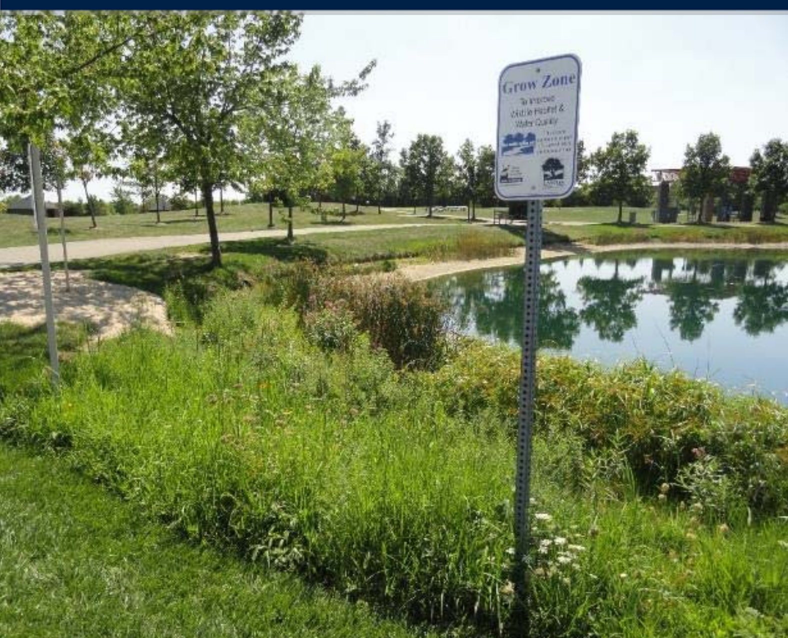
Environmental Impacts of Water Withdrawals & Discharges in Six Great Lakes Communities:

A Role for Green Infrastructure

Prepared for: GREATER LAKES

Reconnecting the Great Lakes Water Cycle



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Preface

Sustainable management of human activity in the Great Lakes and St. Lawrence River system is critical to protect and restore ecosystems, maintain the economic health and vitality of the region, and ensure the livelihood of the millions of people who live here. Challenges continue to threaten the quality and quantity of this freshwater treasure, including a broken water system characterized by aging water, wastewater, and stormwater infrastructure; a legacy of poor land use planning; wasteful behaviors towards water use; and a siloed approach to water management.

Municipalities are on the frontlines when it comes to the Great Lakes and St. Lawrence River, and are uniquely positioned to have a positive effect on this ecosystem through a shift in their approach to water management.

The Greater Lakes: Reconnecting the Great Lakes Water Cycle project, a project of the Great Lakes Commission and supported by the Great Lakes Protection Fund, is exploring and testing environmental and financial rationales for municipalities to adopt water conservation/efficiency and green infrastructure measures. This binational project focuses on six communities: Commerce Township, Lyon Township, and Southwest Oakland Township, all located in Oakland County, Michigan; and the cities of Guelph and Waterloo, and the Region of Waterloo, all located in Ontario.

During this project, we carried out two detailed technical analyses of all six municipalities. One of our project partners, Environmental Consulting & Technology, Inc., prepared a document on the six municipalities entitled ***Environmental Impacts of Water Withdrawals and Discharges in Six Great Lakes Communities: A Role for Green Infrastructure***. The Alliance for Water Efficiency, one of our other project partners, prepared a companion report entitled ***Improving Water Conservation & Efficiency in Six Great Lakes Communities***. Both reports are available on the Greater Lakes website (http://glc.org/projects/water-resources/greater-lakes/).

Our purpose was to learn what will be the greatest benefit - not just to those selected six municipalities - but to all municipalities around the Great Lakes and St. Lawrence River basin. On the *Greater Lakes* website, you will find materials we are confident will help municipalities and concerned citizens evaluate how water is managed in their communities and to carry out actions that will help you achieve your local goals.

The main lessons we learned from these detailed analyses and our other work on this project is that we must develop a more integrated, holistic approach to water management in order to restore the water system to a more natural condition that will better serve both human needs and the needs of wildlife and other parts of the ecosystem.

-- John Jackson, Project Manager, Greater Lakes: Reconnecting the Great Lakes Water Cycle

TABLE OF CONTENTS

Section **Page**

List of Figures

List of Tables

1.0 INTRODUCTION

1.1 Overview

The *Greater Lakes* project was funded by the Great Lakes Protection Fund and sought to positively influence innovation in water resources management at both the water withdrawal and use stage and at the sewage disposal and stormwater discharge stages. The products are aimed at providing guidance and tools to communities seeking innovative and cost-effective solutions to water resources management.

The results of the initial studies are captured in two reports. This report focuses on the environmental impacts of water withdrawals as well as the appropriate discharge of stormwater/wastewater. An accompanying report titled *Improving Water Conservation & Efficiency in Six Great Lakes Communities* focuses on water conservation and efficiency measures and impacts in Great Lakes communities. Both reports and the supporting tools are available on the Greater Lakes website (http://glc.org/projects/water-resources/greater-lakes/).

This report summarizes: 1) the practices that negatively impact regional water resources, 2) how green infrastructure can minimize the impacts of development, and 3) the expected environmental benefits that would be realized with large-scale, regional implementation of green infrastructure.

To test the hypothesis, an analysis was performed in six pilot communities, three in Canada and three in the United States. The analysis provides insights into the larger benefits that can be achieved through the use of effective stormwater management and best management practices (BMPs). By quantifying the full range of environmental benefits and financial outcomes, and employing innovative knowledge transfer strategies, key decision-makers are provided the tools to begin to improve their current water resources practices.

In many parts of the Great Lakes region, the greatest risks to the lakes are contaminated stormwater runoff and contamination from sewage overflows. Climate change is likely to exacerbate these challenges. Fortunately, both challenges can be mitigated with appropriate stormwater management. The environmental impacts of inappropriate water use can be substantial. Allowing unregulated (or under regulated) water withdrawal for human use encourages over-pumping of aquifers, which, in turn, draw water from wetlands, streams, and lakes. Diverting river water or groundwater through the built infrastructure for discharge elsewhere alters the surface water quantity and quality and thereby disrupts the natural flows through streams, rivers, and lakes. This can destroy habitat and disrupt wildlife that depend on that habitat. In addition, uncontrolled stormwater runoff contributes to increased sewage discharges, polluted stormwater runoff, and combined sewer overflows (CSOs), which are all significant threats to Great Lakes health, including human health.

The Greater Lakes project worked with local public works professionals to assemble information on six communities and identify the water management strategies that would: 1) determine how water withdrawal/water use could better protect, conserve, restore, and improve water-dependent natural resources, and 2) determine how that water, once used, could best be returned to the natural environment in a manner and place that provides long-term, sustainable water resources.

Water efficiency improvements reduce water use, water withdrawals, and environmental impacts of this use (as is reported in the companion report *Improving Water Conservation & Efficiency in Six Great Lakes Communities*). However, water efficiency improvements alone would only provide limited improvement to the environment of the six studied communities. The Ontario communities already implemented significant water use restrictions, and the Oakland County communities implemented new plumbing codes in the early 1990s mandating water conserving fixtures and appliances. Of all of the policies identified, only reduction of outdoor water use will likely see an impact on the levels of the groundwater levels in the well head areas.

This project outlines the environmental impacts of water use withdrawals from the six case study communities, and uses these estimates to extrapolate the regional impact of green infrastructure on a large scale. This report also focuses on environmental impacts of green infrastructure implementation. The companion report prepared for the project by the Alliance for Water Efficiency focuses on cost-effective water efficiency improvements.

2.0 BACKGROUND ON WATER USE IMPACTS

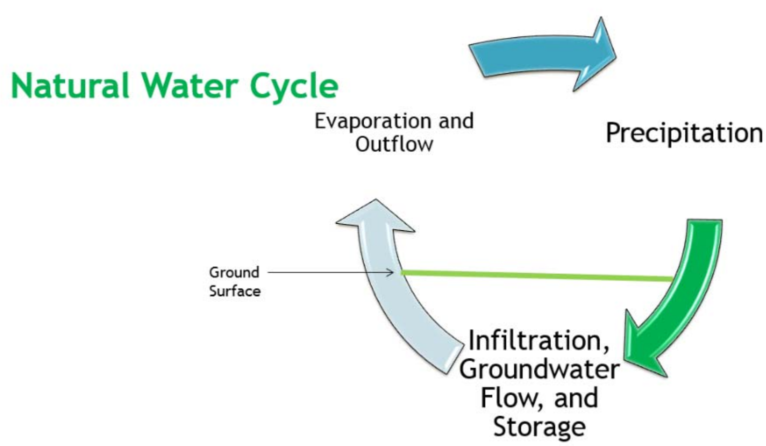
2.1 Impacts on the Water Cycles

The hydrologic cycle is the foundation of effective water resources management. The natural water cycle calls for precipitation to fall on undisturbed land where the majority infiltrates the soil; the groundwater provides enough water supply to support plant life before flowing to streams and rivers. In rare events in which the precipitation rate exceeds the infiltration rate, the excess water – the surface runoff – travels slowly toward a water course impeded by plants and natural obstacles. The slow rate at which the water travels allows additional infiltration and slow rising surface water discharges.

Humans have disrupted this natural cycle in two primary ways: 1) by withdrawing water from the groundwater and/or surface water to be discharged in a different location, and 2) by reducing and/or eliminating infiltration by constructing impervious surfaces and halting the natural infiltration/drainage patterns. Both of these disruptions seemed necessary to support modern life; however, we have come to realize that our systems can be managed and/or designed to provide for human needs and wants with minimum impact to the hydrologic cycle and a substantial reduction in negative environmental impacts.

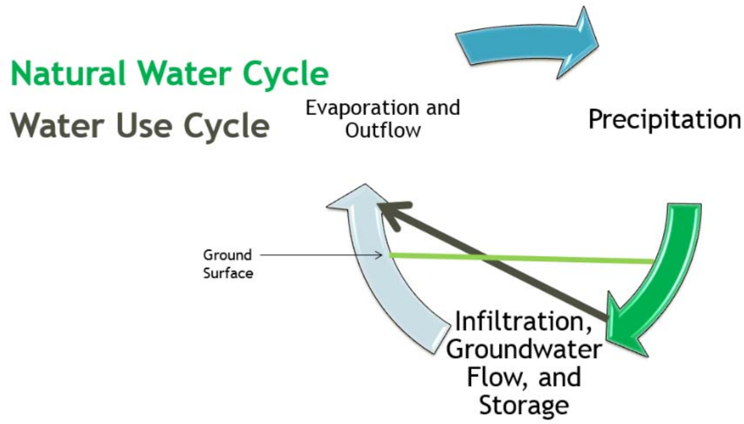
This report focuses on restoring the hydrologic cycle by identifying ways to limit inappropriate withdrawals, cost effectively reducing peak runoff, and increasing infiltration – primarily through the use of green infrastructure. AWE's companion report focuses on reducing the use of domestic water and thereby minimizing the need for costly system upgrades and larger water withdrawals.

Effective water management begins by recognizing the various paths through which water travels. Mankind's impacts on these pathways support development but also limit long-term sustainability. These pathways can be characterized as the natural water cycle, the water use cycle, and the interrupted water cycle.



The **natural water cycle** supports the continuous movement of water on, above, and below the surface of the Earth. Water falls on the ground through precipitation and the majority will infiltrate the ground contributing to the stored groundwater supply. This groundwater provides support to the environment dependent on groundwater or percolates to streams and provides stream base flow. When precipitation exceeds the natural infiltration rate, the excess water flows over land downstream to streams, rivers, lakes, and oceans. Some portion of this water is returned to the atmosphere through evapotranspiration of plants and evaporation from land and water surfaces. The water in the atmosphere subsequently condenses and once again becomes precipitation falling to the Earth's surface.

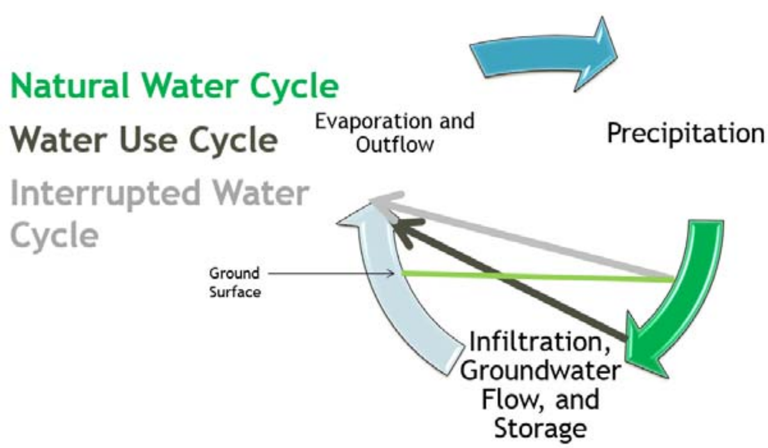
The **water use cycle** interrupts the natural water cycle to withdraw water for human use. It is withdrawn though a piped system from a groundwater or surface water source. It is typically treated, distributed, and consumed by customers. Often the water is discharged to a second location not connected to the water source. It is typically discharged to a wastewater collection system connecting to a wastewater treatment system; the treated effluent is discharged to a receiving stream (or to a groundwater receiving site) far from where the water was initially extracted.



The water use cycle shifts water volumes from the source water location to the receiving water location without benefit of the natural cleansing and recharge. This can have negative impacts on the natural water resource. At the point of withdrawal, there is less water to support other functions, and, in the case of groundwater, the impacts can be substantial if water is withdrawn more rapidly than it is replaced (through recharge). In the wastewater discharge location, more water is made available providing increased stream flow on a continuing basis, but it can also increase the loading of some constituents – particularly nutrients.

The **interrupted water cycle** further affects the natural water cycle by shunting precipitation over pavement or other impervious surfaces where it is directed to a piped stormwater collection system directly to a river. The result is further stopping the groundwater recharge exacerbating the environmental impact on the natural systems.

In separated storm sewer areas, stormwater is transported in one series of pipes separate and distinct from the sewage collection system. While this helps limit the pathways for human sewage from entering the drainage system, stormwater can still wash oil, grease, litter, and other contaminants from streets into the stormwater collection system and rush those pollutants into nearby streams and rivers. Pre-development, the stormwater would have stayed at the location where it fell and infiltrated the ground and



become part of the natural water cycle. Instead, the stormwater and contaminants are shunted into streams where it delivers the urban wash off and causes accelerated erosion in the stream channels.

2.2 Impacts of Water Withdrawal, Use & Conservation

The impact of water withdrawals becomes a concern to local water suppliers when the rate of withdrawal exceeds the replacement of that water. This can lead to both water quantity challenges (shortages) and negative environmental impacts. Water conservation reduces extraction, treatment costs, transmission costs, and the negative environmental impacts that may result from each. Identifying the exact impacts is based on a water use or water withdrawal and other factors including:

- Type of water supply used (e.g., Great Lakes, shallow groundwater, confined groundwater, or surface water)
- Local hydrology and the ability to replace withdrawn water
- Development patterns and the impact of the natural hydrology
- Upstream water use
- Stormwater management system design and wastewater discharge location

Public water supplies move water from one location to another causing impacts in both locations. However, the environmental impacts of every withdrawal is different. As an example, water withdrawal of any amount will have different impacts depending upon whether it is drawn from the Great Lakes, groundwater, or surface water:

- A withdrawal of one million gallons per day of Great Lakes water will have no measurable impact on the surface water levels of a Great Lake. Because of public policy, it is assumed when water is withdrawn from the Great Lakes, the treated wastewater returns to the Great Lakes system.
- A withdrawal of an identical one million gallons of shallow groundwater is likely to have a larger impact on water availability since groundwater moves slowly and can be withdrawn faster than it is replaced. This has the potential to lower local groundwater levels reducing the available water for surface environments, like lakes, streams, ponds, and wetlands with concomitant environmental impacts.
- A withdrawal of an identical one million gallons of deep groundwater may have little impact on nearby surface water levels (i.e., lakes, streams, ponds, and wetlands) but it can impact the availability of groundwater for other uses.
- A similar withdrawal from a river source can reduce the water level and flow of a stream at the withdrawal point, impact its natural conditions, and affect the water-fed ecology and environment. The impacts will be different based on the size, depth, and flow of the stream. Michigan, like most states, has water withdrawal regulations to limit in-stream water quantity and quality. Similarly, the Permit to Take Water (PTTW) program, regulated under the Ontario Ministry of the Environment, requires a permit for withdrawals greater than 50,000 litres of water per day, excluding firefighting and agricultural livestock purposes.

The water, once withdrawn for domestic supply, is treated and transported through the water distribution system to residents and businesses. Most often, it is then collected and transported to the wastewater treatment plant. This movement of water through a man-made water system shifts water from its withdrawal point to a location where treated wastewater is discharged back to the environment. This reduces infiltration as well as reduces low flows between the point of withdrawal and the point of discharge. Both of these changes serve to reduce water depth, increase water temperature, increase the negative impact of sediment oxygen demand, and generally degrade the water quality.

Some water bodies have large assimilative capacities and thus less wastewater treatment is required. Other, more sensitive, areas require costly, advanced wastewater treatment. Besides the water quality aspect of the discharge, the water quantity can impact the hydrology of the receiving area – i.e., whether the discharge is to the Great Lakes themselves, streams of different sizes, or to the ground. Wastewater effluent discharges, while not pristine, can provide additional flow to a stream that can help provide base flow during droughts. Wastewater effluent discharge also does not increase flood risk because its volume is very small relative to stormwater runoff during large rain events that drive flood events.

In addition to managing the drinking water source more efficiently, innovative management of stormwater runoff can save costs and help reduce hydrologic impacts. Best management practices (BMPs) can be implemented to reduce and conserve water used by municipal customers as well as reducing the amount of water flowing back into streams and/or returning to a different water source than from whence it came. This problem is acute in urban areas where there are large amounts of concrete and pavements, which inhibit natural water recharge.

2.3 Economics of a Disrupted Natural Water System

The economic benefits of the natural water system is difficult to quantify. Certainly, the availability of clean drinking water is critical for development. Also, waterside development generally has greater value than inland development; however, it is hard to quantify the importance of a stream or water source to a community. For example, what is the expected increase in property values for waterside locations? What is the cost of flooding? What is the value of sport fishing or a fishing industry? What is the cost to a community of allowing a cold water stream to degrade to a warm water stream incapable of supporting a valued fishery? Although some of these questions can be easily quantified in monetary term, others can only be described as costs of non-monetary societal repercussions.

Flooding is regularly quantified by both the United States government and the insurance industry. Flooding causes billions of dollars in damage to structures, facilities, agriculture, and public and private lands every year in the United States and Canada. The average cost of flood damage between 1983 and 2012 in the United States is estimated to be $7.98 billion (NOAA & NWS, 2013) per flood event. The cost of flooding includes the cost of installing infrastructure for flood prevention.

The “added” value of a natural stream is more difficult to quantify, particularly if the stream is to be viewed as something greater than a drainage course. Standing water is viewed as a cost to a community whether it is an aesthetic issue, a flooded parking lot, impassible roads, or flooded basements.

Urbanization brings impervious areas that also deliver excessive (and often warm) water in a very rapid manner. The excessive stormflows cause streams to erode, widen, and result in wide, flat, warm streams. In addition to physical degradation, the ecosystem is damaged as a result of the warmer water. Warmer water cannot hold as much dissolved oxygen, which is detrimental to cold-water-adapted species – notably trout. Together, these alterations impair cold water streams and impact the habitat of cold water fishes and aquatic life of streams and lakes.

There are also significant economic impacts of hydrologic alterations on the fisheries in the Great Lakes. The U.S. Fish and Wildlife Service determined that in 2010, a combination of the service, state and tribal agencies, and conservation authorities produced 68,000 jobs and $3.6 billion revenue to the nation's economy in fisheries programs (Caudill & Charbonneau, 2010). The U.S. Fish and Wildlife Service also determined a $28:$1 return on investment (U.S. Fish and Wildlife Service, *Net Worth. The Economic Value of Fisheries Conservation*, 2011).

Specifically in in the Great Lakes region, the Midwest Region Fisheries Program contributed largely to this revenue. There were $6.9 million operation investments resulting in a $193 million return on investment within five national fish hatcheries, which distributed 16.4 million fish and 28.2 million fish eggs of native species (U.S. Fish and Wildlife Service, *Fisheries FY2010 Highlights Region 3 - Midwest Region,* 2011). There are also six Fish and Wildlife Conservation offices that contributed $8.2 million in investments, $229.6 million return on investment, and two sea lamprey control stations with $11.5 million investments in 2010 and a $322 million return on investment. Similar information was requested from the Ontario Fish and Wildlife Services branch of the Ministry of Natural Resources and Forestry but it is not publicly available.

The economic significance of freshwater fisheries to the country is now being affected by water use and climate change impacts. Abt Associates conducted a study for the United States Environmental Protection Agency (EPA) to assess the national economic challenges to freshwater fisheries due to climate change impacts (Bell, et al., 1995). The study implemented thermal and economic models and found by the year 2100, all cold and cool water stream fishing opportunities could be lost in 10 states, and another 17 states would lose over 50 percent of their cold water streams. This will lead to losses in cold water species, such as trout. The economic losses of recreational fishing by 2050 is estimated to be $320 million annually. The model also examined changes in climate-induced runoff using simplified assumptions on runoff volume and seasonal variations. The economic losses from climate-induced runoff are between $4 million and $1 billion per year.

3.0 THE IMPACT OF HYDROLOGIC ALTERATIONS

3.1 Potential Groundwater Withdrawal Impacts

Excessive pumping from groundwater wells can decrease the amount of groundwater that would flow naturally into water bodies, such as wetlands, streams, rivers and lakes. When a well is pumped, the water around the well itself is drawn down the furthest, with the groundwater table forming a cone of depression around the well. Surrounding groundwater then flows by gravity to fill the void, which can pull water from nearby streams and lakes.

Excessive pumping from shallow groundwater sources can:

- Divert groundwater away from streams that previously contributed to baseflow. Potential impacts include: perennial streams (streams that flow year-round) could become intermittent, and intermittent streams more ephemeral (streams that flow only during parts of a year).
- Decrease in-stream water quality as stream flow is reduced. Degradation of water quality can stem from a reduction in baseflow contribution.
- Decrease water available to support nearby ecology. Environments and habitats can change when groundwater is drawn down to the point that it no longer supports the environment. This includes wetlands, terrestrial habitat, fisheries, and other aquatic habitat.
- Lead to increased sensitivity to climate change. Shallow groundwater water sources are more susceptible when intense rainfall increases runoff and limits infiltration. In times of drought, the availability of water decreases, impacting public water supply and forcing competition with water dependent ecology also dependent upon the groundwater.

A study from the U.S. Geological Survey (USGS) on Oakland County, Michigan describes some of the groundwater recharge impacts in greater detail.

> *"In humid climates such as that of Oakland County, recharged ground water is slowly transported down gradient toward streams, lakes, rivers, and wetlands, where it is discharged. Thus, just as surface water is flowing from high areas to low areas, groundwater is flowing— much more slowly—from recharge areas to discharge areas. In Oakland County, ground water is typically recharged and groundwater levels rise during April and May, by a combination of melting snow pack and spring rains. Groundwater levels are gradually drawn down through the summer and fall, with the lowest levels typically during September and October, just before the first hard frost…*
>
> *Despite larger quantities of precipitation during the summer months, little or no recharge occurs during the summer because evaporation of water from the surface and transpiration by vegetation consumes nearly all of the available water on the surface and in the soil. These different processes are difficult to quantify individually and are collectively termed "evapotranspiration," or ET. In some watersheds in Oakland County, ET can intercept more than 60 percent of the total precipitation. Evaporated water,*

whether from the land surface or from the oceans, makes up the moisture in the atmosphere and again becomes precipitation" (Aichele, 2005).

3.2 Great Lakes Direct Source Water Withdrawal Impacts

Because of the enormous volume of the Great Lakes, the direct impacts of water withdrawal for supply of potable water are less than the impacts of using a groundwater or river-based supply. There are no measurable impacts on the levels of the Great Lakes or Great Lakes fed ecosystems when extracting water and returning treated wastewater effluent to the Great Lakes system. Transporting that water may add additional energy costs and the associated environmental impact, but water volume is less of a concern because it is very small relative to that of the Great Lakes and the water ultimately returns to the lakes.

A larger concern is the local environmental impacts associated with urbanization. These are linked to development patterns where rainfall and snowmelt are diverted from the ground and flow directly into stormwater or combined sewer systems. Water that would otherwise support wetlands, groundwater, terrestrial habitat, fisheries, and other aquatic habitat is sent directly to nearby outfalls in local streams and the Great Lakes themselves.

Water from the Great Lakes or the rivers that connect the Great Lakes serves as source water in areas that are relatively close to the lakes' shorelines and where population density is high enough to warrant the capital and operating costs associated with pumping infrastructure and treatment system. As such, Great Lakes water generally serves areas with a higher population density. These areas, with higher population densities, also have denser development and higher amounts of impermeable surfaces. These urbanized areas contribute significant runoff and pollution entering waterways; in turn, they are discharged into the Great Lakes, which is a more significant, negative impact than decreasing water levels.

This population density has increased hardscape over time leading to further negative impacts on the environment. Conventional development strategies tend to use highly engineered systems to manage stormwater so that it channels rain and snowmelt directly into a pipe system moving water directly to a receiving stream or lake. This often causes stormwater to transport particles and pollutants to streams and lakes. Further, it prevents water from infiltrating into the ground where natural systems treat the water before slowly returning to nearby streams as groundwater. The direct channeling of stormwater into streams increases risks of flooding, pollution, and alteration of streams through erosion. The resulting sedimentation buries the benthic populations, widens the streams, and disturbs the ecology, including plant and fish life. Development strategies utilizing green infrastructure to reduce direct runoff to streams and encourage infiltration also reduce flooding risks.

3.3 Urbanization & Development Impacts

The greatest environmental impacts to the Great Lakes is urban and agricultural runoff, with agricultural runoff contributing the majority. Urban stormwater drives sewer overflows, polluted runoff, and a decrease in groundwater recharge – all of which have environmental impacts.

In general, impermeable surfaces exacerbate the risk to flooding – local overland flooding, overbank flooding, and excessive infiltration/inflow (I/I) of sewer systems. Inundating sanitary sewers also increases flows at wastewater treatment plants – from combined collection systems and separate sewer systems. Excessive stormwater leads to sanitary sewer overflow (SSOs) and combined sewer overflows (CSOs). In both cases, the stormwater displaces sanitary sewage in the collection system leading to overflows allowing pathogenic sewage to discharge into open water bodies.

Urban stormwater also delivers pollutants to natural drainage systems. Polluted stormwater runoff is commonly transported through municipal separate storm sewer systems (MS4s), from which it is often discharged untreated into local water bodies. These stormwater discharges are considered point sources and require coverage under a national pollutant discharge elimination system (NPDES) permit. Stormwater runoff is generated when precipitation from rain and snowmelt events flows over land or impervious surfaces (e.g., paved streets, parking lots, and building rooftops) and is not allowed to percolate into the ground. As the runoff flows over the land or impervious surfaces, it accumulates debris, chemicals, sediment, or other pollutants that could adversely affect water quality if the runoff is discharged untreated. The primary method to control stormwater discharges is the use of BMPs.

Roads significantly affect local hydrology - Using regional rainfall data, it was calculated that one mile of a 24-feet-wide road diverts approximately 65,000 gallons of water in a one-inch rainfall directly to streams. Over a year, that translates to between one million and 1.5 million gallons of water. The 96 miles of roads in Lyon Township in Oakland County diverts 130 million gallons of water per year from groundwater recharge to streams (Lyon Township & McKenna Associates, 2012). That does not include runoff from lawns, parking lots or other hard surfaces. The Region of Waterloo in Ontario has about 440 miles (700 kilometers) of roads (Roads, 2014). A one-inch rain (2.54 cm) diverts close to four million gallons of water from groundwater recharge to stormwater (not including parking lots, lawns, and other hard surfaces) and over 600 million gallons per year going to the storm sewer system.

Equally important, diverting stormwater from infiltrating into the ground decreases recharge of aquifers. This decrease in groundwater recharge reduces the baseflow of water that percolates to streams over time. Streams with a small baseflow in dry times that receive direct stormwater discharge from large storm events are subject to more extreme stream flashiness – that is, rapidly transitioning from extreme low flows to extreme high flows.

Private properties also increase runoff and inhibit infiltration. Runoff from rooftops often flows into downspouts and then into sewer systems going straight into stormwater infrastructure instead of replenishing the ground water. A one-inch rainstorm generates over 600 gallons of runoff from a 1,250 square foot roof. In a small community with 1,200 roofs, a one-inch rainstorm would generate close to 750,000 gallons of water per event or over 16 million gallons per year. If that runoff was captured in green infrastructure or cisterns, there would be more water available for reuse on lawns or for release later when streams are lower and need baseflow.

Green roof

3.4 Climate Change

Climate change also poses a threat to water system uses (USEPA, 2014). Increasing temperatures is expected to escalate evaporation, which will cause excessive precipitation in other locations. This will prolong droughts in areas of high evaporation and increase the intensity of rainfall and flooding in other areas. Also, warmer air temperatures correlates with snowpack and stream water temperatures. Warmer conditions will melt snow earlier in the season causing a chain reaction; streams will be at their highest flow earlier, and later in the summer season when water demand is the highest, there will be lower flows. For streams, increasing water temperatures due to increased air temperatures multiplied by lower stream flows negatively affect ecosystem habitats because certain cold water ecosystems, like trout streams, will no longer be able to support respective cold water species. These cold water species will be in competition with warm water species, which can adapt to a larger range of water temperatures in these streams.

As demand for water increases, additional stress will be placed on groundwater in areas where already it is used as a source. Drawdowns from pumping and shunting of stormwater directly to streams means there will be less water available for stream baseflow and surface ecology. More frequent extreme events with higher precipitation amounts will result in more stormwater diverted to streams resulting in higher peak stream flows and less water infiltrated and stored in the ground. This then results in lower base stream flows during drought periods.

Besides increasing water temperatures, human resources will be affected significantly from climate change (USEPA, 2014). Water is frequently demanded to produce energy, support agriculture, maintain livestock, and support our urban populations. As more evaporation occurs and there are stronger summer droughts, water competition between these sectors will increase. More intense storms will also overwhelm sewers and wastewater treatment plants, and can cause more CSOs and make streams flashier. With flashier streams and more intense rains, there will be higher runoff and stream velocities that can erode sediment along dirt roads and stream banks. More sediment from increased erosion will further impair lakes and streams.

4.0 GREEN INFRASTRUCTURE BEST MANAGEMENT PRACTICES

4.1 Using Green Infrastructure to Repair the Water Cycle

Green infrastructure can increase infiltration and reduce the negative impact caused by "improved" stormwater management systems. Many of the traditional stormwater drainage practices that have served to disrupt the natural hydrologic cycle are being revisited. Modern drainage and plumbing codes provide acceptable ways of capturing rain water and gray water onsite for re-use while limiting off-site runoff. These newer developments provide rainwater capture systems to hold water close to where it falls for other uses, including irrigation. However, the cost of retrofit is high so the economics of large scale water conservation and drainage modifications must be viewed judiciously if the rate payers are to be well served.

Similarly, in combined sewer collection areas, as well as in "wet" separate systems (i.e., separate sewer systems that are subject to excessive stormwater infiltration/inflow), stormwater is transported in the same pipes that collect wastewater. In small events, the stormwater and the wastewater is treated and discharged to a receiving stream; in larger storms, this uncontrolled stormwater overwhelms the sewer system capacity and either causes sewage to back into homes or the combined sewage is discharged, untreated, into rivers to protect homeowners. Clearly, a more prudent approach is to allow excess stormwater to be temporarily stored, infiltrated, and/or slowly reintroduced into the sewer system for treatment. Thus, green infrastructure is an effective tool in reducing CSOs and sanitary sewer overflows (SSOs).

4.2 Application of Green Infrastructure

Retrofitting green infrastructure into an existing development is difficult, but designing water holding and slowing features into new development is easier and more practical, and it would have very positive effects in preventing significant alterations to local waterways. The other, larger green infrastructure BMPs can be utilized effectively in newer developments to hold and infiltrate water into the sewer system or groundwater.

In areas with available open area, the least cost green solution typically provides some area that allows for managed ponding and a method of increasing infiltration – preferably using climate and habitat appropriate plant species.

In most cases, it would be beneficial to construct a rain garden or bioswale in areas where water comes off of roofs or on downslope areas where water flows toward a street. A 10-foot-long, enhanced rain garden could hold approximately 100 gallons of stormwater during a single storm event. Larger-sized rain gardens would be more effective, and building a larger number would multiply the effects and slow other runoff. A 10-foot-long bioswale could hold about 1,500 gallons. Building rain gardens and bioswales between homes and/or parallel to streets would definitely have a positive impact on slowing the flow of water to storm sewers and reducing the amount of pollutants delivered directly into rivers.

4.3 Vegetated Green Infrastructure

Water use reduction is a very important component of water management and environmental protection; however, in most cases, water use reduction alone cannot have sufficient impact in reducing environmental impacts. Water reduction practices should be augmented with stormwater protection practices.

More effective stormwater management requires the holding of larger volumes of precipitation closer to the point where it falls on the ground; holding it longer to allow maximum infiltration, and releasing it slowly to minimize downstream impacts. Green infrastructure BMPs are beneficial to separated sewer areas to better manage storm events, increase groundwater recharge, and reduce the large volumes of runoff. A variety of BMPs can be used to capture, clean, and infiltrate stormwater before it leaves the site and enters the storm sewer system. Newer technologies optimize the retention of peak flows and increase infiltration capacities – both support the restoration of the natural water cycle.

Recent developments have shown that stormwater BMPs can be used to reduce the volume of stormwater entering a combined sewer system. These practices are being instituted in many Great Lakes cities as a low cost means of controlling CSOs.

Not all green infrastructure is equal, nor is every practice applicable for all sites. This project developed a simple costing tool to allow a community to evaluate the effectiveness (and the costs) of differing green solutions early in the planning process. Since the volume retained will vary by the BMP implemented, the tool was used to compare the potential retention capacity available in each of these elements on a per acre of BMP implemented basis. These estimates are for scoping and comparison purposes only and are intended to identify potential retention volumes. Once a BMP approach is selected, there are other tools/calculators that can provide more precise estimates prior to proceeding to final design. The tool and documentation is available at: http://glc.org/projects/water-resources/greater-lakes/.

As an example of how this tool can be used, Table 4-1 compares the volume that would be captured in a one-acre site from a one-inch rainstorm for a variety of management practices. Note, the required amount of area for each management practice varies, as does the price of installation. Using this information, a community can clearly compare the tradeoffs of costs versus required land area for various management practices.

Table 4-1: Volume captured in a one-acre site from a one-inch rainstorm for a variety of management practices

Management Practice	Proposed Area (ac)	Area (sf)	Volume Captured (cf)	Volume Captured (gal)	Contractor Cost
Urban reforestation	1.00	43,560	489	3,659	$110,000
Forest retention	1.00	43,560	6,850	51,932	$110,000
Wet meadow	1.00	43,560	43,560	325,872	$80,000

Management Practice	Proposed Area (ac)	Area (sf)	Volume Captured (cf)	Volume Captured (gal)	Contractor Cost
Native prairie	1.00	43,560	339	2,539	$30,000
Agriculture	1.00	43,560	339	339	$28,000
Enhanced rain garden	0.01	218	1,234	9,233	$3,800
Bioswales	20.00	linear feet	420	3,142	$900
	0.01	420			

The tool assumes that land cover change is based on the USDA Curve Number approach and the retention component is based on estimating the volume stored based on the specific design. A brief summary of the approach taken is shown below for each BMP (Brenner, Edstrom, McCarthy, Higuchi, & Vernier, 2011). Costs are based upon the average costs of materials and installation.

To help clarify the use of the tool, the following paragraphs describe the BMPs envisioned in the analysis.

Urban Reforestation is a management practice well suited for urban settings with green and open space. Trees can intercept precipitation, increase opportunities for evaporation, and retain rainfall in their biomass, increasing storage of water on-site. Tree plantings also help stabilize soils and stream banks with their root systems, which helps prevent surface erosion. The trees also provide shade reducing the water temperature of runoff. Trees require seasonal watering and wind protection until the urban forest has matured. Other required maintenance techniques include raking leaves, weeding, and trimming.

Forest Retention areas provide shallow stormwater retention areas planted with trees. The retention basin is sized to capture a predetermined amount of stormwater while the trees provide extra water storage capacity in their biomass. Retention basins should be designed to store no more than six inches of water depth to preserve the vitality of the trees. Forest retention will work best in suburban green space and should be placed adjacent to impervious surfaces to be the most effective.

Forest Retention

- ✓ Increases runoff storage and infiltration
- ✓ Detains water from reaching CSO's during peak flows
- ✓ Between 0.25 acres to 1 acre in size

Wet Meadows are meadows planted with upland or wetland plants native to naturally occurring wet meadows in the region. The meadows should have hydric soils, withstand wet and dry conditions, and receive either sheet or piped runoff drainage. The wet meadows allow retention of stormwater to provide an opportunity for groundwater infiltration. Their water storage capacity allows them to minimize peak flows, thereby reducing CSO runoff and discharges. To work well, the wet meadows must be maintained through invasive plant management and periodic replantings.

Native Prairie & Agriculture plots should be used in open urban areas. They will work best with deep rooted vegetation that can withstand wet and dry conditions. To maximize effectiveness, this BMP should be densely planted to slow runoff and provide an opportunity for infiltration.

Rain Gardens are shallow retention basins densely planted with native, deep-rooted plants. Amended soils covering a stone subsurface base provide opportunities for higher rates of infiltration than the surrounding urban compact soils. Rain gardens are designed to not hold more than six inches of standing water in order to protect the plants, which are chosen for their hardiness and ability to withstand both wet and dry conditions. The plants help slow runoff, evapotranspire a portion of the stormwater, and increase rates of infiltration with their root systems. Rain gardens are not designed to hold water for any longer than 24 hours.

Wet Meadow

- ✓ Acts as shallow detention basins
- ✓ Large enough volume can capture discharge from CSO facilities and decrease runoff volume
- ✓ Retains runoff to infiltrate or evaporate
- ✓ Can receive overland or pipe flows
- ✓ Plants that survive in wet and dry conditions are most effective
- ✓ Used on large sites (> 1 acre)

Rain Gardens

- ✓ Depressed vegetated area providing storage
- ✓ Allows runoff to infiltrate into subsurface soils
- ✓ Uses deep rooted vegetation
- ✓ Plants that survive in wet and dry conditions are most effective
- ✓ Minimum size of 200 square feet

Bioswales/Vegetated Swales are designed to slowly transport stormwater to a desired location while providing opportunities for infiltration. Bioswales are essentially ditches with enhanced infiltration and habitat capacity through use of amended soils, stone subbases, and native, deep-rooted plants. The plant species chosen should be able to withstand both wet and dry conditions. Generally, wetland plants can transpire more water and uptake more nutrients than their upland counterparts. This BMP is often used in residential areas, adjacent to parking lots, or smaller open spaces in urban settings where space available for infiltration is limited to linear corridors.

Bioswales can work independently or be designed as a part of a treatment train where multiple swales form a system of transport on a site. Bioswales can reduce the number and cost of storm drains and piping required when developing a site. Required maintenance includes summer irrigation, weeding, occasional replanting, and regular inspection. Inspection is critical in the first year because large storms can wash away seeds and young plants that have not yet developed a deep-root system.

Bioswale

- ✓ A vegetated swale with stone sub-base that transports water above ground
- ✓ Filters stormwater runoff as water migrates through plants
- ✓ Can reduce quantity and cost of storm drains and pipes
- ✓ Can provide habitat for small wildlife
- ✓ Uses grasses and native plants
- ✓ Can be used on smaller land areas, for example, along parking lots
- ✓ Minimum of 10 foot width

4.4 Capturing Peak Flows & Increasing Infiltration Utilizing Technology

Green Infrastructure has many benefits; however, site constraints and large variations in precipitation can tax a system designed to solely reflect naturally-occurring ecological processes. The introduction of additional storage and/or infiltration enhancement technologies can make the resulting system far more responsive and resilient.

Peak rainfall in urban areas is typically the largest challenge, particularly if flooding or sewage overflows is driving the design criteria. In urban areas, less pervious area is available to hold and store stormwater during and after a rain event. Also, compacted soils and urban fill result in lower infiltration rates than soils in more rural areas. Simply stated, the goal of green infrastructure is to store more water on site during a large storm event and promote increased infiltration to replenish groundwater to quickly empty the storage and ready the system for the next storm.

4.5 Enhanced Storage

Rain barrels, while popular in many areas, have limitations and some feel that they are not large enough to have a substantial effect. An 800 square foot roof (i.e., a very small house) generates approximately 900 gallons of runoff during a two-inch rain event. Capturing that water during a rain event and using it for irrigation and/or releasing it to the collection system after the rain event has passed keeps a measurable volume of water out of the collection system during wet weather events, when capacity is most challenged. However, few residential rain barrels are that large. Most rain barrels installed on private property are 50-65 gallon drums. Installing similar systems in large commercial settings provides considerably more benefit. Some large commercial entities have chosen to capture roof runoff and then utilize a large cistern to store tens of thousands of gallons for subsequent use in irrigation. This has a great benefit to the collection system, receiving water, and the groundwater.

Large retailer captures roof drainage to irrigate surrounding green infrastructure

The effectiveness of storage can be improved by assuring the storage volume is empty at the beginning of an event, particularly if the goal is to reduce CSOs, which is completely dependent on maximizing water capture during the large rain events. “Smart” storage is an automated cistern system that captures water when a rain occurs, stores that water for onsite use, and releases any unused water immediately prior to the next predicted event. The cost of “smart” control technologies has fallen dramatically and systems are now available commercially at a reasonable cost. A “smart” cistern can capture more stormwater than an uncontrolled cistern of equal size because its computer programming ensures that the cistern is completely empty in advance of a rain event creating sufficient capacity at the beginning of a rain event, when it is needed most.

4.6 Enhanced Infiltration

The effectiveness of green infrastructure is limited by the ability of the soil to infiltrate large volumes during large events. To limit the amount of surface water leaving the site and maximize the groundwater recharge, devices can be used to improve the infiltration rate. These technologies have been slow to gain acceptance from regulators for fear that groundwater contamination could result. As more data accumulates, application is becoming more accepted.

Infiltration Enhancement being installed along grassed swale

Several new technologies have recently been introduced to increase infiltration rates without threatening the quality of the shallow aquafer. The goal of these technologies is to quickly dewater surface storage (regardless of type) and assure that the top of the unsaturated zone is dewatered before the next event. The soil located below these devices, yet above the groundwater table, apparently provides sufficient filtration that no impact has been seen in groundwater quality. The evacuated volume from the unsaturated area quickly absorbs rainfall and transports it below infrastructure, such as footing drains, storm drains, and sanitary sewers. This has the additional effect of reducing infiltration/inflow and/or sump pump cycling.

These technologies can be installed as standalone systems for “drying out” low lying areas, such as parks, but are typically coupled with some type of above ground or below ground storage. The coupled system relies on storing the peak volume during and shortly after a wet weather event. Unlike the “smart” storage, this is a passive technology requiring very little routine maintenance.

5.0 ESTIMATING ENVIRONMENTAL IMPACTS OF WATER USE IN SIX TARGETED COMMUNITIES

This project targeted three communities in Oakland County, Michigan: Lyon Township, Southwest Oakland Township, and Commerce Township, and three communities in Ontario's Grand River watershed: the City of Guelph, the City of Waterloo, and the Region of Waterloo. These communities provide examples of the variations in environmental impacts that result from differing water resources practices and shows how these affect their different water supplies and natural water courses. This section also includes analysis of how green infrastructure could help address issues in these municipalities.

5.1 Oakland County, Michigan

Oakland County is a suburban county in southeast Michigan, immediately north of Detroit. It has seen significant residential/commercial/industrial development over much of its area over the late 20th and early 21st centuries. Much of this development began as summer cottages surrounding the hundreds of lakes that cover the county. The county covers 910 square miles, with most of the land classified as suburban. Many of the communities were originally small suburbs of Detroit, but are now becoming major economic hubs of their own (Aichele, 2005). As of 2005, the county contained a combination of 63 cities, townships, and villages with a population of 1.2 million (Aichele, 2005).

Oakland County provides water to its residents with sources from the Great Lakes and groundwater wells (Aichele, 2005). One of the major distribution systems is the Detroit Water and Sewerage Department (DWSD) water distribution system, which extracts water from Lake Huron and the Detroit River. About 75 percent of demand in the county is served by the DWSD with an additional 43 million gallons per day taken from groundwater. Much of the more recent development is located in areas beyond the DWSD service area. The county has seen a steadily growing population since about 1900, and in the next 20 years, the population is projected to increase by about 200,000 people, increasing water quantity and usage by 20 million gallons per day (Aichele, 2005).

The climate in Oakland County is typical of the upper Midwest, with precipitation falling in all four seasons (Aichele, 2005). Oakland County receives an average annual precipitation of just less than 30 inches, with actual annual amounts varying by ± 10 inches. Precipitation replenishes groundwater, surface waters in streams and lakes, and this volume is supplemented by the DWSD water source. Climate change is changing the runoff volumes in Oakland County (as elsewhere). This variation in precipitation can also affect water levels in lakes, streams and groundwater. Southeast Michigan continues to experience wetter "rainy seasons" raising water levels and drier seasons causing lower lake levels and lower groundwater levels available to use.

Many parts of ex-urban Oakland County derive drinking water from groundwater sources. These areas are dependent on the groundwater aquifers and their recovery. The geology of the county consists of many glacial features forming a glacial aquifer (Aichele, 2005). In general, the glacial aquifer in the county can produce yields up to 20 gpm, with the groundwater table usually less than 30 feet from the surface. Some groundwater is also pumped from a bedrock aquifer consisting of dolomite, shale, siltstone, and limestone. This aquifer can produce yields surpassing 100 gpm, but much of the water in the deeper portion of the aquifer is saline and unsuitable for drinking water purposes. The bedrock aquifer is located under Holly, Groveland, and Brandon townships and is not present elsewhere in the county.

The southeast corner of the county, including Royal Oak Township and portions of Farmington, Southfield, Bloomfield, Troy, and Avon townships, are overlain with glacial-lake plain sediments that are rich in clay minerals and are poorly-drained. These areas are served Great Lakes drinking water from DWSD. The rest of the county consists of a mixture of glacial till and outwash plains with heterogeneous, poorly-drained lake-clay soils as well as well-drained channel deposits.

These differing soil types throughout the county dictate the amount of infiltration available to replenish the groundwater aquifers used for drinking water. The various soils in Oakland County can retain between two and 24 percent of the soil volume in water. The infiltrated water stored in the soils then drains to streams to provide baseflow during the summer months. The largest groundwater recharge typically occurs in April and May from melting snowpack and decreases. The least recharge occurs in September and October during the dry summer season.

Public water supply is just one use for water in Oakland County. There are a large number of lakes, streams, wetlands, and rivers throughout the county that have historically attracted development and help define its environmental and economic health. Oakland County is unique in that it is the headwaters for five major Great Lakes watersheds: the Clinton, Flint, Huron, Rouge, and Shiawassee rivers. Each of these major rivers begins with very small flows in the headwaters and gathers more surface runoff and groundwater from areas downstream. The “headwater” communities developed around groundwater wells for water use. Today, the lakes and streams are used for boating, fishing, and other recreational activities. Protection and conservation of the environment are critical to ensure the long term health of the local environment and economic and social vitality.

In the near ring suburbs of Detroit, groundwater is also recharged by the very large amounts of Great Lakes water delivered to Oakland County by DWSD that is subsequently used to irrigate lawns. This addition of water has been documented to increase the total volume of water discharging in the Rouge River as well as increasing the low flows of the river.

Development in Oakland County

Increases in flows in sewer systems and in rivers remains of concern to Oakland County as cities continue to grow. The use of the DWSD water supply has actually helped replenish groundwater aquifers in southern Oakland County over time, because areas that are now connected to a Great Lakes water supply were originally pumping groundwater (Aichele, 2005). Groundwater seeps into rivers to provide baseflows for the rivers in the dry summer months, so measuring the baseflows of rivers can provide an estimate to the quantity of water within an aquifer. Measurements of increasing low flows in the Rouge River show the aquifer is recovering, as there has been an increase in the low flows of the river over time since the importation of the DWSD water independently of continued urbanization.

Analysis by the USGS indicates low flows of the Rouge River in Oakland County were down to approximately five cubic feet per second (cfs) in 1960 and have increased to approximately 25 cfs in 1998 (Aichele, 2005). Even with these observed changes in low flows in the Rouge River watershed, the peak flows in rivers in the county have not varied. The water being imported to the Rouge River watershed is clean water replenishing the groundwater that supports the naturally-occurring baseflow. However, other communities in the Rouge River, as well as the Clinton River in Oakland County, are not connected to the DWSD and rely on groundwater. These areas show a decrease in low flows. Often, water is pumped from the groundwater and then discharged to a surface water body (via a wastewater treatment plant discharge). This causes a net loss of water in the groundwater system. Water inputs to the Lower Rouge River and Clinton River from wastewater treatment plants; while beneficial from a flow volume basis, the discharge water is higher in nutrients and has a higher temperature than the groundwater-fed baseflow in the streams.

The lakes within Oakland County are also impacted by water management practices. Most of the lakes in the county receive high inputs of groundwater flows and are closely linked to the level of the groundwater table and the velocity of groundwater flow (Aichele, 2005) (see Figure 5-1). The county contains more than 1,600 lakes, all of which are important ecologically and economically to the county. Regulatory organizations govern many of the lakes using diversion systems, dams, or augmentation wells to maintain lake levels. However, these methods are limited, and when sufficient water quantities are not available, drops in stream flows downstream of the lakes and/or lake level drops are inevitable.

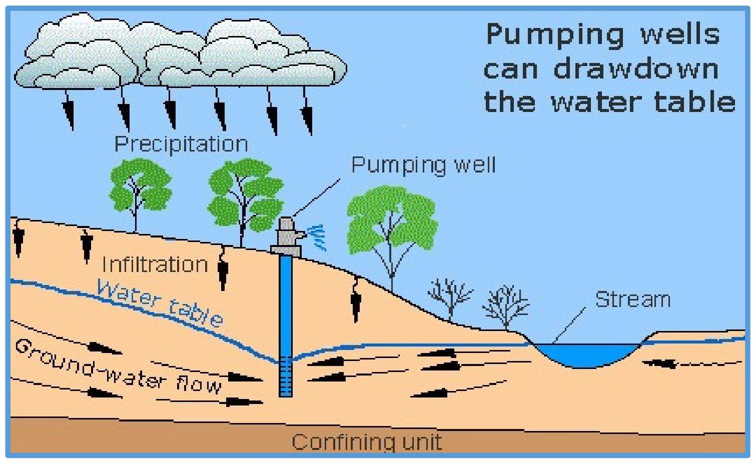


Figure 5-1: Expected response of groundwater flow in response to water withdrawal from well

5.2 Targeted Oakland County Communities

In Oakland County, the development in all three targeted communities is relatively less dense. There are mostly single family homes with large amounts of open space. More recent developments have required curbs and gutters along streets to manage stormwater, which is then discharged into local streams. Older developments and many roads have curbside ditches to channel and move stormwater to the natural water courses (See Figure 5-2).

Both Lyon Township and Southwest Oakland Township use groundwater as a public water supply. Commerce Township purchases its water from the Detroit Water and Sewer Department, which is drawn from a Lake Huron water supply source (DWSD Water Supply Map, 2014).

Both Commerce Township and Southwest Oakland Township discharge their treated wastewater effluent to streams, while Lyon Township operates a groundwater discharge treatment plant, which discharges effluent into the ground via sand beds. The sanitary sewage collected within Southwest Oakland Township is discharged into the Clinton-Oakland Sanitary Disposal Sewer (COSDS) interceptor sewer for treatment at the DWSD wastewater treatment plant in Detroit. Oakland County owns the COSDS, while Oakland Township owns the lateral sewers, which the Water Resource Commissioner (WRC) operates. The Commerce Township wastewater treatment plant has a National Pollutant Discharge Elimination System (NPDES) discharge permit and discharges to Seeley Creek and Lake Berry. Flows include sewage from Commerce Township, White Lake Township and a portion of Novi Township.

Two of the communities in Oakland County, Lyon Township, and Southwest Oakland Township, use groundwater as their public water supply.

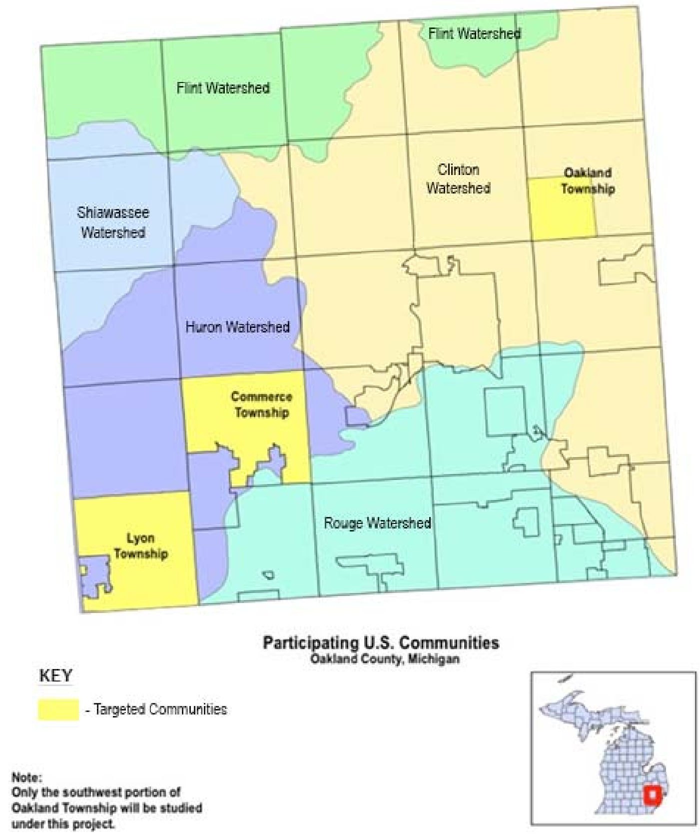


Figure 5-2: Location of three Oakland County, Michigan, municipalities that participated in Greater Lakes analysis

Lyon Township

Lyon Township is located within the southwest corner of Oakland County. The Township owns its own water and wastewater treatment plant. The Water Resources Commissioner's office operates and maintains the water system. A private contractor operates the sewer system and wastewater treatment plant.

Lyon Township uses groundwater for water supply (WSSN 03968) provided by eight wells in four well houses. The water system has approximately 60 miles of water main, two elevated storage tanks, and one pressure district. There are also private wells located within Lyon Township as shown in Figure 5-3.

Township residents draw a base amount of approximately 500,000 gallons per day. This is the approximate amount of water used during the non-outdoor watering season. Outdoor watering on a given day can be significantly higher during the summertime. It is during the outdoor watering season that the wells experience an excessive drawdown. Also, water use increases during drier times and times of drought.

There is significant open space in the area with a relatively low population. Nearby land uses include:

- Golf courses
- Subdivisions
- Open fields
- Ponds
- Lakes

These land uses have minimal impact on the quality of the water source that these wells draw from. Layers of clay protect the water source from potential surface runoff contamination.

The population served by the wells is relatively small and appears to supply sufficient water during most times of the year. Many wells are drilled much deeper than typical wells to anticipate drought conditions when water use is high and infiltration is low to fill the cone of depression.

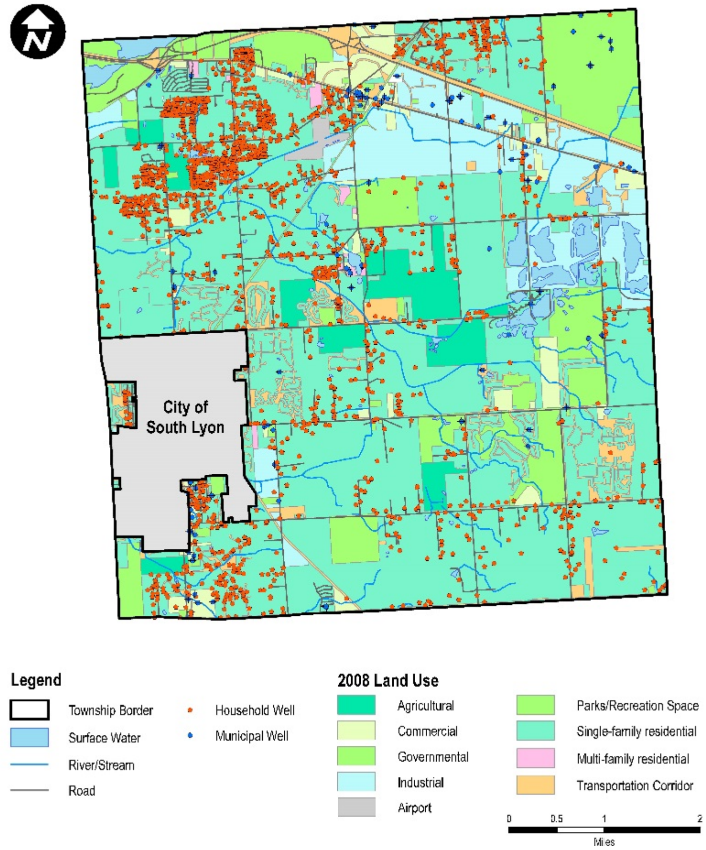


Figure 5-3: Well locations for Lyon Twp. municipal and household water wells

Groundwater is replenished primarily during the spring months when the snowmelt and rainfall saturate the ground. Summers, generally, experience less precipitation and see significantly more evaporation and evapotranspiration.

The Lyon Township wastewater treatment plant is unique among the targeted communities in that it discharges wastewater effluent into the ground via sand beds. This allows for recharge of groundwater to support local aquatic environments and ecology in a way that allows water to be treated and percolate to the groundwater. Treated wastewater in Lyon Township is a small enough volume that it does not oversaturate the ground and overwhelm water dependent ecology. The water remains in the local Huron River watershed, and the water is managed in a manner more conducive to natural water systems. This type of wastewater effluent discharge requires a large area of open space to work effectively.

Southwest Oakland Township

Oakland Township is located in the northeastern corner of Oakland County; however, only the southwest portion of the township was examined. The area is less densely developed with larger lots and significant open green space. There are several golf courses in the community that use large amounts of water for irrigation and provide significant open space.

Oakland Township residents are provided drinking water from a variety of water supply systems. There are seven Type 1 groundwater supply systems in use, and a small area in the southwest receives treated surface water from the City of Rochester Hills purchased from the DWSD and private wells in the township. Oakland County owns the Type 1 water systems, which the WRC office operates and maintains as shown in Figure 5-4.

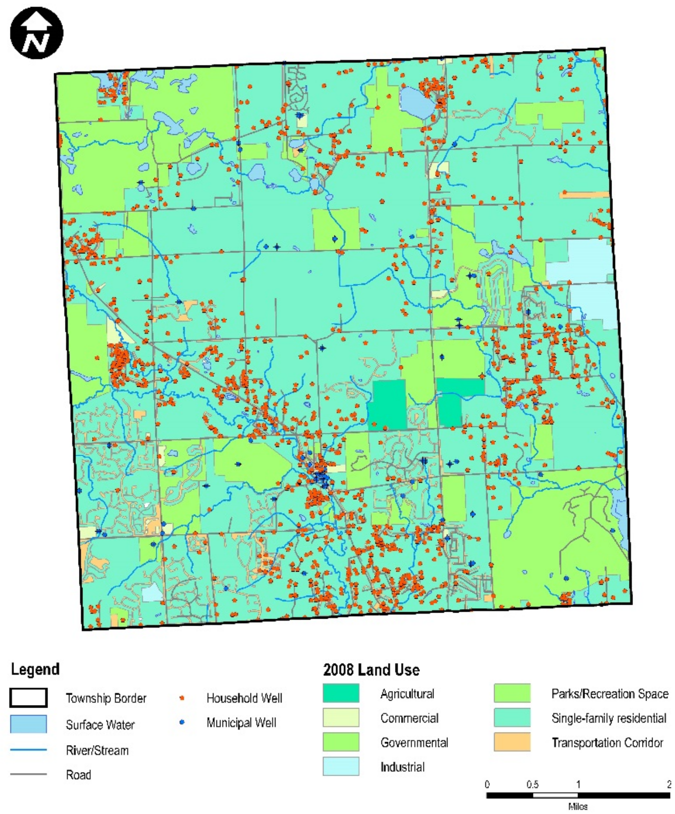


Figure 5-4: Well locations for Oakland Twp. municipal and household water wells

Portions of Oakland Township have access to sanitary sewers, a majority of which discharge into the COSDS interceptor sewer to be transported to the DWSD wastewater treatment plant. There is also a private groundwater discharge wastewater treatment plant in the northeast portion of the township.

The Southwest Oakland Township (WSSN 4878) water system is located in Oakland Township with groundwater supplied by nine wells in five well houses. The treatment consists of a phosphate feed, followed by chlorine disinfectant. The water system has approximately 39 miles of water main with three distinct pressure districts. The over laying sanitary sewer serving Southwest Oakland Township discharges into the COSDS interceptor sewer for treatment at the DWSD wastewater treatment plant. The COSDS is owned by Oakland County, and the lateral sewers are owned by Oakland Township. The OCWRC operates and maintains both systems.

The stormwater runoff of this area drains to Paint Creek – one of only two cold water trout streams located within southeast Michigan. Paint Creek lies to the northwest of Southwest Oakland Township. Tributaries to Paint Creek are located in proximity to two sets of wells in Southwest Oakland Township. Stocking and natural reproduction of brown trout is important ecologically and economically for the region (Fishing the Clinton River Watershed, 2014). However, development in Oakland County has impacted the stream flow of the creek.

> *"...fluctuations from year to year are relatively large. The majority of the surface runoff occurs during the spring months, primarily April and May, and surface runoff constitutes most of the stream flow during that period. In contrast, in August and September, more than 90 percent of the total stream flow is derived from ground water. Decreases in this ground-water contribution would have direct effects on the aquatic habitat within the stream. Therefore, the continued health of the surface-water in Oakland County, such as*

Paint Creek, relies on the continued abundance of ground water to sustain stream flow during periods of low precipitation and high ET" (Aichele, 2005).

Development near the tributaries as well as groundwater withdrawals impacts the stream flow since "improved drainage" intercepts the surface runoff, precludes infiltration, and rushes the runoff to the tributaries via curb and gutter and through pipes. This direct movement of water into streams makes streams flashier, i.e., rapid changes in stream discharge rates transitioning from very low flows to excessive flows.

The pumping of nearby groundwater wells and existing development in Oakland County are unlikely to have an impact on the future health of Paint Creek; however, as additional development occurs in the area, prudent development practices can assure the continued health of Paint Creek. This would include either incentives or requirements to ensure that the development is constructed in a manner that results in maximization of groundwater infiltration in order to support the necessary groundwater-fed base-flow for the tributaries. If development continues in the area, and it allows large-scale use of dense curb and gutter for streets, much of the stormwater that currently feeds the groundwater would be directed away from this critical recharge area.

5.3 Surface Water-Fed Communities

Commerce Township

Commerce Township is located in southwest Oakland County in Michigan near the headwaters of the Huron River watershed with the river running north-south through the township. The township has seen development over the last several years, although with relatively few land use changes and without significant increases in density. The township rests amidst a large number of lakes, with significant open space and water bodies dominating the landscape, providing significant recreational opportunities. The land use includes large expanses of flat farmland and suburban-style development. Commerce Township's (WSSN 01573) water supply is treated surface water provided by DWSD. The water is withdrawn from Lake Huron and is treated at the DWSD Port Huron water treatment plant. It travels approximately 90 miles, through four booster stations and three Pressure Reducing Valve (PRV) vaults at the three metered connections to feed two pressure districts. It is then distributed through approximately 131 miles of water main. The area to which this drinking water is distributed is primarily in the Huron River watershed. Stormwater from the served area is also discharged to the Huron. Wastewater, however, is collected and transported to the Rouge River watershed for treatment and discharge.

The sanitary sewage is collected and treated at the Commerce Township Wastewater Treatment Plant, which serves Commerce Township, White Lake Township, and a portion of Novi Township. Commerce Township's wastewater treatment plant has an NPDES discharge permit and discharges to the Seeley Creek and Lake Berry within the Rouge Watershed.

There is very little direct impact on the Great Lakes volume caused by the Commerce Township water withdrawal. The well locations for Commerce Township is presented in Figure 5-5. The amount of surface water taken for supply is very small relative to the size of the Lake Huron and Great Lakes systems. Therefore, the direct impact from water use of Commerce Township on the levels of the Great Lakes and other water-dependent natural resources cannot be measured. Ultimately, the withdrawn water is returned to the Great lakes via treated effluent discharge or groundwater contributions to stream flows. There is an energy cost to the transport and treatment of this Great Lakes water, but the quality is exceptional and most residents are willing to pay the price. Each booster station requires energy to move water through the system and maintain pressure within the distribution mains. The marginal impact of carbon emissions due to the direct addition of Commerce Township water is relatively small. More water and, therefore, energy, is used during summer months to move the additional water needed to meet summer water demands. Reducing outdoor water use will have an impact on reducing energy use.

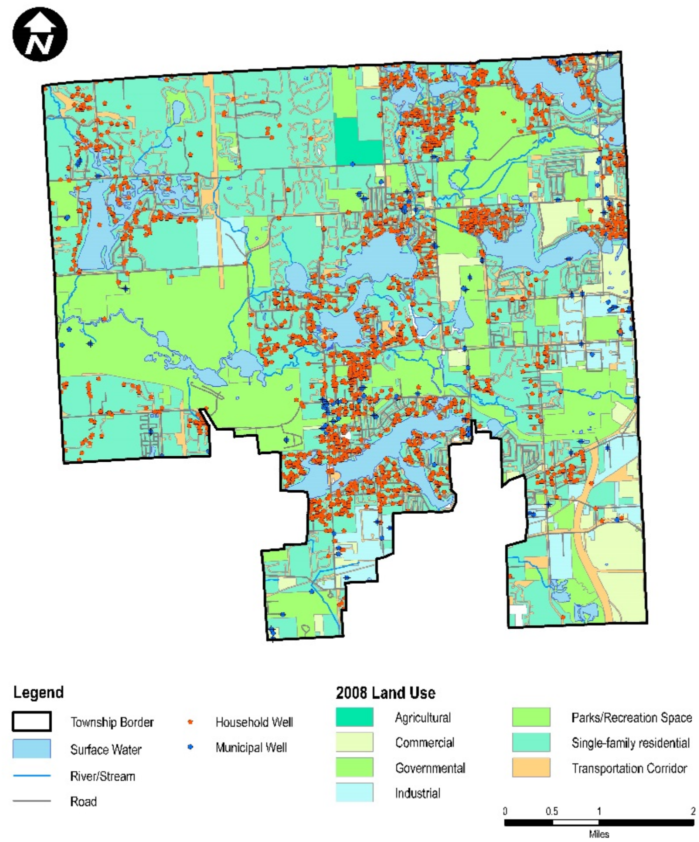


Figure 5-5: Well location for Commerce Twp. municipal and household water wells

Communities in Oakland County continue to seek water from DWSD. The USGS summarized the impacts of Great Lakes water supplementing groundwater in the DWSD area of Oakland County.

> *"The DWSD pumps nearly 125 Mgal/d of water into the county. Although much of this water is used and discharged back to Wayne County for treatment, some is treated and discharged to rivers in Oakland County. In addition, some of the water leaks out of water mains and may recharge underlying aquifers.*
>
> *In the area from Southfield north to the edge of the Rouge watershed, ground water has been replaced by DWSD surface water as the source for domestic use. Thus, the stress on the aquifer caused by pumping has been removed, and additional water is being diverted to the aquifer from DWSD. This effect can be seen in the low-flow record for the River Rouge, where low flows have increased by almost 400 percent since the introduction of DWSD water in the mid-1960s. In the case of the River Rouge, this is relatively clean water seeping through the ground and is probably a net improvement for the system. Some of the water imported into the county is discharged to rivers through wastewater treatment plants in Pontiac and Ferndale. These discharges also*

increase the low flow of the receiving rivers, but in a different way. Although the total amount of water in the Clinton and Lower River Rouge has increased, the stream flow is supplemented by treated wastewater. Although this water has been treated and is relatively clean, it has a higher nutrient content and a higher temperature than the river typically would have" (Aichele, 2005).

Grand River in Ontario

Ontario's Grand River system (see Figure 5-6) is the largest watershed within southwestern Ontario, with a surface area of approximately 6,700 square kilometers and a total population of 920,000 in 2006 (Wong, 2011). The main urban areas include the cities of Cambridge, Waterloo, and Kitchener within Waterloo Region, as well as the cities of Guelph and Brantford. However, these urban areas occupy only five percent of the watershed, as the rest of the watershed supports agriculture. The majority of the drinking water in this watershed is taken from groundwater wells, though some communities also use surface water from the Grand River, inland lakes, and ponds (Wong, 2011).

Ontario's Grand River watershed consists of three physiographical components. The north section of the watershed, called the Upper Grand River sub-basin, has tight till deposits providing little infiltration and groundwater recharge. This area is used mainly for agricultural purposes. The middle of the watershed, or the Central Grand River sub-basin, contains three moraines with sand and gravel deposits providing large amounts of groundwater recharge. This section contains the cities of Guelph, Waterloo, Kitchener, and Cambridge (Wong, 2011). Specifically around Guelph, there is a mixture of glacial outwash, moraines, and other glacial features. These sand and gravel deposits overlie a sandy silt till and dolostone bedrock and act as an aquitard (Guetter, 2004). Most of the groundwater wells in this region are cased and drilled into the dolostone bedrock. The water is then used for either public supply (home use or city operation) or self-supply (domestic, irrigation, livestock, and industrial use) (Guetter, 2004). The southern area of the watershed, called the Lower Grand River sub-basin, is an old lakebed clay plain providing little infiltration and large quantities of runoff (Wong, 2011). The City of Brantford is in the northwest section of this southern clay plain (Wong, 2011).

Figure 5-6: Drainage area of Grand River, Ontario, watershed

The three largest sectors of water use in the Grand River watershed include municipal (60.83 percent), dewatering (6.07 percent), and irrigation for agricultural purposes (6.02 percent) (Wong, 2011). Including all of the water use sectors, the total water demand is estimated to be 152 million cubic meters per year (Wong, 2011). Water consumption can be divided into categories of municipal use, unserviced domestic use, permitted water takings, and agricultural use (Wong, 2011). Municipal use incorporates water delivered through the distribution systems. Overall, the municipal water demand is

102.4 million cubic meters per year. The municipal supply demand increases in the summer months correlating linearly to the water use peaks from seasonal use, with people using extra water to wash cars and water lawns.

Unserviced domestic water refers to residential use not connected to a municipal distribution water system (i.e., potable water is retrieved from individual groundwater wells). The water use for the unserviced population is generally lower than that of the municipal serviced population. The total volume demand of unserviced domestic use is approximately 7.2 million cubic meters per year.

The Permit to Take Water (PTTW) program, regulated under the Ontario Ministry of the Environment, requires a permit for anyone who is taking greater than 50,000 liters of water per day, excluding firefighting and agricultural livestock purposes. The PTTW program allows different total permitted rates per portion of the watershed to conserve water, allowing only 27,600 liters per second (L/s) of groundwater and 27,300 L/s of surface water to be extracted from the watershed (Lake Erie Source Protection Committee, 2012). Under agricultural use, crop irrigation requires a permit under the PTTW program when the farmer uses more than 50,000 liters per day. For livestock watering, there is a water demand of 7.5 million cubic meters per year.

Overall, from irrigation models, the volume of water used for irrigation is 322 liters per second, or 10.2 million cubic meters per year. Approximately 60 percent of the water used for irrigation comes from groundwater. In the summer months, irrigation demands add stresses to the available groundwater (The Governments of Canada and The United States of America, 2009).

In order to help reduce peak water demand, some municipalities have water conservation by-laws in effect during the summer.

Climate change also affects the environment of Ontario's Grand River. Historical precipitation records from 1960 to 2007 show the average annual precipitation in the watershed is approximately 908 millimeters (Boyd, Farwell, & Ryan, 2014). Despite this, the actual observed annual precipitation per year is highly variable, as the watershed experiences cycles of warm and cool, wet and dry years. Larger rainfall intensities lead to more surface runoff and cause greater flooding and erosion. Also, alterations in rainfall patterns affect drought periods. With longer droughts and a concern about increasing temperatures, climate change leads to a practical concern as earlier and faster spring melt coupled with larger demand for water for agriculture lead to increasing water temperatures, which result in lower dissolved oxygen concentrations in the streams negatively affecting the fish populations.

5.4 Targeted Grand River Communities

The Region of Waterloo

Waterloo, Cambridge, and Kitchener within the Region of Waterloo, use groundwater as their primary supply, discharging treated wastewater to the Grand River system. Each community has a series of water wells to support the larger populations, but also use surface river water to augment the supply.

The Regional Municipality of Waterloo provides a variety of services to its three cities and four townships, including providing treated drinking water, which member municipalities then sell to retail customers. Wastewater from retail customers is collected and flows to region-owned wastewater treatment plants, which discharge to the Grand River. Approximately 80 percent of Waterloo Region water comes from groundwater and 20 percent is from surface water (Supply and Distribution, 2010). As of 2009, the region supplied water to a service population of approximately 506,719 through a total of 122 wells and surface water intake and can supply a volume of approximately 292,000 cubic meters of water per day. The cities of Kitchener, Cambridge, Waterloo, the towns of St. Jacobs and Elmira, and two nearby settlements operate on the Integrated Urban System (IUS). The IUS is a complex series of interconnected drinking water distribution systems, taking water from 76 groundwater wells and one surface water intake from the Grand River (Lake Erie Source Protection Committee, 2012). The rest of the rural townships within the region operate on groundwater systems. The largest supplies of water in the watershed include municipal supply, unserviced domestic demand, permitted water takings, and agricultural supply (Wong, 2011). The urban areas in the watershed are expected to increase by 300,000 people in 20 years placing a stress on these water supplies (The Governments of Canada and The United States of America, 2009).

Guelph

The City of Guelph has a population of approximately 115,000 and uses 24 groundwater wells to provide its drinking water (Lake Erie Source Protection Committee, 2012). The existing withdrawal rate exceeds the aquifer's ability to support continued growth, economic development, and expected climate change impacts. To supplement the stressed ground water supply, a recharge program was initiated. The recharge water is withdrawn from surface waters and is allowed to infiltrate to groundwater in three intake zones (recharge areas). Water is withdrawn from the Eramosa River upstream of the Arkell Weir and is delivered to the Arkell Recharge System. The water is infiltrated into the ground through a recharge area and recovered in the Glen Collector System. The intake operates under a PTTW from April 15 to November 15 and is dependent on adequate flows in the river.

The Eramosa River intake consists of a pump attached to a concrete platform approximately six meters from the southern river bank. A small run-of-the-river hydraulic structure or overflow weir is located approximately 85 meters downstream of the intake, creating an impoundment in the vicinity of the intake structure approximately two meters deep. Neither the city nor the Grand River Conservation Authority impose operating hydraulic controls on the weir. The tracer test completed in support of the intake protection zone (IPZ) delineation study indicated that the ponded water upstream of the dam functions as a mixing zone; however, the river velocity is maintained in the downstream direction (Lake Erie Source Protection Committee, 2012).

Development near the Ontario's Grand River

There are many different types of human alterations along Ontario's Grand River Watershed. The Shand, Conestogo, and Guelph dams located upstream in the Grand River control the downstream discharge through the river (Lake Erie Source Protection Committee, 2012). The Central Grand River sub-basin is the most urbanized with the cities of Kitchener, Waterloo, Cambridge, and Guelph. The urbanization there has led to more surface runoff causing localized flooding. The channel has been modified with dikes and reservoirs as well, which regulate the flows through the channel. Flows are decreased during spring melt because the reservoirs are filled using spring melt; and in the summer, the flow is augmented by the reservoirs. Large amounts of groundwater discharge allow for recovery of the Grand River downstream of these urban areas. Another type of modification to the watershed is the use of an artificial recharge system in Arkell, just outside the City of Guelph. This recharge system, called the Arkell Springs Collection System, pumps approximately half of the water taken from the Eramosa River for use by the City of Guelph under a PTTW into an infiltration trench and the water recovers aquifers or discharges back into the river.

The GAWSER continuous streamflow-generation model and the FEFLOW steady state groundwater flow model were both used in a study by the Lake Erie Source Protection Committee to determine the groundwater stresses in different subwatersheds and under different climatic scenarios (Lake Erie Source Protection Committee, 2012). The groundwater reserve was calculated as at least 10 percent of the groundwater discharge flowing into surface water streams. This estimate was taken from a suggestion of the Technical Rules from the Ministry of the Environment. Therefore, any listing in the model less than 10 percent of the average annual percent water demand for the subwatershed was considered to have a “low” stress level. “Moderate” and “significant” stress levels were also determined from the model.

Three subwatersheds were determined to have a “moderate” stress level, including the Eramosa above Guelph, Whiteman’s Creek, and McKenzie Creek subwatersheds; the rest of the Grand River watershed was determined to have a “low” stress level (Lake Erie Source Protection Committee, 2012). Because of increasing urbanization and projected increase in population, a predicted future stress assessment was conducted as well. Due to the presence of the Shand, Conestogo, and Guelph dams located upstream and controlling downstream discharge, little development upstream in the Grand River watershed is expected, which will maintain the same flows through the dams and the regulated downstream flows as at present. Therefore, the increase in population is not expected to have an effect on discharge through the Grand River. Also, due to the surface water intakes being below the water levels in these reservoirs, the forecast of drought along with projected population increase is not expected to diminish water supply. Large amounts of groundwater discharge allow for recovery of the Grand River downstream of these urban areas.

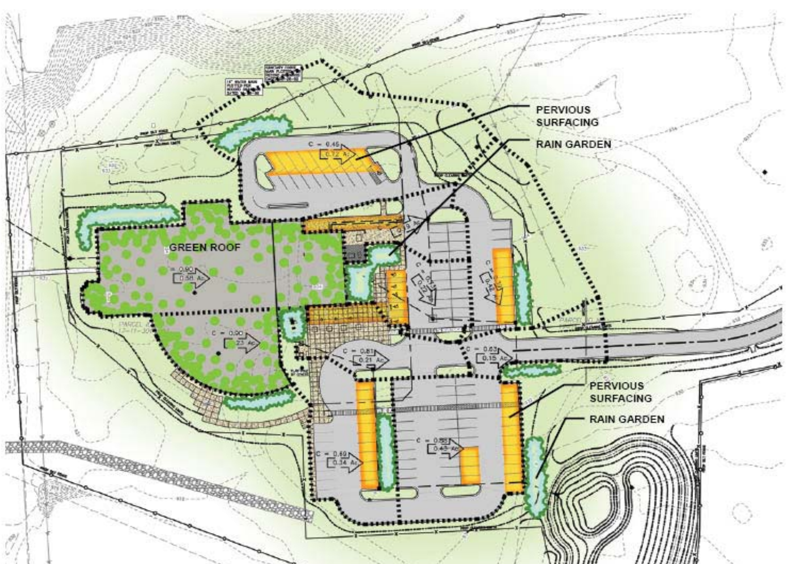
For groundwater, potential stress on the average demand was “moderate” for municipal water supplies to West Montrose, Conestogo, Elmira; Guelph, Guelph/Eramosa, Rockwood; Puslinch Mini-Lakes; and Lynden. The potential stress on average demand was considered “significant” for the Integrated Urban System. When the potential stress on the maximum monthly demand was assessed, all subwatersheds were classified as “low” except for the Integrated Urban System (Kitchener, Waterloo & Cambridge), which was classified as “significant.” A drought scenario was also examined, modeling the groundwater recharge with the lowest annual precipitation record over a 10-year period. This forecasted that Whiteman’s Creek Assessment Area (with a municipal water supply at Bright and Princeton) should also be listed as “moderate.” The “non-municipal supply” impacts are not taken into account in this assessment, which was entirely focused on human drinking water use.

5.5 Using Green Infrastructure in the Target Communities

As part of the Greater Lakes Project, two Oakland County project sites and two Grand River project sites were analyzed using the Greater Lakes Analysis tool. Once again, this analysis tool does not answer all the questions needed to select and/or design an optimal green infrastructure program. It is, however, useful in the very early stages of the green infrastructure planning process because it allows the decision makers to compare costs and space requirements for various management practices sized specifically for their site. It also allows alternative stormwater management designs to be compared while minimizing upfront design costs. Ultimately, the BMPs chosen will be determined by project-specific goals and aesthetic desires for the site, but these analyses can provide useful information for the decision-making process.

The four community projects analyzed using the Greater Lakes Tool provide practical examples of green infrastructure and the expected stormwater infiltration and groundwater recharge practices that could be incorporated into existing and new development. The analysis for all four of these sites compared multiple green infrastructure management practices sized for the proposed runoff volumes. They were compared based on the area needed, proposed construction costs, and proposed maintenance costs.

One of the analyzed sites in Oakland County is a proposed library in Commerce Township, a new development proposed for a greenfield site (See Figure 5-7). The second Oakland County site is a proposed roadway redevelopment in Lyon Township. For each project, the analysis measured proposed stormwater runoff volumes based on proposed area of impervious versus pervious surfaces (See Figure 5-8). Space constraints were different between each site. The library site has high density proposed use with a large library building and extensive impervious parking and patio areas.



ENTIRE PROJECT ANALYSIS AREA: COMMERCE TOWNSHIP LIBRARY
GREEN INFRASTRUCTURE PLAN

Figure 5-7: Example green infrastructure plan for Commerce Twp. library

IMPLEMENTATION COSTS - Commerce Twp Library

	Location	BMP	Size	Unit	Unit Price	Construction Cost	Annual Maintenance Cost	Lowest Year 1 Cost
1	DA 1	Bioinfiltration	1,900	SF	$ 12.00	$ 22,800.00	$ 950.00	$ 16,844.91
		Green Roof	24,646	SF	$ 15.00	$ 369,690.00	$ 10,154.15	
		Blue Roof	24,646	SF	$ 4.00	$ 98,584.00	$ 4,929.20	
		Cistern	1624.389	CF	$ 10.00	$ 16,243.89	$ 601.02	
2	DA 2	Bioinfiltration	750	SF	$ 12.00	$ 9,000.00	$ 375.00	$ 4,823.48
		Green Roof	9929	SF	$ 7.00	$ 69,503.00	$ 4,090.75	
		Blue Roof	9929	SF	$ 9.00	$ 89,361.00	$ 1,985.80	
		Cistern	654.4746	CF	$ 7.00	$ 4,581.32	$ 242.16	
3	DA 3	Bioinfiltration	900	SF	$ 12.00	$ 10,800.00	$ 450.00	$ 11,250.00
		Pervious Concrete	1900	SF	$ 7.00	$ 13,300.00	$ 304.00	
		Pervious Pavers	1900	SF	$ 9.00	$ 17,100.00	$ 68.40	
4	DA 4	Bioinfiltration	1400	SF	$ 12.00	$ 16,800.00	$ 700.00	$ 17,500.00
		Pervious Concrete	3000	SF	$ 7.00	$ 21,000.00	$ 480.00	
		Pervious Pavers	3000	SF	$ 9.00	$ 27,000.00	$ 108.00	
5	DA 5	Bioinfiltration	400	SF	$ 12.00	$ 4,800.00	$ 200.00	$ 5,000.00
		Pervious Concrete	800	SF	$ 7.00	$ 5,600.00	$ 128.00	
		Pervious Pavers	800	SF	$ 9.00	$ 7,200.00	$ 28.80	
6	DA 6	Bioinfiltration	700	SF	$ 12.00	$ 8,400.00	$ 350.00	$ 8,750.00
		Pervious Concrete	1400	SF	$ 7.00	$ 9,800.00	$ 224.00	
		Pervious Pavers	1400	SF	$ 9.00	$ 12,600.00	$ 50.40	
7	DA 7	Bioinfiltration	1300	SF	$ 12.00	$ 15,600.00	$ 650.00	$ 16,250.00
		Pervious Concrete	2500	SF	$ 7.00	$ 17,500.00	$ 400.00	
		Pervious Pavers	2500	SF	$ 9.00	$ 22,500.00	$ 90.00	
8	DA 8	Bioinfiltration	600	SF	$ 12.00	$ 7,200.00	$ 300.00	$ 7,500.00
		Pervious Concrete	1200	SF	$ 7.00	$ 8,400.00	$ 192.00	
		Pervious Pavers	1200	SF	$ 9.00	$ 10,800.00	$ 43.20	
9	DA 9	Bioinfiltration	600	SF	$ 12.00	$ 7,200.00	$ 300.00	$ 7,500.00
		Pervious Concrete	1250	SF	$ 7.00	$ 8,750.00	$ 200.00	
		Pervious Pavers	1250	SF	$ 9.00	$ 11,250.00	$ 45.00	
10	DA 10	Bioinfiltration	650	SF	$ 12.00	$ 7,800.00	$ 325.00	$ 8,125.00
		Pervious Concrete	1350	SF	$ 7.00	$ 9,450.00	$ 216.00	
		Pervious Pavers	1350	SF	$ 9.00	$ 12,150.00	$ 48.60	
11	Entire Site	Underground Storage	7789.794	CF	$ 7.00	$ 54,528.56	$ 2,882.22	$ 57,410.78
12	Entire Building	Cistern	2278.863	CF	$ 10.00	$ 22,788.63	$ 843.18	$ 23,631.81

Lowest Cost Total	$ 103,543.39

Figure 5-8: Greater Lakes costing tool used to minimize cost of capturing one inch of rain at Commerce Twp. library using green infrastructure

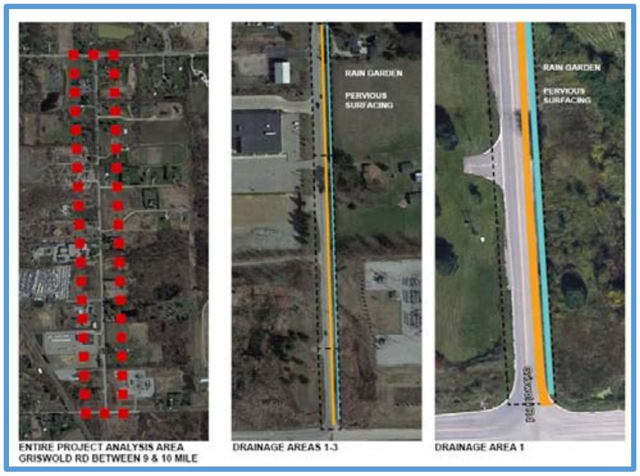


Figure 5-9: Example green infrastructure plan for road reconstruction in Commerce Twp.

The road site has space constraints related to the existing right-of-way width (see Figure 5-9). The road is bordered on either side by low-density residential private property. Although there is a lot of underutilized land adjacent to the road, this private property is not available for stormwater management purposes.

A stormwater analysis similar to what was conducted for the two sites in Oakland County was conducted for two projects in Guelph. Like Oakland County, one site was a municipal campus, in this case, a park with a recreation center on site, and the other was a roadway. For each site, the analysis measured proposed stormwater runoff volumes based on proposed area of impervious versus pervious surfaces. Space constraints were different between each site. The park site has high density proposed use with a large recreation center building, extensive impervious parking and patio areas, and recreation fields including baseball and basketball among others (see Figure 5-10). The road site has space constraints related to the existing right of way width, but there exists additional stormwater management opportunities in existing parkland and vacant lots adjacent to the proposed roadway improvement route (see Figure 5-11). The road is bordered on either side by high density single family residential private property. This private property is not available for stormwater management purposes.

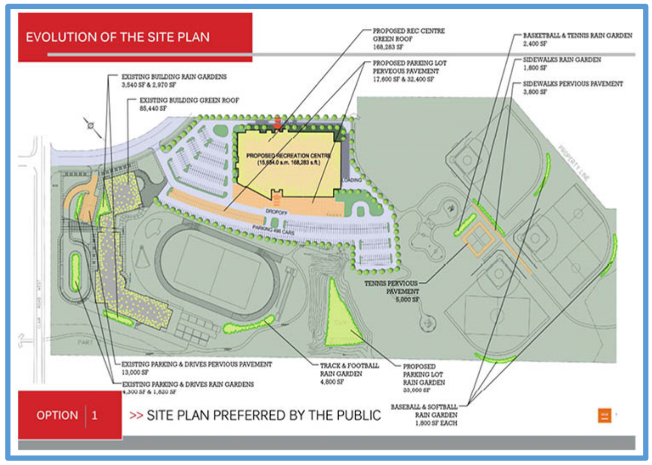


Figure 5-10: Example GI plan for recreation area in Guelph, Ontario

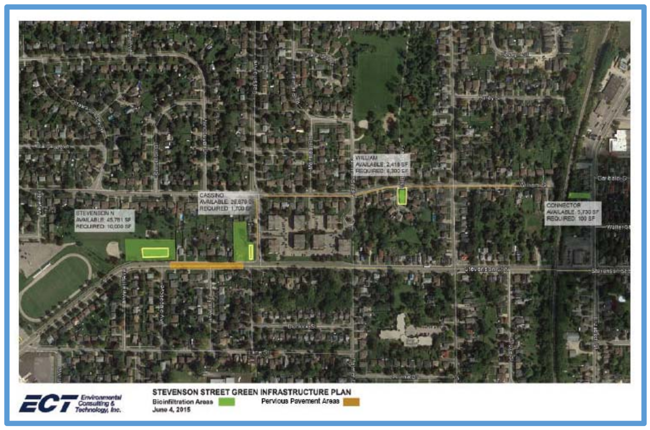
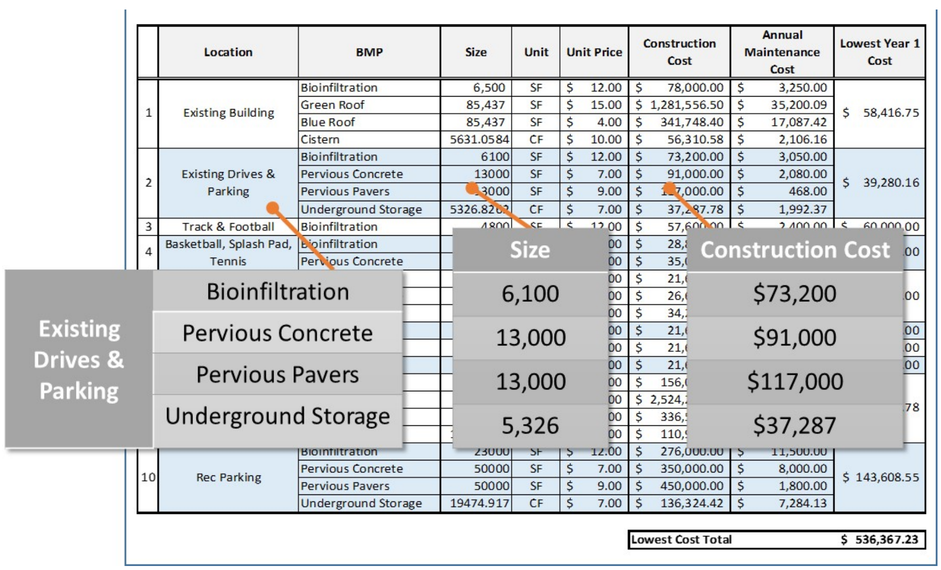


Figure 5-11: Example green infrastructure plan for road construction in Guelph, Ontario

<u>Managing surface runoff</u> - The analysis found the least expensive management practice for both sites to be cisterns (see Figure 5-12). Cisterns, whether above or below ground, have relatively low space requirements, are effective at storing runoff, and are, therefore, effective at reducing peak flows. However, cisterns do not provide additional habitat or infiltration value, and they are often considered unsightly. For projects specifically intended to help recharge groundwater, cisterns would not be the best management to choose unless they were coupled with a management practice designed specifically to encourage infiltration, such as a rain garden, bioswales, or infiltration augmentation device.



	Location	BMP	Size	Unit	Unit Price	Construction Cost	Annual Maintenance Cost	Lowest Year 1 Cost
1	Existing Building	Bioinfiltration	6,500	SF	$ 12.00	$ 78,000.00	$ 3,250.00	$ 58,416.75
		Green Roof	85,437	SF	$ 15.00	$ 1,281,556.50	$ 35,200.09	
		Blue Roof	85,437	SF	$ 4.00	$ 341,748.40	$ 17,087.42	
		Cistern	5631.0584	CF	$ 10.00	$ 56,310.58	$ 2,106.16	
2	Existing Drives & Parking	Bioinfiltration	6100	SF	$ 12.00	$ 73,200.00	$ 3,050.00	$ 39,280.16
		Pervious Concrete	13000	SF	$ 7.00	$ 91,000.00	$ 2,080.00	
		Pervious Pavers	[illegible]3000	SF	$ 9.00	$ [illegible]7,000.00	$ 468.00	
		Underground Storage	5326.82[illegible]	CF	$ 7.00	$ 37,[illegible]87.78	$ 1,992.37	
3	Track & Football	Bioinfiltration	4800	SF	$ 12.00	$ 57,600.00	$ 2,400.00	$ 60,000.00
4	Basketball, Splash Pad, Tennis	Bioinfiltration	[illegible]	[illegible]	[illegible]	$ 28,[illegible]	[illegible]	[illegible]
		Pervious Concrete	[illegible]	[illegible]	[illegible]	$ 35,[illegible]	[illegible]	
10	Rec Parking	Bioinfiltration	23000	SF	$ 12.00	$ 276,000.00	$ 11,500.00	$ 143,608.55
		Pervious Concrete	50000	SF	$ 7.00	$ 350,000.00	$ 8,000.00	
		Pervious Pavers	50000	SF	$ 9.00	$ 450,000.00	$ 1,800.00	
		Underground Storage	19474.917	CF	$ 7.00	$ 136,324.42	$ 7,284.13	

Lowest Cost Total	$ 536,367.23

Figure 5-12: Identifying Least Cost BMPs at a community park

The most expensive management practice considered for the Oakland County library site was a green roof. Although green roofs are considerably more expensive than other options, they are able to make valuable use of rooftop space, which is often the only space available in dense urban settings. In addition, green roofs are beautiful, visible, and provide habitat value. Also, because of their high insulation impact on buildings, reductions in energy use can often offset the relatively high cost of installing a green roof. Return on investments are likely to come much faster from the energy savings of a green roof installation than the stormwater benefits.

Managing Road Runoff - The most expensive management practice considered for the road site was pervious pavers. The entire road did not need to be constructed of pavers to capture the design storm. Still, using them only in the parking lane (the minimum area required to capture the first one inch of runoff), the cost was still higher than other management practices considered. Pervious pavers do not provide habitat value, but they do facilitate infiltration. Sites with high intensity use may find pervious pavers desirable because area dedicated for increased infiltration is not precluded from other uses.

Ultimately, “best” management practices will be determined by project-specific goals and aesthetic desires for the site. The most successful programs, both from a stormwater management and financial perspective, include several management practices incorporated in different locations for different purposes and all coordinated to achieve a larger, regional goal.

6.0 ESTIMATING ECOLOGICAL BENEFITS

This section provides a very rough estimate of the ecological benefits of implementing green infrastructure across the entire Great Lakes basin. Estimating ecological benefits on the grand scale of the Great Lakes is imprecise at best. Green infrastructure is best practiced by placing a large number of small projects in locations and in a manner that provides the largest benefit. A lot can be gained by aggregating the anticipated benefits from proposed small projects, assume similar projects would be installed across a given community, and then extended across all municipalities across the basin.

This analysis quantifies the ecological benefits expected from two municipal complexes (a library in Commence Township, Michigan and a park in Guelph, Ontario) and two road projects in two municipalities (Guelph, Ontario, and Lyon Townships, Michigan). Other ancillary benefits are not quantified, including reduced erosion, improved habitat, and support of a diverse and thriving wildlife population. The detailed description of the analysis is included in Section 5, Estimating Environmental Impacts of Water Use in Six Targeted Communities.

The site-specific management practices evaluated in this project have impressive ameliorative effects on the immediate surrounding areas, but have even broader benefits if installed across the individual municipality and then extended to all municipalities throughout the Great Lakes. The following analysis estimates the potential basin-wide benefits by assuming that each community installed similar projects and the benefits accrued additively (rather than through an exponential accrual used in some studies).

The analysis is limited to stormwater from separated storm sewer systems. It is assumed that stormwater captured in combined areas will be treated at the wastewater treatment plant, and when the entire CSO control program is implemented, very little stormwater would enter the waterways untreated. In combined sewer areas where treatment facilities require power to treat the stormwater, any reduction in volume entering the treatment plant also reduces discharge volume, contaminant levels, as well as reduction in greenhouse gases. Conversely, non-CSO communities realize significant benefits from installing green infrastructure through nutrient reductions at the site where runoff would be initiated.

The analysis examines each country at the municipal level taking into account the degree of local control these governments can exercise. The United States analysis considered villages, cities, towns, and census-designated places (CDPs) as potential locations for installing green infrastructure. CDPs are the statistical counterparts of incorporated places, and are delineated to provide data for settled concentrations of population that are identifiable by name but are not legally incorporated under the laws of the state in which they are located (U. S. Census Bureau, 2012). On the United States' side, cities and villages control much of the local drainage network and regulate private drainage requirements. Townships were excluded because of their relatively-low direct control over individual sites. Counties were excluded to avoid double counting. On the Canadian side, municipalities, towns, cities, villages, and Census Designated Places (CDPs) were all included in the final analysis.

The stormwater analyses were conducted in Guelph and Oakland County to evaluate a variety of approaches to the site-specific challenges. The results were divided into “low” and “high” reduction scenarios based on the amount of overall storage offered by each suite of practices. These suites could then be compared using cost information. These scenarios are meant to show the upper and lower bounds of the amount of stormwater captured and the resulting reduction in runoff volume. The “high” storage scenario represents the highest possible amount of runoff captured and incorporated extensive rain gardens, permeable pavers, as well as vast blue/green roofs. The “low” scenario represents the lowest amount of runoff stored and included relatively-small areas of rain gardens and pavers. Tables 6-1, 6-2, and 6-3 present the total land area required for each management practice in each scenario.

Table 6-1: Volume reductions expected in Guelph through green infrastructure practices

BMP Suite	Area Rain Gardens (ft^2)	Area Permeable Pavers (ft^2)	Area Green/Blue Roof (ft^2)
Low Volume Scenario	15,600	16,874	0
High Volume Scenario	20,250	41,400	34,575

Table 6-2: Separate stormwater runoff (non-CSO) contaminant reduction (basin-wide)

Constituent Reduction	Low Scenario	High Scenario
Total Basin-Wide Runoff Volume Reduction (Acre-Feet)	122,573	192,292
Basin-Wide Total Phosphorous Load Reduction (Tons/Year)	1,516	1,934
Basin-Wide Total Nitrogen Load Reduction (Tons/Year)	10,898	13,936

Table 6-3: Basin-Wide Reduction by Country

United States (5,595,638 acres) -1,873 towns, cities, and census-designated places		
Constituent Reduction	**Low Scenario**	**High Scenario**
Total Basin-Wide Runoff Volume Reduction (Acre-Feet)	39,570	62,077
Basin-Wide Total Phosphorous Load Reduction (Tons/Year)	489	624
Basin-Wide Total Nitrogen Load Reduction (Tons/Year)	3,518	4,499
Canada (1,560,612 acres)-141 towns, cities, and census-designated places		
Total Basin-Wide Runoff Volume Reduction (Acre-Feet)	83,003	130,216
Basin-Wide Total Phosphorous Load Reduction (Tons/Year)	1027	1,309
Basin-Wide Total Nitrogen Load Reduction (Tons/Year)	7,380	9,437

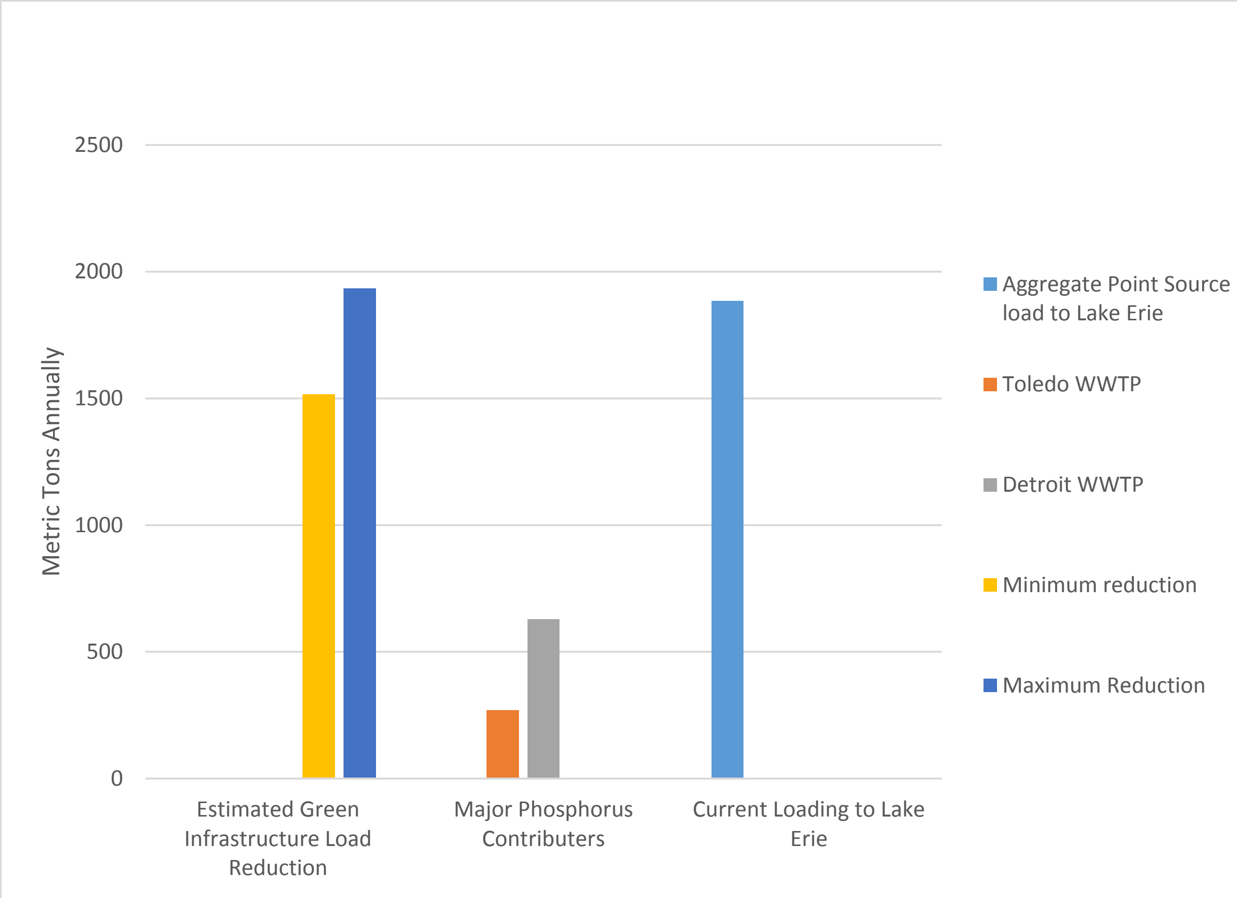
To estimate the benefit of implementing green infrastructure on all municipalities in the Great Lakes, the following steps were executed:

1. The amount of public property within each municipality in the Great Lakes basin was identified.
2. Municipally-held property for Ontario's and the United States' portions of the Great Lakes basin was aggregated. In recognition that certain large towns in Canada contain significant agricultural areas, a correction factor was applied. This correction factor (assumed to be 0.15), was applied to all towns and cities in Ontario within the targeted area exceeded 91 square miles. We identified the percentage of public property within the targeted communities (e.g., Guelph – 22.7 percent), and then assumed that green infrastructure was installed on all public lands within the targeted community to determine the benefits.
3. All Great Lakes communities were assumed to have a similar percentage of public land. The resulting land area for both countries was multiplied by 0.227 to estimate the amount of land available to municipal governments to install green infrastructure.
4. This aggregated land area was modelled using the Virginia Runoff Method calculator spreadsheet, with the suite of treatment applications applied in the city of Guelph.

These results are dramatic yet reasonable when compared to other loads to the Great Lakes. The results show that, by installing a distributed system of green infrastructure in the Great Lakes basin throughout both the United States and Canada, the aggregate load reduction of phosphorus to the Great Lakes could be as high as 1,934 metric tonnes annually. Even at the minimum estimated reduction of 1,516 metric tons annually – a significant amount to help the United States and Canada move closer to their goal of reducing nutrient loading to the Great Lakes.

Figure 6-1 is presented for context and shows the estimated point source loads to Lake Erie and the estimated loading from a few major sites on the lake. The table shows that applying green infrastructure across the lakes on 22.7 percent of the land would be equivalent to removing the discharge from three Detroit wastewater treatment plants. The removed phosphorous is also equivalent to all of point source loads to Lake Erie.

Figure 6-1: Comparing potential phosphorous removal from Great Lakes-wide green infrastructure implementation to known phosphorous loads



Source: MDEQ, 2015; MDEQ, 2016; Ohio EPA, 2010; Scavia, 2014

7.0 CONCLUSION

Interrupting the natural water cycle can cause negative impacts to the natural environment. The impervious surfaces that support modern development also cause urban flooding, polluted runoff, sewer overflows, and groundwater reductions. Green infrastructure, coupled with water efficiency, can reduce these negative impacts. Besides the ecological benefits, large-scale implementation of green infrastructure can also provide the least cost, sustainable approach to stormwater drainage in a manner that also supports green space and an improved quality of life.

Green infrastructure is a cost effective way to collect, retain, and slowly allow water to infiltrate back into the ground naturally. To assure cost effectiveness on a site-specific basis, the differing types of green infrastructure BMPs should be evaluated to determine which would work best given site constraints and public acceptance.

Green infrastructure can also reduce excessive groundwater withdrawals, thereby reducing diversion of groundwater away from streams, improving water quality as stream flow is replenished, supporting water-dependent habitat, and reducing the periods of drought flows, which result from exhausted aquifers that cannot provide baseflow to streams.

This project examined these many effects of water uses in urban, suburban, and agricultural land areas. Six communities were studied including Lyon Township, Southwest Oakland Township, and Commerce Township located within Oakland County, Michigan, and the Region of Waterloo and City of Guelph in Ontario in the Grand River watershed. The proposed solutions varied with the local water resource challenge. Oakland County communities are growing suburban areas of Detroit and contain large amounts of open green space

The primary lessons learned from this project include:

- Water conservation and green infrastructure can keep water closer to where it falls, and increases the amount of water that infiltrates, which benefits the environment.
- An integrated water system approach to water supply and water management planning could reduce cost and improve water availability and quality.
- Impacts of water withdrawals tend to be concentrated at the point of withdrawal. As more water is withdrawn from a single well or water source, the impacts to the local environment increases.
- During drought years, the effect of withdrawing excessive amounts of groundwater exacerbates low flow challenges in the affected rivers as the withdrawn water effectively lowers the water table supporting the baseflow.
- Urbanization leads to increased peak flow volumes and velocities, downstream flooding, and increased contaminated stormwater runoff.
- Water sent directly into streams through stormwater systems limits recharge groundwater. Cumulative impacts of development over time reduces natural groundwater flow that supports stream flow during drought periods and other surface ecology.

- Green infrastructure BMPs can be designed to minimize cost and maximize performance by incorporating site-specific constraints with local needs and desires. In developed areas, the optimal system typically requires integration with the existing gray infrastructure systems to increase efficiency and effectiveness.

The communities around the Great Lakes can both support the larger water-rich geographic region that is the Great Lakes by preserving their local water resources. Implementing well-designed, green infrastructure BMPs on a watershed-scale can restore the natural water cycle and provide sustainable groundwater, stream flows, and the Great Lakes.

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