, and therefore help reduce the UHIE through evaporative cooling. Additionally, constructed shade structures may help induce cooling by minimizing the direct absorption of UVR on hard surfaces with low albedo (Toronto Cancer Prevention Coalition, 2010). The reduction of the UHIE will help minimize the risk of heat related illnesses by decreasing ambient air temperatures and the number of days where extreme heat is recorded.

CO-BENEFITS

CARBON SEQUESTRATION Construction of shade structures may also serves as a mitigation strategy regarding climate change. The carbon sequestration ability of a natural area increases as the biomass in an area increases. Therefore, the addition of natural shade structures in the form of vegetation will result in an increase in CO_2 storage, helping to reduce the greenhouse effect (City of Toronto, 2007).

AIR QUALITY By lowering ambient air temperatures, shading structures help to improve air quality. This occurs due to the absorption of air pollutants by trees such as: O_3, NO_2, SO_2, CO, and particulate matter less than ten microtonnes (Millward & Sabir, 2011). Additionally, smog formation is accelerated by heat. Thus, by lowering the UHIE, the use of shade structures may also help to reduce smog (City of Toronto, 2007).

ENERGY SAVINGS Energy savings may also result by using natural shade structures. Planting trees in the vicinity of buildings promotes cooling by preventing direct solar radiation from being absorbed by walls and windows. This minimizes interior temperatures, resulting in savings by reducing the need for cooling. During the winter, natural shade structures also reduce wind speed in urban environments, helping to lower heating demands. A study completed for the Toronto Atmospheric Fund found that the implementation of urban heat island mitigation controls resulted in a peak-power reduction of 250 MW. Of this reduction, shade trees accounted for 51% of the savings (Konopacki & Akbari, 2001).

In addition to natural shade features, constructed features can also result in improved energy efficiency. A study completed by the Center for Sustainable Building Research examined the impact of awning construction on residential buildings in twelve cities in the United States. The authors concluded that the use of awnings resulted in reductions in cooling energy by reducing solar gain through windows, as well as reductions in peak energy demand. On average, cooling energy was reduced by 22%, and peak energy demand was reduced by 12% (Carmody *et al.,* 2007).

INCREASED RECREATIONAL OPPORTUNITIES One of the key barriers to involvement in outdoor recreational activities is a lack of adequate outdoor space. Providing shade in parks, swimming areas, playgrounds, and sports fields can help improve the comfort of these spaces, encouraging more individuals to use them. Health benefits correlated with increased recreational activity include: stress reduction, improved psychological well-being, and increased physical exercise (Toronto Cancer Prevention Coalition, 2010).

BEST PRACTICES

The following sections outlines best practices regarding the construction of shading features, which are organized into two categories: *Policies and Guidelines, and Planning and Design.* Currently, the incorporation of shading features is not formally addressed in many Canadian municipalities' planning procedures. As a result, these practices were solely adopted from the City of Toronto's shade policies.

POLICIES AND GUIDELINES

City of Toronto - Sun Protection Policy This *Policy* contains guidelines for individuals who have high occupational exposure to solar radiation. The policy stipulates that a risk assessment should be performed for all outdoor work activities that result in high exposure. Sun protection programs must then be designed to minimize the adverse health risks related to radiation. Supervisors and employees are also required to receive training regarding potential effects and protective measures. Employees are responsible for using these protective measures and reporting adverse effects to their supervisors (City of Toronto, 2008).

City of Toronto – Policy for the Provision of Shade at Parks, Forestry, and Recreation Sites The purpose of this Policy is to improve UVR protection at Toronto's parks, forestry and recreation sites through educational strategies and shade structure construction. The policy seeks to make the inclusion of UVR protective measures a part of all new development projects in this department. The document outlines recommendations for planning and altering City sites to incorporate natural and constructed shade structures including permanent and temporary structures. The policy also outlines technical considerations pertaining to shade structures at various outdoor locations. Finally, the process for conducting shade audits is described in this policy (City of Toronto, 2007).

City of Toronto – Climate Change, Clean Air and Sustainable Energy Action Plans These action plans contain a diverse array of measures to mitigate climate change. Included in this report is a policy to increase tree canopy to 34%. This goal relates directly to urban forestry strategies, but provides indirect shading benefits through enhancing natural shading (Toronto Cancer Prevention Coalition, 2010).

City of Toronto – Toronto Green Standard The Toronto Green Standards are designed to promote environmental site and building design features into development projects. They are organized into a tier system, where Tier 1 guidelines are required, and Tier 2 guidelines are voluntary. The standards address shading within the Urban Heat Island Reduction: At Grade section. These guidelines serve to encourage shading of hard surfaces with low albedo such as parking lots and sidewalks.

City of Toronto – Sun Safe Event Planning Guide These guidelines outline measures to be taken by outdoor event planners to minimize overexposure to UVR. These strategies advise event planners to publish materials on the UV Index and Sun Protection Measures, assess sites to determine the existence of shaded areas, to construct cooling stations if necessary, and to distribute print materials on protective measures to attendees (Toronto Public Health, 2010).

PLANNING AND DESIGN

City of Toronto – Shade Audit The City has developed guidelines for completing shade audits to determine outdoor locations where exposure risks are highest. This process is divided into four key steps. First, profiles of site users, usage patterns, and site activities are identified. The next step involves completing an inventory of the site conditions and existing shade structures. By determining the quantity and quality of existing structures, planners can identify gaps which future structures can address. Thirdly, identification of potential risks to site users allows planners to assess if adequate shade structures are in place to prevent harmful UVR exposure. Finally, recommendations are made to address these risks by using: natural shade planning, constructed shade planning, portable shade design features, and promoting education regarding sun protection (Toronto Cancer Prevention Coalition, 2010).

City of Toronto – Shade Audit Software *WebShade* is a development tool that uses design and graphics programs to complete shade analyses. This tool can help planners identify UVR risks and to develop shade projections. *WebShade* was used on a trial basis in Toronto to complete an audit of eight different playground and waterplay sites (Toronto Cancer Prevention Coalition, 2010).

City of Toronto – Shade Plan If a shade audit indicates that there is significant concern regarding the UVR risks at a site, the City recommends for the creation of a *Shade Plan*. These plans are to include: the results of shade audits, a drawing that illustrates the risk areas on sites and the recommendations for improving shade, a design brief that outlines the performance abilities of proposed shade structures, and cost estimates for building the necessary features (Toronto Cancer Prevention Coalition, 2010).

City of Toronto - General Guidelines for Natural Shade Features Natural shade structures involve the use of trees, shrubs, or vines (*Figure 1*). Maximum shade is provided by trees with dense and wide canopies. Species should also be chosen that are suited to an area's soil and climatic conditions to ensure optimum growth. It is also imperative to maintain proper care of vegetation through watering, fertilization, and pruning when necessary. The City of Toronto publishes a *Tree Canopy Density Guide* to allow planners to select species with the greatest UVR protection (Toronto Cancer Prevention Coalition, 2010).

Figure 1: *Natural shade feature*

City of Toronto – General Guidelines for Constructed Shade Features Constructed shade structures may also be utilized to reduce exposure (*Figure 2*). Selection of optimal constructed shade features should reflect the design goals for an area. For instance, plans may require structures to be either permanent or removable. Free standing open air structures are best suited to areas with high frequency of use and when permanent solutions are needed. Also, attached canopies or awnings remain viable options that require minimal maintenance, and are ideal when weathering is a concern. Finally, temporary structures such as umbrellas are ideal when flexible solutions are needed, or for short-term events.

Figure 2: *Constructed open air shade feature*

City of Toronto – Technical Considerations

These *Technical Considerations* describe design and protective measures for shading at sites where exposure risks are highest (City of Toronto, 2007). Relevant recommendations include:

Playgrounds and Childcare Centres

- Designation as high priority areas due to frequent use between 11a.m. - 4 p.m.
- Shading requirements for children and staff
- Priority shading over fixed equipment that children utilize for extended time periods
- Constructing play areas with moveable features that can be relocated
- Using temporary structures during interim periods before permanent features are built
- Ensuring that features do not hinder safety and supervision requirements
- Aiming to incorporate features that have co-benefits such as rain protection or which also serve as play features

Pools and Slash Pads

- These areas should be considered high priority as children are the primary users and minimal skin coverage increases risk
- Providing shade for outdoor staff areas
- Utilizing moveable furniture
- Using tensile structures over water areas rather than permanent structures
- Using adjustable structures to allow for interim pool heating

Sportsfields

- Considerations should be made concerning providing shade for both players that utilize off-field areas, as well as for spectators
- Consider temporary structures for sportsfields that receive seasonal use

Streetscapes

- Selecting trees that are projected to have dense canopy cover, but that do not interfere with the surrounding built environment
- Utilizing overhangs and awnings along streets where it is not feasible to use natural structures
- Precautions should be taken to ensure shaded structures do not result in dark environments that are uninviting and unsafe.
- Shade elements should be strategically positioned in the vicinity of existing benches, bus stops, and waiting areas.

CHALLENGES

EDUCATION AND AWARENESS A lack of knowledge amongst City officials may lead to delays in the establishment of formal planning measures that mandate construction of shade features on municipal properties. Therefore, it remains important to educate these stakeholders regarding the health benefits of these strategies and on best practices. It is also imperative to educate residents and tourists about the risks of solar radiation and corresponding protective measures through promotion of the *Stay Cool Windsor-Essex Heat Alert and Response Program.* Dissemination of resources such as Environment Canada's UV Index and Sun Protection Actions would also be useful as an educational tool.

FUNDING The implementation of best practices to increase shading in the City of Windsor will require the acquisition of long-term funding. Funding will be necessary to support programming, policy development, and construction. In addition to allocating the municipal budget to these activities, applications for external funding sources and the formation of partnerships with community groups will aid in the attainment of necessary funding.

AUDITING The development of shade structures in Windsor will be delayed due to the immediate need to conduct shade auditing. Provision of shading has not been a planning priority in the past. Therefore, records are lacking on the existence of current shade structures, primarily with respect to constructed shade features. In order to understand where exposure risks are greatest and where infrastructure is lacking, auditing will need to be conducted.

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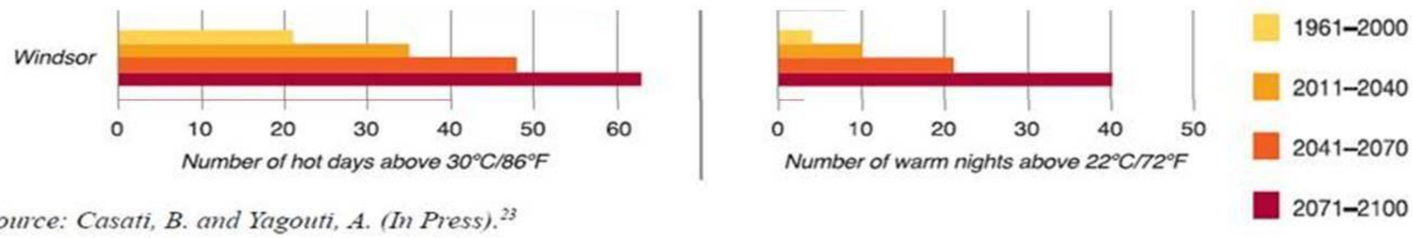
Increase in Heat Education at Community Centres and Pools

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations - EMP ■ Recreation ■ Windsor-Essex County Health Unit	■ Building Adaptive Capacity ☐ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ■ Federal ☐ Private

CONTEXT

Climate change and its related impacts such as extreme heat have been identified in the City of Windsor as significant risks to human health. These risks are expected to be heightened in the future, as the number of days exceeding 30°C in Windsor are predicted to triple by 2071-2100.



Source: Casati, B. and Yagouti, A. (In Press).[23]

Extreme heat events have been associated with sudden, short-term increases in mortality, especially among older adults, those who are chronically ill and the socially disadvantaged. For example in 2003, a summer heat wave hit Europe resulting in over 70,000 deaths, while in 2010 another catastrophic heat wave hit Russia resulting in an estimated 55,000 deaths (Health Canada, 2012). Fortunately, heat related deaths are preventable.

Currently, a Heat Alert and Response System (HARS) is in place called Stay-Cool Windsor Essex. This initiative warns individuals about extreme heat events, and provides community members with the resources and information necessary to mitigate heat-related health risks.

ISSUE

In Canada, extreme heat events are not well documented and attributed deaths are often estimated using sources such as media reports. During extreme heat events, many people succumb to underlying health conditions (respiratory, cardiovascular), while some may experience heat stroke that could result in death (Health Canada, 2011).

The estimated average number of excess deaths during periods of hot weather in 1999 amounted to 120, 41 and 37 for Toronto, Ottawa and Windsor, respectively (Cheng, 2005).

Currently, many Canadians do not follow the prevention advice provided by public health fact sheets and media when extreme heat events occur. Hence, heat-health communication campaigns should target supporting organizations, to raise awareness about heat-health issues and provide direction on preventative measure to minimize health impacts. When community organizations are engaged, they can often bring additional resources to the table along with knowledge of the target audiences and their needs.

The timing of communication activities is critical. Early summer extreme heat events result in higher mortality and morbidity than do those occurring later in the season. Extra communication efforts are needed early in the season to warn and help protect heat-vulnerable individuals (Health Canada, 2011).

In the report *Assessment of Vulnerability to the Health Impacts of Extreme Heat in the City of Windsor* several vulnerable groups were identified. These include seniors, infants and young children, people living with chronic conditions, people using certain medications, occupational groups and physically active people participating in community and outdoor events (Berry, 2011).

The Stay Cool Windsor-Essex campaign has developed several resources for many of the vulnerable groups identified, however gaps in communication still exist.

The City of Windsor's community centres and pools are a key resource in the Stay Cool Windsor Essex Heat Alert and Response Plan. Not only do they serve as cooling centres but they deal directly with several of the vulnerable populations listed above. These centres offer summer day camps for youth, activities for seniors and programming for physically active individuals. In addition, the recreation department works closely with sports organizations and festival groups renting city facilities.

The City of Windsor has also been successful in securing large sporting events such as the 2013 Children's games and the 2014 Ontario Games. Both of these events will attract individuals that may not be acclimatized to the City's heat and humidity or be aware of heat alert messaging.

During extreme heat events, the most important objective is to influence individuals or groups to take protective measures to reduce the risk of heat related illness.

BENEFIT

The primary benefit of increasing heat-health education is the reduction in morbidity and mortality rates. Heat illnesses are preventable.

BEST PRACTICES

Several Canadian communities are developing interventions to reduce heat-health risks and to prepare for the expected increase in the frequency, duration and severity of extreme heat events due to climate change. The City of Windsor, along with the City of Winnipeg, the Assiniboine Region and the City of Fredericton were fortunate to be selected as pilot communities to develop a heat alert and response program with support of Health Canada. In addition, Health Canada has been working with the Cities of Toronto, Kingston and Montreal to enhance their existing response plans. Other communities across Ontario are also in various stages of development of their own programs.

City of Windsor – Stay Cool Windsor-Essex Campaign As part of the Stay Cool Windsor-Essex campaign, the City of Windsor developed a number of outreach strategies to support three priority communication goals:

Goal 1: Inform residents and visitors of the effects of extreme heat and the actions required to reduce the risk;

Goal 2: Educate residents and visitors about extreme heat events and the measures being taken to protect them from health risks.

Goal 3: Educate emergency responders and service providers about key indicators of an extreme heat event and the necessary policies and procedures for responding to or identifying health effects.

As part of the campaign several tools were developed for distribution including;

- Water bottles;
- Fridge magnets;
- Pharmacy bag inserts;
- Colouring placemats;
- Tip posters; and
- Cards for physically active.

The campaign has been enhanced by the participation of several community partners that have assisted in the distribution of the materials; including Fire and Rescue, Ontario Early Year Centres, Windsor Essex County Health Unit and the City's communication department. Copies of the materials have also been mailed directly to local pharmacies, walk-in clinics, long-term care facilities and day care centres.

Palomar Pop Warner Conference – Game Day Extreme Heat Policy Youth football is played across the U.S. in many areas that experience extreme heat. While it is unusual for San Diego to experience extreme heat, the Palomar Pop Warner Conference has developed a policy to educate coaches and board members. The policy looks at preventive measures to protect participants from heat related illness or even death. Games are not routinely cancelled due to extreme heat but the policy includes consideration for additional breaks, extra water and additional shade requirements. The policy also includes special consideration for games play on synthetic turf.

This extensive policy also includes the ability for officials to cancel games if they feel it is unsafe to play.

CHALLENGES

ON-GOING FUNDING The City of Windsor has been fortunate to receive the financial support of Health Canada to develop the Stay Cool Windsor-Essex Campaign. It is estimated that funding received to date will be significant to continue the campaign through 2014. However, there are no dedicated funds to continue the program after the Health Canada funding is exhausted.

LACK OF SUPPORT The risk and consequences of heat illness are still not as well understood by the public as compared to other extreme weather events such as extreme cold and lightning. Heat related illnesses are often underreported leading to a perception that heat may not be causing issues within a community. Education on the risk of heat needs to be enhanced within the community before action will be taken by various community groups.

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Complete an Urban Heat Island Study

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations ■ Geomatics ■ Planning	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ■ Federal ■ Private

CONTEXT

Climate change and its related impacts such as extreme heat have been identified in the City of Windsor as significant risks to human health. These risks are expected to be heightened in the future, as the number of days exceeding 30°C in Windsor are predicted to triple by 2071-2100. This is significant, as a positive association exists between relative mortality (%) and the daily maximum temperature (°C). Furthermore, many groups in Windsor are especially vulnerable to heat. These groups include: seniors, children and infants, individuals living alone, low income residents, individuals with existing chronic diseases, and individuals who experience high occupational exposure to extreme heat (Berry *et al.,* 2011). Currently, a Heat Alert and Response System (HARS) is in place called Stay-Cool Windsor Essex. This initiative warns individuals about extreme heat events, and provides community members with the resources and information necessary to mitigate heat-related health risks. In order to enhance this strategy for the most vulnerable groups and areas in Windsor, it is recommended to conduct an urban heat island mapping study.

ISSUE

Projections of increased frequency, intensity, and duration of extreme heat events may lead to negative human health outcomes such as morbidity, mortality, and exacerbation of chronic disease (Reid *et al.,* 2009). These health issues may also be increasingly pronounced amongst vulnerable populations. To minimize the risk of adverse health effects, it is therefore necessary to complete urban heat island studies that assess exposure to extreme heat and indicators of socioeconomic sensitivity to yield vulnerability assessments. A generalized depiction of this assessment process can be seen in *Figure 1.*

These assessments will result in an enhanced understanding of the areas where vulnerability to heat is highest. This data can be combined with adaptation information in order to support decision-making and the implementation of heat response plans. This allows for the development of strategic adaptation plans, helping municipalities to allocate their resources to areas with the highest risk.

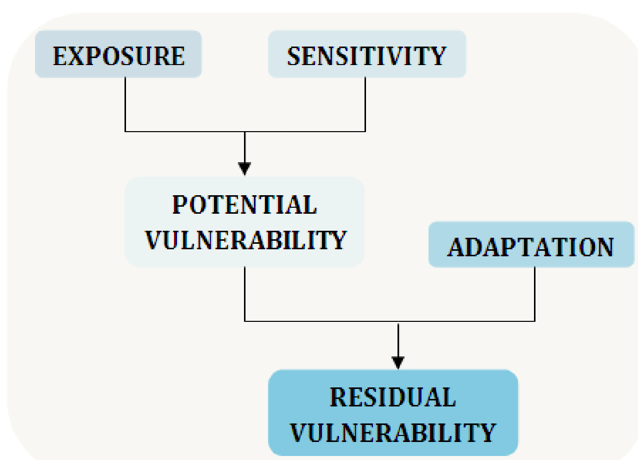

Figure 1: *General vulnerability assessment process*

BENEFIT

Within cities, all populations are not at the same risk to extreme heat, making it important to determine intraurban risk variation using geomatics in order to support decision-making (Reid *et al.,* 2009). Urban heat island studies will result in the production of mapping tools that allow for the identification of Windsor's hot spots. By isolating these hot spots, the City of Windsor will be able to prioritize location-specific actions to reduce them, allowing the municipality to conserve resources. For instance, the frequency and breadth of educational campaigns regarding heat may be heightened in the most vulnerable areas. Through working on efforts to reduce the UHIE and air temperatures within hot spots, this adaptation option may also help to mitigate the increased risk of extreme heat events that is associated with climate change.

Public health intervention strategies such as the presence of cooling centres, community buildings, water distribution, first aid training for community employees, and transportation to cool areas may also be concentrated in high-risk neighbourhoods (Uejio *et al.,* 2011). Furthermore, the City can prioritize the implementation of action items in these areas which are related to urban infrastructure and planning such as the construction of cool and green roofs, use of porous pavement, shade structures, and tree planting.

CO-BENEFITS

IMPROVEMENTS TO HEAT-HEALTH By prioritizing efforts to reduce the urban heat island effect and the adverse impacts of heat in Windsor's hot spots, this adaptation option will help to reduce heat-health vulnerability. Within hot spots, individuals may be more susceptible to negative health outcomes such as: heat cramps, heat exhaustion, heatstroke, increased severity of chronic diseases, and mortality (Uejio *et al.,* 2011). However, the risk of experiencing adverse health effects may be reduced by targeting educational campaigns, public health interventions, and adaptation strategies in vulnerable areas.

BEST PRACTICES

Many urban heat island studies have been completed across municipalities in North America. These studies have been commissioned by a range of groups including government, academic, and non-governmental organizations. The following studies may be consulted to develop a similar methodology for an urban heat island mapping study in Windsor. However, it is important to note that heat exposure and sensitivity indicators used to assess vulnerability should be chosen based on the local conditions of a study area.

NON-GOVERNMENTAL ORGANIZATIONS

Clean Air Partnership – Urban Heat Mapping and Analysis Program (UMAP) Clean Air Partnership is currently developing UMAP in partnership with a range of municipalities in the Greater Toronto Area (GTA). These municipalities include the Region of Peel, City of Hamilton, City of Toronto, and the Town of Ajax. The goal of this program is to enable municipalities to assess the vulnerability of local populations to heat in the GTA, to identify the location of hot spots, and to act as a decision support tool for heat response activities (Behan, 2010). This tool consists of heat-related regional data that can help groups develop vulnerability maps for areas of concern. Data sets included in

UMAP include: demographic data, point data regarding the locations of municipal services, thermal imagery, land use data, street networks, and urban forest data (Behan, 2010). This data can be used by municipalities in conjunction with GIS mapping tools to analyze spatial trends in heat vulnerability, and to develop targeted response programs.

ACADEMIC STUDIES

L. Vescovi et al. – Southern Quebec This study analyzed heat vulnerability in Southern Quebec by utilizing the National Oceanic and Atmospheric Administration (NOAA) vulnerability assessment tutorial and the Environmental Protection Agency's (EPA) guidelines on ecological risk assessment. Overall, the number of socioeconomic indicators used to complete this assessment was minimal, citing only: frequency of people older than 65, frequency of low income earners, frequency of single person households, and frequency of people over 20 with less than a high school education. Data was used to produce two key maps, one illustrating the number of days where temperature exceeded 30°C, and one illustrating the social vulnerability index. These maps were then overlaid to yield a final risk map in GIS demonstrating where the health risk is greatest during extreme heat events. This map was generated for both present and future climate scenarios (Vescovi *et al.,* 2005).

J. Cheng and B. Newbold – Hamilton, ON This study analyzed social vulnerability to heat in Hamilton to identify critical areas for heat response efforts. Data used for this study was obtained from the census. Social indicators used to evaluate vulnerability included: population density, percent of the population older than 85, percent of the population living alone, percent of the population without formal education, percent immigrant population, percent of the population whose first language is not English or French, and percent low family income. It should be noted that the authors only yielded a map demonstrating social vulnerability to heat, and did not combine this data with surface temperature records (Cheng & Newbold, 2010).

D.P. Johnson and J.S. Wilson – Philadelphia, PA
This study examined the relationship between urban heat islands, heat-related mortality, and social vulnerability in Philadelphia, PA in reference to the heat wave during July 3rd-14th, 1993 which led to 118 deaths. The authors combined data on urban heat island intensity and vulnerable population characteristics to develop a linear regression model to predict mortality arising from extreme heat. The authors used Landsat TM imagery to obtain temperature data in conjunction with many indicators of vulnerability such as the percent population that were: Hispanic, Black, Asian, Native American, 65 and over, 65 and over and living below poverty, 5 and under, living below property, and with less than a high school education. The resulting linear regression model yielded predictions of death density per square kilometre (Johnson & Wilson, 2009).

GOVERNMENT STUDIES

City of Toronto - Map-Based Heat Vulnerability Assessment This study is ongoing and is a comprehensive assessment of heat vulnerability that uses decision support maps and multi-criteria analysis. Multi-criteria analysis allows different indicators of heat exposure and sensitivity to be weighted according to their importance in a composite index. Vulnerability indices are the sum of risk factors that will determine if a population will experience an adverse outcome to a phenomenon. The exposure index was developed by evaluating: surface temperature, % tree canopy coverage, distance to nearest green space, proportion of buildings greater than 5 stories, proportion of buildings built before 1986, and population density. Additionally, the sensitivity index assessed: children aged <6 in low income families, low income persons, adults lacking high school education, disability among individuals 25-64, persons not speaking English, low income households that spend >50% of their income on housing, immigrants in Canada since 2006, racialized groups, and emergency visits for respiratory or circulatory disease. Senior's vulnerability indicators mirrored the sensitivity indicators and were assessed separately, but were applied to populations age 65 and over. This distinction was made to yield final vulnerability maps for both the general population and seniors. Finally, a potential vulnerability composite index and map were created to assess overall vulnerability to heat, based on the different weightings of variables in the composite indices *(Figure 2)*. The authors also noted the value of overlaying the vulnerability maps with corresponding point data on adaptation areas such as cooling centres (Rinner *et al.,* 2011).

***Figure 2**: Toronto heat vulnerability (Rinner et al., 2011)*

CHALLENGES

DATA GAPS AND ACCURACY The availability of accurate and current data on indicators of exposure and sensitivity to heat may be limited. For instance, many models exclude health data regarding heat-related morbidity and mortality. While this data exists, it is not comparable with data collected at the census tract level, making it incompatible with demographic data (Behan, 2010). Additionally, representation of vulnerable groups such as the homeless population may be excluded from census data that is commonly used in mapping. There are also concerns about data accuracy and precision. For instance, satellite based temperature measurements may be subject to uncertainty arising from atmospheric conditions and land cover emissivity (Ueijo *et al.,* 2011). Therefore, it may be necessary to validate data using alternative collection methods such as air temperature and humidity probes (Rinner *et al.,* 2011).

LACK OF POLITICAL SUPPORT At the provincial level, the issue of heat with respect to human health is not explicitly mentioned within the Planning Act, and there are no other provincial policy statements that address this risk (Mersereau & Penney, 2008). This makes it difficult for programs to be developed at the municipal level to support geomatics projects concerning heat vulnerability. As a result, there may be knowledge gaps with respect to geomatics practitioners and planners who are not fully informed about the importance of heat-related risks and mitigation strategies. Education may be necessary to facilitate information sharing in order to increase political support for mapping initiatives.

FUNDING Spatial data collection and analysis programs such as GIS software and remote sensing instrumentation have significant costs associated with their use. There are also additional costs required for employees to complete ongoing collection, input, and data analysis (Wilhelmi *et al.*, 2004). This makes it imperative for municipalities to acquire additional funding sources to support long-term mapping projects. Federal funding sources used previously for similar projects include Natural Resources Canada's Regional Adaptation Collaboratives Program and GeoConnections (Mersereau & Penney, 2008). The City of Windsor through the partnership with Health Canada has received financial support to complete the initial mapping study through the summer of 2012.

CONCLUSION

With the support of Health Canada, the Urban Heat Island Study along with vulnerability mapping was completed in 2012. Mapping of vulnerabilities will be completed where possible using the information provided in the "Assessment of Vulnerability to the Health Impacts of Extreme Heat Events in Windsor."

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Develop Clear Policies for Weather Response

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Operations ■ Fire and Rescue Services ■ Community Development and Health	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Windsor's changing climate is expected to result in the increased frequency of severe weather events. Since 1900 the average temperature in Canada has increased by 0.94°C, and an increase in the frequency of natural disasters has also been seen (*See Figure 1)*. In Windsor, these events are most likely to include: extreme heat, winter storms, severe storms and flooding, drought, as well as tornadoes. Such events may cause direct harm to the health and well-being of residents, damage property and infrastructure, as well as disrupt the provision of municipal services.

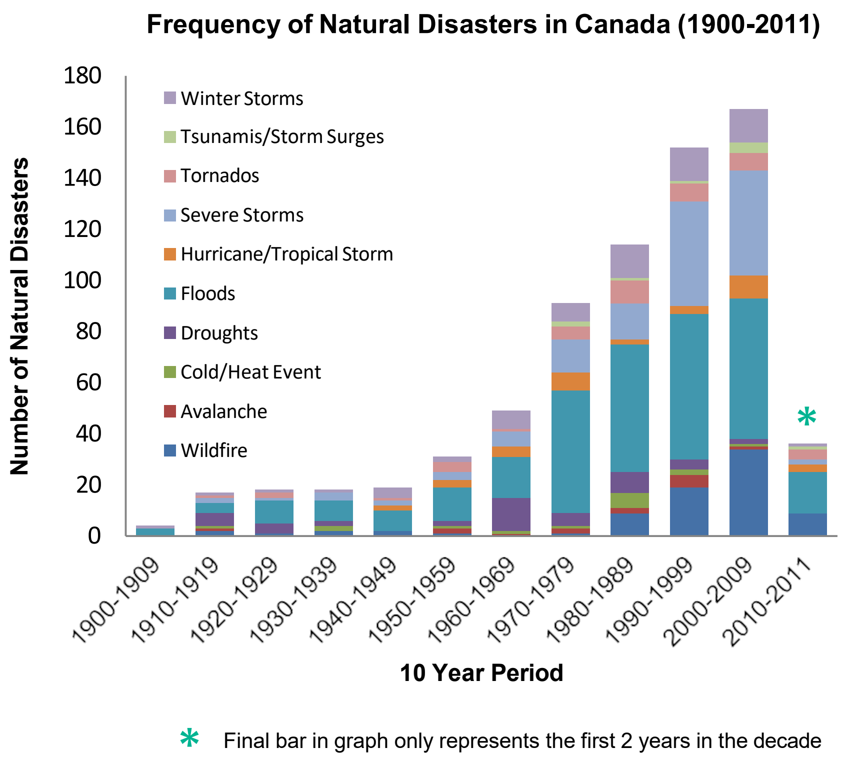

Figure 1: *Natural disasters in Canada from 1900-2011*

To mitigate these adverse impacts and improve the City's resilience to severe weather events, it is recommended that the City of Windsor develops clear policies for weather response. Such policies should enable warnings to take place, clearly describe all roles and responsibilities, outline a communication plan, and contain specific details on plans for interventions, emergency response, and recovery. The City of Windsor currently has an emergency plan for extreme heat in the Stay Cool Windsor-Essex Heat Alert and Response Plan. As well, the City's Emergency Response Plan is enacted for all emergencies that are caused by nature, disease, or accidents, which includes severe weather (City of Windsor, 2009). However, the development of specific policies for individual weather events will result in the most streamlined and efficient preparation, coordination, and response in order to protect human health and physical infrastructure.

ISSUE

Extreme weather poses great risk to human health, with the ability to increase rates of transmission of disease, to cause injury, or to cause fatality amongst affected populations. Additionally, the potential for damage to municipal property, private property, and infrastructure has significant social and economic costs associated with it. Development of clear weather response policies will help to ensure that resources and personnel can be utilized in a coordinated manner to predict and mitigate these risks.

With respect to economic risk, the National Round Table on the Environment and the Economy's (NRTEE) report *"Paying the Price: The Economic Impacts of Climate Change for Canada"* predicts that the costs of climate change will increase from approximately $5 billion to $21-43 billion annually by 2050. Individual costs that must be paid by municipalities may also be extremely significant. For example, the collapse of Finch Avenue in Toronto, ON in 2005 due to flooding led to damages totalling approximately $400 million dollars. Economic costs incurred from weather emergencies may result from: repair of physical damage to facilities and infrastructure, expenditures for response during extreme weather events, and increased insurance premiums (City of Toronto, 2008).

A large variety of municipal services may also be disrupted due to severe weather events. These services include: stormwater management, waste services, parks and facilities, social services, health services, transportation, and utilities. The creation of clear weather policies will ensure that these services are functioning in order to ensure that residents can access the services needed to protect their well-being, and to evacuate when necessary.

BENEFIT

The primary benefit of developing clear policies for weather response is an increase in the resiliency of City departments to respond to major events. By improving resiliency, the municipality will be better enabled to anticipate and respond to risk in order to reduce the number of catastrophic losses resulting from severe weather events (Choi & Fisher, 2003). The City's ability to respond to weather emergencies will be enhanced in a manner that minimizes injuries, fatalities, displacement, property damage, infrastructure damage, service disruption, and economic losses. By developing clear policies for weather response, the amount of time, resources, and money needed to carry out successful emergency response will be conserved, as response plans will be strategically developed (Clean Air Partnership, 2007).

BEST PRACTICES

The following municipal plans and policies represent best practices with respect to weather response planning. For the most part, these plans remain compartmentalized according to different hazard types. However, general policies that outline protocols for severe weather in generally are beginning to emerge as climate change adaptation strategies are developed. While emergency management plans often address severe weather, they have been excluded from the following section as they are universally adopted across municipalities in Ontario due to requirements under the *Emergency Management and Civil Protection Act (2009).*

Best practices are outlined for the following weather scenarios, which are most likely to occur in the City of Windsor:

- All weather
- Extreme heat
- Winter storms
- Flooding

ALL WEATHER

City of Toronto – WeatherWise Partnership

The WeatherWise Partnership was founded in 2011 as a collaboration between the City of Toronto, CivicAction, and approximately fifty other public, private, and non-profit groups. The purpose of the WeatherWise Partnership is to protect residents, infrastructure, organizations, and the environment from the adverse effects of severe weather. The mandate of the Partnership is to identify the primary economic, social, and environmental risks associated with extreme weather, and to develop a strategic action plan to minimize these risks. Key areas they seek to address include: the provision of electrical power during severe weather, urban transportation, flooding, and urban heat. While the project is in its infancy, a strategic action plan is expected to be unveiled at a regional forum at the conclusion of 2012 (City of Toronto, 2012).

EXTREME-HEAT

Middlesex-London Health Unit (MLHU) – Extreme Temperature Protocol

This protocol is carried out by multiple members of the Extreme Temperature Network which includes the MLHU, Canadian Red Cross, Community Health Centre, local hospitals, London Hydro, Fire Services, London Police Service, OPP, and London Transit, amongst others. Heat intervention strategies under this protocol include: opening cooling centres, operating an information line, distributing educational information to vulnerable groups, carrying out the Middlesex London Housing Corporation's 'Check Your Neighbour' campaign, and coordinating outreach services to the homeless (Clean Air Partnership, 2007).

City of Montreal – Heat Health Warning System

This heat response system is a coordinated effort between the Civil Security Centre, Director of Public Health, and the Emergency Preparedness Centre. Response activities related to this plan that are enforced during heat emergencies include: opening air-conditioned cooling centres, keeping splash pads and pools open for extended hours, distributing water, juice, and popsicles to citizens in need, providing transportation services to bring individuals to cooling centres, a communication plan, and a door-to-door initiative to identify vulnerable people who require transportation to cooling centres (Clean Air Partnership, 2007).

City of Toronto – Hot Weather Response Plan

This plan was developed amongst a large number of partners including: Toronto Public Health, Canadian Red Cross, Toronto Community Care Access Centres, Toronto Emergency Medical Services, Toronto Office of Emergency Management, Toronto Police Services, Environment Canada, and the Toronto Housing Corporation. As part of the plan, when Heat Alerts are called, many different heat intervention strategies are implemented to prevent negative health effects. Some of these strategies include: opening cooling centres, issuing media alerts, providing homeless individuals with free TTC token to facilitate transportation to cooling centres, helping to develop on-site plans for lodging and group homes, distributing heat-health brochures, operating a public information telephone line, delivering bottled water, and extending the hours of City pools (Clean Air Partnership, 2007).

Other Greater Toronto Area (GTA) municipalities such as the Town of Oakville, City of Burlington, City of Brampton, City of Pickering, Town of Markham, Town of Ajax, and the Township of King have similar response plans, but with less robust intervention strategies. In the cases of these municipalities, their strategies are generally limited to extending pool hours and opening cooling centres (Clean Air Partnership, 2007).

WINTER STORMS

Greater Victoria – Extreme Weather Response PLAN (EWRP) The EWRP is a collaborative strategy between the City of Victoria, District of Saanich, Township of Esquimalt, BC Housing, Vancouver Island Health Authority, and various community organizations in the Greater Victoria area. The purpose of this strategy is to coordinate a response to meet the shelter and resource needs of the homeless during periods of extreme weather. The EWRP is activated when the Regional Coordinator makes the decision that current weather conditions are severe enough to pose a significant threat to the health and life of homeless individuals. Weather patterns that may trigger the plan are characteristic of winter weather and include: near zero temperatures combined with excessive rain, sleet or freezing rain, snow accumulation, high winds, or temperatures below -2°C (Victoria Extreme Weather Protocol, 2011).

Upon activation of the EWRP, alerts are issued, community partners begin their emergency operations, volunteers are deployed at the Red Cross, the *www.vewp.ca* website is updated, assistance from emergency services is provided, free transportation to shelters is initiated, and the media helps to inform the public of the extreme weather event. All shelters undergo routine inspection and are equipped with trained staff, first aid kits, emergency phone access, sleeping materials, protective materials, and bio-hazardous waste disposal containers (Victoria Extreme Weather Protocol, 2011). Similar plans are in place for many other municipalities in the Greater Vancouver Area.

Kingston, Frontenac and Lennox & Addington (KFL&A) Public Health – Cold Weather Response Plan The Cold Weather Response Plan for the City of Kingston and adjacent communities in Frontenac Country was developed by KFL&A Public Health. The plan outlines actions for four stages of possible winter conditions including: routine conditions, cold alerts, cold warnings, and cold emergencies. Responsibilities for implementing the plan are divided between the City of Kingston and KFL&A Public Health.

If temperatures are -15°C or lower, a cold weather health alert will be issued. Response actions taken during cold alerts include: disseminating public health messages on tips to stay warm, checking on elderly individuals and people with disabilities, opening warming centres, and providing transportation to warming centres. Cold warnings will be issued if temperatures are -25°C or colder, or if the wind chill is -28°C or colder. The response activities for this warning level are the same as those implemented for cold alerts.

A cold emergency is issued if temperatures are at or below -35°C or if a wind chill of -55°C or lower is reached. The previously listed services provided during cold alerts and warnings continue to be available. However, in addition, all individuals are advised to stay indoors, a Citizen Inquiry Centre may be opened, an extensive transportation system will be activated to move people to warming centres, and the City of Kingston's Emergency Plan may be activated.

FLOODING

While flooding in itself is not a weather phenomenon, it is included in this summary as natural flooding is often invoked due to weather conditions such as heavy rains and warm spring temperatures that result in snowmelt.

City of Chilliwack – Fraser River Flood Response Plan The City of Chilliwack encompasses floodplain areas along the Fraser River in British Columbia. To mitigate the risks associated with flooding, a protection plan exists that aims to both prevent flooding, as well as to ensure that evacuation plans are in place. With respect to flood prevention, the City of Chilliwack has built a network of dykes in order to minimize the risk of flooding. Routine monitoring and maintenance is also carried out to ensure that the dykes are effective. The City also employs consultants to conduct modelling in order to inform their decision-making on the design modifications necessary to reduce the risk of flooding. Based on a study completed in 2008, significant portions of the dyke network required upgrading and subsequent improvements have been made along large portions of the dyke network.

To inform flood evacuation procedures, the City monitors water levels relative to the dyke network as well as Mission Gauge readings that monitor the water levels within the river banks. Based on these readings, flood evacuation and dyke patrols may be initiated. Updates regarding water levels are posted on the City's website, Twitter, and Facebook page. They also have an information hotline that can be called by residents seeking information on flood hazards.

The City of Chilliwack carries out a three stage evacuation process when flooding occurs. The first stage is the issuance of an evacuation alert which informs people in a designated area to be prepared to leave their residence on short notice. If flooding is suspected to potentially cause injury or death an evacuation order will be issued. This order will be communicated using electronic media as well as delivery by emergency services personnel. Individuals in affected areas are instructed to proceed along suggested routes to reception centres, and are then directed to an evacuation centre. The final stage of the evacuation process occurs when the order is rescinded and individuals are instructed to return home (City of Chilliwack, 2012).

City of Greater Sudbury – Community Flood Management Plan The Community Flood Management Plan was designed to outline the necessary procedures for flood preparedness and response in Sudbury, a coordinated effort between the City, province, and the Nickel District Conservation Authority. The City is at risk of flooding due to snowmelt, spring rainfall, severe storms, ice jams, dam failures, and water main breaks. Adverse impacts that may result from flooding include: loss of life, injury, property damage, utility failures, communications failures, structural damage, erosion, food and water shortages, public health risks, traffic disturbance, and impairment of emergency service delivery. The plan outlines the roles and responsibilities of all parties involved with flood response, communication strategies, and the procedures used to minimize the adverse impacts of flooding in Sudbury.

When flooding occurs, a large number of actions are carried out by the responsible agencies in order to fulfill two key priorities. The first priority is to protect the safety and well-being of responders and the public. The second priority is to protect public infrastructure such as water systems and communication infrastructure. Responsibilities associated with these two priorities include: activation of the Community Flood Management Plan, activation of the Municipal Emergency Response Plan, liaison with federal, provincial, and community partners, providing assistance to displaced residents, providing transportation, acquisition of emergency response resources, providing information to the public, inspecting evacuated areas, undertaking flood response, monitoring health, conducting rescues, and restoring City services (City of Greater Sudbury, 2012).

CHALLENGES

COMMUNICATION Clear and transparent communication is necessary to ensure that all parties involved in weather response strategies coordinate their actions to minimize the further propagation of hazards to humans, property, and the natural environment. It is also necessary to ensure that the public are alerted regarding severe weather events, necessary response strategies, and evacuation protocols.

Due to the large number of agencies and volunteers that have the potential to be involved with weather response planning, it is vital for such plans to clearly define all roles and responsibilities. Weather response plans should also appoint specific individuals as liaisons in order to collaborate and share information with other groups and government levels. Plans should also be in place to utilize a wide variety of communication channels should one or more of them fail. Such channels include: television, radio, cellular phone lines, landlines, the internet, and in person.

HARMONIZATION Responsibility for the monitoring and implementation of emergency response plans is shared between federal, provincial, and municipal bodies, leading to potential harmonization issues. With respect to severe weather, Environment Canada has a key role in forecasting weather emergencies. As well, the provincial government can declare an emergency and act according to their *Provincial Emergency Response Plan*, as well as through the involvement of Emergency Management Ontario. Non-governmental bodies such as hospitals and schools may also have their own plans in place.

As a result, it is necessary for municipal level weather response plans to clearly outline how their implementation will proceed in collaboration with other actors and agencies. With respect to Windsor specifically, it will be necessary for the *Emergency Response Plan* and any additional severe weather plans to be coordinated in order to most efficiently allocate personnel and resources for disaster response (Oven *et al.,* 2011).

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Create an Extreme Weather Reserve

DEPARTMENT	ADAPTATION TYPE	DRIVER	FUNDING SOURCE
■ Finance ■ Legal (Risk Management Division)	☐ Building Adaptive Capacity ■ Delivery of Adaptation Options	☐ Reactive ■ Anticipatory	■ Municipal ☐ Provincial ☐ Federal ☐ Private

CONTEXT

Within Windsor, climate change is expected to result in an increase in the frequency of extreme weather events. This trend has already been documented in Canada, and a clear upwards trend in the number of natural disasters per decade can be seen *(See Figure 1).* Severe weather events that are likely to increase locally due to climate change include: extreme heat and cold, winter storms, severe rain, high winds, flooding, and drought. Notable events that have occurred recently in the City of Windsor include: record breaking snowfall from 2004-2005, a total of 47 days over 30°C in 2005, and the greatest amount of precipitation on record in 2011.

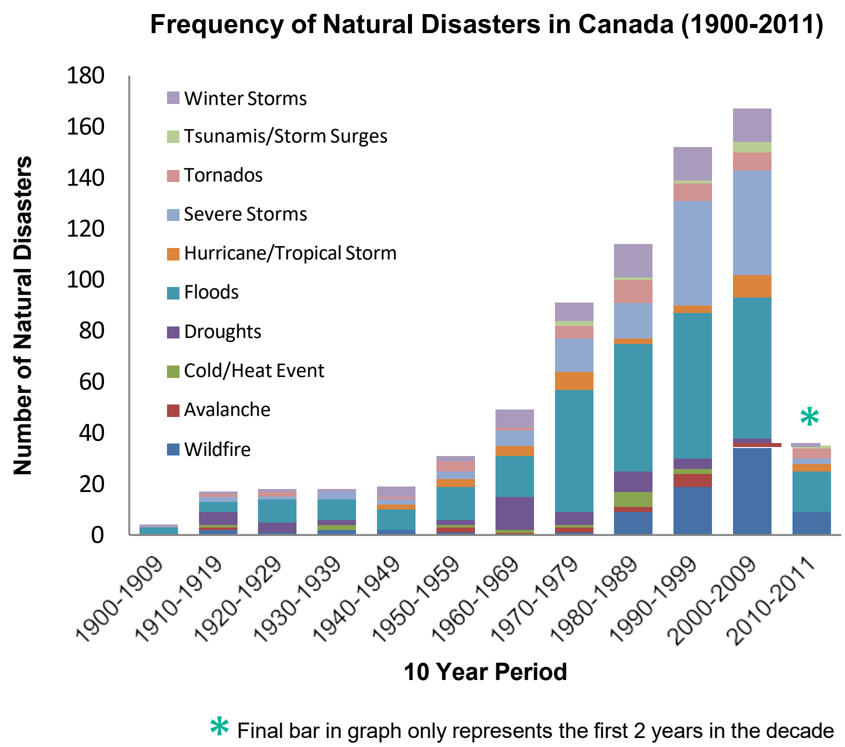

Figure 1: *Natural disasters in Canada from 1900-2011*

Severe weather events may cause considerable damage to infrastructure, property, and disrupt City services. As a result, these events are often associated with large unanticipated operational expenses that fall outside of projected budgets. These costs may be especially high if damage is caused to infrastructure that is not covered by the City's insurance. In order to mitigate these unexpected operational expenses, it is recommended that the City of Windsor creates an extreme weather reserve fund. This reserve will help minimize the economic losses the City may incur in responding to and cleaning up after severe weather events.

ISSUE

As the number of extreme weather events increase in the future, it is also expected that the City will have to pay increasingly high costs to respond to weather emergencies, repair damage, and to restore services. Potential expenses may be incurred in order to: repair City parks and infrastructure, replace infrastructure, clean-up and replace trees, remove snow and debris, coordinate public health and emergency plans, and to provide shelter and support services.

Additionally, municipal governments may be faced with increased insurance costs in the future as insurance companies begin to charge premiums for climate related risks. Furthermore, depending on a municipality's specific policy, their insurance may not cover all possible infrastructure and property that may incur damage. For instance, the City of Toronto's property insurance policy does not cover the City's roads, bridges, sewers, culverts, pipes, ravines, and landscaping. As a result, the City has incurred significant expenses for events such as the burst water lines that caused the Finch Avenue West bridge collapse, causing approximately $400 million in damages paid by the City (City of Toronto, 2008).

The City of Windsor currently has a Budget Stabilization Fund (BSF), which is in place to offset unexpected deficits, which could include unbudgeted expenses created due to severe weather.

BENEFIT

The primary benefit of this adaptation option is to minimize the unexpected financial impact on the City's Operating Budget due to severe weather. The creation of the reserve will ensure that the City can pay for unforeseen weather response activities as well as any damages that are not covered by insurance. This will ensure that the City of Windsor does not experience large cost over-runs or deficits resulting from the unplanned use of Operating Budget funds.

BEST PRACTICES

While the creation of extreme weather reserves is not yet widespread in Canada, the following municipalities currently have reserve funds in place:

- Burlington
- London
- Toronto

City of Burlington – Severe Weather Reserve Fund The Severe Weather Reserve Fund evolved in 2010 from the former Winter Control Reserve Fund. The purpose of the fund is to alleviate the impact of unexpected costs arising from severe weather events. Through establishing the new reserve, the scope of the initial fund was broadened to include severe weather events that occur during all seasons, providing greater financial security. All money that existed in the Winter Control fund was transferred, and a target for the new reserve fund was set at a five-year rolling average of winter control costs (City of Burlington, 2012). The fund is supported by budget surpluses as well as interest that is added annually from the City's General Investment Fund (City of Burlington, 2010a; City of Burlington, 2010b). For instance, in 2010 a $9.3 million budget surplus resulted in this fund being allocated $530,000. As of August, 2011 the balance in the reserve fund was $3,083,550 (City of Burlington, 2011).

City of London – Severe Weather Reserve Fund The City of London created an Operating Budget Contingency Reserve to be used for additional and unexpected operating budget expenses resulting from severe weather events (City of London, 2010). However, unlike both Burlington and Toronto, the reserve is only used for severe winter weather. The initial funding allocated to the fund was $500,000 in 2007 (City of London, 2007). Future generation of funds for this reserve are taken from surpluses from the Environmental and Engineering Services Department during years when winter storm intensity is diminished (Clean Air Partnership, 2011).

City of Toronto – Extreme Weather Reserve Group The City of Toronto created the Extreme Weather Reserve Group following recommendations made in a staff report titled, "Funding Strategies to Mitigate Financial Impacts on the City Due to Extreme Weather Conditions." The reserve was recommended as a risk management tool to address the increasing volatility of extreme weather. The City of Toronto predicted that budget over-expenditure due to severe weather could be as high as tens of millions of dollars annually.

Unlike the City of Burlington and the City of London, their reserve group contains separate accounts for different weather-related risks. These accounts include Parks, Forestry and Recreation, as well as Transportation Services. Initial contributions to the reserve came from the former Winter Control Stabilization Reserve. Continued contributions to the reserve are made if there are budget surpluses (City of Toronto, 2008). As of March 2010, the Transportation Services account contained $19.1 million dollars (Clean Air Partnership, 2011).

CHALLENGES

FUNDING ALLOCATION One of the primary challenges associated with reserve funds is ensuring that they receive appropriate amounts of funding to cover unforeseen financial obligations arising from severe weather. As reserve funds are primarily created through the allocation of money from budget surpluses, the persistence of such funds is dependent on municipalities generating annual revenues. As a result, the future status of reserve funds may be uncertain depending on changes in economic conditions (Clean Air Partnership, 2011).

Additionally, it is common for unused reserve funds to be accessed to cover unrelated municipal expenses, resulting in the purpose of such funds remaining unfulfilled. This has been as issue with respect to the City of Toronto's Extreme Weather Reserve Fund. For instance, upon creation of the fund, the initial amount ($4.816 M) expected to be contributed to the Parks, Forestry and Recreation component of the reserve was reallocated due to corporate budget pressures. Additionally, in 2010 no surplus funds were added to Toronto's reserve as it was used to offset corporate budget pressure in order to attain a zero tax increase in the City.

DETERMINING APPROPRIATE LEVELS FOR RESERVE FUNDS Due to variability in weather events and their related damages, it is difficult for municipalities to predict the appropriate levels for reserve funds to be set at. This may result in a shortage of funding to cover weather-related expenses when they arise, or surpluses that may have been better allocated to another component of City budgets. Therefore, it is important for staff to continue to refine their estimations of financial requirements based on previous City expenditures and historical weather data (City of Toronto, 2008).

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