DRINKING WATER
SOURCE PROTECTION
Our Actions Matter



ASSESSMENT REPORT
Hamilton Region
Source Protection Area

- Initially approved by the Ministry of the Environment and Climate Change on August 5, 2015
- In effect since December 31, 2015
- Amendment approved January 30, 2019
- Proposed Updates: March 15, 2022

Prepared on behalf of the Source Protection Committee

Assessment Report
for the
Hamilton Region Source Protection Area
Version 4.1
March 15, 2022

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For more information about the *Clean Water Act*, *2006* and how you can play a role in protecting drinking water sources in the Halton-Hamilton Source Protection Region, please visit our website: **www.protectingwater.ca**

Conservation Halton

Hamilton Conservation Authority

A Healthy Watershed for Everyone

Executive Summary

Background

The Town of Walkerton's contaminated drinking water tragedy in 2000 prompted the introduction by the Government of Ontario of new legislation to safeguard Ontario's drinking water supplies. The *Clean Water Act, 2006,* is one piece of this legislation. Essentially, the *Act* requires communities to develop science-based protection plans for their existing and future drinking water sources.

This Assessment Report is the foundation of the Source Protection Plan for the Hamilton Region Source Protection Area. The Area comprises lands within the municipalities of the City of Hamilton, the Township of Puslinch/County of Wellington, and the Town of Grimsby/Niagara Region. It is partially served by two municipal drinking water systems located within the Source Protection Area and operated by the City of Hamilton, partially by a municipal system in the neighbouring Niagara Peninsula Source Protection Area, and partially by private services.

- The Woodward system and neighbouring Grimsby system take water from Lake Ontario and distribute it to approximately 96.7 percent of the population within the Hamilton Region Source Protection Area.
- The Greensville well system, situated within Middle Spencer Creek, a subwatershed of the Spencer Creek watershed, serves 0.03 percent.
- The remaining nearly 3 percent of the population rely on private systems, including wells and cisterns.

Significant Findings

Building upon an analysis of the characteristics of Hamilton Area watersheds, water budgets were completed to assess the availability and use of water supplies within the Area. Water quantity stress assessments were then completed to identify areas requiring further study. Finally, threats to water quality from ongoing, potential, or past activities were identified, and the associated risks were assessed.

- **Existing stresses on surface water quantity:** This Assessment Report identifies 5 subwatersheds that are significantly stressed and 9 that are moderately stressed based on monthly demand on the available surface water supply. The municipal surface water intakes in the Source Protection Area are located in Lake Ontario and not within these stressed subwatersheds. Therefore, under the *Clean Water Act, 2006,* these 14 stressed subwatersheds do not warrant further study.

- **Existing stresses on groundwater quantity:** This report also identifies three subwatersheds that are stressed based on monthly and/or annual demand on available groundwater supply. These include the Middle Spencer Creek subwatershed, in which the Greensville municipal well system operates.

- **Future risks to groundwater quantity:** Based on the findings of the stress assessment, an assessment of the risks from overuse, drought and reduced recharge on the Greensville municipal wells was completed. The risk of having water quantity issues is low.

- **Existing stresses on source water quality:** Neither of the two municipal drinking water supplies within Hamilton Region Source Protection Area has existing water quality issues that could render the supplies unusable. Also, neither water supply exhibits a significant threat due to conditions resulting from past land use activities.

- **Existing and future risks to source water quality:** Only within the Greensville wellhead protection areas are vulnerability scores high enough to pose potential significant threats to groundwater quality. Existing activities that could cause an issue at the wells are associated with sewage systems. The numbers of occurrences of this drinking water threat in the Hamilton Area are documented in Section 7 of this Assessment Report. Modelling results also show existing risks to Lake Ontario water quality from activities occurring within and outside the Hamilton Region Source Protection Area.

Follow Up

This Assessment Report is a living document. It is reviewed and updated periodically in compliance with the *Clean Water Act* and as data/information becomes available that could affect the Source Protection Plan. The first Source Protection Plan and Assessments Reports for the Halton-Hamilton Source Protection Region (HHSPR) came into effect on December 31, 2015. At the same time, the Minister of the Ministry of the Environment, Conservation and Parks (MECP) issued an order requiring the submission of a workplan in 2018 to review the Source Protection Plan and Assessments Reports per Section 36 of the *Clean Water Act*. Accordingly, a workplan was developed by HHSPR staff and submitted to MECP. The Minister then issued an amended order in March 2019 requiring certain updates and leading to the second round of source protection planning. This Assessment Report addresses the Minister’s amended order and additional necessary updates for the protection of municipal drinking water sources.

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1. INTRODUCTION

In this section:

- A brief overview of the history and strategies behind the plans to protect Ontario's drinking water

1.1 The Source Protection Planning Process

In May 2000, seven people died and over 2,300 became ill in Walkerton, Ontario as a result of a contaminated municipal water supply. This tragedy sparked a major government inquiry headed by Justice Dennis O'Connor. The inquiry highlighted the need to protect the health of Ontario's residents by protecting the province's drinking water. In his report, Justice O'Connor issued a list of recommendations, and the Province of Ontario subsequently passed new legislation to safeguard Ontario's drinking water supplies. The *Clean Water Act, 2006,* is one piece of this legislation. The Act sets out to protect existing and future sources of drinking water, and thereby protect public health. It is the first step in a **multi-barrier approach** to reduce the risks associated with water contamination and decreasing supplies (see Figure 1.1).

The *Clean Water Act* requires communities to develop collaborative, locally driven, science-based protection plans for their existing and future drinking water supplies. The resulting Source Protection Plans reflect a **watershed**-based approach to drinking water protection. This approach works to protect surface and ground waters and focuses on maintaining a sustainable supply of clean water. Such focus reduces the reliance on water treatment and, as part of the multi-barrier approach, helps to decrease risks to drinking water quality and quantity.

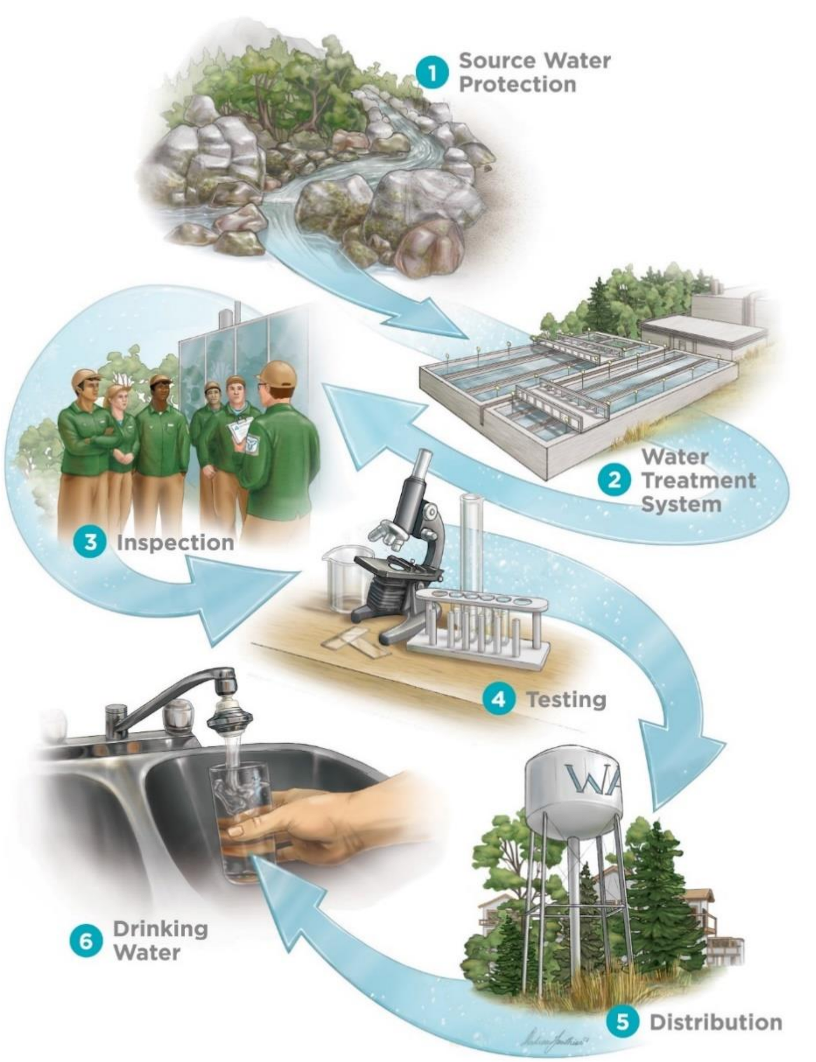


Figure 1.1 The multi-barrier approach (Conservation Ontario)

1.2 The Assessment Report and its Focus

Under the *Clean Water Act*, Source Protection Areas and Regions were formed as the basis for source protection planning and the development of Assessment Reports. The findings within these reports form the foundation for each Area's Source Protection Plan. The Halton-Hamilton Source Protection Region is one of 19 similar Regions or Areas involved in this process and consists of two Source Protection Areas: Halton Region and Hamilton Region (see Figure 1.2).

The Hamilton Region and the Halton Region Source Protection Areas are generally equivalent to the watersheds managed by the two Conservation Authorities: Hamilton Region Conservation Authority (Hamilton Conservation Authority) and The Halton Region Conservation Authority (Conservation Halton), respectively. However, there are minor adjustments to watershed boundaries to reflect better the drainage within those watersheds. This Assessment Report focuses on the Hamilton Region Source Protection Area. A corresponding report addresses the Halton Source Protection Area. (Note: within this report, the Source Protection Area or Hamilton Area refers to the Hamilton Region Source Protection Area unless otherwise identified.)

The first stage in preparing this Assessment Report was an assessment of the characteristics of the Hamilton Area's watersheds. Building upon this, water budgets were completed to assess the availability and use of water supplies within the Area. Water quantity risk assessments were then completed to identify areas requiring further study. Finally, threats to the quality of the water supplies from ongoing, potential, or past activities were identified, and the associated risks were assessed.

All studies and assessments described in this report have been completed following the provincial legislation and guidance of the Ministry of the Environment, Conservation and Parks, Ontario Regulation 287/07 – General, and the 2017 Technical Rules which outline all the requirements for completion of Assessment Reports. In addition, all maps have been completed using the symbology required.

This report was written for the general information and understanding of the public. For the legislated definitions, methods, and general requirements for source protection assessments, the reader is referred to the Act, regulations, and technical rules.

The Halton-Hamilton Source Protection Plans introduce policies that will be used to address the risks to drinking water supplies. In particular, the Plans address the activities identified as existing or potential threats within the Source Protection Area.

1.3 Participants in the Planning Process

The Source Protection Planning process is open and transparent with many opportunities for government, private sector, and community participants to provide input. The Source Protection Committee for Halton-Hamilton Region oversees the development of the Source Protection Plans for its two Source Protection Areas. This committee is comprised of nine stakeholders and a Chair who live or conduct business within the Source Protection Areas. The membership consists of one-third municipal, one-third industrial/commercial, and one-third general public representation. The Halton-Hamilton Source Protection Committee has included representatives from the following stakeholder sectors:

- municipal
- agricultural
- aggregate
- home builder
- commercial

- environmental
- public interest at large

Representatives from the municipalities and Conservation Authorities that have lands within the Halton-Hamilton Source Protection Region have worked cooperatively to complete the assessments necessary to produce this report. Conservation Halton is the lead agency for this program. The agencies involved include:

- The City of Hamilton
- The County of Wellington
- The Township of Puslinch;
- The Regional Municipality of Halton
- The City of Burlington
- The Town of Oakville
- The Town of Milton
- The Town of Halton Hills
- The Region of Peel
- The City of Mississauga
- Conservation Halton
- Hamilton Conservation Authority

Technical experts undertook a critical review of the study methods used in the assessments and their results. They reviewed the water budget evaluation and water quantity risk assessment, the delineation of vulnerable areas, and the assignment of vulnerability scores. Halton-Hamilton Source Protection staff used the direction and comments received from the peer reviewers and other stakeholders to improve the assessment process and to benefit the source protection program.

Halton-Hamilton Source Protection staff consulted the neighbouring Source Protection Areas – Niagara Region, Grand River, and Credit Valley – throughout the development of this report and addressed our common interests. The assessments completed in each Source Protection Area used scientific methods appropriate for the local area. Thus, the use of different methods to complete the required assessments can result in differences in the study outcome and the interpretation and use of the products developed. Hence, caution is advised if comparisons are made.

The municipalities and Conservation Authorities that extend around the Canadian side of Lake Ontario from Niagara to Quinte, Environment and Climate Change Canada, the Ontario Water Works Research Consortium, and the Ministry of the Environment and Climate Change worked together to understand risks to Lake Ontario source water. The working group was called the Lake Ontario Collaborative. Consultants were retained to undertake studies that focused on watershed impacts to the lake water, existing water quality concerns, and on the cumulative impacts in the nearshore environment.

Consultation with the neighbouring Source Protection Areas and the Lake Ontario Collaborative continued through the development of policies to reduce risks to drinking water. This will assist in encouraging a consistent policy approach for adjoining areas.

Many stakeholders beyond the sectors represented on the Source Protection Committee have provided input into the watershed evaluation and risk assessments summarized within this report. The Committee gratefully acknowledges their input. The consultation process on the required technical studies and development of this Assessment Report began in 2006. It continued throughout the next stage of Source Protection Planning, the writing of policies to address the identified threats, and the production of the Source Protection Plan. In order to promote two-way communication, the Committee invited residents, business owners, municipalities, conservation authorities, and other stakeholders to participate in the process. Appendix A summarizes the consultation and collaboration processes followed to date.

2. HAMILTON REGION SOURCE PROTECTION AREA

In this section:

- The location of the Hamilton Region Source Protection Area
- An overview of its physical and human geography

The Hamilton Region Source Protection Area encompasses about 447 square kilometres of land at the western end of Lake Ontario. It is a long thin Area, about 52 kilometres in length and typically about 11 kilometres wide. The Source Protection Area stretches from the Township of Puslinch in the northwest to the Town of Grimsby in the east and is primarily within the City of Hamilton. In addition, because it juts up to 11 kilometres into Lake Ontario to the international border, the Area includes approximately 130 square kilometres of Great Lakes water (see Appendix H Figures 1.2 and 2.1).

The Hamilton Area is slightly smaller than the watershed managed by Hamilton Conservation Authority due to a realignment of the boundaries between Conservation Authorities. This realignment was necessary to reflect better the drainage patterns and the extension of the in-water area to the international boundary in Lake Ontario. The Hamilton Region Source Protection Area borders:

- Grand River Source Protection Area to the west and southwest;
- Halton Region Source Protection Area to the northeast;
- Niagara Region Source Protection Area to the southeast; and
- Lake Ontario to the east.

Five upper and lower tier municipalities have lands within the Source Protection Area; however, only the City of Hamilton (Hamilton) operates municipal water systems within the Source Protection Area. Portions of municipalities located within the Source Protection Area are supplied water from the Grimsby water system located in the neighbouring Niagara Peninsula Source Protection Area. In total these municipal water systems supply 97 percent of the population within the Source Protection Area with reliable, clean drinking water (see Table 2.1).

The Hamilton Region Source Protection Area consists of four relatively large and 15 small watersheds. The headwater areas of three of the large watersheds – Spencer Creek, Red Hill Creek, and Stoney-Battlefield Creeks – form the majority of the **surface water divide** between this and neighbouring Source Protection Areas. The city core of Hamilton makes up the Urban Hamilton Core watershed where storm sewers are the conduits of water flow. Of the 15 small watersheds, 14 are located in the southern end of the watershed between the Niagara Escarpment and Lake Ontario.

The final small watershed is the Urban Hamilton Beach Strip, which lies between Lake Ontario and Hamilton Harbour.

Table 2.1 Hamilton Region Source Protection Area Upper and Lower Tier Municipalities

Upper Tier Municipality	Lower Tier Municipality	Area Within Hamilton Source Protection Area [km²]	Population in Source Protection Area[1]	Percentage of Population in Source Protection Area on Municipal Water Supply[2]
County of Wellington	Township of Puslinch	19	409	0
Regional Municipality of Niagara	Town of Grimsby	1.7	557	17
City of Hamilton		429	464,794	97

Notes: 1. Populations are based on Statistics Canada Population Census 2016.
2. The municipal water system supplying the Town of Grimsby and a portion of the City of Hamilton is not located within the Source Protection Area.

The Table 2.1 shows the population and percentage on municipal water supply, in relation to the source protection areas. Note that the Woodward Drinking Water Subsystem is a large municipal residential system that supplies a significant portion of Hamilton's population with drinking water including Stoney Creek, Dundas, Ancaster, Waterdown, and Glanbrook. The population served is estimated at 536,917. The Greensville municipal system provides water to 36 homes. The source of the information are Annual Drinking Water System reports for 2020.

2.1 Physical Geography

Landform patterns, soils, geology, and land cover influence the quantity, movement, and quality of water flowing through the Source Protection Area. Therefore, an understanding of the natural physical characteristics of the Area is fundamental to the assessment of its drinking water sources. Halton-Hamilton Source Protection staff assembled existing data for each of these characteristics from known sources.

2.1.1 Physiography and Surficial Geology: Landforms

The landforms in the Hamilton Region Source Protection Area are primarily the result of glacial activity that took place in the Late Wisconsinan period, ending about 10,000 years ago. During this period, the Laurentide Ice Sheet advanced and retreated in response to the climatic conditions of the time and helped to shape the landscape that exists today.

During **deglaciation,** the Laurentide Ice Sheet split into **lobes** that occupied the existing Great Lakes basins. The Ontario Lobe advanced over the Hamilton Region Source Protection Area, scouring or smoothing the bedrock surface. It left behind the rock, sand, silt, and clay debris it carried. When the ice melted, large volumes of meltwater flowed through channels, eroding the underlying bedrock and depositing sand and gravel. Meltwater also filled depressions in the land surface and formed ponds. Various physiographic regions formed according to the ways in which the sediment was deposited. The following paragraphs outline and discuss the regions that fall within the Source Protection Area. These regions are illustrated in Appendix H Figure 2.2.

Niagara Escarpment

Niagara Escarpment at Spencer Gorge

The Niagara Escarpment is the most dominant physiographic feature in the Hamilton Region Source Protection Area. Regionally, it extends from the Niagara River to the Bruce Peninsula and continues through the Manitoulin Islands. The escarpment exists because of the relative resistance to erosion of its hard upper rock and the more easily eroded softer rock beneath. Over time, water eroded the softer rocks, which caused the upper rocks to break off, maintaining the steep cliff face with slopes of rubble at its base. The process continued moving the escarpment in a westward direction. This erosion occurred prior to the last glaciation, and it represents a gap in time between the formation of the underlying shale bedrock and the deposition during glacial time of the soil overlying it. The steep cliff face of the Niagara Escarpment parallels the Lake Ontario shoreline, reaching heights of approximately 80 m.

Re-entrants

There are two notable breaks, called re-entrants, in the escarpment within the Hamilton Source Protection Area: the Red Hill Valley and the Dundas Valley. Re-entrants are valleys pointing into the escarpment face. These valleys eroded prior to the Wisconsinan glacial period. Former rivers had sufficient water flow and long periods of time to erode the deep valleys, and subsequent glacial activity and the streams that occupy the valleys today have further modified them.

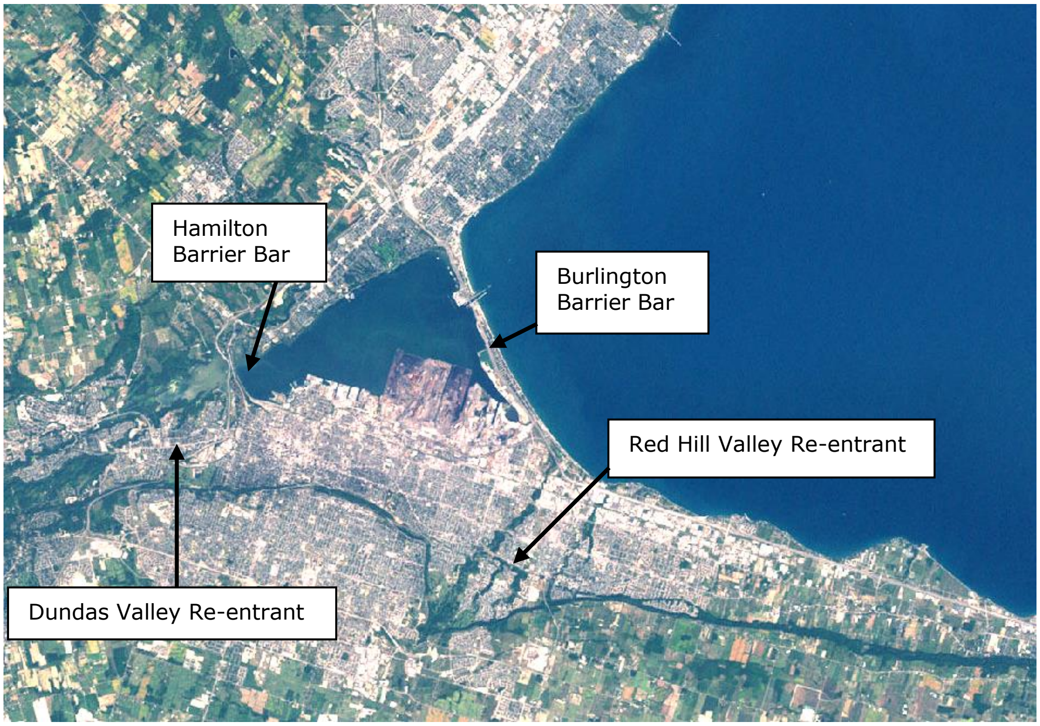
Iroquois Plain

Lake Iroquois formed as the glacial ice receded from the Lake Ontario Basin. The lake occupied a larger area than the current Lake Ontario and had higher water levels. Within the Hamilton Source Protection Area, shoreline cliffs and beaches are located about four kilometres inland at the base of the Niagara Escarpment. These features mark the edge of the former lake at its maximum size. This physiographic region, known as the Iroquois Plain, extends around the shore of Lake Ontario from the Niagara River to the Trent River. Typically, the plain is covered in layers of fine silty sands that formed the former lake bottom.

Barrier Bars

Within the Hamilton Region Source Protection Area, there are two significant sand bars at the western end of Lake Ontario. These bars are former beaches of Lake Iroquois. The easterly Burlington Barrier Bar separates Hamilton Harbour from Lake Ontario and has been developed as a major transportation route occupied by the Queen Elizabeth Way and the Burlington Skyway. The bar has also been developed for urban land uses including housing, light industrial/commercial uses, and parkland. The Burlington Canal breaches this bar where a lift bridge facilitates access to the harbour by large ocean-going ships.

The westerly Hamilton Barrier Bar separates Hamilton Harbour from Cootes Paradise. It is a major transportation corridor, occupied by Highway 403, York Boulevard, and numerous rail tracks. Desjardins Canal breaches the bar.



Barrier bars and re-entrants (Landsat 7 Orthorectified Imagery over Canada, Level 1, 1999)

Flamborough Plain

The northern portion of the Source Protection Area is in the physiographic region known as the Flamborough Plain. Soils overlying the dolostone bedrock are thin and bedrock outcrops are frequent. **Drumlins** are scattered across the region, oriented primarily in a west-east direction and in line with the direction of ice advance. The Wentworth **Till** was deposited in this area. It is primarily sand, with small pieces of the underlying carbonate bedrock. In some locations, it contains many boulders. The drumlins are also comprised of Wentworth Till. This area has poor surface drainage, which results in numerous wetlands, areas of ponded water, and the accumulation of **organic soils.**

Norfolk Sand Plain

Between the Flamborough Plain and the Dundas Valley lies the physiographic region referred to as the Norfolk Sand Plain. This plain of silts and sands extends southwest to Lake Erie. It formed as a delta in Lakes Whittlesey and Warren, both of which existed in the Lake Erie basin during glacial times (see Figure 2.3).

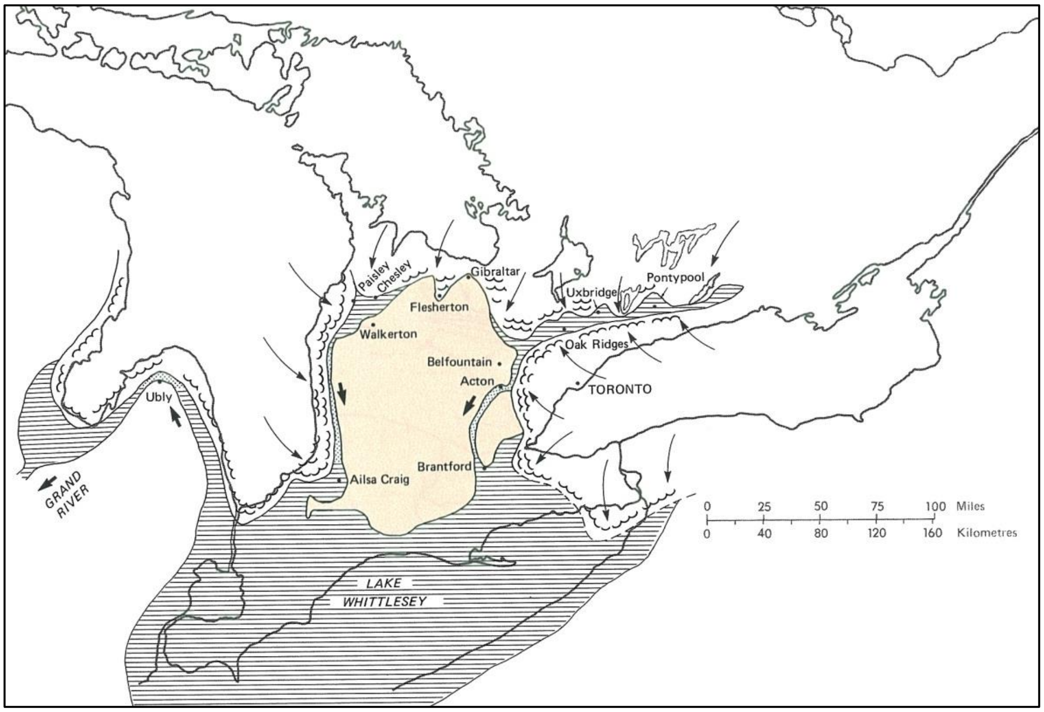


Figure 2.3 Extent of Lake Whittlesey during melting of the Ontario ice lobe (Chapman and Putnam, 1984)

Haldimand Clay Plain

The southern portion of the Source Protection Area is included in the Haldimand Clay Plain. This physiographic region covers much of the Niagara Peninsula to the south. It is characterized by a clay and silt plain that is gently sloping toward Lake Erie. The sediment was deposited at the bottom of Lake Whittlesey. This glacial lake occupied a larger area than the existing Lake Erie basin.

Moraines

The position of moraines in the Source Protection Area represents a pause in the recession of the glacial ice lobe and the deposit of the debris that the ice was carrying. The northwestern extent of the Source Protection Area lies adjacent to the southern extent of the Galt Moraine, one of the moraines included in the Horseshoe Moraines physiographic region. Due to its elevated topography, it divides the surface water drainage between the Hamilton Region and the Grand River Source Protection Areas.

Lying north and south of the Dundas Valley are a group of seven ridges called the Waterdown Moraines. These moraines are made of Halton Till and are only partially located within the Source Protection Area. North of the Dundas Valley, the moraines are silty, stony till, partly covered with sands deposited at the edges of former lakes. South of the valley, two of the ridges exist. The Vinemount Moraine lies close to the brow of the Niagara Escarpment while the Niagara Falls Moraine lies along the southern extent of the Source

Protection Area. The Vinemount Moraine is made of clayey till while the Niagara Falls Moraine comprises sands, gravel, and silt.

A large kame exists at the head of the Dundas Valley above and below the escarpment. A kame is a hill formed by the deposition of sand and gravel in layers that was carried by flowing water off the adjacent glacier.

Esker

One esker exists within the Hamilton Region Source Protection Area. An esker is a long, winding, narrow ridge of sorted sands and gravels. These formed when sediments were deposited in a stream flowing within or beneath the glacial ice. The esker is located in the Flamborough Creek subwatershed of the Spencer Creek watershed. It has a “Y” shape with two branches and stretches about two kilometres in length.

2.1.2 Bedrock Geology: Rock Formations and Landforms

Rock Formations

Sedimentary rocks of Upper Ordovician and Lower Silurian age, approximately 460 to 420 million years old, underlie the Hamilton Region Source Protection Area. The sediments that make up the rocks were deposited in horizontal layers in shallow, inland seas. The composition of the rock of each layer varies due to the environmental conditions when the sediments were deposited. Each layer was deposited on top of the last, making the uppermost layer the youngest. Millions of years may have passed between the periods of deposition recorded in the rocks due to erosional activity of water or ice. Figure 2.4 shows the layers that make up the stratigraphy of the Source Protection Area, and the following paragraphs describe the formations from oldest to youngest. Although the layers of rock originally were deposited as horizontal beds, the rocks have since tilted downwards towards the southwest and were eroded at ground surface. Thus, Figure 2.5 illustrates generally where each rock formation is the uppermost bedrock unit.

Period	Group	Formation/Member
Silurian	Lockport	Guelph
		Eramosa
		Goat Island
		Gasport
	Clinton	Rochester
		Irondequoit
		Rockway
		Merritton
	Cataract	Thorold
		Grimsby
		Cabot Head
		Manitoulin
		Whirlpool
Ordovician		Queenston

Figure 2.4 Sedimentary rocks of the Area in sequence from oldest at the bottom to youngest at the top (based on Brunton and Brintnell, 2011).

Ordovician aged Queenston Formation

The surficial bedrock lying below the Niagara Escarpment within the Source Protection Area is the

Queenston Formation. It comprises easily weathered, red shales with siltstone. This formation is about 140 metres thick within the Source Protection Area. Ice movement and water flow (from beneath or in front of the melting ice) has eroded the shale over hundreds of thousands of years. This erosion has left an irregular bedrock surface under the City of Hamilton core and underlying the eroded Dundas Valley.

Silurian aged rocks

Silurian aged bedrock formations lie exposed on the cliff face of the Niagara Escarpment. They were deposited on top of the eroded surface of the Queenston shale. Ongoing studies of these rock layers suggest that revisions to the previously accepted layer sequence are necessary. Correlation of the rock units of the Niagara Escarpment with the rock units of western New York and Ohio is being done based on the relative position of the layers and the types of **fossils** preserved in the rock. The Ontario Geological Survey completed the studies, which focus on the rocks overlying the shale of the Cabot Head Formation (see Brunton and Brintnell, 2011). The rock sequence, illustrated in Figure 2.4 and used in the discussion below, is consistent with the proposed formation name revisions. The existing formation names are mentioned in the discussion to assist with the transition.

Whirlpool Formation

Lying on top of the Queenston Formation, the Whirlpool Formation comprises light grey to white sandstone containing **quartz** and calcium carbonate. It is approximately four metres thick in the Source Protection Area.

Manitoulin Formation

The overlying Manitoulin Formation is a blue-grey to brown, thinly layered **dolostone** and contains many fossils. This formation does not exist south of Hamilton and, therefore, is quite thin in the Source Protection Area.

Cabot Head Formation

The Cabot Head is a regional formation extending throughout southwestern Ontario. In the Source Protection Area, it has a thickness of between 10 and 15 metres. It is composed of green-grey and red shale and dolostone.

Grimsby Formation

The Grimsby Formation consists mainly of red shale with sandstone beds. It is about two metres thick at Clappison’s Corners and increases in thickness toward the southeast. The Grimsby Formation pinches out just north of Clappison’s Corners and is absent in the northwestern portion of the Source Protection Area.

Thorold Formation

The overlying Thorold Formation is a grey to white sandstone with some beds of green, silty shales. Again, this unit is absent north of Clappison's Corners.

Bedrock layers from Grimsby (at base) through Goat Island Formations at Devil's Punchbowl, Hamilton (photo credit: City of Hamilton)

Merritton Formation

Because the Grimsby and Thorold Formations are absent in the northwestern portion of the Source Protection Area, the Merritton Formation overlies the Thorold Formation in the east and the Cabot Head Formation in the northwest. The Merritton Formation, along with the Rockway Formation, previously has been identified as part of the Reynales Formation. Brett and others (1995) noted that, based on the relative positions of the rock units and on the fossils the units contain, the term Reynales should not be used to describe these units. The Merritton Formation is only about one metre thick in the Source Protection Area and is made up of a distinctive, **bioturbated,** pinkish-brown dolostone with dark shale marking distinct layers. The lower layers are rich in pyrite (composed of iron disulphide) and contain black phosphate pebbles.

Rockway Formation

The Rockway Formation consists of about one-metre thick greenish-grey dolostone with thin layers of shale. As explained above, the rock was previously described as part of the Reynales

Formation, lying below the unsubdivided Amabel Formation. The Rockway Formation contains pyrite and few fossils.

Irondequoit Formation

The overlying Irondequoit Formation is composed almost entirely of fossilized plants called crinoids. This formation was previously included as the bottom unit of the unsubdivided Amabel Formation. It is medium grey to pinkish-grey in colour, and it will turn brown when exposed to the weather.

Rochester Formation

The Rochester Formation is about one metre thick at the Clappison's Corners and Waterdown areas and extends outside the Source Protection Area to the west at this thickness. The Rochester shale consists of a grey, shaley **mudstone** and contains fossils.

Gasport Formation

Most studies in the Source Protection Area included the Gasport Formation in the unsubdivided Amabel Formation. This formation is complex, containing **reef mounds** and **megashoals** comprised primarily of fossils. Its structure is dependent on conditions at the time of formation. The Gasport Formation thins in a southeasterly direction in the Source Protection Area and has been reported at five metres thickness north of the Dundas Valley. The rock is typically white to light grey and has a dark, blue-grey associated with the reef mounds.

Goat Island Formation

The Goat Island Formation is made up of two members: Niagara Falls and Ancaster. The Niagara Falls Member is present along the Niagara Escarpment in the Source Protection Area and can be identified by its distinctive, horizontally striped appearance and crinoid abundance. It has previously been included in the unsubdivided Amabel Formation and is about two-metre thick dolostone. The Ancaster Member overlies or **interfingers** with the Niagara Falls Member and is the cap rock of the Niagara Escarpment in the Hamilton area. This dolostone is medium grey, bioturbated, and contains **chert**.

Eramosa Member

The Eramosa Member (proposed to be a formation by Brunton and Brintnell, 2011) overlies the Goat Island Formation away from the escarpment edge. The Eramosa Dolomite comes to surface in a narrow band paralleling the escarpment edge. The Eramosa is a light brown to black, thin to moderate, layered, shaley dolostone divided into upper and lower members. The Eramosa contains sphalerite (zinc sulphide), galena (lead sulphide) and pyrite (iron disulphide) crystals, which can influence the quality of water flowing through it. Petroleum is extracted from the rock in some locations, and the rock often smells of petroleum when broken.

Guelph Formation

The Guelph Formation is the upper most bedrock unit covering most of the Source Protection Area north of the Dundas Valley and a small portion of the southern extremes. It consists of brown, medium to thick layers of dolostone and is about nine metres thick in the Source Protection Area. Dolostone of the Guelph Formation is of good chemical quality and has few impurities. This rock unit is mined within the Source Protection Area.

Bedrock Landforms

Bedrock Valleys

Within the Hamilton Region Source Protection Area, rivers flowing prior to and during the last glacial period have carved valleys into the bedrock surface. Some of these valleys, referred to as buried bedrock valleys, have been filled with the sediments the water and ice deposited.

The thickness of overburden materials and depth to bedrock, as recorded on water well records, and the alignment of present-day creeks suggest their locations. However, they have not been delineated fully.

Significant deposits of coarser-grained materials fill some of the bedrock valleys. These are the preferred pathways for the movement of water below ground. Therefore, it is important to understand the locations of these bedrock valleys, particularly those potentially allowing water to flow into or out of the watersheds of the Source Protection Area.

The Dundas Valley was carved through the Silurian bedrock of the Niagara Escarpment and into the shale of the Queenston Formation below. The modern-day re-entrant valley extends from Copetown in the west to Lake Ontario. However, the valley is considered to be part of a preglacial drainage system that extended across the Grand River Watershed toward Lake Huron. The eastern end of the ancient valley lies beneath Cootes Paradise and Hamilton Harbour. Drilling records show that the valley extends beneath the Burlington Barrier Bar to elevations of about 110 metres below sea level. The eroded valley has been partially infilled with greater than 180 metres of sediment. The sediment infill consists of gravel of the Wentworth Till overlain by Lakes Whittlesey and Warren clay and silt and at surface by the sands and silts of Halton Till. The valley is about four kilometres wide, and tributaries of Spencer Creek flow across it to discharge into Cootes Paradise.

Another valley exists in the northern portion of the Source Protection Area lying in a southwest-northeast direction between Highway 8 and just north of Harper Corners (see Figure 2.5). The valley is occupied by tributaries of Spencer Creek.

The Red Hill Valley re-entrant extends about eight kilometres between the Niagara Escarpment and Lake Ontario. Portions of the valley below the escarpment have been completely filled. The valley comprises a natural corridor and the recently constructed Red Hill Valley Parkway. Red Hill Creek currently flows through the valley from waterfalls at the escarpment edge to

Windemere Basin in Hamilton Harbour. The valley got its name from the steep red cliffs that form its edges. They are approximately 50 metres high.

Central area of the Dundas Valley. Photo taken from the southern escarpment edge.

Karst Features

Karst defines topography with unique features resulting from the dissolution of bedrock by acidic surface and ground waters over long periods of time. Karst features include caves, sinkholes, disappearing streams, and an enhanced network of connected pathways within the rock. Karstic rock is typically more **permeable,** and groundwater can flow through it at a faster rate. Unless the karst feature is at ground surface, such as along a cliff face, it is difficult to identify because it is typically covered by glacial material or below the surface of the rock.

In general, the bedrock of the Niagara Escarpment has the potential to be karst, but site-specific studies are required to verify its existence and its impact on groundwater flow. Within the Source Protection Area, there are sections above the escarpment that have small enhancements to the subsurface groundwater flow pathways, known as microkarst. These pathways include joints, fractures, bedding planes, and formation contacts. Large volumes of acidic water acted upon these areas, likely over thousands to millions of years. During glacial melting, the available volume of water was much greater than it is today, and the existing groundwater flow follows the pathways carved by this former system.

Studies have identified known areas of karst in the Source Protection Area, including the Eramosa Karst, a cave in West Hamilton and solution features along the crest of the Niagara Escarpment and north of the Dundas Valley (see Figure 2.5).

Karst features, such as springs and sink points, have been mapped in the Waterdown area, north of the Dundas Valley. The Eramosa Karst comprises 16 karst features, seven of them provincially significant. These features include caves, sinking streams, springs, and dry valleys. The area has been designated as three Earth Sciences Areas of Natural and Scientific Interest – Eramosa Karst Feeder Area, Eramosa Karst Core Area, and Eramosa Karst Developed Area – and considered the best example of karst topography in Ontario.

Nexus Cave at the Eramosa Karst Conservation Area, Hamilton

2.1.3 Hydrostratigraphy: Groundwater Resources

How easily water flows through geologic units depends in part on the permeability of the rock or sediment and the driving force that facilitates water movement. The permeability depends on the open spaces of the material and their connection. **Weathering,** fracturing, or karst processes will increase the permeability of the material, and the rock or sediment could yield more water. Rocks and sediments that are quite permeable and have an ample supply of water are used as drinking water supplies. These geologic units are aquifers. Aquitards are geologic units that are less permeable and will not produce a sufficient supply of water for use. The sediment and rock units of the Hamilton Region Source Protection Area are classed as aquifers and aquitards and are discussed below.

Below the Niagara Escarpment, available sources of groundwater with good supply are limited. Soil cover is thin and typically consists of Halton Till or sand. The Queenston Formation shale is characterized as a regionally significant aquitard; however, it is usually weathered in the upper five metres or so, and the fractures transmit water at a sufficient rate to provide adequate yields for individual domestic supplies. Although these groundwater sources are poor aquifers, they are locally important due to the absence of a higher yielding geologic unit. In Hamilton, most of the area below the escarpment is supplied with municipal water.

Recent investigations of the buried bedrock valley sediments underlying the Dundas Valley suggest layers of infill of varying permeability. The sediments at Copetown comprise about 15 metres of gravel and sand at the base, overlain by about 108 metres of clay and silt. The upper sediment is composed of a higher portion of fine to medium sand at the bottom and about 75 metres of layers of sand, silt, and sandy/silty till at the top (Bajc et. al., 2009). The permeable, basal gravel and sand unit yielded over 800 litres of water per minute, and it is undergoing further investigation.

The thicker sediments of the moraines, the esker, and the sand plain lying above the escarpment may provide enough water for a domestic supply.

The most significant groundwater source in the Hamilton Source Protection Area is the dolomite rock of the Gasport and Guelph Formations. Most domestic wells in the Hamilton Source Protection Area, in addition to the Greensville municipal well, are constructed in these formations. The units are thicker in the northwestern portion of the subwatershed and thinner to the southeast.

The Niagara Falls Member, and the Rockway and Merritton Formations, that overly and underlie the Gasport Formation, respectively, have low permeability and slow down the vertical movement of water. The underlying Cabot Head Formation is a thick, regional aquitard that confines the Manitoulin and Whirlpool Formations lying below. Shale and dolostone of the Eramosa also acts as an aquitard, where present. The existence of these aquitards maintains the majority of water flowing horizontally rather than flowing vertically through lower bedrock units. This focus on lateral flow has contributed to the dolostone’s microkarstic nature.

2.1.4 Land Cover

The physical materials that cover the surface of the earth, including both natural and man-made features, are land cover. These materials have a significant impact on the quantity and quality of source waters of the Hamilton Source Protection Area and are discussed below, summarized on Table 2.2, and illustrated on Appendix H Figure 2.6.

Distributed throughout the Hamilton Region Source Protection Area is a wide variety of naturally vegetated areas including **riparian,** marshes, swamps, and woodlands. Some large tracts of natural areas exist; however, some are considered fragmented and/or disturbed. These natural areas support a rich diversity of features, including rare plants and animals and significant habitats, and they perform vital functions within the watersheds. Aquatic, wetland, and terrestrial ecosystems are all represented within the Hamilton Region Source Protection Area.

Environmentally Sensitive Areas (ESAs) are designated, naturally vegetated areas that are given special protection by the City of Hamilton. These are land and water areas containing natural features or ecological functions of such significance that their protection is in the best, long-term interests of the people and environment. Thirty-seven sites within the Source Protection Area meet the specific criteria of the City of Hamilton to be designated an ESA. These natural areas include a variety of different types of habitats, including escarpment woods, waterfalls, valley lands, swamps, and drumlin fields.

Table 2.2 Types and Areas of Land Cover in Watersheds of Hamilton Region Source Protection Area

Land Cover	Spencer Creek		Urban Hamilton Core		Red Hill Creek		Urban Hamilton Beach Strip		Stoney-Battlefield Creeks		Stoney Creek Watercourses		Total
	area [km²]	area [%]	area [km²]	area [%]	area [km²]	area [%]	area [km²]	area [%]	area [km²]	area [%]	area [km²]	area [%]	area [km²]
Wetlands – marsh and swamp	6.9	2.5	0.0	0.0	0.2	0.4	0.0	0.1	0.2	0.8	0.1	0.2	7.4
Treed lands – woodlots, plantations and hedgerows	66.4	24.0	1.2	3.3	4.4	6.8	0.0	0.2	3.2	11.2	4.4	11.7	79.6
Riparian lands – flood plains of all creeks	11.5	4.2	0.0	0.0	1.3	1.9	0.0	0.0	0.6	2.2	0.4	1.1	13.6
Agricultural – pasture, crops, orchards, buildings	85.5	30.9	0.0	0.0	8.1	12.5	0.0	0.0	13.1	45.9	7.7	20.6	114.4
Rock/Sediment – rock and sediment outcrops including pits and quarries	2.6	0.9	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	3.6
Idle – fields, utility corridors	39.6	14.3	0.6	1.6	7.3	11.3	1.3	56.6	3.2	11.1	5.3	14.2	57.3
Built-Up Area Impervious – buildings, roads	48.3	17.5	33.1	90.7	35.6	55.2	0.1	5.6	6.5	22.8	16.4	43.7	140
Built-Up Area Pervious – urban parks	8.4	3.0	1.2	3.2	5.7	8.8	0.0	0.6	0.7	2.6	1.3	3.4	17.3

Notes: 1. Land cover percentages are based on Ministry of Natural Resources and Forestry SOLRIS mapping 2000-2015 and built-up areas 2006 with edits.
2. Area percentages are calculated based on the total area of each watershed.
3. Remaining percentage of land cover in other classes.

Wetlands

A variety of wetland habitat types, significant locally and provincially, exists within the Hamilton Region Source Protection Area. Verified wetlands range from marsh habitat within Cootes Paradise to headwater swamps found above the Niagara Escarpment. Wetlands provide habitats for fish and wildlife and have important hydrological functions. They moderate flow regimes during periods of high flow, extend/enhance stream **baseflow** during the summer months, and are sometimes vital to maintaining or improving downstream water quality. Conversely, the abundance of vegetation in wetlands can also lead to increased dissolved nutrients in the water. The presence of wetlands increases the complexity of the landscape, thereby increasing its biodiversity.

Wetlands are primarily located in the upper reaches of Spencer Creek and at Cootes Paradise. Many of these wetlands are of provincial significance.

Woodlands

Woodland cover within the Hamilton Region Source Protection Area is generally concentrated within the Dundas Valley with patches of forest cover in the rural areas. The extent of forest cover in the Source Protection Area declined considerably as people settled in the area and the urban area expanded. With the abandonment of marginal farmland and the land regeneration, forest lands may increase in the future. There are significant woodlands associated with the escarpment slope and the incised valleys of the major creeks.

Woodland cover throughout the Source Protection Area is mixed deciduous, generally, although a number of mixed coniferous forest habitats are also present. These forested lands provide habitat for a diversity of plant, bird, and mammal species, corridors for wildlife movement, and soil stability. Table 2.2 summarizes the area and percentage of treed cover in the major watersheds within the Source Protection Area. The treed areas include woodlots, plantations, and hedgerows.

Agriculture

Agriculture is a significant land use within the Hamilton Region Source Protection Area, and land covers include buildings, pasture, crops, and orchards. Land cover is seasonal in some fields and can vary year to year. The broad expanse of fields in the rural area of the Source Protection Area allows for the infiltration of water to replenish the water table. This recharge water can become contaminated as it flows across **managed lands.** Activities ongoing on the lands could impact the quality of water leaving the property as runoff or infiltration. Soil erosion on fields with little cover also may affect water quality.

Urban land cover

Land covers in the urban areas include impervious surfaces such as asphalt, concrete, and rail tracks on transportation routes. It also includes buildings of various sizes and densities that are used for various reasons. Pervious surfaces are primarily parklands and lawns.

The hard surfaces promote increased runoff which, in the urban areas, is typically captured by storm sewers and conveyed to watercourses rather than naturally seeping into the ground to replenish groundwater sources. Runoff water will pick up pollutants, and the quality of water in the watercourses can be affected. Water that soaks into the ground where it lands has less opportunity to pick up pollutants. Of note, filtration through soils or biological or chemical processes within the soil can clean the water before it reaches the underlying aquifers.

Pervious surfaces, such as parklands and landscaped areas of domestic or industrial/commercial properties, including golf courses, are also scattered through the Source Protection Area. These areas, depending on the slope of the land, promote the natural infiltration of precipitation and runoff. Again, the activities carried out on these lands could have an impact on the quality of waters leaving the property, whether as runoff or infiltration. Usually, the pervious surfaces identified are covered in grass and used for recreational activities.

Due to their small size and the difficulty of estimating their area, Table 2.2 includes lawns with impervious areas. Pervious areas only include urban parks.

2.2 Human Geography

The Hamilton Source Protection Area lies almost entirely within the City of Hamilton. The core area of Hamilton is ideally situated on the shore of a protected shipping harbour and along major road and rail transportation corridors connecting Niagara to Toronto and the west.

Hamilton's development relied heavily on its industry base. It became an industry leader in the middle of the 19th century when the railway came. The construction of the Burlington Bay Canal in 1832 (now called Burlington Canal) opened up Hamilton Harbour as the head of Lake Ontario for international shipments of raw materials and goods. Hamilton was incorporated as a town in 1833 with a population of about 1,000. In 1846, Hamilton became a city, and its steel industry was expanding.

With the steep cliffs of the Niagara Escarpment and surface water drainage toward Lake Ontario, Hamilton is the city of waterfalls. These waterfalls were instrumental in the development of industries such as grist mills, saw mills, paper mills, flour mills and blacksmithing, and the settlement of these areas. Today, the waterfalls maintain vital ecosystems and bring tourists to the city.

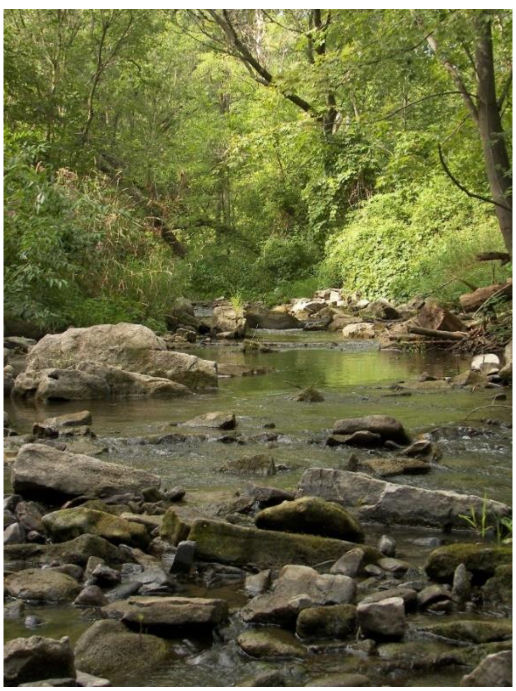
The richness of the Cootes Paradise marsh led to its development and protection. However, degradation ensued due to impacts from the surrounding watershed on its water quality and from the regulation of water levels of Lake Ontario.

On January 1, 2001, the new City of Hamilton was formed through amalgamation of the municipalities of the former Regional Municipality of Hamilton-Wentworth, Hamilton, Ancaster, Dundas, Flamborough, Glanbrook, and Stoney Creek. Based on populations of the year 2006, Hamilton is the third largest city in Ontario and the ninth in Canada. Hamilton's economic base is now shifting toward the service sector.

2.2.1 Existing Policies for the Protection of Water Sources

Policies developed at the provincial, regional, and local levels influence the landscape of Hamilton Region Source Protection Area. Some of the policies in place to protect water resources are discussed below. Source Protection planning builds on these existing policies to increase the protection of water sources by reducing the risk to them. The land masses regulated under the existing provincial policies are shown on Figure 2.7.

Provincial Policy



Provincial initiatives and direction for the protection of water resources can be found in the *Provincial Policy Statement* and the *Greenbelt Plan*, brought into force in 2020 and 2017, respectively. Section 2.2, subsections 2.2.1, and 2.2.2 of the *Provincial Policy Statement* provide for mitigative measures and/or alternative development approaches to protect, improve, or restore sensitive surface and ground water features and their hydrologic functions. Part III indicates that the policies included in the *Provincial Policy Statement* are minimum standards that do not prevent others from improving on these policies, as long as no conflicts arise. Section 3.2.3 of the *Greenbelt Plan*, Water Resource System Policies, also provides policy at the provincial level on the protection of water resources.

Species, other than human, that also use the sources of drinking water in the Source Protection Areas are considered in this assessment. A portion of the water is reserved (see Section 5) for their uses and the species are used as indicators of water quality (see Section 4). The *Endangered Species Act, 2007,* protects species at risk and their habitats. Some species that have their habitat in water bodies within the Hamilton Region Source Protection Area are at risk. The list includes fish, amphibians and reptiles such as Redside Dace, Jefferson Salamander, Blanding's Turtle, Eastern Musk Turtle, Wood Turtle and Milksnake.

Niagara Escarpment Plan

Objectives located within sections of Part I of the *Niagara Escarpment Plan* pertain to land use designations. These objectives speak in general terms about the protection of groundwater and surface water resources in urban centres, recreation areas, and mineral extraction areas.

Specific policies on the protection of surface water and groundwater resources are found in Part II, Section 2.6. In this section, there are policies on setbacks for sewage systems and development, requirements for studies, cutting of trees, sediment and erosion control practices, and water taking.

City of Hamilton Official Plan

The City of Hamilton Official Plan has been split into two policy documents for rural and urban areas.

On March 7, 2012, the Rural Hamilton Official Plan was declared in force and effect except for those portions which are identified on the various schedules, maps and appendices as being under appeal or deferred. The City is drafting amendments to their Comprehensive Zoning By-law and is incorporating the requirements of the Source Protection Plan into these amendments.

The Urban Hamilton Official Plan was declared in force and effect on August 16, 2013, except for the policies, schedules, maps, and appendices that remain under appeal.

The City of Hamilton Official Plans note that the majority of lands within the Hamilton Harbour watershed and part of the City of Hamilton are situated within the Greenbelt Plan boundaries. As such, the general policies on water resource protection found within that Plan are in force. The Hamilton Official Plan does indicate that, where the City policies are more restrictive than the provincial policies, the City's policies will be enforced.

Wellington, Grimsby and Niagara Official Plans

The Official Plans of the County of Wellington, Town of Grimsby, and Region of Niagara all have strategic policies with the objective of protecting surface and ground water resources. Some policies require hydrologic, hydrogeologic, and water budget analysis prior to development approval. Others protect areas of significant karst topography as well as groundwater recharge and discharge areas. Water conservation, maintaining baseflow, and protecting both quantity and quality of ground and surface waters have been addressed to some degree.

2.2.2 Population Distribution and Density

The large urban centre of the Source Protection Area is the amalgamated areas of the Hamilton city core, Stoney Creek, Dundas, and Ancaster. The urban area lies primarily along the south shore of Cootes Paradise, Hamilton Harbour, and Lake Ontario, and it is expanding in a southerly direction on the escarpment and easterly below. A small, developed portion of Waterdown is also located within this Source Protection Area. Access to plentiful, clean water from Lake Ontario has facilitated rapid growth in these areas. The rural areas of the Source Protection Area are reliant on sometimes less dependable well water supplies. Also, development is restricted in the rural area by planning constraints such as the *Green Belt Plan,* the *Niagara Escarpment Plan*, and municipal Official Plans. The settlement of Greensville, located on the escarpment above Dundas, is serviced by well water supplies. One municipal well supplies water to about 108 people in this community, while the others rely on private wells.

Population and employment projections made by the City of Hamilton are compliant with the growth targets of the Provincial initiative, the *Growth Plan for the Greater Golden Horseshoe (June 2006)*. By the year 2031, Hamilton is expected to grow to 660,000 people and 300,000 jobs. Intensification of downtown Hamilton is required, with a minimum of 40 percent of all annual, residential development occurring in this area.

In terms of population density, the City of Hamilton aims to have a minimum density of 250 residents and jobs per hectare of land in its developing areas by 2031. Development in new areas also must meet minimum density targets of not less than 50 residents and jobs combined per hectare of land. This target is as measured over the greenfield area of Hamilton, excluding the natural heritage features. Areas proposed for future development to 2031 in Hamilton lie outside the Hamilton Source Protection Area.

The population distribution within the watersheds and subwatersheds of the Source Protection Area, as shown on Figure 2.8, is summarized in Table 2.3 (Note: the Table covers 2011 and projects distribution for the year 2031). The estimates predict that the smaller watersheds along the shore of Lake Ontario in Stoney Creek will have the largest percentage increase in population density. In a few subwatersheds, the population densities are projected to decline between 2011 and 2031 by up to 34 percent, but mostly there will be increases. The populations shown in the table were used to assess domestic water use when determining the water budgets for the watersheds in the area (see Section 5.2.5).

The City of Hamilton is planning for a significant amount of growth over the next 30 years to the year 2051.The Province of Ontario provides the growth forecasts that the City of Hamilton must plan for:

- An increase of 236,000 people (total population of 820,000 by 2051)
- An increase of 110,000 housing units
- An increase of 122,000 jobs

Through the update to the City's growth strategy, known as GRIDS 2 and the Municipal Comprehensive Review (MCR), the City of Hamilton must determine if all this forecasted growth can be planned within the existing urban boundary through intensification and redevelopment, or if an expansion to the urban boundary is required to plan for a portion of this growth in new greenfield communities.

There are no reserves in the Hamilton Region Source Protection Area as defined in the Indian Act (Canada). Lands owned by the Government of Canada consist of an armoury, port lands at Hamilton Harbour, post offices, and a few office buildings.

Table 2.3 Populations and population densities by watershed/subwatershed

Watershed/ Subwatershed	Area [km2]	Population 2016[1]	Population Density 2016 [population / km2]	Projected Population 2031	Population Density 2031[2] [population / km2]	Increase in Population Density 2016 to 2031 [percent]
Spencer Creek						
Fletcher Creek	25.1	483	19	745	30	36
Upper Spencer Creek	35.9	1487	41	1,529	43	4
Flamborough Creek	13.3	526	40	713	54	27
Westover Creek	10.9	308	28	755	69	59
Middle Spencer Creek	49.7	11176	225	10,024	202	-11
West Spencer Creek	18.1	532	29	966	53	45
Logie's Creek	13.3	734	55	1,515	114	52
Spring Creek	13.1	5685	434	9,019	688	37
Lower Spencer Creek	7.4	8468	1210	11,930	1,615	25
Sydenham Creek	5.3	3744	706	3,015	572	-23
Tiffany Creek	9.1	12,29015350	1687	14,762	1,626	-4
Ancaster Creek	14.0	13421	959	12,626	901	-6
Sulphur Creek	16.9	5706	338	7,064	418	19
Borer's Creek	19.5	11184	574	14,843	762	25
Chedoke Creek	25.1	72287	2880	82,457	3,290	12

Watershed/ Subwatershed	Area [km^2]	Population 2016[1]	Population Density 2016 [population / km^2]	Projected Population 2031	Population Density 2031[2] [population / km^2]	Increase in Population Density 2016 to 2031 [percent]
Urban Hamilton Core	36.5	104905	2874	122,866	3,364	15
Red Hill Creek						
Upper Ottawa	13.8	40055	2903	44,399	3,211	10
Hannon Creek	11.0	10772	979	12,347	1,125	13
Red Hill Valley	13.3	22630	1702	24,046	1,811	6
Green Hill	11.6	42386	3654	43,141	3,708	1
Montgomery Creek	3.7	7240	1957	8,176	2,183	10
Upper Davis Creek	7.3	11946	1636	17,351	2,393	32
Lower Davis Creek	3.8	8368	2202	9,170	2,443	10
Urban Hamilton Beach Strip	2.3	1263	549	1,979	845	35
Stoney-Battlefield Creeks						
Battlefield Creek	7.5	8153	1036	11,315	1,515	28
Stoney Creek	21.0	14189	676	24,510	1,165	42

Table 2.3 continued Populations and population densities by watershed/subwatershed

Watershed/ Subwatershed	Area [km²]	Population 2016[1]	Population Density 2016 [population/ km²]	Projected Population 2031	Population Density 2031[2] [population/ km²]	Increase in Population Density 2011 to 2031 [percent]
Stoney Creek Watercourses						
WC 0	1.6	2178	1361	2,207	1,344	-1
WC 1	3.6	8387	2330	9,939	2,777	19
WC 2	3.0	6122	2041	6,949	2,337	15
WC 3	2.1	4295	2045	3,010	1,436	-30
WC 4	2.8	4552	1626	4,031	1,434	-12
WC 5	6.2	3390	547	7,535	1,219	123
WC 6	1.5	1244	830	1,591	1,052	27
WC 7	4.3	1422	331	4,986	1,155	249
WC 8	0.1	202	2023	107	1,120	-45
WC 9	4.5	2669	593	4,345	963	62
WC 10	0.8	1062	1328	897	1,117	-16
WC 10.1	0.5	1092	2184	532	1,119	-49
WC 11	0.7	1615	2307	768	1,118	-52
WC 12, WC-13	5.8	2178	376	3,752	651	73

Notes: 1. Population based on Statistics Canada "Population and dwelling counts, for dissemination areas, 2016 Census" and Dissemination Block Boundary 2016.

2. Projected populations based on City of Hamilton Traffic Zones (GRIDS, Hemson/Places to Grow Greater Golden Horseshoe Report), Wellington County Official Plan (Growth Forecast Amendment, Table 5-2G), Niagara Region Official Plan.
3. WC-13 was previously included in the watercourses named WC-12.

2.2.3 Land Use

Land cover and the ongoing activities on the land influence the **hydrologic cycle** and the way in which water moves within the Source Protection Area. The cover and activities reflect the use of the land by residents, business owners, and government. Land use and changes to it can have an impact on tributary and **nearshore** lake water flow regimes. Increased or decreased stream flows, increased erosion, sediment transport, and a reduction in water quality can result from land uses that have adverse impacts on the environment. General land uses within the Hamilton Region Source Protection Area are shown on Figure 2.9 and discussed briefly by watershed/subwatershed in Section 3.

Within the developed areas of the urban lands, uses are primarily residential, institutional (schools, hospitals, etc.), golf courses, special purpose, and commercial. Special purpose uses include places of worship, fair grounds, community centres, cemeteries, and sports centres. A number of properties along the escarpment or within valley lands are designated as conservation or parklands.

Generally, industrial uses are concentrated along transportation corridors. Major transportation corridors within the Source Protection Area are: provincial highways, including 400 Series Highways; regional roads; rail corridors; and shipping lanes within Lake Ontario. Industry surrounds the Queen Elizabeth Way and surrounding municipal roads leading from the Niagara Region into the industrial properties adjacent to Hamilton Harbour.

Land uses within rural areas are primarily agricultural. Some settlement areas exist and primarily include residential uses in addition to minor uses such as institutional, commercial, and industrial.

Two licensed, multi-property, aggregate extraction operations exist in the rural area of the northwest portion of the Source Protection Area. One property is licensed in the east but is the site of the Hamilton (Stoney Creek) Landfill and rock is no longer being extracted.

Eleven golf courses/centres exist within the Source Protection Area, including six in the rural area. Parks, conservation areas, and vacant development properties are grouped as other land on Figure 2.9.

Any changes in land uses or the expansion of urban areas within Hamilton could affect the water and wastewater systems used within these areas. Accordingly, the dependence on municipal services and the use of domestic wells and septic systems could change the stresses and risks within the watersheds. These changes will need to be studied in future years.

City of Hamilton urban land uses

3. HAMILTON REGION SOURCE PROTECTION AREA WATERSHEDS

In this section:

- A description of watersheds and subwatersheds within the Source Protection Area
- An overview of Lake Ontario, Burlington Bay, Cootes Paradise

Hamilton Region Source Protection Area includes four larger watersheds and 15 smaller ones. Figure 2.8 illustrates the watershed and subwatershed boundaries. The discussion below describes these watersheds in the context of their physical characteristics and hydrology, as they lie in a west to east direction at the western end of Lake Ontario and according to their location of discharge. The watersheds and subwatersheds are used as the basis for the development of water budgets (see Section 5) and for the technical study to assess stresses on water quantity within the Source Protection Area.

Figure 3.1 shows the stream network in the Source Protection Area, detailing its natural and physical features such as wetlands, reservoirs, and dams. In addition, the following paragraphs make reference to provincially significant wetlands and environmentally sensitive areas.

3.1 Spencer Creek

The Spencer Creek Watershed includes a portion of the Township of Puslinch in the northwest and the remainder lies within the City of Hamilton. It is the largest watershed within the Hamilton Region Source Protection Area, occupying about 58 percent of its land mass as shown in the illustration below. Spencer Creek and its tributaries drain all of the area north of the Dundas Valley, lands within the valley, and lands immediately southeast and draining into the valley. It then empties into Cootes Paradise. The watershed divides into 15 subwatersheds.

Illustration: Spencer Creek Watershed

Fletcher Creek

The cold headwaters of Fletcher Creek drain the southern edge of the Galt Moraine. This is the **surface water divide** influencing the drainage of the Hamilton Region Source Protection Area and the Grand River Watershed in this area. The subwatershed lies within the Flamborough Plain where drainage is poor. Thus, the lands around the tributaries are primarily mapped as the Fletcher Creek Swamp Provincially Significant Wetland or the Fletcher Creek Swamp Forest, a Life Science Area of Natural and Scientific Interest. Tributaries flow around the elevated lands of the many drumlins located in this area. They then unite to flow as one channel into the Beverly Swamp Complex Provincially Significant Wetland before discharging into Upper Spencer Creek.

The Beverly Swamp Complex is a significant hydrologic feature linking the subwatershed/watersheds of Fairchild Creek, Spencer Creek, and Bronte Creek. It occupies about 23 square kilometres of forested swamp, supported primarily by precipitation and surface runoff.

The swamp acts as a natural storage reservoir, moderating stream flow and augmenting stream flows during low flow periods.

Standing waters are present in the swamp from spring to middle to late summer. One to two metres of organic soils have accumulated in the swamp and some peat extraction has occurred. The swamp is also a Life Science Area of Natural and Scientific Interest.

Highway 6 forms the northeastern boundary of the Fletcher Creek subwatershed and the Canadian Pacific Railway line crosses the headwaters area. Land uses are primarily natural treed areas, agricultural and rural residential.

Upper Spencer Creek

Upper Spencer Creek begins in a similar fashion to Fletcher Creek. It drains the Galt Moraine and the wetlands that exist on the limestone plain. The two main headwater tributaries flow through the Valens Conservation Area operated by the Hamilton Conservation Authority. Within this conservation area, the tributaries are part of the Valens Reservoir and Swamp Provincially Significant Wetland, and they empty into the reservoir.

Hamilton Conservation Authority constructed the Valens Dam and Reservoir in 1966. The earth fill dam created a 59-hectare reservoir with a maximum storage of 2,035,000 cubic metres of water. Its original purpose was for low flow augmentation and to reduce downstream flooding during spring runoff. It is also used for recreation and wildlife management.

Above the reservoir, the headwaters are classified as being cold water conditions; however, water leaving the reservoir is warm. The creek flows into the Beverly Swamp Complex where it is joined by Fletcher Creek. The southern portion of the subwatershed includes another drumlin field and an online pond. Small tributaries drain between the drumlins adding to the stream flow of the main channel. Upper Spencer Creek is joined by Flamborough Creek before becoming Middle Spencer Creek.

Land uses in the subwatershed include conservation areas, agricultural, natural treed areas and rural residential, including a rural subdivision. The Canadian Pacific Railway line crosses the headwaters area of the subwatershed.

Picture: A pond on Upper Spencer Creek

Flamborough Creek

Flamborough Creek tributaries drain drumlins and a two-kilometre-long esker that lie at the perimeter of the limestone and sand plains of the subwatershed. The tributaries also drain the Hayesland Alvar and Hayesland Swamp ESAs.

Westover, an Earth Science Area of Natural and Scientific Interest, is located within the Flamborough Creek subwatershed. This area is designated because it includes features of the glacial lakes, Whittlesey, and Warren, which formerly occupied the Lake Erie basin.

Land uses are primarily agricultural, with a golf course. Treed lands buffer the creek.

Middle Spencer Creek

Middle Spencer Creek subwatershed is generally divided into the northwestern Flamborough Plain, the Norfolk Sand Plain, and the kame moraine deposits located near the Dundas Valley. The main channel bends to the south, picks up discharge from its tributaries and Westover and West Spencer Creeks, and then circles back to the east before reaching the escarpment edge. The upper portion of this creek flows through the Hayesland-Christie Wetland Complex Provincially Significant Wetland and the Donald Farm Wetland ESA. As the stream flows eastward, it enters the Christie Stream Valley ESA. Within this ESA lie Christie

Conservation Area and the Christie Reservoir. Water flowing into the reservoir is classed as cool and water leaving as warm.

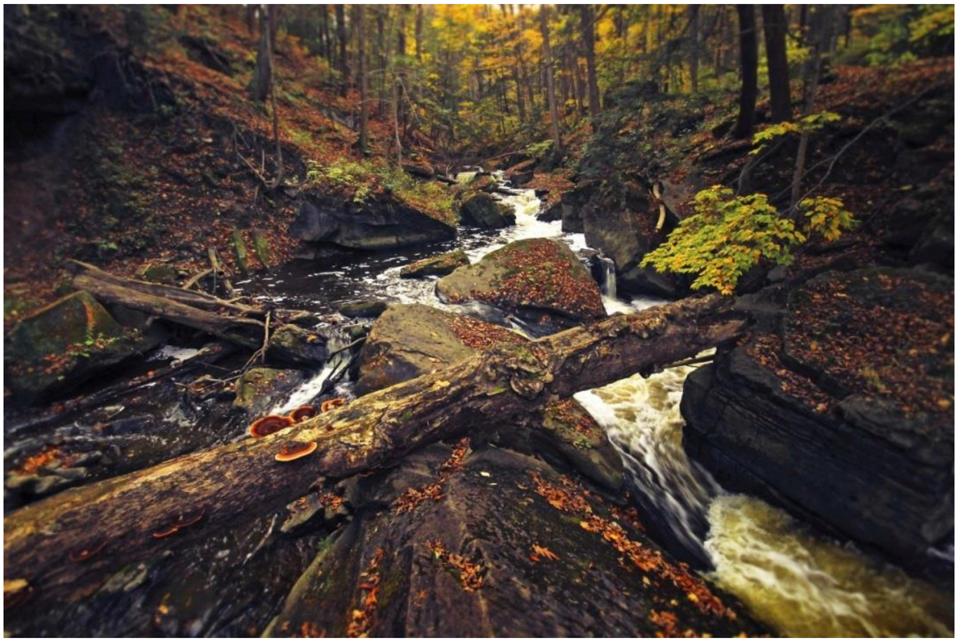
Hamilton Conservation Authority constructed the Christie Dam and Reservoir in 1974. A concrete dam was used to create a 22-hectare reservoir with a maximum capacity of 2,282,000 cubic metres. Its primary purpose is to reduce flooding within the former Town of Dundas. Secondary uses are for low flow augmentation, recreational and wildlife management purposes.

Downstream of the Christie Dam, Middle Spencer Creek flows over the escarpment at the 22-metre-high Webster's Falls and into Spencer Gorge. The gorge is an Area of Natural and Scientific Interest for earth sciences and an ESA. Below the waterfall, Logie's Creek and tributaries that drain the escarpment face join Middle Spencer Creek.

The upper portion of Middle Spencer Creek subwatershed contains primarily agricultural land uses. Two major aggregate extraction operations and three golf courses also exist. Highway 5 crosses the middle of the subwatershed and joins with Highway 8 to the west. Some industrial land uses exist along this transportation corridor.

The community of Greensville is located in the lower portion of the subwatershed, above the escarpment. Residential density is higher than to the north, and the community contains the only groundwater-based municipal water supply in the Hamilton Region Source Protection Area.

Below the escarpment, the Town of Dundas consists of urban land uses. The Canadian National Railway follows the escarpment edge and crosses the lower portion of the subwatershed.



Picture: Scenic Spencer Creek, Hamilton

Westover Creek

Westover Creek parallels Upper Spencer Creek to the west from downstream of Beverly Swamp. It drains Westover Lowland Forest, Westover Southwest Complex, and Hayesland Swamp ESAs. The Sheffield-Rockton Complex is the only small, Provincially Significant Wetland in the subwatershed. The downstream end of the creek is classed as cool water conditions, while upstream of this is classed as warm water. The creek discharges to Middle Spencer Creek within the Century Pines Golf Course. Primarily, the land uses within this subwatershed are agricultural.

West Spencer Creek

West Spencer Creek subwatershed occupies the most westerly extent of the Flamborough and Norfolk Sand Plains and forms a part of the western boundary of the Source Protection Area. A network of tributaries drains the subwatershed, including the Sheffield-Rockton Complex Provincially Significant Wetland, the Westover Southwest Complex, Rockton Northeast Woodlot, and the West Spencer Creek Complex ESAs. West Spencer Creek empties into Middle Spencer Creek where it changes direction to flow east.

Highway 8 crosses the primarily agricultural lands within the subwatershed.

Logie's Creek

The main channel of Logie’s Creek lies between two ridges of the Waterdown Moraines and has its headwaters in the Millgrove South Woodlot. Parallel tributaries drain the more westerly moraine in a southeast direction to empty into the main channel. Logie's Creek Swamp Provincially Significant Wetland surrounds one of the small tributaries.

The waters of Logie's Creek cascade over the escarpment at Tews Falls. This waterfall, at 41 metres, is Hamilton's highest. Immediately downstream of the falls, the waters join Middle Spencer Creek in the Spencer Gorge.

Logie's Creek subwatershed includes one aggregate extraction operation and primarily agricultural lands. Highway 5 crosses this subwatershed.

Spring Creek

The tributaries of Spring Creek drain the face of the Niagara Escarpment and combine into one channel that meanders through the Dundas Valley. The creek joins with Middle Spencer Creek to become Lower Spencer Creek. Some of the upper tributaries have been classed as cool water conditions; however, the downstream meandering creek has been classed as cold water. This suggests groundwater is discharging to the lower reach of the creek.

The small portion of the Spring Creek subwatershed above the escarpment comprises agricultural land uses. The Canadian National Railway follows the escarpment edge and passes through the subwatershed. Land use through the upper portion of the valley is primarily conservation lands, treed land areas, and some agricultural. The downstream portion of the subwatershed has the urban uses of the Town of Dundas.

Lower Spencer Creek

Lower Spencer Creek drains a small portion of the Waterdown Moraines above the escarpment through the Borer's Falls-Rock Chapel ESA, which is located along the escarpment slope. It also drains a portion of the Dundas Valley and the Cootes Paradise ESA. This reach of Spencer Creek discharges into Cootes Paradise, a Provincially Significant Wetland. The subwatershed also includes small tributaries that discharge directly to Cootes Paradise from the south. The area has been designated the Cootes Paradise Drowned Valley Area of Natural and Scientific Interest.

The land uses within the Lower Spencer Creek subwatershed are diverse. Two lines of the Canadian National Railway cross the subwatershed below the escarpment. The small portion of land above the escarpment is for agricultural uses. Within the valley, land uses include conservation lands, urban residential, commercial and industrial, and the McMaster University campus and hospital.

Sydenham Creek

The headwaters of Sydenham Creek drain one ridge of the Waterdown Moraines. At the escarpment edge, three tributaries flow over the Sydenham, Middle Sydenham, and Lower

Sydenham Waterfalls, and across the Spencer Gorge ESA. Below the escarpment, the tributaries combine, and the creek empties into Lower Spencer Creek.

Within the subwatershed, agricultural and urban land uses predominate above and below the escarpment, respectively. Two lines of the Canadian National Railway run along towards the base of the escarpment.

Tiffany Creek

Headwater tributaries of Tiffany Creek drain the Haldimand Clay Plain toward the main channel lying at the base of the southern flank of the Niagara Falls Moraine. This area is designated the Tiffany Creek Headwaters ESA. The Tiffany Creek Provincially Significant Wetland exists as small pockets on a few of the tributaries. The creek flows over the 21-metre- high escarpment at Tiffany Falls and empties into Ancaster Creek.

Tiffany Creek has been altered in areas where development has occurred. Within the subwatershed is the Lincoln M. Alexander Parkway / Highway 403 interchange. The surrounding lands have been developed for commercial and residential purposes. The headwaters area remains as agricultural land uses but are located in the Airport Employment Growth District as designated in the City of Hamilton's Official Plan

Ancaster Creek

Ancaster Creek drains the clay plain above the escarpment, following the base of the kame deposits to the northwest and through the Hamilton Golf and Country Club ESA. It also drains the Niagara Falls Moraine and through the Tiffany Falls ESA. The creek flows 17 metres over the escarpment at Sherman Falls. Below the escarpment, the creek meanders through the Dundas Valley ESA and Ancaster Creek Valley Area of Natural and Scientific Interest, a 20-metre-deep ravine, before it discharges into Lower Spencer Creek. The lower reach of the creek lies within the Cootes Paradise ESA. The creek is mapped as cool water conditions.

The land use in the headwaters area of the subwatershed is agricultural with urban residential downstream. Highway 403 crosses the subwatershed, above the escarpment.

Sulphur Creek

Sulphur Creek subwatershed comprises the escarpment edge at the head of the Dundas Valley and the valley lands to the east. Many tributaries drain the escarpment face and the kame deposits. Almost the entire subwatershed is included in the Dundas Valley ESA. Four Areas of Natural and Scientific Interest have also been designated: Dundas Valley, Dundas Valley Forests, Sulphur Creek Valley, and Ancaster Creek Valley. Sulphur Creek discharges into Ancaster Creek.

Above the escarpment, the land use in the subwatershed is urban residential. Within the Dundas Valley, the land uses are primarily conservation lands and treed areas, with a small portion of agricultural lands in the western end of the valley.

Borer's Creek

The majority of the Borer's Creek subwatershed lies above the Niagara Escarpment and is surrounded on three sides by the Halton Region Source Protection Area. A network of tributaries drain the ridges of the Waterdown Moraines and the Logie's Creek-Parkside Drive Wetland Complex situated between the ridges. The tributaries feed the main channel, and portions have been confirmed to have either cool or cold-water conditions, suggesting groundwater discharge from the moraines. Water flows through the Borer's Falls Conservation Area and over the escarpment at the 15-metre-high Borer's, Lower Borer's, and Rock Chapel Waterfalls. The face of the escarpment is also drained by tributaries of the creek and is designated the Borer's Falls-Rock Chapel ESA and the Rock Chapel Escarpment Area of Natural and Scientific Interest. Borer's Creek drains the northern slope of the Dundas Valley before discharging into Lower Spencer Creek.

Highways 5 and 6 cross this subwatershed, as does the Canadian National Railway. The northeastern corner of the subwatershed includes a portion of urban Waterdown, while the remainder of the subwatershed is primarily agricultural. One golf course operates here.

Chedoke Creek

The Chedoke Creek subwatershed comprises a broad area above the escarpment and tapers down to a very narrow valley where the creek discharges directly to Cootes Paradise. The lands above the escarpment are developed for primarily residential uses. The Linc (the Lincoln M. Alexander Parkway) crosses the width of the subwatershed, and Highway 403 travels its length. Their intersection is near the Iroquoia Heights Conservation Area. Many tributaries discharge at the escarpment, some augmented by storm sewer outflows.

Picture: Chedoke Creek

Short, parallel tributaries drain the face of the escarpment in the Hamilton Escarpment ESA and the main channel parallels Highway 403. The lower reach of the creek, within the Cootes Paradise ESA, has been classed as cool water conditions.

Another transportation corridor, a railway junction, exists below the escarpment and north of a golf course that operates on the escarpment slope.

3.2 Urban Hamilton Core

As the name implies, this subwatershed encompasses the downtown core of the City of Hamilton. It also includes all the waterfront properties and the Port of Hamilton lands. Although most of the subwatershed is residential, a significant amount of industrial and commercial uses also exist here. The area is fully serviced by municipal storm sewers that discharge to Hamilton Harbour.

Illustration: Urban Hamilton Core subwatershed

3.3 Red Hill Creek

The Red Hill Creek watershed is located entirely within the City of Hamilton. It forms the **surface water divide** between the Hamilton Region Source Protection Area and the Niagara Peninsula Source Protection Area to the south. This is reflective of the drainage from the Niagara Falls Moraine. The upper reaches of the creek are typically less developed with development ongoing and proposed; however, most of the watershed is urban. The Red Hill Creek watershed is divided into seven subwatersheds, discussed below.

Illustration: Red Hill Creek watershed

Upper Ottawa

The tributaries of the Upper Ottawa subwatershed drain the Niagara Falls Moraine. The main channel has been altered to parallel the southern extent of the Linc, which crosses the length of the subwatershed. Red Hill Creek enters the Red Hill Creek Escarpment Valley ESA as it nears the Niagara Escarpment edge. This subwatershed is urbanized, primarily as residential properties, though some idle lands exist. The creek cascades 15 metres over the escarpment at Albion Falls and into the Red Hill Valley subwatershed below.

Hannon Creek

Within the Hannon Creek subwatershed, a network of tributaries drains the undeveloped Niagara Falls Moraine. This area is used for agricultural purposes. The tributaries coalesce and their channels are altered through the residential areas downstream. The tributaries feed the main channel, which has been classed as having warm water conditions. The main channel drains the Red Hill Creek Escarpment Valley ESA to its point of discharge into Upper Ottawa subwatershed at the Linc.

Red Hill Valley

The Red Hill Valley subwatershed comprises all of the valley lands below the escarpment and along to Red Hill Creek’s discharge point at Hamilton Harbour. Water flowing over Buttermilk Falls joins with that flowing over Albion Falls and is fed by tributaries that drain the escarpment face over the clay plain, beach deposits, and sand plain within the valley. The creek flows within the Red Hill Creek Escarpment Valley ESA. Also, within the subwatershed is the Hamilton Escarpment ESA.

Following the centre line of the valley and paralleling the creek is the Red Hill Valley Parkway, a major transportation corridor. The Parkway joins the Queen Elizabeth Way at the bottom of the subwatershed to the north. At this point, Red Hill Creek bends to the northwest and discharges to Windermere Basin, in the southeastern corner of Hamilton Harbour. This lower reach of the creek lies within the Van Wagner's Ponds and Marshes ESA.

King's Forest Golf Club operates at the base of the Niagara Escarpment. Downstream of this, the subwatershed is primarily residential and is drained by storm sewers. Within the lower reach, near the Queen Elizabeth Way, the land use changes to commercial and industrial with railways. Land use on the north side of the Queen Elizabeth Way is parkland owned by the City of Hamilton and managed by Hamilton Conservation Authority.

Green Hill

Green Hill subwatershed is entirely urbanized and drainage of the area is through the municipal storm sewer system. It follows the escarpment edge into the Red Hill re-entrant. A small tributary is located at the escarpment edge and flows over Buttermilk Falls into the Red Hill Valley subwatershed.

Montgomery Creek

The headwaters of Montgomery Creek drain lands surrounding this section of the Linc located above the Niagara Escarpment. The western area of the subwatershed includes the Linc / Red Hill Valley Parkway interchange, a major transportation corridor within the City. The surrounding lands are being developed for commercial uses. The eastern portion of this area above the escarpment is fully developed for residential uses and is drained by storm sewers that discharge to the creek. In this area, the tributaries of the creek have intermittent flows.

At the Niagara Escarpment edge, Montgomery Creek drains the Felker's Falls Escarpment ESA. The creek flows over the escarpment at Glendale Falls. The lands immediately downstream of the falls are steeply sloped. Below the escarpment, the creek flows through lands of the Glendale Golf and Country Club before entering the Red Hill Creek Escarpment Valley ESA. This ESA includes the creek and its adjacent, naturally vegetated lands, and it extends to the creek's confluence with Lower Davis Creek. Within the ESA, the creek flows through a well-defined and incised valley.

Upper Davis Creek

Tributaries of Upper Davis Creek drain the Niagara Falls Moraine, Eramosa Karst ESA, and the earth science Areas of Natural and Scientific Interest: Eramosa Karst Feeder Area, Eramosa Karst Core Area, and Eramosa Karst Developed Area. Downstream of the karst area, a tributary has been assessed as having cold water conditions, indicating groundwater discharges in the area.

Surrounding this area are residential properties, and tributaries have been altered to flow through the developed areas. At the escarpment edge, the creek enters the Felker's Falls Escarpment ESA and the Felker's Falls Area of Natural and Scientific Interest. Felker's Falls is

22 metres high and is six metres wide at its crest. Upper Davis Creek flows over these falls year round.

Note: the closed Taro West Landfill property lies within the lower portion of this subwatershed.

Lower Davis Creek

The Lower Davis Creek receives water from the Upper Davis Creek at Felker's Falls. It also drains the lands above the escarpment to the east of Upper Davis Creek. This area includes Terrapure Environmental's (formerly part of Newalta Corporation) Stoney Creek engineered non-hazardous industrial landfill and residential lands to the north. Tributaries also drain the Felker's Falls Escarpment ESA along the face of the escarpment. Below the escarpment, the subwatershed is completely urbanized, primarily as residential properties. The only natural area is within the Red Hill Creek Escarpment Valley ESA. Lower Davis Creek joins Montgomery Creek and flows a short distance to empty into Red Hill Creek.

3.4 Urban Hamilton Beach Strip

The Beach Strip is the name given to the Burlington Barrier Bar that separates Lake Ontario from Hamilton Harbour. It extends to the Burlington Canal. Drainage within this watershed would be to either of these two waterbodies depending on the slope of the land. The eastern side of the bar has been developed as urban residential and some commercial land uses. The western side comprises a portion of the harbour that has been infilled and the commercial and industrial activities now in operation. Dividing the two sides is the Burlington Skyway and the Queen Elizabeth Way.

Illustration: Urban Hamilton Beach Strip

3.5 Stoney-Battlefield Creeks

Stoney and Battlefield Creeks drain the western portion of the former City of Stoney Creek, now within the City of Hamilton. The two creeks combine in their lower reaches and discharge to Lake Ontario. Both subwatersheds are developed for agricultural uses above the escarpment and urban uses below.

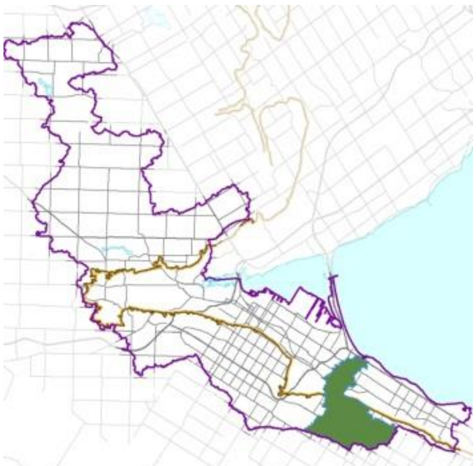


Illustration: Stoney and Battlefield Creeks subwatersheds – west

Battlefield Creek

Tributaries within the Battlefield Creek subwatershed drain the northern flank of the Niagara Falls Moraine to a main channel with westerly flowing water. Water flows within the eastern extent of the Felker's Falls Escarpment ESA and the western extent of the Devil's Punchbowl Escarpment ESA. The creek reaches Centennial Parkway, a major transportation corridor that utilizes an eroded escarpment valley to ascend the Niagara Escarpment. Here, Battlefield Creek flows down a natural valley between residential areas.

A railway line parallels the escarpment and crosses the subwatershed. One golf centre exists in the upper part of the subwatershed, with conservation lands parallel the escarpment edge and in the upper watershed area.

Stoney Creek

The Stoney Creek subwatershed almost completely surrounds the Battlefield Creek subwatershed. A network of tributaries drains the Niagara Falls Moraine in an easterly direction where they connect with the main channel. Water within the main channel flows in a westerly direction along the base of the Vinemount Moraine, an Area of Natural and Scientific Interest. This channel drains the Vinemount South Swamp and Tapleytown Woods ESAs.

The Devil's Punchbowl, at 37 metres high, is the third highest waterfall in Hamilton. It is recognized as an Area of Natural and Scientific Interest and as the Devil's Punchbowl Escarpment ESA. Water flow depends on weather conditions and can be minimal or non-existent at times throughout the year. Below the escarpment, Stoney Creek flows across the sand plain and into the Stoney Creek Ravine ESA, where it is joined by Battlefield Creek before discharging into Lake Ontario.

Agricultural, rural residential uses and conservation lands in the upper part of the subwatershed, and industrial and commercial land uses exist in the lower reach.

3.6 Stoney Creek Watercourses

A series of 14 parallel watercourses exists in the most eastern portion of the Hamilton Region Source Protection Area. These watercourses flow from the escarpment edge in a northward direction. At the escarpment edge are the Devil's Punchbowl Escarpment ESA and two Life Science Areas of Natural and Scientific Interest: Fruitland Escarpment and the Niagara Section Escarpment. All of the watercourses discharge into Lake Ontario and are identified as WC-0 through WC-13, including WC-10.1.

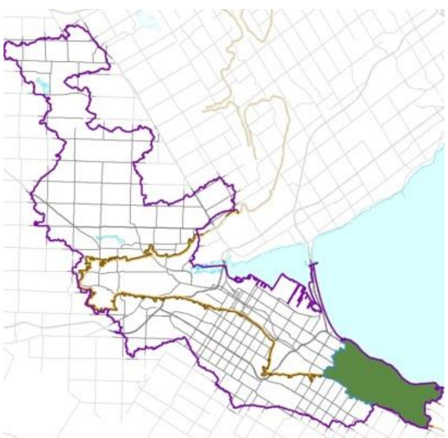


Illustration: Stoney Creek subwatersheds - east

Throughout all the Stoney Creek watersheds, the Queen Elizabeth Way and the Canadian National Railway line parallel the Lake Ontario shoreline. The lands immediately to the south of the Queen Elizabeth Way are developed for industrial and commercial land uses. To the north, the lands are primarily residential. Watersheds WC-0 through WC-4 are entirely urbanized. Moving through the watersheds to the east, the urbanization decreases to those lands near the highway. The area of the headwaters is typically agricultural.

The watercourses primarily drain across a shale plain with some areas covered by Halton till. Few wetlands remain in the area. Designated within WC-0, WC-1, and WC-2 are the Community Beach Ponds ESA. These ponds are small, forest thicket swamp. Within WC-12 are Fifty Mile Wetland Complex, Fifty Creek Valley, and the Fifty Point Conservation ESAs. The Fifty Point Conservation Area includes a marina with fuel and beach.

3.7 Great Lakes Water

3.7.1 Lake Ontario

Lake Ontario borders the Hamilton Source Protection Area to the northeast, and it is the source of drinking water for about 97 percent of the Area's residents. It is the most easterly Great Lake and, at just under 20,000 square kilometres, the smallest in area. Lake Ontario receives a discharge of water from the remaining four Great Lakes through the Niagara River and the Welland Canal, and it empties into the St. Lawrence River.

Only one percent of the Great Lake's water volume is replenished each year by precipitation and discharge from rivers and groundwater. The remaining volume is what remains from the last glacial period. Based on the volume of water held within, and the outflow from Lake Ontario, it takes about six years for water discharged to the lake to flow out of it.

In 1952, the construction of a hydroelectric dam on the St. Lawrence River began. Then in 1960, the regulation of outflows from Lake Ontario was imposed. This regulation altered the natural variability in water levels within the lake and impacted the marsh and shoreline habitat. For about nine months of the year, the Great Lakes Waterway, a system of channels and canals, facilitates the movement of lake freighters and ocean-going ships through all the Great Lakes to the St. Lawrence Seaway. Furthermore, channels are maintained to facilitate the use of the Port of Hamilton, located on the south side of Hamilton Harbour, as an international port.

In June 2014, the International Joint Commission (IJC) submitted their report entitled "Lake Ontario St. Lawrence River Plan 2014" to the Governments of Canada and the United States for their consideration and approval for implementation. The report presents the conclusions of the IJC investigation regarding needed changes to the 1952 and 1956 Orders of Approval for the St. Lawrence River Power Project. Plan 2014 will implement more natural variation in water levels and flows and the generally higher fall-through-spring water elevations will benefit coastal ecosystems around the lake. In most years, Plan 2014 will extend the boating season on Lake Ontario, and slightly increase the production of hydropower, while maintaining navigation for ships.

Approximately 14 percent of the water entering Lake Ontario is runoff from tributaries, 7 percent is from direct precipitation over the lake, and about 75 percent is from upstream Great Lakes and connecting channels (Neff, B.P. and Nicholas, J.R., 2005). The remaining 4 percent is input from groundwater. The contribution from tributaries is small in comparison to the contribution from the upper Great Lakes. However, it is the tributary loadings, along with the storm sewer and the discharges from wastewater treatment plants, which primarily affect the water quality of the nearshore area, where the Lake Ontario water system intakes are located.

Another attempt to quantify water budget components of the Lake Ontario basin was completed to fulfill commitments of the parties to the Great Lakes and St. Lawrence River Basin Sustainable Water Resources Agreement (Great Lakes-St. Lawrence…, 2012). In that Agreement, periodic assessments of the cumulative impacts of withdrawals, consumptive uses and diversions of water from the basin are required. For a 62-year historical period of 1948 through 2010, the water budget components of the Lake Ontario basin were assigned as:

Inflow

- Niagara River - 77 %
- Runoff - 14 %
- Precipitation - 7 %
- Diversions - 3 %

Outflow

- Evaporation - 5 %
- St. Lawrence River - 95 %
- Consumptive Uses - <1 %

Diversions may be intrabasin or interbasin and for Lake Ontario, more water is flowing in than out through diversions. The inflows and outflows from the basin are not equal. This is due to changes in storage in the lake and potentially from the uncertainties of the estimates. Groundwater is not factored into this water budget but is estimated to be a very small component. As a percentage of total inflow, consumptive uses are about three to four percent. Since diversions and consumptive uses are small in comparison to total inflow, their cumulative hydrologic effect on water levels and flows is small.

The temperature and circulation of lake water depends on the season, the wind direction, and other factors and could have an impact on drinking water quality. In summer and autumn, the colder waters at depth and warmer waters near surface stratify the lake, and they do not mix. In this case, strong winds will cause upwelling and downwelling events.

An upwelling event occurs when winds from the west push water away from the shore and cause deeper waters to rise to the surface. Downwelling events are the opposite phenomenon. They occur when winds from the east cause surface waters to move toward the shore and sink down. Downwelling events can transport surface pollutants to the depth of the lake water intakes.

In spring and late autumn, the changes in water temperature cause a vertical mixing of the lake water over a period of up to one week. During this period of turnover, settled solids from the lake bed are re-suspended, and the turbidity of the water near the intakes increases. Turbidity is the cloudiness of water caused by the particles suspended in it, and therefore, the measurement of turbidity is an important test of water quality. Also, turbidity can interfere with the treatment process at the water treatment plants, and municipalities closely monitor it.

Great Lakes Agreements

The Great Lakes and their connecting channels comprise the largest fresh surface water system on earth and require protection. As such, the governments that border and use water from the Great Lakes have signed numerous agreements. The Government of Ontario's current Great Lakes priorities include protection of Ontario's primary drinking water source. The *Clean Water Act*, *2006*, the authority under which this watershed assessment has been conducted, is one of the pieces of legislation that Ontario has introduced to help the province meet its commitments under the agreements.

The Canada-United States Great Lakes Water Quality Agreement, first signed in 1972, was revised in 1978, and amended by protocol in 1987, and 2012. The purpose of the Agreement is to commit all parties to restoring and maintaining the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem. An objective of the Agreement is that the waters of the Great Lakes should be a source of safe, high-quality drinking water. To help Canada meet its obligations under this Agreement, Canada and Ontario signed an Agreement Respecting the Great Lakes Basin Ecosystem in June 2007, extended the agreement until March 31, 2011, and are negotiating a new agreement. Its purpose is to promote cooperation to achieve a healthy, prosperous, and sustainable Great Lakes basin ecosystem for present and future generations.

The 1987 Protocol under the Great Lakes Water Quality Agreement provided for the development and implementation of Remedial Action Plans for 43 Areas of Concern within the Great Lakes. An Area of Concern is defined as a geographic location that human impact has severely degraded. As part of the Canada-Ontario Agreement, a commitment was made to facilitate the cleanup of 15 of the Areas of Concern identified in the Great Lakes Water Quality Agreement. One of these areas is Hamilton Harbour. The Remedial Action Plan focuses on all of Hamilton Harbour and Cootes Paradise.

Also, in response to commitments made under the Great Lakes Water Quality Agreement, the Lakewide Management Plan (LAMP) works as a framework for efforts to restore and protect the uses of Lake Ontario. Environment and Climate Change Canada, the Ontario Ministry of the Environment and Climate Change, the United States Environmental Protection Agency, and the New York State Department of Environmental Conservation are party to the agreement. The Niagara and the St. Lawrence Rivers were added to the Lake Ontario LAMP in the 2012 Protocol.

In terms of drinking water source protection, the most relevant goal of the Lakewide Management Plan is to ensure that the presence of contaminants does not limit people's uses of Lake Ontario's water and does not cause them any adverse health effects. Another goal of the plan is to ensure that society recognizes their impacts on the lake's ecosystem and that it conducts its activities in a way that protects the basin. The Lakewide Management Plan focuses on issues that affect the whole lake, such as critical toxic pollutants, and issues that require a bi-national effort. And finally, Ontario released its Great Lakes Strategy in December 2012. This document empowers all Ontarians to restore water, beaches, and coastal areas around the Great Lakes.

During policy development for the Source Protection Plan under the *Clean Water Act*, the goals and objectives of these Lake Ontario agreements will be considered in order to build on their successes. Education and stewardship actions carried out as part of public engagement under the *Clean Water Act* will serve to improve best management practices and water quality throughout the Source Protection Area.

The provinces of Ontario and Quebec, together with the eight Great Lakes states, signed the 1985 Great Lakes Charter and the 2005 Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement. In doing so, they agreed to cooperatively manage water resources and provide water quantity protection. In 2013, the first assessment of the cumulative impacts of water takings, consumptive uses, and diversions of water from the basin was published. The results inform decision making standards and their application.

The50tress50pment of policies to address water quantity threats within the Hamilton Region Source Protection Area will include review and consideration of these agreements and legislation. Also included are the requirements they place on the diversion, transfer, management, and monitoring of water.

3.7.2 Hamilton Harbour

Hamilton Harbour is located at the most western end of Lake Ontario. Breached sand bars separate the bay from the lake and Cootes Paradise. The Cities of Burlington and Hamilton lie to the north and south, respectively. Grindstone Creek, Falcon Creek, Indian Creek, and the small tributaries of the West Aldershot watershed empty into the bay along the north shore, while Red Hill Creek discharges from the south. The Burlington Canal was excavated through the eastern sand bar and opened in 1832 to provide navigable access to the natural harbour.

Hamilton Harbour is approximately 21.5 square kilometres in size. It supports marinas and an active, international deep water port in Hamilton. Historically, wetlands and shallow water areas existed along its shores. The regulation of Lake Ontario's water levels has affected shoreline habitat, as has filling along the southern shore of the harbour. The filling creates new shipping piers, expands port lands, and reduces the surface area of the water. The Port of Hamilton has 15 commercial wharves and 11 kilometres of shipping berths. The port handles the largest volume of cargo and shipping traffic of all the Canadian Great Lakes ports. Cargo includes iron ore and coal to support Hamilton's steel industry, salt, sand, grains, soybeans, liquid fertilizer, and jet fuel.

The Hamilton Oshawa Port Authority, a non-share capital corporation, owns and leases 250 hectares of land to industrial tenants who use the port facilities. Tenants carry out activities at the port, including storage and shipment of liquid and dry bulk products, manufacturing and repair facilities, warehousing, distribution, and support industries.

Hamilton Harbour

Hamilton Harbour Remedial Action Plan

Hamilton Harbour's ecosystem has been severely degraded as a result of dredging, direct sewage discharges, habitat loss, toxic spills, infilling with contaminated materials, and industrial discharges. Although changes in practices lead to improvements in water quality within the Bay, Hamilton Harbour was designated an Area of Concern (AOC) in Annex 2 of the Great Lakes Water Quality Agreement in 1987. In response, the Hamilton Harbour Remedial Action Plan was published in 1992, and an update released in 2002. Its objective is to take a comprehensive ecosystem approach to restoring and protecting the beneficial uses of the area, with the ultimate goal to complete or have substantially underway all defined remedial actions by the year 2015.

The Remedial Action Plan includes three stages: Stage One determines the severity and causes of the environmental degradation; Stage Two identifies goals and recommends actions to restore and protect ecosystem health; and Stage Three implements the recommended actions and measures the progress made. The Plan is now in Stage Three. When Stage Three is complete, Hamilton Harbour can be delisted as an Area of Concern.

The Hamilton Harbour Remedial Action Plan included 57 52tress5252ddations and 159 tasks to reach the set goals. One of the Stakeholder's Goals (Hamilton Harbour Remedial Action Plan Team, 1992) is:

> "To remove the potential negative impact of Hamilton Harbour's water quality on Lake Ontario's water quality; with particular attention to areas of nearshore public uses and drinking water intake pipes for the Cities of Hamilton and Burlington."

Implementation and monitoring of the Plan activities have been initiated with some tasks complete, such as the remediation of a contaminated infilling site and creation of Bayfront Park. Another project is to address combined sewer overflows in the City of Hamilton. Combined sewers carry both storm water and sanitary wastes in one pipe. Heavy or prolonged periods of rain can increase the volume carried until it is too much for the sewer to handle. It is at these times when the sewers release sewage through the combined sewer overflows into a nearby watercourse.

In addition to the above, the Plan includes upgrading wastewater treatment plants to improve effluent quality discharged into the harbour and the remediation of Randle Reef.

Randle Reef is one of the more contaminated sediment sites in the Canadian Areas of Concern within the Great Lakes. Sediments are contaminated with polycyclic aromatic hydrocarbons (PAHs) at very high concentrations in **coal tar.** The area is a priority for remediation in the Hamilton Harbour Remedial Action Plan and under the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem. In 2015, a $138.9 million project to clean up the reef began. It is estimated the project will generate approximately $165M in economic benefits for the local community, create good middle class jobs, grow business development, and generate tourism. The completed project is also a key step in removing Hamilton Harbour from the list of Great Lakes Areas of Concern. This 3-stage project is led by Environment and Climate Change Canada with funding from the Government of Canada, the Province of Ontario, the City of Hamilton, the City of Burlington, Halton Region, the Hamilton Oshawa Port Authority and Stelco. The first stage is complete. It involved the construction of an in-water, double-walled engineered containment facility (ECF) over the most contaminated sediment in the harbour. The second stage is also complete. It resulted in the contaminated sediment to be safely contained within the ECF. The third and final phase is expected to be completed by 2023 and will involve capping the ECF and transferring responsibility for it to the Hamilton Oshawa Port Authority to create additional land for the port.

3.7.3 Cootes Paradise

Cootes Paradise is an 840-hectare wildlife sanctuary located at the western end of Burlington Bay. It contains a shallow, freshwater coastal marsh that is 250 hectares in size. The Royal Botanical Gardens owns and manages the sanctuary, which is bordered by the Cities of

Burlington and Hamilton. Cootes Paradise marsh is an important waterfowl staging habitat and the largest nursery habitat for fish in the region. It is designated a Provincially Significant Class 1 Wetland and an Area of Natural and Scientific Interest. It is also listed as an Environmentally Sensitive Area by the City of Hamilton.

Highway 403 bordering Cootes Paradise

In the 1800s, Cootes Paradise was almost entirely covered with emergent aquatic plants that provided shelter and migration stop-overs for a variety of birds, animals, and fish. However, by 1985 the aquatic vegetation was reduced by 85 percent. This reduction had a negative impact on water quality and marsh habitat. Many things contributed to this change in the natural ecology of the marsh. People overusing the wetland, the construction of the Desjardins Canal, and the introduction of carp and invasive species have all taken their toll. The regulation of water levels within Lake Ontario has altered the natural variability in water levels within the marsh and has also affected its ecosystem. Of concern, and under study and remediation by the City of Hamilton, are the outflows from the Dundas Wastewater Treatment Plant and several combined sewer overflows that also discharge into Cootes Paradise.

Tributaries of the North Cootes Paradise, Spencer Creek, Borer's Creek and Chedoke Creek watersheds, all within the Hamilton Region Source Protection Area, discharge to Cootes Paradise. Changes to the quality of the water of these creeks have had an impact on the water quality of Cootes Paradise. Agricultural practices as well as residential, commercial, and industrial development have added nutrients, pesticides, chemical runoff, and eroded sediment to the water.

4. WATER MANAGEMENT AND MONITORING

In this section:
- An overview of water monitoring
- Water use
- Water systems within the Hamilton Region Source Protection Area

Hamilton Region Conservation Authority and local municipalities have managed the water resources within their jurisdictions for decades. Watershed and subwatershed studies, aquifer management programs, education and outreach, monitoring of water quality and quantity, stewardship actions, and resident incentive programs preceded the implementation of the drinking water source protection program. Accordingly, a significant amount of data was available from these agencies and other stakeholders to complete this assessment of the risks to drinking water sources within the Hamilton Region Source Protection Area.

In order to support development applications, the municipalities of the Source Protection Area typically require studies to assess potential impacts on surface water and groundwater resources. Some of these studies have been reviewed and the data extracted to enhance the data generated through the agency monitoring programs. The following sections summarize the monitoring data.

4.1 Meteorological Data

The Hamilton Region Source Protection Area is located in the climatic area referred to specifically as the Great Lakes-St. Lawrence Region. It is a temperate zone that experiences four seasons. Environment and Climate Change Canada has climate records collected at stations within or near the Hamilton Region Source Protection Area and covering more than 100 years. The locations of the meteorological stations used in this assessment are shown on Figure 4.1 and the details are summarized in Appendix B.1.

Precipitation **54tress** for the period between 1971 through 2000 ranged between 910.1 millimetres per year at Hamilton A station, located at the Hamilton International Airport, and 973 millimetres per year at Millgrove station, in the northern part of the Source Protection Area. Below the Niagara Escarpment, and between 1961 through 1990, the normal precipitation received was 847.8 millimetres per year at Hamilton Municipal Lab and 866.8 millimetres at the Hamilton RBG station. Precipitation received is typically lower near Lake Ontario.

Monthly **precipitation depths** vary across the Source Protection Area (see Figure 4.2) and throughout the year. Precipitation is lowest in January and February at all stations. The timing of maximum, monthly precipitation received varies between stations. Millgrove station records the highest precipitation in May, while Hamilton RBG records decreasing values at this time and the highest values in August. Precipitation recorded at Copetown station shows a steady increase over the summer months until September. In general, the monthly precipitation received below the escarpment at the edge of the lake is less than that recorded above.

Temperature 55tress are similar across the Hamilton Region Source Protection Area. The dominant control on temperature within the Source Protection Area is Lake Ontario. The lake moderates the climate on the surrounding land by absorbing solar radiation in the summer and releasing the stored heat over the winter. The temperatures recorded at the Hamilton RBG station, situated close to the lake, are slightly higher throughout the year than the other stations located inland. The coolest month in the Source Protection Area is January and the hottest is July (see Figure 4.2).

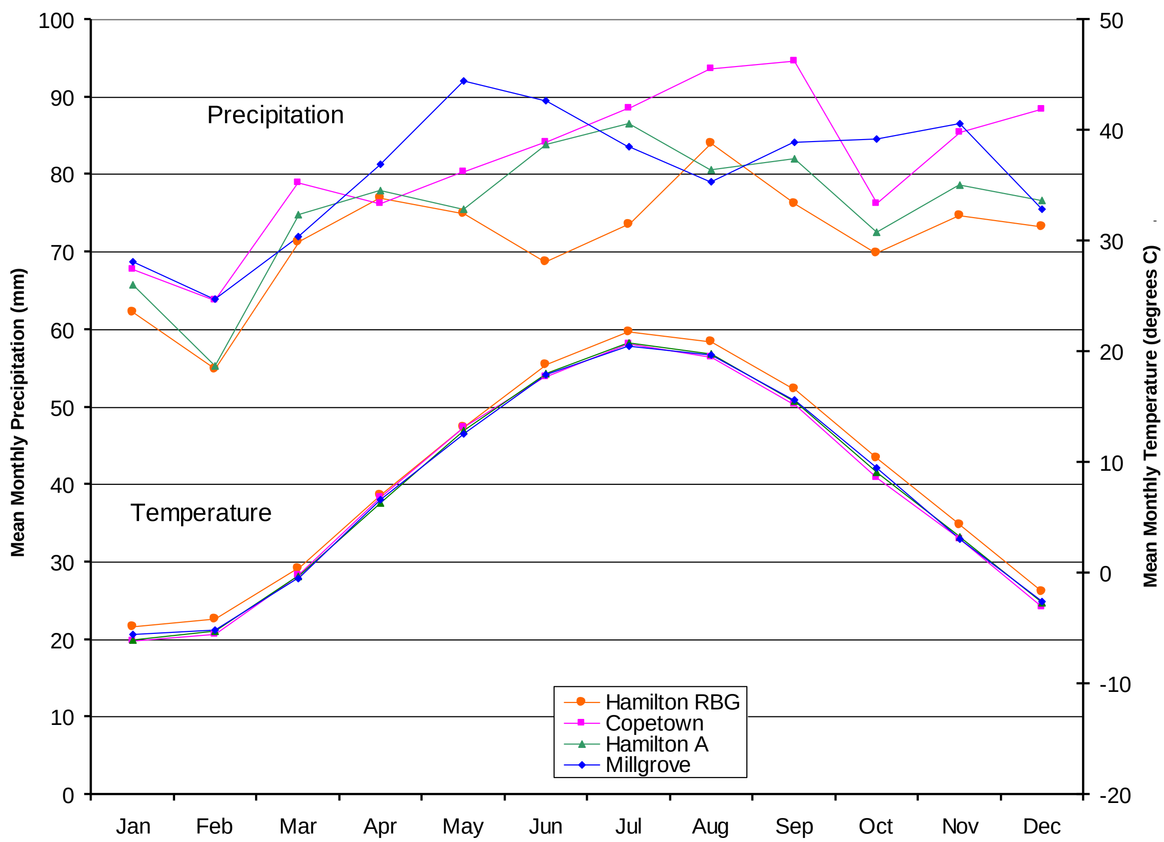


Figure 4.2 Mean monthly precipitation and temperature data for the Hamilton Region Source Protection Area

4.1.1 Long-term Climate Data

The climate of the earth is naturally variable, albeit at quite a slow pace. Many warming and cooling periods have occurred since the earth formed. The most recent glacial period, the Wisconsinan, ended about 10,000 years ago. The scientific community generally accepts that there are impacts on this natural cycle due to the activities of people since the industrial revolution and our subsequent dependence on fossil fuels.

Climate change within the Source Protection Area is being studied more at the provincial, national, and continental levels. Local municipalities are reviewing the completed studies and have begun assessing the potential impacts on their infrastructure.

Within the Area's watersheds, long term climate data is available for review. The data shown in Figure 4.3 combine the historical data from Environment and Climate Change Canada's Hamilton meteorological station with the data from the Hamilton RBG and Hamilton RBG CS stations. The Figure provides a glimpse of potential trends in precipitation and air temperature received between 1866 and 2010. Only data from those years with a near complete record have been plotted.

As shown, the average precipitation (precipitation 56tress) increased more between 1961-1990 and 1971-2000 than the most recent period of 1981-2010. The average temperature (temperature 56tress) has remained fairly constant with only a 0.1 degree increase in the most recent period.

Data collection methods and quality control procedures have changed over the years and may affect the accuracy of the data and the comparability of the three sets of data. However, the data shows a similar range in precipitation quantities received each year, with maximum and minimum values obtained in 1870 and 1939, respectively. The data show that typical depths of precipitation range between 700 and 1000 millimetres and that significant fluctuation from year to year is common. The data clearly show the precipitation anomalies as the droughts of 1877, the 1930s, 1963, and 2002. The 1870s data shows that the most precipitation fell in those years; however, since 1977, there is a greater frequency of years receiving over 1,000 millimetres.

The air temperature data record is more stable, ranging generally between 8 and 10 degrees Celsius. The temperatures of the 1940s and early 1950s were higher than the climate normal between 1961 and 1990. The same is true for the temperatures as monitored at the Hamilton RBG CS station between 1999 and 2008.

Projected changes to the climate in the Great Lakes region, based on modelled scenarios, include a rise in average annual temperature by about 1.6 to 4.4 degrees Celsius by 2050 relative to the 1961-1990 baseline conditions (Mortsch et al., 2006). It is predicted that warming of air temperature will occur in all seasons, and the modelled scenarios suggest that the greatest warming will occur in the winter months. Annual precipitation is also expected to increase, except if the modelled warm and dry scenario conditions prevail. The increase in precipitation is predicted to be between 0.1 percent and 21.5 percent and again is typically at a higher percentage increase in the winter months (Mortsch et al., 2006).

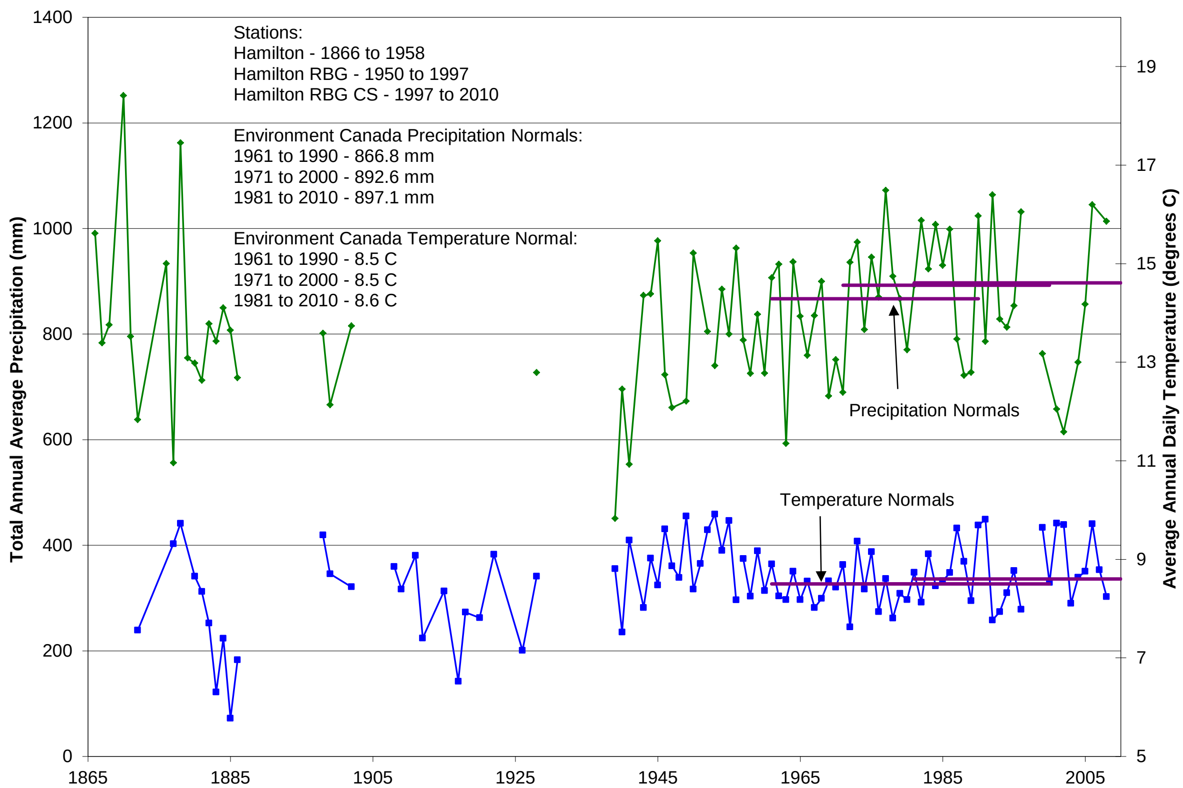


Figure 4.3 Long-term Climate Data for the Hamilton area

Impacts of Climate Change

The predicted changes to air temperature and precipitation discussed above could result in an increase in water temperature, a shift in winter precipitation to more rain than snow, less snowpack, and an earlier spring melt. They could also result in an increase in ice-free days on the Great Lakes and the potential for ice-free winters. More ice-free days will lead to more evaporative losses from the lakes and the lowering of water levels. However, studies by Mortsch et al., (2006) have indicated that, although the water levels in other Great Lakes will decline below historical values, Lake Ontario's water levels will not follow suit. A modelled worst case scenario of warm and dry conditions predicts a water level drop of 0.37 metres by 2050.

Since 1960, the outflow from Lake Ontario has been regulated to moderate impacts from weather extremes for shipping and hydroelectric power generation. The current target water level range is between 74.2 and 75.4 metres above the International Great Lakes Datum (IGLD 1985). During the low water supply period of the mid-1960s, Lake Ontario levels were maintained higher than they would have been naturally. In contrast, during the high-water supply periods of the early and mid-1970s, mid-1980s, and 1993, water levels were maintained at lower levels. It is anticipated that, during the periods of sustained high or low water supplies that result due to climate change, the regulation of Lake Ontario outflows will be optimized. This will benefit the communities and ecosystems of the lake and downstream.

Within the Source Protection Area watersheds, an increase in extreme weather events is expected to increase flooding and soil erosion. This will result in degraded surface water quality due to the suspension of sediment, nutrients, and pesticides. However, an increase in droughts is also predicted. Based on historical evidence, this will increase hardship for those reliant on shallow wells and small waterbodies for their water supplies. The lowering of the water table due to dry conditions, when the supply of water is reduced and the demand is increased, can render shallow wells unusable. Currently, municipalities implement watering bans within their communities to reduce high water demand during periods of low water supply. These bans are successful, and municipalities have maintained their water supplies. Hamilton Conservation Authority and the province also implement the Low Water Response Program. This three-level program uses voluntary and then mandatory reductions in water takings to benefit the natural environment.

A change in climatic conditions may also result in the invasion of alien species. This could impact the quality of surface waters, as is the case with zebra mussels in Lake Ontario (see Section 4.2.2). There could be positive impacts on agricultural and warm weather recreational activities due to a rise in temperature and longer growing season, but the availability of a sufficient supply of water when it is needed is paramount.

An analysis of potential impacts within the Source Protection Area from climate change should be completed in future years as the science behind predicting impacts improves and local studies are completed.

4.2 Surface Water Monitoring

Primarily, surface water data are collected through monitoring programs established by the Conservation Authority, the Provincial Water Quality Monitoring Network (PWQMN), the Water Survey of Canada, and stakeholders operating businesses within the area. Long term surface water monitoring locations used by agencies are shown on Figure 4.1 and the details are provided in Appendix B.2.

4.2.1 Surface Water Quantity

Gauges to monitor surface water levels on a continuous basis (HYDAT stations) are located on major tributaries within some of the watersheds of the Source Protection Area and on Lake Ontario. The Water Survey of Canada has operated nine gauges within the Source

Protection Area, including one since 1956. Five of these gauges are still in use, generating continuous water level and estimated stream flow data. One of them recorded lake water levels at the Burlington Canal. The long term HYDAT station data are included as charts in Appendix B.3.

In addition to the continuous measurement at HYDAT stations, Hamilton Conservation Authority and others improve the monitoring coverage by the periodic measurement of stream flows at a greater number of locations and within more subwatersheds.

Hamilton Conservation Authority also records surface water management data as they collect water level and outflow records for the Valens and Christie Lake reservoirs. The City of Hamilton maintains records of the wastewater treatment plant discharges. In addition, other surface water taking and discharge records, such as from quarry dewatering and golf course irrigation, are collected within the Source Protection Area. Permit to take water holders are required to collect and record the volumes of water taken daily and each year submit the records to the ministry’s online Water Taking Reporting System (WTRS) database.

The fluctuation in stream flows within the Source Protection Area typically correlates with the seasonal fluctuations in air temperature, evaporation, the amount of precipitation received, and the amount of urbanization along the watercourse. The highest surface water flows typically occur in the months of March and April, consistent with the melting of snow and increased runoff. The lowest stream flows correspond with the typically hotter summer and the early autumn months of July through September, when vegetation growth has peaked.

Dense vegetation increases the interception of precipitation before it reaches the ground, and it increases losses due to **evapotranspiration.** Urbanized areas have more variable stream flows, primarily due to the alteration of channels and the increase in hard surfaces such as roads, buildings, and parking lots, which increase “flashy” surface runoff.

The storage-and-release functions of the reservoirs within the Source Protection Area also affect the month-to-month variations in the stream flows. The reservoirs store water from snowmelt and spring runoff. Water is gradually released over the summer months in order to augment low flows in the creeks. Therefore, the operation of the reservoirs reduces stream flow peaks in the spring and increases stream flows in the summer.

During the summer months, when precipitation received is at a minimum and evapotranspiration is at a maximum, the Source Protection Area is in a water deficit situation. Throughout this period, groundwater discharge maintains stream flow in some locations. Water released from the reservoirs and other municipal and industrial discharges also help to maintain flow.

Historical data indicate significant variability in monthly and annual stream flows in the monitored creeks. Stream flows typically reflect the precipitation received and, therefore, are much lower in dry years. In 2007, Hamilton Region Source Protection Area experienced a drier than normal year, receiving 208 millimetres less precipitation at the Hamilton Airport than the amount normally received in a year. As a result, stream flows declined substantially, with some creeks going dry.

In contrast to the above, the Source Protection Area experienced higher than normal precipitation in 2008, receiving 198 millimetres more precipitation than normal at the Hamilton Airport. The additional rain resulted in stream flows typically above normal. Moreover, the intense rain storms caused localized flooding, and a hail storm on August 5, 2008 caused much damage.

Logie's Creek, Hamilton

As noted previously, Lake Ontario water levels and outflows have been regulated since 1960. The Canadian Hydrographic Service reports the average lake levels as recorded at all stations on the lake and referenced to the International Great Lakes Datum (IGLD 1985). Between 1960 and 2009, the minimum and maximum monthly lake levels were 73.83 metres (recorded in January 1965) and 75.73 metres (recorded in May 1973), respectively.

Water Survey of Canada reported daily water levels for Lake Ontario at the Burlington Canal (02HB017) for the 49 year period between 1970 and 2018. The daily average water levels range between a low of 74.20 metres (measured on January 4, 1999), and a high of 75.94 metres (measured on May 25, 2017). The instantaneous high-water level of 76.46 metres occurred at 5:34 a.m. on April 10, 1973. The lowest water levels typically occur between November and February.

Within a year, the difference between the maximum and minimum water levels measured at the Burlington Canal averages about 0.8 metres. The maximum difference recorded is 1.54 metres. This water level range does not take into account **storm surges**, **setdowns** and any fluctuation in water level due to ship traffic that occur within the day. The 100-year maximum storm surge at Burlington has been determined as 0.94 metres (Lewis et. Al., 1990). Since monitoring began at the Burlington Canal, the daily average water level has never dropped below the regulated target minimum lake level of 74.2 metres. However, in January 1965 the lake level was the lowest average monthly record at 73.83 metres.

4.2.2 Surface Water Quality

Watersheds

Although the creeks within the Source Protection Area are not used as water sources for municipal drinking water supplies, they all discharge into Lake Ontario. The lake is the source water for most of the population of the Area and, accordingly, the quality of the tributary water will influence the quality of that source water. Tributary water may also infiltrate and influence the quality of the groundwater below.

Hamilton Conservation Authority monitors surface water quality in partnership with the Ministry of the Environment, Conservation and Parks and the City of Hamilton. The agency uses five locations that are part of the Provincial Water Quality Monitoring Network (PWQMN) and two City of Hamilton monitoring stations. Since 2002, surface water samples have been collected monthly between April and November. The samples are analyzed for parameters including nutrients, major ions, metals, and bacteria.

Subwatershed and site-specific studies, generally in support of development applications, are also completed throughout the Source Protection Area. These studies typically report on surface water quality. The long-term surface water quality data reviewed are summarized in Appendix B.4.

The City of Hamilton’s wastewater collection system includes 23 combined sewer overflows (where sewage and storm water are mixed). When the capacity of the combined sewer is exceeded, raw sewage discharges into nearby waterbodies through these overflow points. This can also occur at sanitary sewer pumping stations and at wastewater treatment plants that have bypasses in case of excess capacity. These releases reduce the potential for property damage.

In order to reduce overflow events, the City of Hamilton has installed storage tanks at nine of the overflows with a combined storage volume of over 314,000 cubic metres. The city can divert combined sewage flows to the tanks during intense rainstorms and release it back to the sewer when capacity exists. These tanks are designed to reduce the frequency of overflows and the volume of raw sewage that enters the waterbodies.

Combined sewer overflow outfalls discharge to Hamilton Harbour, Cootes Paradise, Windermere Basin, Red Hill Creek, and Sherman Inlet.

The impact of the combined sewer overflows on water quality in the Source Protection Area depends on the frequency of intense rainfalls that exceed the capacity of the storm water system. Historically, overflows at some outfalls were in excess of 40 times per year. A new, combined sewer overflow pipe in the valley of Red Hill Creek is reported to decrease the number of discharges into the creek from about 20 to 27 times per year to about one to three. Although typically infrequent, the overflows are untreated, diluted sewage.

The discharge from the wastewater treatment plants are continuous but of better quality due to the treatment process. The Dundas Wastewater Treatment Plant discharges to the Desjardins Canal and into Cootes Paradise. Discharge from the Woodward Avenue wastewater treatment plant is to Red Hill Creek, just upstream of Windermere Basin.

Most water quality parameters that are measured across the watersheds meet the Ministry of the Environment, Conservation and Parks objectives for surface waters. These objectives are listed in Water Management – Policies, Guidelines, Provincial Water Quality Objectives, Appendix A: Provincial Water Quality Objectives (1999; https://www.ontario.ca/environment-and-energy/water-management-policies-guidelines-provincial-water-quality-objectives. The exceptions are typically total phosphorus, some metals, and bacteria, which often exceed their criteria. The objectives are set at concentrations that protect the aquatic environment.

Suspended Solids

Many of the creeks within the Area's watersheds respond quickly to rain storms with high runoff. This results in increased amounts of sediments suspended in the water column. These suspended sediments can restrict the amount of light penetration, and chemicals can be leached from the sediments, which results in a change in the water quality.

Increased erosion from urban development and certain land use activities can increase the amount of sediment carried by the watercourse and affect water quality.

Metals

The concentrations of metals varied in surface water samples collected across the Source Protection Area. Iron concentrations have exceeded the provincial objective of 0.3 milligrams per litre at most stations at some time. Occasionally, cadmium, chromium, cobalt, and zinc are also measured at concentrations above their objectives at various locations within the watersheds. The inclusion of sediment within the samples collected or the dissolution of these metals from the creek bottom and bank sediment can result in the elevated concentrations and they may be from a natural source. The occurrence of the elevated concentrations across the watersheds rather than in a localized spot also suggests a natural source.

The concentrations of cadmium, chromium, cobalt, copper, cyanide, lead, nickel, mercury, manganese, and zinc have been measured at concentrations that could impact the aquatic environment downstream of treated or raw sewage discharges.

Localized, elevated metal concentrations in stream water may be from industrial or wastewater discharges or rarely from pesticide applications. A rising trend in zinc concentration has been identified in all PWQMN stations as shown on Chart 4.1.

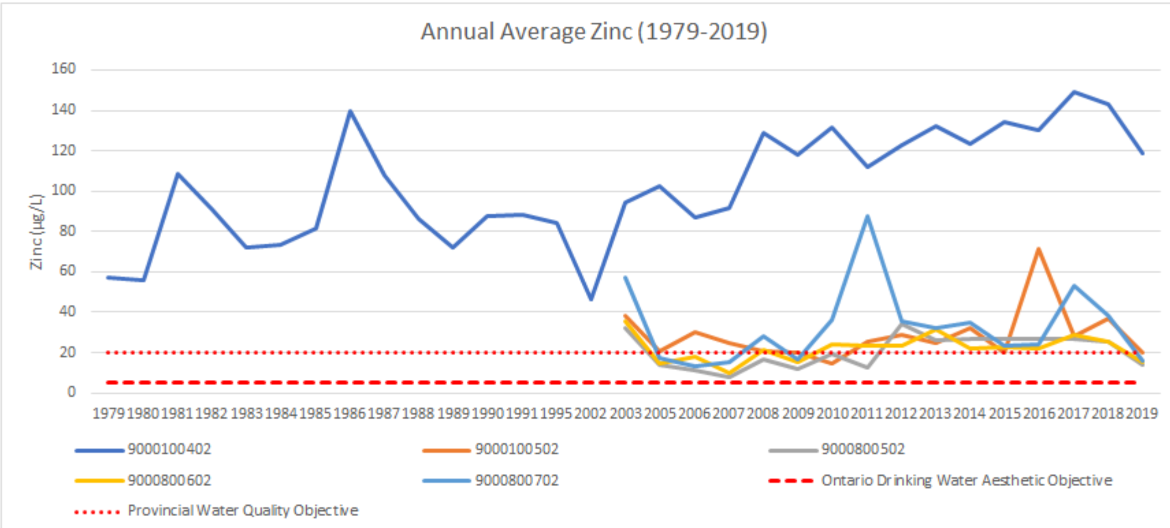


Chart 4.1 Zinc concentrations at PWQMN stations

Phosphorus

Total phosphorous concentrations greater than 0.03 milligrams per litre, the provincial objective for total phosphorous in streams, are also typical in the area. Phosphorus is generally limited in the natural environment, and when occurring at elevated concentrations, it will cause plant and algae growth within watercourses. *Cladophora*, or nuisance algae, is a problem in many stream reaches within the Source Protection Area. The sources of phosphorus include commercial fertilizers, manure, septic systems, soaps/detergents, naturally from sediment, and air deposition. Water samples collected from Upper Spencer Creek at Safari Road (PWQMN Station 9000800702) consistently contained small amounts of phosphorus at concentrations less than the Provincial objective over the past seven years. In contrast, almost all water samples collected at the other monitoring stations had concentrations greater than this value. Total phosphorus concentrations in PWQMN stations are presented in Chart 4.2.

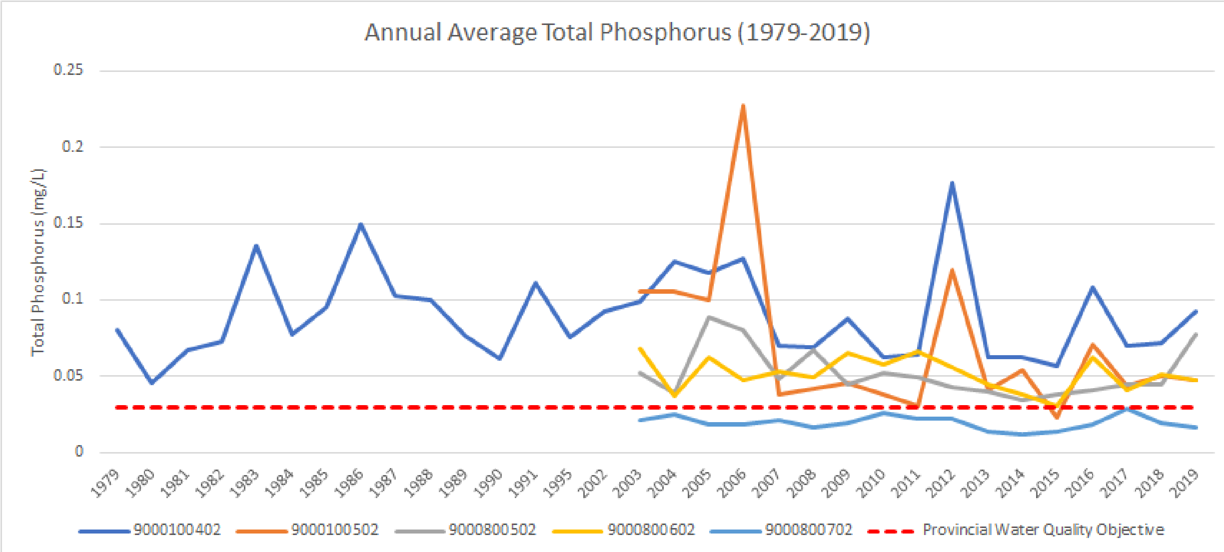


Chart 4.2 Total Phosphorus concentrations at PWQMN stations

Bacteria

The **indicator bacterium,** *Escherichia coli* (*E. coli*), has been detected at elevated concentrations at most surface water sampling stations between 2004 and 2009. The provincial objective is a count of 100 per 100 millilitres of water sample based on a geometric mean of at least five samples. *E. coli* occurs naturally in the intestines of animals, including people, and can enter watercourses from wildlife, water runoff from manure storage or use areas, runoff from animal pastures, discharge from faulty septic systems, and from wastewater treatment plant discharges.

Water samples collected at the three westerly stations have significantly lower concentrations than those to the east. The highest concentrations are from water samples collected at stations downstream of outfalls, where estimated counts of colony forming units have been up to tens of thousands. The presence of *E. coli* in the water suggests that other disease-causing organisms also may be present.

Chloride and Sodium

The concentrations of chloride in the surface water samples analyzed vary considerably within one year, but concentrations are typically highest during the summer months. Groundwater that discharges from clays and shale are typically enriched in salts. The streams that are supplied by this groundwater are also enriched. This could explain the increased concentrations in summer months when the streams rely more on groundwater sources. In the western two watercourses, the concentrations remain relatively low at less than 100 mg/L (PWQMN Station 9000800502, 9000800602 and 9000800702) as compared with those in the east, which are located in more urbanised areas (PWQMN Sation 9000800402 and PWQMN 9000800502) that reach maximum values of 400 mg/L. Road salting, water softeners, and wastewater treatment effluent are typical human sources of chloride and sodium. Chloride concentrations in surface water are presented on Chart 4.3.

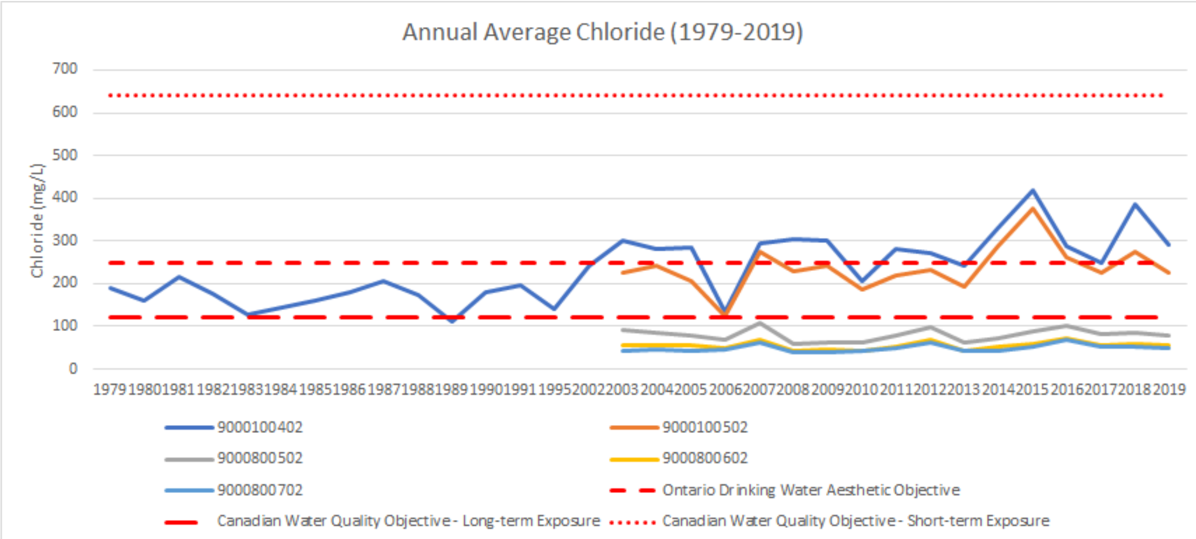


Chart 4.3 Chloride concentrations at PWQMN stations

Pesticides

A few pesticides have been analyzed periodically in the water samples collected at a few stations between 1981 and 2004. In the samples collected, these parameters typically were not detected or they were at or below the Ministry of the Environment and Climate Change objective. Bans on the cosmetic use of pesticides have been in effect since 2009; therefore, concentrations of the associated chemicals are not expected to rise.

Aquatic Health

Since 1999, the Hamilton Conservation Authority has been monitoring the **benthic invertebrate community** in some of its watercourses. Then in 2004, they initiated their Aquatic Resource Monitoring Program (ARMP) as a way to monitor the health of the aquatic ecosystem over the long-term. This program integrates assessments of water chemistry, using the macroinvertebrate community as an indicator, with the fish communities and their habitats. The health of the ecologic system is based on the simultaneous analysis and quantification of these interrelated parameters. Hamilton Conservation Authority uses a total of 39 monitoring stations within its watershed. Six of these established stations are monitored annually, while the remainder are grouped and monitored every three years.

Benthic invertebrates are good indicators of long-term impacts on water and habitat quality in a creek. The types of species present, their abundance, and the diversity of the community are all assessed.

In order to assess the biotic health of the stream, the fish species, their abundance, and their food sources are monitored. Changes in the fish community over time may be due to water quality but may also be the result of changes in water levels, obstructions to fish movement in the streams, or changes in groundwater discharge that affect water temperature.

Appendix B.5 summarizes the health of the aquatic ecosystems within the major creeks, based on the assessments made at each monitoring location.

In general, the watersheds/subwatersheds are healthy but showing signs of stress. The creeks are healthiest where reaches are undisturbed, and they are impaired in developed areas. Storm sewer drainage, runoff from roads, increased erosion, and lack of riparian cover all contribute to poor aquatic health.

Surface Water Quality Score

Hamilton Conservation Authority uses a scoring system to assess the surface water quality of subwatersheds. This system is based on the results of water quality monitoring at the PWQMN stations and the findings of the Aquatic Resource Monitoring Program. The results are summarized in Table 4.1 and show that the headwaters of Spencer Creek have the best water quality.

Table 4.1 Surface water quality scoring in Hamilton Region creeks

PWQMN Number	Subwatersheds	Grade Score	Grade Description
9000800702	Upper Spencer, Fletcher Creek	A	Excellent
900800602 and 900800502	Upper Spencer (downstream of 9000800702), Flamborough Creek, Westover Creek, West Spencer Creek, Middle Spencer Creek, Logie's Creek	B	Good
Ancaster	Ancaster Creek	C	Fair
9000100402	Upper Ottawa, Hannon Creek	C	Fair
9000100502	Green Hill, Montgomery Creek, Upper Davis Creek, Lower Davis Creek, Red Hill Valley	B	Good
Stoney Creek	Stoney Creek	C	Fair

Hamilton Harbour and Cootes Paradise

The Hamilton Harbour Remedial Action Plan Stage 2 report identified many concerns that need to be addressed in order to remediate this waterbody

(http://www.hamiltonharbour.ca/resources/
documents/HamiltonHarbourRAPStageTwoSummaryReport,1992.pdf). Poor water quality, including reduced clarity, low oxygen levels, and elevated nutrient concentrations exist in the bay, resulting in algae growth. Also, there are elevated bacteria levels at the City's two swimming beaches. However, monitoring has shown declining trends in concentrations and an67tress67l improvement in water quality within the bay. Concentrations of phosphorus and ammonia and bacteria counts have dropped substantially, and water clarity normally meets the target of visibility to two metres depth.

Bacteria and Wastewater Treatment

It was first thought that bacterial contamination came solely from discharges from the four wastewater treatment plants (Skyway in Burlington, Waterdown, Dundas, and Woodward Avenue in Hamilton) and the combined sewer overflows that discharge directly to these features. The combined discharge from these facilities amounts to 50 percent of the water flowing into Hamilton Harbour. Water quality sampling and testing throughout the bay showed that bacteria levels at the two swimming beaches were much higher than farther offshore. Further investigation revealed the source of the bacteria to be waterfowl. The City of Hamilton implemented a successful waterfowl management plan to combat this problem, and nearshore water quality has improved where the plan is in use.

Overflow control structures have upgraded some of the combined sewer overflows at the western end of the bay, reducing the discharge of raw sewage to the bay. Also, upgrades to the wastewater treatment plants have improved effluent quality. Since 2004, Halton Region's Skyway Wastewater Treatment Plant has met the Remedial Action Plan water quality targets for its effluent. Both the City of Hamilton and Halton Region are in the process of improving their treatment systems, which will improve water quality to the levels required to meet criteria for final harbour water quality.

Toxic Substances

The Remedial Action Plan for Hamilton Harbour recommends the remediation of contaminated sediments and the elimination of the discharge of toxic substances to the harbour. Contaminants of concern in Hamilton Harbour (at concentrations that pose significant risk to fish and wildlife) are: polychlorinated biphenyls (PCBs); polycyclic aromatic hydrocarbons (PAHs); zinc; cadmium; lead; iron; mercury; and arsenic. The contamination is primarily the result of past industrial and municipal activities. Improved processes and the implementation and monitoring of the Ministry of the Environment and Climate Change's Municipal-Industrial Strategy for Abatement (MISA) program (which regulates discharge quality from some industries located within the watershed) have successfully reduced the release of contaminants into the harbour waters.

In terms of toxic substances, Hamilton Harbour water quality has improved to the extent that concentrations of metals comply with the provincial guidelines for surface waters. In addition, concentrations of polycyclic aromatic hydrocarbons and polychlorinated biphenyls in suspended sediments have declined due to the burial of the contaminated sediments by cleaner material. Polychlorinated biphenyls are a concern due to bioaccumulation, a process where the compound is taken up by the aquatic invertebrates that live in the bottom sediment. These invertebrates are eaten by fish, which are then eaten by birds or people. The polychlorinated biphenyls accumulate in the higher species. Accordingly, the province provides the public with recommended consumption guidelines and/or restrictions on many fish species and specific sizes of fish from the harbour.

At Randle Reef, concentrations of polycyclic aromatic hydrocarbons (PAHs) in the sediments are high, while concentrations of metals are at toxic levels. Polycyclic aromatic hydrocarbons have immediate and long-term toxic impacts on fish and wildlife. In 2015, a $138.9 million project to clean up Randle Reef began and is a key step in removing Hamilton Harbour from the list of Great Lakes Areas of Concern. This 3-stage project involves the construction of an in-water, double-walled engineered containment facility (ECF) over the most contaminated sediment in the harbour. The project is expected to be completed by 2023.

The Skyway (Burlington) and Woodward (Hamilton) wastewater treatment plants are undergoing major upgrades to improve treatment performance. In the summer of 2013, federal, provincial and Hamilton officials celebrated the completion of the $20.6-million rehabilitation of Windermere Basin, a 25-hectare plot of reclaimed industrial land.

Source Water Quality

The active Burlington and Hamilton water supply intakes are located approximately 4.8 and 5.0 kilometres from the Burlington Canal, respectively. Water quality at the intakes is subject to the influence of dilute Hamilton Harbour discharge. Water flows through the canal due to differences in water levels and differences in temperature between the lake and bay. Furthermore, wind direction and speed can be important. As a result, the direction of flow in the canal changes, as does its speed. It is estimated that, on average, water stays in the bay for 90 days before flowing through the canal. Thus, the Hamilton Harbour-Lake Ontario exchange is a significant process that influences water quality both in the lake and in the bay.

Under certain flow conditions, and if the source of a contaminant were close to the Burlington Canal, contaminants could enter Lake Ontario without much mixing within the bay. This scenario has been studied for the Skyway and Woodward Avenue Wastewater Treatment Plants’ outflows. The quick movement of contaminants flowing out benefits the water quality of the bay, but it results in poorer quality water at the nearshore of the lake. Due to the typical, slow, counter-clockwise circulation patterns in Lake Ontario, the bay’s discharge usually moves toward the south-southeast (toward the Hamilton municipal intakes). Occasionally, however, currents are to the northeast (toward the Burlington municipal intakes). At the western end of Lake Ontario, flow from the east along the north shore of the lake must slow and change direction in order to flow south and then east along the southern shore. This makes currents and chemical transport slower in this area than further along the shore.

Water quality **plume** tracking by the Ministry of the Environment in 1982 (Poulton, et al., 1986) indicated the bay discharge at water surface could flow up to 4.5 kilometres from the canal. The results of this study indicate a potential for the bay plume to reach the location of the Hamilton and Burlington Water Treatment Plant intakes during suitable conditions of wind and current.

Depending on the current conditions and turbulence in the canal flow, the bay water is diluted approximately nine times as it flows a distance of 1,250 metres from the canal (Poulton, et al., 1986). Since the Burlington and Hamilton water intakes are about five kilometres from the canal, the dilution is even greater before it reaches these intakes. Natural processes, such as biological degradation of harmful components and the **adsorption** and settling of persistent toxics into bottom sediments, also act to purify the water before it reaches the intakes.

Studies completed by the Ministry of the Environment in the 1980s and the regular sampling and analysis of the intake water (through the Drinking Water Surveillance Program) show no clear evidence of any impact by Hamilton Harbour on the water supply for the Burlington and Hamilton water intakes.

Lake Ontario

The nearshore zone of the lake is the source water for municipal water supplies. Physical alterations and nutrient enrichment have an impact on this zone, as does the chemical pollution resulting from urbanization and industrialization.

Changes in land cover within the watersheds have direct and indirect impacts on water quality within the lake. Increased runoff and reduced groundwater recharge (due to the hardening of the land surface), contamination sources, and altered flow conditions (due to dams, reservoirs, and water takings), all impact the nearshore environment.

It is important to understand the physical processes that influence the water flow at the western end of Lake Ontario in order to understand the potential impacts on drinking water quality. Upwelling and downwelling, alongshore, nearshore and offshore currents, circulation patterns, and ice formation all can influence water quality in the nearshore environment.

Although the Lake Ontario nearshore zone (from which the municipality takes its water) is impacted, it has relatively good quality water. The City of Hamilton and the Ministry of the Environment and Climate Change regularly monitor the lake water at the intakes for chemical, physical, and bacteriological parameters.

Monitoring Programs

Researchers have been studying the quality of water within Lake Ontario for many years. Generally, monitoring of water quality is carried out by:

- Environment and Climate Change Canada

- Ministry of the Environment and Climate Change
- The City of Hamilton

through the

- Drinking Water Surveillance Program
- Drinking Water Information System
- Great Lakes Index Station Network
- Great Lakes Surveillance Program
- Provincial Water Quality Monitoring Network
- Beach sampling
- Other project specific sampling.

There are two Great Lakes Index Stations near the Hamilton Region Source Protection Area. One is within Hamilton Harbour (258) and one is offshore from Hamilton in Lake Ontario (3051). The Ministry of the Environment and Climate Change collects water samples at these locations and analyzes them for physical parameters, nutrients, metals, and suspended solids. Based on 1997 data, the Ministry of the Environment reported that Lake Ontario water quality near Hamilton is typically poorer than the general lake quality. The nearshore zone is impacted by the large, urbanized centre.

Since the 1960s, Environment and Climate Change Canada has been monitoring Lake Ontario's water quality. A recent assessment of long-term trends in major ions and nutrients (Dove, 2009) concluded that phosphorus, chloride, and sodium concentrations declined to minimum values in the early 2000s. They have since increased slightly. Recent measured chloride and sodium concentrations show increases, but they have not attained the higher values of the 1970s and 1980s. About 45 percent of the chloride input is attributed to the discharge to Lake Ontario from Lake Erie, and the rest is attributed to road salt use and industrial inputs.

Nitrate plus nitrite nitrogen concentrations have been increasing since the 1960s; however, the rate of increase has slowed in recent years, and concentrations are very low. Sources of nitrogen to the lake are human and animal wastes, fertilizers, and atmospheric deposition.

The lake's water transparency also has improved significantly. The improvements in water quality and clarity have been credited to better pollution controls, sewage treatment, and for some parameters, to the uptake and filtering activities of the invasive dreissenid (zebra and quagga) mussels.

Lake Ontario Cooperative Monitoring Years include 2003, 2008 and 2013. The 2008 year was held in cooperation with the Great Lakes Fishery Commission's Lake Ontario Committee. This study addressed research and monitoring needs that are critical for the effective management and restoration of the Lake Ontario ecosystem.

Part of the program was to understand better the nearshore-offshore nutrient transport mechanisms. The 2008 study showed that phosphorus levels offshore remained below the Great Lakes Water Quality Agreement's target of 10 parts per billion. In the nearshore area of the lake, phosphorus levels are much higher. The complexity of nearshore nutrient cycling and the interactions between tributary inflows, lake currents, seasonal changes, waves, and invasive quagga and zebra mussels is ongoing. To complement the research of the study partners, efforts are underway in Canada and the United States to reduce the amount of nutrients entering the lake through its tributaries.

The Drinking Water Surveillance Program administered by the Ministry of the Environment and Climate Change is the most comprehensive database in terms of the number of parameters sampled for the evaluation of source water quality. This evaluation is in terms of non-microbiological parameters such as metals, pesticides, and volatile organics. The currently available data for the Woodward Water Treatment Plant span the twelve years between 1998 and 2009. No exceedances of Ontario Drinking Water Quality health related standards occurred for the Hamilton intake.

The City of Hamilton retained Environment and Climate Change Canada to study impacts on water quality in the vicinity of the Woodward intake #1. This intake experiences occasional high turbidity in the source water and taste and odour issues with treated water in the summer. They were considering moving the intake to avoid these conditions. The study included monitoring of currents, waves, water temperature, and water quality. Water near the Woodward intakes is not stratified, and water quality is influenced by wind induced currents as well as upwelling and downwelling events. Changes to taste and odour of the water occurred during the monitoring period and were related to strong downwelling events.

Turbidity

As mentioned earlier in the report, turbidity is one of the primary influences on water quality. Seasonal turnover of Lake Ontario during spring and autumn and high winds can stir up lake bottom sediments and increase the turbidity levels of the source water. Storm events can also increase turbidity of the creeks which, in turn, can impact the quality of the nearshore waters of the lake near the intakes. Suspended sediment can carry contaminants with it to the intakes, and it can interfere with the treatment process.

Algae

In response to an increase in algal blooms and water quality concerns, the City of Hamilton is studying the cause. There are concerns about harmful algal blooms, including *Cladophora,* planktonic, and other macroalgal blooms affecting the water quality at the Woodward intakes. The algal blooms are sporadic, varying seasonally and annually in severity and location. The blooms can be accompanied by the release of toxins that can affect public health and compounds that change the taste and odour of drinking water.

Cyanobacteria, also known as blue-green algae, and actinomycetes bacteria release geosmin. Geosmin causes water to have a musty taste and odour. Cyanobacteria also release a toxin called microcystin, which is very harmful to people. Environment and Climate Change Canada's research at the Woodward intake #1 has shown that downwelling events, following a period of warmer temperatures, and increased algal growth are responsible for the taste and odour events. The City of Hamilton has protocols in place for monitoring and sampling of microcystin since 2011 and the levels have been below the maximum acceptable concentration (MAC) for treated drinking water.

Phosphorus

Phosphorus is the nutrient of concern in lake water. At concentrations greater than 0.02 milligrams per litre, it promotes the growth of algae. Phosphorus concentrations in Hamilton Harbour and in creek discharges can impact the near shore water quality for the Woodward intakes. Environment and Climate Change Canada's lake water sampling and analysis results indicate the concentrations of total phosphorus in the vicinity of the intakes are similar throughout the water column and are less than the provincial objective. The annual phosphorus loading to the lake from Sixteen Mile Creek, estimated from water samples analyzed as part of the Lakewide Management Plan, was 7.44 metric tonnes, compared with 6.32 from Bronte Creek and 0.69 from Fourteen Mile Creek (Makarewicz et al., 2012).

Pathogens

The Province's objective for *E. coli* is set for recreational use of the water at a count of 100 per 100 millilitres of water sample based on a geometric mean of at least five samples. When it is present at concentrations greater than its criterion, beaches are no longer safe for people to use. In 2009, the City of Hamilton's health department collected samples of Lake Ontario water four days per week for 16 weeks of the summer. The samples were collected along the beach strip from the Burlington Canal to Confederation Park. The health department reports the results as the percentage of days that the beaches remained open, having acceptable bacterial counts.

Based on the results of this study, it appears that the quality of the nearshore water worsens in an easterly direction; however, all of the beaches along Lake Ontario remained open for over 87 percent of the monitoring period. Thus, the Woodward intake water could be vulnerable to microbiological contamination, though the concentrations of bacteria are usually low. Also, the water treatment plant is able to disinfect the raw water effectively before it is distributed. These factors indicate that the presence of the bacteria does not represent an imminent threat to the water supply.

The Lake Ontario Collaborative's work on threats and issues at Lake Ontario intakes includes a study by Environment and Climate Change Canada. This study looked at waterborne pathogen occurrence in the vicinity of the mouth of the Credit River, in the Credit Valley Source Protection Area (Edge, et. Al, 2013). The objective of the study was to establish microbial water quality indicators, source tracking tools, and a benchmark to track future trends within the lake.

In 2007 and 2008, Environment and Climate Change Canada collected water samples from the lake surface and lake bottom for offshore sites, and from rivers and untreated water from three of the Region of Peel's Water Treatment Plants. All samples were analyzed for bacteria (*Campylobacter* sp.), protozoan (*Cryptosporidium* sp. And *Giardia* sp.), and viral (culturable enteric virus) pathogens. Environment and Climate Change Canada indicates that the results of the study suggest that the source water in this location is relatively clean. Waterborne pathogens were detected in the source water for each water treatment plant, although infrequently and at low concentrations. *Giardia* was detected most often. No single parameter was found to be predictive of pathogen occurrence at all three water treatment plants. *E. coli* concentrations were often below detection or not trending with pathogen concentrations. The monitoring showed that tributary discharges could deliver high concentrations of indicator bacteria to surface waters above an offshore water treatment plant intake in response to a rain event, but the summer thermocline in the lake was a barrier to downward transport to the water intakes near the lake bottom.

In 2007, Halton Region undertook sampling and analysis of source water for protozoan at the Burlington water intakes, which are located approximately 10 kilometres away from the Woodward intake. *Cryptosporidium* was not detected in the collected sample, and *Giardia* cysts were measured within the range measured at the Peel intakes. The treatment of *Giardia*, *Crypotosporidium*, and viruses is challenging for drinking water treatment systems.

Emerging Contaminants

Contaminants of emerging concern include pharmaceuticals, personal care products, endocrine disruptors, antibiotics, and antibacterial agents. The public has expressed concern regarding the implications of these trace contaminants in treated drinking water. Justice O'Connor's recommendations in Part II of the Walkerton Report (2002) include a statement that "water providers must keep up with scientific research on endocrine disrupting substances and disseminate the information." These contaminants may be found where people or animals are treated with medications and where people use personal care products, such as cosmetics and hair and skin care products.

The Ministry of the Environment undertook a survey of the occurrence of pharmaceuticals and other emerging contaminants in samples of the source and treated water collected in 2005 and 2006. The samples were collected from six, lake-based water systems, and were analyzed for 25 antibiotics, 9 hormones, 11 pharmaceuticals, and bisphenol A. The survey results showed that 15 antibiotics, 7 pharmaceuticals, and bisphenol A were detected in at least one sample of source water at trace levels. The concentrations measured, however, were below therapeutic levels and the estimated, maximum acceptable daily intake for drinking water. The report suggests that an individual would have to drink thousands of glasses of water in a day to reach the maximum acceptable level for any of the compounds detected. The Ministry of the Environment also showed that five of the compounds were removed with the existing treatment processes.

Physical Concerns

The risk to the water supply also comes from the potential for the intakes to be damaged or blocked by mussel growth or other debris. The City of Hamilton adds chlorine to the mouth of the intake pipes to control the growth of mussels, and divers regularly inspect the intakes. The City of Hamilton has reported no issues due to ice, lake water levels, or boating/shipping traffic near their intakes.

4.3 Groundwater Monitoring

A monitoring network of wells (installed throughout the Source Protection Area) and driller's records for well construction and testing provide the data to map groundwater flow patterns and to assess water quantity and quality changes with time. Figure 4.4 shows the monitoring network used in recent years, and Appendix B.5 provides the details.

The network comprises municipal pumping and observation wells as well as nine wells that are part of the Provincial Groundwater Monitoring Network (PGMN). Hamilton Conservation Authority, in partnership with the Ministry of the Environment and Climate Change, monitors the Provincial Groundwater Monitoring Network. The City of Hamilton also monitors many municipal, domestic, and commercial wells for projects that arise throughout the years. This monitoring may be a one-time occurrence or may be part of a longer study. The findings of the monitoring studies are used to evaluate stresses on the groundwater system due to natural processes (e.g., drought conditions) and the activities of people (e.g., land uses and water takings), and to propose better groundwater management strategies and mitigation measures to protect groundwater resources.

4.3.1 Groundwater Levels and Flow

Groundwater moves through geologic formations due to the Earth's gravity force from areas of high elevation and pressure to areas of low elevation and pressure. Groundwater moves preferentially through the most permeable units, such as sand and gravel, which offer the least resistance to flow.

A regional glimpse of potential groundwater flow within the Source Protection Area is realized when water levels measured in shallow **water table** wells (when the wells are not being pumped) are plotted and interpolated into a regional surface (see Figure 4.5). Within the Source Protection Area, the water table generally lies at about three metres depth within shallow bedrock or above where soils are thicker.

Within the Hamilton Region Source Protection Area, the ultimate, lowest elevation toward which groundwater is moving is Lake Ontario. The Dundas Valley has a significant influence on groundwater flow direction. Thus, northwest of the Dundas Valley, groundwater flow direction is primarily toward the valley to the southeast.

The Provincial Groundwater Monitoring Network data indicate stable or increasing groundwater levels since monitoring began in about 2002. It also indicates seasonal fluctuations varying between 0.5 and 2 metres (Appendix B.6). Seasonal low values typically occur in September.

As discussed in Section 2.1.3, groundwater flows at a greater rate through the more permeable areas of the dolostone bedrock above the escarpment. The bottom of the upper dolostone formations is at a higher elevation than the bedrock surface below the escarpment. The dolostone is underlain by the Cabot Head aquitard, which limits the vertical movement of groundwater through the rock. Therefore, groundwater moves laterally and seeps from the escarpment face, or water moves through the rock debris at the edge of the escarpment to the base of the slope. Some of the watercourses discussed in Section 3 are supported by this groundwater discharge.

Below the escarpment, water moves through the surface soils and the **weathered zone** of the underlying shale of the Queenston Formation. The Dundas and Red Hill Valleys influence this flow. Groundwater discharges into the Dundas Valley support cold and cool water fisheries habitat in many reaches.

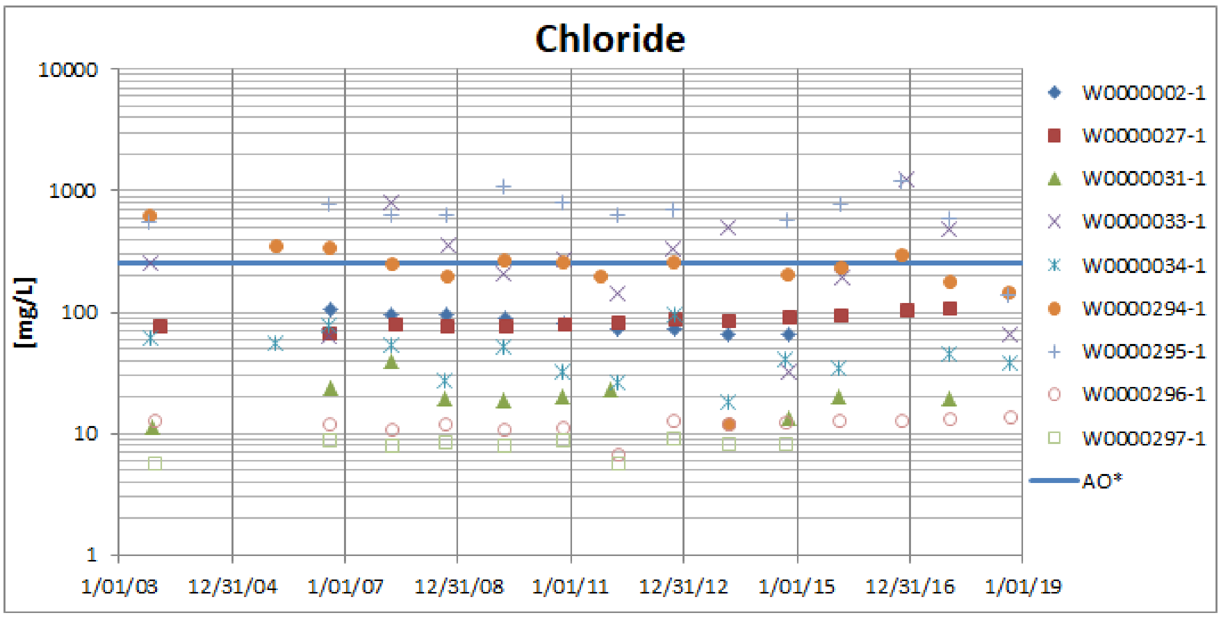
Local impacts on groundwater levels occur in the vicinity of pumping wells, particularly those pumping large volumes of water for many hours each day. These wells include municipal water wells, bottled water company wells, and rural industrial water supply wells. Quarries that are dewatering also influence the local water levels and groundwater flow patterns. These localized impacts are not evident at the regional scale as used on Figure 4.5.

4.3.2 Groundwater Quality

Groundwater quality varies across the Source Protection Area depending on the geologic materials through which it flows. The quality of groundwater is monitored primarily using the nine wells of the Provincial Groundwater Monitoring Network (PGMN), the municipal wells, a network of 88 monitoring wells managed by the City of Hamilton in collaboration with Hamilton Conservation Authority, and the municipal and private studies, as required. Water quality records in the Ministry of the Environment and Climate Change Water Well Information System indicate that groundwater sources in the Source Protection Area are generally of fresh quality. Approximately 8.5 percent of the wells that have had water quality characterizations produce salty, sulphurous, or mineral water, and they are not considered useable without treatment. A summary of groundwater quality as monitored through the Provincial Groundwater Monitoring Network is included in Appendix B.7.

Above the Niagara Escarpment, drinking water usually is withdrawn from the dolostone bedrock. Typically, water quality is hard due to the dissolution of calcium and magnesium from the rock. If it is not treated, this will form calcium deposits within plumbing systems, appliances, and on fixtures. Water softeners replace the calcium and magnesium with sodium from sodium chloride salt.

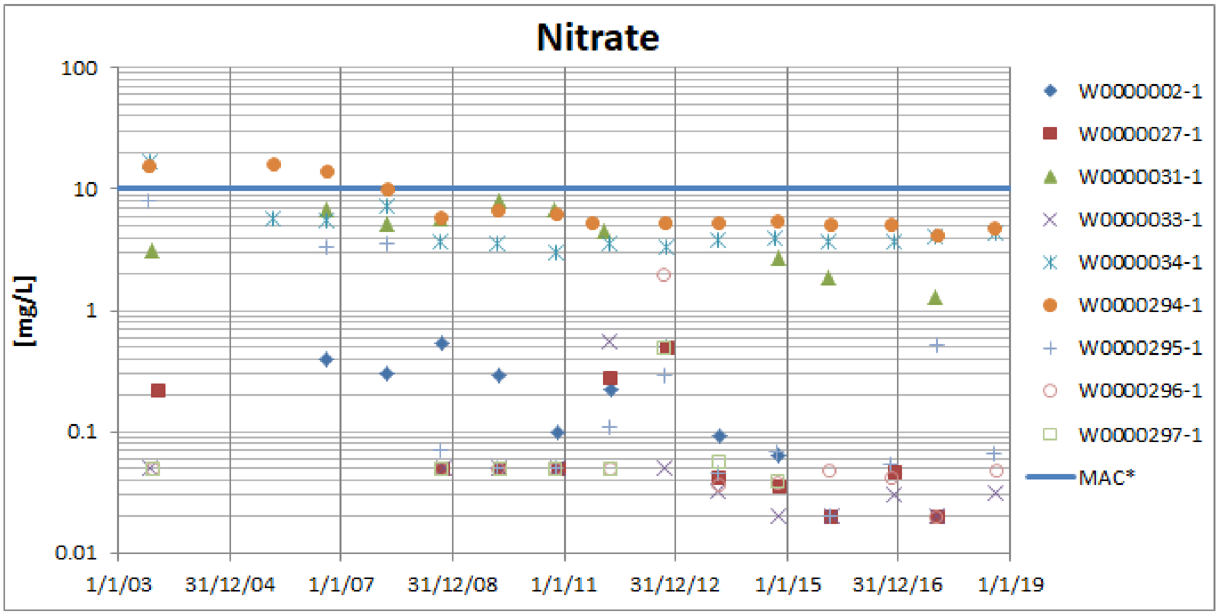
Road salt also is a source of sodium and chloride in the Source Protection Area. Normally, natural concentrations of sodium and chloride in the dolostone bedrock are low, but levels can increase significantly and vary seasonally in areas where road salt is used. Two monitoring wells in one location but at different depths (W0000294 and W0000295) consistently have very high chloride concentrations in the 200 to over 1000 milligrams per litre range as shown on Chart 4.4 and high sodium concentrations ranging between 170 and 350 milligrams per litre. The deeper well W0000295 water has higher concentrations. This well also has high nitrate concentrations, typically above the provincial standard.



*Aesthetic Objective – Ontario Drinking Water Standards, Objectives and Guidelines

Chart 4.4 Chloride concentrations in PGMN wells

In contrast, the shallow well W0000294 has low nitrate concentrations suggesting that the contaminants do not originate close to the well. Increased nitrate concentrations in groundwater are usually attributed to septic system effluent, fertilizer use and agricultural activity impacts. Nitrate concentrations in PGMN wells are presented in Chart 4.5.



*Maximum Acceptable Concentration – Ontario Drinking Water Standards, Objectives and Guidelines

Chart 4.5 Nitrate concentrations in PGMN wells

In some areas, iron and manganese concentrations are elevated above background low values of less than 0.3 and 0.02 milligrams per litre, respectively, and household treatment systems are in use. Although they do not cause health issues, excess iron and manganese can stain fabrics and plumbing fixtures. Sulphate concentrations are occasionally high, which can have a laxative effect.

In July 2006, the City of Hamilton issued a public health advisory warning that, potentially, the concentrations of lead in the water pumped from some private wells located above the escarpment in Hamilton were greater than the Ontario Drinking Water Standard. The source of the lead is the naturally occurring mineral galena (lead sulphide) that exists within the dolostone bedrock of the Eramosa Formation. The lead concentrations in water samples collected at the PGMN wells are low.

Contaminants of emerging concern

As with municipal supplies that take surface water, there is also concern for groundwater municipal water sources due to the possibility of contamination from chemicals of emerging concern such as pharmaceuticals, personal care products, endocrine disruptors, antibiotics, and antibacterial agents. The Ministry of the Environment undertook a survey of the occurrence of pharmaceuticals and other emerging contaminants in samples of source and treated water collected in 2005 and 2006 (Ministry of the Environment, 2010). These samples included two from municipal groundwater sources. Although the samples were analyzed for 25 antibiotics, 9 hormones, 11 pharmaceuticals and bisphenol A, only 1 pharmaceutical, ibuprofen, was detected in one out of five samples. Therefore, the impacts on groundwater source water quality are likely quite localized, and it is necessary to make a more concentrated effort to assess the presence of these compounds in source water for each municipal supply.

4.4 Groundwater / Surface Water Interactions

Interactions between groundwater and surface water occur in areas where groundwater discharges to surface or where surface water bodies recharge groundwater.

Discharge occurs as baseflow to streams, seeps, and springs. Discharge of cold groundwater to streams has a significant influence on moderating stream temperatures, thereby providing suitable habitat for temperature sensitive fish species. Cool water tributaries have an average, daily maximum temperature of approximately 18 degrees Celsius, while cold water streams average approximately 14 degrees Celsius. Many of the smaller creeks within the Source Protection Area have not been classified yet based on stream temperature, but this mapping will be updated as studies are completed.

Groundwater discharge zone

Based on the existing data, long reaches of cold water conditions exist in the headwaters area of Upper Spencer Creek and Fletcher Creek subwatersheds and in the centre of the Dundas Valley. Shorter reaches of cold water conditions also exist near the escarpment edge. Many of the remaining major tributaries of Spencer Creek that have been studied are classified as cool water. Reservoirs warm the surface waters and warm water streams persist downstream. The creeks mapped in the eastern portion of the Hamilton Region Source Protection Area have primarily warm water conditions. Creeks receiving groundwater discharge are shown as cold or cool on Figure 4.6.

In the western end of the Hamilton Area, tributaries are generally shallow and rarely incised into the bedrock surface. Despite this, groundwater contributes significant flow to these tributaries, providing cool or cold water habitat to sustain viable fish populations in the creeks, even during periods of drought. Contrary to this, the till plain above the escarpment drains poorly. This has resulted in the formation of the extensive Beverly Swamp.

The interaction of groundwater and surface water also takes place where surface water recharges the water table. The water table and surface water levels can rise and fall seasonally and from year to year because of changes in precipitation received. The relative difference in water pressures between two points will influence the direction and rate of water flow. The upward movement of groundwater to a creek results in discharge, and the creek gains water. When the water table drops and surface water infiltrates into the underlying sediment, the creek loses water. Creeks under these conditions are called gaining streams and losing streams. These conditions can change and a creek may be both gaining and losing at different times of the year.

4.5 Water Use

Throughout history, people have settled where there is an available and sustainable supply of clean water. This continues today, with limits placed on the growth of an area dependent on finding additional water resources. Municipal water supplies are used for many purposes including industrial, commercial, institutional and recreational activities, and for fire protection. Outside the municipal urban areas, private water supplies consist of wells, surface water systems, and cisterns. Private well systems and the natural environment use the same sources of water that, under the *Clean Water Act*, the government seeks to protect for municipal supply. In this way, maintaining a sustainable supply of clean water within the aquifers of Hamilton Region Source Protection Area and in Lake Ontario will benefit all residents and business operators.

The Ministry of the Environment and Climate Change's Permit to Take Water Database provides an insight into the uses of water within the Source Protection Area. This database comprises details of all water users that take more than 50,000 litres of groundwater or surface water each day and have obtained a permit. Exemptions to the requirement to obtain a permit exist for ordinary water taking for household and farm use, direct watering of livestock, and firefighting. To simplify and streamline approval process for some water takings for road construction and construction site dewatering, in 2016, the government of Ontario introduced a new on-line system allowing applicants to register under Environmental Activity and Sector Registry program rather than to obtain a permit to take water. The permit summary below is based on a September 2020 version of the database. In total, 58 permits were active in the Hamilton Region Source Protection Area at this time. Table 4.2 details the purpose of their water taking.

Agricultural uses of water requiring a permit include the activities carried out on a farm, nursery or greenhouse operation, such as the washing of animals, barns and equipment, irrigation, pesticide mixing, and frost protection. Commercial water use permits exist for bottled water production, the irrigation of golf courses, and aquaculture. Typically, aggregate extraction operations carry out dewatering while industrial water use permits are for manufacturing.

Table 4.2 Summary of Permit to Take Water Takings (as of September 2020)

Source	**Agriculture**	**Commercial**	**Dewatering**	**Industrial**	**Remediation**	**Water Supply**	**Recreational (Reservoirs)**	**Miscellaneous (Fire water**	**Total**
Surface Water	6	2		3		1	2	2	16
Groundwater	14	3	4	3	1	4		1	30
Surface Water and Groundwater	9	1	1	1					12
Total	**29**	**6**	**5**	**7**	**1**	**5**	**2**	**3**	**58**

Figure 4.6 Stream Temperature Conditions

The public uses a few wells with artesian conditions that exist along the escarpment edge. These wells are drilled into bedrock where water is under sufficient pressure for it to rise in the well and flow freely at the surface. At Ancaster Sulphur Spring, two wells tap groundwater with high concentrations of sulphur. This water is not fit for drinking, but some people use it for therapeutic purposes. The wells were originally used to supply water to Sulphur Spring's Hotel mineral spa in the 1800s.

4.5.1 Municipal Water Supply Systems

The Hamilton Region Source Protection Area municipal drinking water systems comprise one Lake Ontario and one well-based system (see Table 4.3 and Figure 4.7). The Woodward municipal system that draws water from Lake Ontario supplies water to the urban areas of

Hamilton, including Dundas, Ancaster, and Waterdown. This system also supplies areas of Halton Region and parts of the communities of Caledonia, Cayuga, and York in Haldimand County, which are all located outside of the Source Protection Area (see Figure 4.8). The municipal groundwater system that pumps from wells supplies water to a portion of the settlement of Greensville.

The municipal water systems operate under the requirements of Ontario's *Safe Drinking Water Act, 2002*, its regulations, and the specific requirements of their licences and permits. The *Safe Drinking Water Act* was enacted to regulate the treatment and distribution of water. The *Drinking Water Systems Regulation* (O.Reg. 170/03) sets out treatment and testing requirements, which are beyond the scope of this study, to understand and protect the water supplied to consumers.

Greensville well FDG01 and treatment plant (photo credit: City of Hamilton)

Table 4.3 Municipal Water Systems of the Hamilton Region Source Protection Area

	Name of Water Treatment Plant	
	Woodward	**Greensville**
Operating Municipality	City of Hamilton	City of Hamilton
Source of Water	Lake Ontario	Groundwater
System Classification	Large municipal residential	Small municipal residential
Drinking Water System Class	1	2
Water System Type	I	I
Intake Class	A	
System Licence	005-101	005-103
Treatment Plant Rated Capacity [m^3/day]	926,000	199
Estimated number of users	536,917	108

Notes:
Drinking Water System Class 1 = Large municipal residential system
Drinking Water System Class 2 = Small municipal residential system
Water System Type I = existing municipal drinking water system serving a major residential development
Intake Class A = Great Lakes intake
Capacity and number of users based on drinking water system, not source protection area boundaries

Per annual drinking water system reports for 2020:

- Woodward Drinking Water Subsystem is a large municipal residential system – population served is estimated at 536,917.
- Greensville municipal system provides water to 36 homes.

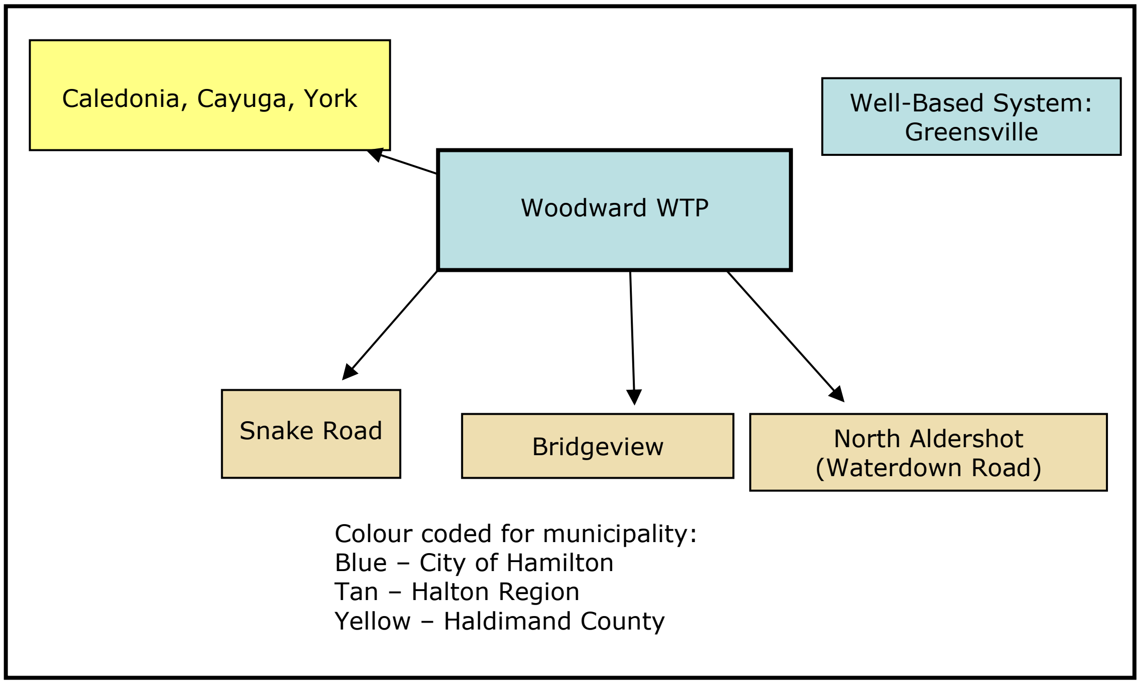


Figure 4.8 Hamilton Water Systems and their connections (WTP = Water Treatment Plant)

Lake-based Municipal Water System

The City of Hamilton is licensed to operate one water treatment plant that draws water from Lake Ontario. As summarized in Table 4.4, there are three pipes listed on the licence. Two pipes (1 and 3) are in operation. The intake pipes extend between 640 and 945 metres into Lake Ontario and can draw water from depths of between 7.3 and 8.5 metres. Water is pumped to the Woodward Treatment Plant and undergoes treatment and water quality testing before being distributed to the area's communities.

Treatment at the Woodward Plant includes coagulation, flocculation, filtration, chlorination, and chloramination to produce clean, safe drinking water. The intakes have zebra mussel control at the intake cribs, consisting of chlorination to discourage the mussels from attaching to and clogging the pipe opening.

The depths of the intakes as listed in Table 4.4 refer to below the average elevation (74.8 metres) between the operational target minimum and maximum levels of 74.2 and 75.4 metres (IGLD, 1985) of Lake Ontario. As discussed in Section 4.2.1, historical levels of Lake Ontario have dropped below this value. The lowest average monthly lake elevation was 73.83 metres recorded in January 1965, one metre lower than the average target value. A short-term drop in water levels of several hours may also occur due to wind action and changes in atmospheric pressure.

Woodward Water Treatment Plant and Woodward Avenue Wastewater Treatment Plant (photo credit: City of Hamilton)

Based on the historical data and the possibility of extremely low Lake Ontario water levels at the same time, due to wind action, the intake depths could be reduced by up to two metres. This depth still provides over six metres of water overlying the operating intake pipes from which it could pump water. The City of Hamilton has indicated that they have not had any water quantity operational difficulties due to the water levels in Lake Ontario.

As discussed in Section 4.2.2, source water supplying the Woodward Water Treatment Plant is of good quality. The treatment process is capable of producing safe drinking water that meets the Ontario drinking water standards.

Well-based Municipal Water System

The City of Hamilton operates one well-based water system in the Hamilton Region Source Protection Area. The details of the Greensville system are summarized in Table 4.5.

The Greensville well field is located north of Harvest Road and provides water to 36 nearby homes. Hamilton does not plan to increase the existing number of connections on this well-based system.

Groundwater pumped from this municipal well field undergoes treatment and water quality testing before it is distributed. Treatment at the Greensville Water Treatment Plant includes filtration, ultraviolet radiation, and chlorination.

Greensville well FDG01 is classified as obtaining water from a supply that is under the direct influence of surface water (GUDI). Ontario Regulation 170/03 (Drinking Water Systems) made under the *Safe Drinking Water Act, 2002* lists criteria to make the assessment. Only one criterion – a bedrock well within 500 metres of a surface waterbody – applies to the Greensville well. Spencer Creek lies about 350 metres to the southwest of the well. Studies have shown that the groundwater source is of good quality, and the geologic materials surrounding the well provide effective in-situ filtration.

Table 4.4 Woodward Water System Details

	Woodward		
	Pipe 1	**Pipe 2**	**Pipe 3**
Status	Operational	Non-operational	Operational
Construction Date	1992	1924	1928
Distance Offshore [m]	945	640	915
Pipeline Diameter [mm]	2440	1220	1520
Depth of Water [m]	8.5	7.3	8.0
Zebra Mussel Control	Yes		Yes
Permit to Take Water Number	8634-9JGP3N		
Permit to Take Water Maximum Daily Limit [m^3]	909,000		

Table 4.5 Well-based Municipal Water System

	City of Hamilton Greensville FDG01	City of Hamilton Greensville FDG02[1]
Construction Date	1972, upgraded	2013
Number of Wells	1	1
Status	active	being commissioned
Well Depth [m]	12.2	21.3
Well Diameter [mm]	150	152
Source Aquifer	Eramosa Formation	Eramosa Formation
Geology	dolostone	dolostone
Permit to Take Water Number	2476-9F5KM6	
Permit to Take Water Maximum Daily Limit [m^3]	197.28	

Note: 1. At the time of testing and assessment FDG02 was called TW-2-13

4.5.2 Non-municipal Residential and Designated Facility Systems

The Ministry of the Environment and Climate Change (under Ontario Regulation 170/03) regulates residential systems that operate year-round but are owned and operated by private companies or individuals. This regulation also applies to water systems serving designated facilities such as schools, youth or health care facilities, and children's camps. Ministry of the Environment and Climate Change records indicate that seven of these systems are in use in the Hamilton Source Protection Area.

4.5.3 Small Drinking Water Systems

Small drinking water systems are defined and regulated through Ontario Regulation 318/08 and 319/08 under the *Health Protection and Promotion Act* and include non-residential and seasonal residential systems. As of December 1, 2008, the responsibility for these systems rests with the Ministry of Health and Long-Term Care, and the municipal health departments administer the regulations.

Businesses that use water from a private source and make drinking water available to the public may own or operate a small drinking water system. These systems can supply restaurants, seasonal trailer parks, summer camps, community centres, libraries, gas stations, motels, churches, and many other public facilities. The Public Health Departments and Ministry of the Environment and Climate Change records indicate that 60 small drinking water systems are used in the Hamilton Region Source Protection Area. The locations of these systems on record in the Source Protection Area are shown on Figure 4.7.

Hamilton public health inspectors are conducting site-specific risk assessments on these small drinking water systems. These assessments will determine what owners and operators must do to keep their drinking water safe.

4.5.4 Private Domestic Wells

A private, domestic well is a well that supplies water for ordinary purposes to a single household or farm and does not require a Permit to Take Water. Based on the Ministry of the Environment and Climate Change's well records, there are approximately 2,384 private wells that are potentially in use within the Hamilton Region Source Protection Area. However, it is likely that some of these wells are no longer used and have been decommissioned or abandoned.

Private wells are located in the rural areas of the Source Protection Area, outside of the municipally serviced developed areas, and they typically line the roadways (see Figure 4.7). The majority of these private wells draw water from bedrock sources. Below the escarpment, the bedrock wells draw water from the weathered Queenston Formation. In general, the wells below the escarpment do not supply a lot of water, but pumping rates can be sufficient for normal domestic use. Above the escarpment, domestic wells usually take water from the dolostone formations and have much higher yields.

Wells that draw water from overburden soils are usually located in the kame deposits at the head of the Dundas Valley or in the moraine and esker deposits elsewhere.

4.6 Water Returns

4.6.1 Municipal Wastewater Treatment Systems

Municipal wastewater collection and treatment systems are used within the urban areas of Hamilton (see Table 4.6).

Municipal wastewater systems return a large portion of the water taken for municipal uses back to the environment. Although water is taken from Lake Ontario to supply most of Hamilton, it is returned to Cootes Paradise from the Dundas plant and to Red Hill Creek from the Woodward Avenue plant, just upstream of Hamilton Harbour. Eventually, this water will make its way back to the lake. The Greensville well takes groundwater and this water is returned to the ground through septic systems.

The locations of the treatment plants, pumping stations, and discharges are shown on Figure 4.9.

Table 4.6 Municipal Wastewater Treatment Plant Details

Wastewater Treatment Plant	Municipality Served	Design Capacity [m³/day]	Daily Average Flow[1] [m³/day]	Waterbody Receiving Discharge
Woodward Avenue	Hamilton	409,000	,300,000	Red Hill Creek / Windermere Basin
King Street	Dundas	18,200	12,056	Desjardins Canal / Cootes Paradise

Note: 1. Data from City of Hamilton 2020 Annual Report

4.6.2 Private Sewage Systems

In the rural areas of the Source Protection Area, homes and businesses use individual or communal sewage systems. Septic systems with tile beds are typical; however, sewage lagoons and holding tanks are in use in some locations. It is assumed that every rural household and business has a sewage system in use in the Source Protection Area. Private sewage systems and lagoons return a large portion of the water taken in the rural area back to the environment. Included in the effluent is everything that has been poured down household drains and flushed down toilets. As a result, septic systems can be sources of nutrients, bacteria, and chemicals that can affect the quality of ground and surface waters.

4.6.3 Other Returns

Discharge and irrigation activities also return water used in the rural areas of the Source Protection Area to the environment. For instance, quarries discharge the water collected to keep their operation dry for working. They typically discharge to nearby watercourses. Agricultural and golfing operations return water through irrigation of their crops and courses. Infiltration trenches or wells, where water is pumped back into the ground, are also used to return water back to its source. Finally, other industrial processes, such as cooling, also may return water to the environment.

The province typically regulates the quality and quantity of the discharge water through Certificates of Approval.

5. WATER BUDGET AND WATER QUANTITY ASSESSMENTS

In this section:

- An explanation of the water cycle
- Water budgets for Tier 1, Tier 2
- Water supply and demand in the Hamilton Region Source Protection Area
- Stress assessments

The water budget and water quantity stress assessments for the Hamilton Region Source Protection Area help to develop an understanding of water availability, water movement, water uses, and water stresses within the Area's watersheds. These assessments were completed in stages through the development of a conceptual model and successively more focused studies. Although groundwater divides are not typically aligned with surface watershed boundaries, the completion of this study for submission to the provincial government required that surface subwatersheds be used as our study areas for water quantity stress assessments (Technical Rule 20).

The studies followed a tiered approach. Tier 1 is a simple assessment at a subwatershed scale to quantify the movement of both ground and surface waters across the entire Source Protection Area. This assessment determines the stress level in each subwatershed to meet the study year (2007) and future (year 2031) demands. Only those areas identified as having potential water quantity issues and including a municipal water supply were assessed in more detail.

Based on the water demand stresses identified, only one subwatershed – Middle Spencer Creek – required a Tier 2 assessment. The Tier 2 required a more detailed look at the water budget of the subwatershed. The process to evaluate the water budgets and assign stress levels to each subwatershed is summarized in the following sections. Because the subwatershed remained stressed, a Tier 3 water budget was required.

A Tier 3 local area risk assessment focuses on the area around the municipal wells and assesses the risk of the municipal supplies not having a sufficient quantity of water available to provide the current and future populations under a variety of conditions. Based on the findings of the Tier 3 assessment a risk level for water quantity issues is assigned.

A full discussion of the Tiers 1 and 2 water budget and water quantity stress assessment methodology and results is provided in the document, "Tier 1 Water Budget and Water Quantity Stress Assessment for the Halton-Hamilton Source Protection Region and Tier 2 Water Budget and Water Quantity Stress Assessments for the Upper West Branch of Sixteen Mile Creek and Middle Spencer Creek Subwatersheds", prepared by Halton-Hamilton Source Protection staff (2010). This document includes reports on the model development and vulnerability analyses prepared by Earth*fx* for Halton Region and the City of Hamilton.

Earth*fx* was also retained by Conservation Halton to complete the Tier 3 assessment. An initial Tier 3 assessment of well FDG01 was completed in 2014 and a full discussion of the model setup, validation and calibration is provided in the report: "Tier 3 Water Budget and Local Area Risk Assessment for the Greensville Groundwater Municipal System – Phase 1 Model Development and Calibration Report," prepared by Earth*fx* and dated May 22, 2014, and a full discussion of the Tier 3 water quantity risk assessment methodology and results is provided in the report: "Tier 3 Water Budget and Local Area Risk Assessment for the Greensville Groundwater Municipal System – Risk Assessment Report," prepared by Earth*fx* and dated March 13, 2015.

The City of Hamilton has since proposed to add a backup well to the Greensville municipal system to provide a better level of service to the 36 homes serviced by the municipal well supply. Earth*fx* was retained by Conservation Halton to update the numerical model to include the proposed new well. A full discussion of the updated Tier 3 water budget and water quantity risk assessment is provided in the report: "Tier 3 Water Budget and Local Area Risk Assessment for the Greensville Groundwater Municipal System. Updated Risk Assessment Report," prepared by Earth*fx* and dated July 3, 2017.

All technical reports are available on the Halton-Hamilton Source Protection website at www.protectingwater.ca under Documents and Maps/Assessment Reports/Technical Reports.

5.1 The Hydrologic Cycle

Water is a limited renewable resource that is replenished through the hydrologic cycle. This water cycle describes the continuous movement, transformation, and storage of water on, above, and below the earth's surface (see Figure 5.1).

The driving forces to keep the hydrologic cycle going are solar radiation, or energy from the sun, and Earth's gravity. The sun heats the earth's surface, causing water to evaporate from waterbodies and soil, transpire from vegetation, and **sublimate** from snow and ice. Evapotranspiration is the combination of these processes. The Earth's gravity causes water to flow over land, to infiltrate into the ground, to recharge aquifers and eventually to discharge into waterbodies.

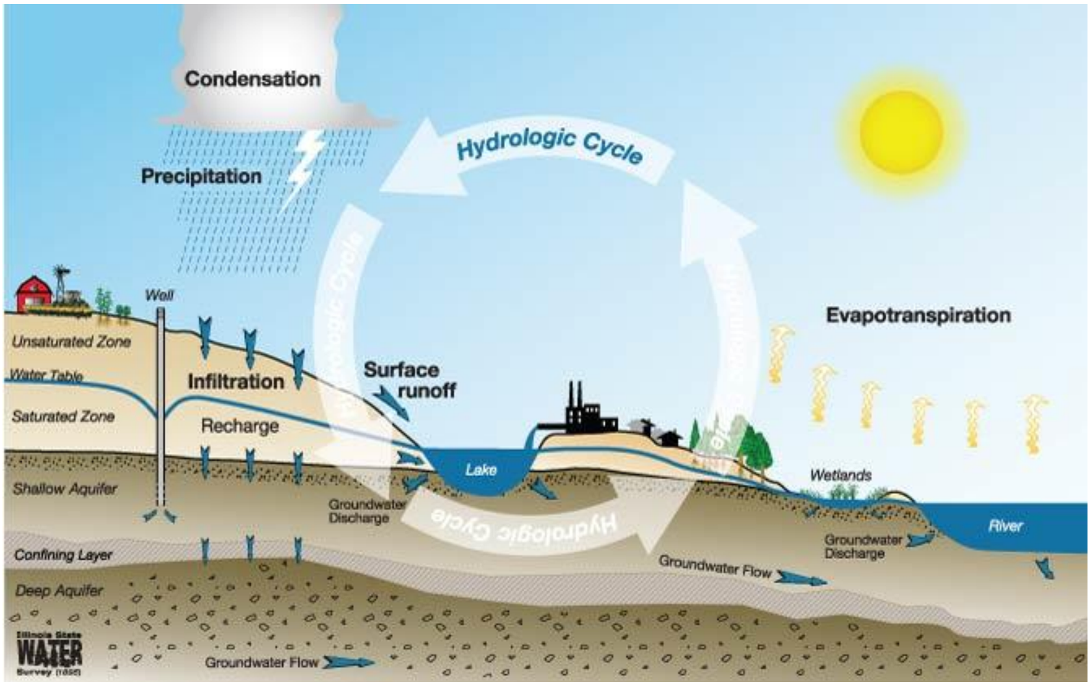


Figure 5.1 Hydrologic Cycle (Illinois State Water Survey, 2009)

In the Great Lakes basin, much of the region's moisture evaporates from the surface of the lakes. Rising air currents take the water vapour into higher and cooler altitudes where it then condenses and forms clouds. Precipitation returns the moisture to the earth, which then flows as surface runoff or infiltrates into the soil.

The soil type, slope of the land surface, and land cover will influence the percentage of precipitation that runs off or infiltrates. In general, sandy soils and flat lands support infiltration, while clay soils and steep slopes support increased runoff. Vegetation decreases surface runoff when precipitation is intercepted before it reaches the ground and affects infiltration by water uptake through plant roots. The water infiltrating into the ground will either flow close to ground surface and seep out into waterbodies as groundwater discharge, or it will infiltrate deeper and recharge the water table. Whether water flows as surface water or groundwater, ultimately it is flowing toward the lowest energy state, i.e., the oceans. While water flows on or near ground surface, or is stored in lakes and seas, it is subject to evapotranspiration processes that keep the hydrologic cycle going.

5.2 Tier 1 Water Budgets

The purpose of a Tier 1 Water Budget is to:

- provide a quantitative measure of the various components of the hydrologic cycle (precipitation, runoff, evapotranspiration, and recharge);
- evaluate groundwater and surface water supplies and reserves; and to
- calculate average groundwater and surface water demands.

Environment and Climate Change Canada's meteorological stations continuously measure precipitation. However, runoff, actual evapotranspiration, and recharge within the Source Protection Area are not measured data. These water budget components were estimated based on the results of a numerical surface water model developed for the entire Halton-Hamilton Source Protection Region. Earthfx Incorporated (Earthfx), on contract with the municipalities of Halton Region and the City of Hamilton, developed this model. Earthfx also developed a numerical groundwater flow model for the City of Hamilton to delineate protection areas around the municipal wells (see Section 6.2.3). Halton-Hamilton Source Protection staff used the model output to quantify groundwater flows into the study areas.

The demands on the water supplies used are a mixture of estimated and actual data.

Tier 1 water budgets were completed on a subwatershed basis for the two larger watersheds in the Hamilton Region Source Protection Area – Spencer Creek and Red Hill Creek. A watershed basis was used for the other areas. These watersheds/subwatersheds are consistent with those delineated by Hamilton Region Conservation Authority. The Conservation Authority uses these delineations for water management purposes, and the study areas were kept consistent to assist their work.

5.2.1 Water Budget Components

As mentioned above, the water budget components of actual evapotranspiration, runoff, and recharge were estimated using a surface water numerical model. Earthfx selected a modified version of the United States Geological Survey Precipitation-Runoff Modeling System (PRMS) code to simulate surface water and climatic processes in the study areas.

The PRMS model was developed using data from nine Environment and Climate Change Canada meteorological stations located across the Halton-Hamilton Source Protection Region. These stations have long records of continuously recorded precipitation and temperature data. Only the Toronto Pearson Airport station has measured global solar radiation data in the area. This data was obtained and used as input to the model.

The modelling period of October 1, 1989, through September 30, 1997 was selected as an existing climate dataset was available that had undergone a rigorous review and analysis as part of the City of Toronto's Wet Weather Flow Management Master Plan (Aquafor Beech Ltd, 2003). The analysis showed that the dataset was sufficient to provide a meaningful estimate of average annual recharge, as it covered a range of consecutive dry, wet and average years.

To represent the physical characteristics of the areas, among others, the following data were used to construct the model:

- topographic such as slope of land and direction of the slope;
- vegetative cover and imperviousness;
- land uses such as natural, urban or agricultural; and
- soil properties, such as permeability.

To develop hydraulic response units used by the model, the data were assigned to areas of land with similar hydrologic properties. These units were distributed in a 100 metre by 100 metre grid across the modelled area.

The PRMS model encompasses Halton Region and Hamilton in order to capture a larger number of stream gauge calibration points. This also captures a broader range of soil types and land use conditions. The model was calibrated using total and baseflow stream data as measured at HYDAT stations within the modelled area. This ensured that the model results closely approximate the actual hydrologic conditions. The results suggest that, on a regional scale, the model is adequate to access water quantity stresses. This is particularly true during the summer months when stream flows are low and more vulnerable.

The PRMS simulated values of the water budget components were averaged over the eight-year simulation period to determine annual average and monthly average rates for the study period. Appendix C.1 includes a summary of these values. Figure 5.2 graphically depicts the evapotranspiration, runoff, and recharge components of the water budgets (for each watershed and subwatershed within the Source Protection Area) as the annual average percentage of the precipitation.

Precipitation Estimates

The annual, average precipitation varies in the Source Protection Area. Generally, the value decreases from west to east, with average values of 989 and 917 millimetres of water above and below the escarpment, respectively.

Evapotranspiration

The distribution of actual evapotranspiration is mostly influenced by surficial geology and land use. Actual evapotranspiration is lower in the urban areas, likely due to the extensive storm drainage network and less vegetative cover. On average, the actual evapotranspiration within the Hamilton Region Source Protection Area is about 57 percent of the total precipitation.

Runoff

Variations in annual, average runoff are due to differences in effective precipitation (precipitation after interception losses) and local variations in imperviousness and soil type. For the most part, land use and slope of land controls runoff, which is usually high in urbanized areas due to large expanses of hard surfaces and good drainage networks. On average, the total runoff is about 22 percent of the total precipitation.

Recharge

Simulated rates of annual average recharge to groundwater were applied as input to the groundwater model. Generally, the recharge values are higher where coarse granular deposits or fractured bedrock are at ground surface. Consequently, the recharge values are higher on the limestone plain above the escarpment and where sand exists at ground surface below. The average annual recharge rate for the Hamilton Region Source Protection Area is 202 millimetres with a range between 97 and 310 millimetres.

5.2.2 Surface Water Supply

The water supply to a subwatershed or watershed comes from precipitation received, flow from upstream, and groundwater discharges. Some of the watersheds in the Hamilton Region Source Protection Area also receive discharges of water into their creeks from industrial facilities. Stream flow, or the rate at which water is flowing in the creeks, is the combination of these water sources and represents the available water for use. The Technical Rules (Part 1.1) define the surface water supply as the monthly median flow of the water body.

Halton-Hamilton Source Protection staff used the calibrated PRMS model to estimate the stream flows in each of the subwatersheds or watersheds in the Hamilton Region Source Protection Area. To obtain the daily, average stream flow data, the PRMS model was run for each of the subwatersheds separately. The data were summarized, and the monthly medians were calculated for each of the subwatersheds and watersheds for the modelled period. Cumulative flow rates were calculated for downstream subwatersheds. (All results are summarized in Appendix C.2.)

The monthly, median stream flows were compared to the HYDAT stream flow data to assess the reliability of the model to predict actual conditions. As noted previously, the results indicate that the HYDAT stream flows are reasonably matched by the simulated stream flows, particularly during the summer months when the possibility of water quantity stress is high.

5.2.3 Groundwater Supply

Groundwater supply is the sum of the recharge water that has infiltrated through the soil to the water table and the groundwater flowing through the subsurface into the subwatersheds.

Subwatersheds are delineated based on the surface water drainage areas, and generally do not align with groundwater watersheds; however, the Tiers 1 and 2 water budget assessments use the surface watersheds as the area of potential groundwater supply. The Tier 3 water budget focuses on the local area, defined as the actual **cone of influence** of the municipal well and other wells in the vicinity.

It should be noted that there might be more than one aquifer in a subwatershed. For example, a saturated sand layer and a saturated, fractured rock formation separated by a clay layer form two aquifers. Groundwater from all aquifers at reasonable depths within the subwatershed or watershed is considered available for use and therefore part of the groundwater supply.

Groundwater flow modelling

The groundwater flow model used in this assessment is based on the United States Geological Survey's MODFLOW code. This three-dimensional code is recognized worldwide and has been extensively tested and verified in similar settings to the Hamilton Region Source Protection Area. The MODFLOW code is well-suited for modelling regional and local-scale flow in multi-layered aquifer systems. Also, it easily can account for irregular boundaries, complex stratigraphy, and spatial variations in hydrogeologic properties. Earthfx followed best practices for groundwater modelling and professional judgment when applying and calibrating the numerical model. In addition, supporting programs were used to facilitate data input and output and to calculate groundwater budgets.

The modelled area includes the City of Hamilton jurisdiction west of the Dundas Valley. The city does not have well-based municipal water supplies to the east. In addition, because the model was developed specifically to delineate protection areas around municipal wells, it was unnecessary to include the eastern area.

The average, annual recharge distribution was summarized based on the results of the PRMS model and applied as input to the City of Hamilton's MODFLOW groundwater model. Statistical tests, in which the observed and simulated groundwater levels and stream baseflow estimates were compared, helped to determine whether the calibration of the model met the required goodness-of-fit criterion.

The primary targets for regional water level calibration were the observed static water levels that were obtained from the Ministry of the Environment and Climate Change's Water Well Information System database for the modelled area. Simulated discharge from the groundwater flow model was compared against estimated baseflows that were determined through hydrograph separation. The calibration results indicated that the model was a reasonable regional representation of actual conditions within the Source Protection Area.

Halton-Hamilton Source Protection staff summarized the lateral groundwater flow into each assessed subwatershed and watershed based on the results of the groundwater flow model. Outside the modelled domain, the lateral flows were not estimated. The sum of the recharge and lateral flows into each subwatershed and watershed constitute the available groundwater supply. Where the lateral flows were not estimated, the recharge represents the total groundwater available for further calculations. These values are summarized in Appendix C.3.

5.2.4 Water Reserve

A volume of water from each subwatershed was set aside as a reserve (Technical Rules 1(2) and 1(3)). This was done to account for the ecological uses of water within a watershed and other human uses that were not accounted for in the water demand estimates. Ecological uses of the water resources within a watershed are difficult to quantify, so standard estimates for surface water and groundwater were used.

Since a majority of the subwatersheds in the Hamilton Region Source Protection Area do not have measured, continuous stream flows, the estimated 10th percentile of the simulated stream flows (based on the results of the PRMS model) were used as a surface water reserve. It should be noted that, for some of the subwatersheds, the difference between the average monthly median stream flows and the 10th percentile stream flows is very small. This leaves relatively little water available as the surface water supply, especially during the summer months.

The groundwater reserve was estimated ^{as} ten percent of the total groundwater supply. In the eastern portion of the area, the groundwater supply used in the calculations was only the precipitation values. Thus, the reserve is ten percent of the recharge rate. Reserve values for each assessed subwatershed/watershed are summarized in Appendix C.2b for surface water and Appendix C.3 for groundwater.

5.2.5 Water Demand

Groundwater and surface water demands are estimated separately for all subwatersheds within the Hamilton Region Source Protection Area. The groundwater demand is estimated on an annual and monthly basis, while the surface water demand is estimated only on a monthly basis. The difference in method is because of the ability of groundwater supplies to be sustained by the withdrawal of water from storage within the soil and/or rock. Surface water sources require a continuous supply of water from precipitation or groundwater discharge or they risk depletion. Data sources used to estimate water demands include:

1. Permitted sources, such as:

    - actual water takings of permitted users;
    - actual municipal water takings and projected future municipal water takings; and
    - Permit to Take Water database from the Ministry of the Environment and Climate Change.

2. Non-permitted sources, such as:

    - domestic water takings based on population estimates for the years 2006 (Statistics Canada) and 2031 (municipal traffic zone projections); and
    - agricultural water takings based on standard water use coefficients.

Permitted Sources

The *Ontario Water Resources Act* and the *Water Taking and Transfer Regulation* (O. Reg. 387/04) requires anyone taking more than 50,000 litres per day of water to obtain a permit, with the exception of water taking for domestic use, livestock watering, and firefighting. The Ministry of the Environment and Climate Change stores details of the permits in a Permit to Take Water Management Database.

Version 1 (August 2006) of this permit database was used for the Tier 1 water budget assessment. A considerable effort was made to improve this dataset by reviewing and/or correcting the information in the database up to January 2009, such as:

- water handling rather than takings;
- distribution of takings for multiple source permits;
- groundwater versus surface water taking classification;
- temporary permits;
- duplicate entries;
- maximum rates of takings for each source; and
- spatial locations of the sources.

Details of thirty-six permits relevant to the Halton-Hamilton Source Protection Region were also added. Permits with an expiry date of March 21, 2003, or later and not duplicated were classified as "active" permits for this assessment due to the potential for renewed permits to exist.

In the Hamilton Region Source Protection Area, there are 27 sources of surface water included in 17 permits and 61 sources of groundwater in 35 permits. Two permits have both groundwater and surface water sources listed. Table 5.1 provides a summary of the number of permits by general purpose and Figures 5.3 and 5.4 show the locations of all surface water and groundwater active permit sources, respectively. A summary of the permitted rates of water taking according to watershed/subwatershed and water use is included in Appendix C.4. The recreational permits are for operation of the Valens and Christie Lake reservoirs by Hamilton Region Conservation Authority. The miscellaneous permit is for a fire water pond.

Permit holders usually apply for and receive water taking permits for higher rates of pumping than their actual requirements. This practice gives them the flexibility needed during unusual weather or operating conditions. However, in order to assign stress levels to water resources, a better understanding of water takings is required.

Professional judgment was used to assign water takings to all permits active within the area. Four methods were utilized:

- use of actual water takings, if available;
- use of the maximum permitted water taking per minute and the average hours of taking as reported in the Permit to Take Water database;
- use of the maximum daily water taking as reported in the database; or
- use of the actual water takings data to estimate average water takings for other operations in the same sector.

Table 5.1 Summary of the Number of Active Permits to Take Water in the Hamilton Region Source Protection Area (current to August 2009)

Permitted Source	Agriculture	Commercial	Dewatering	Industrial	Remediation	Miscellaneous	Recreational	Water Supply	Total
Surface Water	11	2	0	0	0	0	2	0	**15**
Groundwater	15	3	3	4	2	1	0	5	**33**
Surface Water and Groundwater	0	2	0	0	0	0	0	0	**2**
Total	**26**	**7**	**3**	**4**	**2**	**1**	**2**	**5**	**50**

Note: Great Lake-based permits are excluded.

Actual Water Takings

The use of the actual water takings improves the reliability of the water quantity stress assessment because it accounts for seasonal variability and excess capacity.

Water taking permit holders in the Hamilton Region Source Protection Area were contacted and asked to provide records of their actual water takings in recent years. A total of 24 permit holders responded. Actual water taking records were received from:

- two golf course irrigation permit holders. It should be noted that there are 6 permits classified as commercial for golf course irrigation;
- three quarry dewatering permit holders;
- ten agricultural water taking;
- one municipal well supply system;
- three communal and/or campground water supply systems;
- three industrial food processing operations;
- one remediation type permit holder; and
- one miscellaneous type permit holder.

Actual Municipal Water Takings

As discussed in Section 4.5.1, Hamilton operates one well system and two lake intakes in the Source Protection Area. Based on the 2006 Statistics Canada census, approximately 97 percent of the residents in the Hamilton Region Source Protection Area rely on municipal water systems. The estimated populations served by Lake Ontario and municipal well sources are 96.97 and 0.03 percent, respectively. Water taking from the lake was not considered in the water budget analysis.

For the Tier 1 water budget and stress assessment, the actual water takings from well FDG01 in the year 2007 were used as typical volumes required to supply the existing population (see

Table 5.2). The Technical Rules: Assessment Report defines the study year as the calendar year immediately before the Terms of Reference, prepared by the Source Protection Committee, was required to be submitted to the province. For Hamilton Region Source Protection Area the Terms of Reference was submitted in 2008, which makes 2007 the legislated study year. As mentioned in Section 4.2.1, the Source Protection Area received significantly less than normal precipitation in 2007. Consequently, the 2007 data represents water taking in a drier than normal year and, therefore, are conservative values.

Table 5.2 Summary of the Actual Municipal Groundwater Demand

Municipality	Water Supply System	Actual Water Use [m^3]		
		2005	2006	2007
City of Hamilton	Greensville	17,460	13,790	12,781

Annual water taking volumes measured at the water system in previous years have been higher than those measured in 2007. The water takings reported for Greensville prior to 2007 were estimates based on the number of connections and expected use. The 2007 data are actual metered results and were used in this assessment.

Table 5.3 summarizes the monthly groundwater takings for the Greensville well during 2007. A significant increase in demand occurs during the summer months. The significant variation in municipal monthly demands on the groundwater resources of the watersheds can result in summertime stresses. Municipalities must consider this variability when designing water systems and allocating water to new users.

Table 5.3 Monthly Actual Municipal Groundwater Demand in 2007

Well System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Greens-ville	846	821	864	986	1,082	1,484	1,485	1,490	1,393	764	771	795

Note: All values in m^3.

Demands on water resources to supply municipal takings in the year 2031 were also considered in the water quantity stress assessment. The Greensville municipal well is not intended to expand in the future. Accordingly, the 2007 actual water takings were used for future scenarios.

Non-Permitted Sources

Domestic Water Demands

The estimation of current, private domestic water takings is based on the assumption that the population residing outside of municipally serviced areas use private groundwater sources. Existing and future domestic water use calculations were based on a conservatively estimated water consumption rate of 335 litres per person each day. This value was an average residential water use in 2001 from municipal supply systems across Canada (Environment Canada, 2007). The population distribution for domestic water takings was based on the 2006 Statistics Canada census results, which show that approximately three percent of the population in Hamilton Region Source Protection Area is not serviced by municipal water systems.

Agricultural Water Demand

Many agricultural activities use less than 50,000 litres of water each day and some activities are exempt, so a water taking permit is not required. To ensure all water uses were accounted for, a method was developed using standard water use coefficients (de Loe, 2005). This method requires the assessment of animal and crop water uses.

The 2006 Agricultural Census results were obtained from Statistics Canada on a subwatershed basis. This data includes the area of crop lands and pasture lands, the types of crops grown, and the number and type of animals within each subwatershed. In order to calculate animal water use, the number of animals is multiplied by their standard water use coefficient. For crops, the total area of each crop is multiplied by: the percent of the area irrigated, the number of irrigation events per season, and the volume of water applied at each irrigation event. The animal and crop water uses were added to estimate the total agricultural water use in each subwatershed. This total water use was then apportioned into groundwater and surface water components for each subwatershed by assigning lands within 300 metres of **third order** or greater streams to surface water use and the remainder to groundwater use.

The results from this method were compared with the known permitted values and, to be conservative, the greater of the two values was assigned to each subwatershed. Subsequently, this value was carried forward in the calculation of total water demand for that subwatershed.

Water used for irrigation

Consumptive Water Demand

Consumptive Factors

The water quantity stress assessment is completed using the consumptive water demand rather than the total amount of water being taken from any surface water or groundwater system. The consumptive water use refers to the amount of water removed from a hydrological system and not returned back to the same system in a reasonable time. The consumptive water use is defined based on the source of the water and the subwatershed from which it is taken. For example, water taken from a stream or aquifer and not returned back to the same stream or aquifer will be considered as consumptive with respect to its source.

Consumptive factors were assigned for all permitted and non-permitted use categories. To address seasonality of the water demands, such as irrigation in the summer months and snow making in the winter, a monthly use factor was also used to assign the water taking only to the months when it is likely to occur. The province provided a table of suggested factors that could be used if actual values were not available (Ministry of the Environment, 2007). To be consistent, if evidence did not exist to change the default consumptive factor, the same consumptive factor was applied to all water takings for a given sector. Tables of the factors used to estimate consumptive uses are provided in Appendix C.5.

Data were not available to quantify the actual sources of water taken during quarry dewatering activities. The water removed to permit dry working conditions is the sum of direct precipitation, surface water drainage, and groundwater inflow. Only the groundwater component would be considered consumptive as its source and receiving watercourse are not the same. A quarry dewatering consumptive factor of 0.25 was applied to the actual takings of all operations as a reasonable estimation.

This factor considers:

- the change from source to receiving watercourse;
- crude estimates of the percentage of groundwater in discharge water;
- the potential for recharge to the source from the watercourse;
- the proximity of the quarry to the escarpment edge, where a portion of the groundwater discharges to form the headwaters of many creeks; and
- the provincial suggested consumptive factor of 0.25 for dewatering.

Eight golf courses provided their actual water takings to assist with this assessment. To improve the estimates of water taking data of the remaining permit holders, the known data were compared with the permitted rates for those courses. The percentage of use for each month was used to estimate monthly demand for the remaining courses before the consumptive factor was applied.

A consumptive factor of 0.2 was applied to domestic and municipal water takings, because it is assumed that all the systems take groundwater and that, after use, water is being returned to the same source through septic tile beds. This is the provincial suggested consumptive factor (see Appendix C.5).

Annual and monthly consumptive demand

The total consumptive demand for the subwatersheds is the sum of all permitted and non-permitted uses. In order to complete the monthly water quantity stress assessments, it was required that monthly consumptive demands are calculated for groundwater and surface water takings. There is no requirement to monitor water taking in domestic wells and, accordingly, no monthly use data to assess monthly demand. Therefore, it was assumed that water taking in domestic wells would vary similarly to municipal water takings.

Appendix C.6 lists the total annual and monthly consumptive surface water and groundwater demands that are carried forward to the water quantity stress assessment.

Figure 5.5 illustrates the relative differences between permitted, actual, and consumptive water takings for the Greensville municipal well.

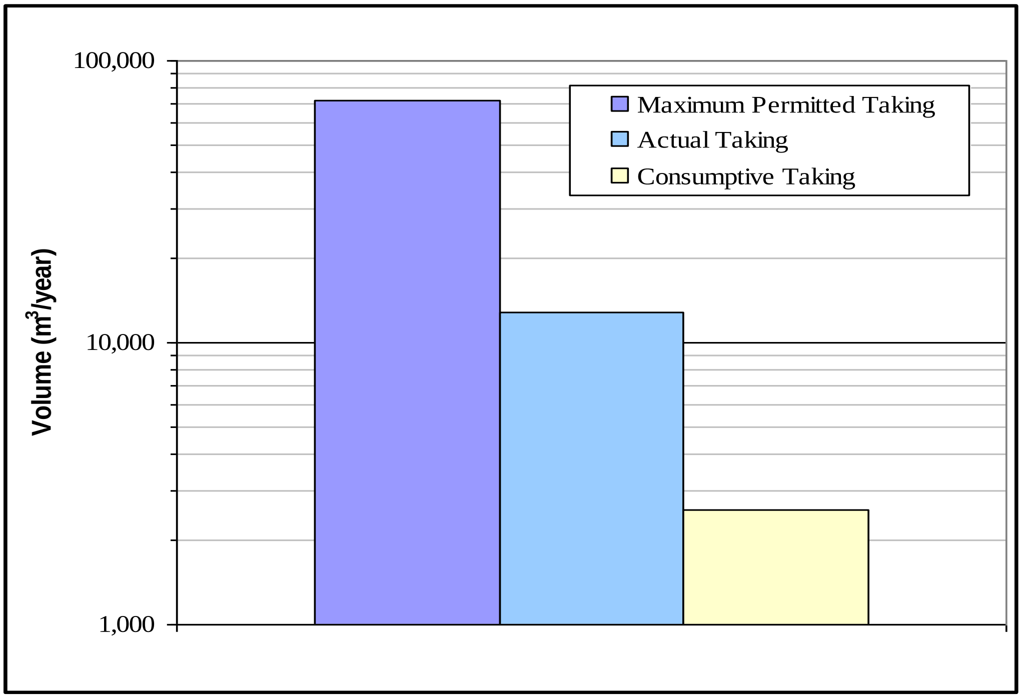


Figure 5.5 Annual permitted, actual, and consumptive water taking for the Greensville municipal water supply

Groundwater consumption

As illustrated on Figure 5.6, the consumptive taking for drinking water supplies in the Hamilton Region Source Protection Area accounts for 1 percent of the total water takings. This demand includes the Greensville municipal well and communal permitted water systems. Private domestic wells account for more water use at 12 percent of the water demand within the Area. The most significant groundwater consumptive takings are for dewatering and agricultural uses at 42 and 28 percent, respectively.

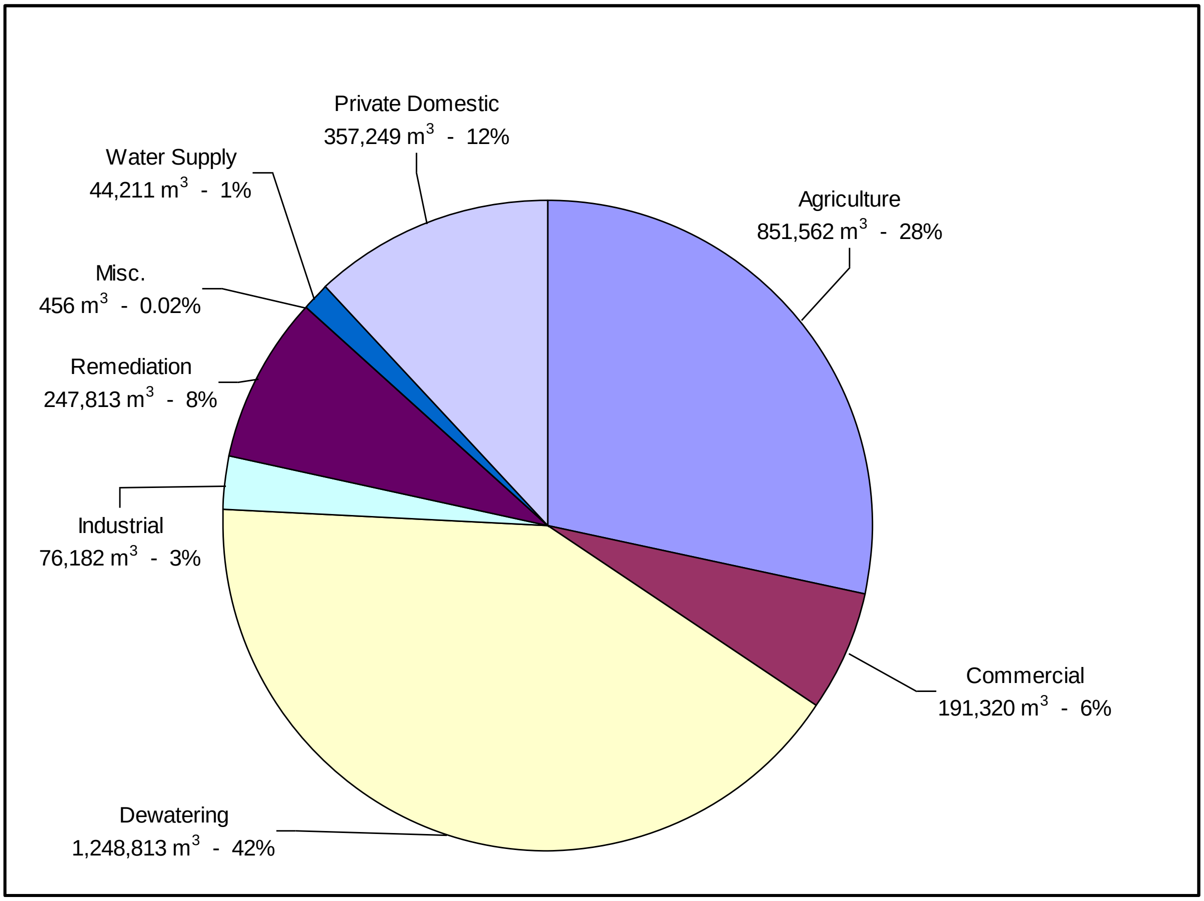


Figure 5.6 Groundwater consumptive demand by general purpose

Surface water consumption

Figure 5.7 graphically shows the consumptive surface water taking by general purpose. Surface water is only used for two purposes – agriculture and commercial. At 90 percent, agricultural use is the primary water taking within the Source Protection Area. Commercial uses in this area are strictly for golf courses.

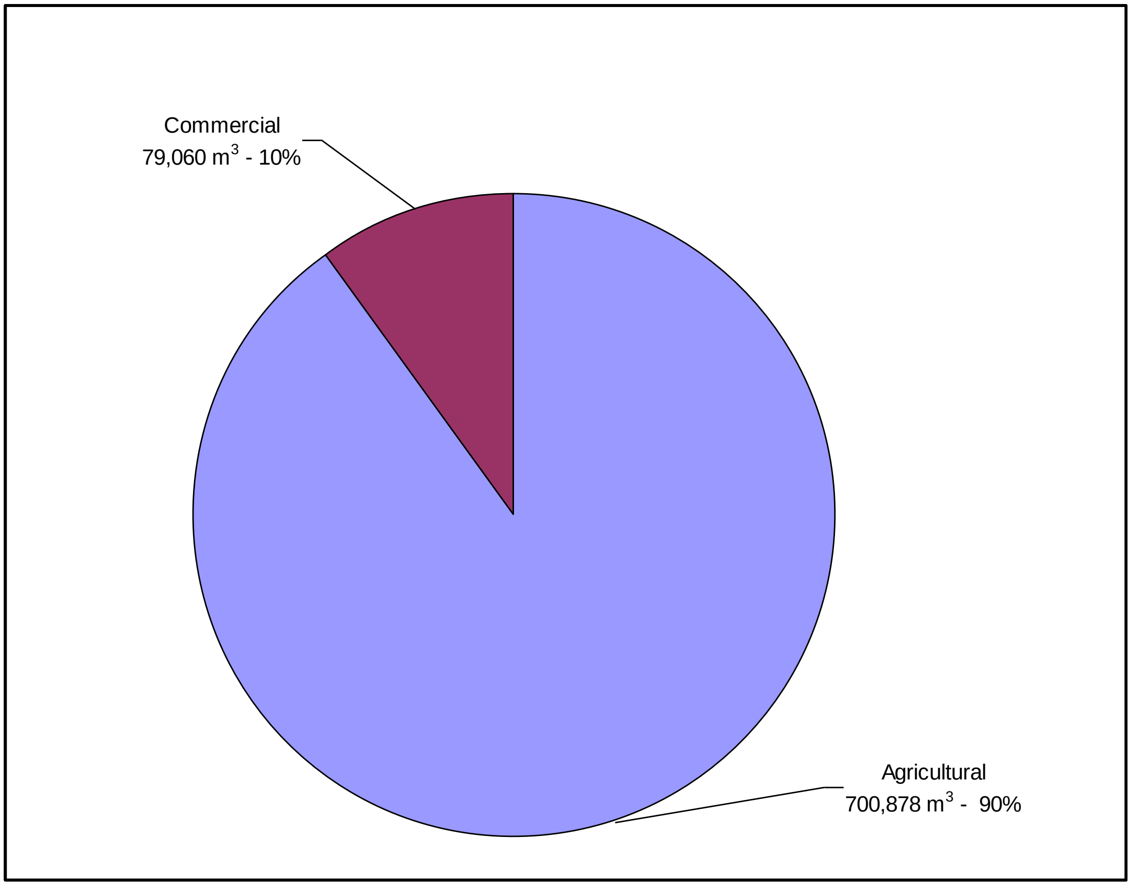


Figure 5.7 Surface water consumptive demand by general purpose

5.3 Tier 1 Water Quantity Stress Assessments

The Tier 1 level of stress assessment is a screening process which requires estimating the percentage of the consumptive water demand to the available water supply. This percentage is referred to as “percent water demand.”

Summary tables of the findings of the water quantity stress assessments are included in the following sections for those subwatersheds where moderate or significant stress levels are assigned.

5.3.1 Surface Water Monthly Stress Assessment

The percent water demand for surface water is estimated on a monthly basis since annual average flows for surface water have little significance when assessing stresses. The surface water stress assessment is completed for each month of the year using monthly averages of:

- consumptive surface water demand;
- surface water supply; and
- surface water reserve,

and the following equation (Technical Rule 1(2)):

$$\text{Percent Water Demand} = \frac{\text{Qdemand}}{\text{Qsupply} - \text{Qreserve}} \times 100$$

where:

- Qdemand is the monthly surface water consumptive use;
- Qsupply is the monthly surface water supply, estimated as a monthly median stream flow; and
- Qreserve is the 10^{th} percentile of monthly stream flow reserved for ecological uses and other human uses not accounted for in the Qdemand.

These values are discussed in Sections 5.2.5, 5.2.2, and 5.2.4, respectively.

The percent water demand is then compared with stress thresholds as summarized in Table 5.4.

Table 5.4 Surface Water Stress Threshold

Stress Level Assignment	Monthly Maximum Percent Water Demand
Significant	≥ 50
Moderate	> 20 and < 50
Low	≤ 20

Additional criteria for the assignment of a moderate stress level are:

- if the monthly maximum percent water demand is between 18 and 20 percent and a sensitivity analysis of the data suggests that the stress level could be moderate.

In order to assign stress levels, the calculated percent water demand for surface water within each subwatershed was compared with the threshold and other criteria. Table 5.5 summarizes the results of the stress assessment for significant and moderate stress, and Figure 5.8 illustrates these results. A complete listing of the subwatershed stress levels is included in Appendix C.7.

There are five subwatersheds within the Hamilton Region Source Protection Area with significant stress levels and nine that are assigned moderate stress levels. Most of the surface water stresses occur in subwatersheds outside the urban areas, where agricultural and commercial takings are substantially higher.

In the Hamilton Region Source Protection Area, the only surface water drinking water source is Lake Ontario. Accordingly, there are no surface drinking water intakes in the stressed subwatersheds, and they do not warrant a Tier 2 level of stress assessment.

Stoney Creek Watercourse 11 watershed has a stress level of 18.8 percent in July, resulting in a low stressed condition. This condition requires a sensitivity analysis to determine if the stress level could be moderate. The sensitivity analysis includes a review of the determination to look for ways to improve on the data and/or assumptions made. There are no additional stream flow data available to re-calibrate the PRMS model to improve on the water supply estimate.
Also, the only water demands in the watershed are non-permitted agricultural water takings. The de Loe method was used to estimate agricultural water takings in an unbiased manner across the entire Source Protection Area. There are no municipal drinking water systems within this watershed. Therefore, there is no reason to upgrade the surface water stress level of the watershed to moderate.

Table 5.5 Surface Water Stress Assessment Summary

Watershed	Subwatershed	Municipal Well	Stress Level	
			Moderate	Significant
Spencer Creek	Ancaster Creek		x	
	Borer's Creek			x
	Flamborough Creek			x
	Logie's Creek		x	
	Middle Spencer Creek	Greensville	x	
	Spring Creek			x
	Sulphur Creek		x	
	Sydenham Creek		x	
	Tiffany Creek		x	
	West Spencer Creek			x
Red Hill Creek	Hannon Creek			x
	Lower Davies Creek			
Stoney Creek Watercourses	WC 7		x	
	WC 10.1		x	
	WC 12		x	

There are many subwatersheds within the Hamilton Region Source Protection Area with percent water demands of more than 100 percent. This could be the result of:

- over-estimating the actual values for permitted water takings when data were not available;
- the actual takings being greater than the available water supply, meaning that the water taking depletes the water reserved for surface waterbody ecological functions;
- the small size of many of the creeks within the Source Protection Area that have minimal stream flows. The stream flows were estimated using the PRMS model and may be under-estimated; and
- assumptions that were made to assign agricultural activities to groundwater or surface water sources for their water use. In some areas, the assumptions that surface water was used just because a creek was nearby may cause errors.

Agricultural water takings for fruit, crops, and trees were reviewed

5.3.2 Groundwater Stress Assessment

The percent water demand for groundwater is estimated on an annual and monthly basis under study year (2007 – called existing conditions in the Technical Rules) and future (year 2031) conditions. The Technical Rules defines the study year as the calendar year immediately before the most recent Terms of Reference for completion of the work required by the *Clean Water Act* was submitted to the Ministry of the Environment. This document was submitted in 2008.

The groundwater stress assessments are completed using the following equation (Technical Rules 1(3)):

$$\text{Percent Water Demand} = \frac{Q_{demand}}{Q_{supply} - Q_{reserve}} \times 100$$

where:

- Qdemand is the annual or monthly groundwater consumptive use;
- Qsupply is the annual or monthly groundwater supply, with monthly supply being simply the annual supply divided by 12, calculated as a sum of estimated groundwater recharge and estimated groundwater inflow into a subwatershed; and
- Qreserve is 10 percent of the groundwater supply reserved for ecological uses and other human uses not accounted for in the Qdemand.

These values are discussed in Sections 5.2.5, 5.2.3, and 5.2.4, respectively.

The values listed in Table 5.6 were used to assign groundwater stress levels.

Table 5.6 Groundwater Stress Thresholds

Stress Assignment	Average Annual Percent Water Demand	Monthly Maximum Percent Water Demand
Significant	≥ 25	≥ 50
Moderate	> 10 and < 25	> 25 and < 50
Low	≤ 10	≤ 25

The assignment of a low stress would be raised to moderate if either of the following circumstances exists:

- if, at any time after January 1, 1990, the well did not have sufficient water or was shut down due to a decrease in the groundwater level during normal operation; or
- if the monthly or annual percent water demand is between 23 and 25 percent or 8 and 10 percent, respectively, and a sensitivity analysis of the data used to prepare the Tier 1 water budget suggests that the stress level for the subwatershed could be moderate.

Existing Conditions – Annual and Monthly Groundwater Stress Assessment

The available data used for the annual and monthly groundwater quantity stress assessments included 2006 populations, the actual water taking data of 2007, and some actual water taking data from 2008. Use of the actual water takings provided by the permit holders improved the overall assessment. The existing conditions assessment has been deemed to be representative of the study year – 2007 conditions because the 2007 municipal takings were used.

Appendix C.8 summarizes the evaluation of the current annual and monthly percent water demand and assigned groundwater quantity stress level for each subwatershed in the

Hamilton Region Source Protection Area. Figures 5.9 and 5.10 show the assigned stress levels.

Within the Hamilton Region Source Protection Area, there is one subwatershed exhibiting significant groundwater quantity stress:

- Lower Davis Creek subwatershed within the Red Hill Creek watershed – annual stress only.

Within the Hamilton Region Source Protection Area, there are three subwatersheds exhibiting moderate groundwater quantity stresses:

- Lower Davis Creek subwatershed – monthly stress only,
- Logie's Creek subwatershed within the Spencer Creek watershed – annual and monthly stresses; and
- Middle Spencer Creek subwatershed within the Spencer Creek watershed – annual stress only.

The Lower Davis Creek subwatershed has a water taking to remediate contaminated groundwater. Logie's Creek and Middle Spencer Creek both have aggregate dewatering contributing to the stresses. The Greensville municipal drinking water system is situated within the Middle Spencer Creek subwatershed. Therefore, this subwatershed requires further assessment at a Tier 2 level.

Future Conditions – Annual and Monthly Groundwater Stress Assessment

Future conditions annual and monthly stress assessments were undertaken for the year 2031. This was done in order to utilize the population planning projections available from the municipalities. These stress assessments used the future municipal water takings and the private domestic water taking estimates, based on population projections, as an estimate of future demand. The water supply and reserve values remained the same as those used in the current conditions assessment.

The results of the 110tresss assessments for each watershed/subwatershed are summarized in Appendix C.9. Because it is not intended that the Greensville municipal well be expanded, the only demand change for the calculations is the private domestic supplies. Therefore:

- the results of the future conditions annual stress assessment are the same as the current conditions annual stress assessment results, and
- the results of the future conditions monthly stress assessment are the same as the current conditions monthly stress assessment results.

Groundwater Stress Assessment Summary

The groundwater stress assessment identified three subwatersheds in the Hamilton Region Source Protection Area that exhibit either annual or monthly significant or moderate stress levels (see Table 5.7).

Table 5.7 Groundwater Stress Level Summary

Watershed	Subwatershed	Current Conditions Stress Level		Future Conditions Stress Level	
		Annual	Monthly	Annual	Monthly
Red Hill Creek	Lower Davis Creek	Significant	Moderate	Significant	Moderate
Spencer Creek	Logie's Creek	Moderate	Moderate	Moderate	Moderate
	Middle Spencer Creek	Moderate	Low	Moderate	Low

5.4 Tier 2 Water Budget and Water Quantity Stress Assessment – Middle Spencer Creek

A more focused water budget and water quantity stress assessment is required for a subwatershed where the percent water demand is determined to be moderate or significant at the Tier 1 level and where it contains a municipal drinking water system. The main purpose of this Tier 2 analysis is to confirm or contradict the stress assignment completed in Tier 1.

The Tier 2 analysis is a more comprehensive study of the water budget elements and the water quantity stress assessment components: demand, supply, and reserve. Based on the results of the Tier 1 assessment for the Hamilton Region Source Protection Area, only one subwatershed requires a Tier 2 assessment. This subwatershed is Middle Spencer Creek, in which the Greensville municipal well is located.

Numerical modelling of the groundwater system and surface water flows was used at the Tier 1 assessment level to estimate groundwater and surface water supplies. A detailed review was completed for the water demand estimate, and the method suggested by the province to quantify the reserve was used. As a result, methods available for enhancement of the stress assessment are limited.

The PRMS model fully encompasses the Middle Spencer Creek subwatershed; therefore, the recharge estimate will not vary. The consumptive demands were also estimated carefully, and there is no available data to improve the consumptive demand estimate. Based on the subwatershed scale of assessment, there are no modifications at a Tier 2 level that would alter the stress assessment.

Therefore, based on the best available scientific data and using the subwatershed as the study area, the Middle Spencer Creek subwatershed is moderately stressed in terms of groundwater quantity at a Tier 2 level. Accordingly, the Technical Rules require that a Tier 3 water budget and a local area risk assessment be completed.

5.5 Tier 3 Water Budget and Local Area Risk Assessment – Middle Spencer Creek

A Tier 3 water budget and local area risk assessment focuses on the municipal supply within the stressed subwatershed. It assesses the risk of the municipal supply not having sufficient quantity of water available to provide the existing and future populations with water.

As mentioned earlier, the Greensville well system required this Tier 3 assessment based on stresses on groundwater within the subwatershed in which the system is located. However, because the surface watersheds are not aligned with the ground watersheds, the study area was expanded to include additional subwatersheds of Spencer Creek and Grindstone Creek (Figure 5.11). Earth*fx* Incorporated was retained to develop an integrated groundwater/surface water numerical model for the study area to assess the sustainability of the municipal system. The model used is based on the U.S. Geological Survey (USGS) GSFLOW code (Markstrom et al., 2008). GSFLOW is a coupled groundwater and surface water flow model that integrates the USGS Precipitation-Runoff Modeling System (PRMS) and the USGS Modular Groundwater Flow Model (MODFLOW). The model simultaneously simulates flow across the land surface, within streams and lakes, and within subsurface saturated and unsaturated materials. This approach was necessary to properly simulate quarry operations, and seepage from and discharge to the numerous wetlands, streams, and a reservoir in the area, and represents a significant improvement over the Tier 1 and 2 modelling work.

Two Tier 3 assessments have been completed for the Greensville municipal well system. The first assessment was completed in 2014 and included only well FDG01. The second assessment was completed in 2017 and included an additional municipal well and updated information. The Tier 3 assessments were led by the Halton-Hamilton Source Protection staff in cooperation with the City of Hamilton. The assessments included the necessary work to improve the understanding of the geologic and hydrostratigraphic models in the local area and refine, where possible, the elements of the water balance, water supply, and water demand. The following sections summarize the findings of the most recent assessment. The City of Hamilton has indicated that demands will not be put on this water system to produce more water in the future and the risk assessment was completed under this premise.

5.5.1 Tier 3 Water Budget Components

The Tier 3 water budget builds on the data/information/results of the Tier 1 and 2 studies to refine the quantitative measures of the hydrologic cycle for the subwatershed and to re-evaluate groundwater and surface water supplies and demands.

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The Tier 1 water budget components were derived from two stand alone models: a calibrated steady-state groundwater flow model and a transient surface water model under existing land use and water taking conditions. The integrated groundwater/surface water model developed for the Tier 3 study was run in transient mode to refine the water budget for this study. Accordingly, a much more detailed water budget with modelled water inflows and outflows into the subwatershed was estimated.

A long-term modelling period of October 1, 1947, through September 30, 2016 was created and used for model verification and quantification of long-term average conditions. The climate data were derived from Environment and Climate Change Canada climate stations and augmented by data from stations operated by the City of Hamilton, Hamilton Conservation Authority, and McMaster University. The data were processed with the method developed by Schroeter et. Al. (2000) to obtain hourly rainfall intensities, which were required for the simulations.

In terms of the water budget, the primary input to the Middle Spencer Creek subwatershed is precipitation. The annual precipitation value used in this study is 858 mm. Lateral groundwater inflow adds to the available water, as does stream flow and a small amount of overland runoff. Water outputs include well pumping, lateral groundwater outflow, evapotranspiration, overland runoff, and stream flow. Behind the scenes, the surface water sub-model and groundwater sub-model provide inputs to each other in the form of stream, lake, and wetland leakage in and out, discharge to soil, and recharge of groundwater.

A summary of the Tier 3 water budget for the Middle Spencer Creek Subwatershed is presented in Table 5.8.

Table 5.8 Tier 3 water budget for Middle Spencer Creek Subwatershed

Inflows and Outflows	mm/year
Precipitation	858
Lateral groundwater inflow	42
Overland runoff in	3
Stream inflow	742
Total Model Inflow	**1,645**
Well pumping	20
Lateral groundwater outflow	35
Actual Evapotranspiration	588
Overland runoff out	3
Stream outflow	998
Total Model Outflow	**1,645**

Note: values subject to round off

5.6 Tier 3 Local Area Risk Assessment – Greensville Well Field

A Tier 3 risk assessment determines if a municipal supply is sustainable under current and possible future demands, average climate and drought conditions, and current and future land uses. The assessment focuses on the municipal well supply and its surrounding area.

5.6.1 Municipal Water Takings

To assess risk to the municipal water supply, the municipal water takings must be defined for three demand scenarios:

1. existing demand: estimated as an average demand during a representative study period, which was determined for this study to be 2007 to 2014. The existing demand on well FDG01 is 40.9 cubic metres per day. In consultation with the City of

Hamilton water operators it was determined that the existing demand on FDG01 would be split between FDG01 and the new well, FDG02, on a cycle of 6 days pumping of the new well for every one day of pumping of FDG01.

2. committed demand: the increase in the water takings needed if the area served was fully developed as per the Official Plan. Based on discussions with City of Hamilton staff, there will be no additional hook-ups to the Greensville well system and the committed demand is zero.

3. planned demand: the additional water takings anticipated for planned systems and any demand above the maximum permitted taking for an existing system. City of Hamilton staff have indicated that demands will not be put on this water supply for increased capacity in the future. Hence, there is zero planned demand.

Also, necessary to assess potential impacts on municipal water takings is an understanding of the minimum safe level in the wells (Table 5.9). The safe additional drawdown in the municipal wells is defined as the additional depth that the water level within a pumping well could drop and still maintain the wells allocated pumping rate. It is calculated as the drawdown that is available in addition to the drawdown created by the existing conditions pumping rate. Based on historical operation and testing of well FDG01 by City staff, the safe water level for this well is the pump intake elevation plus one metre. The minimum safe water level for well FDG02 is the elevation of the uppermost water bearing fracture as identified by Stantec (2014). Graphs of the well characteristics in profile, which illustrate the operating constraints relative to water levels, are included as Appendix D.1.

Table 5.9 Safe additional drawdown for the Greensville supply wells

Well	Average Pumped Water Level [m AMSL]	Pump Intake Setting [m AMSL]	Minimum Safe Level* [m AMSL]	Available Drawdown [m]
FDG01	229.8	224.3	225.3	4.5
FDG02[1]	233.1[2]	224.4[3]	227.4[4]	5.8

Notes:

1. At the time of testing and assessment this well was called TW-2-13
2. Average pumped water level estimated from results of the step-test conducted by SNC-Lavalin (2016)
3. No permanent pump setting yet identified for FDG02. Pump setting for pumping test used (Lotimer & Associates, 2016)

4. Minimum safe level for FDG02 based on elevation of uppermost water bearing fracture, as recommended by Stantec (2014)

5.6.2 Other Uses

The *Clean Water Act* requires that other water uses be considered in the Tier 3 studies. These other uses include:

- wastewater assimilation
- agricultural, commercial and industrial water takings
- navigation
- recreation
- aquatic habitat
- Provincially significant wetlands

Wastewater generated within the local area is managed by private septic systems so there are no requirements for wastewater treatment plant discharge assimilation in streams. The water takings by non-domestic wells were assessed for impacts from municipal water taking and all impacts were considered acceptable. A portion of Middle Spencer Creek upstream of the Christie Dam is a navigable waterway, however, no specific requirements to maintain flows to facilitate navigation have been identified. Christie Lake is primarily used for flood control and to augment downstream flows during dry summer months, however, it is also used for recreational activities including non-motorized boating, swimming and fishing.

Some of the streams in the study area are classified as cold water, which means cold water fisheries rely on groundwater discharged in these reaches. Wetlands can also be dependent on groundwater inputs to maintain their function. Water takings can lower groundwater elevations and decrease groundwater discharge and streams and wetlands could suffer adverse impacts. The Tier 3 assessed whether a decrease in groundwater discharge to wetlands and streams would occur due to increased pumping or decreased recharge because of drought conditions or land use changes.

5.6.3 Local and Vulnerable Areas

The study area for the risk assessment is called the local area, which is delineated by the assessment of:

a) the zone around the municipal well where water levels are influenced because of pumping;
b) the zone influenced by pumping of other water takings that intersect with the zone influenced by the municipal well; and
c) the areas where a reduction in recharge would have a measureable impact on the zone influenced by the municipal well when pumping.

These assessments result in the identification of the:

- WHPA-Q1: combined zone of a) plus b) above

- WHPA-Q2: combined zone of a) plus b) plus c) above
- Local area: combined WHPA-Q1 and WHPA-Q2

The GSFLOW model developed to estimate the Tier 3 water budget was used to delineate these areas based on allocated quantities of water pumped at the municipal wells. A drawdown threshold of one metre was utilized to establish reasonable cones of influence that could have practical implications for the municipal well water levels. This value was established through a thorough review of seasonal variations in monitoring wells with continuous data.

To delineate the WHPA-Q1 for the municipal wells, the other water takings in the study area were characterized and included in the model. Those with Permits to Take Water in the study area are listed in Appendix D.2 and shown on Figure D.1. Actual water takings for permit holders were obtained from the Provincial Water Taking Reporting System and consumptive values estimated using factors provided by the Ministry of the Environment (2007; see page 98 and Appendix C.5). Domestic water takings were also included in the modelling with a well assigned to each dwelling not connected to the municipal water supply. The water flow through the two quarries located in the study area was modelled rather than estimated based on water takings.

To establish the cone of influence, the model was run under existing land use without and then with water taking at municipal and non-municipal wells. The allocated pumping rate was used for municipal wells and the consumptive use rates for other water users. The cone of influence for all wells combined was determined by subtracting the simulated results with pumping from the non-pumping results.

To delineate the WHPA-Q2 the existing and proposed 2031 land uses were characterized to ascertain potential changes in groundwater recharge that could impact the cone of influence around the municipal wells. The proposed land use changes in the Greensville well field area primarily relate to residential development to the west of the municipal wells, infilling within the settlement area, and build-out of the quarries. The residential development may increase imperviousness of the area as it currently is agricultural fields.

The future changes In land use were modelled to determine their effect on the Greensville wells. The land use changes did not have a measurable impact on the cone of influence at the municipal wells and the areas of change were not added to the geographic area of the WHPA-Q1. In other words, there are no proposed land use changes that would impact the sustainability of water quantity for the municipal well supply at Greensville and the WHPA-Q2 is equivalent to the WHPA-Q1.

Based on the model results, the WHPA-Q1 area is coincident with the WHPA-Q2 area, and as a result, the local area is identical to both and is shown on Figure 5.12. The size of the local area is primarily dictated by drawdown in the deeper Gasport/Goat Island aquifer, which is impacted by quarry operations. This aquifer is separated from the municipal aquifer near the wells by competent, low permeability bedrock.

5.6.4 Risk Assessment Scenarios

The Director's Technical Rules includes a set of scenarios that were modelled to inform the risk assessment about the sustainability of the municipal supplies. These scenarios for groundwater sources are summarized in Table 5.10 and consider the impact on water availability due to changes in climate, land use, and municipal water taking.

Table 5.10 Risk assessment scenario details

<table>
<tr><th rowspan="2">Scenario</th><th rowspan="2">Time Period</th><th colspan="3">Model Scenario Details</th></tr>
<tr><th>Land Cover</th><th>Municipal Pumping</th><th>Model Simulation</th></tr>
<tr><td>C</td><td>Average conditions (2007-2009)</td><td>Current Land Use</td><td>Existing Demand</td><td>Steady-state model with average annual recharge</td></tr>
<tr><td>D</td><td>10-year drought (1957-1966)</td><td>Current Land Use</td><td>Existing Demand</td><td>Transient model</td></tr>
<tr><td>G(1)</td><td rowspan="3">Average conditions (2007-2009)</td><td>Projected Land Use</td><td>Allocated plus Planned Quantity of Water</td><td rowspan="3">Steady-state model with average annual recharge</td></tr>
<tr><td>G(2)</td><td>Current Land Use</td><td>Allocated plus Planned Quantity of Water</td></tr>
<tr><td>G(3)</td><td>Projected Land Use</td><td>Existing Demand</td></tr>
<tr><td>H(1)</td><td rowspan="3">10-year drought (1957-1966)</td><td>Projected Land Use</td><td>Allocated plus Planned Quantity of Water</td><td rowspan="3">Transient model</td></tr>
<tr><td>H(2)</td><td>Current Land Use</td><td>Allocated plus Planned Quantity of Water</td></tr>
<tr><td>H(3)</td><td>Projected Land Use</td><td>Existing Demand</td></tr>
</table>

Note: The 10-year drought period (1957-1967) used climate data for 1953-1967 to give the transient model a start-up period

The various scenario model runs are discussed in detail in Earth*fx*'s report (July 2017) and the results, in terms of what additional drawdown was achieved versus the safe additional drawdown, are summarized in the following paragraphs and Tables 5.12 and 5.13.

Scenario C assesses the ability of the municipal wells to maintain existing pumping rates under average climate conditions. Results indicate the wells are sustainable under current land use and water taking demands with an average climate.

Scenario D tests the sustainability of the municipal supplies under existing conditions against a real 10-year drought period. The 10-year period of 1957 through 1966 includes seven of ten water years with below-average precipitation volumes. The maximum drawdown modelled at each municipal well under drought conditions was less than the safe additional drawdown available. Therefore, the results suggest that the municipal wells are sustainable through long-term drought if pumped at existing rates.

Scenario G tests three conditions under average climate to assess changes in pumping rate and land use. Pumping at the municipal wells to their allocated rates and decreases in recharge because of changes in land use maintained municipal well water levels within their safe drawdown levels. Therefore, the results suggest that the municipal wells are sustainable under average climate conditions and proposed land use changes.

Scenario G also tests whether an increase in municipal taking to meet allocated and planned demand for municipal supplies is sustainable without adversely affecting other water uses under current and future land uses. The modelling suggested that the Greensville well field is sustainable when pumped at allocated water rates with negligible impacts on other uses.

Scenario H tests the sustainability of the municipal wells under the same pumping rates and land use changes as modelled in Scenario G, however, this scenario tests under drought conditions. The analysis indicated that the Greensville well field is sustainable while pumping at allocated rates under drought conditions and projected land use.

Table 5.11 Simulated additional drawdown at the municipal wells for Scenarios D and H

Well	Safe Additional Drawdown [m]	Additional Drawdown (m)			
		Scenario D	Scenario H(1)	Scenario H(2)	Scenario H(3)
FDG01	4.5	1.68	2.14	2.19	1.64
FDG02	5.8	1.68	2.03	2.13	1.58

Notes: Additional drawdown values calculated using monthly average head for September 1956 (pre-drought) of Scenario D as baseline. Values include corrections for convergent head losses and non-linear head losses.

Table 5.12 Simulated drawdown at the municipal wells for Scenarios C and G

Well	Safe Additional Drawdown [m]	Additional Drawdown [m]			
		Scenario C	Scenario G(1)	Scenario G(2)	Scenario G(3)
FDG01	4.5	0.68	0.55	0.58	-0.03
FDG02	5.8	1.61	0.43	0.47	-0.04

Notes: Scenario C drawdown calculated using non-pumping baseline water level. Additional drawdown values calculated using Scenario C results as baseline. Values include corrections for convergent head losses and non-linear head losses.

5.6.5 Risk Level

As discussed above, each risk assessment scenario listed in Table 5.11 is modelled independently and a risk level assessed for water taking in the local area. The circumstances requiring an assignment of significant or moderate risk are summarized in Appendix D.3. These circumstances consider whether a groundwater supply system is able to meet typical demand, the potential impacts on other water uses from operation of the municipal well, and whether the system is capable of meeting peak demand (tolerance). In addition, an assessment of the uncertainty of the analysis is undertaken.

The Greensville well field was assigned a risk level of low based on its high tolerance to risk for satisfying peak demand and because it has full redundancy of supply from the two wells. As summarized in Tables 5.12 and 5.13, the well system is capable of meeting demands during current and future land use conditions, during average climate and drought. Furthermore, impacts from municipal pumping on other water uses were not identified. As discussed in Section 5.7.2, Earth*fx* determined that the uncertainty of the risk assessments was low.

5.7 Limitations of the Water Budget and Water Quantity Stress Assessment

5.7.1 Tiers 1 and 2 Water Quantity Stress Assessments

The evaluation of the limitations for the subwatershed scale water quantity stress assessment means the appraisal of:

- Uncertainty in supply – due to measured and estimated hydrologic parameters (i.e., recharge, interflow, stream flow) that are contributing to the final percent water demand score; and
- Uncertainty in demand – in the consumptive water demand estimate that is contributing to the final percent water demand score.

Uncertainty is the level of confidence in the assessment based on the data, method, and knowledge of the people undertaking the assessment.

The water budget evaluation and stress assessment were completed following the requirements of the *Clean Water Act*, *2006,* and its regulations, as well as the Technical Rules: Assessment Report (November 16, 2009). To understand the reasons for undertaking the studies as discussed in the previous sections, please refer to these documents. The assessment carried out has been peer reviewed and, based on the methods prescribed, is deemed to be a reasonable estimate of the water quantity stresses in the Source Protection Area.

A summary of the limitations of the water budget evaluation and water quantity stress assessment is included in the following sections. However, a more fulsome discussion is included in the document, “Tier 1 Water Budget and Water Quantity Stress Assessment for the Halton-Hamilton Source Protection Region and Tier 2 Water Budget and Water Quantity Stress Assessments for the Upper West Branch of Sixteen Mile Creek and Middle Spencer Creek Subwatersheds” prepared by Halton-Hamilton Source Protection staff (2010).

Water Supply

The uncertainties of the surface water supply estimation are related to the uncertainties of the measured data used to develop and calibrate the PRMS model. These data include the climate and hydrologic values measured at stations in the vicinity of the Source Protection Area.

All hydrologic models are simplifications of actual hydrologic responses within a natural system. The model is calibrated using measured data, i.e., stream flows. On a regional basis, the overall estimate of total flow produced by the PRMS model is 6.9 percent higher than the observed total flow. The overall, predicted baseflow calibration exceeds the HYDAT baseflow separation processed measurements by 4.9 percent. These overestimations generally are during winter and spring months, when water supplies are sufficient to meet demand and stresses are not predicted. Despite these errors, the results suggest that, on a regional scale, the calibration is adequate for development of a water balance for the area. However, uncertainty in the data varies. The PRMS model boundaries extend beyond the Source Protection Area to include additional climate and HYDAT stations to estimate the input and calibration parameters better. Only one climate station reported solar radiation data, and many of the stations had a limited period of record.

The groundwater flow model was calibrated with calculated baseflows as well as measured groundwater elevations. This resulted in more certain, simulated results of recharge and lateral groundwater flows. The City of Hamilton groundwater flow model was developed at a regional scale using the best available data. However, the foundation of model development is the Water Well Information System, which has high uncertainty associated with it.

Note: the simulated results from the models should be considered carefully and the limitations associated with their use for site-specific assessments should be understood.

Water Demand

Uncertainties regarding water demand lie primarily with the assumptions made about non-permitted sources and the use of maximum permitted rates of water taking. The estimates of private domestic takings are conservative. However, as the takings are a small percentage of the total demand, changes in the volumes taken will change the percent water demands minimally.

The calculation of the agricultural water takings is uncertain, with assumptions made about sources and uses. The use of maximum permitted rates of water taking when actual values weren't available will lead to an overestimation of the water demand stresses. Therefore, the water demand was estimated for source protection planning purposes, and the methods used should be understood in order to apply the data elsewhere.

5.7.2 Tier 3 Water Quantity Risk Assessments

A summary of the limitations of the water quantity risk assessment is included in the following paragraphs. However, a more fulsome discussion is included in the documents, "Tier 3 Water Budget and Local Area Risk Assessment for the Greensville Groundwater Municipal System – Updated Risk Assessment Report", prepared by Earth*fx* Incorporated (July 3, 2017).

The evaluation of the limitations of the water quantity risk assessment included an uncertainty analysis. The following factors were evaluated to determine whether the uncertainty is high or low:

- the distribution, variability, quality and relevance of the data used to evaluate the scenarios
- the degree to which the methods and models used to evaluate the scenarios accurately reflects the hydrologic system of the local area for both steady state and transient conditions
- the extent and level of calibration and validation achieved for any groundwater and surface models used or calculations and general assessments completed
- the quality assurance and control procedures used in evaluating the scenarios

An assignment of low uncertainty was given to the risk assessment for the Greensville well field for the following reasons. The integrated modelling approach used in the Tier 3 study requires that the model be calibrated to all available data simultaneously. This means that the model's uncertainty is constrained by both surface water and groundwater measurements.

The static water level data used for calibration of the model provided good regional coverage and the continuous groundwater level data along with stream flow and lake stage data provided good calibration targets. The integrated model represented the surface and subsurface hydrologic processes within the study area with a specific focus on the interaction and feedback between the groundwater and surface water systems. The model flows and levels were calibrated to a wide range of climate conditions including extreme wet and dry conditions, and across multiple seasons.

6. VULNERABILITY ASSESSMENTS

In this section:

- Intake protection zones 1, 2 and 3
- Highly vulnerable aquifers
- Significant groundwater recharge areas
- Wellhead protection areas

Within the Source Protection Area, there are areas where pollutants could affect the quality of our water sources or where people's activities could impact the amount of water available for use. These areas are called vulnerable.

The Ministry of the Environment and Climate Change has designated four areas to be delineated and studied with respect to vulnerability. These areas warrant a higher level of protection from potential threats to the quality and/or quantity of drinking water sources and include:

- Intake protection zones;
- Highly vulnerable aquifers;
- Significant groundwater recharge areas; and
- Wellhead protection areas.

The detailed technical studies conducted to inform the Assessment Report vulnerability assessments are available at: www.protectingwater.ca

6.1 Surface Water Vulnerability Analysis

One drinking water system draws water from Lake Ontario within the Hamilton Region Source Protection Area. After treatment, this system distributes that water within the City of Hamilton, portions of Halton Region, and Haldimand County. The Woodward system has three intake pipes, although two are currently in use. In addition, the Grimsby Lake Ontario-based system, located in the Niagara Peninsula Source Protection Area, supplies water to residents and businesses within a small area of the most eastern portion of the Hamilton Region Source Protection Area (see Section 6.3).

To protect the quality of Lake Ontario water, the nearshore environment in the vicinity of the intakes was assessed. Also, areas were delineated that, through the implementation of policies, could offer protection to the water supply. These delineated areas are called intake protection zones. Ultimately, three zones are required to be assessed.

The Woodward intake protection zones one and two were delineated and their vulnerability assessed by Stantec Consulting Ltd. (2007) on contract with the Lake Ontario Collaborative, and HCCL (2008) a subcontractor of Stantec Consulting. The City of Hamilton provided the results of their study to be used for source protection planning.

6.1.1 Intake Protection Zone One: Delineation

The area considered to be most vulnerable to contamination is the area closest to the intake. The reason for this vulnerability is due to an assumed lack of time for dilution to reduce the concentration of any contaminant released within the zone. Also, there is an assumed lack of time for the operator of the water system to react to the release.

To protect this vulnerable area, a circle with one kilometre radius is drawn, centred on the intake crib (see Figure 6.1) and projected to the lake bottom. This zone is called “intake protection zone one” or IPZ-1. Since the intake pipes extend less than one kilometre from shore, these circles intersect land. Where this happens, Technical Rule 62 requires that the onshore extent is restricted to the **Conservation Authority Regulated Limit** or 120 metres, whichever is greater. The Hamilton IPZ-1s have a landward extent of 120 metres measured from the shoreline.

6.1.2 Intake Protection Zone One: Vulnerability Score

The vulnerability score assigned to the three IPZs reflects the susceptibility of the intakes to contaminants and is determined based on local knowledge and professional judgment. The score is based on multiplying the following factors:

- an area vulnerability factor assigned a set value of 10; and
- a source vulnerability factor, which considers the distance of the intake from shore, the depth of the intake from water surface, and the historical water quality concerns at the intake. This factor is assigned a value of 0.5 to 0.1, based on the perceived risk to the intake water.

The intakes are relatively shallow in a depth of between 7.3 and 8.5 metres of water and at a moderate distance from shore at 640 to 945 metres. The water quality records indicate concerns with turbidity and taste and odour events, particularly during downwelling events. Otherwise, the source water quality is good.

Source Vulnerability Factor

The MECP Technical Rules providing overarching technical methodologies under the Clean Water Act, the source vulnerability factor (Vsf) is based on these key factors:

- **depth of the intake from the top of the water surface;**
- **distance of the intake from land; and**
- **history of water quality concerns at the surface water intake**.

The provincial Design Guidelines for Drinking Water Systems (MOECC, 2008) prescribe that the preferred submergence for raw water intakes is ten (10) metres; however, three (3) metres or more is satisfactory. It does not recommend a preferred distance from shore. The State of Michigan Department of Environmental Quality (MDEQ), as part of its Source Water Protection Program (MDEQ, 2004), categorize surface water intakes in four ways according to distance offshore and depth to intake:

- near shore, shallow water intakes;
- near shore, deep-water intakes;
- offshore, shallow-water intakes;
- offshore, deep-water intakes.

Table 6.1 shows the decision matrix that considers intake depth and distance from the shoreline along with the corresponding source vulnerability factor sub-scores within the range of 0.5 to 1 per technical rule 95.1.

Table 6.1: Source Vulnerability Factor Decision Criteria: Intake Distance and Depth

Criteria for Intake Distance and Depth (MDEQ, 2004)	**Source vulnerability factor sub-score (range: 0.5 to 1)**
Nearshore, shallow water: Less than 300m and less than 6m (high vulnerability)	1
Nearshore, deep water: Less than 300m and greater than 6m; or Offshore, shallow water: Greater than 300m and less than 6m (high to moderate vulnerability)	0.75
Offshore, deep water: Greater than 300m and greater than 6m (moderate vulnerability)	0.5

Table 6.2 shows the decision matrix that considers historical water quality concerns and corresponding source vulnerability factor sub-scores within the range of 0.5 to 1 per technical rule 95.1.

Table 6.2: Source Vulnerability Factor Decision Criteria: Water Quality Concerns

Criteria for History of Water Quality Concern	Source vulnerability factor sub-score (range: 0.5 to 1)
There is a **known water quality issue** as defined and identified under the Clean Water Act, 2006	1
Several parameter results measured are frequently above Ontario Drinking Water Quality Standards (ODWQS) and the plant operator and/or municipal staff confirm raw water quality concerns	0.83
Some parameter results measured are above ODWQS and there are plant operator concerns	0.67
A **minimal** number of source water parameter results are above the ODWQS for treated drinking water and there are no water treatment plant operator concerns	0.5

Formula for Source Vulnerability Factor (Vsf):

(Sub-score for intake distance and depth + Sub-score for history of water quality concerns)/2

Table 6.3 shows the reassessment of the source vulnerability factor for the Woodward intakes.

Table 6.3: Source Vulnerability Factor Reassessment per Technical Rule 95.1

Lake Ontario Intake	Distance from shore, m	Intake Depth, m	MDEQ, 2004 Category	Sub-score a*	Historical water quality concerns	Sub-score b*	Vsf (a+b)/2	Vsf**
Woodward 1	945	8.5	Offshore, deep water	0.5	Minimal/ none	0.5	**0.500**	**0.5**
Woodward 2	640	7.3	Offshore, deep water	0.5	Minimal/ none	0.5	**0.500**	**0.5**
Woodward 3	915	8.0	Offshore, deep water	0.5	Minimal/ none	0.5	**0.500**	**0.5**

The **Table 6.4** shows the IPZ-1 vulnerability assessments. Note that the vulnerability scores are not high enough to have significant risk level threats.

Table 6.4: Vulnerability Assessments for Intake Protection Zones-1

Lake Ontario Intake	**IPZ-1 Vulnerability Score**		
	Source Vulnerability Factor (Vsf)	Area Vulnerability Factor (Vaf)	**Vulnerability Score (Vsf X Vaf)**
Woodward	0.5	10	**5**

6.1.3 Intake Protection Zone Two: Delineation

The intake protection zone two, or IPZ-2, is delineated using a combination of hydrodynamic modelling within the lake and the calculation of time-of-travel within in-land pathways that discharge near the lake intakes. Three-dimensional modelling, with backward particle tracking, was used to delineate the in-water portion of the intake protection zone two. HCCL, a subcontractor of Stantec Consulting, completed the in-lake modelling for delineation of the IPZ-2. They used the Princeton Ocean Model to delineate a zone with a time-of-travel for water to reach the intakes within two hours (HCCL, 2007 in Stantec, 2007 and HCCL, 2008.). Two hours has been set as the minimum amount of time needed for operators of the water treatment plant to react to a contamination concern.

Model development required the evaluation of physical and environmental information, including bathymetry, wind direction and speed, wave heights, watershed inputs, local currents, regional currents, and raw water quality. Based on historical measurements of wind and wave conditions, values were selected as input to the hydrodynamic model that would only have a ten percent chance of being exceeded in any given year (ten-year design conditions).

The model was run for 10-year wind events for the eight primary compass directions and 10-year wave and wind events from three critical directions. Wave fetches from the east are very large across the lake, while those from the west are minimal. The model domain extended along the Halton shoreline, past Hamilton to Grimsby, encompassing the western end of Lake Ontario. The offshore boundary was modelled as an open boundary. An assessment of the performance of the model was made against existing data and compared well with velocity trends. The resulting IPZ-2 delineation is shown on Figure 6.1.

The western end of Lake Ontario is complex because alongshore currents slow and turn to continue along the opposite shoreline. A shallow shoal located to the southeast of the intakes influenced the particle tracking in an easterly direction. Significant turbulence within the wave breaking zone is expected to spread contaminants in a short period of time. HCCL extended the IPZ-2 boundary to the shoreline when particle tracks reached the location of the wave breaking zone. In this zone, the particles may have encountered the model boundary rather than completing their two-hour travel time. Due to the proximity of the three Woodward intakes and the cell size within the model, one modelled output defines the IPZ-2 of all three intakes.

The model output indicated that the time of travel from the Burlington Canal to the Woodward intakes is about 2.5 hours. This suggests that, given additional time, the discharge from the bay could reach the Woodward intakes.

Within the in-water delineated zone, stream discharges and storm sewer networks are identified as preferential pathways for contaminants to enter the lake. Stantec Consulting evaluated these pathways and delineated the in-land portion of the intake protection zone two (August 2007). The tributaries discharging into the delineated in-lake portion of the protection zone are Stoney Creek, Battlefield Creek, and some of the Stoney Creek Watercourses.

At the time of delineation of this protection zone, stream flows were unavailable. Bank-full flow, which is equivalent to a two-year storm, should be used to determine the time for water to travel via the watercourses to the intakes. Therefore, professional judgment was required to extend the IPZ-2 inland. The tributary watercourses were included in the delineation to their full length or to the foot of the Niagara Escarpment. Setbacks from the watercourses are the Conservation Authority Regulated Limit or 120 metres, whichever is greater. In addition to this, the storm sewer network and outfall locations were considered during the mapping (see Figure 6.2). This delineation is expected to be conservative and a reasonable estimate of the intake protection zone. Once the appropriate data is collected, the IPZ-2 for the Woodward intakes will be refined and reported on in an updated Assessment Report.

Modelling results indicate that the local wind and wave stresses in the moderate to shallow water depths near the intakes are responsible for the in-water delineation of the intake protection zone. The results also indicate that the input from the watershed discharges is negligible. Whether the discharge from a pathway would actually influence the water quality at the intakes is dependent on the varying wind and wave conditions. Optimum conditions have not been assessed.

6.1.4 Intake Protection Zone Two: Vulnerability Score

The vulnerability score assigned to the IPZ-2 reflects the susceptibility of the intakes to contaminants. The score is based on multiplying the following factors:

- an area vulnerability factor, which considers the percentage of the zone that is land, the land characteristics (cover, soil type, permeability, slope), and the hydrological and hydrogeological conditions. This factor can have a value of 7, 8, or 9; and

- a source vulnerability factor, which considers the distance of the intake from shore, the depth of the intake from water surface, and the historical water quality concerns at the intake. This factor can have a value of 0.5 to 1.0.

The source vulnerability factors are the same as those used to assign vulnerability scores in the intake protection zone one based on intake siting, construction and source water quality.

A decision matrix by Stantec Consulting used in other assessment reports was used, with an adaption considering tile drained areas with storm runoff catchment areas and permeability with the soil type. **Table 6.5** shows the application of the decision matrix to the sub-score range of 7 to 9.

Table 6.5: Area Vulnerability Factor Decision Matrix adapted from Stantec

Factor	Sub-score 7 (low)	Sub-score 8 (moderate)	Sub-score 9 (high)	Sub-factor score
Percent land of the IPZ-2	Less than 33%	33-66%	More than 66%	Based on area within the IPZ-2
Land Characteristics				(Land cover + soil type + permeability + slope) sub-scores/4
Land cover	Mainly forest	Agricultural and/or mixed vegetated and developed	Mainly developed	
Soil type and permeability	Sandy	Silty clay	Clay	
Percent Pervious (percent impervious)	More than 66% (Less than 33%)	33-66% (33-66%)	Less than 33% (More than 66%)	
Slope from setbacks	Less than 2%	2-5%	More than5%	
Transport Pathways				(storm catchment + #storm outfalls etc.) sub-scores/2
Storm catchment area	Less than 33%	33-66%	More than66%	
#storm outfalls, watercourses and drains, per 1000 ha	0-3	4-7	More than7	

Formula for Area Vulnerability Factor (Vaf):
(Sub-score for percent land of IPZ-2 + Sub-score for land characteristics + Sub-score for transport pathways)/3

The **Table 6.6** provides the reassessed land characteristics and contaminant transport pathways factors which contribute to the overall area vulnerability factor for each intake of the Hamilton Region source protection area.

Table 6.6: Area Vulnerability Factor (Vaf) Reassessment of IPZ-2

Lake Ontario Intake	Percent land of IPZ-2 (a)	Land cover in IPZ-2 (b1)	Soil type and permeability of IPZ-2 (b2)	Percent pervious of land portion of IPZ-2 (b3)	Slope from setbacks in IPZ-2 (b4)	Land characteristics: average sub-score "b" = (b1+b2+b3+b4)/4	Storm catchment area in IPZ-2 (c1)	#storm outfalls, watercourses and drains, per 1000 ha of IPZ-2 (c2)	Transport pathways: average sub-score "c" = (c1+c2)/2	Vaf, rounded to a whole number per rule 93 (a+b+c)/3
Woodward	56% (sub-score 8.000)	Mainly developed (sub-score 9)	80% of the area has clayey soils at surface (low permeability), about 20% of the area has shallow fractured bedrock (higher permeability) and higher permeability soils ("averaged out" sub-score of 9)	69% (sub-score 7)	15% of the land portion of IPZ-2 has a 14% slope, 85% of IPZ-2 has a slope of less than 1% (sub-score 7)	**8.000**	Entire land portion of IPZ-2 is serviced with storm sewers.(sub-score 9)	Several, >7. (sub-score 9)	**9.000**	**8**

The **Table 6.7** below shows the IPZ-2 vulnerability assessments. Note that the vulnerability scores are not high enough to have significant risk level threats in IPZ-2s.

Table 6.7: Vulnerability Assessments for Intake Protection Zones-2

Lake Ontario Intake	**Reassessed IPZ-2 Vulnerability Score**		
	Source Vulnerability Factor (Vsf)	Area Vulnerability Factor (Vaf)	**Vulnerability Score (Vsf X Vaf)**
Woodward	0.5	8	**4.0**

6.1.5 Intake Protection Zone Three

Intake protection zone three, or IPZ-3, was delineated and the water quality risk assessment completed in partnership with the Lake Ontario Collaborative. Additional modelling was undertaken independently to validate the reliability of the Lake Ontario model to predict contaminant flow in the western end of the lake. Intake protection zone three is an area where modelling has demonstrated that contaminants released during an event may be transported to the intakes and cause an adverse effect. The IPZ-3 is mapped outside of an IPZ-1 and IPZ-2.

Modelling Surface Water Ltd., retained by the Lake Ontario Collaborative, developed a lake-wide three-dimensional hydrodynamic and water quality computer model using MIKE-3 software to complete the modelling necessary to understand the complex water circulation within the lake (Dewey, 2011). The model was run in nested mode using a 2,430-metre grid for the whole lake and smaller grids within this for the nearshore area. The model simulates the currents in the nearshore areas where municipal water intakes exist. The horizontal grid sizes varied but were typically 810 metres or 270 metres for the modelling discussed here. The vertical resolution was either 30 layers at 3 metres thickness or 40 layers at 2 metres thickness. The MIKE-3 software simulates seasonal thermal conditions, with stratification of the lake waters in the summer and variable lake levels during the modelled period. The model was calibrated for water flow, mixing and dispersion using 1992 data from an actual six hour release of tritium from the Pickering Nuclear Facility. The tritium was measured in water samples collected at municipal intakes from Oshawa to Hamilton. Concentrations measured in the Halton-Hamilton Region were well below the current Ontario drinking water quality standard of 7,000 Becquerels per litre (Bq/L). The Lake Ontario model was used to assess the risk to water quality at all municipal intakes included in the Lake Ontario Collaborative study from Niagara to Quinte.

Dr. Ram Yerubandi and Jun Zhao of Environment and Climate Change Canada developed a three-dimensional hydrodynamic model of Hamilton Harbour using the Estuary, Lake and Coast Ocean Model software for previous studies (Yerubandi, et al., 2009). This model uses a horizontal grid size of 80 m x 80 m to represent the 89 m wide Burlington Canal and therefore, has a more detailed representation of the shoreline than the lake model. There are 36 vertical levels with higher resolution of 1 m in the upper 30 m of the water column for better representation of the thermocline. The model was used to simulate two scenarios similar to those assessed by the Lake Ontario model and one new scenario. The results of the two models were compared to understand better the validity of using the Lake Ontario model to simulate the hydraulics and contaminant transport within the harbour.

For the scenarios modelled, actual wind conditions were simulated for the period April through August 2008 in the lake model, and May through July in the harbour model, to capture the variability in wind direction and the resultant reversal of currents along the northern shore of Lake Ontario and through the Burlington Canal. First-order decay was used in the simulations of *E.Coli* releases.

The risk to the source water is based on modelled activities that could occur in the area and have been designated a potential threat to the drinking water system. The modelled results also assisted with the prediction of impacts on water quality at the City of Hamilton's intakes from activities that are occurring outside the Source Protection Area. The modelled scenarios for activities within and near the Hamilton Region Source Protection Area include effluent discharges without disinfection from wastewater treatment plants due to total plant failures at all plants between Port Dalhousie and Toronto, fuel handling and storage at a bulk facility and off-loading from a ship in Oakville, fuel release to creeks in neighbouring source protection areas from ruptured liquid hydrocarbon pipelines, and fuel release to the Burlington Canal from a truck tanker spill. A brief description of each scenario modelled is provided below, however, for a full description of the Lake Ontario model setup, calibration, and simulations the reader is directed to the report "Spill Scenario Modelling for Lake Ontario Intakes, Halton-Hamilton Focus" prepared by the modeller, Dr. Ray Dewey (http://protectingwater.ca/docandmaps. cfm?smocid=1452&parentcatid=836).

Dr. Ram Yerubandi and Jun Zhao of Environment and Climate Change Canada also prepared a brief report on the modelling that they undertook in 2013 simulating spills within Hamilton Harbour. This report, entitled "Numerical Modeling of Transport of Spills in Hamilton Harbor" is also available on the same website.

The intake protection zone three delineations within the Source Protection Area are shown on Figure 6.1. The significant threat activity locations from within and outside the Source Protection Area and described below are shown on Figure 6.3.

A wastewater treatment plant could become inoperable in the event of an electrical power outage. During this period, the disinfection system would not work and sewage would flow through the plant without treatment. An outage could last for many days and two scenarios of a total plant failure were modelled to assess the risk to the drinking water source. The Lake Ontario model released *E. coli* at a concentration of 5,000,000 count/100 mL for two days from the Skyway and the Woodward wastewater treatment plants (modelled separately). A seven-day release of a tracer was simulated by the Hamilton Harbour model. Both models showed the spreading of the *E. coli* in harbour waters and out the Burlington Canal to the lake. Concentrations of *E. coli* at the Hamilton and Burlington municipal intakes reached concentrations greater than 100 *E. coli*/100 mL, the threshold set by the Lake Ontario Collaborative for a significant threat activity. The typical *E. coli* concentration in the lake remains below this value and higher concentrations could be of concern. Although the Woodward and Burlington wastewater treatment plants are capable of treating much higher concentrations of *E. coli* between May and October, *E. coli* is a relatively good indicator of the presence of other water pathogens that also must be treated. Furthermore, turbidity in the nearshore water may shelter pathogens and lessen the effectiveness of the disinfection processes.

The IPZ-3 for discharges from wastewater treatment plants to surface water through a means other than a designed bypass was drawn to encompass all of the harbour with a setback on land of 120 metres, and the contaminant pathway in Lake Ontario from the outlet of the Burlington Canal to the IPZ-2 as delineated from the lake modelling results (Figures 6.1 and 6.2). Identifying the entire harbour as part of the IPZ-3 is the worst case based on mixing of waters due to varying wind and current conditions.

An overflow event at a pumping station based on extreme wet weather was discussed with the municipalities. Halton Region indicated that the pumping stations in the harbour area are typically small and not subject to frequent releases. Moreover, wet weather events increase the dilution of the sanitary sewage concentrations. The City of Hamilton indicated that the pumping stations along the beach strip do not have bypasses on them and are maintained through regular pump-outs. Therefore, a scenario was not modelled.

The Burlington Skyway and lift bridge cross the Burlington Canal and carry heavy vehicular traffic. A scenario was developed for a tanker truck carrying fuel involved in an accident on the lift bridge, releasing its cargo into the Canal. A full load of fuel is about 34,000 to 37,000 litres of benzene and the scenarios modelled released this benzene over one hour at the entrance to the Canal. Wind direction determined the extent of the benzene impacts and the contaminant was shown by both models to move along the shoreline of the lake to the south to impact the Woodward intake source water and to the northeast to impact the Burlington, Burloak and Oakville intake source waters. The Ontario Drinking Water Quality Standard for benzene is 0.005 milligrams per litre (mg/L) and was used as the threshold to identify a significant threat activity. Both models predicted benzene concentrations greater than the threshold at the municipal intakes. The transportation of fuel is not a threat activity prescribed by the Ministry of the Environment and Climate Change in regulation and would have to be identified as a local threat by the Source Protection Committee. Since it is not a local threat at this time, this activity cannot be identified as a significant threat. The Committee can address the threat activity through other policy options in the Source Protection Plan.

A bulk fuel storage scenario in a neighbouring source protection area was modelled as a release of 26 million litres of gasoline from a tank over a six-hour period. The modelling released the equivalent benzene concentration to the mouth of the closest creek. However, additional review has indicated that this scenario does not reflect site conditions. The fuel tanks are actually located in a different watershed and a release of fuel would not flow to the creek as modelled. The Source Protection Committee did not reach consensus on the designation of this activity as a significant threat because the conditions modelled do not reflect a plausible scenario. The designation as a significant threat remains at the request of the Ministry of the Environment and Climate Change because a credible scenario may result in similar findings. The Committee will undertake additional assessment when provincial funding is available.

The off-loading of fuel from a ship to an underground pipeline that feeds a bulk storage facility was modelled by Modelling Surface Water Ltd. using three scenarios. The dock is located within the IPZ-1 and IPZ-2 of the Burloak intake and the overlapping IPZ-2 of the Burlington intakes in Halton Region Source Protection Area. The time of the spill was kept constant at 15 minutes as personnel were expected to be nearby. The quantity of gasoline released was varied between 20,000 and 100,000 litres and the associated quantity of benzene varied accordingly. Although this activity is undertaken in Oakville, it was identified as a significant threat for the Hamilton source water when the largest volume is released.

Liquid hydrocarbon pipeline rupture scenarios were modelled for a pipeline that crosses creeks in the neighbouring source protection area. The modelling period was April through

July 2008 with spill duration either two or six hours. A flow rate of 0.00125 m^3/s of benzene was modelled. An assumption was made that all the benzene within the gasoline dissolved into creek water and was carried in its entirety to the mouth of the creek where the lake model predicted its flow to the intakes. The Ministry of the Environment and Climate Change indicated that it is reasonable to extrapolate the results to pipeline spills of any crude oil, condensate or liquid petroleum product (see Appendix F) into the same creek farther upstream. They have directed the Halton-Hamilton Source Protection Committee to include these significant threats. The simulations identified significant threats to the source water of the Woodward intakes from a gasoline spill to Sixteen Mile Creek when the spill was of six-hour duration.

Another pipeline rupture was simulated only by the Hamilton Harbour model. In this scenario, a pipeline that lies on the bottom of the western end of the harbour was ruptured at the northern and southern shores. A spill of 28,000 litres for one hour did not adversely affect the water quality at the Hamilton and Burlington intakes.

6.1.6 Intake Protection Zone: Limitations

Stantec (2007) and HCCL (2008) discuss intake protection zone mapping and the assignment of uncertainty for IPZ-1 and IPZ-2. The uncertainty associated with the delineation of IPZ-1 is low since this is a set distance with no interpretation. The assignment of the vulnerability score is also of low uncertainty because it is based on factual construction data. For the delineation of IPZ-2, the in-lake modelling effort was restricted due to data and resource availability. As mentioned previously, the hydrology at the western end of Lake Ontario is complex and varies spatially and temporally. The lack of good data to support the variability of conditions increased the uncertainty in the results. HCCL suggest that the model provides adequate representation of the velocities for this study, but caution that a conservative interpretation of the results should be used.

The in-land delineation of the intake protection zone is also highly uncertain due to the absence of stream flow data to assess the time of travel within the watercourses. The conservative approach used, however, is likely to capture all threats potentially affecting the intakes.

Based on the confidence that the delineation and vulnerability scoring has captured the potential threats effectively, Stantec has assigned an uncertainty rating of low. However, due to the need to define the potential threats more accurately and the risks to the drinking water source, the overall rating assigned is high.

The delineation of intake protection zone three is set at high uncertainty for the scenario modelled within the Hamilton Region Source Protection Area. The lake modelling was based on assumptions, flow rates, and spatial scenarios that are preliminary in nature and not accepted by stakeholders as good representations of worst case scenarios based on actual conditions. The model was calibrated to general hydrodynamics and for the wastewater treatment plant by-pass scenario, decay was used. The extrapolation of results from liquid hydrocarbon pipeline releases to upstream pipelines carrying different materials, of potentially different pipe size, and with potentially different release volumes is not widely accepted by pipeline owners, source protection staff, and others.

6.2 Groundwater Vulnerability Assessment

A groundwater vulnerability assessment is completed to map areas on the ground surface where pollutants can more easily seep below ground and contaminate the groundwater supply. Ultimately, delineation of these areas will protect the quality and quantity of groundwater resources through awareness and policy development and enforcement.

The residents living and working in the rural area of Hamilton Region Source Protection Area primarily rely on groundwater for their source of water. Both municipal and private wells tap the Area's aquifers, and this valuable resource must be protected. The vulnerable areas mapped and discussed in the following sections are highly vulnerable aquifers, significant groundwater recharge areas, and wellhead protection areas.

The presence of constructed pathways, such as subsurface utility corridors, abandoned boreholes and excavations, may alter the interpretation recorded in this report. Constructed pathways may facilitate the movement of contaminants vertically or laterally below ground surface resulting in a faster or more widespread distribution. Constructed pathways were assessed within Hamilton SPA WHPAs and a summary of the assessment is provided in section 6.2.3 of this report.

6.2.1 Highly Vulnerable Aquifers

Highly vulnerable aquifers are defined as subsurface, geologic formations that are sources of drinking water which could, relatively easily, be impacted by the release of pollutants on the ground surface. These aquifers are typically shallow. Where aquifers are layered one on top of the other with confining sediment or rock units between, it is only the upper aquifer that is mapped.

Highly vulnerable aquifers were mapped following Part V.1 of the Technical Rules and using the groundwater intrinsic susceptibility index method (Ministry of the Environment, 2001). This work was completed as part of the Groundwater Resource Inventory Program undertaken with the assistance of Ontario Geological Survey (Conservation Halton, 2007). Factors considered to assess vulnerability of an aquifer are the depth to the aquifer and to the water table, the properties of the overlying soil and/or rock, and the aquifer composition. The Ministry of the Environment and Climate Change's Water Well Information System and other borehole logs (completed for studies conducted within the Source Protection Area) were used in the characterization of aquifers. Figure 6.4 shows the interpolated surface based on the results of the vulnerability mapping.

As illustrated on Figure 6.5, a significant part of the Source Protection Area contains highly vulnerable aquifers. Within much of this area, the water table is shallow, the overburden is thin and permeable (or absent), and the aquifer is fractured bedrock. The vulnerability of the aquifer decreases only where soils are thicker, such as on moraines and drumlins.

For the purposes of source protection planning, the areas mapped as highly vulnerable, using the intrinsic susceptibility index method, translated to a vulnerability score of six (Technical Rules Part VII.1). This score is used for assessment of risk to drinking water supplies (see Section 7).

Highly Vulnerable Aquifers Limitations

The analysis of highly vulnerable aquifers is based on limited data analyzed on a regional scale and using basic methodology. The intrinsic susceptibility index method used for the highly vulnerable aquifers delineation uses the modified Water Well Information System and interpolates the values between the wells in the database to obtain a smooth vulnerability distribution. Caution must be used in interpreting or applying the vulnerability map for local areas, and confirmation of the site-specific vulnerability requires more detailed investigation.

As studies are completed within the Hamilton Region Source Protection Area, and as the additional borehole data is included in the interpretation, the mapping may change. Accordingly, based on the data and method used for this assessment, the uncertainty is high.

6.2.2 Significant Groundwater Recharge Areas

Recharge areas are locations on the ground surface that have appropriate characteristics to facilitate the infiltration of precipitation and surface water runoff below ground surface to the water table. A recharge area is significant when large volumes of water, relative to the source protection area as a whole, are involved. This recharge water can include dissolved chemicals that the runoff has accumulated. Therefore, these areas have been mapped in agreement with the 2017 Technical Rules to provide, through policies, protection of the quantity of groundwater available.

Earthfx, under contract with the City of Hamilton, determined estimations of the recharge distribution in order to develop a groundwater flow model for the northern portion of the city. Earthfx used the United States Geological Survey's Precipitation-Runoff Modelling System (PRMS) code to calculate the recharge distribution across the Source Protection Area (Earthfx Incorporated, 2010). The development of this model was discussed previously in Section 5.2. Soil properties, topography, land cover, and precipitation were used as some of the input data to the model.

Due to geology, recharge within the Hamilton Region Source Protection Area varies significantly, above and below the Niagara Escarpment and along the lakeshore. Typically, the till and shale units below the escarpment limit infiltration. This causes a higher percentage of precipitation received to leave the watershed as runoff. Within the Iroquois

Plain, along the Lake Ontario shoreline, sand deposits at the surface of the ground increases infiltration. This area is mostly developed, and the sand deposits are covered by impervious surfaces and drained by municipal storm sewer systems.

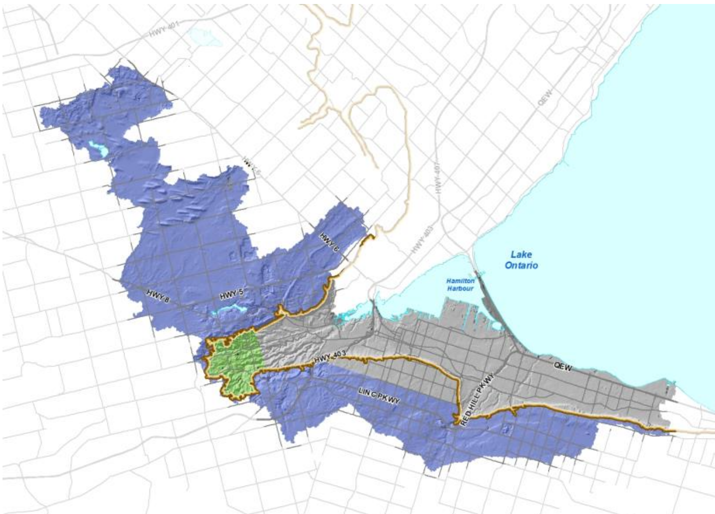

Figure 6.6 Significant Groundwater Recharge Areas – analysis areas. Urban area – grey; below escarpment – green; above escarpment – blue.

Above the escarpment, the sandier soils and fractured dolostone increase the likelihood that recharge will occur. Accordingly, the Source Protection Area was divided into three areas for evaluation: above and below the escarpment and the urban area (see Figure 6.6).

The urban area was not considered in the assessment of significant groundwater recharge areas because the area does not use groundwater as a drinking water source. Also, much of the precipitation that falls in this area is directed to the storm sewer network or to the many incised creek valleys.

Dividing the Source Protection Area into three sections provides for a better assessment of the significance of the recharge occurring.

Recharge areas were deemed to be significant when the annual recharge rate in the area was greater than the average across its assessment area, i.e., the area above or below the escarpment, excluding the urban area, by fifteen percent or more (Technical Rule 44(1)). Thus, the calculated significant recharge rates are greater than 239.0 millimetres and greater than 177.6 millimetres, for above and below the escarpment, respectively.

The Technical Rules require that a hydrological link exist between a significant groundwater recharge area and an aquifer that acts as a drinking water source. Based on the extensive coverage of water wells in the Source Protection Area, the mapped areas are considered to supply a drinking water system. To complete the mapping, small, isolated delineated areas (0.03 square kilometres or less) were removed, and small holes in the larger delineated areas were filled in.

The mapped areas of significant recharge are shown on Figure 6.7. Below the escarpment, only a small linear area in the southwestern extent of the Dundas Valley is determined to be significant. Above the escarpment, the central area of Spencer Creek (in the area of the Norfolk Sand Plain and the Flamborough Plain) is identified primarily as significant. Small portions of the Stoney Creek and Red Hill Creek watersheds are also deemed as significant groundwater recharge areas.

The Technical Rules require that the identification of significant groundwater recharge areas within the study area delineated during a Tier 3 water budget and water quantity risk assessment (see Section 5) be reassessed. To keep the relative nature of the assessment across the entire Area, without emphasis in the small Tier 3 study area, the delineated significant recharge areas were not refined.

Significant Groundwater Recharge Areas Limitations

The evaluation of the recharge distribution in the Source Protection Area required the use of the PRMS code. A more detailed breakdown of the uncertainty associated with the model developed is included in Section 5.6. The uncertainties of the recharge estimation are related to the uncertainties of measured data used to develop and calibrate the model.

The PRMS model was calibrated using monthly and annual total flows and estimated baseflow values with reasonable accuracy. Therefore, its recharge distribution appears adequate for the calculation of significant groundwater recharge. Also, peer reviewers accepted that the methodology used to define significant groundwater recharge areas is suitable.

The delineation of significant groundwater recharge areas is based on a regional assessment of available data, and additional studies may be required to apply the findings to a specific property. The uncertainty of this regional delineation is low.

6.2.3 Wellhead Protection Areas

Delineation of Wellhead Protection Areas for Water Quality

A wellhead protection area (WHPA) is an area on the ground surface that reflects a zone in an aquifer where groundwater is flowing toward a pumping well. Activities undertaken in this area may release pollutants that could seep into the soil and contaminate the groundwater used by both domestic and municipal wells.

The use of a properly built and calibrated groundwater flow model is considered the best science-based method for delineating wellhead protection areas and calculating vulnerability scores. The City of Hamilton retained Earth*fx* Incorporated in 2010 to develop a groundwater flow model to delineate a wellhead protection area for the Greensville municipal well FDG01. The model used for this initial study is the same as discussed in Section 5.2 and used to assist with completion of the Tiers 1 and 2 water budget assessment. The recharge distribution used as input to the MODFLOW groundwater flow model was estimated using the output from the PRMS code. The output from the MODFLOW model, including simulated groundwater levels and flow rates, along with the aquifer's **effective porosity,** were used as input to the United States Geological Survey's MODPATH code to calculate average groundwater velocities.

Modelling of the vulnerability of the Greensville well field was updated following the addition of a backup well by the City of Hamilton and development of the Tier 3 model described in section 5.5. The fully integrated GSFLOW model was used for this assessment and run in transient mode, allowing the climate and water levels to fluctuate over the modelled 29-year time period.

The wellhead protection areas for the two wells were delineated using this updated model to reflect the current knowledge and understanding of the surface water and groundwater interactions and flows, and the water takings.

Backward particle tracking, i.e., sending particles from the well out into the aquifer, is used to calculate time-specific capture zones that are then used to define the wellhead protection areas. This approach is conservative since it accounts for horizontal travel time in the hydraulically connected portions of the aquifer and does not include the travel time through the overlying soil or rock above the water table. The actual time for surface water and contaminants to reach the well could be longer.

To finalize the delineation, lines are drawn manually to enclose the particle tracks for two-year, five-year, and twenty-five-year travel times to define the boundary of the wellhead protection areas.

The well water quality vulnerability assessment is documented in "Updated Vulnerability Analysis and Scoring of Wellhead Protection Areas for the Greensville Wellfield, City of Hamilton, Ontario", prepared by Earth*fx* Incorporated and dated March 2017. The report is available at www.protectingwater.ca.

Drinking Water Protection Area signage – City of Hamilton

As previously discussed, the City of Hamilton does not anticipate growth in the number of users of the Greensville system. The existing maximum permitted pumping rate predicts the largest extent the capture zones will be for this well system.

The level of risk to the water quality at the wells is in relation to the time it takes for a contaminant to travel to the wells and the time available for assessment and mitigation to take place. For example, if a chemical spill occurs a considerable distance away from a well, an assessment will be required. The assessment considers whether the spilled chemical will reach the well and how long it will take; whether the chemical is a health risk or an aesthetic parameter; whether the concentrations of the chemical at the well will exceed the provincial standard; and whether the existing treatment process is adequate to remove or reduce the concentrations of that chemical. If sufficient time is available, a mitigation system may be installed to limit the movement of the chemical to the well or the water treatment process may be modified to adequately lower the concentrations. If time is available, the risk to the water supply is lower.

Accordingly, for the purposes of this study, the wellhead protection area has been divided into the following parts:

- WHPA-A – an area of 100 metre radius around the wellhead;
- WHPA-B – the zone through which it takes groundwater to travel between two years and the 100-metre distance;
- WHPA-C – the zone through which it takes groundwater to travel between five and two years;
- WHPA-D – the zone through which it takes groundwater to travel between 25 and five years;

- WHPA-E – the area on ground surface through which surface water flows in two hours to a point close to the well. This wellhead protection area is only delineated when studies have shown that surface water can relatively easily seep through the soil and impact the quality of the water at the well. This type of well is known as groundwater under the direct influence of surface water, or a GUDI well; and
- WHPA-F – the area on ground surface around a GUDI well where event-based modelling has shown that a release of a contaminant in the area may be transported to the well and cause an adverse effect.

The wellhead protection areas for the Greensville municipal wells include wellhead protection areas A through D and are shown on Figure 6.8.

The shape and extent of the wellhead protection areas are influenced by multiple factors and are site specific. Some of the factors are:

- local geology;
- type of an aquifer (**confined versus water table and/or semi-confined aquifer**);
- interactions between the aquifer and surface water bodies;
- interference between pumping wells and other takings; and
- recharge distribution.

Depending on the local conditions, some of the influences may be greater than others. The final delineation is the result of the interaction between all or some of these factors, the groundwater flow patterns and gradients, and the aquifer hydrogeological parameters.

The wellhead protection areas for the Greensville municipal wells reach a divide and flatten out because of the cone of depression created by the Lafarge Quarry processing area where the aquifer rock has been removed. This divide marks the location of a high-point from which groundwater in the aquifer flows to the north toward the quarry and to the south toward the municipal wells.

Greensville water supply at FDG01 was assessed by Stantec Consulting Ltd. (February 2004) as groundwater potentially under the direct influence of surface water (GUDI), based on the following criteria:

- The soils in the area consists of sand and gravel overlying the bedrock aquifer and the assessed susceptibility of the aquifer to contamination from surface was considered high; and
- Spencer Creek is located approximately 350 metres southwest of the well, which is closer than the minimum distance specified in the *Safe Drinking Water Act* for a similar well.

Further study by Stantec Consulting Ltd. (November 2005) concluded that the soils and bedrock provided effective in-situ filtration for the water supply. This conclusion was based on microbial data, particle counts and turbidity measurements.

As shown on Figure 6.8, the wellhead protection areas of the Greensville wells do not intercept watercourses that could increase the hydrologic connection between surface water and the groundwater supply.

This information suggests that a wellhead protection area E is not required to be delineated for these wells.

Wellhead Protection Areas Limitations

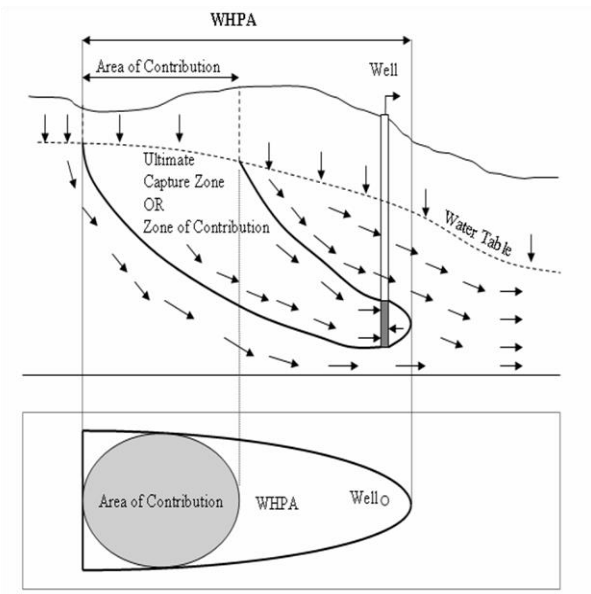

Figure 6.9 Conceptualization of capture zone, wellhead protection area, and area of contribution (modified from Franke et al.

The uncertainty associated with delineation of wellhead protection areas is dependent on the reliability of the groundwater flow model used. The uncertainty associated with the groundwater model is discussed in Section 5.6. The model is a good tool to understand natural systems; however, many datasets are required as inputs to the model and they vary in quality and coverage.

The Tier 3 model is developed at a regional scale. Local variability in aquifer and aquitard properties, recharge rates, and interference between pumping wells can change the delineation of the wellhead protection areas. However, given the level of effort and sophistication of the methods and models used for this study, the overall uncertainty is generally low.

The integrated surface water and groundwater models have undergone a successful peer review process and have been deemed adequate for the purposes for which they were developed. Thus, the simulated wellhead protection areas should reasonably capture the areas of concern for delineation of potential threats to the drinking water source. The modelled results should be considered carefully for any other application to site-specific conditions.

Vulnerability within Wellhead Protection Areas

As mentioned above, a wellhead protection area identifies an area on the ground surface that reflects a zone in the aquifer where groundwater is flowing to the pumping well. This area is not necessarily equal to the actual area contributing water to the well in a given amount of time. The contributing area is the location on the ground surface where water seeping through the soil will actually reach the well (see Figure 6.9). It is this area that requires the highest degree of protection because it is this area that is most vulnerable to surface contamination.

To assess the vulnerability within the wellhead protection area, Earth*fx* Incorporated was retained to utilize the groundwater model already developed for the Tier 3 water quantity study and to estimate the surface to well **advection times** (SWAT). The Province considers the assessment of surface to well advection times as the most advanced method of analysis to assess vulnerability of the source water.

Flow from surface through the unsaturated and saturated soil/rock overlying the aquifer and then through the aquifer to the well is considered for this analysis. The use of a numerical model to estimate the travel times from the water table to the well is a scientifically sound method and assesses the vulnerability of the contributing areas in a conservative way. Flow through the **unsaturated zone** is complex and quite variable depending on the soil properties, moisture content, amount of infiltration, and depth to the water table. The advection times through the unsaturated zone were calculated using the provincial guidance and values range between 1 and 25 years close to the municipal wells. The unsaturated zone calculations are considered highly uncertain due to the lack of reliable data noted above and the method's lack of inclusion of soil conditions. Further study of these calculations and the supporting data is warranted.

Furthermore, the time-of-travel through the unsaturated material is highly uncertain as it may vary with the mode of contamination, i.e., an occasional release, a constant leak, or a large spill that actually saturates the soil.

The time it takes for groundwater to flow to a well is called the water table to well advection time (WWAT). Particles are released at the water table within and around the 25-year time-of-travel zone, and their movement to the well is tracked. Some of these particles did not reach the well within 25 years or bypassed the well altogether. Waters that bypass the well are expected to continue **downgradient** or discharge into a local surface water feature, such as a stream or wetland.

The calculated times for water to travel through the unsaturated zone are added to the modelled times for groundwater to travel through the saturated zone to the well. These surface to well advection times are categorized as low for over 25 years, medium for 5 to 25 years, and high for 0 to 5 years of travel. The mapped groundwater vulnerability areas are overlain on the wellhead protection areas A through D in order to assign vulnerability scoring consistent with the criteria of the Ministry of the Environment and Climate Change, as summarized in Table 6.1. The vulnerability maps of the Greensville wells are shown on Figure 6.10.

Table 6.1 Wellhead Protection Area Vulnerability Scores

Groundwater Vulnerability Category	Location Within a Wellhead Protection Area			
	WHPA-A	WHPA-B	WHPA-C	WHPA-D
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	2	2

Vulnerability within the Greensville wellhead protection area was also mapped using the results of the intrinsic susceptibility index method discussed in Section 6.2.1. Figure 6.11 shows the results. This method assesses the vulnerability from surface to the water table based on limited data. The water table to well advection time method maps the contributing area to the well most reliably using travel times through the aquifer and these results are used to assess the risk to the well water supply due to threats.

Transport Pathways in Wellhead Protection Areas

Staff identified and assessed contaminant transport pathways in WHPAs as described in detail in the associated technical study (Conservation Halton, 2021). A transport pathway in a WHPA is a human-made feature below ground surface that increases the vulnerability of the sources of our drinking water supplies. Transport pathways bypass the natural protection provided by soil and rock layers and natural processes, resulting in a greater risk of contamination of our water sources.

Per technical rules 39 through 41, the area vulnerability around groundwater supplies can be increased because of a presence of an anthropogenic transport pathway upon consideration of:

- Hydrogeological conditions
- The type and design of transport pathways
- The cumulative impact of any transport pathways, and
- The extent of any assumptions used in the assessment of the vulnerability of groundwater.

The following potential transport pathways within WHPAs were reviewed:

- Wells constructed prior to Ontario Regulation 903
- Municipal linear infrastructure
- Geothermal systems
- Communications infrastructure
- Gas mains
- Any other excavations
- Pits and quarries
- Oil and gas wells
- Pipelines.

Wells transport pathways

The MECP Water Well Record Information System (WWIS) database was used for the wells transport pathways analysis. The WWIS houses water well record information submitted by drillers when a new well is constructed or abandoned. Some of the information included on the water well record is well location, drilling date, name of the owner, stratigraphy encountered during drilling including depths and soil/ rock description, groundwater level depth and pumping test data, well construction details including total depth, well screen size and location, casing diameter, basic water quality data, well contractor name and license, etc. The following criteria were used by staff to identify potential transport pathways in WHPAs A-D:

1. Wells constructed prior to the Ontario Regulation 903 (Wells);
2. Clusters of six or more wells within 100m radius; and
3. Reported margin of error of a well's location to be 30m or less.

Note that municipal drinking water system wells are excluded from the analysis. The criteria are similar to analyses conducted by neighboring source protection areas (SPAs) and SPRs including the Niagara Peninsula SPA and the Credit Valley, Toronto and Region and Central Lake Ontario (CTC) SPR. In order to increase vulnerability due to the wells transport pathways, a 30-metre area of influence was delineated around the identified transport pathway well within WHPAs. This area of influence receives a vulnerability increase by one category: low to medium or medium to high. This in turn results in an increase in vulnerability score. Where the vulnerability is already high, no change is made. In the Greensville WHPA, no wells transport pathways were identified.

Linear infrastructure and other types of transport pathways

In HHSPR, linear infrastructure, excavations, etc. that intersected water table or were within 2 metres of the top of aquifer were adjudged to have higher risk and were confirmed as transport pathways.

The depth to water table and the top of aquifer surfaces were obtained from groundwater models that were used to delineate each specific WHPA. These were exported into GIS software for a desktop analysis. Potential transport pathways identified below the water table or within 2 metres of the top of aquifer were confirmed as transport pathways. To avoid identifying features as transport pathways in areas where there are upward gradients (artesian conditions) and upward water movement, an assessment of artesian conditions was completed. In areas where potentiometric surface obtained from a steady state groundwater model is within average annual groundwater level fluctuation of 2.1 m (based on local PGMN wells) a potential transport pathway would be confirmed as a transport pathway. Where potentiometric surface is more than 2.1 m above ground surface a potential transport pathway would not be confirmed as a transport pathway as there is less chance for vertical gradient reversal.

The linear infrastructure transport pathway assessment identified one area within the Greensville WHPA where a local storm sewer intersects groundwater table. This section of storm sewer is located in WHPA-A and therefore no changes to vulnerability score is possible.

Pits and quarries within WHPA are assessed on a site-specific basis. The methodology to complete the transport pathways assessment is as follows:

1. If a specific pit or quarry was inactive and represented in the numerical model (which was used to estimate the time of travel from the water table to a municipal well intake and subsequent unsaturated zone time of travel estimate to assess intrinsic vulnerability), such quarry would not be a transport pathway. If there is a proposal for more extraction within the area which intersects with WHPA, methodology in point 2 below is used.
2. If a specific pit or quarry was not represented in the model or is still active, and there is enough information available about the depth of licensed extraction, subsurface conditions, and state of rehabilitation, the same criteria for linear infrastructure would be used; otherwise the entire aggregate operation would be identified as a transport pathway.

There were no pit and quarry operations identified in the Greensville WHPA.

An assessment of geothermal systems as transport pathways follows same criteria as for linear infrastructure. There are mainly two types of geothermal systems: deep vertical and shallow (either vertical or horizontal). The deep vertical systems require an Environmental Compliance Approval (ECA) from MECP, while shallow systems require a building permit from local municipalities. There were no ECA for geothermal systems identified in any of HHSPR WHPAs. Staff is waiting for information on shallow geothermal systems from the City of Hamilton.

Communication infrastructure and gas main data was not available during preparation of this report. Considering the depth of this type of infrastructure is usually very shallow and was assumed at 1 metre, there are no areas within the Greensville WHPA where communication infrastructure or gas mains would meet the criteria to become a transport pathway.

There are no oil and gas wells and pipelines identified within HHSPR WHPAs.
The details of the comprehensive transport pathways assessment carried out can be found in the technical report by Conservation Halton (2021).

6.3 Neighbouring Source Protection Areas

The Hamilton Region Source Protection Area is surrounded by the Niagara Peninsula, Grand River, and Halton Region Source Protection Areas. The delineation of vulnerable areas within these areas has also been completed. Mapped highly vulnerable aquifers and significant groundwater recharge areas cannot extend outside of the Source Protection Area due to the methodology used. However, wellhead protection areas and intake protection zones can. The delineation, vulnerability assessment and threats assessment for these vulnerable areas have been completed by the Source Protection Authority in the area in which they originate.

The Freelton well, FDF03, is located at the western edge of the Halton Region Source Protection Area (see Figure 6.12). Its wellhead protection area has a long arm that extends into the northwestern edge of the Hamilton Area in the Township of Puslinch. Wellhead protection areas C and D extend into this area. No existing significant threats have been identified.

Intake protection zone two for the Grimsby intake in Niagara Region extends onto land in the eastern corner of the Hamilton Region Source Protection Area (see Figure 6.13). The threats assessment completed by Niagara Peninsula has determined that no threats exist in this portion of the vulnerable area.

The City of Guelph and Guelph/Eramosa Township, in the Lake Erie Source Protection Region, are completing a Tier 3 water budget and water quantity risk assessment for their municipal drinking water wells. Results indicate that the water quantity wellhead protection areas extend into the Halton Region and the Hamilton Region Source Protection Areas. A process to assess threats to water quantity of the municipal system and write policies to ensure sustainability of the wells is underway. The results of their study will be included in an amendment to this report.

7. DRINKING WATER ISSUES AND THREATS

In this section:
- Drinking water issues
- Drinking water threats – activities
- Drinking water threats - conditions
- Potential threat areas

An assessment of existing and possible drinking water issues and threats was completed for the Hamilton Region Source Protection Area. The *Clean Water Act*, *2006*, its regulations, and Part XI of the Technical Rules require that known concerns with the quality or quantity of the source water of a drinking water system must be described or listed. It is also required that those areas within the Source Protection Area where a drinking water threat of significant, moderate, or low level could occur must be mapped. The following sections discuss issues and threats that exist or may develop in the Area.

7.1 Drinking Water Issues

Drinking water issues result from the presence of a chemical or pathogen at an intake or well related to a municipal drinking water system that is:

- present at a concentration that may result in the deterioration of the quality of the water for use as a source of drinking water; or
- increasing in concentration and a continuation of the trend would result in the deterioration of the quality of the water for use as a source of drinking water.

The parameter identified must be listed in Schedule 1, 2, or 3 of the Ontario Drinking Water Quality Standards (Ontario Regulation 169/03) or Table 4 of the Technical Support Document for Ontario Drinking Water Standards, Objectives, and Guidelines (Ministry of the Environment, 2006).

If there is evidence of a widespread presence of a parameter at intakes or wells, drinking water issues may also be identified in highly vulnerable aquifers and significant groundwater recharge areas under similar circumstances as listed above. For these areas, the parameter must not be listed in Schedule 1 of the Ontario Drinking Water Quality Standards, i.e., not *E. coli* or total coliforms.

7.1.1 Greensville Drinking Water System

The Greensville municipal water supply takes its water from a dolostone bedrock source. The quality of the source water is good, and the treated water meets the Provincial standards. Water quality analysis results for well FDG01 for various periods between 1999 and 2010 were reviewed to assess the potential for issues with the Greensville supply. A partial list of the raw water quality data reviewed for the period 2002 to 2010 is included as Appendix B.9. These analyses indicate nearly no detections of *E. coli*, volatile organic compounds, or pesticides in the raw and treated water. Concentrations of metals measured were at acceptable levels. However, elevated concentrations of nitrate, sodium, and chloride were noted.

Nitrate

Historically, nitrate concentrations in the well source water were approaching the provincial health related standard of 10 milligrams per litre. They have since decreased to be in the 5 to 7 milligrams per litre range. Nitrate is a component of fertilizers, manure, and sewage, and therefore groundwater concentrations can be elevated near farm operations and septic systems. The City of Hamilton monitors the trend in nitrate concentrations in this water supply and has taken measures to limit increases in the groundwater supply through planning initiatives.

Chloride and sodium

Concentrations of chloride and sodium in the Greensville well source water are elevated above background values. Increasing chloride and sodium concentrations can be from road de-icing, the use of water softeners in the vicinity of the well, and from natural sources. The concentrations of both parameters are relatively consistent, with no apparent trends.

Chloride has an aesthetic objective in drinking water set at a maximum of 250 milligrams per litre. At this concentration, it may impart an unpleasant salty taste to the water, but it is not a health-related parameter. The concentrations of chloride in source water and treated water samples have been measured above the objective. Sodium has an aesthetic objective in drinking water of a maximum of 200 milligrams per litre also due to changes in the taste of the water at high concentrations. When concentrations of sodium exceed 20 milligrams per litre in a well supply the Medical Officer of Health is notified. Local physicians can use this information when advising patients on sodium restricted diets. Sodium concentrations have been relatively consistent in the data reviewed and remain less than the objective.

The City of Hamilton has not identified that the existing sodium and chloride concentrations could result in the water supply being unsuitable for use. Therefore, based on the results of groundwater and treated water analyses as measured at the Greensville well supply, no drinking water issues have been identified.

7.1.2 Woodward Drinking Water System

The Woodward system takes water from Lake Ontario. The general quality of nearshore water within the lake influences the quality of the water taken. The results of analyses of raw and treated water samples analyzed between 1998 and 2010 were reviewed for elevated and or rising trends in concentrations. A partial list of the raw water quality data reviewed for the period 1998 to 2007 is included as Appendix B.9. The quality of the water is good, and treated water meets the Provincial standards. However, increases in turbidity and changes in the taste and odour of the water do occur on occasion. The City of Hamilton has studied these events to assess possible options to improve the quality of the intake water. Based on the historical data, no drinking water quality issues have been identified for the Woodward water system.

7.1.3 Water Systems in Highly Vulnerable Aquifers and Significant Groundwater Recharge Areas

Limited data is available for review to understand the localized impacts to source water within the mapped areas of highly vulnerable aquifers and significant groundwater recharge areas. As and when this information becomes available, the data will be reviewed, and issues identified where defensible. Future updates to this Assessment Report will include the results of these assessments.

7.2 Drinking Water Threats - Activities

The *Clean Water Act* requires the identification of activities considered threats to drinking water supplies be undertaken in vulnerable areas of the Source Protection Area. Accordingly, an assessment of all the activities listed in Section 1.1(1) of Ontario Regulation 287/07 and occurring in all vulnerable areas was completed. However, the activities counted and discussed below are only those activities that pose a significant risk to drinking water supplies.

The twenty activities that are prescribed as drinking water quality threats are related to the following:

1. Waste disposal sites – their establishment, operation or maintenance;
2. Sewage systems – their establishment, operation, or maintenance;
3. Agricultural source material – application to land;
4. Agricultural source material – storage;
5. Agricultural source material – management;
6. Non-agricultural source material – application;
7. Non-agricultural source material – handling and storage;
8. Commercial fertilizer – application;
9. Commercial fertilizer – handling and storage;
10. Pesticide – application;
11. Pesticide – handling and storage;
12. Road salt – application;
13. Road salt – handling and storage;
14. Snow – storage;
15. Fuel – handling and storage;
16. Dense non-aqueous phase liquid – handling and storage;
17. Organic solvent – handling and storage;
18. Chemicals used to de-ice aircraft – management of runoff; and
21. Land associated with livestock – use of for grazing, pasturing, confinement, or as a yard

22. The establishment and operation of a liquid hydrocarbon pipeline.

In 2018, the Ontario Regulation 287/07 was amended to add the “establishment and operation of a liquid hydrocarbon pipeline” to the list of prescribed drinking water threat activities, as indicated in the list above.

Also listed in Ontario Regulation 287/07 are two water quantity threat activities, as follows:

19. An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body; and
20. An activity that reduces the recharge of an aquifer.

These threats are considered following completion of a Tier 3 local water quantity risk assessment.

Technical Rule 119 allows the addition to the list of local threats that have a sufficient hazard rating and that have the approval of the Ministry of the Environment’s appointed Director. The conveyance of oil by way of a pipeline that crosses an open body of water was previously identified as a local threat within the Hamilton Region Source Protection Area. It is now considered as a prescribed drinking water threat, as described in detail in the next section.

Another potential threat discussed locally is the possibility of a spill of a hazardous chemical along one of the many transportation corridors within the Source Protection Area. Whether it occurred on a road or rail line, or in a shipping lane, such a spill could pose a threat to a drinking water source. The Lake Ontario Collaborative modelled a spill of fuel into the Burlington Canal from a tanker truck crossing the lift bridge. The modelled results show this scenario would be a significant threat if the activity was added as a local threat. This possible threat and others that may be identified will be considered in an amendment to this report.

7.2.1 Water Quality Threats

The Province has designated circumstances that would make the water quality activities listed above threats to a drinking water supply. These circumstances typically refer to the quantity of chemical/material or land, the chemical released, and the affected source water. The risks to drinking water associated with each of these circumstances have been assessed in relation to the vulnerability scores assigned within each of the vulnerable areas. The Ministry of the Environment and Climate Change has produced circumstances for each combination of vulnerable area and vulnerability score for three threat categories and three risk levels. The threat categories are:

1. chemical
2. pathogen
3. dense non-aqueous phase liquid (DNAPL)

The risk levels are :

1. significant
2. moderate
3. low

The circumstances can be reviewed on the provincial webpage - Source Water Protection Portal at http://swpip.ca using the Source Water Protection Threats Tool and Table of Drinking Water Threats.

Significant Threats to Groundwater

Based on the circumstances, the only vulnerable areas in the Hamilton Region Source Protection Area where significant threats are possible are within the Greensville wellhead protection areas. In these areas, the vulnerability scoring that results in significant threats is eight or ten for chemical threats, ten for pathogen threats, and all scores within WHPA-A through WHPA-C for dense, non-aqueous phase liquids.

Sources of the data acquired to complete the threats assessment are documented in Section 10. The assessment used a complex geographical information system (GIS) in which data stored in databases were linked to the vulnerable areas, and the significant threats were counted.

The circumstances under which threats are possible are very specific. For example, the volume of material stored or handled and the chemical that could be released must be known. Since the necessary site-specific data was lacking, several assumptions were used in order to carry out the analyses.

The primary assumption made for the assessment of each of the threats was the worst-case scenario (i.e., smallest tank size that can result in a significant threat and presence of the specified chemicals, etc.). If a significant threat was identified under the worst-case scenario, an attempt was made to verify the actual circumstances, if time allowed in the first round of source protection planning leading to the first plan coming into effect at the end of 2015. Verification methods included review of additional sources of information and/or contact with the landowner. The assumptions made and the verification processes used for each prescribed threat are discussed below. The field verified significant threats counts are reflected each year through annual progress reports available at the source protection region website.

Significant Threats to Surface Water

Only Lake Ontario event-based modelling results can identify significant drinking water threats to surface water in the Hamilton Area. These results indicate that the quality of the lake water at the Woodward municipal water intakes could be significantly affected by existing activities occurring along the shoreline within and outside the Source Protection Area. The results of the modelling work are summarized in Section 6.1.5.

Drinking water threats prescribed in Ontario Regulation 287/07 that were modelled within the Halton-Hamilton Source Protection Region include the operation of sewage systems, and the handling and storage of fuel, and the establishment and operation of a liquid hydrocarbon pipeline. The release of liquid hydrocarbon from a pipeline that crosses Sixteen Mile Creek and Joshua’s Creek in Halton Region was simulated. Additional event-based modelling of activities occurring along the Halton Region to Toronto shoreline and in Port

Dalhousie and Grimsby was also undertaken. If activities occurring outside of this Area have been identified as significant threats to local municipal source water, the neighbouring Source Protection Committee will address those threats.

7.2.2 Managed Lands and Livestock Density

Some of the threat assessments require that cumulative impacts be considered. To address these impacts, lands have been grouped and the intensity of the activities assessed. The groupings are used to calculate the percentage of managed lands and livestock density. Managed lands are defined by the Technical Rules to include lands to which agricultural source material, commercial fertilizer, or non-agricultural source material is applied.

To ensure that all impacts were considered, the percentages of managed lands include non-agricultural managed lands, such as lawns, parks, golf courses, and sports fields, in addition to agricultural crop lands. An assessment was completed of the type and quantity of livestock in the vulnerable areas, in order to quantify the nutrient units generated within the grouped areas. Appendix E includes a summary of the methodology used to calculate managed lands percentages and to quantify nutrient units in the Source Protection Area. Figures 7.1 through 7.5 represent the outcome of the assessments in terms of the percentage of managed lands and livestock density that were used for some of the threat assessments.

7.2.3 Potential Threats Summary

1. Waste disposal sites

Waste disposal sites include all operations regulated by Part V of the *Environmental Protection Act*. The activities that are deemed to be threats are the establishment, operation, or maintenance of these facilities. These activities include:

- application of untreated septage to land;
- storage, treatment, and discharge of tailings from mines;
- landfarming of petroleum refining waste;
- landfilling of hazardous waste;
- landfilling of municipal waste;
- landfilling of solid non-hazardous industrial or commercial waste;
- liquid industrial waste injection into a well;
- polychlorinated biphenyls (PCB) waste storage;
- storage of hazardous waste at disposal sites; and
- storage of certain hazardous wastes.

Waste disposal sites have both chemical and pathogen threats. Active and closed landfill sites and chemical storage areas were considered for this assessment.

2. Sewage systems

The *Ontario Water Resources Act* defines sewage as drainage, storm water, commercial wastes and industrial wastes. The activities that are deemed to be threats under the *Clean Water Act* are the establishment, operation or maintenance of a system that collects, transmits, treats, or disposes sewage.

These activities include:

- combined sewer discharge from a stormwater outlet to surface water;
- discharge of untreated stormwater from a stormwater management facility;
- industrial effluent discharges;
- sanitary sewers and related pipes;
- septic systems;
- septic system holding tanks;
- sewage treatment plant bypass discharge to surface water;
- sewage treatment plant effluent discharges (includes lagoons); and
- storage of sewage.

Municipal and private sewage systems, including residential septic systems, are the most common threats in this category. The threat also stems from activities associated with combined sewer overflows, sanitary and combined sewer pipes, and discharges from wastewater treatment plants and pumping stations. The City of Hamilton reported that in 2020 there were 12 bypasses at the Woodward Wastewater Treatment Plant and 103 discharges from combined sewer overflows at 12 locations.

Stormwater is also included as sewage in legislation, although it is not commonly thought of in this way. Stormwater ponds collect runoff from roads, parking lots, lawns, and fields. This runoff may include (such as those used to salt roads), pesticides, and metals.

Data obtained from the City of Hamilton were used, along with air photos, to assess threats associated with sewage treatment systems. Thus, in this case, fewer assumptions had to be made, and the assessments adequately identify the existing threats. It was assumed that every residence and business in the rural area without either municipal servicing, a lagoon, or regulated private wastewater treatment system had a septic system with a leaching bed.

3. Agricultural source material

Agricultural source material (ASM) is the term used in Ontario Regulation 267/03 made under the *Nutrient Management Act,* 2002 to describe the following:

- manure produced by farm animals, including associated bedding materials;
- runoff from farm-animal yards and manure storages;
- washwaters from agricultural operations;
- organic materials produced by **intermediate operations;**

- **anaerobic digestion** output that meets criteria specified in Ontario Regulation 267/03; and
- regulated compost, as defined in Ontario Regulation 106/09 (Disposal of Dead Farm Animals).

The activities prescribed in regulation under the *Clean Water Act* as threats to drinking water supplies are the storage, management or application to land of any of the materials listed above. These materials typically contain chemicals and pathogens that could alter the quality of the source water.

To identify areas where agricultural activities were ongoing within the Source Protection Area, data from the following sources were obtained and reviewed:

- the Municipal Property Assessment Corporation (MPAC);
- Statistics Canada 2006 Agricultural Census;
- the Ministry of Natural Resources Southern Ontario Land Resource Information System (SOLRIS); and
- air photos.

According to the technical guidance provided by the Ministry of the Environment, the level of risk to drinking water supplies from chemicals associated with the storage, management, or application of agricultural source material is based on the intensity of managed lands and the quantity of **nutrient units** generated within the vulnerable areas. The conservative assumption made is that a higher nutrient unit density results in a greater concentration of nutrients and an increased potential for nutrient contamination of source waters. The combination of managed lands and livestock density of an area is used as a surrogate of nutrients present as a result of generation, storage and land application within the area. This surrogate is used to determine the potential impact of a single property on water quality through the release of nutrients.

Pathogen threats associated with these activities are not determined based on quantity of agricultural source material. Application threats are based on location and storage threats are based on temporary or permanent storage facilities that are above or below grade.

The threat associated with the management of agricultural source material is the use of land or water for aquaculture. This activity could release pathogens.

Threats associated with these materials are only possible where the vulnerability score within the vulnerable areas is 6 or higher for groundwater sources and 4.4 or higher for surface water sources.

4. Non-agricultural source material

Non-agricultural source material (NASM) is defined in the *Nutrient Management Act* as:

- **pulp and paper biosolids**;
- **sewage biosolids**;

- anaerobic digestion output that meets criteria specified in Ontario Regulation 267/03; and
- any other material that is not from an agricultural source and can be applied to land as a nutrient.

The handling, storage, and application of non-agricultural source material are activities that are threats to drinking water supplies. These activities have both chemical and pathogen threats. The percentage of managed lands and livestock density within the vulnerable areas determines the level of chemical risk for the application of non-agricultural source material to account for cumulative impacts. For pathogen threats, it is the source of the material and not the quantity that are assessed to assign a risk level.

To assess the handling and storage chemical threats associated with non-agricultural source material, the storage location and whether it is above or below grade and in a permanent or temporary facility are all considered. The source of the material and storage location above or below grade are considered in the assessment of pathogen threats.

Halton Region owns and operates six wastewater treatment facilities, producing over 35,000 tonnes of biosolids per year. Halton Region manages its Biosolids Land Application Program by applying liquid municipal biosolids from the wastewater treatment plants to agricultural lands within Halton and in other municipalities. In addition, the Region manages a permanent biosolids storage facility in Oakville that is used to store liquid municipal biosolids prior to land application. The Region's biosolids storage facility is an approved facility under the Environmental Protection Act. Temporary field nutrient storage site for liquid prescribed materials (Biosolids) are not employed in the Region's program. Liquid municipal biosolids are the only type of NASM that the Region produces and manages within its boundaries.

In 2005, the City of Hamilton undertook a Biosolids Master Plan to address the challenges associated with the existing practice of biosolid management at the Woodward Wastewater Treatment Plant. Work began on a new Biosolids Management Process in June 2017 and began operations in May 2020. The new management process takes up to 60,000 wet tonnes of wastewater biosolids and dries it into a food grade pellet or Product regulated under the Canadian Food Inspection Agency. The Biosolids Management Project was created to develop a long-term sustainable solution for the City's biosolids, moving away from a wet sludge Class B material to a Class A product through a pelletization process. The end product can now be sold and used as fertilizer or used as fuel replacement. This project is only treating material from the City of Hamilton, receiving dewatered biosolids from both the Woodward and Dundas wastewater treatment plants.

5. Commercial fertilizer

The General Regulation requires the consideration of the storage, handling, and application of commercial fertilizers as activities that are threats to drinking water supplies. Unlike the source material applications, the threat related to these activities is the release of nutrients (nitrogen and phosphorus) only. When assigning the risk level for commercial fertilizer application, the intensity of managed lands and livestock density are considered. The assumption used was that a farmer will use manure when available, but a golf course will always use commercial fertilizers. The threat assessment for the storage of fertilizer considers how and how much of the chemical is stored.

6. Pesticide

Salt storage dome

The quality of drinking water sources may be degraded when chemicals are released during the application, storage, or handling of pesticides. For this reason, these activities are chemical threats under the *Clean Water Act*. The risk level is determined by the size of the land parcel to which the pesticide is applied, the chemical released, and the vulnerable area in which it is applied. For the storage and handling of pesticides, the risk level is determined by the location and type of storage facility (i.e., at the manufacturer, wholesaler, or retailer, or by a commercial user), the quantity of pesticide stored, and the chemical that could be released into the environment. Pesticide licenses were reviewed as well as land uses, including golf courses and farm crop lands.

7. Road salt

The application, handling, and storage of road salt are chemical threats to drinking water supplies. The conservative assumption used for the risk analysis is that road salt is applied during the winter months to impervious surfaces. Roads and parking lots were considered impervious and were drawn from high resolution digital imagery. The risk level for storage and handling of road salt depends on the coverage of the salt pile, the quantity of salt stored, and the release of sodium and chloride to the environment.

In assessing the threat, the percentage of impervious surfaces within each square kilometre of the vulnerable areas within the Source Protection Area was calculated. Then, risk levels were assigned based on this percentage as compared to the thresholds listed in the reference tables. Figure 7.8 illustrates the percentage of impervious lands to which road salt might be applied in the vulnerable areas of the Source Protection Area.

8. Snow dumps

Municipalities and commercial snow removal operators use designated areas to store snow removed from roads and parking lots during the winter months. The snow stored can contain impurities such as road salt, metals, and petroleum hydrocarbons. Therefore, the storage of snow is a chemical threat to drinking water supplies. Depending on the size of the storage area, a significant release of chemicals to groundwater or surface water can occur. The minimum area considered for a significant threat is 1 hectare stored above ground and 0.1 hectare stored below. The City of Hamilton provided the locations of their snow dumps for this assessment. The locations of other snow dumps are not known. These will be studied and the results added to this assessment in an updated report.

9. Fuel

The handling and storage of fuel are activities regarded as chemical threats to drinking water supplies. Risk levels depend on whether the fuel is stored above or below ground, the volume of fuel, the type of fuel, and whether it is stored at a bulk plant, retail location, home, or other facility. The risk with a leaking underground storage tank is greater than an above ground tank because of the inability to conduct visual inspections of underground tanks. For this assessment, the worst case scenario of all fuel being stored underground was assumed. The local gas company was contacted to partially eliminate those addresses within the wellhead protection area where homes were not heated by oil. Only when threats were identified was the scenario verified.

Fuel storage

10. Dense non-aqueous phase liquid

Dense non-aqueous phase liquids are chemical compounds that are denser than water and do not dissolve readily in water. They will sink downward through the water column and the soil or rock until their flow is impeded. These liquids flow with gravity and are difficult to track below ground. This class of compounds includes chlorinated solvents such as tetrachloroethylene (PCE) and trichloroethylene (TCE).

DNAPLs have been readily used in vast quantities for decades in industrial and commercial applications such as dry cleaning, cleaning/degreasing solvents, electronics, aerosols, plastics, pesticides, pharmaceuticals, wood preservation, asphalt operations, varnishes and the repair of motor vehicles and equipment. These chemicals can also be found in small quantities in common household products such as adhesives and cleaners.

Because it is so difficult to clean up water supplies affected by dense non-aqueous phase liquids, their storage and handling is a threat to the drinking water supply at greater distances from the well or intake than other chemical and pathogen threats. Data sources were reviewed to identify industrial, commercial, or municipal properties that could use these chemicals.

11. Organic solvent

Organic solvents are chemical compounds containing carbon that dissolve other substances. The storage or handling of these compounds are a chemical threat to drinking water supplies because of the possibility of a leak or spill to the environment. The compounds considered in this assessment are pentachlorophenol, carbon tetrachloride, methylene chloride, and chloroform. For any other organic solvents, a local threat would need to be identified. The location of the activity, storage above or below ground surface, the volume of the solvent, and the type of solvent are considered when assessing the risk level. The worst case scenario of minimum volume that results in a significant threat and storage underground were used for this assessment. Only when threats were identified were the assumptions verified.

12. Chemicals used to de-ice aircraft

The de-icing of aircraft during the winter months is an important component of flight safety. However, the management of the run-off from the spraying operation does pose a chemical threat to drinking water supplies. The assumption made when assessing risk level is that the number of flights and the size of the planes being de-iced increases with the size of the airport, and so does the amount of runoff that could potentially be released to the environment. Therefore, the size of the airport was considered, along with the chemical used, to assess the risk level of this threat. No airports were identified within the Source Protection Area.

The John C. Munro Hamilton International Airport is located within the Niagara Peninsula Source Protection Area.

13. Land associated with livestock

The generation of agricultural source material in areas where livestock graze, are pastured, or are confined can pose a threat to drinking water. Runoff water from these areas can have elevated concentrations of nutrients and pathogens, which could affect both groundwater and surface water sources. Only the nutrient units generated by animals that can be pastured, or that occupy a confined area or yard, were considered for this assessment.

In general, pasturing or confining farm animals creates a significant chemical threat within a wellhead protection area only when the generation of nutrient units is over the threshold listed in the reference tables. However, pathogen threats exist wherever these activities occur.

14. Establishment and operation of a liquid hydrocarbon pipeline

Five companies own pipelines that transport liquid hydrocarbon products in in the Halton-Hamilton Region Source Protection Region (HHSPR). These companies are Sun-Canadian Pipe Line (Sarnia to Toronto line and Sarnia to Hamilton line), Imperial Oil, Enbridge Pipelines (Line 9 and Line 11), Trans Northern Pipeline Inc. (TNPI), and Westover Express Pipeline (Line 10, operated by Enbridge). These pipelines cross open bodies of water including creeks, Hamilton Harbour, and Lake Ontario. They cross intake protection zones (IPZs) and highly vulnerable aquifers (HVAs) in the HHSPR.

During the first round of source protection planning, liquid hydrocarbon pipelines were not included as a prescribed drinking water threat under the *Clean Water Act, 2006*. The Halton-Hamilton source protection committee (HHSPC) was one of six committees that included oil pipelines in their source protection plan as a local threat, at that time.

Four companies transport liquid hydrocarbon products in pipelines in the Hamilton Region Source Protection Area. The pipelines are of various sizes, typically between 150 and 760 mm.

The Lake Ontario Collaborative did not model this threat activity in the Hamilton Area. They did model this threat in the neighbouring Halton Area, simulating ruptures of a pipeline that crosses near the mouths of Sixteen Mile Creek and Joshua’s Creek. The Ministry of the Environment and Climate Change indicated that it is reasonable to extrapolate the results to pipeline spills of any crude oil, condensate or liquid petroleum product (see Appendix F) into the same creeks farther upstream. They have directed the Halton-Hamilton Source Protection Committee to include these significant threats. Only the spill into Sixteen Mile Creek was simulated as reaching the Hamilton intakes at greater than the threat threshold. The Collaborative chose the Ontario Drinking Water Quality Standard for benzene of 0.005 milligrams per litre as the threshold for a significant threat. An overview of the modelling completed is provided in Section 6.1.5.

In July 2018, the “establishment and operation of a liquid hydrocarbon pipeline” was added as a prescribed drinking water threat through an amendment made to the General Regulation (O. Reg. 287/07) under the Clean Water Act to consistently require the assessment of risk that liquid hydrocarbon pipelines pose to sources of drinking water across all source protection areas.

As a result, in the comprehensive updates for the source protection plan being undertaken per Section 36 of the *Clean Water Act*, these pipelines can pose significant, moderate or low risks to drinking water in certain vulnerable areas as determined in the provincial Table of

Drinking Water Threats. The Technical Rules set out the circumstances of occurrence include the following, for specified chemicals in any quantity:

- pipelines above ground or above a water
- pipelines below ground and not crossing underneath a water body
- pipelines within or under a water body.

The specified chemicals of concern, that could be released to water due to a rupture of a liquid hydrocarbon pipeline, are any quantity of: benzene, toluene, ethylbenzene, and xylene (collectively known as BTEX), and petroleum hydrocarbons F1 (nC6-nC10), F2 (>nC10-nC16), F3 (>nC16-nC34), F4 (>nC34).

This new prescribed threat captures pipelines designated for transmitting or distributing liquid hydrocarbons to terminals and distribution centers; it does not capture pipelines that move liquefied natural gas or liquid petroleum gas. It also does not capture pipelines operated by the Ministry of Natural Resources and Forestry (MNRF) as defined in the Oil, Gas and Salt Resources Act, or those that operate within a property such as a refinery. Pipelines that convey liquid fuel within a single property would fall under the prescribed threat 'handling and storage of fuel.'

7.3 Drinking Water Threats - Conditions

A condition is the result of past activities. It could be an area of known contamination in the soil or sediment or a known plume in groundwater that is impacting, or has the potential to impact, a drinking water source. The term "condition" does not apply to properties where the activity is still ongoing. Part XI.3 of the Technical Rules requires that the following conditions must be listed as drinking water threats if they are known to exist and refers to provincial standards listed in Soil Ground Water and Sediment Standards for Use Under Part XV.1 of the *Environmental Protection Act* (April 15, 2011) http://www.ontario.ca/environment-and-energy/soil-ground-water-and-sediment-standards-use-under-part-xv1-environmental:

1. The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, significant groundwater recharge area, or wellhead protection area.
2. The presence of a single mass of more than 100 litres of one or more dense nonaqueous phase liquids in surface water in a surface water intake protection zone.
3. The presence of a contaminant in groundwater at a concentration that exceeds the applicable potable groundwater standard, listed in Table 2 of the Soil, Ground Water and Sediment Standards made under the *Environmental Protection Act* in a highly vulnerable aquifer, significant groundwater recharge area, or a wellhead protection area.
4. The presence of a contaminant in surface soil that exceeds the surface soil standard for industrial/commercial/community property use listed in Table 4 of the Soil, Ground Water and Sediment Standards in a surface water intake protection zone.

5. The presence of a contaminant in sediment at a concentration that exceeds the appropriate standard, listed in Table 1 of the Soil, Ground Water and Sediment Standards in an intake protection zone.

6. The presence of a contaminant in groundwater that exceeds the potable groundwater standard listed in Table 2 of the Soil, Ground Water and Sediment Standards and is discharging into an intake protection zone.

7. Data sources used to evaluate potential conditions within the Source Protection Area include:

- a contaminant sources assessment completed for the City of Hamilton by SNC-Lavalin Engineers & Contractors in association with Charlesworth & Associates (April 2006);
- a field survey carried out by Waterloo Hydrogeologic, Inc. (now Schlumberger Water Services) to augment the above assessment and create a threats inventory (Waterloo Hydrogeologic, 2007);
- Ministry of the Environment, Conservation and Parks files on record for sites within Hamilton SPA vulnerable areas;
- sediment quality data from various sources, including Ministry of the Environment, Conservation and Parks, Environment and Climate Change Canada, Hamilton Region Conservation Authority; and
- discussions held with the City of Hamilton, Hamilton Region Conservation Authority, and stakeholders in the vicinity of the Greensville well.

Based on these sources, no conditions were identified in the Hamilton Region Source Protection Area.

7.4 Drinking Water Threats Assessment

7.4.1 Water quality threats assessment

Technical Rules 9 (1)(e) and (f) require that the locations be counted where an activity is engaged in or a condition resulting from a past activity exists that are significant drinking water threats.

No significant threats due to conditions were identified. Threats due to activities are summarized in Table 7.1.

The threat activity associated with the Woodward Avenue Wastewater Treatment Plant is a significant threat to the Burlington municipal water intakes in the Halton Region Source Protection Area. In addition, some threat activities ongoing in other jurisdictions are significant threats to the Woodward water intakes. These significant threats are summarized in Table 7.2. It should be noted that although there are a number of significant threats identified, the concentrations of the contaminants of concern may be only slightly greater than the criteria used to identify significance and would not cause concern for the water treatment plant operators.

The wellhead protection areas for the Greensville municipal well system include residential properties, a school and a park. Based on current practices, the only identified existing significant threat to the quality of the source water is the operation of septic systems. Small residential septic systems are considered a pathogen threat, while the larger school septic system could also be a chemical threat. These significant threats are possible in a portion of the wellhead protection area (see section 7.5) and properties may be within or partially within these areas. As such, the location of the septic system on each property partially within the significant threat areas must be verified.

To address the existing and potential future significant threats to the quality of the drinking water sources, appropriate policies must be included in the Source Protection Plan. These policies will address threat activities occurring within vulnerable areas in the Hamilton Region Source Protection Area. Threat activities occurring outside this Area will be addressed by policies in the relevant Plan. However, policies in the Plan for the Hamilton Region Source Protection Area will address the identified significant threats in mapped vulnerable areas that extend into our Area.

When funding is available, source protection staff will continue the assessment of potential threats along the shore of Lake Ontario, including Hamilton Harbour, and modelling will be completed, where warranted. The findings of the study will be reported in an updated Assessment Report, and if required, policies to address the threats identified will be developed as part of an amended Source Protection Plan.

Table 7.1 Significant threats to the source water quality of the Greensville municipal wells and Woodward municipal intakes from local activities

Drinking Water Threat	Number of Occurrences	
	Greensville	**Woodward**
Sewage system operation	34 pathogen, 1 chemical	1 pathogen

Note: The threat count is based on airphoto interpretation. The field verified threats counts are provided yearly through annual progress reports available at the source protection region website.

Table 7.2 Lake Ontario cross-boundary significant threats (based on peak concentrations) identified through the event-based modelling approach

Threat Activity	Source of Significant Threat	Receptor of Significant Threat
Sewage system operation	Woodward Avenue	Burlington Intakes
	Mid-Halton WWTP	Woodward Intake
	Skyway WWTP	Woodward Intake
Fuel – handling and storage	Bulk Fuel Storage	Woodward Intake
	Ship Off-loading	Woodward Intake
Liquid hydrocarbon pipelines that crosses an open body of water*	Sixteen Mile Creek	Woodward Intake

Notes: WWTP = wastewater treatment plant
* The release of liquid hydrocarbons into one creek at one location was modelled, however, by extending the results upstream the number of pipeline crossings of the creek increases to 111 locations where the threat activity occurs.

The total number of significant threats to the Woodward municipal intakes source water is six.

7.4.2 Water quantity threats assessment

The Technical Rules require an assessment of drinking water threats when a risk level of significant or moderate is assigned to a municipal water supply. As discussed in Section 5.6.5, Earth*fx* Incorporated assigned a risk level of low to the Greensville well supply and, therefore, no water quantity threat activities are identified.

7.5 Potential Threat Areas

Technical Rule 9 (1) requires that maps be produced to show the areas where significant, moderate, and low threats could occur within the Source Protection Area if the associated threat activities were taking place. Figures 7.7 and 7.8 show these areas for water quality threats in wellhead protection areas and intake protection zones, while Figure 6.5 shows the area for highly vulnerable aquifers (HVAs). Significant drinking water quality threats are possible only within the wellhead protection areas with vulnerability scores of 10 or 8. Moderate and low threats are possible in the intake protection zones 1 and 2, and highly vulnerable aquifers. The intake protection zone maps illustrate the locations where event-based modelling has shown that there are significant drinking water threats to the lake-based source water. Figure 7.8 maps where local activities could impact local municipal intakes. Figure 7.9 illustrates where local activities could impact municipal intakes in other jurisdictions. The drinking water threat activities and the circumstances that apply within these vulnerable areas can be reviewed at http://swpip.ca using the Source Water Protection Threats Tool and Table of Drinking Water Threats.

The information in Table 7.3 summarizes the possible level of threat to the municipal source water from prescribed and approved local activities that could affect the water quality within the vulnerable areas of the Hamilton Region Source Protection Area.

As mentioned previously, threats to the quantity of the source water for the municipal water supplies were not identified because the risk that the activities pose is low.

Table 7.3 Applicable water quality threat levels for the vulnerable areas of the Hamilton Region Source Protection Area

Vulnerable Area	Vulnerability	Threat Level Possible								
		Chemical			Pathogen			Dense Non-Aqueous Phase Liquid		
		S	M	L	S	M	L	S	M	L
WHPA-A	10	x	x	x	x	x		x		
WHPA-B	10	x	x	x	x	x		x		
WHPA-B	8	x	x	x		x	x	x		
WHPA-B	6		x	x			x	x		
WHPA-C	8	x	x	x				x		
WHPA-C	6		x	x				x		
WHPA-C	2							x		
WHPA-D	6		x	x					x	x
HVA	6		x	x					x	x
IPZ-1	5			x		x	x			
IPZ-2	4.0									
IPZ-3	Not assigned	Significant threats as determined through assessment								

Note: Risk Levels - S = significant, M = moderate, L = low

8. SUMMARY

In this section:

- Summary of the required process
- Summary table of water quantity stresses
- Summary table of threats to municipal supplies
- Next steps

This Assessment Report, which addresses drinking water supply and quality within the Hamilton Region Source Protection Area, is the result of a combined effort by staff, the Halton-Hamilton Source Protection Committee, the Halton Region and Hamilton Region Source Protection Authorities, Hamilton Conservation Authority, stakeholders and the public at large. Together, these groups have worked to assess the stresses on the supply of water and the threats to its quality.

The results of these assessments are documented in this report and summarized below.
The process involved in the compilation of this report began after the Town of Walkerton's contaminated drinking water tragedy in 2000. As discussed in Section 1, this event prompted the Provincial Government to introduce new legislation to safeguard Ontario's drinking water supplies. The *Clean Water Act,* one piece of this legislation, requires communities to develop protection plans for their existing and future drinking water supplies.

8.1 Scope: the Hamilton Region Source Protection Area

The scope of this Assessment Report covers the Hamilton Region Source Protection Area. This area includes: lands within the municipalities of the City of Hamilton; the Township of Puslinch/County of Wellington; and the Town of Grimsby/Niagara Region.

The report focused on the City of Hamilton's two drinking water systems. The Woodward system takes water from Lake Ontario, and along with the Grimsby system and following treatment, distributes it to about 97 percent of the population within this Source Protection Area. In addition, this system provides water to portions of Halton Region and Haldimand County. Hamilton's second drinking water system, the Greensville municipal wells, provides water to about 0.03 percent of the population within the Source Protection Area.

8.2 Methodology

The required methods used in the assessments reported on in this document and undertaken to comply with the requirements of the *Clean Water Act* are outlined in the following documents:

- 2017 Technical Rules by the Ministry of the Environment, Conservation and Parks; and
- Technical Bulletins prepared by the Ministry of the Environment, Conservation and Parks on various relevant studies.

For further explanation, these documents can be retrieved from our website at www.protectingwater.ca

8.3 Summary of Water Quantity Stresses and Risks

As explained within the body of this report, the water budget and water quantity stress assessment identified 14 subwatersheds within the Hamilton Region Source Protection Area that are either moderately or significantly stressed. This assessment is based on the monthly demand on the available surface water supply.

The assessment of the Area also identified three subwatersheds that were stressed based on monthly and/or annual demand on available groundwater supply. One of these subwatersheds, Middle Spencer Creek of the Spencer Creek watershed, is the subwatershed in which the Greensville municipal well operates. Accordingly, it was required that a focused study be undertaken to look at the local area surrounding the well to assess risks to the water supply. This assessment found that the Greensville well supply has low risk of not sustaining the quantity of water demanded.

Table 8.1 provides a summary of the results of the water budget and water quantity stress assessment detailed within this report. The existing stresses for the study year of 2007 and future stresses for 2031 on groundwater supplies are the same.

8.4 Summary of Vulnerable Area Delineation and Threats

In order to carry out the water quality risk assessment for this report, protection areas were delineated, and their vulnerability assessed where activities could affect municipal drinking water supplies. These areas are:

- where water is supplying the municipal drinking water supplies – wellhead protection areas and intake protection zones
- where groundwater is susceptible to contamination – highly vulnerable aquifers
- areas where infiltrating water recharges a substantial portion of the groundwater supply – significant groundwater recharge areas

The next step was to evaluate whether the drinking water supplies had any existing water quality issues. In addition, it was necessary to locate any threats from existing or past activities within the vulnerable areas that could cause an issue at the well or intake. Finally, it was essential to determine where activities would be a threat to a municipal drinking water supply, if that activity began.

Based on the possible vulnerability scoring within the vulnerable areas, only the Greensville wellhead protection areas can have threats at a significant level in groundwater. Therefore, Table 8.2 summarizes the possible existing significant threats to the Greensville municipal water supply from ongoing activities.

Table 8.1 Hamilton Region Source Protection Area Water Quantity Stress Level Summary

Watershed	Subwatershed	Municipal Well	Stress Level					
			Surface Water		Groundwater			
			Monthly		Monthly		Annual	
			Moderate	Significant	Moderate	Significant	Moderate	Significant
Spencer Creek	Ancaster Creek		x					
	Borer's Creek			x				
	Flamborough Creek			x				
	Logie's Creek		x		x		x	
	Middle Spencer Creek	Greensville	x				x	
	Spring Creek			x				
	Sulphur Creek		x					
	Sydenham Creek		x					
	Tiffany Creek		x					
	West Spencer Creek			x				
Red Hill Creek	Hannon Creek			x				
	Lower Davies Creek				x			x
Stoney Creek Watercourses	WC 7		x					
	WC 10.1		x					
	WC 12		x					

Neither Woodward nor Greensville had drinking water quality issues identified. Also, based on the data reviewed, no conditions resulting from past land use activities exist within the Hamilton Region Source Protection Area.

Table 8.2 Significant threats to the Greensville municipal source water

Drinking Water Threat	Number of Occurrences
Sewage Systems	34 pathogen, 1 chemical

The Lake Ontario Collaborative has completed event-based modelling to assess risk to source water for municipal intakes located between Port Dalhousie and Quinte and to identify intake protection zone threes. The modelled scenarios predict significant threats to the Woodward municipal intakes' source water from the discharge of *E.coli* from a wastewater treatment plant during a total plant failure, and when fuel (benzene) is released during off-loading from a ship at a pier in Oakville. Modelling also showed that a release of fuel from a bulk fuel storage facility could impact the municipal source water. The Source Protection Committee did not reach consensus on the designation of this activity as a significant threat because the conditions modelled do not reflect a plausible scenario. The designation as a significant threat remains at the request of the Ministry of the Environment and Climate Change because a credible scenario may result in similar findings. The Committee will undertake additional assessment when provincial funding is available.

As explained in Section 6.1.5, modelling completed by the Lake Ontario Collaborative indicates that a release of liquid hydrocarbon from a rupture of the pipeline into Sixteen Mile Creek will significantly affect the quality of source water at Woodward intakes, as well as in some areas of Halton Region and Mississauga. The Ministry of the Environment and Climate Change indicated that it is reasonable to extrapolate the results to pipeline spills of any crude oil, condensate or liquid petroleum product (see Appendix F) into the same creek farther upstream. They have directed the Halton-Hamilton Source Protection Committee to include these significant threats.

Table 8.3 summarizes the significant threats from these activities for the Woodward municipal intakes and the locations of the significant threats are shown on Figure 7.10.

Additional study is required to assess the possibility of additional significant threats to lake source water.

Table 8.3 Significant threat count from all sources to the Woodward municipal intakes source water

Drinking Water Threat Activities	Number of Occurrences
Local	1
Other Source Protection Areas	5
Total	**6**

8.5 Conclusion

This Assessment Report is the foundation for development of a Source Protection Plan for the Hamilton Region Source Protection Area. As such, it is a living document. In compliance with the *Clean Water Act, 2006,* the report will be reviewed and updated periodically and as data/information becomes available that could affect the Source Protection Plan.

This Assessment Report identifies technical work, research, data collection, and verification of assessments completed that should be undertaken and reported on in an updated report. The studies include:

- a reassessment of the risk to drinking water sources that the bulk fuel storage in Oakville poses
- further assessment of the need for and delineation of additional intake protection zone 3 for the Woodward Lake Ontario intakes
- collection of stream flow data to improve the delineation of the intake protection zone two for the Woodward intakes
- verification of site-specific conditions to improve the threats assessment
- an assessment of issues to drinking water systems in the highly vulnerable aquifer and significant recharge areas
- consideration of the inclusion of local threats in updated assessments
- research to reduce the uncertainty surrounding the use of the travel times through the unsaturated zone as part of the vulnerability assessment within the wellhead protection areas
- monitoring and assessment of the impacts of climate change on water resources in the Source Protection Area as predictive science improves and local studies are completed
- an assessment of impacts on water budget components due to development within the Source Protection Area
- inclusion of the findings of the City of Guelph and Guelph/Eramosa Township Tier 3 assessment including a count of significant threat activities occurring in the Area

The work will be completed when funding is available.

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APPENDIX A: COLLABORATION AND CONSULTATION

Appendix A.1 Collaboration

Source protection planning under the *Clean Water Act* is a community-wide initiative that requires municipal representatives, residents and business owners to work together with provincial agencies and Conservation Authorities. To facilitate the local development of Source Protection Plans, the Conservation Authorities are appointed as Source Protection Authorities and either work alone or in partnership with neighbouring areas.

In this area, Halton Region Conservation Authority (Conservation Halton) and Hamilton Conservation Authority work together as the Halton-Hamilton Source Protection Region. Although the Halton Region Source Protection Authority serves as the lead agency, the two authorities work cooperatively to manage the project.

The Source Protection Authorities are responsible for establishing the Source Protection Committee and overseeing the source protection process. They provide administrative, scientific and technical support and resources to the committee during the development of the assessment reports and the source protection plans. Technical experts were hired as Halton-Hamilton Source Protection staff to undertake these tasks. The project manager was responsible for preparation of this assessment report.

The Halton-Hamilton Source Protection Committee comprised 16 members during the planning stages of the program between 2007 and 2015 and during implementation comprises 10 members. The first chair of the Source Protection Committee, Doug Cuthbert, was appointed by the Minister of the Environment and Climate Change in 2007 and remained chair until 2013. Robert Edmondson was then appointed by the Minister as chair in 2014. The other nine members of the committee were appointed by the Source Protection Authority. As required by law, the committee is composed as follows:

- one-third municipal representatives
- one-third agricultural, industrial or commercial representatives
- one-third general public representation, including health and environmental interests

The committee is required to work cooperatively with municipalities, conservation authorities and provincial agencies and to represent the broad interests of those that live and work within the region.

Current membership
The Halton-Hamilton Source Protection Committee members at this time are listed below with their period of involvement:

Chair

Robert Edmondson – 2014 to present

Municipal Sector

Councillor Judi Partridge, City of Hamilton – 2011 to present
David Rodgers, Aberfoyle Aquascience – 2016 to present

Daniel Banks, Regional Municipality of Halton - 2018 to present

Agricultural Sector

Gavin Smuk, Ontario Federation of Agriculture – Hamilton-Wentworth – 2007 to present

Scott Stewart, Halton Region Federation of Agriculture, 2021 - present

Industrial/Commercial Sectors

Sarah Lock, Trans-Northern Pipeline Inc. (TNPI), 2020 – present

General Public/Environmental Interest

Dana Couture, Aquatic Biologist, 2018 – present
Carla Coveart, GM BluePlan Engineering, 2019 - present
Christopher Murray, Environmental Scientist, 2021 - present

The following persons also participate in discussions at meetings of the Halton-Hamilton Source Protection Committee, as non-voting Liaisons:

- Designated representative of the Ministry of the Environment, Conservation and Parks: Elizabeth Forrest (Liaison Officer, Source Protection Programs Branch)
- Designated representative of the Halton Region Source Protection Authority: Dr. Barbara Veale (Director, Planning and Watershed Management, Conservation Halton)
- Designated representative of the Hamilton Region Source Protection Authority: Scott Peck (Deputy CAO/Director, Watershed Planning & Engineering, Hamilton Conservation Authority)

Representative of the medical officers of health for the health units in any part of the source protection region: Richard MacDonald (Manager, Food and Water Safety, City of Hamilton Public Health Services).

Past Membership

The following are past members of the committee and contributed to the process:

Past Chair

Doug Cuthbert - 2007 to 2013

Municipal Sector

Chris Shrive, City of Hamilton – 2008 to 2014
Dave Kerr, City of Hamilton – 2007 to 2008
Mary Lou Tanner, Halton Region – 2007 to 2008
Councillor Margaret McCarthy, City of Hamilton – 2007 to 2010
Jacqueline Weston, Halton Region – 2008 to 2010
Bert Posedowski, City of Hamilton – 2014 to 2016
Barry Lee, Halton Region – 2007 to 2015
David Simpson, Halton Region – 2010 to 2016
Councillor Susan Fielding, Township of Puslinch – 2007 to 2015

Adam Gilmore, Halton Region – 2016 to 2018

Agricultural Sector

Nick DiGirolamo, Ontario Federation of Agriculture – Halton – 2007 to 2017
Bert Andrews, Ontario Federation of Agriculture – Halton – 2017 to 2020

Industrial/Commercial Sectors

Michael Kandravy, Suncor Energy Products Partnership – 2016 to 2019
Teri Yamada, IPM Council of Canada – 2007 to 2012
Peter Ashenhurst, Home Builders Sector - 2007 to 2013
Melanie Horton, Aggregate Sector – 2007 to 2016
Michael Barton, Home Builders Sector – 2014 to 2016

General Public Interest

Adam Kuehnbaum – 2007 to 2011
Andrea Doherty – 2011 to 2016
Dave Braden – 2007 to 2018
Glenn Powell – 2007 to 2020

Environmental Interest

Paul Attack – 2009 to 2014
Betty Hansen – 2007 to 2009
Mark Sproule-Jones – 2008 to 2009
Daisy Radigan – 2014 to 2016
Turlough Finan – 2009 to 2019

Technical experts assisted in the peer review of the underlying studies in this report. Consultants who completed the technical studies are referred to in the body of the text. The methodology used to delineate wellhead protection areas and assign vulnerabilities within them was peer reviewed by AMEC Earth and Environmental under the management of Simon Gautrey. The water budget and water quantity stress assessment was peer reviewed by a committee comprised of Dr. Paulin Coulibaly of McMaster University, Dr. Dave Rudolph of Waterloo Hydrogeology Advisors Inc., Simon Gautrey and Aaron Farrell of AMEC Foster Wheeler Environment & Infrastructure, and representatives of the appropriate municipality and conservation authority.

Advisors to the program during development of this Assessment Report included:

- Tea Peshava Ministry of the Environment, Conservation and Parks (MECP) Liaison
- Mary Wooding, MECP Liaison
- John Westlake, Ministry of the Environment Liaison
- Scott Bates, Ministry of Natural Resources Liaison
- Nicole Mathews, Halton Region, Medical Officer of Health Liaison – 2007 to 2010
- David King, Hamilton Health Services, Medical Officer of Health Liaison – 2011 to 2014
- Tony Colaco, Halton Region, Medical Officer of Health Liaison - 2014 to present
- Ken Cornelisse, Ministry of Natural Resources Technical Representative – Guelph District
- Robert Fancy, Ministry of Natural Resources Technical Representative – Aurora District
- Kathy Menyes, Conservation Halton Liaison
- Scott Peck, Hamilton Conservation Authority Liaison

We thank everyone for their contribution.

Appendix A.2 Consultation

The Source Protection planning process is open and transparent with many opportunities for government, private sector, and community participants to provide input. The public were invited to get involved in protecting their drinking water sources and to share their local knowledge and drinking water concerns with the Source Protection Committee. The Committee and staff took the source protection message to the public as well as inviting them to come meet with us.

Stakeholder Meetings

Focused stakeholder meetings were held in the rural communities where the municipal drinking water systems are located. Their purpose was to:

- Engage and inform community leaders and representatives on the Halton-Hamilton Drinking Water Source Protection Program;
- Ask for public views, comments, and suggestions on completion of the Assessment Report work; and
- Initiate a discussion on Drinking Water Source Protection Plan ideas.

Representatives of each community were invited to attend a session with Source Protection Committee members and the municipality. Details of the meetings and participants are documented in Table 1.

Table 1 Focus Stakeholder Meeting Details

Meeting Date and Time	Meeting Location	Representatives in Attendance
May 19, 2009 7 to 9 pm	Christ Church Flamboro, 92 Highway #8, Flamborough	Residents, Greensville Against Serious Pollution (GASP), Conserver Society of Hamilton and District, Developer, Flamboro Downs
May 27, 2009 7 to 9:30	Halton Region Museum Hearth Room 5181 Kelso Road, Milton	Dufferin Aggregates, Milton Ratepayers Association, Conservation Authority Lands Division
June 17, 2009 7 to 9:30 pm	Carlisle Community Centre 1496 Centre Road Carlisle	Residents, Flamboro Springs, Agriculture, Friends of Rural Communities and the Environment (FORCE), Benson Chemicals, St. Marys Cement

Staff also participated in many community events with the objective of raising awareness about the *Clean Water Act* and source protection planning amongst the residents of Halton Region and Hamilton Region Source Protection Areas. Presentations were given and display booths were used. A brochure and municipal supply fact sheets were important give-aways at these events. Some of the events we attended are listed below.

- City of Hamilton open houses held under the Ontario Drinking Water Stewardship Program
- City of Hamilton well and septic contractors workshop held under the Ontario Drinking Water Stewardship Program
- Halton Region well water information sessions
- Rockton and Milton Fall Fairs, Milton Cornfest, Burlington Ribfest
- RBC Canadian Open
- Presentation to Realtors Association of Hamilton-Burlington
- Presentation to Conservation Halton Agricultural Advisory Committee
- Presentation to Hamilton Conservation Authority's Water Management Advisory Board.

Notification to Landowners

Once the wellhead protection areas were delineated, two letters were sent to landowners. The first was a general introduction to source protection planning and made the landowner aware that their property was situated within a wellhead protection area. This letter was sent out on July 22, 2010, following the initial study and about June 30, 2017 for the update study to all landowners with properties in wellhead protection areas A through C, i.e., up to the 5-year time of travel and in 2017 to all landowners within the water quantity wellhead protection areas.

The second letter was the legislated notification that our studies had shown that the landowner was engaged in an activity that is a significant threat to the municipal drinking water supply. For the first assessments, a total of 599 letters were sent to landowners in the Halton Region Source Protection Area and 55 were sent to landowners in the Hamilton Region Source Protection Area. The letters were sent out between September 9 and 15, 2010. This letter identified the subject wellhead protection area and the threats identified. The letter was part of a package that included factsheets about the municipal water supply, and the Ontario Drinking Water Stewardship Program administered by the Halton-Hamilton Watershed Stewardship program and the Ontario Soil and Crop Association. A copy of the general letter and attachments is included as Appendix A.2a.

A second letter will be sent in the fall of 2017 to the Greensville landowners within the revised wellhead protection areas for quality and quantity threats.

Consultation on the Draft Proposed Assessment Report

The Source Protection Committee released the Draft Proposed Assessment Reports for the two Source Protection Areas for public review and comment on September 9, 2010. The reports were available on the program website at www. protectingwater.ca for review and/or downloading.

Notification of the release was accomplished through:

- Local newspapers – sample notice is included as Appendix A.2b.
  - Hamilton Spectator
  - Hamilton Free Press
  - Flamborough Review
  - Milton Canadian Champion;
- Conservation Halton Focus newsletter – circulation 110,000 in Burlington, Oakville and Milton;
- E-mail of notification to those subscribed through the program website and to those who registered with us as interested parties at community events;
- E-mail to municipal clerks (see distribution list below) and conservation authorities with follow-up hard copies of the appropriate report(s). The clerks/receptionists were requested to post the notification and to make the report(s) available to anyone wishing to review them;

<u>Distribution List</u>
  - Halton Region
  - City of Burlington
  - Town of Oakville
  - Town of Milton
  - Town of Halton Hills
  - City of Hamilton
  - Township of Puslinch
  - Conservation Halton
  - Hamilton Conservation Authority

- E-mail notification to John Hall – Hamilton Harbour Remedial Action Plan coordinator;

- E-mail notification to Conrad Debarros – contact for Lake Ontario Lakewide management Plan; and
- Verbal communication and e-mails to neighbouring Source Protection Area project managers, chairs, and staff.

The Source Protection Committee held four public meetings in the two Source Protection Areas as follows:

- October 1 - 9 to 11 a.m. at Country Heritage Park Administration Building, Niagara Conference Room, 8560 Tremaine Road, Milton;
- October 1 - 7 to 9 p.m. at Lakeland Community Centre, Lakeland Hall, 180 Van Wagner's Beach Road, Hamilton;
- October 4 - 9 to 11 a.m. at Christ Church Flamboro, 92 Highway 8, Flamborough; and
- October 4 - 7 to 9 p.m. at Halton Regional Centre, Dakota/Glenorchy Rooms, 1151 Bronte Road Oakville.

A total of thirteen people attended the public meetings.
Comments received until October 26, 2010, were presented to the Source Protection Committee for discussion at a meeting held that day. One member of the public submitted comments on the draft Halton Region report. The City of Hamilton Public Health Services submitted comments on the Hamilton Region report and the Ministry of the Environment submitted comments on both reports.

Following discussion of the comments received and staff's response, the Source Protection Committee endorsed the finalization of the Proposed Assessment Reports and their release to the Source Protection Authorities for circulation. The Act requires that a summary of any concerns that were raised by municipalities during consultations and that were not resolved to the satisfaction of the municipalities also be submitted to the Authority. No such concerns have been raised by our partner municipalities.

Consultation on the Proposed Assessment Report

The public consultation period on the Proposed Assessment Report was held between November 5 and December 5, 2010. The public was invited to submit written comments to the Source Protection Authority.

Copies of the report were given to the clerk of the larger municipalities within the Source Protection Area to be available for public review. Notification of their release for review and comment was through e-mail and the source protection website.

Consultation on Updated Assessment Reports

Version 1.3 of this Assessment Report was approved by the Ministry of the Environment on June 30, 2011. An update, version 2.1, was subsequently approved on February 9, 2012. The updates were focused on the inclusion of the results of the Lake Ontario Collaborative assessment of surface water threats. Consultation on the updates was targeted to those affected by the changes, namely the landowners whose activities were modelled.

Version 2.3 of the report focused on the surface water threat assessment as was consulted on for 30 days in March/April 2014 and a public meeting was held in the Halton Region Source Protection Area on March 24, 2014, between 7 and 9 at the Gellert Community Centre, 10241 Eighth Line, Georgetown.

Version 2.6 includes revisions and additions:

- revised wording and inclusion of additional significant threat activities for the Lake Ontario municipal intake
- updated wording to reflect the completion of the Source Protection Plan
- editorial revisions to discuss updates to legislation, technical reports, and data

Version 2.6 was released by the Halton-Hamilton Source Protection Committee for a 60-day public consultation period on December 1, 2014. Landowners, stakeholders, the public and municipalities were notified of this release through letters, e-mail, media releases and a newspaper notice. This outreach was focused mainly in the Milton area since the amendments to the documents primarily affect that area. A public meeting was held January 22, 2015 at the Nassagaweya Tennis Centre and Community Hall, Milton. All comments received during the public consultation were considered by the Source Protection Committee prior to finalizing the documents for submission to the Ministry of the Environment and Climate Change. Version 2.6 was revised slightly with some new formatting and editorial corrections as Version 2.7.

The Clean Water Act, 2006 enables source protection plans and assessment reports to be revised using one of four methods listed below. Per the Ministry of the Environment, Conservation and Parks (MECP), the method used depends on factors such as the level of complexity of the revisions and how time sensitive they are.

1. a locally initiated amendment under section 34;
2. a Minister ordered amendment under section 35;
3. an update resulting from the review under section 36; or
4. an amendment under section 51 of O. Reg. 287/07 for minor/administrative revisions.

The Version 3.1edits are a combination of an update under Section 34 of the *Clean Water Act, 2006* to include the findings of the recent Greensville municipal supply studies and an update under Section 51 of Ontario Regulation 287/07 to fix identified typographical and formatting errors and small inconsistencies with the current understanding of activities in the Source Protection Area. The Halton Region and Hamilton Region Source Protection Authorities and the Halton-Hamilton Source Protection Committee are of the opinion that this update to the documents is advisable. A public information centre was held July 11, 2017, in Greensville on the findings of the Greensville studies and another was held November 16, 2017 on this version of the report. The public was consulted between October 16 and December 1, 2017. The public consultation was held in conjunction with that required by the City of Hamilton for the new Greensville well Class Environmental Assessment process.

Comprehensive Updates to the Source Protection Plan
Per Section 36 of the Clean Water Act

The current edits to the document are tracked as Version 4.1. The edits are comprehensive updates made under Section 36 of the Clean Water Act, per the Minister's amended Order of March 2019. The comprehensive updates based on best available data include: watershed characterization updates, removal of reference of vulnerability scores and water quality threats for significant groundwater recharge areas, removal of sodium and chloride references from the circumstances related to on-site sewage systems and holding tanks, updates to circumstances for the handling and storage of fuel in intake protection zones, liquid hydrocarbon pipeline activities as prescribed drinking water threats, alignment of terminology to the Technical Rules 2017, and consideration of transport pathways in wellhead protection areas.

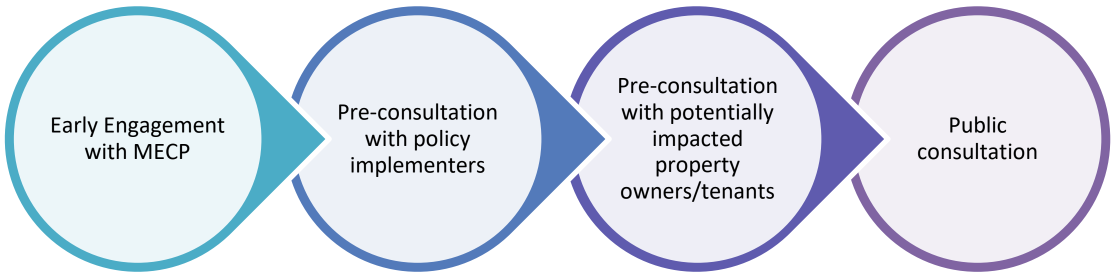
Upon approval of the first source protection plan for the Halton-Hamilton Source Protection Region (HHSPR) on December 31, 2015, the Minister of the MECP issued an order requiring the subsequent submission of a workplan by November 30, 2018, to review source protection plans per Section 36 of the Clean Water Act. These workplans were required across Ontario, leading to the second round of source protection planning across the province.

The HHSPR workplan includes tasks to review both science and policies, to support the continued protection of drinking water sources. It is available at: https://bit.ly/3k6pyu0. The HHSPR workplan was reviewed by MECP, resulting in the Minister issuing an amended order in March 2019 pursuant to Section 36 of the Clean Water Act. This amended order specifies the mandatory items from the workplan.

Through 2019-2022, HHSPR staff are undertaking updates to the assessment reports, source protection plan, and explanatory document per Section 36. Through an established municipal working group, municipal staff are engaged. The updates are brought to the Halton-Hamilton Source Protection Committee (HHSPC) for review and endorsement.

Early Engagement and Consultation Stages

The engagement and consultation stages are shown in the figure below and described in detail.



Early engagement

Early engagement with MECP ensures that the MECP is engaged before technical and policy work is finalized, in order to provide essential early feedback. Early engagement helps to ensure that technical reports and information that supports the assessment report changes are evaluated by MECP to meet the requirements of the technical framework (prescribed under the Clean Water Act, including the Director's Technical Rules and Tables of Drinking Water Threats) in effect at the time of the updates. Comments from the MECP are to be addressed by providing responses, before moving to the next stage.

Pre-consultation

Pre-consultation refers to the regulatory requirements within O. Reg. 287/07 (s.35 to s.39) and the amended Minister's orders under section 36, to consult with impacted implementing bodies and persons/businesses believed to be engaged in significant drinking water threat activities that are affected by the updates. This must be done prior to conducting broader public consultation.

More specifically, it refers to the requirement to send notices to these persons or bodies, including government ministries that have obligations under the Clean Water Act. The implementing bodies and persons/businesses believed to be engaged (in significant drinking water threat activities) are to be made aware of the source protection plan and assessment report revisions and given an opportunity to provide feedback as early in the process as possible. The SPA determines if pre-consultation with implementing bodies and persons/businesses engaged is done concurrently or at different times, taking into consideration the nature of the policy updates and various factors influencing each update.

Municipal council resolutions

Prior to conducting public consultation for locally initiated amendments under section 34, the Clean Water Act requires the SPA to obtain a municipal council resolution from municipalities affected by the amendments. There is no legislative requirement to obtain a municipal council resolution as part of amendments or updates under sections 35 or 36 of the Clean Water Act, unless explicitly stated in the Minister's order. However, municipalities have the discretion to pass resolutions expressing comments on the proposed updates. Where a municipality has provided council resolutions, the SPA must submit those to the ministry with the proposed revisions.

The Minister's amended Section 36 order for the HHSPR does not require municipal council resolutions for Section 36 updates.

Public consultation

The public consultation requirements for revisions are similar to those during initial source protection plan development; however, per the MECP, for locally initiated amendments and s.36 orders issued to date, only one public consultation opportunity is required and there is no requirement for a public meeting. The SPA may have a public meeting depending on local circumstances and the scope and scale of the changes. The public consultation period must be for a minimum of 35 days (or as otherwise noted in a Minister's order).

Notification of public consultation must be provided by the SPA to all implementing bodies; persons believed to be engaged in significant drinking water threat activities; affected municipalities; and other miscellaneous bodies identified in O. Reg. 287/07 under ss.50(2) (e.g. Niagara Escarpment Commission, planning boards, contacts for Great Lakes water quality agreements, etc).

Following public consultation, any comments received during public consultation are to be submitted to the MECP as part of the submission package. MECP has provided SPAs with other submission details and supporting information requirements.

Source of most of the information: "Source Protection Planning Bulletin – Overview of Requirements for Plan and Assessment Report Amendments and Updates under sections 34, 35 and 36 of the Clean Water Act", by Ministry of the Environment, Conservation and Parks, October 2019. Note that bulletins and other resources developed by the Ministry of the Environment, Conservation and Parks may potentially be updated by them.

Table A2: Comprehensive Updates to the HHSPR Source Protection Plan

No.	Step	Timeline
1	Need for revisions/updates identified (Minister's Order issued under S. 35 or S. 36; SPA initiated S. 34; other)	2018 to 2020 (Completed)
2	Development of amendments/update (in consultation with the HHSPC)	April 2019 to May 2021 (Completed)
3	Early engagement (with MECP)	June to July 2021 (Completed)
4	Pre-consultation: a) with MECP and all policy implementers; and b) with persons/businesses believed to be engaged in significant threats.	September to December 2021 (Completed)
5	Municipal endorsement (Not applicable for Section 36 updates)	Not applicable for Section 36 updates
6	Public consultation (minimum 35 days)	December 2021 to February 2022
7	Submission to MECP Must be within 6 months of completion of consultation.	By May 30, 2022

The comments received during the consultation stages and responses to the comments are provided in the proposed updated Source Protection Plan available at: www.protectingwater.ca

Appendix A.2a Sample Landowner Notification Letter

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

HALTON-HAMILTON SOURCE PROTECTION REGION

September 9, 2010

«First_Name_1» «Last_Name_1» «First_Name_2» «Last_Name_2»
«Mailing_Address»
«Ncity», «Province» «NPostal_Code»

Re: Your property at «NLocation»

As follow-up to our letter to you dated July 22, 2010, we would like to provide you with more information about the local Drinking Water Source Protection Program as administered by your Conservation Authority.

As shown on the attached factsheet map, your property is located within the «AreaName» wellhead protection area. This is an area where certain activities may pose risks to the quality of that drinking water supply.

The Ministry of Environment (MOE) has identified 19 activities across Ontario that pose a significant threat to the quality of municipal drinking water (see insert). A significant threat as defined by the Clean Water Act, is an activity that may negatively impact water quality, if not properly managed. Sources such as the 2006 Agricultural Census, Municipal Property Assessment Corporation (MPAC) data and Municipal Potential Threats databases, have identified the following activity (ies) on your land:

«Threat1»
«Threat2»
«Threat3»
«Threat4»
«Threat5»
«Threat6»

We need to verify that these activities are actually occurring on your property. We are also contacting you to involve you early in the process to share information about source protection and other programs that may impact you including possible partnership funding should you be engaged in an activity the MOE has deemed a significant drinking water threat. You may already have been contacted by the Hamilton-Halton Watershed Stewardship Program, which has been notifying landowners of the financial assistance available to assist with the cost of eligible projects. Also, you may have been in contact with your local Soil and Crop Improvement Association Representative regarding this funding. For more information on the stewardship program, please see the enclosed factsheets.

www.protectingwater.ca

Appendix A.2a continued. Sample Landowner Notification Letter

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

HALTON-HAMILTON SOURCE PROTECTION REGION

Draft Assessment Reports, describing our watersheds and summarizing potential risks, are now complete. You are encouraged to review the reports, prepared for both the Halton Region and Hamilton Region Source Protection Areas. The reports include maps showing the areas that are highly vulnerable to groundwater contamination.

You may download the reports from our website at www.protectingwater.ca or view printed copies at the following locations, Monday to Friday during regular office hours

- Halton-Hamilton Source Protection office, 4052 Milburough Line, Campbellville
- Conservation Halton, 2596 Britannia Road West, Burlington
- Hamilton Conservation Authority, 838 Mineral Springs Road, Ancaster (Hamilton)
- City of Hamilton, Clerk's Counter, 77 James Street North, Hamilton
- Halton Region, Citizen's Reference Library and Clerk's Counter, 1151 Bronte Road, Oakville
- City of Burlington, Clerk's Department, 426 Brant Street, Burlington
- Town of Oakville, Service Oakville Counter, 1225 Trafalgar Road, Oakville
- Town of Milton, Clerk's Department, 150 Mary Street, Milton
- Town of Halton Hills, Corporate Services Counter, 1 Halton Hills Drive, Halton Hills
- County of Wellington, Clerk's Counter, 74 Woolwich Street, Guelph
- Township of Puslinch, Municipal Office, 7404 Wellington Road #34, RR#3, Guelph
- Region of Peel, Clerk's Counter, 10 Peel Centre Drive, 5th Floor, Suite A, Brampton
- City of Mississauga, Clerk's Office, 300 City Centre Drive, 2nd Floor, Mississauga
- Town of Grimsby, Clerk's Counter, 160 Livingston Avenue, Grimsby.

We encourage you to attend one of the public meetings where staff and committee members will be available to discuss the reports and the Drinking Water Source Protection program before and after the formal presentations scheduled for 9:30 a.m. and 7:30 p.m. at the following locations:

- October 1, 2010 between 9 and 11 a.m. at Country Heritage Park Administration Building, Niagara Conference Room, 8560 Tremaine Road, Milton
- October 1, 2010 between 7 and 9 p.m. at Lakeland Community Centre, Lakeland Hall, 180 Van Wagner's Beach Road, Hamilton
- October 4, 2010 between 9 and 11 a.m. at Christ Church Flamboro, 92 Highway 8, Flamborough,
- October 4, 2010 between 7 and 9 p.m. at Halton Regional Centre, Dakota/Glenorchy Rooms, 1151 Bronte Road Oakville.

Please note that details about your property will not be made public. At this stage, we are simply counting the potential significant threats in each of the vulnerable areas as as required by the *Clean Water Act, 2006*. However, during the next stage of the process, when source protection plans will be developed, details will be shared with your municipality.

We welcome your comments on the Draft Assessment Reports **before October 14, 2010** at:

Halton-Hamilton Source Protection office
4052 Milburough Line, RR #2,
Campbellville, ON L0P 1B0

www.protectingwater.ca

Appendix A.2a continued. Sample Landowner Notification Letter

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

HALTON-HAMILTON SOURCE PROTECTION REGION

or email at: sourceprotection@hrca.on.ca or fax: (905) 854-9220.

We invite you to learn more about Drinking Water Source Protection, the Assessment Reports and how you can protect drinking water sources. Please check our website at **www.protectingwater.ca** to learn about our program and for more details about the upcoming public meetings. You may also be interested in visiting the Ministry of the Environment website at **www.ene.gov.on.ca**

We look forward to hearing from you and would be pleased to answer any questions.

Yours truly,

Diane L Bloomfield

Diane L. Bloomfield, M.Sc., P.Geo.
Project Manager

Encl. Ministry of the Environment threats listing
Vulnerable Area Factsheet
Ontario Soil and Crop Association ODWSP Factsheet
Hamilton-Halton Watershed Stewardship Program Financial Assistance Factsheet

www.protectingwater.ca

Appendix A.2a continued. Sample Landowner Notification Letter

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

HALTON-HAMILTON SOURCE PROTECTION REGION

Prescribed Threats to Drinking Water Supplies

Under the *Clean Water Act, 2006,* and in Ontario Regulation 287/07 s.1.1(1), the Ministry of the Environment has identified 19 threats to the quality of municipal drinking water supplies. They are as follows:

1. The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.
2. The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.
3. The application of agricultural source material to land.
4. The storage of agricultural source material.
5. The management of agricultural source material.
6. The application of non-agricultural source material to land.
7. The handling and storage of non-agricultural source material.
8. The application of commercial fertilizer to land.
9. The handling and storage of commercial fertilizer.
10. The application of pesticide to land.
11. The handling and storage of pesticide.
12. The application of road salt.
13. The handling and storage of road salt.
14. The storage of snow.
15. The handling and storage of fuel.
16. The handling and storage of a dense non-aqueous phase liquid.
17. The handling and storage of an organic solvent.
18. The management of runoff that contains chemicals used in the de-icing of aircraft.
19. The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O.Reg. 385/08, s.3.

www.protectingwater.ca

Appendix A.2a continued. Sample Landowner Notification Letter

Hamilton-Halton Watershed Stewardship Program

Hamilton-Halton Watershed Stewardship Program

A Partnership Program of:

Conservation Halton

Hamilton Conservation Authority
Healthy Streams...Healthy Communities!

For more information, contact a Watershed Stewardship Technician from the Hamilton-Halton Watershed Stewardship Program at (905) 525-2181 Ext. 181 or (905) 336-1158 Ext. 263.

Important Information for Property Owners

This factsheet provides grant rates and caps for water quality and habitat improvement projects as of 2010.

Contact HHWSP program staff for more information on eligibility criteria and technical assistance.

Have an idea for a project not listed here? We are always looking for project ideas and future funding opportunities. Feel free to call us to share your ideas.

BENEFICIAL MANAGEMENT PRACTICES FOR HABITAT AND WATER QUALITY IMPROVEMENTS

Project Category	Eligible Projects	Grant Rate Up To (%)	Grant Cap Up To ($)	Eligible Areas
Livestock Waste Management	Livestock Restriction, Alternate Watering Devices, Crossings	75	$ 10,000	Properties within the Hamilton and Halton Conservation Authority watersheds
	Clean Water Diversion/Barnyard Runoff Control	75	$ 12,000	
	Milkhouse Washwater Disposal	75	$ 12,000	
	Manure Storage	75	$ 12,000	
Homestead or Business	Well Decommissioning/ Upgrading	80	$ 4,000	Properties within; 100-m radius of a municipal wellhead, 200-m radius of a municipal surface water intake, or 2 year time of travel around a municipal well
	Small Business Pollution Prevention Review	100	$ 12,000	
	Septic Systems Inspections and Upgrades	80	$ 7,000	
	Advanced Septic Systems	80	$ 15,000	
	Runoff and Erosion Control	Varies by project. Contact HHWSP for more details.		
	Well Decommissioning	100	$ 1,000	Properties in the City of Hamilton
Erosion Control Structures	Grassed Waterways	75	$ 5,000	Properties within the Hamilton and Halton Conservation Authority watersheds
	Water & Sediment Control Basins	75	$ 5,000	
	Streambank Stabilization	75	$ 5,000	
	Drop Inlets, Spillways, and Rock Chutes	75	$ 5,000	

Hamilton-Halton Watershed Stewardship Program

Appendix A.2a continued. Sample Landowner Notification Letter

Hamilton-Halton Watershed Stewardship Program

Eligibility Guidelines

To qualify for current funding the following criteria must be met:

- Projects must be within the eligible area.
- Projects must demonstrate an improvement to local surface and/or groundwater quality.
- The landowner must demonstrate good land stewardship practices.
- The landowner must contribute financially to the project in some capacity.

The landowner must complete a water quality improvement application and sign the project agreement contract.

FARM AND NON-FARM HABITAT AND WATER QUALITY IMPROVEMENTS

Project Category	Eligible Projects	Grant Rate Up To (%)	Grant Cap Up To ($)	Eligible Areas
Habitat Restoration or Enhancement	In-stream	75	$ 10,000	Properties within the Hamilton and Halton Conservation Authority watersheds
	Riparian	75	$ 10,000	
	Forest	75	$ 10,000	
	Wetland	75	$ 10,000	
	Prairie	75	$ 10,000	
	Meadow	75	$ 10,000	

How to Apply for Grants

Contact the Hamilton-Halton Watershed Stewardship Program at the Hamilton Conservation Authority or Conservation Halton to determine if your project meets the eligibility requirements of the program. Please note that an on-site consultation with Watershed Stewardship Program staff will be required to determine eligibility.

Projects that will result in the best benefits to water quality will be prioritized for funding.

Once your project has been deemed eligible, program staff will provide you with a funding application, and if needed, assistance in completing the application.

Project Agreements

While the type of agreement you may be required to sign will vary based upon the funding source, generally, we ask that property owners undertaking projects agree to;

- the scope of the project as described in the funding application
- submit paid invoices, quotes, cancelled cheques and other related documents for eligible expenses prior to reimbursement
- allow program staff and any associated visitors to visit and/photograph the site for monitoring purposes*
- allow program staff to utilize photos for promotional materials*

*Program staff will request your permission prior to said activities, and these activities will not interfere with property operations.

Hamilton-Halton Watershed Stewardship Program
c/o Hamilton Conservation Authority
P.O. Box 81067, 838 Mineral Springs Road
Ancaster, Ontario L9G 4X1
www.conservationhamilton.ca
Hamilton office: (905) 525-2181, ext. 181
Halton office: (905) 336-1158, ext.263

Interested in learning more about natural features on your property?

Call us to arrange a free on-site consultation!

Hamilton-Halton Watershed Stewardship Program

Appendix A.2a continued. Sample Landowner Notification Letter

Ontario Drinking Water Stewardship Program (ODWSP) 2010-2011

Environmental Cost-Share Funding Opportunities for Farmers in Source Water Protection Areas

This farm has an ENVIRONMENTAL FARM PLAN

Do you farm on a parcel of land that is within or extends into a wellhead protection area or intake protection zone?

Are you planning to complete any of these projects?

- Decommissioning abandoned wells or upgrading existing wells
- Septic system inspections and upgrades
- Runoff and erosion protection measures
- Livestock manure storage
- Fuel, fertilizer or pesticide storage system

If YES, you may be eligible for up to 100 per cent cost share!

The Province of Ontario will provide financial assistance through the Ontario Drinking Water Stewardship Program (ODWSP) for the protection of drinking water sources on properties that may be affected by the Clean Water Act, 2006.

For registered farms that satisfy current eligibility requirements for the cost-share program associated with the Canada-Ontario Environmental Farm Plan, ODWSP funding is delivered alongside the Canada-Ontario Farm Stewardship Program (COFSP) through the Ontario Soil and Crop Improvement Association (OSCIA). Upon verification of the eligibility of the registered farm and the proposed project, the process to acquire ODWSP cost share is quite simple.

All other property owners should contact their local Conservation Authority to express interest in ODWSP and to verify eligibility. A separate application process will be followed.

Early actions projects are a first step in protecting municipal drinking water sources. ODWSP provides attractive incentives to farmers willing to take action now. Source protection plans, expected to be finalized in 2012 on a region-by-region basis by the local Source Protection Committee, will determine the full extent of measures necessary on individual properties to protect wellheads and surface water intakes.

Cost share is available through ODWSP to a registered farm business for selected environmental projects implemented on a parcel of agricultural land that is within or extends into:

- The 100-meter radius of a municipal well; or
- The approved 2-year time of travel zone for a municipal wellhead; or
- The 200-meter radius around a municipal surface water intake; or
- The approved intake protection zone-one (IPZ-1) of a municipal surface water intake.

In order for a municipal wellhead 2-year time of travel zone or a municipal surface water intake (IPZ-1) to be considered an approved eligible area for the purpose of ODWSP, at least one of the following conditions must be met:

- The 2-year time of travel and/or the IPZ-1 have been incorporated into a Municipal Official Plan; or
- The municipality has accepted the 2-year time of travel and/or the IPZ-1 delineation by council resolution specifically for the Municipal Official Plan or the ODWSP; or
- The Source Protection Committee has endorsed a map delineating the 2-year time of travel and/or the IPZ-1 for use in public meetings/consultations related to the source protection planning process.

Both EFP and COFSP are funded through Growing Forward, supported by Agriculture and Agri-Food Canada (AAFC) and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), under the Best Practices suite. The programs are administered by Ontario Federation of Agriculture, acting on behalf of the Ontario Farm Environmental Coalition. The Ontario Soil and Crop Improvement Association (OSCIA) delivers the programs to agricultural producers.

Canada | Ontario Farm Environmental Coalition | Ontario | Growing Forward

Appendix A.2a continued. Sample Landowner Notification Letter

Here is a brief description of the Best Management Practice (BMP) categories and cost-share programs available to eligible farm businesses, and further information on eligibility and the application process. BMP categories and practice codes have been carefully selected from the COFSP list that best satisfy the objective of protecting drinking water sources. Please note the following:

1. For projects where cost share is anticipated through both ODWSP and COFSP, the participation details and critical dates as presented in "COFSP Project Eligibility Policy and Procedures, Beginning April 1, 2009" will apply. A copy of the document may be obtained from a local Program Representative or the OSCIA web site. Additional requirements are noted in this brochure.
2. Funding is allocated by OSCIA on a first-come, first-served basis for eligible projects, until available funding for that program year is committed.
3. To make a cost-share claim on an approved project, the date of the submission to Guelph OSCIA must comply with the deadline for the particular program year presented in Chart A of "COFSP Project Eligibility Policy and Procedures, Beginning April 1, 2009." Projects must be complete and operational at time of submitting the Claim Form; OSCIA cannot issue cost-share payments for incomplete projects.
4. Funding received from other programs for the proposed project must be declared on the Claim Form and will be reviewed by OSCIA Guelph to determine the applicable cost-share amount. Under no circumstances can combined cost share from all off-farm sources exceed 100 per cent of project establishment costs.
5. Participants in ODWSP will be required to sign a "Permission to Share Information" form, acknowledging MOE may share producer and project information gathered by OSCIA with partnering agencies.
6. Producers who believe they may have parcels of agricultural land and proposed projects eligible for ODWSP can make an inquiry with a local OSCIA Program Representative for access to maps of the designated areas.
7. The material and opportunities presented in this document replace those contained in the 2008-2009 version of ODWSP.
8. The maximum contribution a farm business may receive from the Ontario Ministry of the Environment through ODWSP is $75,000. Producers who participated in Source Protection Program 2007-2008 or ODWSP 2008-2009, will carry forward into ODWSP 2009-2011 all MOE cost-share received for projects claimed during those periods.
9. The maximum contribution a farm business may receive through COFSP between April 1, 2009 and March 31, 2013 is $30,000.
10. The BMP category codes identified in the table correspond to those in the booklet "COFSP Project Eligibility Policy and Procedures, Beginning April 1, 2009" with the exception of category 50 - Septic Systems, and category 52 - Connection to Municipal Water Trunk Line.
11. COFSP literature, Growing Forward Enrollment forms and COFSP Project Proposal Applications are available from OSCIA Program Representatives, or from local Conservation Authorities.
12. Information presented is the best available at time of printing. Check with a local OSCIA Program Representative for applicable updates. Material is subject to change without notice as the cost-share programs evolve.
13. ODWSP cost share cannot be obtained through both OSCIA and a Conservation Authority for the same project.

BMP Category Code	BMP Category	Practice Code	Eligible BMPs	COFSP Cost Share	COFSP Category cap	ODWSP Cost Share	ODWSP Category Cap	Total* Combined Cost Share
01	**Improved Manure Storage and Handling**	0101	Increased storage to meet winter spreading restrictions (including satellite storage)	30%	$30,000	70%	$60,000	100%
		0102	Improved features to prevent risks of water contamination (leaks, spills)					
		0103	Slurry storage covers to reduce odours and greenhouse gas emissions and liquid volume					
		0104	Containment systems for solid manure (includes covers)					
		0105	Assessment and monitoring of existing manure storage infrastructure					
02	**Manure Treatment**	0201	Dewatering systems, nutrient recovery systems	30%	$30,000	70%	$60,000	100%
		0202	Composting of manure					
		0203	Anaerobic digester systems					
03	**Manure Land Application**	0301	Specialized modifications to equipment for improved manure application.	30%	$10,000	70%	$10,000	100%
04	**In Barn Improvements for Water Efficiency**	0401	More efficient livestock watering devices and cleanout systems to reduce water use and decrease manure volumes	30%	$15,000	70%	$40,000	100%
05	**Farmyard and Horticultural Facilities Runoff Control**	0501	Upstream diversion around existing farmyards, existing greenhouse and container nursery operations; includes downstream protection (e.g. catch basins, storage for runoff, constructed wetlands	50%	$20,000	50%	$20,000	100%
		0502	Construction of impermeable base and/or roof for minimizing runoff from livestock pen areas and confinement areas					
08	**Product and Waste Management**	0801	Improvements to permanent on-farm storage and handling of agricultural products (e.g. pesticides and petroleum products)	30%	$15,000	70%	$30,000	100%
		0802	Improved on-farm storage, handling, and disposal of agricultural waste (e.g. manure from livestock transport, fruit and vegetable cull piles, wood waste)					
		0803	Composting of agricultural waste (e.g. fruit or vegetable waste)					
09	**Water Well Management**	0901	Sealing and capping old water wells	50%	$6,000	50%	$4,000	100%
		0902	Protecting existing water wells from surface contamination					
10	**Riparian Area Habitat Management**	1001	Alternative watering systems to manage livestock: gravity fed, solar, wind, grid line, alternative power, pump and waterline systems	50%	$20,000	50%	$20,000	100%
		1002	Buffer establishment (up to 60 metres in width in riparian areas): permanent native or non-invasive introduced species of grass, legumes, herbaceous plants, trees and shrubs					
		1003	Fencing to improve grazing systems. Eligible fencing projects would be those that are designed to prevent access to riparian areas within the farm property. A farm would be expected to have adequate boundary fencing already in place					
		1004	Habitat restoration or establishment in riparian areas (includes native prairie and savannah)					

Appendix A.2a continued. Sample Landowner Notification Letter

BMP Category Code	BMP Category	Practice Code	Eligible BMPs	COFSP Cost Share	COFSP Category cap	ODWSP Cost Share	ODWSP Category Cap	Total* Combined Cost Share
		1005	Grazing management: cross fencing to relieve grazing pressure on riparian systems					
		1006	Improved stream crossings for livestock or equipment					
11	**Erosion Control Structures (Riparian)**	1101	Constructed works in riparian areas: ditch bank stabilization; shoreline stabilization; grade control structures; Water and Sediment Control Basins (WaSCoBs); grassed waterways; contour terraces; gully stabilization; tile outlet structures; sediment traps; weirs	50%	$20,000	50%	$20,000	100%
12	**Erosion Control Structures (Non Riparian)**	1201	Constructed works in non riparian areas: ditch bank stabilization; grade control structures; Water and Sediment Control Basins; grassed waterways; contour terraces; gully stabilization; constructed wind screens (e.g. snow fence)	50%	$20,000	50%	$20,000	100%
15	**Cover Crops**	1501	Establishment of non-harvested, non-grazed cover crops	30%	$2,000	70%	$5,000	100%
		1502	Equipment modification for inter-row seeding of cover crops (e.g. relay crops)					
24	**Resource Planning**	2401	Nutrient Management Planning (NMP) - Consultative Services to develop nutrient management plans; planning and decision support tools	50%	$3,000	25%	$1,500	75%
		2404	Soil Erosion Control Planning - Consultative Services to develop soil erosion control plans					
		2408	Riparian Health Assessment - Consultative Services for assessing riparian health					
50	**Septic Systems**	5001	Visual inspection of existing system by a qualified inspector (i.e. Ontario Building Code agencies- Health Units, licensed pumpers and installers); Consists of a walk around, and open hatch inspection as necessary. A one-time pumping to facilitate inspection is permissible.	N/A	N/A	80%	$7,000	80%
		5002	System modification or replacement: includes filters and other components aimed at extending the life of existing systems; and replacement of outdated or faulty systems with approved conventional designs; or full system dismantling and replacement with lateral pipe to municipal sewer line.					
		5003	80 per cost share up to $15,000 may be available through ODWSP for advanced septic systems. Advanced septic systems are capable of reducing environmental impact. For more information on innovative septic system design, please contact a qualified industry professional or visit www.obc.mah.gov.on.ca/PageFactory.aspx?PageID=50					
52	**Connection to Municipal Drinking Water Trunk Line**	5201	Connection to municipal drinking water service line / trunk line, and the decommissioning of the existing well - both projects must be completed in order to receive funding.	N/A	N/A	80%	$4,000 **	80%

Additional Notes for Well Decommissioning/Upgrading Projects (BMP categories 09 and 52)

- Construction of a new well or frontage fees for a municipal line are not eligible.
- Cost estimates provided in the Project Proposal Application (PPA) must be supplied by a licensed well contractor and the name of the contractor must be identified in the PPA.
- Work must be completed by a qualified industry professional who meets the requirements specified in Ontario Regulation 903 Wells. Information on licensed well contractors can be found on the MOE web site http://209.47.226.245/ or contact the Water Well Help Desk at 1-888-396-WELL (9355).
- If you have an existing well record for the well you are proposing to decommission or upgrade, please include a copy with the PPA. For instructions on how to obtain a copy of an existing well record, contact the Water Well Help Desk. A search request form must be submitted to the Ministry before the search is conducted.
- In category 52, costs associated with installing new trunk lines, or connection related to a new farm operation, are not eligible for cost-share.
- At time of the final project inspection by an OSCIA Program Representative and completion of the Claim Form, you must also submit a copy of the new well record that was completed by the Well Contractor, a copy of the contractor's valid Well Contractor License, and any other required permits or approvals.

Additional Notes for Septic System Inspections and Upgrades (BMP category 50)

- Septic systems are not eligible for cost-share through COFSP; funding through OSCIA is available for ODWSP only. Additional financial and technical assistance for septic systems may be available through programs delivered by Conservation Authorities. Producers should contact their local watershed office to determine availability.
- Projects not eligible for ODWSP are, but are not limited to: routine maintenance septic tank pumping, septic installations that are part of new home construction, and septic system upgrades that are required to meet the needs of a home addition.
- If the proposed project is the replacement of an existing septic system, a copy of a report and recommendation from a licensed sewage installer or inspector must be submitted with the PPA. For modifications/upgrades to an existing system, a report from a licensed sewage disposal contractor who pumped and inspected the tank is recommended.
- If the results of the inspection reveal the septic system has deficiencies, the septic tank pumping and inspection costs will only be eligible for funding if the identified problem(s) with the septic system is corrected. If the system turns out to be in good working order, the cost-share can be applied to the septic tank pumping and inspection.
- At time of final project inspection by an OSCIA Program Representative and completion of the Claim Form, you must also submit a copy of the sewage system inspection report verifying the system complies with the Ontario Building Code, and other required permits or approvals (e.g. a copy of the building permit).

Additional Notes for Runoff and Erosion Protection, and Additional BMPs (BMP categories: 01, 02, 03, 04, 05, 08, 10, 11, 12, 15 and 24)

- If a service provider is to do the proposed construction, the applicable cost estimates provided in the Project Proposal Application (PPA) must be supplied by a qualified contractor and the name of the contractor must be identified in the PPA.
- To be eligible for ODWSP, riparian buffer strips must be a minimum of 10 meters in width moving outwards towards the field from the top of bank of the surface water source.
- For BMP category 10, only riparian area projects will be considered for support in ODWSP.
- Projects not eligible for ODWSP are, but are not limited to: Category 10 projects in upland areas; replacement of retaining walls or other existing structures; construction of steel or concrete solid retaining walls and gabion basket walls for erosion control; and maintenance of tile drain outlets.
- If regulatory permits or approvals were required for the project, a copy must be submitted to the OSCIA Program Representative when the final project inspection is conducted and the Claim Form completed.

* Cost Share percentages apply to eligible project costs up to the specified category caps for each program. **The same ODWSP category cap includes 0901 and 0902

Appendix A.2a continued. Sample Landowner Notification Letter

Who is Eligible to participate in ODWSP?

In order to be eligible for the ODWSP for 2009-2011, a farm business must satisfy all of these criteria:

1. Be a legal farm entity with a unique Farm Business Registration Number (FBRN) or equivalent;
2. Have an Environmental Farm Plan (EFP) deemed appropriate through peer review. Currently the Third Edition EFP Workbook will be required;
3. Have selected a Best Management Practice (BMP) from the eligible list in this brochure that relates directly to an action identified in the peer-reviewed EFP action plan, and effectively moves a "1" or "2" rating towards a "3" or "4" (best) rating.
4. Own, rent, lease or manage an agricultural parcel where the proposed project will be located, that is within or extends into:
   - The 100-meter radius of a municipal well; or
   - The approved 2-year time of travel zone for a municipal wellhead; or
   - The 200-meter radius around a municipal surface water intake; or
   - The approved intake protection zone-one (IPZ-1) of a municipal surface water intake.

In order for a municipal wellhead 2-year time of travel zone or a municipal surface water intake (IPZ-1) to be considered an approved eligible area for the purpose of ODWSP, at least one of the following conditions must be met:

- **The 2-year time of travel and/or the IPZ-1 have been incorporated into a Municipal Official Plan; or**
- **The municipality has accepted the 2-year time of travel and/or the IPZ-1 delineation by council resolution specifically for the Municipal Official Plan or the ODWSP; or**
- **The Source Protection Committee has endorsed a map delineating the 2-year time of travel and/or the IPZ-1 for use in public meetings/consultations related to the source protection planning process.**

Making an Application

1. Forward an Application

The application process occurs in two steps. First, complete a Growing Forward Program Enrollment Form. Providing this information prepares the farm business for participation in both the environment and business development program opportunities delivered by OSCIA. Second, complete the COFSP Project Proposal Application for the program year you are seeking cost share for the proposed project, and ensure the OSCIA Program Representative includes reference to ODWSP in the top right-hand corner of the first page. There is no separate application form for ODWSP. If the project is eligible, applicable ODWSP cost-share will be added on to the allocation by OSCIA. Critical dates associated with each program year can be found in Chart A included in "COFSP 2009 Project Eligibility Policy and Procedures" or the 2009 COFSP brochure.

Most BMP categories require a specific information package that includes a Project Justification and Assurances Form, that must be submitted to OSCIA Guelph before approval to proceed with the proposed project may be granted. Check with the OSCIA Program Representative for all required documentation.

2. Obtain Conditional Approval

Depending on the project, OSCIA Guelph may grant "final approval to proceed," or "conditional approval" which may require the submission of additional documentation. At this stage the cost-share allocation from COFSP and ODWSP (as applicable) are made based on the total estimated cost figure submitted on the PPA.

3. Complete the Project and Arrange for Final Inspection

The applicant must adhere to the project claim submission deadline for the particular year of the program (see Chart A in 2009 COFSP brochure) to complete the project, notify the OSCIA Program Representative and have the final inspection conducted, provide copies of all invoices and acceptable proof of payment, and sign the claim form provided by the OSCIA Program Representative. The submission deadline date for ODWSP 2010-2011 fiscal year is January 15, 2011. OSCIA Guelph will issue the cost-share cheque for COFSP and ODWSP (as applicable).

Important Note on Retroactivity

For eligible producers on properties that may be affected by the Clean Water Act 2006, retroactive funding may be available through ODWSP only for projects already issued a federal cost-share contribution from OSCIA on or after September 19, 2006. If you think this may apply to your situation, it is important to speak with a local OSCIA Program Representative. It is the responsibility of the participant to initiate the retroactive payment process with OSCIA for applicable ODWSP projects.

Contact:

Ontario Soil and Crop
Improvement Association
1 Stone Road West
Guelph, Ontario N1G 4Y2

1-800-265-9751

www.ontariosoilcrop.org

More information on the ODWSP may be found on the Ontario Ministry of the Environment web site: www.ontario.ca/cleanwater

The information presented is the best available at time of printing. Check with a local OSCIA Program Representative for applicable updates.

Aussi disponible en francais.

January, 2010

Appendix A.2b Sample Newspaper Notice

DRINKING WATER SOURCE PROTECTION

ACT FOR CLEAN WATER

Halton-Hamilton Source Protection Region

Watershed Assessment Reports Released for Public Review

You are encouraged to review the Draft Proposed Assessment Reports for the Hamilton Region and Halton Region Source Protection Areas. The reports were prepared under the Clean Water Act, 2006, for the Halton-Hamilton Source Protection Committee. They include:

- descriptions of the watersheds in the Hamilton Conservation Authority and Conservation Halton jurisdictions;
- descriptions of vulnerable areas where the risk is higher that a source of drinking water may become contaminated or depleted; and
- a summary of the potential risks to municipal drinking water supplies based on existing and potential activities.

Source Protection Plans that include policies to address significant drinking water threats will be developed based on these assessments.

We welcome your comments on the two reports until **October 14, 2010**. Your comments will be considered when the reports are finalized later this year.

Review the reports

Visit our website at **www.protectingwater.ca** and follow the links to review or download copies of the reports. Printed copies can be reviewed at municipal and conservation authority offices. A list of locations is provided on our website.

We also encourage you to attend one of the public meetings where staff and committee members will be available to discuss the reports and the Drinking Water Source Protection process before and after the formal presentations scheduled for 9:30 a.m. and 7:30 p.m. at the following locations:

- October 1 - 9 to 11 a.m. at Country Heritage Park Administration Building, Niagara Conference Room, 8560 Tremaine Road, Milton
- October 1 - 7 to 9 p.m. at Lakeland Community Centre, Lakeland Hall, 180 Van Wagner's Beach Road, Hamilton
- October 4 - 9 to 11 a.m. at Christ Church Flamboro, 92 Highway 8, Flamborough
- October 4 - 7 to 9 p.m. at Halton Regional Centre, Dakota/Glenorchy Rooms, 1151 Bronte Road Oakville.

Provide comments in writing by October 14, 2010 to:

Halton-Hamilton Source Protection Office
4052 Milburough Line, R.R. #2
Campbellville, ON L0P 1B0

e-mail: sourceprotection@hrca.on.ca
fax: (905) 854-9220

Find out more at www.protectingwater.ca

APPENDIX B: MONITORING DATA

Appendix B.1 Meteorological Stations

Station Code	Station Name	Subwatershed/CA	Available Period of Record
6151512	Christie Conservation[1]	Middle Spencer Creek	1976-1994
6151866	Copetown	GRCA	1970-1993
6133050	Grimsby Allan	Niagara Peninsula	1970-1975
6133052	Grimsby Chateau Gai[1]	WC12	1978-1981
6133055	Grimsby Mountain	WC9	2005 - present
6153264	Hamilton Marine Police[1]	City Core	1980-1983
6153290	Hamilton Municipal Lab[1]	Red Hill Valley	1967-1994
6155183	Millgrove[1]	Logie's Creek	1951-2006
615E498	MT Albion Conservation[1]	Hannon Creek	1976-1983
6156470	Peters Corners[1]	West Spencer Creek	1952-1970
6159127	Valens[1]	Upper Spencer Creek	1968-1994
6153298	Hamilton Psychiatric Hospital[1]	Chedoke Creek	1961-1993
6153301	Hamilton RBG CS	North Cootes Paradise	1997- present
6153194	Hamilton Airport	Niagara Peninsula	1959 - present
6153300	Hamilton RBG[1]	Hamilton Harbour	1950-1997

Note: 1. Precipitation stations located within the Hamilton Region Source Protection Area.

Appendix B.2 Long-term Surface Water Monitoring Locations

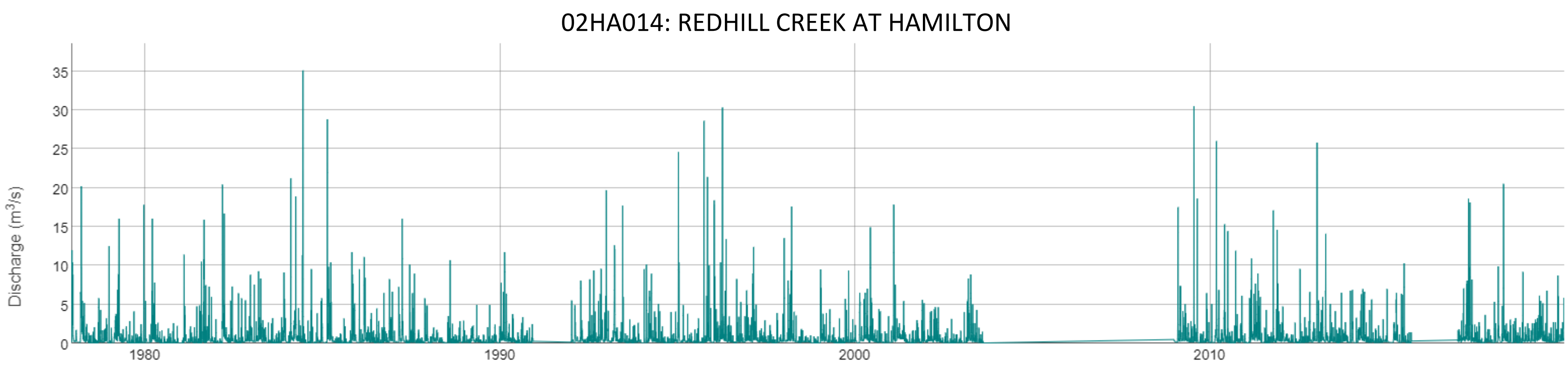
PWQMN Number	Station Name	Watershed	Subwatershed	Period of Record
9000100402	Mountain Brow Blvd, Albion Falls, Hamilton	Red Hill Creek	Upper Ottawa	1979 to 2009
9000100502	Queenston Rd, Hamilton	Red Hill Creek	Red Hill Valley	2002 to 2009
9000800502	Market St, Dundas	Spencer Creek	Middle Spencer Creek	2002 to 2009
9000800602	Hwy 5, upstream Christie Reservoir	Spencer Creek	Middle Spencer Creek	2002 to 2009
9000800702	Safari Rd, downstream Beverly Swamp	Spencer Creek	Upper Spencer Creek	2002 to 2009

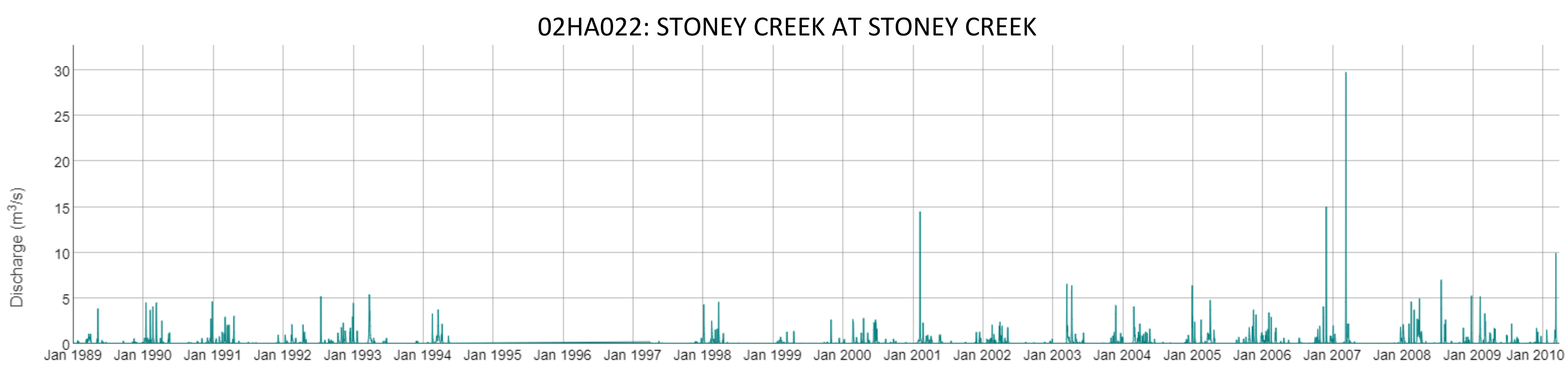
Appendix B.3 HYDAT Station Summary

Station ID	Station Name	Watershed	Subwatershed	Catchment Area [km^2]	Period of Record
02HA014	Redhill Creek at Hamilton	Red Hill Creek	Red Hill Valley	66.4	1977 to present
02HA022	Stoney Creek at Stoney Creek	Stoney-Battlefield Creek	Stoney Creek	13.5	1989 to 2014
02HA023	Redhill Creek at Albion Falls	Red Hill Creek	Upper Ottawa	23.5	1989 to 2003
02HB007	Spencer Creek at Dundas	Spencer Creek	Middle Spencer Creek	161	1959 to present
02HB010	Spencer Creek at Dundas Crossing	Spencer Creek	Middle Spencer Creek	166	1960 to 1984
02HB015	Spencer Creek near Westover	Spencer Creek	Upper Spencer Creek	63.5	1971 to present
02HB017	Lake Ontario at Burlington	Lake Ontario			1970 to 2012
02HB021	Ancaster Creek at Ancaster	Spencer Creek	Ancaster Creek	9.14	1986 to present
02HB023	Spencer Creek at Highway 5	Spencer Creek	Middle Spencer Creek	132	1987 to present

Note: HYDAT station hydrographs on the following pages were produced using Oak Ridges Moraine Groundwater Programs Hydrology web tool.

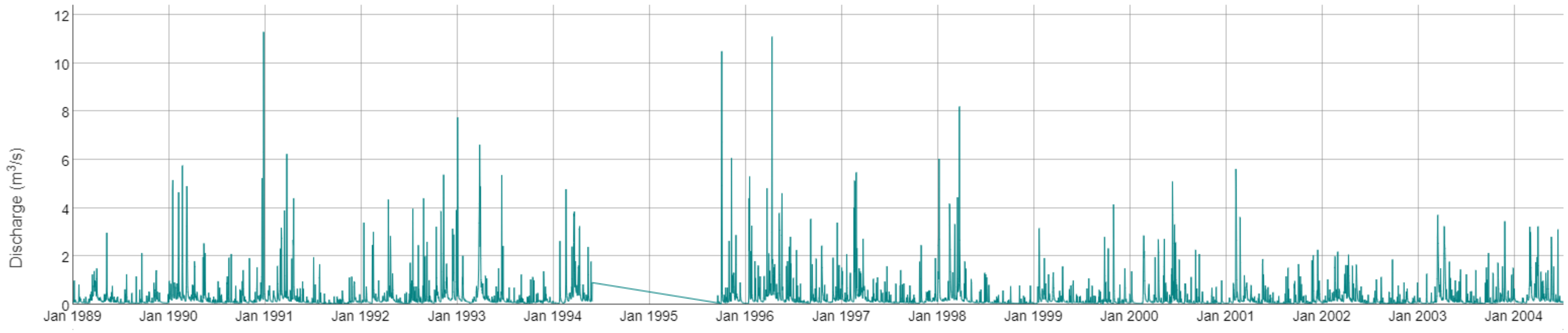
Appendix B.3 continued Surface Water Discharge



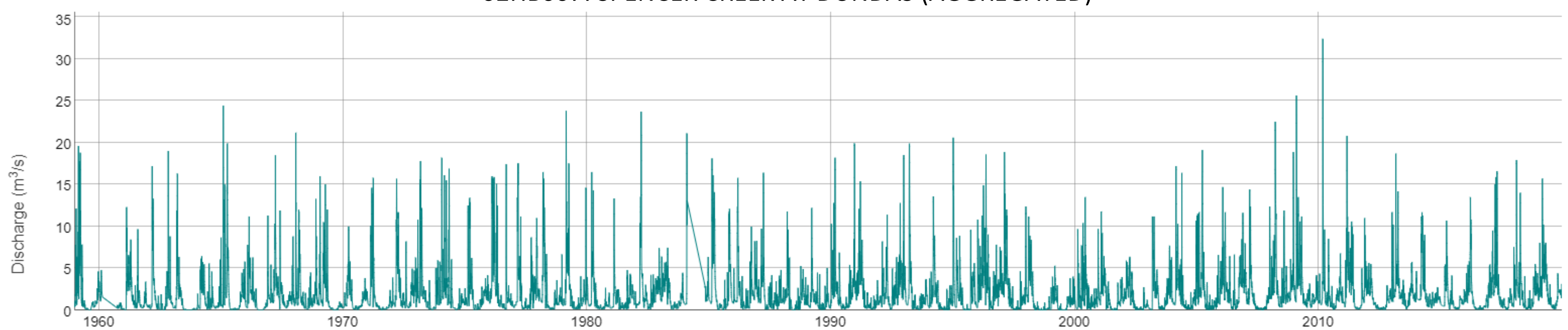


Appendix B.3 continued Surface Water Discharge

02HA023: RED HILL CREEK AT ALBION FALLS

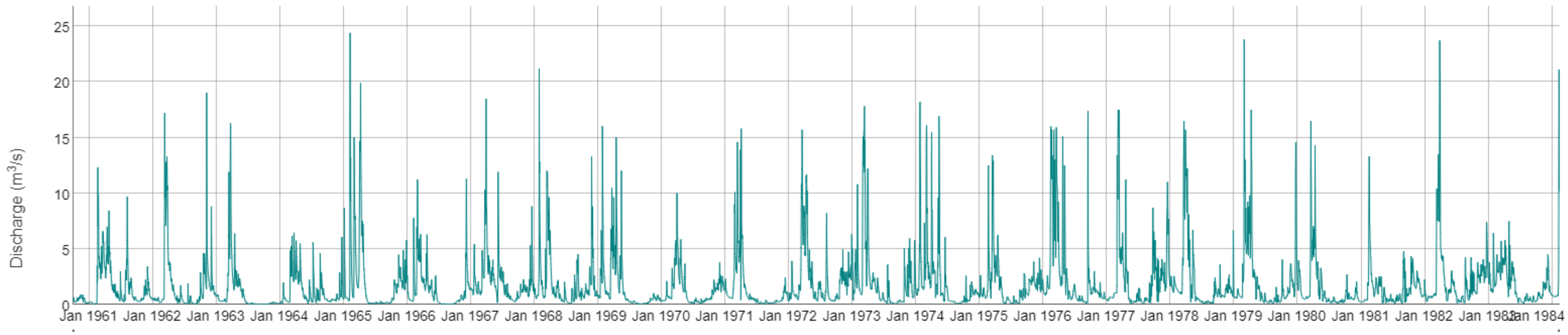


02HB007: SPENCER CREEK AT DUNDAS (AGGREGATED)

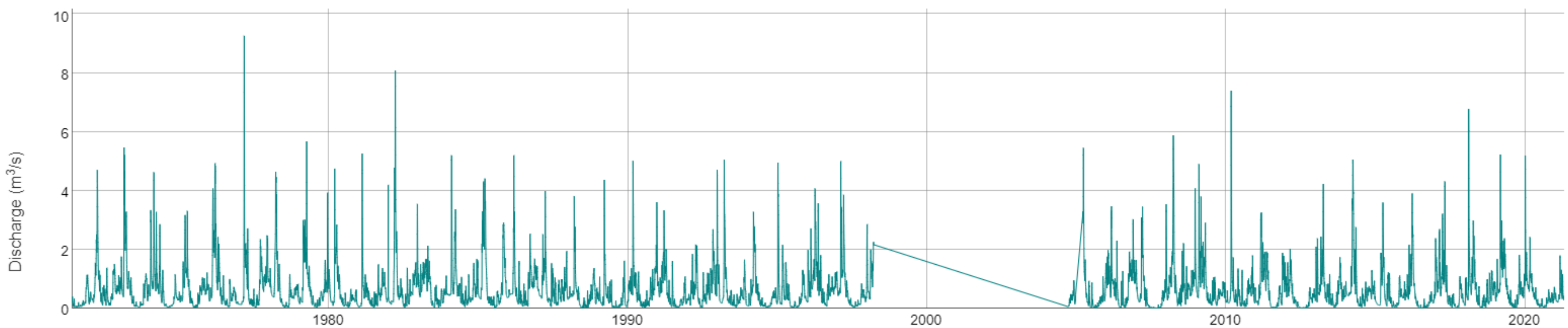


Appendix B.3 continued Surface Water Discharge

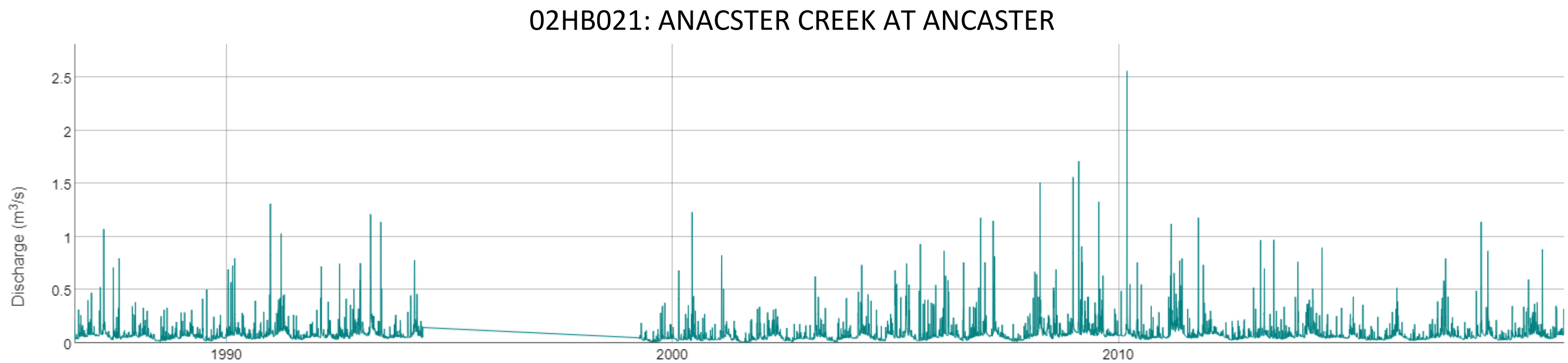
02HB010: SPENCER CREEK AT DUNDAS CROSSING

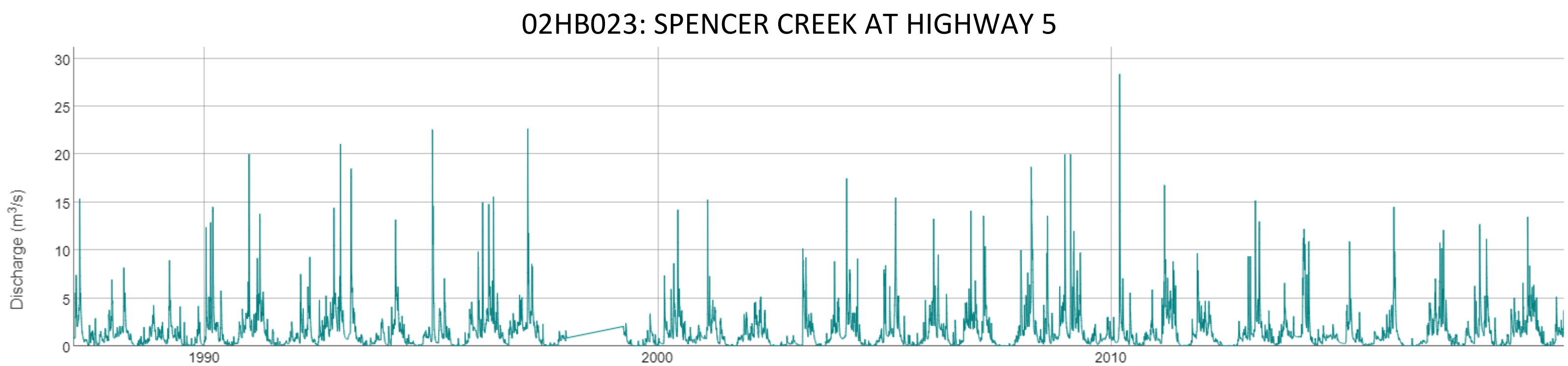


02HB015: SPENCER CREEK NEAR WESTOVER

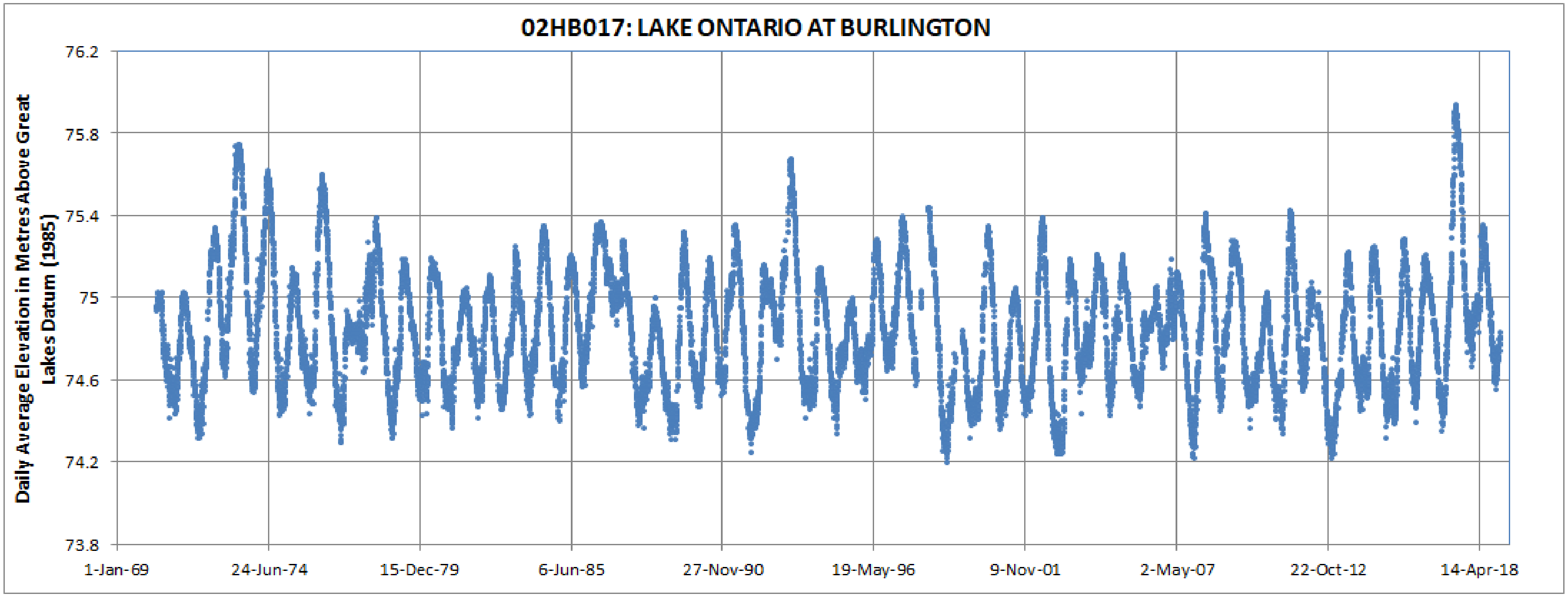


Appendix B.3 continued Surface Water Discharge





Appendix B.3 continued Surface Water Discharge



Appendix B.4 Surface Water Quality Data – PWQMN Stations sampled between 2003 and 2019

			9000100402 (Redhill Ck at Mountain Brow Blvd)	9000100402	9000100402	9000100502 (Redhill Ck at Queenston Rd)	9000100502	9000100502
Parameter	Units	PWQO	Min	Average	Max	Min	Average	Max
Alkalinity as CaCO3	mg/L		32.10	193.55	268.00	0.50	166.11	257.00
Aluminium	µg/L	75	-0.23	281.60	2130.00	-22.20	205.21	1890.00
Ammonium	mg/L		0.00	0.07	0.42	0.00	0.08	1.66
Barium	µg/L		19.80	59.32	78.60	21.70	49.97	90.00
Beryllium	µg/L	1100	-0.25	0.02	0.61	-0.63	0.01	0.51
Bismuth	µg/L		-12.40	-2.54	2.21	-16.10	-2.53	4.23
Cadmium	µg/L	0.5	-2.05	1.06	3.69	-1.51	0.88	3.48
Calcium	mg/L		18.10	112.37	154.00	25.00	90.28	147.00
Chloride	mg/L	120	14.60	287.52	973.00	17.20	238.66	632.00
Chromium	µg/L	8.9	-6.60	0.63	6.54	-6.55	0.26	5.03
Cobalt	µg/L	0.9	-4.24	0.62	3.59	-1.23	0.50	3.37
Conductivity	µS/cm		148	1594	3420	290	1388	5200
Copper	µg/L	5	0.62	4.31	21.40	1.11	3.80	20.10
Dissolved Inorganic Carbon	mg/L		30.80	46.18	54.10	20.60	41.98	51.90
Dissolved Organic Carbon	mg/L		1.90	2.37	3.80	2.00	2.57	3.70

Dissolved Oxygen	mg/L		1.01	11.32	20.95	1.69	12.63	20.57
Filtered Reactive Phosphate	mg/L		0.00	0.05	0.56	0.00	0.03	0.23
Hardness as $CaCO_3$	mg/L		63.30	412.86	556.00	84.20	342.95	538.00
Iron	µg/L	300	17.00	307.14	1470.00	18.90	234.56	3560.00
Lead	µg/L	5	-16.10	-1.23	18.40	-17.60	-1.91	19.40
Lithium	µg/L		-0.39	16.35	64.20	-4.26	14.60	69.60
Magnesium	mg/L		4.39	28.84	41.10	5.26	26.74	41.40
Manganese	µg/L		13.70	41.79	175.00	5.30	46.25	646.00
Molybdenum	µg/L	40	-11.40	3.80	7.79	-1.08	2.63	7.40
Nickel	µg/L	25	-2.59	1.76	7.99	-3.86	0.88	7.06
Nitrates	mg/L		0.01	1.68	3.80	0.01	1.03	3.18
Nitrite	mg/L		0.00	0.04	0.31	0.00	0.02	0.17
pH	pH Units	6.5-8.5	6.45	8.31	9.05	2.10	8.32	8.83
Potassium	mg/L		1.01	4.41	7.18	1.97	4.23	8.46
Silicates	mg/L		1.78	3.42	4.38	0.76	2.00	3.86

Notes: Data collected 2003 through 2019 by Hamilton Conservation Authority
mg/L = milligrams per litre; µg/L = micrograms per litre; µS/cm = microsiemens per centimetre
PWQO = Provincial Water Quality Objectives (Ministry of the Environment, 1999)
Negative values indicate parameter was below the laboratory method detection limit

Appendix B.4 continued Surface Water Quality Data – PWQMN Stations sampled between 2003 and 2019

			9000100402 (Redhill Ck at Mountain Brow Blvd)	9000100402	9000100402	9000100502 (Redhill Ck at Queenston Rd)	9000100502	9000100502
Parameter	Units	PWQO	Min	Average	Max	Min	Average	Max
Silver	µg/L	0.1	-7.14	-0.36	15.80	-6.71	-0.43	7.41
Sodium	mg/L		10.90	170.63	566.00	20.10	145.45	411.00
Strontium	µg/L		272.00	2806.42	4210.00	332.00	1814.61	2860.00
Temperature	°C		2.60	14.54	22.40	2.60	16.84	30.60
Tin	µg/L		-86.60	-10.43	27.50	-61.40	-7.78	23.40
Titanium	µg/L		-0.04	4.46	17.10	-0.83	3.33	19.80
Total Kjeldahl Nitrogen	mg/L		0.05	0.59	2.30	0.05	0.58	2.88
Total Nitrogen	mg/L		0.67	1.97	4.02	0.05	1.13	2.98
Total Phosphorus	mg/L	0.03	0.00	0.09	0.91	0.01	0.07	0.74
Total Suspended Solids	mg/L		1.60	16.87	271.00	0.50	16.67	300.00
Uranium	µg/L		-4.02	5.80	22.10	-4.12	4.70	18.70
Vanadium	µg/L		-3.10	1.78	10.70	-3.45	1.43	10.30
Zinc	µg/L	20	47.60	124.74	197.00	-0.14	28.36	271.00
Zirconium	µg/L	4	-0.51	-0.07	0.66	-0.57	-0.09	0.44

Notes: Data collected 2003 through 2019 by Hamilton Conservation Authority
mg/L = milligrams per litre; µg/L = micrograms per litre; µS/cm = microsiemens per centimetre
PWQO = Provincial Water Quality Objectives (Ministry of the Environment, 1999)
Negative values indicate parameter was below the laboratory method detection limit

Appendix B.4 continued Surface Water Quality Data – PWQMN Stations sampled between 2003 and 2019

			9000800502 (Spencer Ck at Market St)	9000800502	9000800502	9000800502 (Spencer Ck at Market St)	9000800502	9000800502
Parameter	Units	PWQO	Min	Average	Max	Min	Average	Max
Alkalinity as CaCO3	mg/L		79.10	213.82	376.00	79.10	213.82	376.00
Aluminium	µg/L	75	5.50	109.82	639.00	5.50	109.82	639.00
Ammonium	mg/L		0.00	0.02	0.11	0.00	0.02	0.11
Barium	µg/L		10.70	49.77	84.20	10.70	49.77	84.20
Beryllium	µg/L	1100	-0.14	0.01	0.21	-0.14	0.01	0.21
Bismuth	µg/L		-8.83	-1.34	4.29	-8.83	-1.34	4.29
Cadmium	µg/L	0.5	-1.76	0.67	2.72	-1.76	0.67	2.72
Calcium	mg/L		37.80	79.28	138.00	37.80	79.28	138.00
Chloride	mg/L	120	33.40	80.43	152.00	33.40	80.43	152.00
Chromium	µg/L	8.9	-2.43	0.09	1.45	-2.43	0.09	1.45
Cobalt	µg/L	0.9	-1.00	0.33	1.90	-1.00	0.33	1.90
Conductivity	µS/cm		450	805	1480	450	805	1480
Copper	µg/L	5	0.36	2.06	7.36	0.36	2.06	7.36
Dissolved Inorganic Carbon	mg/L		48.40	52.08	54.80	48.40	52.08	54.80
Dissolved Organic Carbon	mg/L		5.20	7.25	8.50	5.20	7.25	8.50
Dissolved Oxygen	mg/L		1.30	10.42	16.96	1.30	10.42	16.96
Filtered Reactive	mg/L		0.00	0.02	0.13	0.00	0.02	0.13

Phosphate								
Hardness as $CaCO_3$	mg/L		139.00	320.38	590.00	139.00	320.38	590.00
Iron	µg/L	300	46.10	223.53	768.00	46.10	223.53	768.00
Lead	µg/L	5	-15.20	-1.01	10.30	-15.20	-1.01	10.30
Lithium	µg/L		-0.88	10.95	40.30	-0.88	10.95	40.30
Magnesium	mg/L		7.98	28.63	59.60	7.98	28.63	59.60
Manganese	µg/L		14.20	50.42	141.00	14.20	50.42	141.00
Molybdenum	µg/L	40	-2.59	7.04	44.50	-2.59	7.04	44.50
Nickel	µg/L	25	-2.13	0.90	4.13	-2.13	0.90	4.13
Nitrates	mg/L		0.08	2.03	122.00	0.08	2.03	122.00
Nitrite	mg/L		0.00	0.01	0.06	0.00	0.01	0.06
pH	pH Units	6.5-8.5	7.68	8.47	8.82	7.68	8.47	8.82
Potassium	mg/L		0.84	5.85	20.30	0.84	5.85	20.30
Silicates	mg/L		1.62	2.60	3.30	1.62	2.60	3.30

Notes: Data collected 2003 through 2019 by Hamilton Conservation Authority

mg/L = milligrams per litre; µg/L = micrograms per litre; µS/cm = microsiemens per centimetre

PWQO = Provincial Water Quality Objectives (Ministry of the Environment, 1999)

Negative values indicate parameter was below the laboratory method detection limit

Appendix B.4 continued Surface Water Quality Data – PWQMN Stations sampled between 2003 and 2019

			9000800502 (Spencer Ck at Market St)	9000800502	9000800502	9000800602 (Spencer Ck at Hwy 5)	9000800602	9000800602
Parameter	Units	PWQO	Min	Average	Max	Min	Average	Max
Silver	µg/L	0.1	-7.46	-1.14	2.80	-7.18	-1.25	2.79
Sodium	mg/L		2.37	43.02	72.40	18.80	29.95	58.60
Strontium	µg/L		46.80	1664.41	7510.00	227.00	331.83	460.00
Temperature	°C		1.60	14.82	25.30	0.50	14.58	30.40
Tin	µg/L		-26.30	-3.85	16.50	-17.50	-3.77	14.50
Titanium	µg/L		-0.37	2.14	18.20	-0.34	1.84	20.10
Total Kjeldahl Nitrogen	mg/L		0.05	0.70	1.36	0.14	0.78	1.73
Total Nitrogen	mg/L		0.25	1.01	2.11	0.35	1.05	2.01
Total Phosphorus	mg/L	0.03	0.00	0.05	0.28	0.01	0.05	0.19
Total Suspended Solids	mg/L		0.70	10.67	114.00	0.50	8.68	97.40
Uranium	µg/L		-2.18	3.70	18.40	-2.55	2.57	10.30
Vanadium	µg/L		-0.31	1.08	6.33	-0.92	0.99	10.00
Zinc	µg/L	20	3.71	21.66	61.20	5.28	22.66	61.30
Zirconium	µg/L	4	-0.36	-0.03	0.52	-0.15	0.00	0.45

Notes: Data collected 2003 through 2019 by Hamilton Conservation Authority
mg/L = milligrams per litre; µg/L = micrograms per litre; µS/cm = microsiemens per centimetre
PWQO = Provincial Water Quality Objectives (Ministry of the Environment, 1999)
Negative values indicate parameter was below the laboratory method detection limit

Appendix B.4 continued Surface Water Quality Data – PWQMN Stations sampled between 2003 and 2019

			9000800702 (Spencer Ck at Safari Rd)	9000800702	9000800702
Parameter	Units	PWQO	Min	Average	Max
Alkalinity as CaCO3	mg/L		69.90	236.16	303.00
Aluminium	µg/L	75	-3.27	26.10	321.00
Ammonium	mg/L		0.00	0.05	0.59
Barium	µg/L		23.90	56.51	97.10
Beryllium	µg/L	1100	-0.11	0.01	0.19
Bismuth	µg/L		-8.04	-1.34	3.31
Cadmium	µg/L	0.5	-1.09	0.60	2.39
Calcium	mg/L		35.50	65.84	99.80
Chloride	mg/L	120	27.00	49.05	97.20
Chromium	µg/L	8.9	-1.77	-0.04	1.98
Cobalt	µg/L	0.9	-1.06	0.31	1.86
Conductivity	µS/cm		237	623.17	858.00
Copper	µg/L	5	-0.45	0.89	2.84
Dissolved Inorganic Carbon	mg/L		54.00	64.53	72.90
Dissolved Organic Carbon	mg/L		6.90	10.60	12.50
Dissolved Oxygen	mg/L		0.12	8.33	20.34
Filtered Reactive Phosphate	mg/L		0.00	0.00	0.01
Hardness as $CaCO_3$	mg/L		165.00	280.10	399.00
Iron	µg/L	300	25.10	139.45	769.00
Lead	µg/L	5	-13.20	-1.08	13.20
Lithium	µg/L		-3.33	2.83	9.94
Magnesium	mg/L		15.60	26.88	36.30
Manganese	µg/L		5.32	62.12	671.00
Molybdenum	µg/L	40	-3.20	0.97	3.20
Nickel	µg/L	25	-3.16	-0.10	3.44
Nitrates	mg/L		0.01	1.98	166.00
Nitrite	mg/L		0.00	0.01	0.04
pH	pH Units	6.5-8.5	6.60	8.23	8.68
Potassium	mg/L		1.02	1.65	5.41

Silicates	mg/L		2.68	3.88	4.80

Notes: Data collected 2003 through 2019 by Hamilton Conservation Authority
mg/L = milligrams per litre; µg/L = micrograms per litre; µS/cm = microsiemens per centimetre
PWQO = Provincial Water Quality Objectives (Ministry of the Environment, 1999)
Negative values indicate parameter was below the laboratory method detection limit

Appendix B.4 continued Surface Water Quality Data – PWQMN Stations sampled between 2003 and 2019

			9000800702 (Spencer Ck at Safari Rd)	9000800702	9000800702
Parameter	Units	PWQO	Min	Average	Max
Silver	µg/L	0.1	-7.45	-1.24	2.58
Sodium	mg/L		13.40	26.15	52.80
Strontium	µg/L		196.00	307.79	709.00
Temperature	°C		0.10	14.06	28.80
Tin	µg/L		-15.70	-3.40	11.10
Titanium	µg/L		-0.72	0.52	3.68
Total Kjeldahl Nitrogen	mg/L		0.13	0.66	1.27
Total Nitrogen	mg/L		0.22	0.73	1.14
Total Phosphorus	mg/L	0.03	0.01	0.02	0.08
Total Suspended Solids	mg/L		0.50	5.15	114.00
Uranium	µg/L		-2.85	2.30	9.73
Vanadium	µg/L		-1.06	0.61	9.51
Zinc	µg/L	20	3.05	34.24	370.00
Zirconium	µg/L	4	-0.29	-0.12	-0.01

Notes: Data collected 2003 through 2019 by Hamilton Conservation Authority
mg/L = milligrams per litre; µg/L = micrograms per litre; µS/cm = microsiemens per centimetre
PWQO = Provincial Water Quality Objectives (Ministry of the Environment, 1999)
Negative values indicate parameter was below the laboratory method detection limit

Appendix B.5 Aquatic Ecosystem Health

Year 1 Stations			Monitoring Years	
Watershed	**Subwatershed**	**Station Name**	**2004**	**2007**
Spencer Creek	Fletcher Creek	FLE308-C1	Excellent	
Spencer Creek	Fletcher Creek	FLE312-B2	Good	Good
Spencer Creek	Flamborough Creek	FLM316-A1	Good	Good
Spencer Creek	Flamborough Creek	FLM317-A1		
Spencer Creek	Middle Spencer Creek	MSP319-A1	Fair	
Spencer Creek	Middle Spencer Creek	MSP323-A1	Good	
Spencer Creek	Upper Spencer Creek	USP315-A1	Excellent	
Spencer Creek	West Spencer Creek	WSP324-A3	Fair	
Year 2 Stations			**Monitoring Years**	
Watershed	**Subwatershed**	**Station Name**	**2005**	**2008**
Spencer Creek	Ancaster Creek	ANC367-A2		Good
Spencer Creek	Ancaster Creek	ANC369-A1	No Fish	
Spencer Creek	Sulphur Creek	ANC375-A1	No Fish	
Spencer Creek	Borer's Creek	B0R349-A1	Fair	
Spencer Creek	Borer's Creek	B0R354-A2		
Spencer Creek	Logie's Creek	L0G326-A2	Good	Fair
Spencer Creek	Lower Spencer Creek	LSP378-A1	Good	Good
Spencer Creek	Lower Spencer Creek	LSP379-C1		
Spencer Creek	Spring Creek	SPR343-A1	Fair	Fair
Spencer Creek	Spring Creek	SPR346-A2	Fair	Fair
Spencer Creek	Sulpher Creek	SUL350-A1	Fair	Good
Spencer Creek	Sulpher Creek	SUL356-K1	Fair	Fair
Spencer Creek	Sulpher Creek	SUL361-A1	Good	Fair
Spencer Creek	Tiffany Creek	TIF374-A3	No Fish	No Fish
Spencer Creek	Tiffany Creek	TIF382-F1	No Fish	No Fish
Year 3 Stations			**Monitoring Years**	
Watershed	**Subwatershed**	**Station Name**	**2006**	**2009**
Stoney-Battlefield Creeks	Battle-field Creek	BATB6-A2	Fair	Fair
Stoney-Battlefield Creeks	Battle-field Creek	BATB6-A4		Fair

Appendix B.5 Aquatic Ecosystem Health

Year 1 Stations			Monitoring Years	
Stoney Creek Numbered Watercourses	WC 12	FIF123-A1	No Fish	No Fish
Stoney Creek Numbered Watercourses	WC 12	FIF126-A1	Fair	Fair
Red Hill Creek	Lower Davis Creek	LDA2201-A1	Good	Good
Red Hill Creek	Lower Davis Creek	LDA2201-A3	No Fish	No Fish
Red Hill Creek	Montgomery Creek	MON2101-A3	Degraded	Fair
Stoney-Battlefield Creeks	Stoney Creek	STOS3-A2	No Fish	Fair
Stoney-Battlefield Creeks	Stoney Creek	ST0S6-A1		
Stoney-Battlefield Creeks	Hannon Creek	UHA3001-A1	Fair	Fair

Annual Monitoring Stations			Monitoring Years					
Watershed	**Sub-watershed**	**Station Name**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Spencer Creek	Ancaster Creek	ANC368-A1	Fair					Fair
Spencer Creek	Middle Spencer Creek	MSP330-A1	Fair	Fair	Fair	Fair	Good	Fair
Spencer Creek	Middle Spencer Creek	MSP339-A1	Good	Excellent	Fair			Excellent
Red Hill Creek	Red Hill Valley	RED1009-A1		No Access			Fair	Fair
Stoney-Battlefield Creek	Stoney Creek	STOS6-A3		No Fish			Fair	Fair
Spencer Creek	Upper Spencer Creek	USP315-C3	Degraded	Fair	Fair			Fair

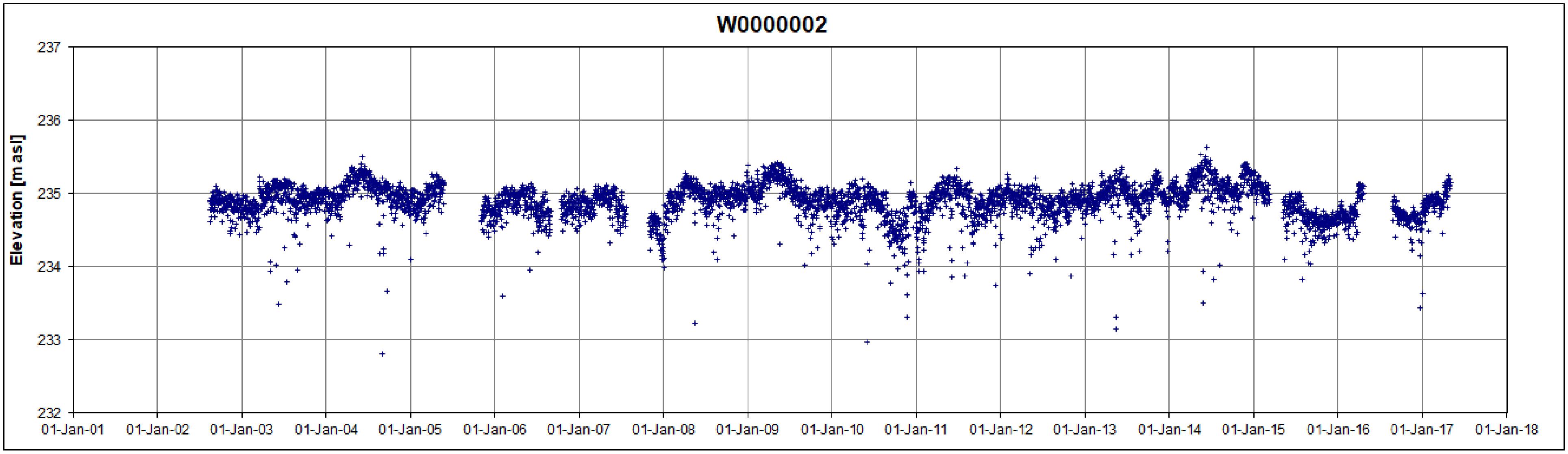
No access: due to construction works
No fish: the site was surveyed, but no fish species were sampled
Year 1 Stations: a drought during summer 2007 effected ability to sample the majority of the creeks.

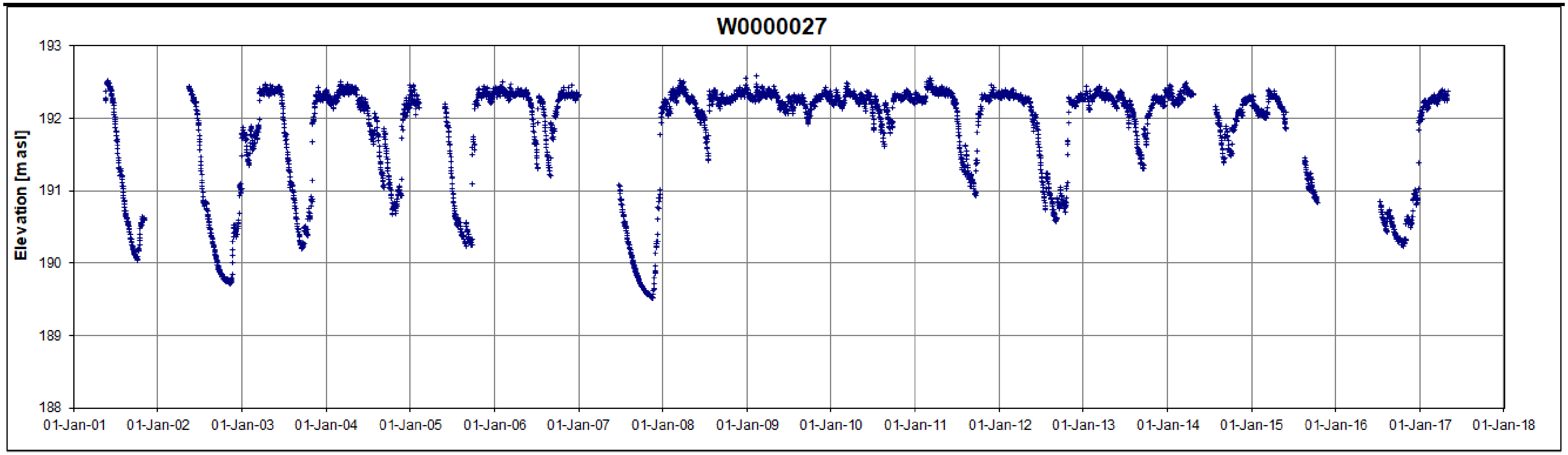
Appendix B.6 Groundwater Monitoring Network – PGMN Wells

Well ID	Northing	Easting	Well Top Elevation [m AMSL]	Well Depth [m]	Geology	Period of Record
W0000002	581880	4792796	245	31.2	dolostone	2001 to present
W0000027	605372	4782676	198	7.2	dolostone	2001 to present
W0000031	572609	4808042	293	27.43	dolostone	2001 to present
W0000033	595084	4782942	191	16.46	dolostone	2001 to present
W0000034	573435	4797993	263	8.53	dolostone	2001 to present
W0000294	575048	4794350	254	7.8	gravel	2003 to present
W0000295	575049	4794349	254	10.99	dolostone	2003 to present
W0000296	572256	4801838	279	12.06	sand	2003 to present
W0000297	572255	4801837	279	5.6	sand	2003 to 2013

Note: m AMSL = metres above mean sea level

Appendix B.7 Groundwater Levels

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192
191
190
189
188
01-Jan-01
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01-Jan-03
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01-Jan-07
01-Jan-08
01-Jan-09
01-Jan-10
01-Jan-11
01-Jan-12
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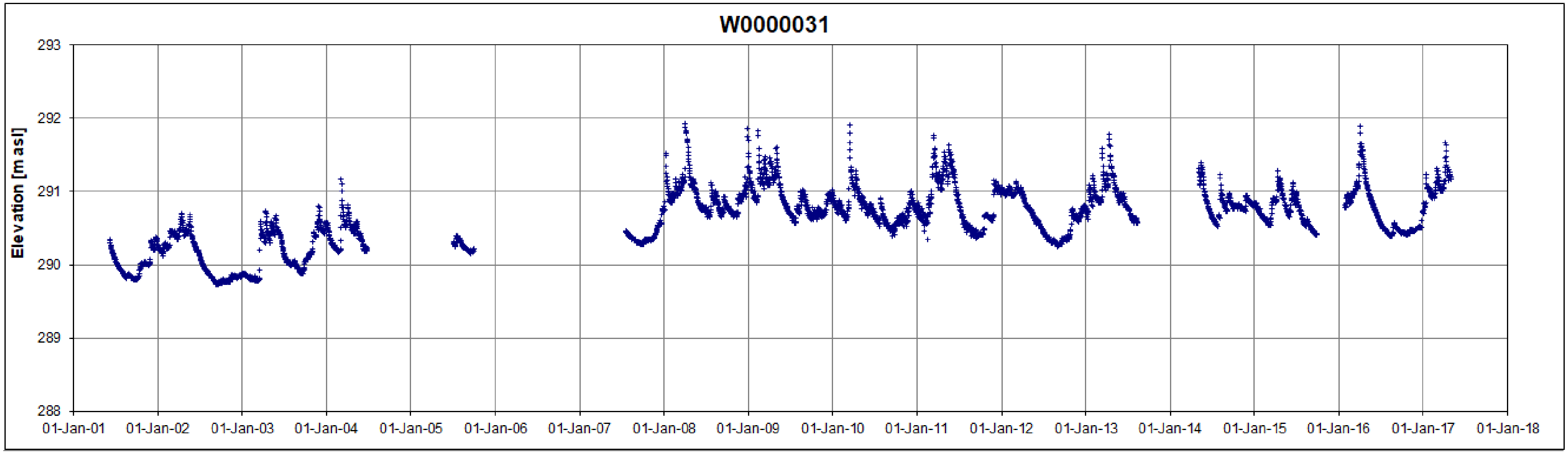
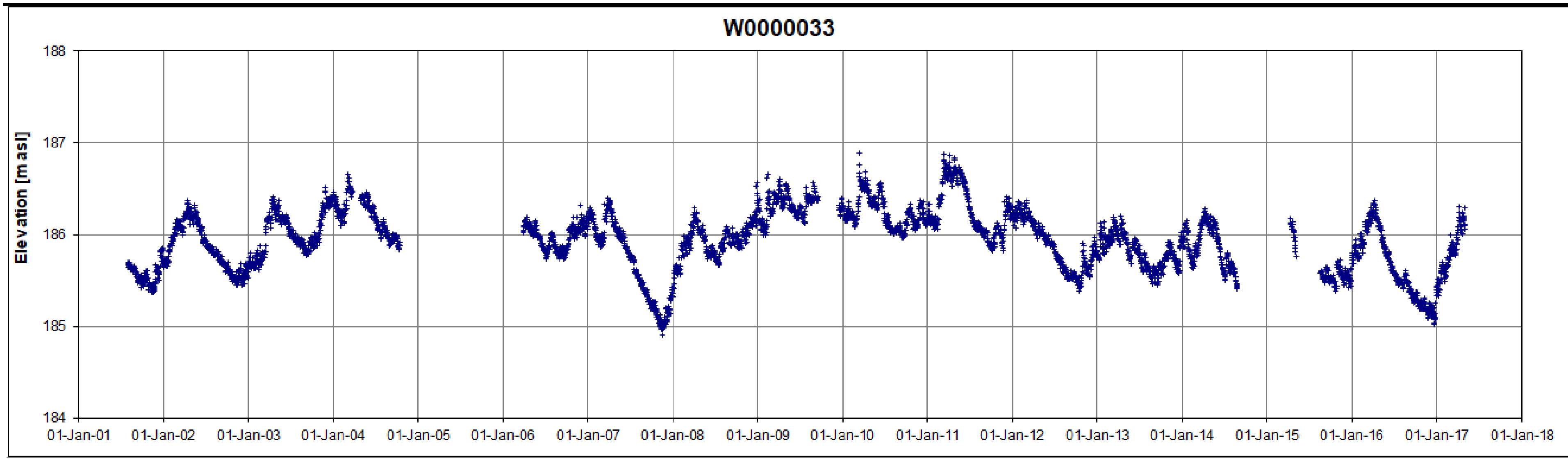
01-Jan-14
01-Jan-15
01-Jan-16
01-Jan-17
01-Jan-18

Appendix B.7 continued Groundwater Levels

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186
185
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01-Jan-01
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01-Jan-10
01-Jan-11
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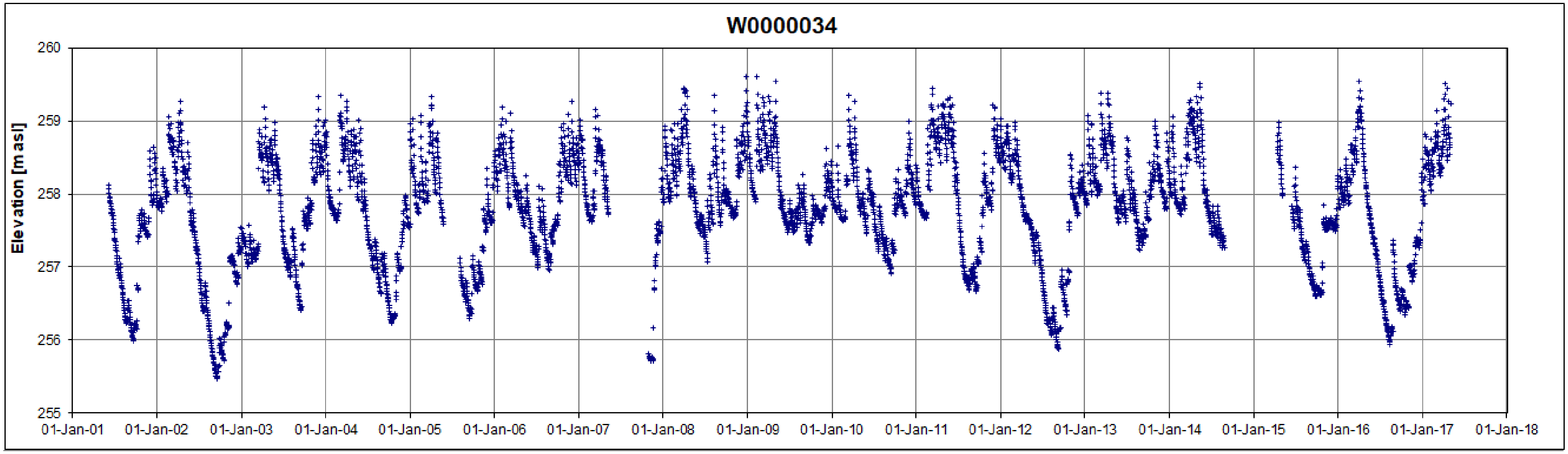
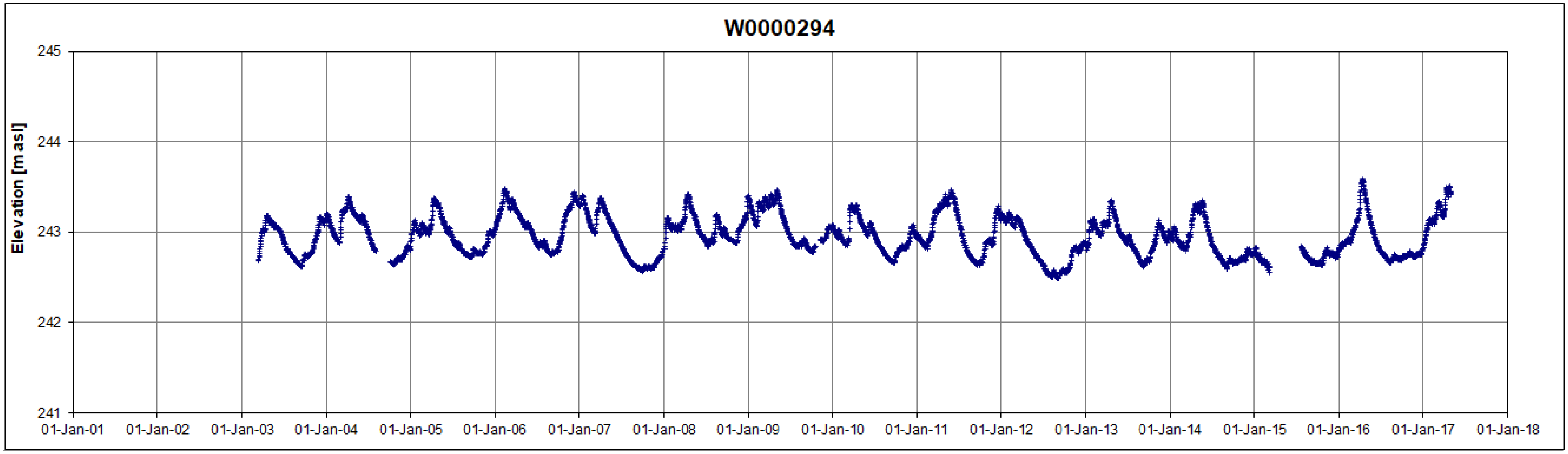
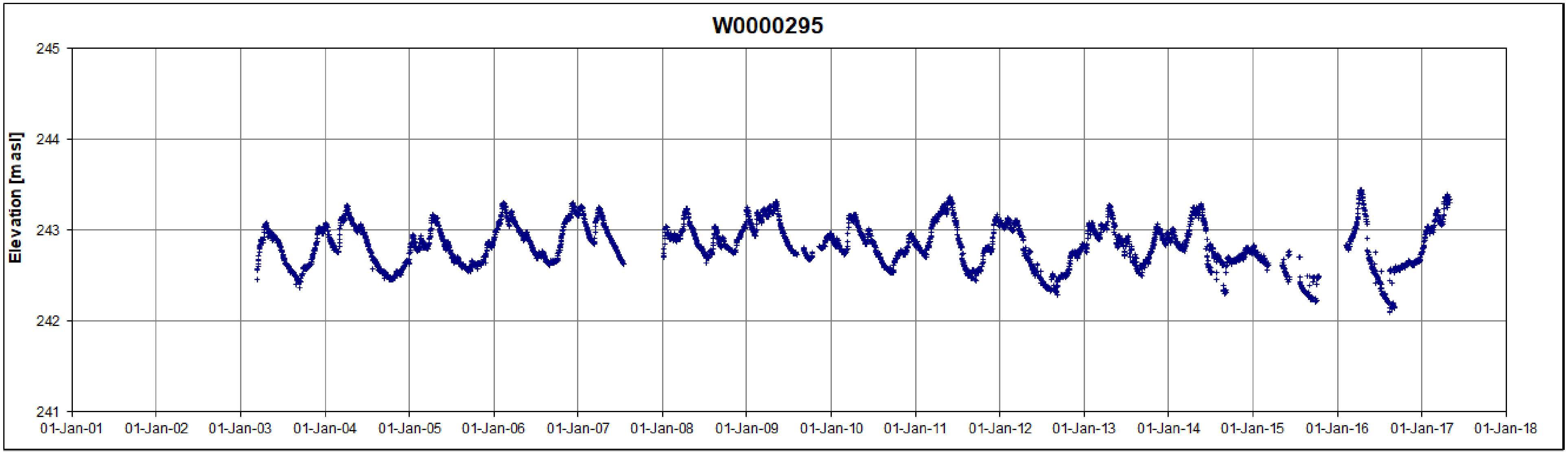
01-Jan-17
01-Jan-18

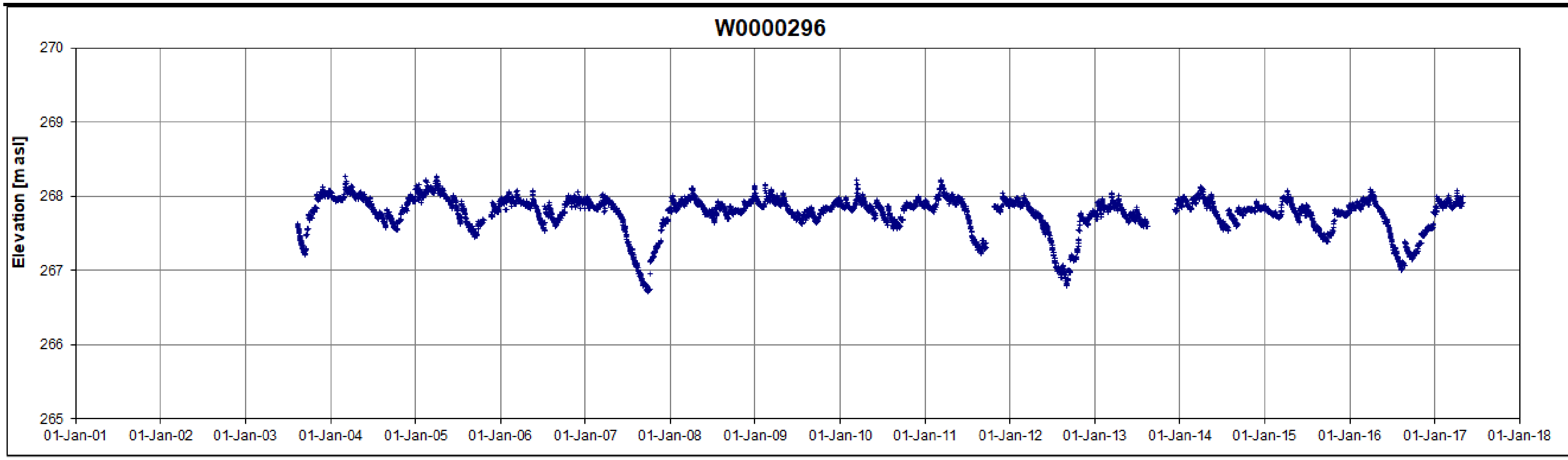
Appendix B.7 continued Groundwater Levels





Appendix B.7 continued Groundwater Levels

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01-Jan-08
01-Jan-09
01-Jan-10
01-Jan-11
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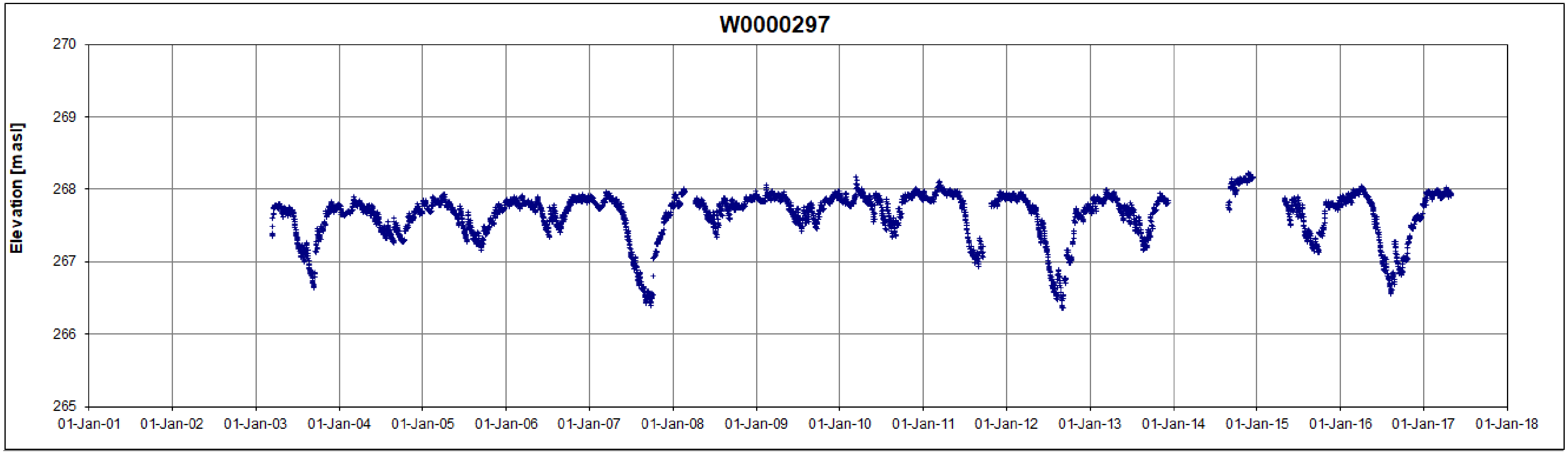
01-Jan-18

Appendix B.7 continued Groundwater Levels



Appendix B.8 Groundwater Quality – PGMN Wells (2001-2018)

Parameter	Unit	ODWQS	W0000002		W0000027		W0000031		W0000033		W0000034	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Alkalinity (as CaCO3)	mg/L		238	256	214	287	257	296	75.8	127	302	425
Aluminum	mg/L		0.0002	0.011	0.0002	0.008	0.0004	0.008	0.0003	0.009	0.0004	0.012
Antimony	mg/L	0.006	0.00032	0.0007	0.0005	0.0009	0.00037	0.0007	0.00005	0.0005	0.00035	0.0009
Arsenic	mg/L	0.01	0.0001	0.0005	0.0002	0.00113	0.0001	0.0002	0.0001	0.00743	0.0003	0.0007

Barium	mg/L	1.0	0.029	0.0376	0.008	0.01	0.0382	0.062	0.0055	0.0278	0.031	0.042
Benzene	mg/L	0.001	0	<0.0001	0	<0.0001	0	<0.0001	0	<0.0001	0	<0.0001
Boron	mg/L	5.0	0.128	0.236	0.149	0.202	0.011	0.0165	0.619	1.01	0.016	0.027
Cadmium	mg/L	0.005	0	0.0001	0.00002	0.0002	0.00005	0.0001	0	0.0001	0.00009	0.00012
Carbon tetrachloride	mg/L	0.002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
Chloride	mg/L		65.1	106	68	109	11.4	39	32.5	1250	18.4	96.6
Chromium	mg/L	0.05	0.0001	0.002	0.0001	0.0047	0.0002	0.0022	0.0001	0.0023	0.0001	0.0022
Copper	mg/L		0.0004	0.0011	0.0004	0.011	0.0004	0.006	0.0011	0.0053	0.0013	0.0034
Dichloromethane	mg/L	0.05	0	<0.0005	0	<0.0005	0	<0.0005	0	<0.0005	0	<0.0005
Fluoride	mg/L	1.5	1.2	1.48	0.32	0.51	0.05	0.08	0.17	0.46	0.07	0.14
Hardness (as CaCO3)	mg/L		425	600	1190	1400	210	350	1100	2400	115	520
Iron	mg/L		0.078	0.48	0.123	0.3	0.003	0.04	0.01	4.21	0.005	0.013
Lead	mg/L	0.01	0.00005	0.0002	0.00001	0.0002	0.0009	0.00105	0.00004	0.0016	0.0006	0.00461
Manganese	mg/L		0.0112	0.02	0.0642	0.0889	0.00006	0.0003	0.0259	0.313	0.0001	0.0094
Nitrate	mg/L	10.0	0.064	0.53	0.02	0.5	1.27	7.9	0.02	0.55	2.98	17.1
PCB	mg/	0.003	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000

	L		2	2	2	2	2	2	2	2	2	2
pH	pH		7.7	8.1	6.47	7.91	7.93	8.37	7.83	8.09	7.62	8.2
Selenium	mg/L	0.01	0.0001	0.0006	0.0001	0.003	0.0002	0.001	0.0001	0.006	0.0004	0.0016
Sodium	mg/L		28.4	53	33.2	41.6	7.61	17	123	430	8.36	59.9
Sulphate	mg/L		177	327	910	1250	16.3	27	1310	1780	11.4	48.6
Tetrachloroethylene	mg/L	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Uranium	mg/L	0.02	0.0004	0.0008	0.00003	0.00007	0.0005	0.0007	0.00001	0.0001	0.0004	0.0007
Vinyl Chloride	mg/L	0.001	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
Xylene (Total)	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Zinc	mg/L		0.0021	0.034	0.0009	0.013	0.101	0.130	0.0007	0.0076	0.0405	0.066

Notes: ODWQS = Ontario Drinking Water Quality Standards – used only for comparison purposes. These values are standards for treated water.

Appendix B.8 continued Groundwater Quality – PGMN Wells (2001-2018)

Parameter	Unit	ODWQS	W0000294		W0000295		W0000296		W0000297	
			Min	Max	Min	Max	Min	Max	Min	Max
Alkalinity (as CaCO3)	mg/L		171	295	229	304	234	297	248	282
Aluminum	mg/L		0.0006	0.0113	0.00011	0.012	0.0003	0.009	0.006	0.012
Antimony	mg/L	0.006	0.00027	0.0009	0.0005	0.0011	0.0003	0.0009	0.00037	0.00104
Arsenic	mg/L	0.01	0.0002	0.0029	0.00038	0.0024	0.0048	0.0075	0.0024	0.0036
Barium	mg/L	1.0	0.0225	0.08	0.227	0.411	0.0417	0.0476	0.0487	0.075
Benzene	mg/L	0.001	0	<0.0001	0	<0.0001	0	<0.0001	0	<0.0001
Boron	mg/L	5.0	0.017	0.0315	0.013	0.077	0.017	0.0216	0.073	0.650
Cadmium	mg/L	0.005	0.00003	0.00011	0.00003	0.0001	0	0.0001	0.00001	0.0001
Carbon tetrachloride	mg/L	0.002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
Chloride	mg/L		147	638	137	1210	6.7	14	5.7	9.2
Chromium	mg/L	0.05	0.0003	0.0052	0.0001	0.0137	0.0001	0.0012	0.0001	0.0009
Copper	mg/L		0.0007	0.0021	0.008	0.004	0.0001	0.002	0.0002	0.014
Dichloromethane	mg/L	0.05	0	<0.0005	0	<0.0005	0	<0.0005	0	<0.0005
Fluoride	mg/L	1.5	0.07	0.14	0.07	0.27	0.56	0.82	0.46	0.65
Hardness (as CaCO3)	mg/L		150	688	410	1000	250	380	300	360
Iron	mg/L		0.003	0.029	0.04	0.155	1.2	1.62	0.634	1.8
Lead	mg/L	0.01	0.00005	0.00048	0.00004	0.0007	0.0001	0.00016	0.00003	0.00004
Manganese	mg/L		0.0001	0.0018	0.253	0.696	0.0291	0.0339	0.0138	0.0409
Nitrate	mg/L	10.0	4.21	16.1	0.02	7.88	0.02	0.2	0.04	0.5
PCB	mg/L	0.003			<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
pH	pH		7.75	8.36	7.69	8.49	7.78	8.2	7.91	8.21
Selenium	mg/L	0.01	0.0009	0.003	0.0001	0.0006	0.0001	0.001	0.0001	0.0002
Sodium	mg/L		139	260	234	516	5	8	5.4	11
Sulphate	mg/L		34.8	82.4	70.5	110	57	106	66.6	77.5

Tetrachloroethylene	mg/L	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Uranium	mg/L	0.02	0.0003	0.0013	0.0039	0.00605	0.0005	0.00097	0.0001	0.00068
Vinyl Chloride	mg/L	0.001	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
Xylene (Total)	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Zinc	mg/L		0.0007	0.0336	0.0021	0.027	0.056	0.0821	0.0011	0.009

Notes: ODWQS = Ontario Drinking Water Quality Standards – used only for comparison purposes. These values are standards for treated water.

Appendix B.9 Municipal Raw Water Quality (up to 2020)

Parameter	Unit	ODWQS[1]	Woodward		Greensville	
			Minimum	Maximum	Minimum	Maximum
Alkalinity (as $CaCO_3$)	mg/L	*30-500*	83	97	90	369
Aluminum	mg/L	*0.1*			<0.0003	0.13
Antimony	mg/L	*0.006*	0.0001	0.00098	<0.00002	0.0001
Arsenic	mg/L	*0.01*	0.0006	0.0012	<0.0001	0.0001
Barium	mg/L	*1.0*	0.0193	0.0276	0.11	0.181
Benzene	µg/L	*1*	<0.05		<0.2	
Boron	mg/L	*5*	0.019	0.028	0.023	0.084
Bromide	µg/L				<0.2	
Cadmium	mg/L	*0.005*	0.00001	0.00011	0.000011	0.000028
Calcium	mg/L				128	183
Carbon Tetrachloride	µg/L	*2*	<0.2		<0.1	
Chloride	mg/L	*250*	20	43.4	187	317
Chromium	mg/L	*0.05*	0.0001	0.0015	<0.0001	0.002
Copper	mg/L	*1*	0.0003	0.024	<0.0001	0.08
Dichloromethane	µg/L	*50*	<0.5		<0.3	
Fluoride	mg/L	*1.5*	<0.04	0.74	0.1	0.13
Glyphosate	µg/L	*0.28*	<1		<1	
Iron	mg/L	*0.3*	<0.003	0.222	<0.003	0.49
Lead	mg/L	*0.01*	0.00002	0.00055	0.00005	0.052
Manganese	mg/L	*0.05*	0.00078	0.017	<0.00001	0.014
Nitrate (as N)	mg/L	*10*	0.24	0.46	4.63	9.56
Nitrite (as N)	mg/L	*1*	<0.01		<0.01	0.04
pH		*6.5-8.5*	6.67	8.5	7.16	8.14
Selenium	mg/L	*0.01*	0.0001	0.00122	0.0002	0.0003
Sodium	mg/L	*200*	11.6	18.2	107	182
Sulphate	mg/L	*500*	22.9	27.8	51.9	78

Total Hardness (as $CaCO_3$)	mg/L	*80-100*	116	126	418	585
Total PCBs	µg/L	*3*	<0.05		<0.05	
Turbidity	NTU	*5*[2]	<0.05	116	0.05	0.76
Uranium	mg/L	*0.02*	0.000219	0.0004	0.000554	0.000722
Zinc	mg/L	*5*	0.0006	0.0056	0.005	0.17

Notes: 1. Ontario Drinking Water Quality Standards, objectives and guidelines. Provided for comparison purposes only. They apply to treated water.

2. Aesthetic objective at the point of consumption. 3. When only a minimum value is recorded, all results were less than the method detection limit.

APPENDIX C: TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

Assessment completed in 2009 based on:

- 2006 Statistics Canada population data
- 2007 Municipal water takings
- August 2008 MOECC Permit to Take Water database
- 2008 MNR updated land cover mapping
- 2009 Water Survey Canada surface water flow database
- 2008 MOE Well Water Information System
- 1997 Environment and Climate Change Canada climate dataset

Appendix C.1 Water Budget Components

Watershed / Subwatershed	Area [km²]	P [mm]	AET [mm]	R [mm]	RO [mm]
Spencer Creek					
Fletcher Creek	25.12	988	618	194	181
Upper Spencer Creek	35.92	1001	603	228	174
Flamborough Creek	13.30	1024	594	264	169
Westover Creek	10.89	1010	581	286	146
Middle Spencer Creek	49.68	1022	595	230	201
West Spencer Creek	18.11	1006	590	262	158
Logie's Creek	13.28	1061	589	258	217
Spring Creek	13.11	1000	627	149	229
Lower Spencer Creek	7.39	865	482	201	186
Sydenham Creek	5.27	1022	608	190	228
Tiffany Creek	9.08	964	580	140	249
Ancaster Creek	14.01	972	563	187	226
Sulphur Creek	16.90	988	600	193	199
Borer's Creek	19.48	1009	600	195	218
Chedoke Creek	25.06	944	510	163	275
Urban Hamilton City Core	36.52	921	458	214	252
Red Hill Creek					
Upper Ottawa	13.83	946	539	124	286
Hannon Creek	10.97	946	589	123	238
Red Hill Valley[2]	13.28	908	499	182	230
Green Hill	11.64	938	454	195	291
Montgomery Creek	3.75	941	539	175	231
Upper Davis Creek	7.25	943	566	146	235
Lower Davis Creek	3.75	940	517	191	234
Urban Hamilton Beach Strip[2]	2.34	59	34	8	17
Stoney Creek					
Battlefield Creek	7.47	939	538	220	184
Stoney Creek	21.03	939	577	164	202

Appendix C.1 continued Water Budget Components

Watershed / Subwatershed	Area	P	AET	R	RO
	[km^2]	[mm]	[mm]	[mm]	[mm]
Stoney Creek Watercourses					
WC 0	1.64	933	519	123	295
WC 1	3.58	937	471	187	281
WC 2	2.97	937	465	200	274
WC 3	2.10	936	459	207	272
WC 4	2.81	936	473	218	247
WC 5	6.18	936	516	235	189
WC 6	1.52	935	485	261	191
WC 7	4.32	936	544	230	166
WC 8	0.10	934	502	97	337
WC 9	4.51	935	483	310	144
WC 10	0.80	934	531	162	245
WC 10.1	0.48	933	583	117	239
WC 11	0.69	933	561	116	262
WC 12	5.76	935	559	218	161
Cootes Paradise (Hamilton)[2]	1.16	72	44	14	13

Notes: 1. P = precipitation; AET = Actual Evapotranspiration; R = Recharge; RO = Runoff

2. PRMS model did not fully encompass this subwatershed, and therefore the data is incomplete. Data not used in averages.

Appendix C.2a Surface Water Supply

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Spencer Creek												
Fletcher Creek	0.234	0.177	0.267	0.403	0.260	0.094	0.033	0.014	0.034	0.059	0.219	0.243
Upper Spencer Creek	0.604	0.458	0.699	1.024	0.675	0.257	0.115	0.060	0.117	0.196	0.587	0.636
Flamborough Creek	0.183	0.135	0.208	0.241	0.158	0.057	0.022	0.010	0.029	0.053	0.163	0.179
Westover Creek	0.143	0.115	0.170	0.206	0.139	0.058	0.034	0.021	0.035	0.061	0.138	0.142
Middle Spencer Creek	1.961	1.450	2.187	2.868	1.967	0.758	0.303	0.154	0.342	0.600	1.830	2.034
West Spencer Creek	0.234	0.177	0.261	0.311	0.219	0.088	0.045	0.027	0.052	0.083	0.220	0.239
Logie's Creek	0.169	0.120	0.170	0.243	0.180	0.071	0.021	0.010	0.027	0.051	0.172	0.204
Spring Creek	0.099	0.066	0.154	0.188	0.126	0.047	0.013	0.003	0.007	0.019	0.091	0.100
Lower Spencer Creek	2.570	1.899	3.002	3.853	2.647	1.013	0.382	0.187	0.401	0.743	2.374	2.626
Sydenham Creek	0.052	0.041	0.066	0.073	0.054	0.022	0.009	0.004	0.006	0.014	0.041	0.045
Tiffany Creek	0.064	0.045	0.094	0.114	0.080	0.030	0.009	0.003	0.004	0.013	0.052	0.057
Ancaster Creek	0.364	0.259	0.478	0.619	0.422	0.157	0.048	0.021	0.039	0.091	0.339	0.365
Sulphur Creek	0.159	0.104	0.197	0.292	0.193	0.071	0.021	0.009	0.020	0.043	0.162	0.171
Borer's Creek	0.217	0.154	0.244	0.290	0.210	0.081	0.025	0.009	0.020	0.046	0.169	0.190
Chedoke Creek	0.220	0.201	0.330	0.311	0.233	0.091	0.032	0.017	0.018	0.051	0.177	0.207
Urban Hamilton City Core	0.448	0.42	0.519	0.467	0.371	0.152	0.073	0.052	0.066	0.130	0.372	0.421
Red Hill Creek												
Upper Ottawa	0.084	0.077	0.125	0.144	0.108	0.041	0.012	0.003	0.003	0.017	0.065	0.076
Hannon Creek	0.065	0.059	0.099	0.117	0.084	0.030	0.008	0.002	0.001	0.008	0.049	0.055
Red Hill Valley	0.507	0.466	0.729	0.737	0.555	0.231	0.115	0.063	0.073	0.171	0.417	0.450
Green Hill	0.105	0.100	0.138	0.134	0.111	0.055	0.038	0.024	0.027	0.056	0.099	0.100
Montgomery Creek	0.032	0.029	0.052	0.047	0.034	0.014	0.008	0.005	0.005	0.012	0.027	0.028
Upper Davis Creek	0.051	0.045	0.074	0.083	0.060	0.023	0.010	0.005	0.006	0.014	0.042	0.044
Lower Davis Creek	0.086	0.077	0.131	0.133	0.096	0.039	0.020	0.011	0.013	0.030	0.073	0.075
Urban Hamilton Beach Strip	0.0175	0.02	0.023	0.023	0.017	0.006	0.002	0.000	0.000	0.001	0.011	0.013

Appendix C.2a continued Surface Water Supply

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Stoney Creek												
Battlefield Creek	0.079	0.073	0.124	0.109	0.077	0.035	0.023	0.015	0.019	0.038	0.071	0.070
Stoney Creek	0.249	0.235	0.426	0.360	0.255	0.106	0.061	0.036	0.045	0.095	0.208	0.209
Stoney Creek Watercourses												
WC 0	0.011	0.011	0.017	0.015	0.011	0.004	0.001	0.000	0.000	0.002	0.007	0.010
WC 1	0.034	0.033	0.048	0.043	0.033	0.015	0.010	0.007	0.008	0.016	0.028	0.031
WC 2	0.030	0.029	0.040	0.035	0.028	0.013	0.010	0.007	0.007	0.015	0.025	0.027
WC 3	0.022	0.021	0.028	0.024	0.019	0.010	0.007	0.005	0.006	0.011	0.018	0.020
WC 4	0.031	0.029	0.040	0.035	0.027	0.013	0.010	0.007	0.008	0.016	0.026	0.027
WC 5	0.071	0.065	0.103	0.086	0.064	0.032	0.024	0.017	0.020	0.038	0.061	0.063
WC 6	0.019	0.018	0.024	0.020	0.016	0.009	0.007	0.005	0.006	0.011	0.016	0.017
WC 7	0.049	0.044	0.071	0.064	0.044	0.021	0.014	0.009	0.012	0.024	0.042	0.044
WC 8	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
WC 9	0.065	0.059	0.083	0.077	0.055	0.029	0.024	0.017	0.022	0.041	0.061	0.062
WC 10	0.007	0.007	0.010	0.009	0.007	0.003	0.002	0.001	0.001	0.002	0.005	0.006
WC 10.1	0.003	0.003	0.004	0.005	0.003	0.001	0.000	0.000	0.000	0.000	0.002	0.002
WC 11	0.005	0.004	0.008	0.007	0.005	0.002	0.000	0.000	0.000	0.000	0.002	0.003
WC 12	0.062	0.051	0.087	0.085	0.058	0.026	0.018	0.012	0.016	0.029	0.052	0.055
Cootes Paradise (Hamilton)	0.0044	0.00	0.010	0.005	0.004	0.001	0.000	0.000	0.000	0.001	0.004	0.004

Appendix C.2b Surface Water Reserve

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Spencer Creek												
Fletcher Creek	0.100	0.118	0.187	0.242	0.172	0.056	0.016	0.008	0.010	0.027	0.113	0.151
Upper Spencer Creek	0.263	0.299	0.491	0.627	0.449	0.163	0.060	0.034	0.045	0.092	0.321	0.400
Flamborough Creek	0.087	0.084	0.139	0.147	0.102	0.034	0.009	0.006	0.016	0.023	0.093	0.118
Westover Creek	0.067	0.071	0.120	0.128	0.091	0.038	0.018	0.012	0.018	0.028	0.082	0.092
Middle Spencer Creek	0.888	0.913	1.467	1.726	1.278	0.460	0.152	0.082	0.182	0.275	0.999	1.302
West Spencer Creek	0.107	0.115	0.175	0.188	0.143	0.058	0.024	0.015	0.030	0.040	0.125	0.153
Logie's Creek	0.082	0.073	0.116	0.143	0.114	0.040	0.010	0.004	0.018	0.025	0.091	0.131
Spring Creek	0.036	0.036	0.059	0.088	0.077	0.025	0.005	0.001	0.004	0.006	0.049	0.065
Lower Spencer Creek	1.135	1.170	1.868	2.246	1.691	0.596	0.189	0.097	0.219	0.327	1.297	1.690
Sydenham Creek	0.022	0.022	0.039	0.040	0.033	0.013	0.004	0.002	0.003	0.005	0.025	0.030
Tiffany Creek	0.022	0.024	0.040	0.056	0.047	0.015	0.004	0.002	0.002	0.004	0.027	0.036
Ancaster Creek	0.145	0.152	0.232	0.332	0.257	0.084	0.023	0.009	0.025	0.034	0.185	0.243
Sulphur Creek	0.064	0.064	0.096	0.162	0.120	0.038	0.010	0.004	0.014	0.016	0.091	0.117
Borer's Creek	0.090	0.085	0.139	0.161	0.131	0.045	0.012	0.005	0.011	0.017	0.091	0.124
Chedoke Creek	0.092	0.107	0.167	0.165	0.135	0.049	0.015	0.007	0.010	0.016	0.089	0.118
Urban Hamilton City Core	0.221	0.239	0.350	0.259	0.213	0.085	0.033	0.022	0.035	0.049	0.204	0.250
Red Hill Creek												
Upper Ottawa	0.028	0.035	0.058	0.071	0.063	0.021	0.006	0.002	0.001	0.004	0.031	0.043
Hannon Creek	0.020	0.027	0.044	0.057	0.050	0.014	0.003	0.001	0.000	0.002	0.023	0.032
Red Hill Valley	0.202	0.239	0.387	0.384	0.329	0.125	0.052	0.032	0.031	0.061	0.226	0.266
Green Hill	0.048	0.055	0.088	0.073	0.066	0.031	0.017	0.012	0.011	0.022	0.058	0.062
Montgomery Creek	0.013	0.015	0.025	0.025	0.020	0.008	0.004	0.002	0.003	0.005	0.015	0.017
Upper Davis Creek	0.019	0.023	0.037	0.042	0.036	0.013	0.005	0.003	0.003	0.006	0.022	0.027
Lower Davis Creek	0.034	0.039	0.064	0.070	0.058	0.021	0.009	0.006	0.006	0.012	0.041	0.046

Watershed / Subwatershed	Jan [m^3/s]	Feb [m^3/s]	Mar [m^3/s]	Apr [m^3/s]	May [m^3/s]	Jun [m^3/s]	Jul [m^3/s]	Aug [m^3/s]	Sep [m^3/s]	Oct [m^3/s]	Nov [m^3/s]	Dec [m^3/s]
Urban Hamilton Beach Strip	0.007	0.008	0.015	0.012	0.010	0.003	0.001	0.000	0.000	0.000	0.004	0.006
Stoney Creek												
Battlefield Creek	0.035	0.041	0.063	0.061	0.047	0.019	0.010	0.008	0.008	0.015	0.044	0.045
Stoney Creek	0.103	0.124	0.196	0.196	0.155	0.058	0.027	0.019	0.019	0.037	0.122	0.131

Note: Surface Water Supply is a monthly median stream flow

Appendix C.2b continued Surface Water Reserve

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Stoney Creek Watercourses												
WC 0	0.004	0.005	0.010	0.008	0.007	0.002	0.000	0.000	0.000	0.000	0.003	0.005
WC 1	0.015	0.018	0.030	0.024	0.020	0.008	0.005	0.004	0.003	0.006	0.017	0.018
WC 2	0.013	0.016	0.026	0.020	0.017	0.007	0.004	0.004	0.003	0.006	0.015	0.016
WC 3	0.010	0.012	0.019	0.013	0.012	0.005	0.003	0.003	0.003	0.005	0.011	0.011
WC 4	0.014	0.017	0.026	0.019	0.016	0.007	0.005	0.004	0.004	0.007	0.016	0.016
WC 5	0.033	0.039	0.061	0.048	0.039	0.017	0.011	0.009	0.009	0.016	0.039	0.039
WC 6	0.009	0.011	0.016	0.011	0.009	0.005	0.003	0.003	0.003	0.005	0.011	0.011
WC 7	0.022	0.025	0.041	0.037	0.028	0.011	0.006	0.005	0.005	0.010	0.026	0.027
WC 8	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WC 9	0.033	0.037	0.056	0.046	0.033	0.015	0.010	0.009	0.009	0.017	0.041	0.039
WC 10	0.003	0.003	0.006	0.005	0.004	0.001	0.001	0.001	0.000	0.001	0.003	0.003
WC 10.1	0.001	0.001	0.003	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.001	0.001
WC 11	0.001	0.002	0.004	0.004	0.003	0.001	0.000	0.000	0.000	0.000	0.001	0.002
WC 12	0.027	0.029	0.048	0.049	0.036	0.014	0.008	0.007	0.006	0.013	0.033	0.033
Cootes Paradise (Hamilton)	0.002	0.002	0.003	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.001	0.002

Note: Surface Water Supply is a monthly median stream flow

Appendix C3 Groundwater Supply

Watershed / Subwatershed	Annual Recharge [m³/sec]	Annual Lateral Inflow [m³/sec]	Annual Q_{SUPPLY} [m³/sec]	Monthly Q_{SUPPLY} [m³/sec]	Annual $Q_{RESERVE}$ [m³/sec]	Monthly $Q_{RESERVE}$ [m³/sec]
Spencer Creek						
Fletcher Creek	0.1541	0.0052	0.1593	0.01328	0.0159	0.00133
Upper Spencer Creek	0.2591	0.0020	0.2610	0.02175	0.0261	0.00218
Flamborough Creek	0.1112	0.0034	0.1146	0.00955	0.0115	0.00096
Westover Creek	0.0987	NA	0.0987	0.00823	0.0099	0.00082
Middle Spencer Creek	0.3628	0.0797	0.4426	0.03688	0.0443	0.00369
West Spencer Creek	0.1503	0.0686	0.2189	0.01824	0.0219	0.00182
Logie's Creek	0.1086	0.0002	0.1088	0.00907	0.0109	0.00091
Spring Creek	0.0617	NA	0.0617	0.00514	0.0062	0.00051
Lower Spencer Creek	0.0470	0.0018	0.0489	0.00408	0.0049	0.00041
Sydenham Creek	0.0317	0.0137	0.0454	0.00378	0.0045	0.00038
Tiffany Creek	0.0403	NA	0.0403	0.00336	0.0040	0.00034
Ancaster Creek	0.0830	NA	0.0830	0.00692	0.0083	0.00069
Sulphur Creek	0.1032	NA	0.1032	0.00860	0.0103	0.00086
Borer's Creek	0.1201	0.0032	0.1233	0.01028	0.0123	0.00103
Chedoke Creek	0.1293	NA	0.1293	0.01078	0.0129	0.00108
Urban Hamilton City Core	0.2471	NA	0.2471	0.0206	0.0247	0.0021
Red Hill Creek						
Upper Ottawa	0.0545	NA	0.0545	0.00454	0.0054	0.00045
Hannon Creek	0.0428	NA	0.0428	0.00357	0.0043	0.00036
Red Hill Valley	0.0767	NA	0.0767	0.00639	0.0077	0.00064
Green Hill	0.0718	NA	0.0718	0.00598	0.0072	0.00060
Montgomery Creek	0.0207	NA	0.0207	0.00173	0.0021	0.00017
Upper Davis Creek	0.0335	NA	0.0335	0.00279	0.0033	0.00028
Lower Davis Creek	0.0228	NA	0.0228	0.00190	0.0023	0.00019
Urban Hamilton Beach Strip	0.0006	NA	0.0006	0.00005	0.0001	0.00001
Stoney Creek						
Battlefield Creek	0.0520	NA	0.0520	0.00433	0.0052	0.00043
Stoney Creek	0.1093	NA	0.1093	0.00911	0.0109	0.00091

Note: Monthly Q_{SUPPLY} equals Annual Q_{SUPPLY}/12
Monthly $Q_{RESERVE}$ equals Annual $Q_{RESEVRE}$/12

Appendix C3 continued Groundwater Supply

Watershed / Subwatershed	Annual Recharge	Annual Lateral Inflow	Annual Q_{SUPPLY}	Monthly Q_{SUPPLY}	Annual $Q_{RESEVRE}$	Monthly $Q_{RESEVRE}$
	[m³/sec]	[m³/sec]	[m³/sec]	[m³/sec]	[m³/sec]	[m³/sec]
Stoney Creek Watercourses						
WC 0	0.0064	NA	0.0064	0.00053	0.0006	0.00005
WC 1	0.0213	NA	0.0213	0.00178	0.0021	0.00018
WC 2	0.0189	NA	0.0189	0.00158	0.0019	0.00016
WC 3	0.0138	NA	0.0138	0.00115	0.0014	0.00012
WC 4	0.0195	NA	0.0195	0.00163	0.0019	0.00016
WC 5	0.0460	NA	0.0460	0.00383	0.0046	0.00038
WC 6	0.0125	NA	0.0125	0.00104	0.0013	0.00010
WC 7	0.0314	NA	0.0314	0.00262	0.0031	0.00026
WC 8	0.0003	NA	0.0003	0.00003	0.0000	0.00000
WC 9	0.0443	NA	0.0443	0.00369	0.0044	0.00037
WC 10	0.0041	NA	0.0041	0.00034	0.0004	0.00003
WC 10.1	0.0018	NA	0.0018	0.00015	0.0002	0.00002
WC 11	0.0025	NA	0.0025	0.00021	0.0003	0.00002
WC 12	0.0398	NA	0.0398	0.00332	0.0040	0.00033
Cootes Paradise (Hamilton)	0.0005	0.0043	0.0048	0.00040	0.0005	0.00004

Note: Monthly Q_{SUPPLY} equals Annual Q_{SUPPLY}/12
Monthly $Q_{RESERVE}$ equals Annual $Q_{RESEVRE}$/12
NA – Not available

Appendix C.4 Permit to Take Water Permitted Takings Summary

Watershed / Subwatershed	Agricultural		Commercial		Dewatering	Industrial	Misc.	Remediation	Water Supply	Total	
	SW	GW	SW	GW	GW	GW	GW	GW	GW	SW	GW
Spencer Creek											
Upper Spencer Creek				597,344					406,325	0	1,003,670
Flamborough Creek	27,300	637,710		68,080		71,398			48,190	27,300	825,378
Westover Creek		104,350		75,123			450			0	179,923
Middle Spencer Creek	1,458,071	1,224,788	216,752	597,754	16,592,970	257,757			191,625	1,674,823	18,864,893
West Spencer Creek	199,364	104,350								199,364	104,350
Logie's Creek		234,096			18,410,809					0	18,644,905
Ancaster Creek			327,240							327,240	0
Urban Hamilton City Core								36,792		0	36,792
Red Hill Creek											
Hannon Creek						35,173				0	35,173
Montgomery Creek				303,698						0	303,698
Upper Davis Creek								231,264		0	231,264
Lower Davis Creek								3,365,373		0	3,365,373
Stoney Creek Watercourses											
WC 7	204,450									204,450	0

Notes: 1. All values in cubic metres per year.
2. Miscellaneous (Misc.) includes aesthetic, recreation, ecological and flow augmentation uses.

3. Lake Ontario based water takings are not included.
4. SW = Surface Water Taking; GW = Groundwater Taking

Appendix C.5 Consumptive Use Factors (Ministry of the Environment, 2007)

Category	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Agriculture	Field and Pasture Crops	0.8	Industrial	Manufacturing	0.25
Agriculture	Fruit Orchards	0.8	Industrial	Other - Industrial	0.25
Agriculture	Market Gardens /Flowers	0.9	Industrial	Pipeline Testing	0.25
Agriculture	Nursery	0.9	Industrial	Power Production	0.1
Agriculture	Other – Agricultural	0.8	Institutional	Hospitals	0.25
Agriculture	Other – Miscellaneous	0.8	Institutional	Other – Institutional	0.25
Agriculture	Sod Farm	0.9	Institutional	Schools	0.25
Agriculture	Tender Fruit	0.8	Miscellaneous	Dams and Reservoirs[1]	0.0
Agriculture	Tobacco	0.9	Miscellaneous	Heat Pumps	0.1
Commercial	Aquaculture	0.1	Miscellaneous	Other - Miscellaneous	1
Commercial	Bottle Water	1	Miscellaneous	Power Production	0.1
Commercial	Campgrounds	0.2	Miscellaneous	Pumping Test	0.1
Commercial	Golf Course Irrigation	0.7	Miscellaneous	Wildlife Conservation	0.1
Commercial	Mall/Business	0.25	Recreational	Aesthetic	0.25
Commercial	Other Commercial	1	Recreational	Fish Ponds	0.25
Commercial	Snowmaking	0.5	Recreational	Other - Recreational	0.1
Construction	Construction	0.75	Recreational	Wetlands	0.1
Construction	Dewatering Construction	0.25	Recreational	Groundwater	0.1
Construction	Other - Construction	0.75	Remediation	Groundwater	0.5
Construction	Road Building	0.75	Remediation	Other	0.25
Dewatering	Construction	0.25	Remediation	Other - Remediation	0.25
Dewatering	Other – Dewatering	0.25	Water Supply	Campground	0.2
Dewatering	Other -	0.25	Water Supply	Communal	0.2

Appendix C.5 Consumptive Use Factors (Ministry of the Environment, 2007)

Category	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
	Industrial				
Dewatering	Pits and Quarries	0.25	Water Supply	Municipal	0.2
Dewatering	Other – Dewatering	0.25	Water Supply	Other Water Supply	0.2
Industrial	Aggregate Washing	0.25			
Industrial	Brewing and soft Drink	1			
Industrial	Cooling Water	0.25			
Industrial	Food Processing	1			

Note: Reservoir consumptive factor changed to zero because the “taking” at a dam or reservoir occurs only during the months when there is an abundance of water and any increase in evaporation from the larger surface area of the open body of water is accounted for through surface water modelling.

Appendix C.6a Monthly Surface Water Consumptive Demand

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Spencer Creek												
Fletcher Creek	0.0001	0.0001	0.0001	0.0001	0.0002	0.0005	0.0006	0.0004	0.0002	0.0001	0.0001	0.0001
Upper Spencer Creek	0.0004	0.0005	0.0004	0.0005	0.0007	0.0019	0.0024	0.0017	0.0007	0.0004	0.0005	0.0004
Flamborough Creek	0.0003	0.0003	0.0003	0.0003	0.0006	0.0018	0.0023	0.0021	0.0006	0.0003	0.0003	0.0003
Westover Creek	0.0001	0.0001	0.0001	0.0001	0.0003	0.0011	0.0015	0.0010	0.0003	0.0001	0.0001	0.0001
Middle Spencer Creek	0.0011	0.0012	0.0011	0.0043	0.0058	0.0116	0.0306	0.0288	0.0061	0.0011	0.0012	0.0011
West Spencer Creek	0.0004	0.0004	0.0004	0.0042	0.0045	0.0049	0.0095	0.0093	0.0038	0.0014	0.0011	0.0004
Logie's Creek	0.0004	0.0005	0.0004	0.0004	0.0006	0.0016	0.0019	0.0014	0.0006	0.0004	0.0004	0.0004
Spring Creek	0.0002	0.0002	0.0002	0.0002	0.0007	0.0031	0.0041	0.0026	0.0007	0.0002	0.0002	0.0002
Lower Spencer Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000
Sydenham Creek	0.0002	0.0002	0.0002	0.0002	0.0002	0.0006	0.0008	0.0005	0.0002	0.0002	0.0002	0.0002
Tiffany Creek	0.0001	0.0001	0.0001	0.0001	0.0002	0.0009	0.0011	0.0007	0.0002	0.0001	0.0001	0.0001
Ancaster Creek	0.0001	0.0001	0.0001	0.0001	0.0043	0.0056	0.0060	0.0039	0.0025	0.0001	0.0001	0.0001
Sulphur Creek	0.0002	0.0002	0.0002	0.0002	0.0006	0.0025	0.0033	0.0021	0.0006	0.0002	0.0002	0.0002
Borer's Creek	0.0007	0.0008	0.0007	0.0007	0.0013	0.0041	0.0053	0.0035	0.0013	0.0007	0.0007	0.0007
Chedoke Creek	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0004	0.0003	0.0001	0.0000	0.0000	0.0000
Urban Hamilton City Core	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Red Hill Creek												
Upper Ottawa	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Hannon Creek	0.0001	0.0001	0.0001	0.0001	0.0002	0.0008	0.0010	0.0007	0.0002	0.0001	0.0001	0.0001
Red Hill Valley	0.0001	0.0001	0.0001	0.0001	0.0002	0.0006	0.0008	0.0005	0.0002	0.0001	0.0001	0.0001
Green Hill	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Montgomery Creek	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002	0.0002	0.0001	0.0000	0.0000	0.0000
Upper Davis Creek	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0003	0.0002	0.0001	0.0000	0.0000	0.0000
Lower Davis Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
Urban Hamilton Beach	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix C.6a Monthly Surface Water Consumptive Demand

Watershed / Subwatershed	Jan [m^3/s]	Feb [m^3/s]	Mar [m^3/s]	Apr [m^3/s]	May [m^3/s]	Jun [m^3/s]	Jul [m^3/s]	Aug [m^3/s]	Sep [m^3/s]	Oct [m^3/s]	Nov [m^3/s]	Dec [m^3/s]
Strip												
Stoney Creek												
Battlefield Creek	0.0001	0.0001	0.0001	0.0001	0.0002	0.0009	0.0011	0.0007	0.0002	0.0001	0.0001	0.0001
Stoney Creek	0.0003	0.0003	0.0003	0.0003	0.0006	0.0021	0.0027	0.0018	0.0006	0.0003	0.0003	0.0003

Appendix C.6a continued Monthly Surface Water Consumptive Demand

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Stoney Creek Watercourses												
WC 0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WC 1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WC 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WC 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WC 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WC 5	0.0002	0.0002	0.0002	0.0002	0.0002	0.0004	0.0004	0.0003	0.0002	0.0002	0.0002	0.0002
WC 6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001
WC 7	0.0002	0.0003	0.0002	0.0002	0.0018	0.0018	0.0018	0.0018	0.0019	0.0018	0.0022	0.0002
WC 8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WC 9	0.0003	0.0003	0.0003	0.0003	0.0005	0.0013	0.0017	0.0011	0.0005	0.0003	0.0003	0.0003
WC 10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WC 10.1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
WC 11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WC 12	0.0005	0.0006	0.0005	0.0005	0.0008	0.0021	0.0027	0.0019	0.0008	0.0005	0.0005	0.0005
Cootes Paradise (Hamilton)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix C.6b Monthly Groundwater Consumptive Demand

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Spencer Creek												
Fletcher Creek	0.00067	0.00073	0.00068	0.00075	0.00098	0.00219	0.00257	0.00196	0.00113	0.00064	0.00066	0.00065
Upper Spencer Creek	0.00358	0.00392	0.00360	0.00383	0.00416	0.00645	0.00694	0.00592	0.00459	0.00346	0.00356	0.00348
Flamborough Creek	0.00092	0.00100	0.00092	0.00123	0.00428	0.00767	0.02124	0.01990	0.00511	0.00207	0.00093	0.00090
Westover Creek	0.00064	0.00070	0.00065	0.00069	0.00259	0.00674	0.00830	0.00552	0.00218	0.00063	0.00065	0.00063
Middle Spencer Creek	0.01680	0.02337	0.02901	0.02648	0.05138	0.05565	0.06713	0.05938	0.04736	0.03520	0.03978	0.04792
West Spencer Creek	0.00068	0.00073	0.00068	0.00076	0.00142	0.00471	0.00593	0.00475	0.00156	0.00064	0.00067	0.00065
Logie's Creek	0.01406	0.01806	0.01065	0.01689	0.02057	0.02565	0.01417	0.01657	0.01586	0.02110	0.01901	0.01916
Spring Creek	0.00062	0.00066	0.00063	0.00074	0.00082	0.00131	0.00135	0.00125	0.00107	0.00056	0.00058	0.00058
Lower Spencer Creek	0.00009	0.00010	0.00009	0.00011	0.00013	0.00022	0.00024	0.00021	0.00016	0.00008	0.00009	0.00009
Sydenham Creek	0.00054	0.00059	0.00055	0.00058	0.00078	0.00183	0.00221	0.00161	0.00083	0.00053	0.00055	0.00054
Tiffany Creek	0.00006	0.00006	0.00006	0.00007	0.00009	0.00021	0.00024	0.00019	0.00011	0.00005	0.00006	0.00006
Ancaster Creek	0.00056	0.00059	0.00057	0.00067	0.00075	0.00123	0.00128	0.00117	0.00098	0.00051	0.00053	0.00053
Sulphur Creek	0.00040	0.00043	0.00041	0.00048	0.00057	0.00111	0.00122	0.00102	0.00073	0.00037	0.00038	0.00038
Borer's Creek	0.00163	0.00177	0.00164	0.00179	0.00266	0.00717	0.00878	0.00627	0.00292	0.00157	0.00163	0.00159
Chedoke Creek	0.00020	0.00021	0.00020	0.00023	0.00032	0.00077	0.00091	0.00069	0.00038	0.00018	0.00019	0.00019
Urban Hamilton City Core	0.00058	0.00064	0.00058	0.00061	0.00059	0.00061	0.00059	0.00059	0.00061	0.00058	0.00060	0.00058
Red Hill Creek												
Upper Ottawa	0.00003	0.00003	0.00003	0.00004	0.00004	0.00008	0.00008	0.00007	0.00006	0.00003	0.00003	0.00003
Hannon Creek	0.00038	0.00042	0.00039	0.00042	0.00043	0.00054	0.00054	0.00052	0.00048	0.00037	0.00039	0.00038
Red Hill Valley	0.00001	0.00002	0.00001	0.00002	0.00003	0.00008	0.00010	0.00007	0.00003	0.00001	0.00001	0.00001
Green Hill	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Montgomery Creek	0.00000	0.00000	0.00000	0.00000	0.00338	0.00376	0.00373	0.00247	0.00191	0.00000	0.00000	0.00000
Upper Davis Creek	0.00072	0.00078	0.00072	0.00075	0.00067	0.00072	0.00071	0.00066	0.00064	0.00058	0.00059	0.00062
Lower Davis Creek	0.00690	0.00517	0.00792	0.00791	0.00562	0.00649	0.00862	0.00857	0.00874	0.00841	0.00399	0.00373

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Urban Hamilton Beach Strip	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000
Stoney Creek												
Battlefield Creek	0.00021	0.00022	0.00021	0.00024	0.00031	0.00068	0.00078	0.00061	0.00038	0.00019	0.00020	0.00020
Stoney Creek	0.00055	0.00058	0.00056	0.00065	0.00075	0.00132	0.00141	0.00123	0.00096	0.00050	0.00052	0.00052

Note: Values are presented in cubic metres per second to be consistent with the supply and reserve tables. To obtain monthly total in cubic metres multiply the value by the number of days for that month and then by 86,400.

Appendix C.6b continued Monthly Groundwater Consumptive Demand

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Stoney Creek Watercourses												
WC 0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
WC 1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000
WC 2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000
WC 3	0.00004	0.00004	0.00004	0.00004	0.00005	0.00006	0.00006	0.00006	0.00006	0.00003	0.00003	0.00003
WC 4	0.00001	0.00001	0.00001	0.00001	0.00002	0.00003	0.00003	0.00002	0.00002	0.00001	0.00001	0.00001
WC 5	0.00030	0.00033	0.00030	0.00034	0.00037	0.00056	0.00059	0.00053	0.00044	0.00029	0.00030	0.00029
WC 6	0.00001	0.00002	0.00001	0.00001	0.00002	0.00003	0.00003	0.00002	0.00002	0.00001	0.00001	0.00001
WC 7	0.00027	0.00029	0.00027	0.00029	0.00032	0.00050	0.00054	0.00047	0.00037	0.00026	0.00027	0.00026
WC 8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
WC 9	0.00039	0.00042	0.00039	0.00041	0.00058	0.00149	0.00182	0.00130	0.00062	0.00038	0.00040	0.00038
WC 10	0.00012	0.00013	0.00012	0.00013	0.00018	0.00045	0.00056	0.00040	0.00019	0.00012	0.00012	0.00012
WC 10.1	0.00001	0.00001	0.00001	0.00001	0.00001	0.00003	0.00003	0.00002	0.00001	0.00001	0.00001	0.00001
WC 11	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
WC 12	0.00076	0.00082	0.00076	0.00083	0.00109	0.00250	0.00297	0.00222	0.00122	0.00073	0.00075	0.00074
Cootes Paradise (Hamilton)	0.00007	0.00007	0.00007	0.00008	0.00009	0.00013	0.00012	0.00012	0.00012	0.00006	0.00007	0.00007

Note: Values are presented in cubic metres per second to be consistent with the supply and reserve tables. To obtain monthly total in cubic metres multiply the value by the number of days for that month and then by 86,400.

Appendix C.6c Annual Groundwater Consumptive Demand

Watershed / Subwatershed	Private Domestic [m³]	Agricultural [m³]	Municipal/ Communal [m³]	PTTW[1] [m³]	Total [m³]	Total[2] [mm]
Spencer Creek						
Fletcher Creek	14,120	21,750	0	0	35,870	1.4
Upper Spencer Creek	28,950	35,846	16,179	59,734	140,710	3.9
Flamborough Creek	10,474	135,399	1,531	21,562	168,966	12.7
Westover Creek	6,718	58,921	0	13,413	79,052	7.3
Middle Spencer Creek	88,319	292,263	26,500	897,530	1,304,612	26.3
West Spencer Creek	14,682	44,713	0	0	59,395	3.3
Logie's Creek	21,976	58,613	0	475,647	556,236	41.9
Spring Creek	24,350	2,433	0	0	26,783	2.0
Lower Spencer Creek	3,451	757	0	0	4,208	0.6
Sydenham Creek	4,278	25,138	0	0	29,415	5.6
Tiffany Creek	2,008	1,313	0	0	3,321	0.4
Ancaster Creek	21,819	2,803	0	0	24,622	1.8
Sulphur Creek	14,962	4,776	0	0	19,738	1.2
Borer's Creek	24,703	79,350	0	0	104,053	5.3
Chedoke Creek	6,494	5,261	0	0	11,754	0.5
Urban Hamilton City Core	479	0		18,396	18,875	0.5
Red Hill Creek						
Upper Ottawa	1,180	295	0	0	1,476	0.1
Hannon Creek	4,407	794	0	8,614	13,815	1.3
Red Hill Valley	274	785	0	0	1,059	0.1
Green Hill	0	7	0	0	7	0.0
Montgomery Creek	0	156	0	40,272	156	10.8
Upper Davis Creek	2,072	472	0	18,847	21,391	3.0
Lower Davis Creek	5,300	377	0	210,570	216,246	57.6

Appendix C.6c Annual Groundwater Consumptive Demand

Watershed / Subwatershed	Private Domestic [m³]	Agricultural [m³]	Municipal/ Communal [m³]	PTTW[1] [m³]	Total [m³]	Total[2] [mm]
Urban Hamilton Beach Strip	150	0		0	150	0.1
Stoney-Battlefield Creeks						
Battlefield Creek	6,409	4,705	0	0	11,114	1.5
Stoney Creek	19,994	5,103	0	0	25,097	1.2

Appendix C.6c continued Annual Consumptive Groundwater Demand

Watershed / Subwatershed	Private Domestic	Agricultural	Municipal/ Communal	PTTW[1]	Total	Total[2]
	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[mm]
Stoney Creek Watercourses						
WC 0	25	0	0	0	25	0.0
WC 1	45	105	0	0	150	0.0
WC 2	29	121	0	0	150	0.1
WC 3	1,435	0	0	0	1,435	0.7
WC 4	125	420	0	0	545	0.2
WC 5	6,334	5,867	0	0	12,201	2.0
WC 6	0	574	0	0	574	0.4
WC 7	3,972	6,809	0	0	10,781	2.5
WC 8	0	0	0	0	0	0.0
WC 9	2,544	20,106	0	0	22,650	5.0
WC 10	776	6,138	0	0	6,914	8.6
WC 10.1	0	370	0	0	370	0.8
WC 11	9	62	0	0	71	0.1
WC 12	11,576	28,964	0	0	40,540	7.0
Cootes Paradise (Hamilton)	2,810	0		0	2,810	2.4

Notes: 1. PTTW consumptive demand excluding agricultural and municipal takings, which are reported in their specific columns;
2. Total as millimetres of water per unit area.

Appendix C.6d Future Monthly Groundwater Demand

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Spencer Creek												
Fletcher Creek	0.00077	0.00083	0.00078	0.00088	0.00111	0.00237	0.00275	0.00214	0.00130	0.00073	0.00076	0.00075
Upper Spencer Creek	0.00391	0.00429	0.00394	0.00422	0.00458	0.00705	0.00751	0.00648	0.00510	0.00376	0.00387	0.00379
Flamborough Creek	0.00109	0.00118	0.00110	0.00144	0.00455	0.00805	0.02164	0.02029	0.00546	0.00226	0.00109	0.00106
Westover Creek	0.00093	0.00101	0.00094	0.00104	0.00296	0.00727	0.00881	0.00603	0.00267	0.00089	0.00092	0.00090
Middle Spencer Creek	0.01705	0.02364	0.02927	0.02677	0.05168	0.05605	0.06752	0.05977	0.04775	0.03543	0.04002	0.04816
West Spencer Creek	0.00090	0.00097	0.00091	0.00103	0.00170	0.00511	0.00632	0.00514	0.00194	0.00084	0.00087	0.00086
Logie's Creek	0.01444	0.01846	0.01103	0.01734	0.02105	0.02633	0.01483	0.01723	0.01650	0.02144	0.01936	0.01952
Spring Creek	0.00192	0.00204	0.00195	0.00230	0.00248	0.00367	0.00363	0.00353	0.00328	0.00173	0.00181	0.00180
Lower Spencer Creek	0.00010	0.00011	0.00010	0.00012	0.00014	0.00024	0.00026	0.00022	0.00018	0.00009	0.00009	0.00009
Sydenham Creek	0.00076	0.00082	0.00076	0.00084	0.00105	0.00222	0.00259	0.00199	0.00119	0.00073	0.00075	0.00074
Tiffany Creek	0.00005	0.00005	0.00005	0.00005	0.00008	0.00019	0.00022	0.00017	0.00009	0.00004	0.00004	0.00004
Ancaster Creek	0.00045	0.00048	0.00046	0.00054	0.00061	0.00104	0.00110	0.00098	0.00080	0.00041	0.00043	0.00043
Sulphur Creek	0.00132	0.00140	0.00134	0.00158	0.00175	0.00277	0.00283	0.00263	0.00229	0.00119	0.00124	0.00124
Borer's Creek	0.00433	0.00465	0.00440	0.00504	0.00612	0.01206	0.01353	0.01103	0.00752	0.00401	0.00417	0.00413

Watershed / Subwatershed	**Jan [m³/s]**	**Feb [m³/s]**	**Mar [m³/s]**	**Apr [m³/s]**	**May [m³/s]**	**Jun [m³/s]**	**Jul [m³/s]**	**Aug [m³/s]**	**Sep [m³/s]**	**Oct [m³/s]**	**Nov [m³/s]**	**Dec [m³/s]**
Chedoke Creek	0.00004	0.00004	0.00004	0.00004	0.00011	0.00048	0.00063	0.00041	0.00011	0.00004	0.00004	0.00004
Urban Hamilton City Core	0.00057	0.00063	0.00057	0.00059	0.00057	0.00059	0.00057	0.00057	0.00059	0.00057	0.00059	0.00057
Red Hill Creek												
Upper Ottawa	0.00001	0.00001	0.00001	0.00001	0.00001	0.00003	0.00004	0.00003	0.00001	0.00001	0.00001	0.00001
Hannon Creek	0.00032	0.00035	0.00032	0.00033	0.00034	0.00042	0.00042	0.00040	0.00036	0.00031	0.00032	0.00031
Red Hill Valley	0.00001	0.00001	0.00001	0.00001	0.00002	0.00006	0.00008	0.00006	0.00002	0.00001	0.00001	0.00001
Green Hill	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Montgomery Creek	0.00000	0.00000	0.00000	0.00000	0.00338	0.00376	0.00373	0.00247	0.00191	0.00000	0.00000	0.00000
Upper Davis Creek	0.00067	0.00073	0.00066	0.00069	0.00060	0.00062	0.00062	0.00057	0.00055	0.00054	0.00054	0.00057
Lower Davis Creek	0.00677	0.00503	0.00779	0.00776	0.00545	0.00626	0.00839	0.00834	0.00852	0.00829	0.00387	0.00360
Urban Hamilton Beach Strip	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Stoney Creek												
Battlefield Creek	0.00019	0.00020	0.00019	0.00022	0.00029	0.00065	0.00075	0.00058	0.00035	0.00018	0.00018	0.00018
Stoney Creek	0.00422	0.00449	0.00431	0.00507	0.00545	0.00798	0.00786	0.00770	0.00720	0.00382	0.00398	0.00397

Note: Values are presented in cubic metres per second to be consistent with the supply and reserve tables. To obtain monthly total in cubic metres multiply the value by the number of days for that month and then by 86,400.

Appendix C.6d continued Future Monthly Groundwater Demand

Watershed / Subwatershed	Jan [m³/s]	Feb [m³/s]	Mar [m³/s]	Apr [m³/s]	May [m³/s]	Jun [m³/s]	Jul [m³/s]	Aug [m³/s]	Sep [m³/s]	Oct [m³/s]	Nov [m³/s]	Dec [m³/s]
Stoney Creek Watercourses												
WC 0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
WC 1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000
WC 2	0.00000	0.00001	0.00000	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000
WC 3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
WC 4	0.00002	0.00002	0.00002	0.00002	0.00002	0.00003	0.00004	0.00003	0.00003	0.00002	0.00002	0.00002
WC 5	0.00092	0.00099	0.00094	0.00108	0.00116	0.00169	0.00168	0.00162	0.00149	0.00085	0.00088	0.00087
WC 6	0.00001	0.00002	0.00001	0.00001	0.00002	0.00003	0.00003	0.00002	0.00002	0.00001	0.00001	0.00001
WC 7	0.00088	0.00094	0.00089	0.00103	0.00110	0.00161	0.00162	0.00155	0.00141	0.00081	0.00084	0.00084
WC 8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
WC 9	0.00053	0.00057	0.00053	0.00058	0.00076	0.00174	0.00207	0.00155	0.00085	0.00051	0.00053	0.00052
WC 10	0.00010	0.00011	0.00010	0.00010	0.00015	0.00042	0.00052	0.00036	0.00016	0.00010	0.00010	0.00010
WC 10.1	0.00001	0.00001	0.00001	0.00001	0.00001	0.00003	0.00003	0.00002	0.00001	0.00001	0.00001	0.00001
WC 11	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
WC 12	0.00101	0.0010	0.0010	0.0011	0.0014	0.0029	0.0034	0.0026	0.0016	0.0009	0.0009	0.0009

		9	2	4	2	6	1	7	5	6	9	8
Cootes Paradise (Hamilton)	0.00022	0.0002 3	0.0002 2	0.0002 6	0.0002 8	0.0004 0	0.0003 8	0.0003 9	0.0003 7	0.0002 0	0.0002 1	0.0002 1

Note: Values are presented in cubic metres per second to be consistent with the supply and reserve tables. To obtain monthly total in cubic metres multiply the
value by the number of days for that month and then by 86,400.

Watershed/ Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Stress Level
Spencer Creek													
Ancaster Creek	0.0	0.1	0.0	0.0	2.6	7.7	23.7	33.2	17.8	0.1	0.1	0.1	Moderate
Borer's Creek	0.6	1.1	0.7	0.6	1.6	11.5	41.1	78.8	15.3	2.4	0.9	1.1	Significant
Chedoke Creek	0.0	0.0	0.0	0.0	0.1	0.8	2.7	2.8	0.9	0.1	0.0	0.0	Low
Flamborough Creek	0.3	0.7	0.5	0.3	1.0	7.9	18.4	57.9	4.4	1.1	0.5	0.5	Significant
Fletcher Creek	0.1	0.2	0.1	0.1	0.2	1.3	3.7	7.2	0.7	0.3	0.1	0.1	Low
Logie's Creek	0.5	1.0	0.8	0.4	0.9	5.1	17.1	24.1	7.0	1.6	0.5	0.6	Moderate
Lower Spencer Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	Low
Middle Spencer Creek	0.1	0.2	0.2	0.4	0.8	3.9	20.3	40.2	3.8	0.3	0.1	0.2	Moderate
Spring Creek	0.4	0.8	0.2	0.2	1.5	14.2	56.8	138.8	23.8	1.8	0.6	0.7	Significant
Sulphur Creek	0.2	0.5	0.2	0.1	0.8	7.9	31.6	41.1	9.5	0.7	0.3	0.3	Moderate
Sydenham Creek	0.6	0.9	0.6	0.5	1.2	6.9	15.2	26.9	8.7	1.8	1.1	1.1	Moderate
Tiffany Creek	0.2	0.3	0.1	0.1	0.6	6.1	23.4	46.3	10.0	0.7	0.3	0.3	Moderate
Upper Spencer Creek	0.1	0.3	0.2	0.1	0.3	2.1	4.4	6.4	1.0	0.4	0.2	0.2	Low
West Spencer Creek	0.3	0.7	0.4	3.4	5.9	16.1	45.7	79.1	17.2	3.2	1.1	0.4	Significant
Westover Creek	0.1	0.3	0.2	0.1	0.6	5.8	9.2	10.2	1.6	0.3	0.2	0.2	Low
Urban Hamilton City Core	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
Red Hill Creek													
Green Hill	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	Low
Hannon Creek	0.2	0.3	0.2	0.2	0.6	5.0	20.9	73.5	19.3	1.4	0.4	0.4	Significant
Lower Davis Creek	0.0	0.0	0.0	0.0	0.1	0.6	1.1	1.5	0.3	0.1	0.0	0.0	Low
Montgomery Creek	0.1	0.2	0.1	0.1	0.4	2.9	5.6	6.7	1.8	0.3	0.2	0.2	Low
Red Hill Valley	0.0	0.0	0.0	0.0	0.1	0.6	1.2	1.6	0.4	0.1	0.0	0.0	Low
Upper Davis Creek	0.1	0.2	0.1	0.1	0.3	2.4	5.9	8.5	2.0	0.4	0.2	0.2	Low
Upper Ottawa	0.0	0.0	0.0	0.0	0.0	0.2	0.8	2.4	0.8	0.0	0.0	0.0	Low
Urban Hamilton Beach Strip													
Stoney-Battlefield Creeks													

Watershed/ Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Stress Level
Battlefield Creek	0.2	0.4	0.2	0.2	0.8	5.4	8.6	10.9	2.2	0.5	0.4	0.4	Low
Stoney Creek	0.2	0.3	0.1	0.2	0.6	4.4	8.2	10.5	2.2	0.5	0.3	0.3	Low

Appendix C.7 Surface Water Stress Assessment

Appendix C.7 continued Surface Water Stress Assessment

Watershed/ Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Stress Level
Stoney Creek Watercourses													
WC 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
WC 1	0.1	0.1	0.1	0.1	0.1	0.5	0.6	0.9	0.4	0.2	0.1	0.1	Low
WC 2	0.0	0.1	0.0	0.0	0.1	0.2	0.3	0.4	0.2	0.1	0.1	0.1	Low
WC 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
WC 4	0.0	0.1	0.0	0.0	0.1	0.2	0.2	0.3	0.2	0.1	0.1	0.1	Low
WC 5	0.5	0.8	0.5	0.5	0.9	2.5	3.2	4.4	2.0	0.9	0.9	0.8	Low
WC 6	1.0	1.7	1.3	1.2	1.7	4.5	5.4	7.1	3.3	1.5	1.8	1.5	Low
WC 7	0.8	1.4	0.8	0.9	10.4	18.5	22.8	43.9	26.8	12.5	14.1	1.4	Moderate
WC 8	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.0	0.0	Low
WC 9	1.0	1.6	1.2	1.1	2.2	9.4	12.3	15.3	3.9	1.3	1.6	1.4	Low
WC 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
WC 10.1	0.8	1.0	0.9	0.7	1.7	10.7	39.9	27.7	23.7	7.6	1.7	1.4	Moderate
WC 11	0.2	0.3	0.2	0.2	0.5	3.0	18.8	13.1	11.2	2.4	0.5	0.4	Low
WC 12	1.5	2.6	1.3	1.4	3.6	17.8	28.0	35.0	8.6	3.0	2.8	2.3	Moderate
Cootes Paradise (Hamilton)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low

Note: Values are percent water demand

Appendix C.8a Monthly Groundwater Stress Assessment – Existing Conditions

Watershed / Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Stress Level
Spencer Creek													
Fletcher Creek	0.5	0.5	0.5	0.5	0.7	1.5	1.8	1.4	0.8	0.5	0.5	0.5	Low
Upper Spencer Creek	1.6	1.5	1.6	1.6	1.8	2.7	3.0	2.6	1.9	1.5	1.5	1.5	Low
Flamborough Creek	0.9	0.9	0.9	1.2	4.2	7.3	21.0	19.7	4.9	2.0	0.9	0.9	Low
Westover Creek	0.7	0.7	0.7	0.8	3.0	7.5	9.5	6.3	2.4	0.7	0.7	0.7	Low
Middle Spencer Creek	4.3	5.4	7.4	6.6	13.1	13.8	17.2	15.2	11.7	9.0	9.8	12.3	Low
West Spencer Creek	0.3	0.3	0.4	0.4	0.7	2.4	3.1	2.5	0.8	0.3	0.3	0.3	Low
Logie's Creek	14.6	17.1	11.1	17.0	21.4	25.8	14.7	17.2	16.0	21.9	19.1	19.9	Moderate
Spring Creek	1.1	1.1	1.2	1.3	1.5	2.3	2.5	2.3	1.9	1.0	1.0	1.1	Low
Lower Spencer Creek	0.2	0.2	0.2	0.2	0.3	0.5	0.6	0.5	0.4	0.2	0.2	0.2	Low
Sydenham Creek	1.4	1.3	1.4	1.4	1.9	4.4	5.5	4.0	2.0	1.3	1.3	1.3	Low
Tiffany Creek	0.2	0.2	0.2	0.2	0.3	0.6	0.7	0.5	0.3	0.2	0.2	0.2	Low
Ancaster Creek	0.8	0.7	0.8	0.9	1.0	1.6	1.7	1.6	1.3	0.7	0.7	0.7	Low
Sulphur Creek	0.4	0.4	0.4	0.5	0.6	1.2	1.3	1.1	0.8	0.4	0.4	0.4	Low
Borer's Creek	1.5	1.5	1.5	1.6	2.4	6.4	8.1	5.8	2.6	1.4	1.4	1.5	Low
Chedoke Creek	0.2	0.2	0.2	0.2	0.3	0.7	0.8	0.6	0.3	0.2	0.2	0.2	Low
Urban Hamilton City Core	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	Low
Red Hill Creek													
Upper Ottawa	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	Low
Hannon Creek	1.0	1.0	1.0	1.1	1.1	1.4	1.4	1.4	1.2	1.0	1.0	1.0	Low
Red Hill Valley	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	Low
Green Hill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
Montgomery Creek	0.0	0.0	0.0	0.0	18.5	19.9	20.4	13.5	10.1	0.0	0.0	0.0	Low
Upper Davis Creek	2.4	2.4	2.4	2.4	2.3	2.3	2.4	2.2	2.1	2.0	1.9	2.1	Low
Lower Davis Creek	34.3	23.4	39.4	38.1	27.9	31.2	42.8	42.6	42.0	41.8	19.2	18.5	Moderate

Appendix C.8a Monthly Groundwater Stress Assessment – Existing Conditions

Watershed / Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Stress Level
Urban Hamilton Beach Strip	0.7	0.7	0.7	0.8	0.9	1.2	1.2	1.2	1.2	0.6	0.6	0.7	Low
Stoney-Battlefield Creeks													
Battlefield Creek	0.4	0.4	0.5	0.5	0.7	1.4	1.7	1.3	0.8	0.4	0.4	0.4	Low
Stoney Creek	0.6	0.6	0.6	0.7	0.8	1.3	1.5	1.3	1.0	0.5	0.5	0.5	Low

Appendix C.8a continued Monthly Groundwater Stress Assessment – Existing Conditions

Watershed / Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Stress Level
Stoney Creek Watercourses													
WC 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
WC 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
WC 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
WC 3	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.5	0.5	0.3	0.3	0.3	Low
WC 4	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	Low
WC 5	0.7	0.7	0.7	0.8	0.9	1.3	1.5	1.3	1.0	0.7	0.7	0.7	Low
WC 6	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	Low
WC 7	1.0	0.9	1.0	1.0	1.2	1.8	2.0	1.7	1.3	0.9	0.9	0.9	Low
WC 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Low
WC 9	1.0	1.0	1.0	1.0	1.5	3.7	4.7	3.3	1.5	1.0	1.0	1.0	Low
WC 10	3.3	3.2	3.3	3.3	4.9	12.1	15.3	10.9	5.0	3.2	3.2	3.2	Low
WC 10.1	0.4	0.4	0.4	0.4	0.6	1.6	2.0	1.4	0.6	0.4	0.4	0.4	Low
WC 11	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	Low
WC 12	2.1	2.1	2.2	2.3	3.1	6.9	8.4	6.3	3.4	2.1	2.1	2.1	Low
Cootes Paradise (Hamilton)	1.6	1.6	1.7	1.9	2.1	2.8	2.8	2.9	2.7	1.5	1.5	1.5	Low

Note: Values are percent water demand

Appendix C.8b Annual Groundwater Stress Assessment – Existing Conditions

Watershed / Subwatershed	Recharge [m³/sec]	Demand [m³/sec]	Lateral Inflow [m³/sec]	Q_{SUPPLY} [m³/sec]	$Q_{RESERVE}$ [m³/sec]	Percent Water Demand	Stress Level
Spencer Creek							
Fletcher Creek	0.1541	0.0011	0.0052	0.1593	0.0159	0.8	Low
Upper Spencer Creek	0.2591	0.0045	0.0020	0.2610	0.0261	1.9	Low
Flamborough Creek	0.1112	0.0054	0.0034	0.1146	0.0115	5.2	Low
Westover Creek	0.0987	0.0025	NA	0.0987	0.0099	2.8	Low
Middle Spencer Creek[1]	0.3628	0.0413	0.0797	0.4426	0.0443	10.4	Moderate
West Spencer Creek	0.1503	0.0019	0.0686	0.2189	0.0219	1.0	Low
Logie's Creek	0.1086	0.0176	0.0002	0.1088	0.0109	18.0	Moderate
Spring Creek	0.0617	0.0008	NA	0.0617	0.0062	1.5	Low
Lower Spencer Creek	0.0470	0.0001	0.0018	0.0489	0.0049	0.3	Low
Sydenham Creek	0.0317	0.0009	0.0137	0.0454	0.0045	2.3	Low
Tiffany Creek	0.0403	0.0001	NA	0.0403	0.0040	0.3	Low
Ancaster Creek	0.0830	0.0008	NA	0.0830	0.0083	1.0	Low
Sulphur Creek	0.1032	0.0006	NA	0.1032	0.0103	0.7	Low
Borer's Creek	0.1201	0.0033	0.0032	0.1233	0.0123	3.0	Low
Chedoke Creek	0.1293	0.0004	NA	0.1293	0.0129	0.3	Low
Urban Hamilton City Core	0.2471	0.0006	NA	0.2471	0.0247	0.3	Low
Red Hill Creek							
Upper Ottawa	0.0545	0.0000	NA	0.0545	0.0054	0.1	Low
Hannon Creek	0.0428	0.0004	NA	0.0428	0.0043	1.1	Low
Red Hill Valley	0.0767	0.0000	NA	0.0767	0.0077	0.0	Low

Appendix C.8b Annual Groundwater Stress Assessment – Existing Conditions

Watershed / Subwatershed	Recharge [m³/sec]	Demand [m³/sec]	Lateral Inflow [m³/sec]	Q_{SUPPLY} [m³/sec]	$Q_{RESERVE}$ [m³/sec]	Percent Water Demand	Stress Level
Green Hill	0.0718	0.0000	NA	0.0718	0.0072	0.0	Low
Montgomery Creek	0.0207	0.0013	NA	0.0207	0.0021	6.9	Low
Upper Davis Creek	0.0335	0.0007	NA	0.0335	0.0033	2.2	Low
Lower Davis Creek	0.0228	0.0069	NA	0.0228	0.0023	33.4	Significant
Urban Hamilton Beach Strip	0.0006	0.0000	NA	0.0006	0.0001	0.9	Low
Stoney-Battlefield Creeks							
Battlefield Creek	0.0520	0.0004	NA	0.0520	0.0052	0.8	Low
Stoney Creek	0.1093	0.0008	NA	0.1093	0.0109	0.8	Low

Appendix C.8b continued Annual Groundwater Stress Assessment – Existing Conditions

Watershed / Subwatershed	Recharge [m^3/sec]	Demand [m^3/sec]	Lateral Inflow [m^3/sec]	Q_{SUPPLY} [m^3/sec]	$Q_{RESERVE}$ [m^3/sec]	Percent Water Demand	Stress Level
Stoney Creek Watercourses							
WC 0	0.0064	0.0000	NA	0.0064	0.0006	0.0	Low
WC 1	0.0213	0.0000	NA	0.0213	0.0021	0.0	Low
WC 2	0.0189	0.0000	NA	0.0189	0.0019	0.0	Low
WC 3	0.0138	0.0000	NA	0.0138	0.0014	0.4	Low
WC 4	0.0195	0.0000	NA	0.0195	0.0019	0.1	Low
WC 5	0.0460	0.0004	NA	0.0460	0.0046	0.9	Low
WC 6	0.0125	0.0000	NA	0.0125	0.0013	0.2	Low
WC 7	0.0314	0.0003	NA	0.0314	0.0031	1.2	Low
WC 8	0.0003	0.0000	NA	0.0003	0.0000	0.0	Low
WC 9	0.0443	0.0007	NA	0.0443	0.0044	1.8	Low
WC 10	0.0041	0.0002	NA	0.0041	0.0004	5.9	Low
WC 10.1	0.0018	0.0000	NA	0.0018	0.0002	0.7	Low
WC 11	0.0025	0.0000	NA	0.0025	0.0003	0.1	Low
WC 12	0.0398	0.0013	NA	0.0398	0.0040	3.6	Low
Cootes Paradise (Hamilton)	0.0005	0.0001	0.0043	0.0048	0.0005	2.0	Low

Notes: 1. Contains Greensville municipal well
NA = Not available

Appendix C.9a Monthly Groundwater Stress Assessment - Future Conditions

Watershed / Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Stress Level
Spencer Creek													
Fletcher Creek	0.5	0.5	0.6	0.6	0.8	1.6	2	1.5	0.9	0.5	0.5	0.5	Low
Upper Spencer Creek	1.7	1.7	1.7	1.8	2	3	3.3	2.8	2.1	1.6	1.6	1.6	Low
Flamborough Creek	1.1	1.1	1.1	1.4	4.5	7.7	21.4	20	5.2	2.2	1	1	Low
Westover Creek	1.1	1.1	1.1	1.2	3.4	8.1	10.1	6.9	3	1	1	1	Low
Middle Spencer Creek	4.4	5.5	7.5	6.6	13.2	13.9	17.3	15.3	11.8	9.1	9.9	12.3	Low
West Spencer Creek	0.5	0.5	0.5	0.5	0.9	2.6	3.3	2.7	1	0.4	0.4	0.4	Low
Logie's Creek	15	17.5	11.5	17.4	21.9	26.5	15.4	17.9	16.6	22.3	19.5	20.3	Moderate
Spring Creek	3.5	3.4	3.6	4.1	4.5	6.5	6.6	6.5	5.8	3.2	3.2	3.3	Low
Lower Spencer Creek	0.2	0.2	0.2	0.3	0.3	0.5	0.6	0.5	0.4	0.2	0.2	0.2	Low
Sydenham Creek	1.9	1.9	1.9	2	2.6	5.3	6.4	5	2.9	1.8	1.8	1.8	Low
Tiffany Creek	0.1	0.1	0.1	0.1	0.2	0.5	0.6	0.5	0.2	0.1	0.1	0.1	Low
Ancaster Creek	0.6	0.6	0.6	0.7	0.8	1.4	1.5	1.3	1	0.6	0.6	0.6	Low
Sulphur Creek	1.4	1.4	1.5	1.7	1.9	2.9	3.1	2.9	2.4	1.3	1.3	1.4	Low
Borer's Creek	4	3.9	4	4.5	5.6	10.7	12.4	10.1	6.7	3.7	3.7	3.8	Low
Chedoke Creek	0	0	0	0	0.1	0.4	0.6	0.4	0.1	0	0	0	Low
Urban Hamilton City Core	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	Low
Red Hill Creek													
Upper Ottawa	0	0	0	0	0	0.1	0.1	0.1	0	0	0	0	Low
Hannon Creek	0.8	0.8	0.8	0.9	0.9	1.1	1.1	1	0.9	0.8	0.8	0.8	Low
Red Hill Valley	0	0	0	0	0	0.1	0.1	0.1	0	0	0	0	Low
Green Hill	0	0	0	0	0	0	0	0	0	0	0	0	Low
Montgomery Creek	0	0	0	0	18.5	19.9	20.4	13.5	10.1	0	0	0	Low
Upper Davis Creek	2.3	2.2	2.2	2.2	2	2	2.1	1.9	1.8	1.8	1.8	1.9	Low
Lower Davis Creek	33.7	22.8	38.7	37.3	27.1	30.1	41.7	41.4	41	41.2	18.6	17.9	Moderate
Urban Hamilton Beach	0	0	0	0	0	0	0	0	0	0	0	0	Low

Strip												
Stoney-Battlefield Creeks												
Battlefield Creek	0.4	0.4	0.4	0.5	0.6	1.4	1.6	1.3	0.7	0.4	0.4	0.4	Low
Stoney Creek	4.4	4.2	4.5	5.1	5.6	8	8.1	8	7.2	4	4	4.1	Low

Appendix C.9a continued Monthly Groundwater Stress Assessment – Future Conditions

Watershed / Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Stress Level
Stoney Creek Watercourses													
WC 0	0	0	0	0	0	0	0	0	0	0	0	0	Low
WC 1	0	0	0	0	0	0	0	0	0	0	0	0	Low
WC 2	0	0	0	0	0	0.1	0.1	0.1	0	0	0	0	Low
WC 3	0	0	0	0	0	0	0	0	0	0	0	0	Low
WC 4	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	Low
WC 5	2.3	2.2	2.3	2.6	2.9	4	4.1	4	3.6	2.1	2.1	2.1	Low
WC 6	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	Low
WC 7	3.2	3.1	3.2	3.6	4	5.6	5.8	5.6	4.9	2.9	2.9	3	Low
WC 8	0	0	0	0	0	0	0	0	0	0	0	0	Low
WC 9	1.4	1.3	1.4	1.4	2	4.3	5.3	4	2.1	1.3	1.3	1.3	Low
WC 10	2.7	2.7	2.7	2.7	4.2	11.1	14.3	10	4.1	2.7	2.7	2.7	Low
WC 10.1	0.4	0.4	0.4	0.4	0.6	1.6	2	1.4	0.6	0.4	0.4	0.4	Low
WC 11	0	0	0	0	0.1	0.2	0.2	0.2	0.1	0	0	0	Low
WC 12	2.9	2.8	2.9	3.1	4	8.1	9.7	7.6	4.5	2.7	2.7	2.8	Low
Cootes Paradise (Hamilton)	5.1	5	5.2	6	6.5	9	9	9	8.4	4.6	4.7	4.8	Low

Note: Values are percent water demand

Appendix C.9b Annual Groundwater Stress Assessment - Future Conditions

Watershed / Subwatershed	Recharge [m³/sec]	Demand [m³/sec]	Lateral Inflow [m³/sec]	Q_{SUPPLY} [m³/sec]	$Q_{RESERVE}$ [m³/sec]	Percent Water Demand	Stress Level
Spencer Creek							
Fletcher Creek	0.1541	0.0013	0.0052	0.1593	0.0159	0.9	Low
Upper Spencer Creek	0.2591	0.0049	0.0020	0.2610	0.0261	2.1	Low
Flamborough Creek	0.1112	0.0056	0.0034	0.1146	0.0115	5.4	Low
Westover Creek	0.0987	0.0029	NA	0.0987	0.0099	3.2	Low
Middle Spencer Creek	0.3628	0.0416	0.0797	0.4426	0.0443	10.5	Moderate
West Spencer Creek	0.1503	0.0022	0.0686	0.2189	0.0219	1.1	Low
Logie's Creek	0.1086	0.0181	0.0002	0.1088	0.0109	18.5	Moderate
Spring Creek	0.0617	0.0025	NA	0.0617	0.0062	4.5	Low
Lower Spencer Creek	0.0470	0.0001	0.0018	0.0489	0.0049	0.3	Low
Sydenham Creek	0.0317	0.0012	0.0137	0.0454	0.0045	2.9	Low
Tiffany Creek	0.0403	0.0001	NA	0.0403	0.0040	0.2	Low
Ancaster Creek	0.0830	0.0006	NA	0.0830	0.0083	0.9	Low
Sulphur Creek	0.1032	0.0018	NA	0.1032	0.0103	1.9	Low
Borer's Creek	0.1201	0.0068	0.0032	0.1233	0.0123	6.1	Low
Chedoke Creek	0.1293	0.0002	NA	0.1293	0.0129	0.1	Low
Urban Hamilton City Core	0.0006	0.0000	NA	0.0006	0.0001	0.0	Low
Red Hill Creek							
Upper Ottawa	0.0545	0.0000	NA	0.0545	0.0054	0.0	Low
Hannon Creek	0.0428	0.0004	NA	0.0428	0.0043	0.9	Low
Red Hill Valley	0.0767	0.0000	NA	0.0767	0.0077	0.0	Low
Green Hill	0.0718	0.0000	NA	0.0718	0.0072	0.0	Low
Montgomery Creek	0.0207	0.0013	NA	0.0207	0.0021	6.9	Low
Upper Davis Creek	0.0335	0.0006	NA	0.0335	0.0033	2.0	Low
Lower Davis Creek	0.0228	0.0067	NA	0.0228	0.0023	32.6	Significant
Urban Hamilton Beach Strip	0.0006	0.0000	NA	0.0006	0.0001	0.0	Low
Stoney-Battlefield Creeks							
Battlefield Creek	0.0520	0.0003	NA	0.0520	0.0052	0.7	Low
Stoney Creek	0.1093	0.0055	NA	0.1093	0.0109	5.6	Low

Appendix C.9b continued Annual Groundwater Stress Assessment - Future Condition

Watershed / Subwatershed	Recharge [m^3/sec]	Demand [m^3/sec]	Lateral Inflow [m^3/sec]	Q_{SUPPLY} [m^3/sec]	$Q_{RESERVE}$ [m^3/se]	Percent Water Demand	Stress Level
Stoney Creek Watercourses							
WC 0	0.0064	0.0000	NA	0.0064	0.0006	0.0	Low
WC 1	0.0213	0.0000	NA	0.0213	0.0021	0.0	Low
WC 2	0.0189	0.0000	NA	0.0189	0.0019	0.0	Low
WC 3	0.0138	0.0000	NA	0.0138	0.0014	0.0	Low
WC 4	0.0195	0.0000	NA	0.0195	0.0019	0.1	Low
WC 5	0.0460	0.0012	NA	0.0460	0.0046	2.9	Low
WC 6	0.0125	0.0000	NA	0.0125	0.0013	0.2	Low
WC 7	0.0314	0.0011	NA	0.0314	0.0031	4.0	Low
WC 8	0.0003	0.0000	NA	0.0003	0.0000	0.0	Low
WC 9	0.0443	0.0009	NA	0.0443	0.0044	2.3	Low
WC 10	0.0041	0.0002	NA	0.0041	0.0004	5.2	Low
WC 10.1	0.0018	0.0000	NA	0.0018	0.0002	0.7	Low
WC 11	0.0025	0.0000	NA	0.0025	0.0003	0.1	Low
WC 12	0.0398	0.0016	NA	0.0398	0.0040	4.5	Low
Cootes Paradise (Hamilton)	0.0005	0.0003	0.0043	0.0048	0.0005	6.4	Low

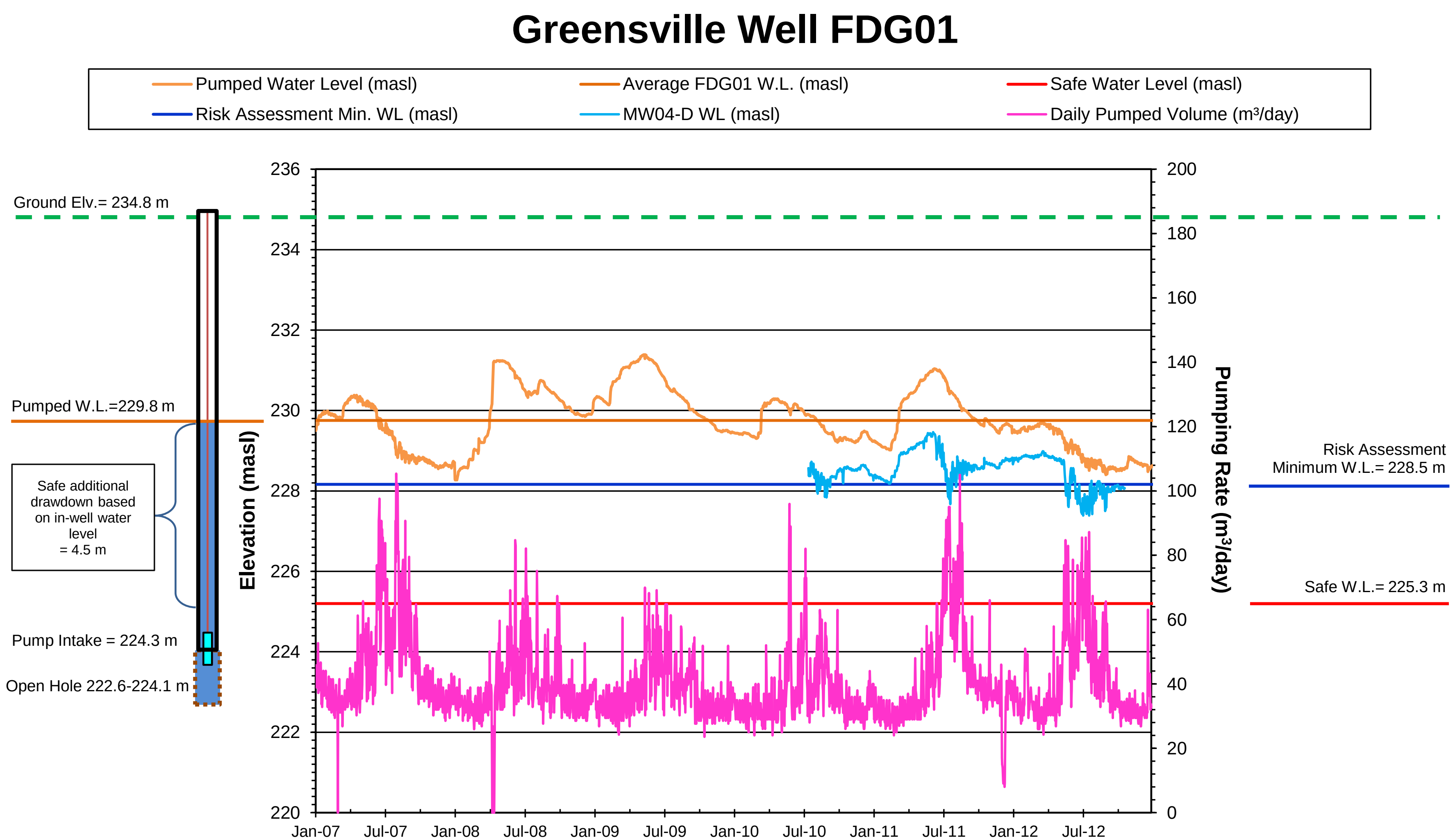
Notes: NA – Not available

APPENDIX D: TIER 3 WATER BUDGET AND WATER QUANTITY RISK ASSESSMENT

Assessment completed in two phases in 2012/17 based on:

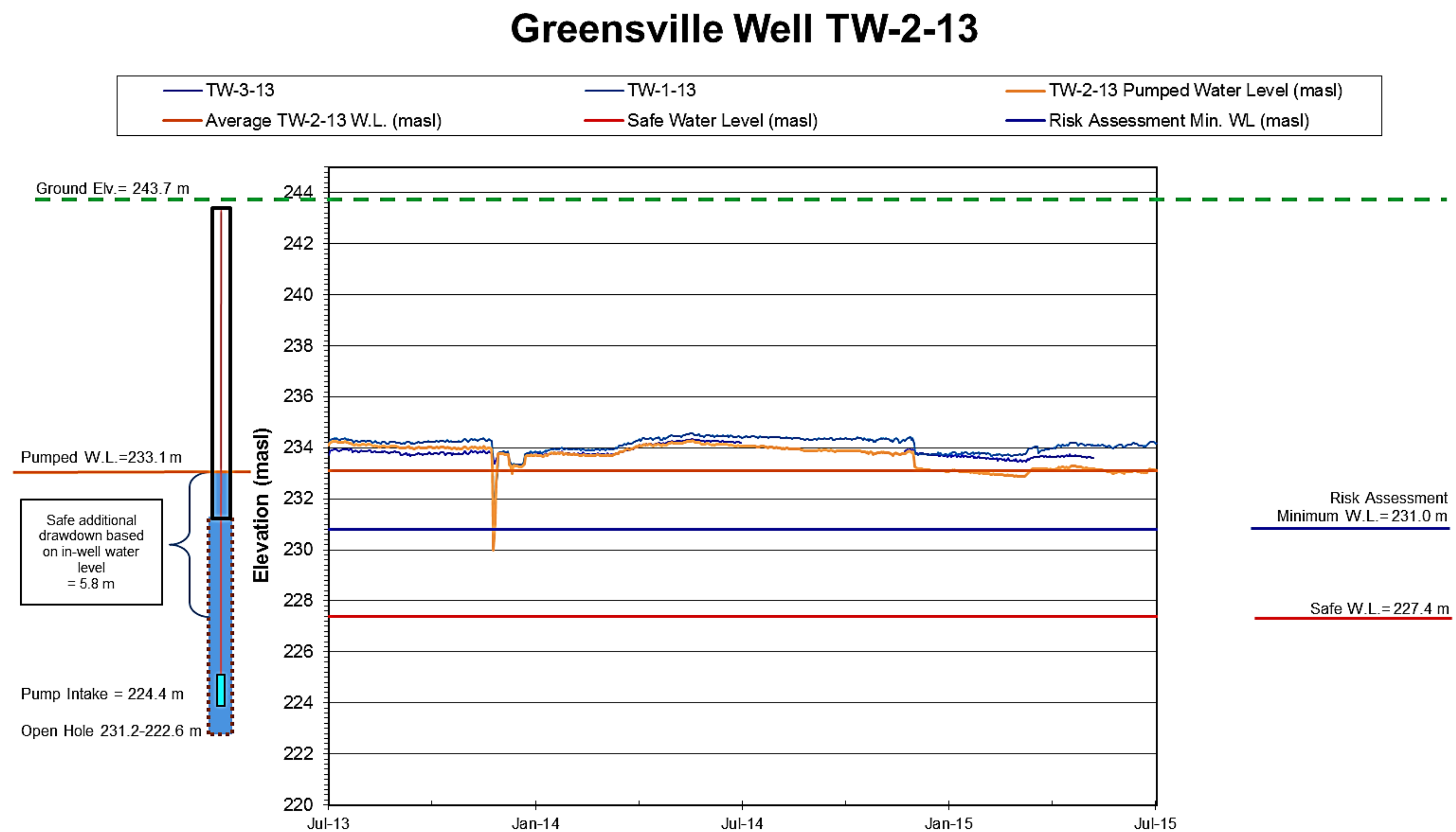
- 2015 MNRF updated land cover mapping
- 2007-2014 Municipal water takings
- 2016 MOECC Permit to Take Water database
- 2011 Water Survey Canada surface water flow dataset
- 2016 MOECC Well Water Information System
- 2016 groundwater levels from various sources for various periods
- 2014 MOECC Water Taking Reporting System
- 2016 Environment and Climate Change Canada climate dataset

Appendix D.1. Municipal Well Constraint Graphs



Note: Safe additional drawdown in the Greensville municipal supply well FDG01 is based upon a minimum operational water level limit of 1 m above the pump intake and the average in-well water level for the period of 2007 to 2012. Pump intake is set at a depth of 10.54 m below ground surface (Lotowater, 2008).

Appendix D.1. Municipal Well Constraint Graphs



Note: Safe additional drawdown in the Greensville municipal supply well TW-2-13 is based upon a minimum operational water level limit remaining above the upper-most water bearing fracture found at 227.4 masl. Pump intake is set at a depth of 20 m below top of casing (Lotimer & Associates, 2016).

Appendix D.2 Permitted water takings in the Tier 3 study area

Permit Number	Water Source[1]	Source Name	Major Category	Specific Purpose	Max. Taking (m^3/d)	Max. Days per Year
02-P-2003	GW	Dugout pond	Agricultural	Nursery	750	15
	GW	Dugout pond	Agricultural	Nursery	750	15
03-P-2180	GW	Dugout pond	Agricultural	Field and Pasture Crops	2,087	50
03-P-2181	GW	Dugout Pond	Agricultural	Field and Pasture Crops	2,087	50
03-P-2210	GW	Dugout Pond	Agricultural	Field and Pasture Crops	2,087	50
03-P-2390	GW	Dugout pond	Agricultural	Field and Pasture Crops	1,637	150
03-P-2395	GW	Dugout Pond	Agricultural	Field and Pasture Crops	1,637	180
0400-AB4J3S	GW	Kikkert Pond	Agricultural	Nursery	445	20
0661-9HAN4F	GW	PW1	Commercial	Golf Course Irrigation	491	214
	GW	Irrigation Pond	Commercial	Golf Course Irrigation	3,240	214
1033-7DPPAH	GW	Pond	Agricultural	Nursery	1,091	200
	GW	Well	Agricultural	Nursery	274	200
1101-7K9QQL	GW/SW	South Quarry Sump	Dewatering	Pits and Quarries	50,406	365
	GW/SW	North Quarry Sump	Dewatering	Pits and Quarries	15,720	365
	GW/SW	Truckfill	Dewatering	Pits and Quarries	3,032	365
	GW/SW	Railway Cut	Dewatering	Pits and Quarries	17,568	365
	GW/SW	Beagle Club	Dewatering	Pits and Quarries	1,368	365
1245-9MHJ35	GW	Pond 1	Agricultural	Other - Agricultural	566	40
1333-968HG7	GW	Chris' s Pond	Agricultural	Field and Pasture Crops	2,087	50
1586-9SPK7B	GW	PW 1	Commercial	Golf Course Irrigation	368	185
	GW	Pond 1	Commercial	Golf Course Irrigation	398	215
1767-967QGH	GW	Dave's Pond	Agricultural	Field and Pasture Crops	2,084	50
2047-7D4PL7	GW	Westover Farm Pond	Agricultural	Nursery	450	4
2066-A3YQJ4	GW	PW-1	Agricultural	Other - Agricultural	111	365
	GW	PW-2	Agricultural	Other - Agricultural	52	365
	GW	PW-3	Agricultural	Other - Agricultural	125	365
	GW	PW-4	Agricultural	Other - Agricultural	170	365
2266-8FENER	GW	Irrigation Pond	Agricultural	Field and Pasture	818	365

Permit Number	Water Source[1]	Source Name	Major Category	Specific Purpose	Max. Taking (m^3/d)	Max. Days per Year
				Crops		
2435-8XGPYV	SW	Pond on Grindstone Creek	Agricultural	Field and Pasture Crops	273	200
2476-9F5KM6	GW	Greensville Well FDGO1	Water Supply	Municipal	197	365
Being Commissioned	GW	Greensville Well TW-2-13[2]	Water Supply	Municipal	130	366
2666-8AELTJ	GW	Farm 1- Well # 2 (88-P-2009)	Agricultural	Field and Pasture Crops	353	365
	GW	Farm 1 - Well # 3 (00-P-2388)	Agricultural	Field and Pasture Crops	137	365
	GW	Farm 2 TW1 (5428-6FUQN8)	Agricultural	Field and Pasture Crops	504	365
3004-AD7MSR	GW	Home Pond	Agricultural	Field and Pasture Crops	2,087	80

Appendix D.2 continued Permitted water takings in the Tier 3 study area

Permit Number	Water Source	Source Name	Major Category	Specific Purpose	Max. Taking (m^3/d)	Max. Days per Year
3105-6P3LES	GW	Fire Water Pond	Miscellaneous	Other - Miscellaneous	75	6
	GW	Fire Water Pond Make-up water well	Miscellaneous	Other - Miscellaneous	75	6
3148-AB5M54	GW	Pond 1	Agricultural	Nursery	750	200
3708-9Z6PUA	GW	Well #1	Industrial	Food Processing	524	365
	GW	Well #2	Industrial	Food Processing	182	365
3752-8FQNWN	GW	Ponds 1, 2, 3	Agricultural	Other - Agricultural	1,146	275
4082-8GSR7D	SW	Hanes Pond	Agricultural	Other - Agricultural	970	30
4176-9T6QGR	GW	Well PW1-98	Commercial	Golf Course Irrigation	1,637	154
	GW	Pond 3	Commercial	Golf Course Irrigation	1,637	214
5032-7DDLBA	GW	Pond D (lined)	Agricultural	Nursery	500	120
	SW	Ponds A and B	Agricultural	Nursery	1,361	120

		(intermittent)				
	SW	Pond C (intermittent tributary of West Spencer)	Agricultural	Nursery	500	120
	GW	Well (WWR #6809976)	Agricultural	Nursery	131	120
5112-83SJ4Q	GW	Dugout Pond	Industrial	Aggregate Washing	4,910	180
5415-7JXSB7	SW	West Farm Pond	Agricultural	Nursery	450	5
5651-92BRWG	GW	Pond	Agricultural	Field and Pasture Crops	909	50
5725-8NVQRL	SW	Thompson Pond	Agricultural	Other - Agricultural	654	20
5866-9QLL32	GW	Well 1	Agricultural	Market Gardens / Flowers	1,309	210
	GW	Pond 1	Agricultural	Market Gardens / Flowers	1,364	210
	GW	Pond 2	Agricultural	Market Gardens / Flowers	1,364	210
5884-8YXLJW	GW	PW-1	Commercial	Golf Course Irrigation	491	153
	GW	Irrigation Pond	Commercial	Golf Course Irrigation	1,287	180
	GW	Clubhouse Well	Water Supply	Other - Water Supply	43	365
6012-7QARLZ	SW	Spencer Creek	Agricultural	Nursery	2,700	365
6573-ACWHZD	GW	Weston Pond	Agricultural	Field and Pasture Crops	1,905	80
6581-A48RAW	GW/SW	Sump 1	Dewatering	Pits and Quarries	17,502	365
	GW/SW	Sump 1 (Ready-Mix)	Industrial	Other - Industrial	720	365
	GW/SW	Sump 2	Dewatering	Pits and Quarries	0	365
6781-8SNQ9Q	GW	Krulikoski Pond	Agricultural	Nursery	518	60
	GW	Sproule Pond	Agricultural	Nursery	518	60
6808-9PGP4V	GW	Griffith Farm Pond A	Agricultural	Nursery	900	214
	GW	Griffith Farm Pond B	Agricultural	Nursery	900	214
	GW	Griffith Farm Old Pond	Agricultural	Nursery	400	214
7233-6Z3LQW	GW	Kikkert Pond	Agricultural	Nursery	445	20
7620-98RR56	GW	Well	Agricultural	Market Gardens / Flowers	173	140
	GW	Pond 1	Agricultural	Other - Agricultural	1,100	150
	GW	Pond 2	Agricultural	Other - Agricultural	1,100	180

Appendix D.2 continued Permitted water takings in the Tier 3 study area

Permit Number	Water Source	Source Name	Major Category	Specific Purpose	Max. Taking (m^3/d)	Max. Days per Year
7788-8GKMGE	SW	Pond 1	Agricultural	Other - Agricultural	455	20
	SW	Pond 2	Agricultural	Other - Agricultural	455	20
7825-84BPPQ	GW	Well B	Water Supply	Campgrounds	262	184
8078-83KL59	GW	New Supply Well WR 6813823	Water Supply	Communal	150	365
	GW	Park Well WR 6807806	Water Supply	Communal	150	365
8168-8FUQW7	SW	Reservoir A	Agricultural	Other - Agricultural	1,188	275
	SW	Reservoir B	Agricultural	Other - Agricultural	768	20
8488-8SLQ3S	GW	Olga's Pond	Agricultural	Nursery	518	60
8606-9RWHE9	SW	Spencer Creek	Commercial	Golf Course Irrigation	1,178	184
	SW	Storage Pond	Commercial	Golf Course Irrigation	1,309	184
	SW	Irrigation Pond	Commercial	Golf Course Irrigation	1,746	184
8664-9TUQ4H	GW	Pond A	Agricultural	Field and Pasture Crops	996	120
	GW	Pond BC	Agricultural	Field and Pasture Crops	996	120
	GW	Pond E	Agricultural	Field and Pasture Crops	996	120
	GW	Well 141	Agricultural	Field and Pasture Crops	85	365
	GW	Well 142	Agricultural	Field and Pasture Crops	85	365
8704-7JXNYM	SW	Christie Reservoir (Spencer Creek)	Agricultural	Field and Pasture Crops	763	273
8777-8BZT2W	GW	Pond A	Agricultural	Field and Pasture Crops	2,726	100
	GW	Pond B	Agricultural	Field and Pasture Crops	2,726	100
	GW	Washplant Well	Agricultural	Field and Pasture Crops	197	365
	SW	Spencer Creek	Agricultural	Field and Pasture Crops	2,726	70
8811-AB6QAH	GW	Well #1	Water Supply	Other - Water Supply	328	365
	GW	Well #2	Water Supply	Other - Water Supply	328	365
8841-	SW	Pond #22	Agricultural	Other - Agricultural	518	30

73AL2E	SW	Pond #23	Agricultural	Other - Agricultural	518	30
8868-7UPJ4P	GW	1A	Agricultural	Nursery	540	244
	GW	1B	Agricultural	Nursery	540	244
	GW	2A	Agricultural	Nursery	1,533	244
	GW	2B	Agricultural	Nursery	730	244
	GW	2C	Agricultural	Nursery	306	244
	GW	3A	Agricultural	Nursery	680	244
	GW	3B	Agricultural	Nursery	540	244

Note: 1. SW means surface water, GW means groundwater
2. TW-2-13 is now called FDG02

Appendix D.3 Tier 3 Risk Assessment Scenarios and Circumstances

Local Area – Significant Risk	
Scenarios	**Circumstances**
Scenario C Existing demand, existing land use, average climate **Scenario D** Existing demand, existing land use, 10-year drought	At any time, in either the steady-state or transient scenarios (C and D), the existing groundwater supply system within the local area wells is not able to meet existing demand. This circumstance would be identified by simulated water levels at a well falling below the safe water level. The tolerance of the groundwater supply system is considered to be low, based on its inability to meet the existing peak demands. The assignment of low tolerance is generally associated with an existing municipal system that has historically experienced water quantity shortages.
Scenario G(1), G(2), G(3) Allocated plus Planned demand, projected land use, average climate **Scenario H(1), H(2), H(3)** Allocated plus Planned demand, projected land use, 10-year drought	At any time, in either the steady-state or transient scenarios (G and H), the groundwater supply system within the local area is unable to meet the simulated demand (existing plus committed plus planned). This circumstance would be identified by simulated water levels at a well falling below the safe water level.
Scenario G(2) Allocated plus Planned demand, projected land use, average climate	The difference between the Allocated and the Planned quantity of water would result in a reduction to flows or levels of water creating an unacceptable impact. The difference between the allocated and the planned quantity of water would result in a reduction in groundwater discharge to aquatic habitat that is classified as a cold water stream by an amount that is greater than: (i) 20% of the estimated stream flow that is exceeded 80% of the time (Q_{P80}), or (ii) 20 % of the estimated average monthly baseflow of the stream.
Local Area – Moderate Risk	

Scenario G(2) Allocated plus Planned demand, projected land use, average climate	The difference between the Allocated and the Planned quantity of water would result in a reduction to flows or levels of water creating a measurable and potentially unacceptable impact. The difference between the Allocated and the Planned quantity of water would result in a reduction in groundwater discharge to aquatic habitat that is classified as a cold water stream by an amount that is: (i) at least 10% but not greater than 20% of the estimated stream flow that is exceeded 80% of the time(Q_{P80}), or (ii) at least 10% but not greater than 20% of the estimated average monthly stream baseflow. The difference between the Existing and Allocated demand would result in a reduction to flows or levels of water creating a measurable and potentially unacceptable impact. The difference between the Existing and the Allocated demand would result in a reduction in groundwater discharge to aquatic habitat that is classified as a cold water stream by an amount that is: (i) at least 10% of the estimated stream flow that is exceeded 80% of the time (Q_{P80}), or (ii) at least 10% of the estimated average monthly stream baseflow

APPENDIX E: METHODS USED TO CALCULATE THE PERCENTAGE OF MANAGED LANDS AND LIVESTOCK DENSITY WITHIN VULNERABLE AREAS

Percentage of Managed Lands and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers

Halton-Hamilton Source Protection staff calculated percentage of managed lands and livestock density using the methodology provided in:

- Ministry of the Environment Technical Bulletin: Proposed Methodology for Calculating Percentage of Managed Lands and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers, December 2009; and
- Draft Clarification of Issues in Regard to Managed Lands, Ministry of the Environment, April 26, 2010.

1. Managed Lands

For the purpose of the threats assessment under the *Clean Water Act, 2006,* managed lands means lands to which agricultural source material, commercial fertilizer and/or non-agricultural source material can be applied. Managed lands can be sub-divided into:

- agricultural managed lands - including areas of cropland, fallow fields, and pastures that may receive nutrients; and
- non-agricultural managed lands - including golf courses, sports fields, lawns, and other grassed areas that may receive nutrients.

The percentage of managed lands is required to be identified within each of the delineated vulnerable areas where the vulnerability score for that area is high enough for activities to be considered significant, moderate, or low threats to drinking water.

Specifically, managed lands were identified using the property classes of the Municipal Property Assessment Corporation (MPAC) and the land classes of the Southern Ontario Land Resource Information System (SOLRIS). The property codes were used to exclude non-managed land properties from the analysis. MPAC property polygon extents often include natural areas that would be unlikely to receive manure and fertilizer applications. The SOLRIS dataset was used to remove woodlots, water bodies, extraction areas, wetlands, and road networks from the analysis area. Areas classified as built-up pervious in the SOLRIS layer were assumed to have 50 percent grassed areas. Golf courses were assumed to be 100 percent managed.

1.1 Intake Protection Zones and Wellhead Protection Areas

For intake protection zones (IPZs) and wellhead protection areas (WHPAs) the percentage of managed land within each part of the vulnerable area (IPZ-1 and 2), WHPA-A, through E) was calculated as the sum of the areas of agricultural managed land and non-agricultural managed land, divided by the total land area, and then multiplied by 100.

1.2 Highly Vulnerable Aquifers

For the highly vulnerable aquifers (HVAs), the analysis was refined by intersecting a one square kilometre grid, centred on the centroid of the Source Protection Area, with the vulnerable area. These vulnerable areas are quite large and contiguous. The use of a grid provides results on a scale that identifies areas with the potential for cumulative impacts. Within each of the grid cells, the percentage of managed lands was calculated as the sum of the areas of agricultural managed land plus non-agricultural managed land, divided by the respective size of the vulnerable area within that cell, and then multiplied by 100.

2. Livestock Density

Livestock density is used in the threats assessment as a measure of the potential for generating, storing, and applying to land, agricultural source material as a source of nutrients within an assessment area. It is equated to nutrient units per acre.

Nutrient unit values for the MPAC livestock types were estimated using the conversion factors provided in Table 2 of MOE (2009).

No properties within the intake protection zones were classed as housing livestock. Thus, livestock density mapping was not completed in these areas.

2.1 Wellhead Protection Areas

Properties within wellhead protection areas with the potential to house livestock were identified from the Municipal Property Assessment Corporation (MPAC) farm classification system. Farm operations are classed, for example as dairy, swine, beef, etc. To estimate the nutrient units produced on each property, an assumption was used that all farm buildings that could house animals would hold the maximum for their size. In each part of the wellhead protection area, livestock density was estimated by measuring the square footage of farm buildings using high resolution digital imagery. Conversion factors from Table 1 (MOE, 2009) were used to estimate the equivalent nutrient units based on barn area and animal type. Livestock density was then estimated by dividing the total nutrient units estimated for all properties within each part of the wellhead protection area (WHPA-A through E) by the total area of properties containing livestock.

2.2 Highly Vulnerable Aquifers

Properties within highly vulnerable aquifers with the potential to house livestock were also identified from the Municipal Property Assessment Corporation (MPAC) farm classification system. The size of farm buildings that could house livestock was determined using MPAC database structure codes and first floor area. Once the size of the buildings and the type of livestock operation determined, Table 1 (MOE, 2009) was used to estimate equivalent nutrient units.

Livestock density was estimated by intersecting a one square kilometre grid, centred on the centroid of each Source Protection Area, with the vulnerable area. Use of the grid identifies areas with the potential to produce higher volumes of agricultural source material in a conservative way. A sum of the nutrient units pro-rated to within the vulnerable area of each grid cell was divided by the area of agricultural managed lands within this cell to estimate the livestock density.

3. Managed lands and livestock density analysis limitations

Nutrient unit calculations are meant to approximate the maximum potential nutrient unit production of farm livestock operations. Since, there has been no quantitative estimate of actual occupancy levels of livestock facilities, MPAC and SOLRIS data do not necessarily reflect the current land or building use activity on each property, or a building's capability to house livestock. Moreover, as no database is available to indicate which areas of the properties actually receive agricultural source material for land application, field verification would be required for results that are more accurate.

APPENDIX F: DIRECTOR’S OPINION LETTER – LOCAL THREAT

Ministry of
the Environment

Source Protection Programs
Branch

14th Floor
40 St. Clair Ave. West
Toronto ON M4V 1M2

Ministère de
l'Environnement

Direction des programmes de protection
des sources

14e étage
40, avenue St. Clair Ouest
Toronto (Ontario) M4V 1M2

Ontario

ENV1174IT-2011-79

August 9, 2011

Ms. Diane L. Bloomfield
Halton-Hamilton Source Protection Region Project Manager
Halton-Hamilton Source Protection Committee
4052 Milburough Line RR2
Campbellville ON L0P 1B0

Dear Ms. Bloomfield:

Thank you for your letter of July 11, 2011, where you requested a Director's opinion regarding the addition of the following activity as local drinking water threat, in vulnerable areas for all intakes for Halton Region and Hamilton Region Source Protection areas, under Rule 119 of the technical rules:

1. The conveyance of oil by way of a pipeline that crosses a body of open water and would be designated as transmitting or distributing "liquid hydrocarbons", including "crude oil", "condensate", or "liquid petroleum products", and not including "natural gas liquids" or "liquefied petroleum gas", within the meaning of the Ontario Regulation 210/01 under the *Technical Standards and Safety Act*, or is subject to the *National Energy Board Act*.

In accordance with my authority under Rules 119, 120, or 121, I am of the opinion that the hazard rating is greater than 4 for both activities. The information on the activities, circumstances under which the activities would be drinking water threats and the assigned hazard rating for each threat related to your proposed request is provided below.

As per your request letter, we understand you will be evaluating this activity using the spill scenario for the event based modelling approach (EBA), from the work for the Lake Ontario Collaborative and allowed under technical rule 130. Under the EBA, the hazard rating is not relevant to the evaluation of the threat. The hazard rating is required to confirm that the activity is a threat that can be considered using the EBA.

Your rationale for the inclusion of these local threats along with a copy of this letter must be included in your assessment report.

1

Sincerely,

Ian Smith, Director
Source Protection Programs Branch
Ministry of the Environment

c: Keith Willson, Manager, Source Protection Approvals
Paul Heeney, Manager, Source Protection Implementation
Katie Fairman, Manager, Source Protection Planning (A)
John Westlake, Supervisor, Source Protection Implementation (A)
Melanie Ward, Group Leader, Source Protection Approvals
Clara Tucker, Watershed Management Specialist, Source Protection Planning

Table 1: A spill of gasoline (containing benzene) from a ruptured pipeline as it crossed tributaries flowing into Lake Ontario

Activity	Circumstance	Hazard Rating IPZ
The conveyance of oil by way of a pipeline	1. The conveyance of oil by way of a pipeline that would be designated as transmitting or distributing "liquid hydrocarbons", including "crude oil", "condensate", or "liquid petroleum products", and not including "natural gas liquids" or "liquefied petroleum gas", within the meaning of the Ontario Regulation 210/01 under the Technical Standards and Safety Act, or is subject to the National Energy Board Act. 2. The rupture of a pipeline in an area where the pipeline crosses a body of open water and may result in the presence of BTEX in surface water.	9.4

APPENDIX G: GLOSSARY OF TERMS

Glossary of Terms

Adsorption: the adhesion of a chemical onto the surface of a particle.

Advection time: the time it takes for water to transport unreactive contaminants.

Anaerobic digestion: the breakdown of organic matter by bacteria, without oxygen.

Baseflow: water flowing in a stream that comes from groundwater seepage, not runoff.

Benthic invertebrate community: the distribution and numbers of aquatic animals without backbones that live on or in the sediments of a creek.

Bioturbated: the effect of a process in which organisms disturb the sediments, particularly through burrowing or boring. The burrows that exist in rock are fossils.

Chert: a hard, dense rock composed of microcrystalline quartz.

Coal tar: a by-product of the burning of coal without oxygen.

Cone of influence: the zone around the municipal well where water levels are influenced by the pumping of the well at its actual rate.

Confined aquifer: an aquifer bounded on top and bottom by much less permeable formations.

Conservation Authority Regulated Limit: the area bordering watercourses that is regulated under the Conservation Authorities Act, where development is prohibited unless permission is obtained.

Deglaciation: the uncovering, usually by melting, of land formerly covered by a glacier.

Dolostone: an altered limestone rock made from calcium-magnesium carbonate.

Downgradient: indicates in the direction of higher energy to lower energy and is generally from high water levels to low water levels.

Drumlins: inverted, spoon shaped hills. Drumlins are created when till is deposited and moulded by glaciers. They lie in the direction of ice movement.

Effective porosity: the ratio of a material's connected, void spaces that contribute to fluid flow to the total volume of the material.

Evapotranspiration: the term used to define water losses due to evaporation and transpiration. Evaporation is the change of water from a liquid to a vapour and requires the addition of heat energy. Transpiration is the process whereby plants take up water through their roots and release it to the atmosphere through their leaves.

Fossil: the remains, imprints, or traces of organisms that lived in a prior geologic age, e.g., a shell, footprint, or burrow.

Hydrologic cycle: also known as the water cycle. See Section 5.1 for a detailed discussion.

Indicator bacterium: *Escherichia coli* is monitored regularly as an indication of the presence/absence of disease causing organisms. It is used to identify contaminated water.

Interfingers: the relationship between rocks when the lateral boundary between them fluctuates.

Intermediate operation: an operation that uses materials to generate a product with different characteristics than the original materials.

Lobe: a projection of the ice sheet from its edge or margin.

Managed Lands: includes all land that is augmented with commercial fertilizers, manure, and/or other source materials.

Megashoals: long, linear, and quite narrow landforms comprising, in this Area, marine organisms deposited by water.

Mudstone: basically, hardened mud. Mudstone is similar to shale because it is made from very small particles; however, mudstone has no layers.

Multi-barrier approach: an integrated system of water management aimed at reducing the contamination of drinking water from source to tap. The approach includes the protection of water supplies, appropriate treatment and testing, reliable distribution systems, and professional training for water managers.

Nearshore: the zone of the lake that includes the area where longshore currents move parallel to the shoreline.

Normals: the averages of the data measured over a specific period. These data are typically used for expected future conditions.

Nutrient unit: is a way of quantifying the amount of nutrients that farm animals generate. A nutrient unit is the amount of nutrients that give the fertilizer replacement value the lower of 43 kilograms of nitrogen or 55 kilograms of phosphate.

Organic soils: soils that contain at least 30 percent of organic matter such as decaying vegetation or animal manure. Peat is an organic soil.

Permeable: allowing the passage of fluid.

Plume: a zone of contaminants in water that is moving away from the source of the contaminants.

Precipitation depths: precipitation is reported as a depth of water received in millimetres.

Pulp and paper biosolids: solid or liquid material that results from the treatment of wastewater generated by a manufacturer of pulp, paper, recycled paper, or paper products, including corrugated cardboard.

Quartz: a common mineral composed of silica.

Reef mounds: large layered structures built by marine organisms.

Riparian: areas associated with the banks of a watercourse.

Salt Storage Facility: a designated area for the storage of road salt or salt/sand mixtures transported to the site in bulk.

Setdown: a lowering of the water levels in the lake due to wave action or increased atmospheric pressure.

Semi-confined aquifer: a partially confined aquifer due to overlying and underlying less permeable formations through which recharge and discharge still occurs.

Sewage biosolids: solid or semi-solid residue following treatment of sewage and removal of effluent.

Snow Storage Facility: a designated purposely designed storage area used for the stockpiling of snow transported to the site for storage and melting.

Storm surge: a rise in water levels in the lake above normal due to wind stress or a reduction in atmospheric pressure on the water surface.

Sublimate: the process by which snow and ice become water vapour without first melting to liquid.

Surface Water Divide: a line that forms the boundaries of watersheds. On either side of the divide, water moves in opposite directions.

Third order streams: streams that are formed by the convergences of two or more second order streams. Generally, they are considered to contain enough water to act as a source of water for agriculture. The ordering of streams is determined in this way: the first instance of a headwater stream is a first order stream and, where two first order streams meet, they become a second order stream, and so on.

Till: the name given to the rock, sand, silt, clay mixture that is deposited directly by ice.

Unsaturated zone: the soil and rock that lie above the water table where pores and void spaces are not entirely filled with water. The saturated zone lies below the water table where all void spaces are filled with water.

Watershed: an area of land that drains water into a waterbody such as a lake or river. Watershed may refer to the drainage of surface water or groundwater and the two drainage areas may not be coincident in a given area.

Water table: the water surface underground where the water pressure is equal to atmospheric pressure. It is the upper surface of the zone where all pores in the rock or soil are filled with water.

Water table aquifer: an unconfined aquifer where its upper boundary is the water table.

Weathered zone: refers to the upper surface of a bedrock formation that has been exposed to climatic elements, runoff water, and in this case, glacial ice. It is broken and eroded. Weathering typically increases the permeability of the rock.

Weathering: a general term used to describe the breakdown of rock and soil by chemical and physical processes caused by exposure to the Earth's climate.

APPENDIX H: MAPS AND FIGURES