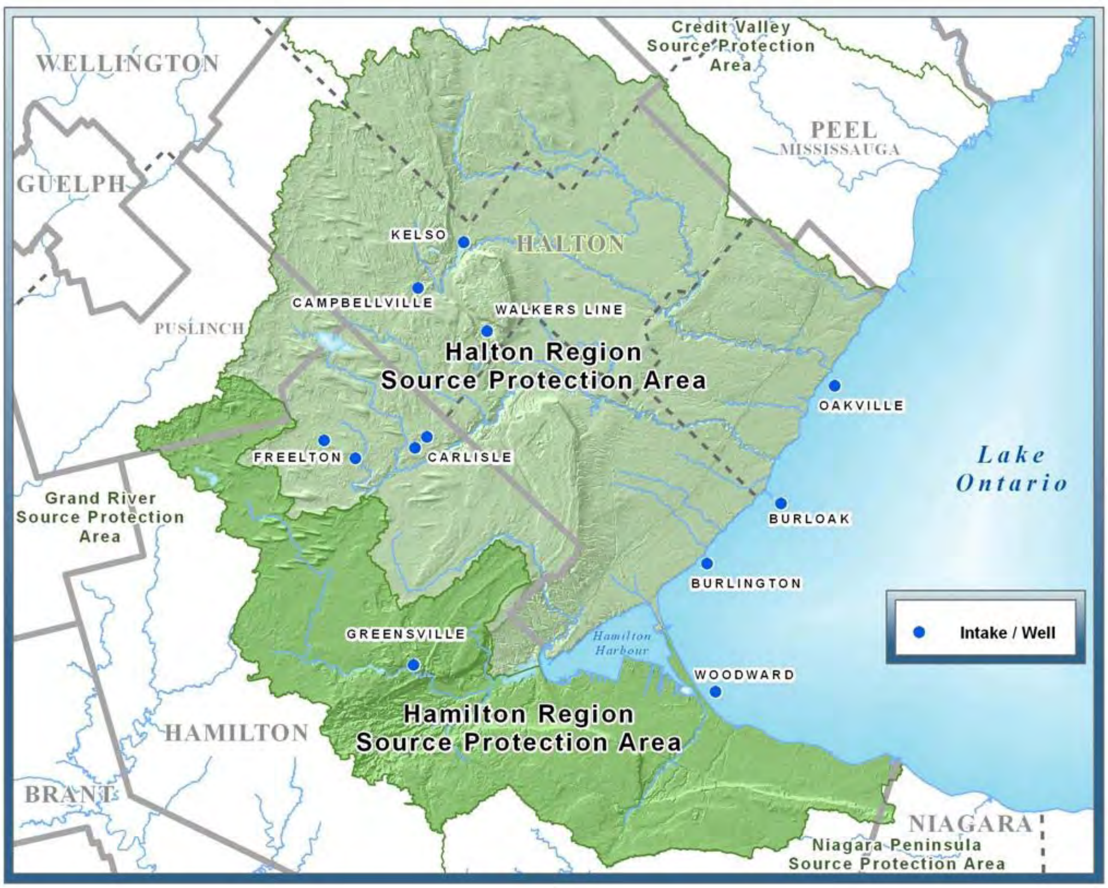
REPORT ON TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT FOR HALTON-HAMILTON SOURCE PROTECTION REGION

AND

REPORT ON 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

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August 27, 2010

REPORT ON

TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT FOR THE HALTON-HAMILTON SOURCE PROTECTION REGION

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TIER 2 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENTS FOR THE UPPER WEST BRANCH OF SIXTEEN MILE CREEK AND MIDDLE SPENCER CREEK SUBWATERSHEDS

Executive Summary

Report on Tier 1 Water Budget and Water Quantity Stress Assessment for the Halton-Hamilton Source Protection Region (Halton-Hamilton SPR) and Report on Tier 2 Water Budget and Water Quantity Stress Assessments for the Upper West Branch of Sixteen Mile Creek and Middle Spencer Creek Subwatersheds were prepared by the Halton-Hamilton SPR staff. The Regional Municipality of Halton (Halton Region) and the City of Hamilton (Hamilton) assisted the Halton-Hamilton SPR by providing valuable data sets as well as numerical surface water and groundwater flow models.

The Halton-Hamilton SPR comprises the Halton Region Source Protection Area (Halton Region SPA) and the Hamilton Region Source Protection Area (Hamilton Region SPA). The total area of the Halton-Hamilton Region SPR is about 1,420 km^2 and the population of the region is about 900,000 people.

The Halton Region SPA comprises three (3) large watersheds: Sixteen Mile Creek, Bronte Creek and Grindstone Creek, and a number of smaller watersheds along the shores of Lake Ontario, Burlington Bay and Cootes Paradise. These smaller watersheds were grouped into four (4) watersheds defined as North Shore Group 1 through North Shore Group 4.

The Hamilton Region SPA comprises Spencer Creek watershed, the Red Hill Creek watershed, the Stoney Creek watershed, the Stoney Creek Numbered Watercourses watersheds, the Urban Hamilton Beach Strip watershed, the Urban Hamiton City Core watershed and the Cootes Paradise (Hamilton) watershed.

The Halton-Hamilton SPR contains six (6) municipal wellfields:

- Kelso;
- Campbellvile;
- Walkers Line;
- Carlisle;
- Freelton; and
- Greensville.

There are also four (4) surface water systems, which take water from Lake Ontario.

This report follows the specifications of the Clean Water Act, 2006, S.O. 2006, chapter - 22 as amended (CWA). The CWA requires a tiered approach for water budget evaluation and Water Quantity Stress Assessment (WQSA). This report also complies with the Technical Rules: Assessment Report (MOE, November 2009). The water budget is a major component of the watersheds Assessment Report. It deals with developing an understanding of water availability, water movement, water uses and water stresses within the watersheds.

The purpose of the Tier 1 analysis was to estimate the hydrologic stresses in subwatersheds making up the Halton-Hamilton SPR. In order to identify subwatersheds that are stressed from the water quantity perspective this water budget assumes average climatic conditions and average water takings. The WQSA is completed separately on a groundwater and a surface water basis.

The overall purpose of the Tier 1 Water Budget was to provide a quantitative measure of various components of the hydrologic cycle (precipitation, runoff, evapotranspiration and recharge), to evaluate groundwater and surface water supplies and reserves and to calculate average groundwater and surface water demands. Based on the above work groundwater and surface water WQSAs were completed. Subwatersheds with municipal drinking water systems identified as under stress through the Tier 1 assessment required a more detailed Tier 2 approach.

Tier 1 and Tier 2 Water Budget Report Scope

The following is a summary of different tasks completed to satisfy the Province's requirements:

1. Water Budget elements estimate;
2. Surface water supply and groundwater supply estimates;
3. Surface water reserve and groundwater reserve estimates;
4. Surface water demand and groundwater demand estimates;
5. Tier 1 surface water stress assessment and Tier 1 groundwater stress assessment; and
6. Tier 2 groundwater stress assessment.

Water Budget Element Estimate

The water budget elements, such as: actual evapotranspiration, runoff and recharge were estimated using a distributed hydrologic model. A Precipitation Runoff Modelling System (PRMS) code was adopted for the study area. The PRMS model was developed using daily precipitation and daily minimum and maximum temperature data from nine (9) weather stations. A number of spatially distributed parameters, such as:

- Parcel-based land use;
- SOLRIS land cover;
- Surficial geology class;
- Digital elevation model (DEM), etc.

were used in the model development.

The model was calibrated using total and baseflow stream data. The results show that there is a significant difference between the water budget elements above and below the Niagara Escarpment. The recharge rate above the Escarpment is significantly higher, especially in the Halton region SPA. There are also differences of water budget elements between the urbanized and undeveloped areas.

Surface water supply

The calibrated PRMS surface water model was the source of the surface water supply estimate. The monthly median streamflow data for the modelling period was aggregated for all the subwatersheds of the Halton-Hamilton SPR.

Groundwater supply

Groundwater supply is defined as the sum of the groundwater recharge and the lateral flows through the boundaries of a subwatershed. The recharge component of the groundwater supply was summarized based on the PRMS model. The lateral flows were estimated using the groundwater MODFLOW models developed for Halton Region and the City of Hamilton. The two groundwater flow models were calibrated using water levels from the MOE Water Well Information System Database and HYDAT streamflow data.

Surface water and groundwater reserves

The surface water reserves were estimated as the 10^{th} percentile median streamflows.

The groundwater reserves were assumed to be ten (10) percent of the total groundwater supplies.

Surface water and groundwater demands

One of the most time consuming and detailed tasks of the water budget report was a review of all the data pertaining to surface water and groundwater demand. Two (2) main sources of water demand are permitted and non-permitted takings.

1. Permitted sources:

   - Permit To Take Water (PTTW) database from Ministry of the Environment (MOE); and
   - Actual municipal water takings and projected future municipal water takings.

2. Non-permitted sources:
   - Domestic water takings based on population estimates (present 2006 and future 2031); and
   - Agricultural water takings based on Census of Agriculture (2006).

The 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. Consumptive factors were assigned to all takings and consumptive water demand values were used for the WQSA analyses.

Tier 1 stress assessment

Following the estimate of surface water and groundwater supplies, reserves and consumptive water demands, the surface water and groundwater stress analyses were performed.

The results of the surface water stress assessment showed significant stress levels in 17 subwatersheds and moderate levels in 16 subwatersheds in the Halton-Hamilton SPR. As there are no surface drinking water intakes in these subwatersheds, they do not warrant a Tier 2 level of stress assessment.

The groundwater stress assessment identified five (5) subwatersheds across the Halton-Hamilton SPR that exhibit either annual or monthly stress levels.

Of the five (5) subwatersheds with groundwater quantity stresses the Upper West Branch subwatershed of Sixteen Mile Creek and the Middle Spencer Creek subwatershed contain municipal drinking water systems. Tier 2 level of WQSA was required for these subwatersheds.

Tier 2 stress assessment

The Tier 1 WQSA for the Upper West Branch of Sixteen Mile Creek subwatershed was based on the results of the groundwater flow model. The Tier 2 stress assessment involved using the same results of the groundwater flow model and an estimate of the potential lateral flow through the northern boundary of the subwatershed, which was modeled as no flow boundary. The Tier 2 WQSA for the Upper West Branch subwatershed confirmed the potential of moderate hydrologic stress under current demand conditions.

The Tier 1 WQSA for the Middle Spencer Creek subwatershed was based on the results of the calibrated Hamilton groundwater flow model and the calibrated PRMS surface water model. A detailed review of water demand data was also completed at the Tier 1 level of stress assessment. Therefore, refinement of the assessment was not possible at a Tier 2 level and the subwatershed is considered to be moderately stressed.

Conclusions and Recommendations

The following is a summary of recommendations resulting from the Water Budget and Water Quantity Stress Assessment analyses for the Halton-Hamilton SPR:

1. In the Halton-Hamilton watersheds the only drinking water sources relying on surface water are located in Lake Ontario; therefore none of the subwatersheds exhibiting Tier 1 surface water moderate or significant stress levels requires Tier 2 Water Budget and WQSA.
2. The Upper West Branch of Sixteen Mile Creek subwatershed exhibits moderate stress level at the Tier 2 Water Budget analysis, and therefore, requires a groundwater Tier 3 Water Budget and Local Area Risk Assessment.

3. The Middle Spencer Creek subwatershed exhibits moderate stress level at the Tier 2 Water Budget and WQSA analysis, and therefore requires a groundwater Tier 3 Water Budget and Local Area Risk Assessment.

4. Halton-Hamilton SPR should engage the private sector, the municipalities and government agencies to work together to understand better the water demands and supplies across our watersheds. This would improve decision making to help maintain availability of safe drinking water at present and for the future generations.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1 INTRODUCTION

The overall purpose of the Tier 1 water budget process is to provide a quantitative measure of various components of the hydrologic cycle (precipitation, runoff, evapotranspiration and recharge), to evaluate groundwater and surface water supplies and reserves, calculate average groundwater and surface water demands and perform groundwater and surface water quantity stress assessments (WQSAs). The water budget and WQSA process follows the Clean Water Act, 2006 and the Technical Rules: Assessment Report (November, 2009). Areas identified as under stress through the Tier 1 assessment require a more detailed Tier 2 approach.

The WQSA process is dependent on the water budget results for evaluating the long term reliability of the Halton-Hamilton Source Protection Region (Halton-Hamilton SPR) drinking water sources and it helps in identifying the water quantity threats contributing to areas where reliability is a problem.

The water budget is a major component of the watersheds Assessment Report. It deals with developing an understanding of water availability, water movement, water uses and water stresses within the watersheds.

The purpose of the Tier 1 analysis is to estimate the hydrologic stresses in subwatersheds making up the Halton-Hamilton SPR. In order to identify the areas that are stressed from the water quantity perspective this water budget assumes average climatic conditions and average water takings. The WQSA is completed separately on a groundwater and a surface water basis.

This document contains the Report on Tier 1 Water Budget and WQSA for the Halton-Hamilton SPR and the Report on Tier 2 Water Budget and WQSA for the Upper West Branch of Sixteen Mile Creek and Middle Spencer Creek Subwatersheds. This report uses results of a surface water flow model and groundwater flow models developed by Earth*fx* Incorporated (Earthfx). Earthfx was retained by the Regional Municipality of Halton (Halton Region) and the City of Hamilton (Hamilton) to develop two regional groundwater flow models, to delineate Wellhead Protection Areas (WHPA) for municipal wells within the boundaries of Halton-Hamilton SPR and to assess vulnerability scoring within these WHPAs for their respective areas (see sections 2 and 3).

This report also identifies data and knowledge gaps, which may be addressed in the future to obtain an improved understanding of the water budget and the WQSA of the Halton-Hamilton SPR.

This report is a summary of work completed for the sole purpose of the Clean Water Act Water Budget assessment and WQSA for the Halton-Hamilton SPR and the results should be used with caution for any other purposes.

1.1 Halton-Hamilton Source Protection Region Watersheds

The Halton-Hamilton SPR encompasses two source protection areas: Halton Region Source Protection Area (Halton Region SPA) and Hamilton Region Source Protection Area (Hamilton Region SPA). **Figure 1.1** shows the boundary of the Halton-Hamilton SPR and the two SPAs.

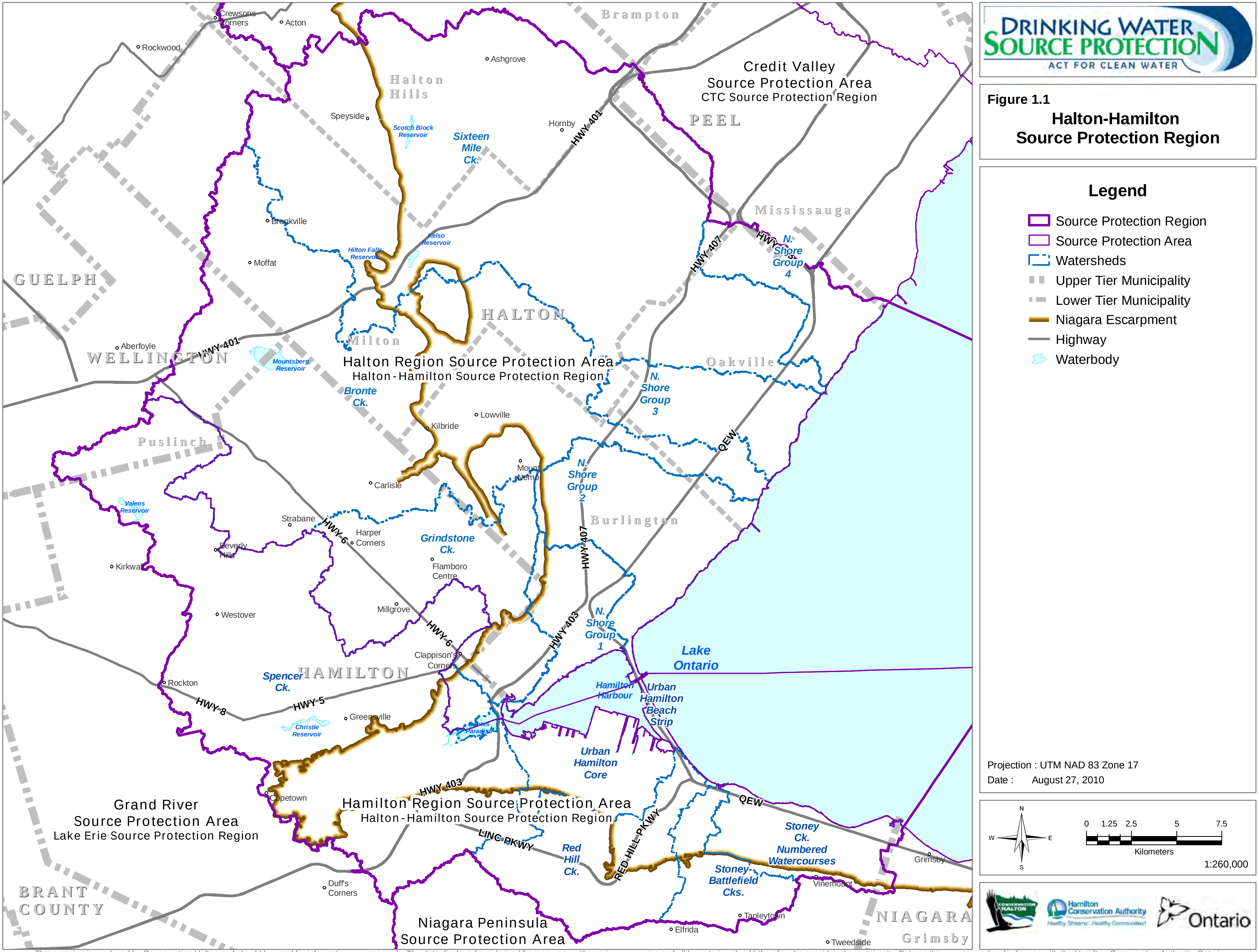

Figure 1.1
Halton-Hamilton Source Protection Region

This mapping is produced by Conservation Halton and should be used for information purposes only. The data displayed are derived from sources with varying accuracies and all boundaries should therefore be considered approximate. Data on this map is used under license with the Hamilton Conservation Authority, Ontario Ministry of Natural Resources, Halton Region, City of Hamilton, Ministry of Environment, Ontario Geological Survey, Natural Resources Canada, Teranet Enterprises Inc. and other agencies. Copyright 2010.

The Halton Region SPA comprises subwatersheds/watersheds of all streams entering into Lake Ontario from Joshua Creek to North Cootes Paradise watershed, with a total area of 970 km^2. The Hamilton Region SPA comprises the subwatersheds of all the streams and creeks flowing either directly into Lake Ontario or Cootes Paradise and Burlington Bay from Spencer Creek to Stoney Creek Watercourses, with the total area of 447 km^2.

The Halton Region SPA encompasses most of Halton Region and its four local municipalities – Town of Oakville, City of Burlington, Town of Milton and Town of Halton Hills, part of Hamilton, part of the Township of Puslinch within the County of Wellington, and part of the City of Mississauga within the Regional Municipality of Peel.

The Hamilton Region SPA is predominantly located in the City of Hamilton, Town of Grimsby and Township of Puslinch.

The abutting Source Protection Areas of the Halton-Hamilton SPR are:

1. The Credit Valley Region SPA located to the north and east;
2. The Grand River Conservation Region SPA located to the west and north; and
3. The Niagara Peninsula Region SPA located to the south-east.

Further division of the two SPAs is included in section 1.3.1 Spatial Scale.

The current (2006) population of the Halton Region SPA is 450,589, which is expected to grow by 284,779 people by the year 2031. The current (2006) population of the Hamilton Region SPA is 448,195, which is expected to grow by 94,513 people by the year 2031. With this growth in population, there will be increased demands for drinking, industrial, commercial, and other water uses on the water resources of the watersheds. It should be noted that most of the drinking water demands in the future will be served by systems based on Lake Ontario water.

Currently there are five (5) groundwater based municipal systems in the Halton Region SPA: Kelso, Walkers Line, Campbellville, Carlisle and Freelton, and there is one groundwater municipal system in the Hamilton Region SPA, located in Greensville.

There are no inland municipal surface water takings in the Halton-Hamilton SPR.

1.2 Legislation and Framework

The objective of the water budget analysis is to understand and to identify subwatersheds where the sustainability of municipal drinking water supplies is questionable and to identify the causes of the limited sustainability within identified subwatersheds, such that appropriate risk management practices can be implemented. The Clean Water Act, 2006, chapter - 22 as amended (CWA) requires a tiered approach for water budget evaluation and WQSA. This report follows the Technical Rules: Assessment Report.

The water budget is a compendium of where water supplies and demands will be quantified and where water movement within the watershed will be understood. A number of factors, in particular water availability and water uses or water quantity stresses, will influence the level of detail of water budgeting required for a particular watershed.

The MOE identified a four (4) step approach to developing water budgets. This is reflected in **Figure 1.2**.

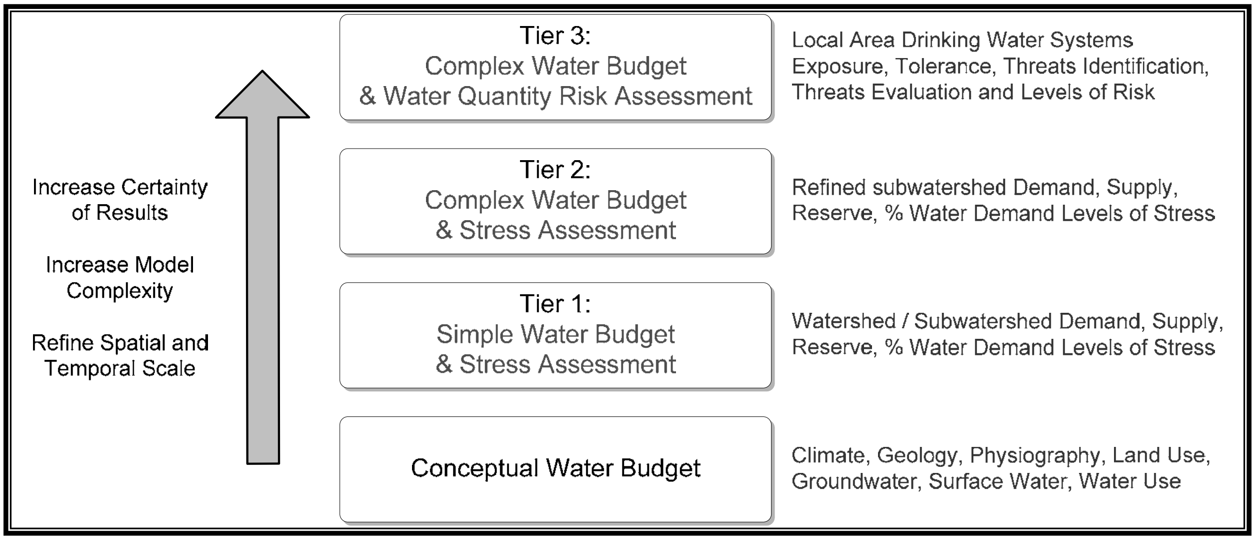

Figure 1-2: Tiered Approach to Water Budget

The first step of this assessment was a conceptual understanding of the water budget. It required extensive data collection, mapping and analyses of the information compiled. The conceptual understanding of the Halton Region SPA and Hamilton Region SPA provided an overview of the watersheds to help determine how groundwater and surface water interact and move through the watershed. The Halton-Hamilton SPR staff completed two conceptual reports:

1. Draft Final Report on Conceptual Understanding of Water Budget for the Conservation Halton Watershed, dated November 8, 2007; and
2. Preliminary Conceptual Water Budget Report for the Hamilton Conservation Authority Watershed, dated April 7, 2008.

Following the development of each of the conceptual water budgets, Tier 1 Water Budgets were required to be developed for every subwatershed in the Halton-Hamilton SPR utilizing the best available data.

The Tier 1 stress assessment evaluates the ratio of the consumptive water demand for permitted and non-permitted users to available water supplies minus water reserves within the spatial scale under consideration. This process is followed for the present conditions and future scenario for year 2031. Based on the above mentioned ratio, a significant, moderate or low stress level is assigned to each subwatershed. A moderate stress level is also assigned to subwatersheds containing municipal drinking water systems, which at any time after January 1, 1990 had problems meeting the demand due to low water levels in the vicinity of the takings.

The subwatersheds that have moderate or significant stress levels and contain municipal drinking water systems require a more refined Tier 2 Water Budget and WQSA analysis.

The Tier 2 Water Budget usually requires a more detailed approach in estimating the water budget elements through complex numerical surface water and groundwater flow modelling. In the Tier 2 Water Budget, a second WQSA is undertaken only for the areas that are under moderate and/or significant stress levels and that contain municipal supplies. The Tier 2 WQSA uses the refined water budget components and follows the same approach as the Tier 1 stress assessment.

If the results of the Tier 2 WQSA show that any of the subwatersheds have significant or moderate stress levels, a Tier 3 Water Budget and Local Area Risk Assessment is undertaken for local areas of the municipal groundwater wells that are located within stressed subwatersheds.

1.3 Water Budget and Stress Assessment Scale

The water quantities in the various hydrologic cycle components vary both spatially and temporally. Water budget studies must consider this variability and how it relates to the intended objectives of the study (MOE, 2007).

The spatial and temporal scales considered in the Halton-Hamilton SPR Tier 1 water budget analysis are discussed in the following sections.

1.3.1 Spatial Scale

The Halton-Hamilton Source Protection team used the Halton Region SPA and Hamilton Region SPA boundaries to define the study area. These hydrologic boundaries were created in cooperation with the Conservation Halton and the Hamilton Conservation Authority Geographic Information Systems (GIS) staff as well as adjacent conservation authorities (CA) GIS staff.

The selection of the appropriate assessment scale is a critical step in water quantity stress assessment.

Management subwatersheds and watersheds as delineated by the local Conservation Authorities were used to complete the water budget evaluation. This scale is appropriate for the Water Budget and WQSA of subwatersheds containing municipal drinking water systems and it provides the CAs with useful data.

The Halton Region SPA comprises 57 Conservation Halton management subwatersheds, which are shown on **Figure 1.3**. For the ease of the water budget assessment and discussion of the results the 57 subwatersheds were grouped in seven (7) watersheds. Three of the watersheds are natural watersheds: Sixteen Mile Creek watershed, Bronte Creek watershed and Grindstone Creek watershed and four watersheds are conglomerates of watersheds/subwatersheds which drain directly into Lake Ontario and Burlington Bay. These four watersheds are labeled North Shore Group watershed 1 through 4. **Table 1.1** is a summary of the Halton Region SPA subwatersheds and watersheds. The North Shore Group watersheds boundaries are shown in **Figure 1.1**.

Table 1.1: Halton Region SPA Subwatershed Summary Information

Watershed	Subwatershed	Area [km²]
Sixteen Mile Creek	East Branch	29.64
	East Branch Lisgar	25.88
	Lower Middle Branch	42.32
	Lower Middle Tributary	7.18
	Main Branch	24.67
	Middle East Branch	41.65
	Middle Branch	54.96
	Morrison-Wedgewood Diversion	16.05
	Upper West Branch[1]	72.87
	West Branch	57.21
		372.42
Bronte Creek	Flamboro Creek[1]	9.42
	Indian Creek	40.81
	Kilbride Creek	41.23
	Limestone Creek[1]	36.60
	Lower Main Branch	35.33
	Lowville Creek	10.07
	Mount Nemo Creek	4.51
	Mountsberg Creek	55.08
	Strabane Creek	18.43
	Upper Main Branch[1]	52.72
	Willoughby Creek	12.20
		316.39
Grindstone	201	22.73
	204	6.66
	210	8.02
	214	8.07
	215	14.64
	218	1.68
	220	8.19
	222	2.52
	224	5.68
	228	8.07
	230	1.65
	232 (Alternate)	2.45
		90.37
North Shore Group 1	407 Diversion	5.23
	Cootes Paradise (Halton)	0.71
	Falcon Creek	5.42
	Indian Creek	6.07
	North Cootes Paradise (232)	6.27
	Upper Hager Creek	4.23
	Upper Rambo Creek	6.29
	West Aldershot (East)	4.36
	West Aldershot (West)	0.18
		38.76
North Shore Group 2	Appleby Creek	14.08
	Beach Strip East Side	0.70
	Beach Strip West Side	0.26
	Lower Hager Creek	1.80
	Lower Rambo Creek	3.42
	Roseland Creek	9.40
	Sheldon Creek	17.67
	Shoreacres Creek	14.00
	Tuck Creek	10.45
		71.79
North Shore Group 3	Fourteen Mile Creek	34.76
	McCraney Creek	12.21
		46.98
North Shore Group 4	Ford Plant Special Area	0.55
	Joshua's Creek	21.62
	Lower Morrison Creek	5.92
	Lower Wedgewood Creek	5.49
		33.58
Halton Watershed		**970.29**

[1] Subwatershed contains municipal wellfield

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 1.3 **Halton Region Source Protection Area**

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Municipal Well
- Waterbody

Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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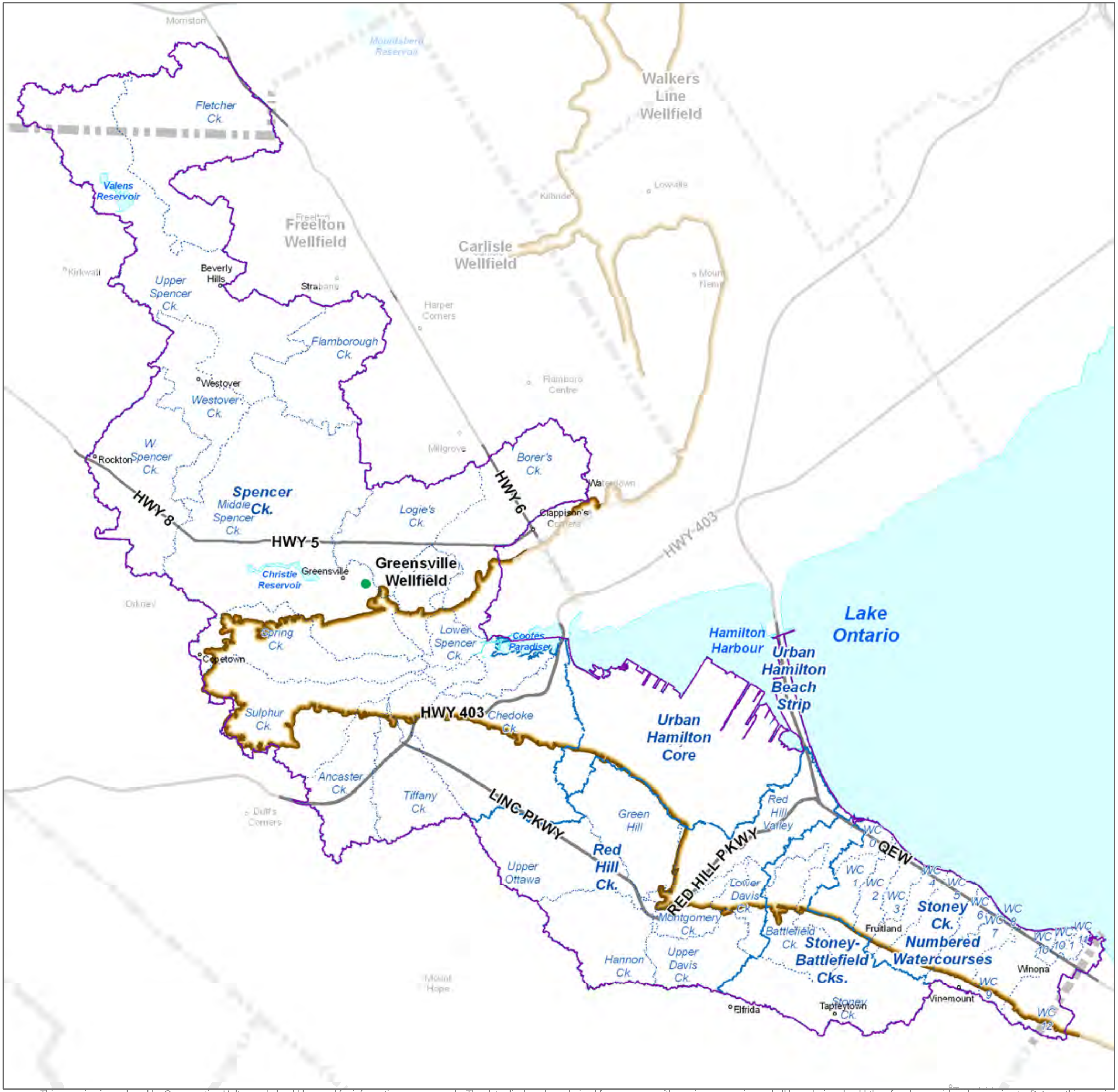

Figure 1.4

Hamilton Region Source Protection Area

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Municipal Well
- Waterbody

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6

Kilometers

1:200,000

The Hamilton Region SPA comprises 41 of Hamilton Conservation Authority's management subwatersheds, which are shown on **Figure 1.4**. These subwatersheds were grouped into seven (7) watersheds, i.e., Spencer Creek, Red Hill Creek, Stoney Creek and Stoney Creek Watercourses, Urban Hamilton Beach Strip, Urban Hamilton City Core and Cootes Paradise (Hamilton). **Table 1.2** is a summary of the Hamilton Region SPA subwatersheds and watersheds.

Table 1.2: Hamilton Region SPA Subwatershed Summary Information

Watershed	Subwatershed	Area [km^2]
Spencer Creek	Ancaster Creek	14.01
	Borer's Creek	19.48
	Chedoke Creek	25.06
	Flamborough Creek	13.30
	Fletcher Creek	25.12
	Logie's Creek	13.28
	Lower Spencer Creek	7.39
	Middle Spencer Creek[1]	49.68
	Spring Creek	13.11
	Sulphur Creek	16.90
	Sydenham Creek	5.27
	Tiffany Creek	9.08
	Upper Spencer Creek	35.92
	West Spencer Creek	18.11
	Westover Creek	10.89
		276.59
Red Hill Creek	Green Hill	11.64
	Hannon Creek	10.97
	Lower Davis Creek	3.75
	Montgomery Creek	3.75
	Red Hill Valley	13.28
	Upper Davis Creek	7.25
	Upper Ottawa	13.83
		64.46
Stoney Creek	Battlefield Creek	7.47
	Stoney Creek	21.03
		28.50
Stoney Creek Watercourses	WC 0	1.64
	WC 1	3.58
	WC 2	2.97
	WC 3	2.10
	WC 4	2.81
	WC 5	6.18
	WC 6	1.52
	WC 7	4.32
	WC 8	0.10
	WC 9	4.51
	WC 10	0.80
	WC 10.1	0.48
	WC 11	0.69
	WC 12	5.76
		37.46
Urban Hamilton Beach Strip		2.34
Urban Hamilton City Core		36.52
Cootes Paradise (Hamilton)		1.16
Hamilton Watershed		**447.04**

[1] Subwatershed contains municipal wellfield

Tables 1.1 and **1.2** indicate that many of the subwatersheds are very small. The emphasis in choosing the assessment area size was on the subwatersheds encompassing municipal drinking water systems to be of the recommended size. To keep the assessment process consistent all the assessment areas were established in the similar fashion.

Special attention should be paid to the Halton-Hamilton SPR subwatersheds, which contain drinking water systems. There are in total 14 municipal wells in six (6) wellfields in the Halton-Hamilton SPR. **Table 1.3** is a summary of the Halton-Hamilton SPR municipal wellfields and their locations.

Table 1.3: Halton-Hamilton SPR Municipal Pumping Wells

SPA	Watershed	Subwatershed	Wellfield	Active Wells	Backup Wells	Total
Halton	Sixteen Mile Creek	Upper West Branch	Kelso	4	0	**4**
	Sixteen Mile Creek	Upper West Branch	Campbellville	1	1	**2**
	Bronte Creek	Limestone Creek	Walkers Line	1	0	**1***
	Bronte Creek	Upper Main Branch	Freelton	1	1	**2****
	Bronte Creek	Flamboro Creek	Carlisle	4	0	**4**
Hamilton	Spencer Creek	Middle Spencer Creek	Greensville	1	0	**1**

* - Although there are two (2) wells at Walkers Line, one (1) well is capped and not currently in use;

** - At present there are three (3) wells in Freelton. One of the existing wells is not used as a production well due to poor water quality and it will be decommissioned in the near future. This well is not used in the Water Budget report as an active well; instead, a newly drilled replacement well is used.

Kelso, Walkers Line, and Campbellville wellfields are operated by Halton Region while the Freelton, Carlisle and Greensville wellfields are operated by the City of Hamilton. **Figures 1.3** and **1.4** show the locations of the municipal wells within the Halton Region SPA and Hamilton Region SPA, respectively.

Four (4) out of the five (5) key assessment subwatersheds that contain municipal wellfields are within the Ministry of Natural Resources (MNR) suggested range of 20 to 100 km^2. The Flamboro Creek subwatershed containing the Carlisle drinking water municipal system is smaller than 20 km^2.

1.3.2 Temporal Scale

The water quantities within various water budget components vary over time. To address these changes the surface water budget assessments are prepared on a monthly basis only and the groundwater budget assessments are prepared on an annual and monthly basis.

The water budget analyses and the water quantity stress assessments are dependent on the available data. The Halton-Hamilton SPR team receives data on an on-going basis. To complete the Tier 1 and Tier 2 Water Budget report no additional data has been used to update the water budget and water quantity stress assessment since October 1, 2009.

1.4 Scope of Tier 1 and Tier 2 Water Quantity Stress Assessment

The purpose of the Tier 1 analysis is to estimate the hydrologic stress of subwatersheds in order to identify areas that are stressed utilizing the existing information collected during the conceptual understanding phase.

A simple approach to estimate the various elements of the hydrologic cycle including precipitation (P), evapotranspiration (ET), recharge (R), and runoff (RO) is sufficient for a Tier 1 analysis. It was recommended by the MOE that if suitably calibrated complex models were already available, they should be used instead of other more simple approaches.

At Tier 1, the water quantity stress assessment is undertaken for two (2) scenarios:

1. current conditions – Halton-Hamilton SPR study year is 2007, population estimates are based on available data for 2006 and some of the reported actual water takings are for 2008, and
2. future demand conditions (year 2031).

The water quantity stress assessment is evaluated independently for groundwater and surface water.

The water quantity stress assessment in a subwatershed is undertaken in four (4) steps:

1. Water budget analysis is used to determine the water supply and the water reserve and water demand is estimated for surface water and groundwater flow systems. In Tier 1, the current water supply (i.e., available water) is used to evaluate the future demand scenario;
2. The percent water demand is computed on an average annual and monthly basis for groundwater takings and on monthly basis for surface water takings;
3. The percent water demand thresholds are utilized to classify the stress level, and
4. The stress category is determined as the maximum stress level.

Estimations of annual and monthly water supply, consumptive water demand, water reserve and stress assessment are completed as defined in the Technical Rules.

1.4.1 Groundwater Quantity Stress Assessment

The groundwater quantity stress is determined by calculating the average annual and maximum monthly percentage consumptive water demand for each subwatershed and comparing these values to the thresholds defined in **Table 1.4**.

The following equation is used for annual and monthly Percent Groundwater Demand:

$$\%WaterDemand = \frac{Q_{DEMAND}}{Q_{SUPPLY} - Q_{RESERVE}} \times 100$$

The terms of the equation are determined as:

Term	Definition	Calculation
Q_{DEMAND}	Groundwater Consumptive Demand	Q_{DEMAND} is calculated as the estimated average annual and monthly rate of groundwater takings not returned to the source of taking within a reasonable timeframe
Q_{SUPPLY}	Groundwater Supply	Q_{SUPPLY} is the sum of the estimated annual recharge rate and the estimated groundwater inflow into a subwatershed. Monthly Q_{SUPPLY} equals the annual value divided by 12
$Q_{RESERVE}$	Groundwater Reserve	$Q_{RESERVE}$ is calculated as 10% of the total groundwater supply

Table 1.4: Groundwater Stress Thresholds

Stress Level 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 groundwater consumptive demand (Q_{DEMAND}) for each subwatershed was calculated using the actual municipal water takings, an estimate of private domestic water needs, an estimate of agricultural water requirements, and either reported actual Permit to Take Water (PTTW) takings or an estimate of the PTTW takings.

Results of the surface water model (Earthfx, 2009) based on the United States Geological Survey (USGS) Precipitation-Runoff Modeling System (PRMS) code (Leavesely, 1983) code and groundwater flow models (Earthfx, 2009) based on MODFLOW code were used for the groundwater supply (Q_{SUPPLY}) estimate (see sections 2 and 3). Specifically, recharge was estimated using the PRMS model and groundwater lateral inflows into each subwatershed were estimated using MODFLOW model.

Ten percent (10%) of the total groundwater supply was used as the groundwater reserve ($Q_{RESERVE}$).

1.4.2 Surface Water Quantity Stress Assessment

The same equation used for the groundwater calculation was used to estimate the surface water Percent Water Demand. The Percent Water Demand is estimated on a monthly basis since annual average flows for surface water have little significance. The terms of the surface water demand equation are as follows:

Term	Definition	Calculation
Q_{DEMAND}	Surface water Consumptive Demand	Q_{DEMAND} is calculated as the portion of estimated monthly rate of surface water takings in a subwatershed that is not returned to the surface water body that is the source of the water taking
Q_{SUPPLY}	Surface water Supply	Q_{SUPPLY} is calculated as the monthly median flow within a stream or into a lake or reservoir
$Q_{RESERVE}$	Surface water Reserve	$Q_{RESERVE}$ is calculated as the 10th percentile monthly flow within a stream or into a lake or reservoir

The surface water quantity stress was determined by calculating the maximum monthly percentage consumptive water demand for each subwatershed and comparing values to the thresholds defined in **Table 1.5** below:

Table 1.5: Surface Water Stress Thresholds

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

The Halton-Hamilton SPR obtained the PRMS model developed by Earthfx (2009) from the Region of Halton and the City of Hamilton. The model estimates Q_{SUPPLY} (surface water supply) and $Q_{RESERVE}$ (surface water reserve) for each subwatershed within the Halton-Hamilton SPR. Section 2.2 of this report provides details on the Earthfx PRMS model.

1.5 Assumptions/Constraints

The water budget analyses and the water quantity stress assessment are dependent on the available data, its quality and accuracy. Both water demand and water supply values are estimates and depend heavily on the available data. The best data for water demand is the reported actual water taking data. The remaining portion of the water demand is based on the following estimates:

- population and the amount of water used per day per capita;
- agricultural takings based on the spatial distribution of farms and proximity to surface water bodies; and
- other permitted water takings based on either the maximum permitted takings or a type of category of taking (see section 4 for details about water demand estimates).

The water supply depends on the input parameter data used to develop and calibrate the groundwater flow and surface water flow models: e.g., there is a limited number of weather stations collecting precipitation and temperature data, stations to monitor streamflow data or high quality water level monitoring stations. The water supply depends also on the software packages used for the simulations and the conceptual models developed for the study area.

2 WATER BUDGET

2.1 Water Budget Elements

An understanding of the hydrologic cycle and the various processes governing it is very important in developing a watershed based water budget. The hydrologic cycle describes how water moves through the environment. The quantitative estimate of water moving through the hydrologic cycle allows for understanding of the water budget components.

Within a defined boundary, a water budget consists of various inputs of water into the system, various outputs of water from the system and changes in storage. The water budget components can be represented as follows:

INPUTS = OUTPUTS ± CHANGE IN STORAGE

According to the above equation, water inputs into the watershed will be balanced by the outputs and the changes in storage within the watershed. It is reasonable to assume the changes in storage will be negligible over a long period of time. The results of the surface water model are annual average values of the modeling period and thus the water budget equation can be simplified to:

INPUTS = OUTPUTS

In hydrologic terms, the equation can be written as:

$$P = AET + R + RO$$

Where:
P – Total Precipitation, [millimeters (mm)];
AET – Actual Evapotranspiration, [mm];
R – Recharge, [mm]; and
RO – Total Runoff, [mm].

The total runoff in the above equation is a sum of the direct runoff (overland runoff) and an interflow (groundwater that does not recharge the water table).

2.2 Surface Water Model

2.2.1 Model Selection and Objectives

The results of the PRMS surface water model developed for Halton Region and the City of Hamilton were used by the Halton-Hamilton SPR for the Tier 1 water budget elements estimate and recharge distribution estimate for their groundwater flow models. The PRMS model has the ability to simulate the water budget components of the hydrologic cycle such as: precipitation, snowpack accumulation and melt, depression storage, interception and through-fall (the portion of precipitation which passes through the plant canopy), overland runoff, infiltration, actual evapotranspiration, subsurface storage, interflow, groundwater recharge and groundwater discharge to surface water bodies.

Earthfx who developed the model, has local experience and the necessary knowledge and skills to conceptualize and develop a reliable surface water model.

The main purpose of the development of the PRMS model by Earthfx was to identify and understand the groundwater recharge distribution for the Halton Region groundwater flow model and the City of Hamilton groundwater flow model.

The developed PRMS model encompasses more than the Halton-Hamilton SPR. The model coverage allows for a smooth transition between the two SPAs and as a result creates a more reliable input parameter into the two separate groundwater flow models, ensuring more consistent results.

PRMS is a modular, physically based, distributed-parameter modeling system allowing for evaluation of impacts of precipitation, climate, topography, vegetative cover, land use and various other parameters on streamflow and general basin hydrology. Hydrologic response to precipitation events and snowmelt can be simulated to evaluate changes in water balance relationships, flow regimes, soil-water relationships and groundwater recharge. The model can be calibrated to historical streamflow measurements at known locations to assure the model results closely approximate the actual hydrologic processes.

The conceptual PRMS model of a watershed is a series of interconnected storage reservoirs including interception storage in the vegetation canopy, depression storage, snowpack, shallow soil moisture zone, subsurface water and groundwater. Flows going into or out of reservoirs represent various hydrologic processes (US Geological Survey, 2006).

The PRMS model development, input data description and model calibration is summarized in the Vulnerability Analysis for the Milton and Campbellville Wellfields report completed in 2010 for Halton Region and in the Vulnerability Assessment and Scoring of Wellhead Protection Areas report completed in 2010 for the City of Hamilton. Copies of these reports are included in **Appendix A** and **Appendix B**, respectively.

The PRMS model was developed in conjunction with the MODLFOW groundwater models. An iterative process was used in the development of the surface and groundwater flow models, which included comparison and corrections to recharge estimations and model properties. To simulate a coupled surface water and groundwater flow model, the final PRMS run recharge was used as an input to the groundwater flow models and it was not changed in the calibration of them.

The PRMS hydrologic model schematic is presented in **Figure 29** of **Appendix A** report.

2.2.2 Model Setup

The distribution of the input parameters and watershed partitioning features of the PRMS are designed to account for spatial variation in watershed characteristics. The applied PRMS code provides water budget summaries for Hydrologic Response Units (HRU). HRUs are defined as drainage areas with similar hydrologic properties. Heterogeneity within an individual HRU is accounted for by aerially weighted averages for each parameter. The USGS PRMS code was modified by Earthfx to allow each HRU to represent a single 100 m by 100 m model grid cell. This allowed for relatively easy linkage of the results of the PRMS model (recharge) to the groundwater flow models, which are also cell based. Some additional changes to the PRMS code include:

- addition of an inverse distance square interpolation method for precipitation data for each model cell;
- addition of Hargreaves method for PET estimation using solar radiation and temperature, and
- addition of re-directing a percentage of runoff from impervious surfaces back to pervious areas within HRUs.

2.2.3 Model Input Parameters

The PRMS model was run in "daily" mode, which means that daily precipitation and temperature data were required as input parameters. The modelling period of October 1, 1989 to September 30, 1997 was chosen because it included a range of years with continuous precipitation data, which represents the typical range of precipitation received in the Halton-Hamilton SPR. This 8-year period was an existing dataset which was assembled for the City of Toronto's Wet Weather Flow Management Master Plan (WWFMMP) (Aquafor Beech Ltd, 2003). The WWFMMP was a multi agency study, involving 6 separate consultants, as well as a steering committee. The 8-year precipitation data set underwent a rigorous review and analysis as part of the WWFMMP. Through this analysis, this dataset was deemed sufficient to provide a meaningful estimate of average annual recharge, as it covered a range of consecutive dry, wet and average years. Calibration over a longer period (i.e., 30 year climate normal) would have required significantly more modelling effort, but not increased the confidence in the results.

Nine (9) Environment Canada climate stations with continuously recorded precipitation data and seven (7) stations with daily maximum and minimum temperature data were used. **Table 2.1** identifies which Environment Canada stations were used to estimate precipitation and temperature distribution across the model domain. Two stations within our source protection region were last used in 1997 and 1999.

To provide a continuous coverage the precipitation and temperature data was interpolated over the model domain using an inverse-distance squared method at the beginning of each time step of the model.

Table 2.1: Precipitation and Temperature Stations Used in the PRMS Simulation

Station ID	Gauge Name	Easting	Northing	Data Type	Start Year	End Year
6152695	Georgetown WWTP	590078	4831755	P/T	1962	2005
615N745	Oakville Southeast WPCP	610518	4815398	P/T	1970	2001
6155183	Millgrove	583792	4796499	P/T	1951	2005
6153300	Hamilton RBG	590599	4792885	P/T	1950	1997
6151064	Burlington TS	594578	4798493	P/T	1951	1999
6157431	Sandhill	595165	4852191	P	1981	-
6142400	Fergus Shand Dam	553688	4842471	P/T	1939	-
6149387	Waterloo Wellington A	549895	4810973	P/T	1970	2002
6141100	Cambridge-Stewart	556731	4799921	P	1973	2000

Note: P – Precipitation data available
T – Temperature data available

Only the Toronto Pearson Airport station (6158350) has measured global solar radiation data in the area. This data was obtained and used as input.

To represent the spatial distribution of the physical and physiographic characteristics of the area, the model used the following data sources:

- Parcel-based land use;
- SOLRIS land cover;
- Surficial geology;
- Surficial drainage, and
- Topographic data.

Land use properties were assigned to land use classes derived from SOLRIS land-use data compiled from LANDSAT data (**Table 12** in **Appendix A**). Soil properties as summarized in **Table 13** of **Appendix A** were assigned to each surficial geology class (obtained from Ontario Geological Survey (OGS) map data (**Figure 14**, **Appendix A**)).

The spatially distributed information was utilized to obtain distributed hydrologic responses across the model domain.

Deposits in areas of hummocky topography (e.g. the Paris and Galt Moraines) were assumed to have less runoff and, therefore, higher recharge rates than similar deposits in non-hummocky areas because of focused recharge in places where runoff collects. This was simulated by assigning lower runoff coefficients to these areas.

Discharges from waste water treatment plants and reservoirs were not simulated at this level of the assessment. It was assumed that any changes to the stream flows caused by these features were measured at the downstream gauge stations used for model calibration and therefore simulated in the model.

For further PRMS model input parameters and model set-up discussions please see **Appendix A** section 2.7.1 and **Appendix B** section 4.5.1.

2.2.4 Model Validation

The PRMS model encompasses a larger region than the Halton-Hamilton SPR study area to capture a larger number of stream gauge calibration points, and a broader range of soil types and land use conditions. Catchments from across Halton Region and the northern portion of the City of Hamilton were included in the PRMS calibration. The PRMS model was calibrated to total flow and baseflow measurements at the gauges.

Table 16 in **Appendix A** is a summary of the PRMS model calibration details. It includes a comparison between the simulated and measured total flows and baseflows at nine (9) locations across the Halton-Hamilton SPR and 14 locations outside of the SPR. **Figure 27** in **Appendix A** shows the location of the HYDAT stations used for calibration. It should be noted, however, that the accuracy of the measurements of total flow can be somewhat variable; particularly at low and very high flow rates. It is also important to note the limitations of baseflow separation techniques, and that the baseflow separation calibration “targets” should not be considered as a direct measurement of groundwater discharge. The flow values were averaged for the simulation period and not the entire period of record. **Figure 30** in **Appendix A** is a scatterplot of the observed total flow values versus the PRMS simulated flows. Ideally, all points should fall on the 45° line. The plot demonstrates that the model was able to simulate the observed flows at the low range quite well. On a regional basis, the results in **Table 16** in **Appendix A** demonstrate that 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. Despite these errors, the results suggest that, on a regional scale, the calibration is quite reasonable.

The following **Figures 2.1** through **2.6** show a comparison between the simulated average monthly median flows and measured average monthly median flows at three HYDAT stations in Halton Region SPA and three HYDAT stations in Hamilton Region SPA. These figures show that there is a reasonable match between the simulated and measured flows, especially during the summer months when streamflows are low and therefore, are more vulnerable to become stressed. **Figures 2.2** and **2.4** show a sum of median flows from two stations as there are two stations in these subwatersheds on two different tributaries.

The locations of the HYDAT stations used for the comparison are shown in **Figures 2.7** and **2.8** in the Halton Region SPA and the Hamilton Region SPA, respectively.

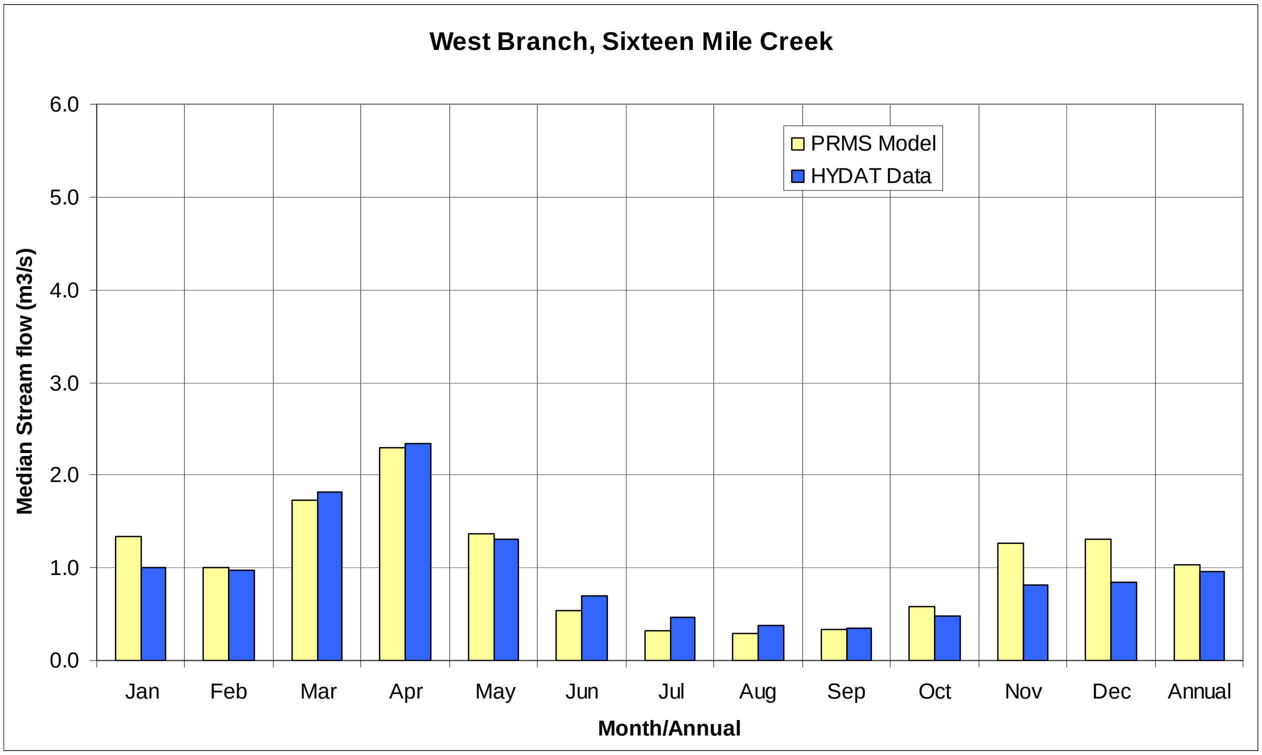

Figure 2.1 HYDAT Station 02HB004 Simulated vs. Measured Flows

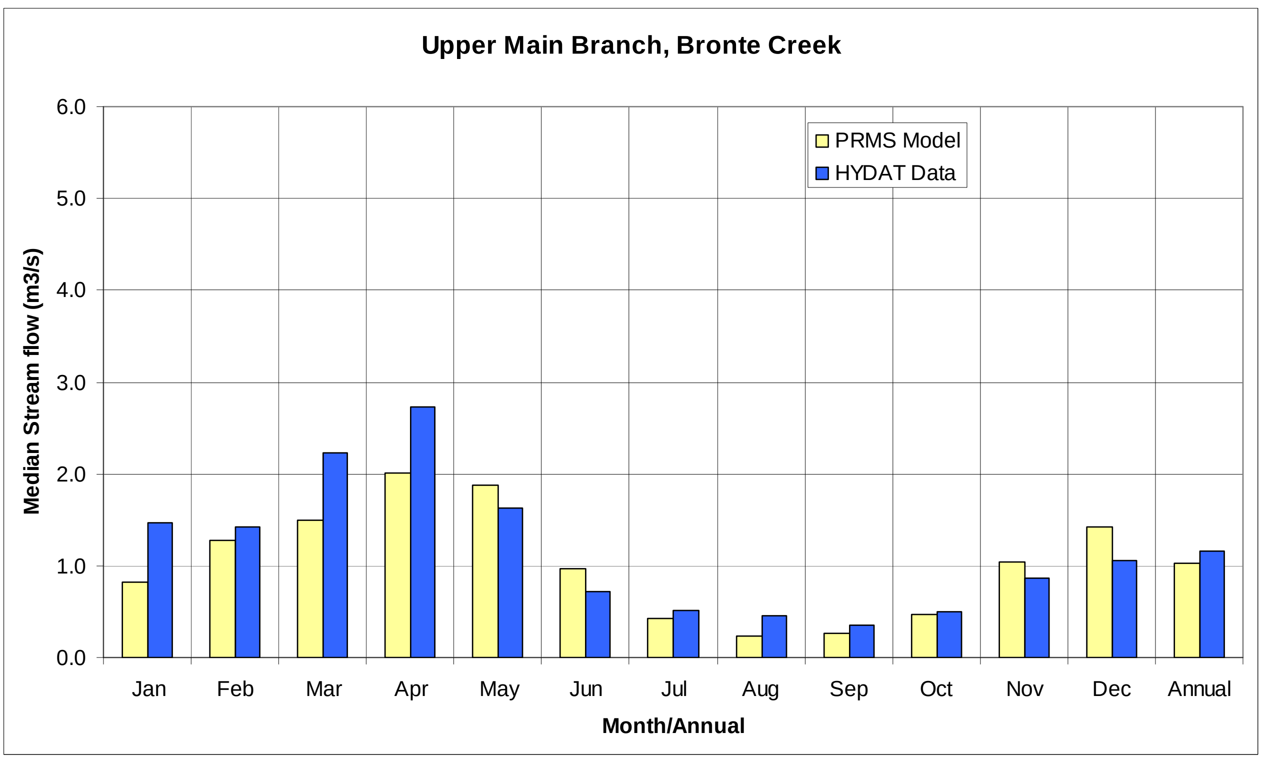

Figure 2.2 HYDAT Stations 02HB016 + 02HB022 Simulated vs. Measured Flows

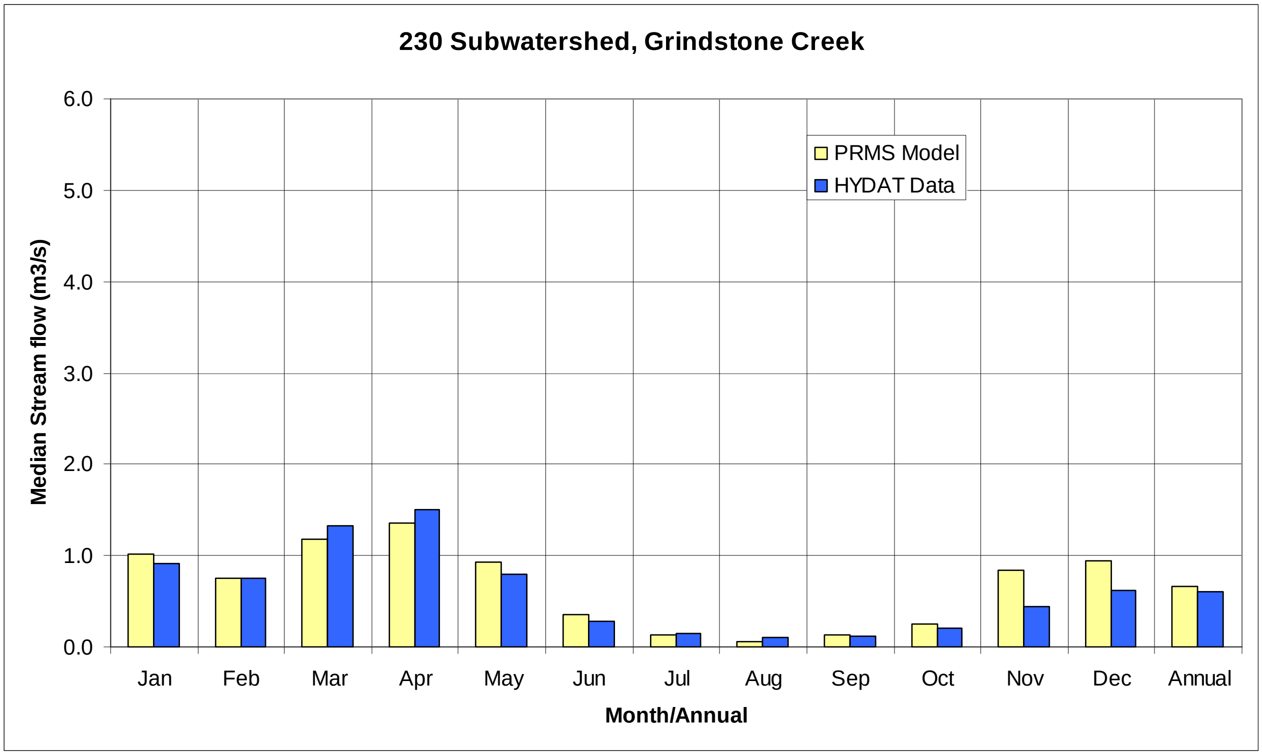

Figure 2.3 HYDAT Station 02HB012 Simulated vs. Measured Flow

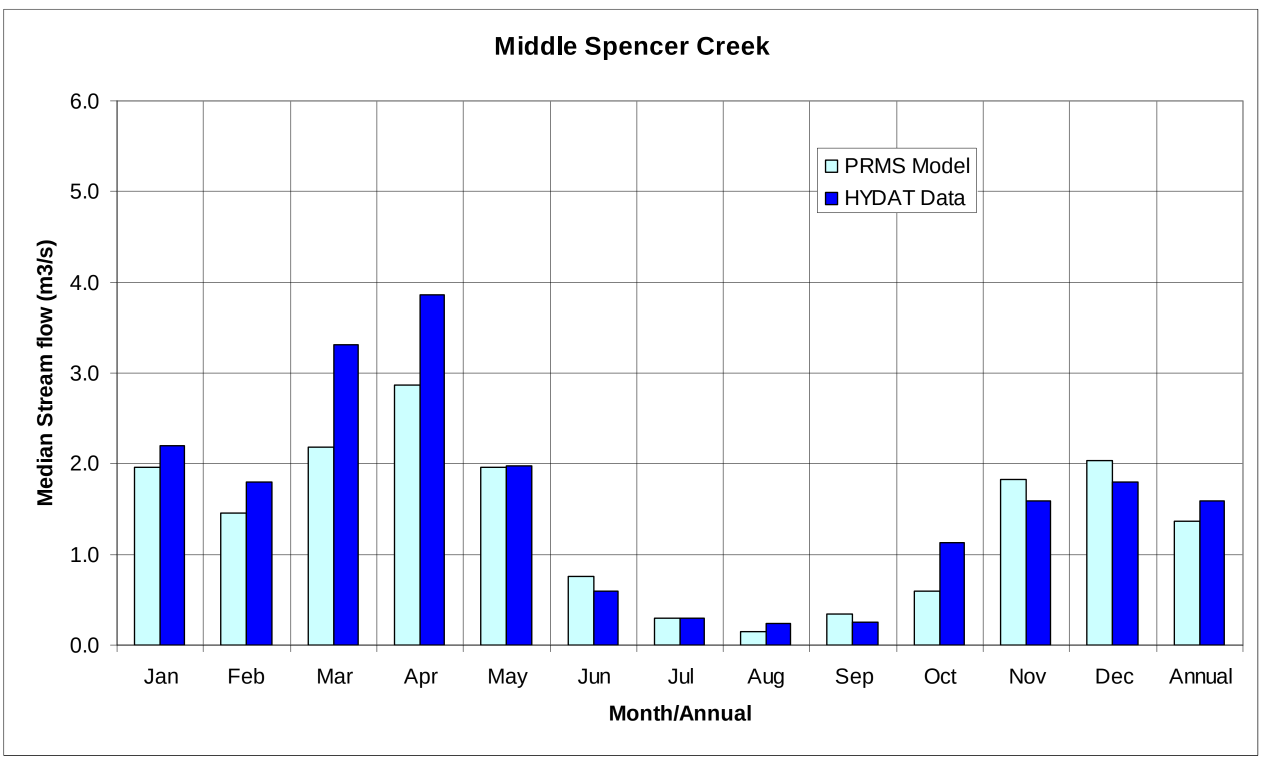

Figure 2.4 HYDAT Station 02HB007 + 02HB010 Simulated vs. Measured Flows

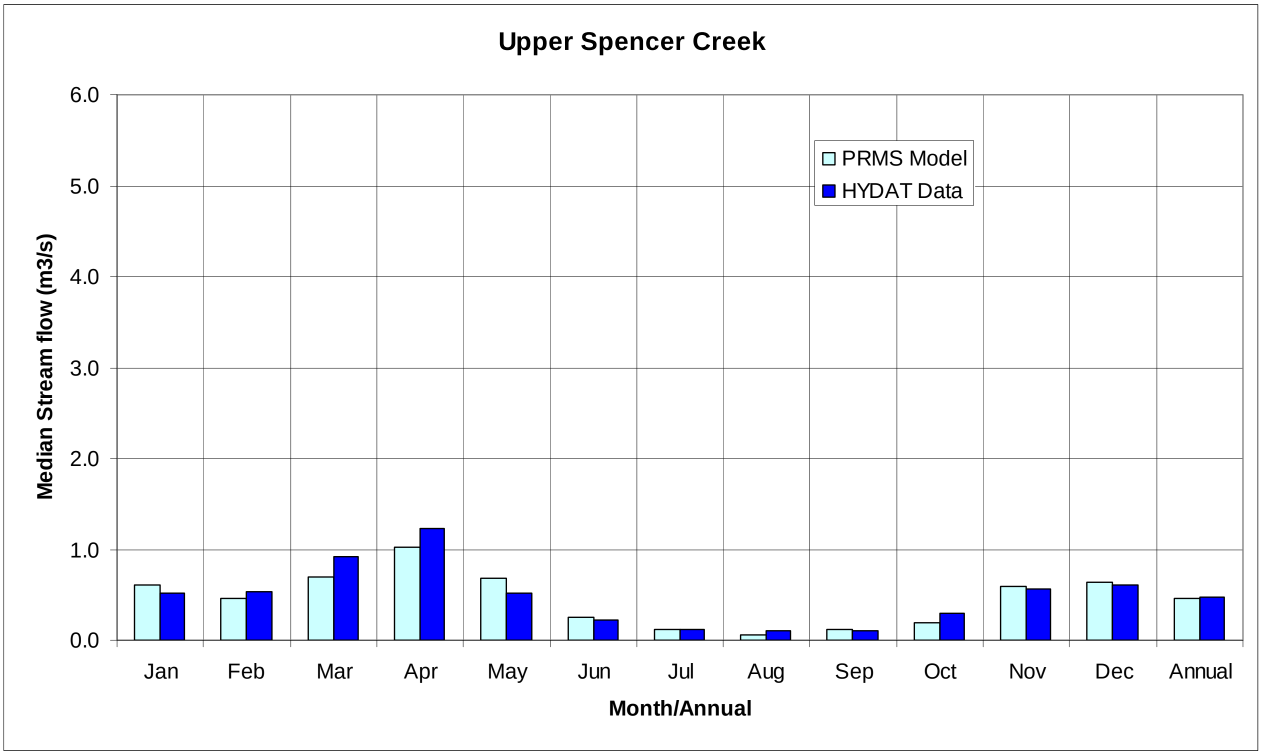

Figure 2.5 HYDAT Station 02HB015 Simulated vs. Measured Flows

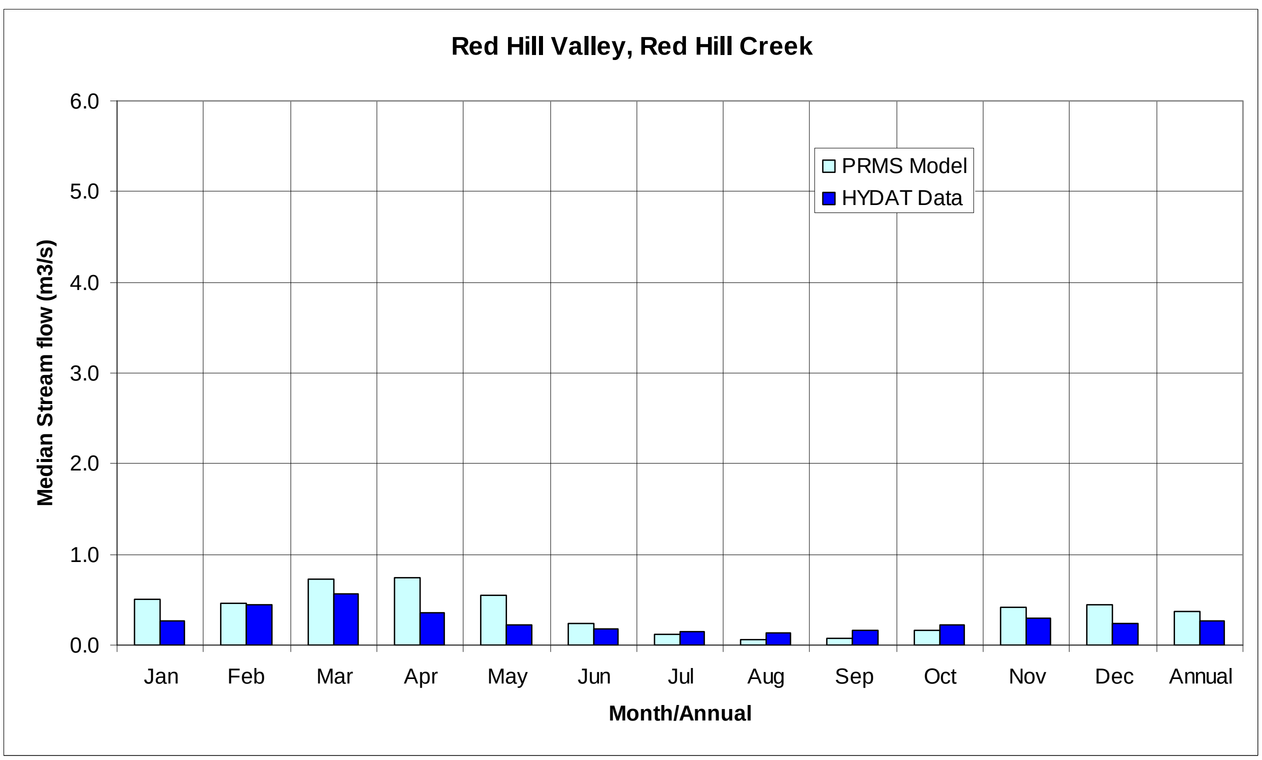

Figure 2.6 HYDAT Station 02HA014 Simulated vs. Measured Flow

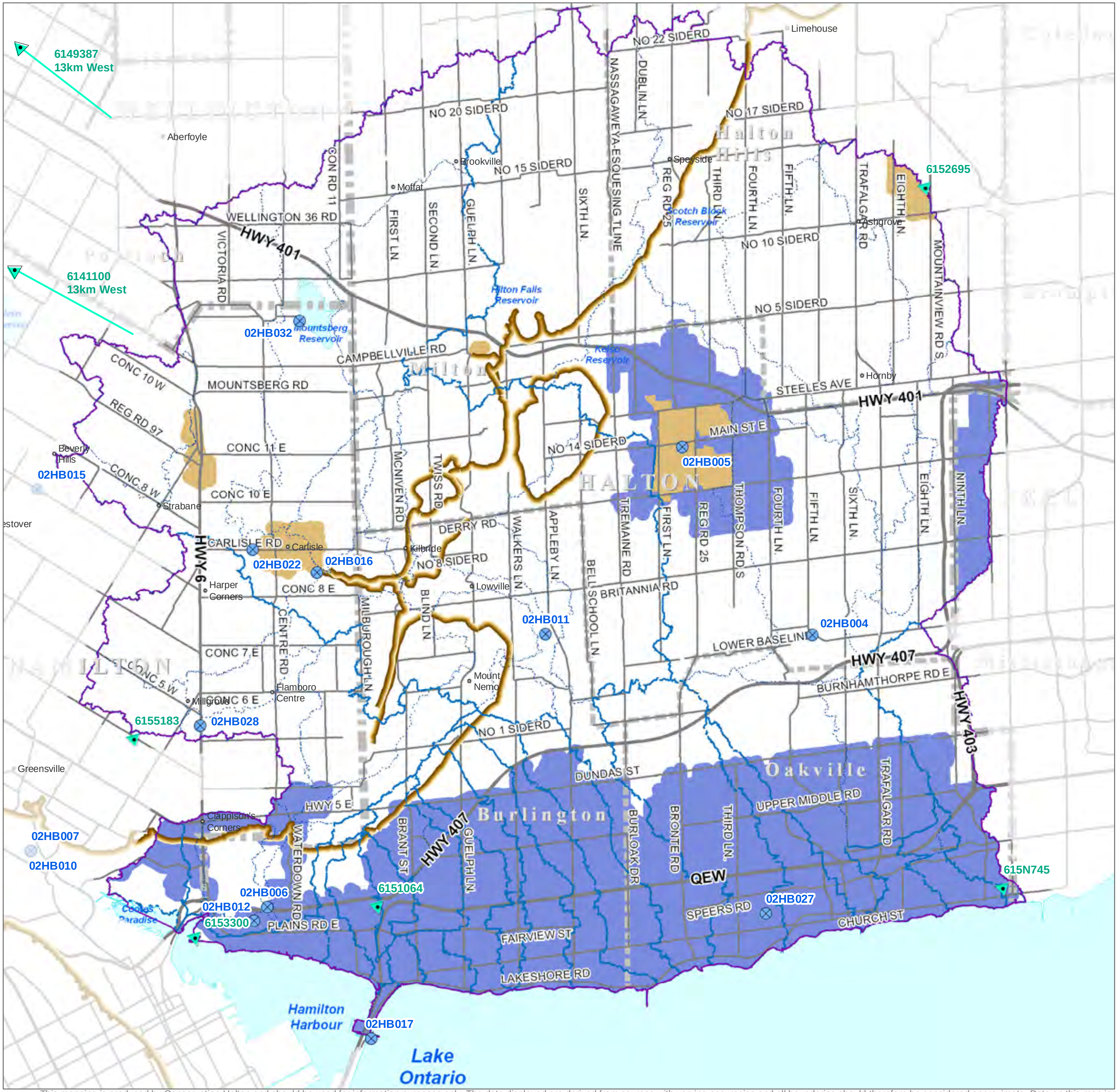

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Figure 2.7

Streamflow & Climate Stations & Water Servicing

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment

Roads
- Highway
- Regional
- Waterbody
- Climate Station (CDCD)
- Streamflow / Water Level Gauge (HYDAT)

Water Sservicing
- Private Groundwater
- Municipal Groundwater
- Municipal Surface Water

Source : (HYDAT) Water Survey of Canada / Environment Canada (2007). (CDCD) Canadian Daily Climate Database, Environment Canada (2008) Servicing based on a 250 metre buffer of Municipal Water Mains.

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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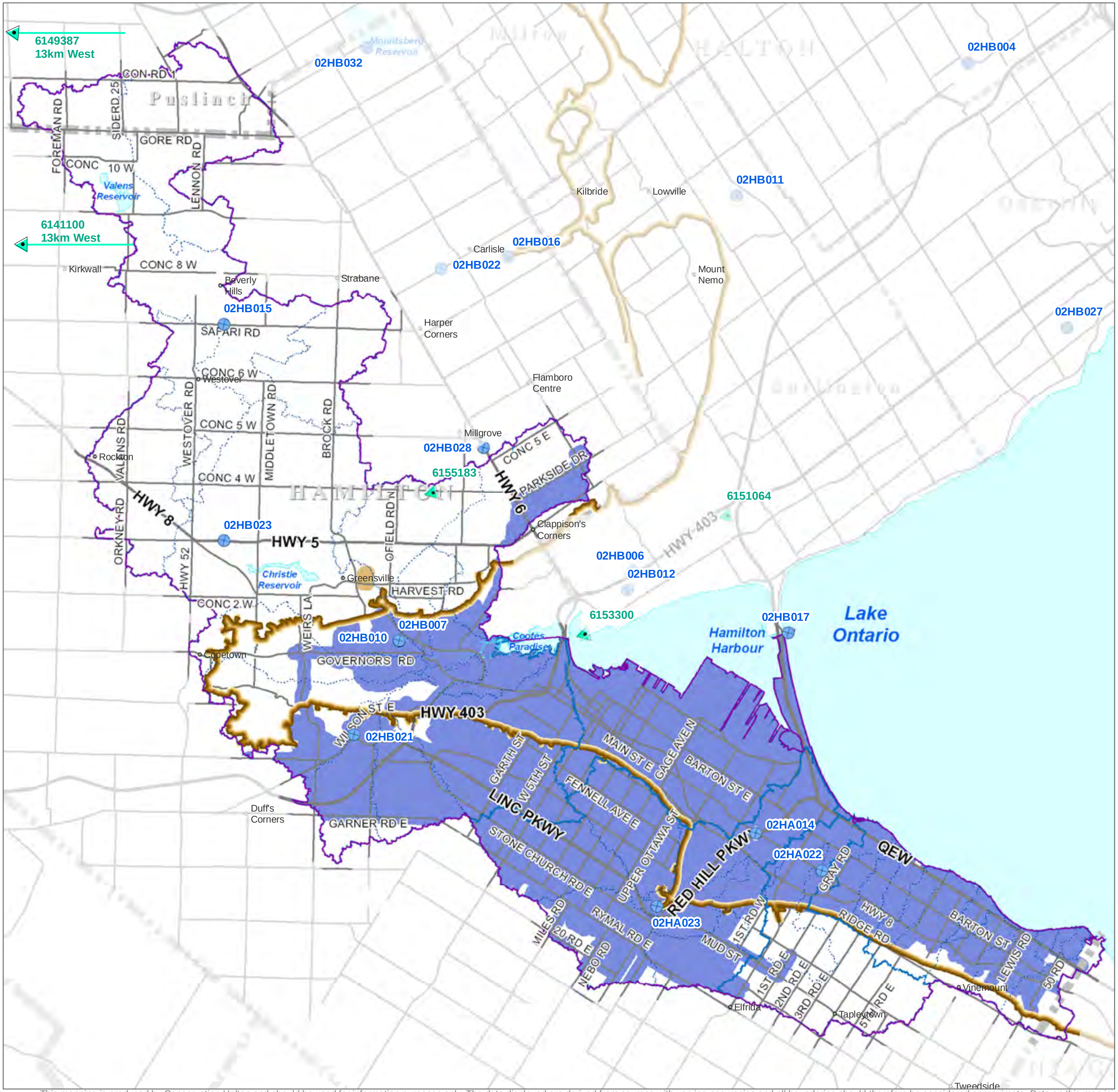
Figure 2.8

Streamflow & Climate Stations & Water Servicing



Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment

Roads

- Highway
- Regional
- Waterbody
- Climate Station (CDCD)
- Streamflow / Water Level Gauge (HYDAT)

Water Servicing

- Private Groundwater
- Municipal Groundwater
- Municipal Surface Water

Source : (HYDAT) Water Survey of Canada / Environment Canada (2007). (CDCD) Canadian Daily Climate Database, Environment Canada (2008) Servicing based on a 250 metre buffer of Municipal Water Mains.

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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2.2.5 Results

The PRMS simulated values of the water budget components on a daily basis. This data was averaged on an annual basis over the 8-year simulation period (from 1989 to 1997) to determine annual average rates for the study period.

Figures 2.9 through **2.12** present spatially distributed water budget components across the Halton Region SPA and **Figures 2.13** through **2.16** show the water budget components in the Hamilton Region SPA. These results are based on a final PRMS run.

Figures 2.9 and **2.13** present the annual average precipitation in millimeters per year (mm/year) as interpolated from daily precipitation data. The high precipitation rates observed at the Millgrove gauge during the simulation period appear to be consistent with the long-term record at the gauge as summarized in **Table 9** of **Appendix A**. The average precipitation values for the modeled period in the Halton Region SPA above and below the Niagara Escarpment (Escarpment) are 970 mm and 914 mm respectively. The average precipitation in the Hamilton Region SPA above and below the Escarpment is about 989 mm and 917 mm, respectively.

Figures 2-10 and **2-14** present the annual average of simulated actual evapotranspiration values which include interception and depression storage losses. Values vary over the study area due to local variations in interpolated daily temperature, slope aspect, soil properties, imperviousness and vegetative cover. The distribution of actual evapotranspiration appears to be mostly depicted by surficial geology and land use. Actual evapotranspiration is lower in the urban areas likely due to the fact that they are well drained and there is less water available for evaporation. On average the actual evapotranspiration within the Halton Region SPA is about 60 percent of the total precipitation. The average actual evapotranspiration within the Hamilton Region SPA is about 57 percent of the total precipitation.

Figures 2.11 and **2.15** show simulated annual average runoff from both pervious and impervious surfaces. Variations are due to differences in effective precipitation (i.e. precipitation after interception losses) and local variations in imperviousness and soil type. Runoff is mostly dominated by the land use of the area and is usually the highest in heavily urbanized areas. On average the total runoff within the Halton Region SPA and the Hamilton Region SPA is about 19 percent and 22 percent of the total precipitation, respectively.

Finally, **Figures 2.12** and **2.16** present simulated rates of annual average net recharge to groundwater (averaged over the 8-year simulation period). These rates were applied to the Halton Region and City of Hamilton groundwater flow models. In general the recharge values are higher above the escarpment, where either thin layer of till deposits or coarse granular deposits exist at the surface overlying fractured bedrock or the fractured bedrock is exposed at the surface. Consequently, on average the recharge values are lower below the escarpment, where vast areas are characterized by fine grained surficial deposits. The average recharge value within the Halton Region SPA is about 21 percent of the total precipitation. The average value within the Hamilton Region SPA is 21 percent of the total precipitation.

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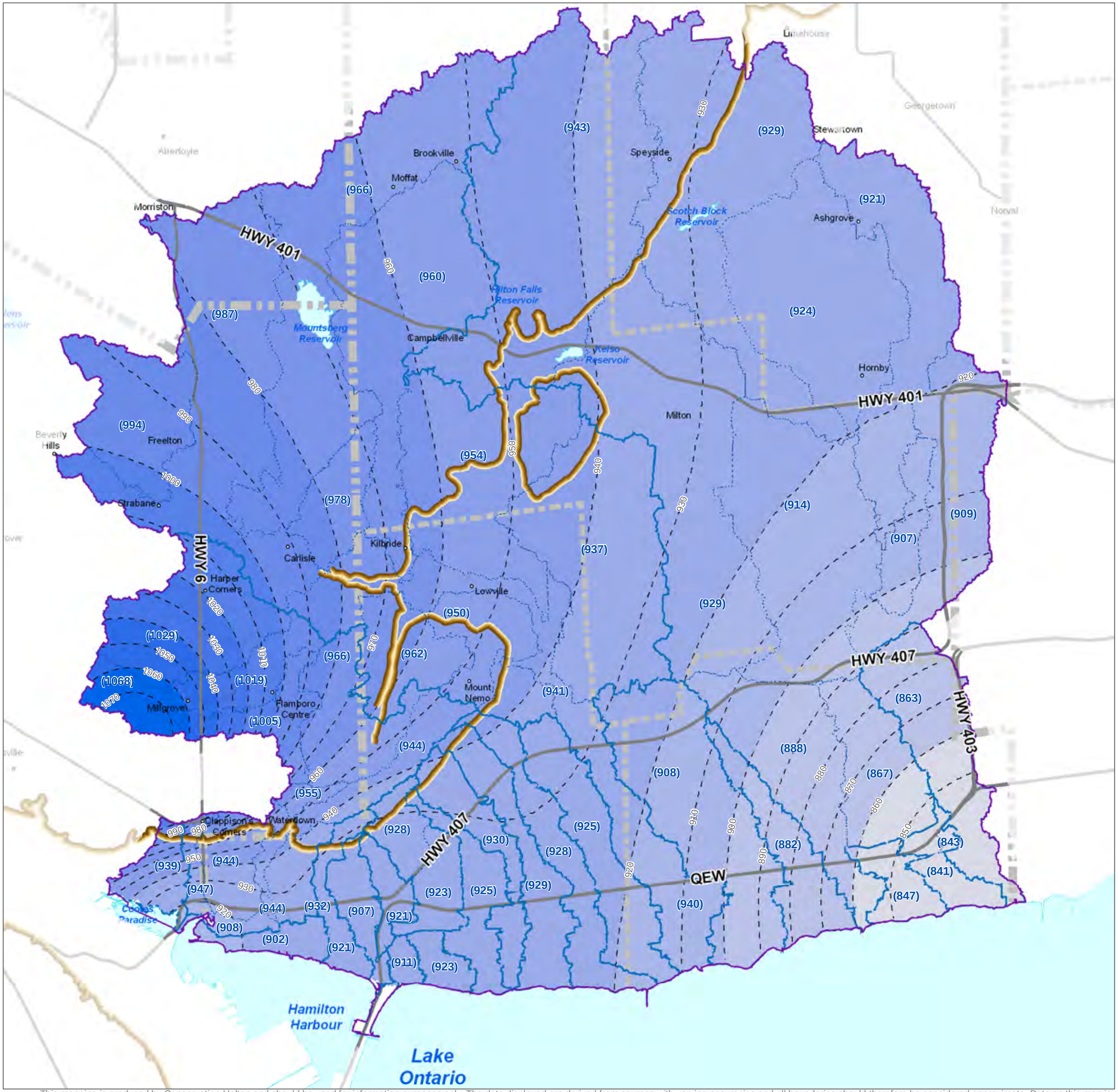
Figure 2.9

Precipitation



Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual Precipitation (mm)

- Contours (10 mm interval)
- < 840
- 840 - 860
- 860 - 860
- 860 - 900
- 900 - 920
- 920 - 940
- 940 - 960
- 960 - 980
- 980 - 1000
- 1000 - 1020
- 1020 - 1040
- 1040 - 1060
- 1060 - 1080

Note : Label is Average Annual Precipitation (mm) for the entire Subwatershed.

Source : Halton Region / City of Hamilton / Earthfx PRMS Model (2010).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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Figure 2.10

Actual Evapotranspiration

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual AET (mm)

- < 320
- 320 - 360
- 360 - 400
- 400 - 440
- 440 - 480
- 480 - 520
- 520 - 560
- 560 - 600
- 600 - 640
- 640 - 680
- 680 - 720

Note : Label is Average Annual AET (mm) for the entire Subwatershed.

Source : Halton Region / City of Hamilton / Earthfx PRMS Model (2010).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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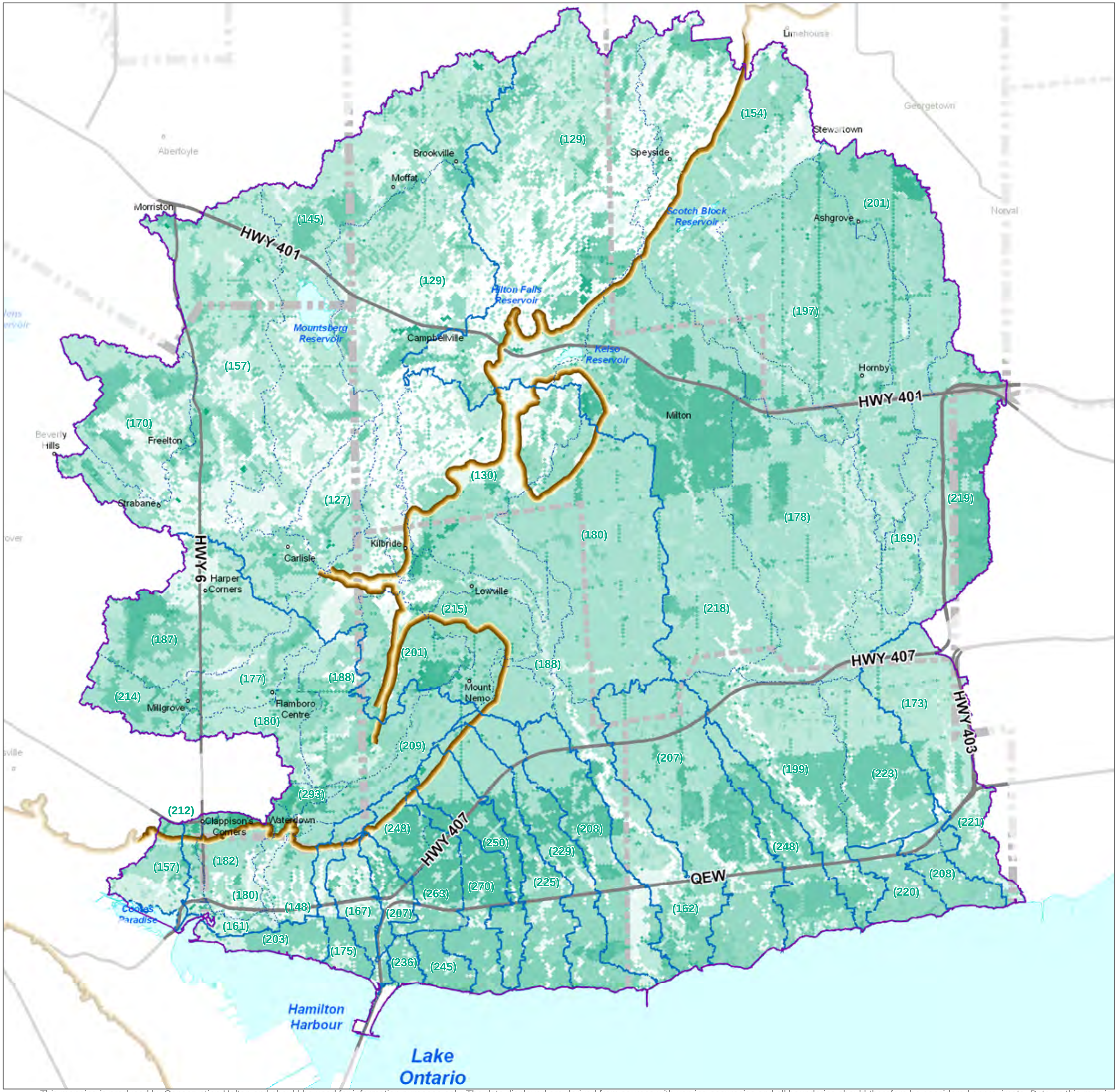

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Figure 2.11

Runoff

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual Runoff (mm)

- < 40
- 40 - 80
- 80 - 120
- 120 - 160
- 160 - 200
- 200 - 240
- 240 - 280
- 280 - 320
- 320 - 360
- 360 - 400
- 400 - 440
- 440 - 480

Note : Label is Average Annual Runoff (mm) for the entire Subwatershed.

Source : Halton Region / City of Hamilton / Earthfx PRMS Model (2010).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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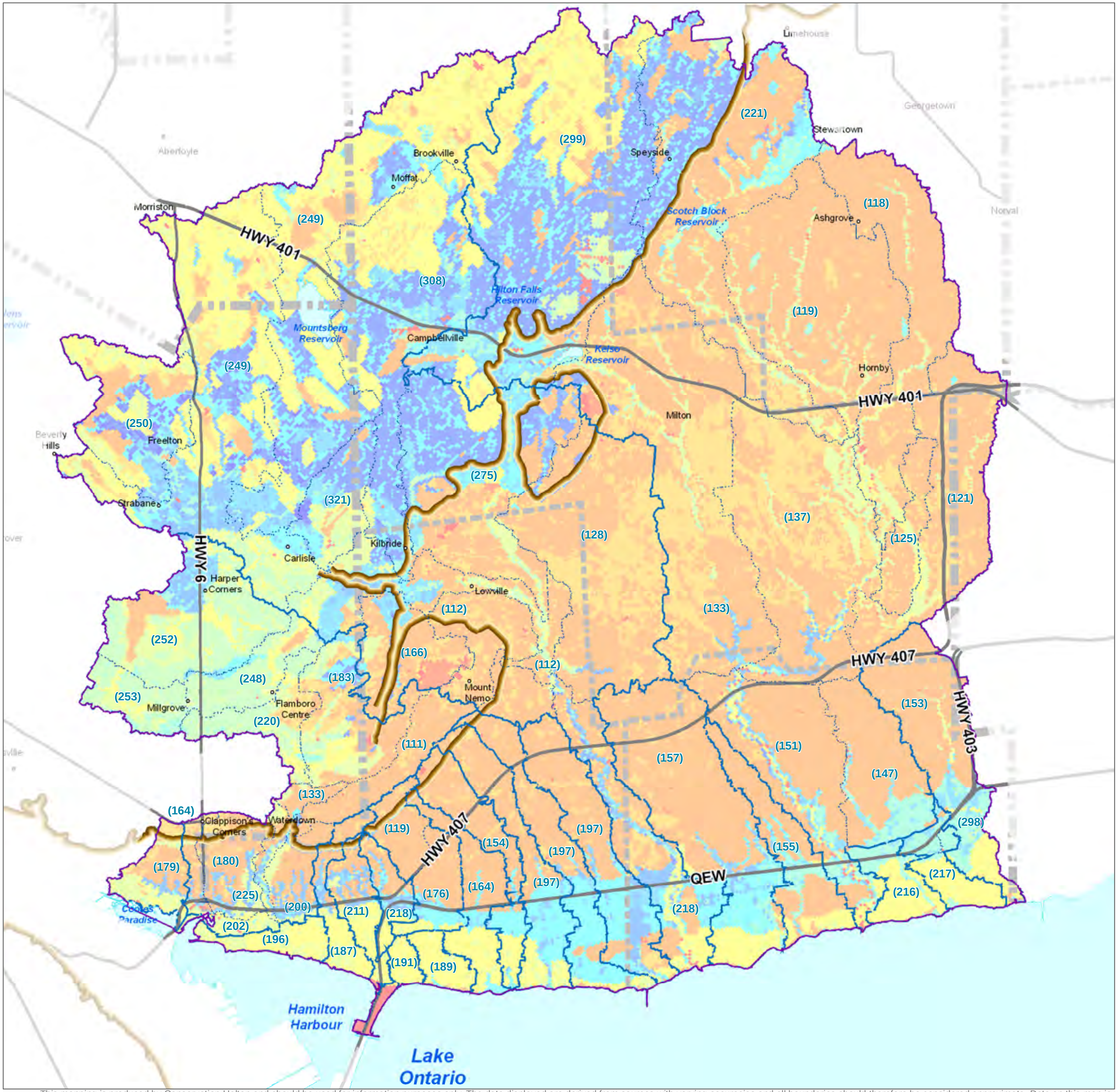
Figure 2.12

Recharge



Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual Recharge (mm)

- < 40
- 40 - 80
- 80 - 120
- 120 - 160
- 160 - 200
- 200 - 240
- 240 - 280
- 280 - 320
- 320 - 360
- 360 - 400
- 400 - 440
- 440 - 480
- 480 - 520

Note : Label is Average Annual Recharge (mm) for the entire Subwatershed.

Source : Halton Region / City of Hamilton / Earthfx PRMS Model (2010).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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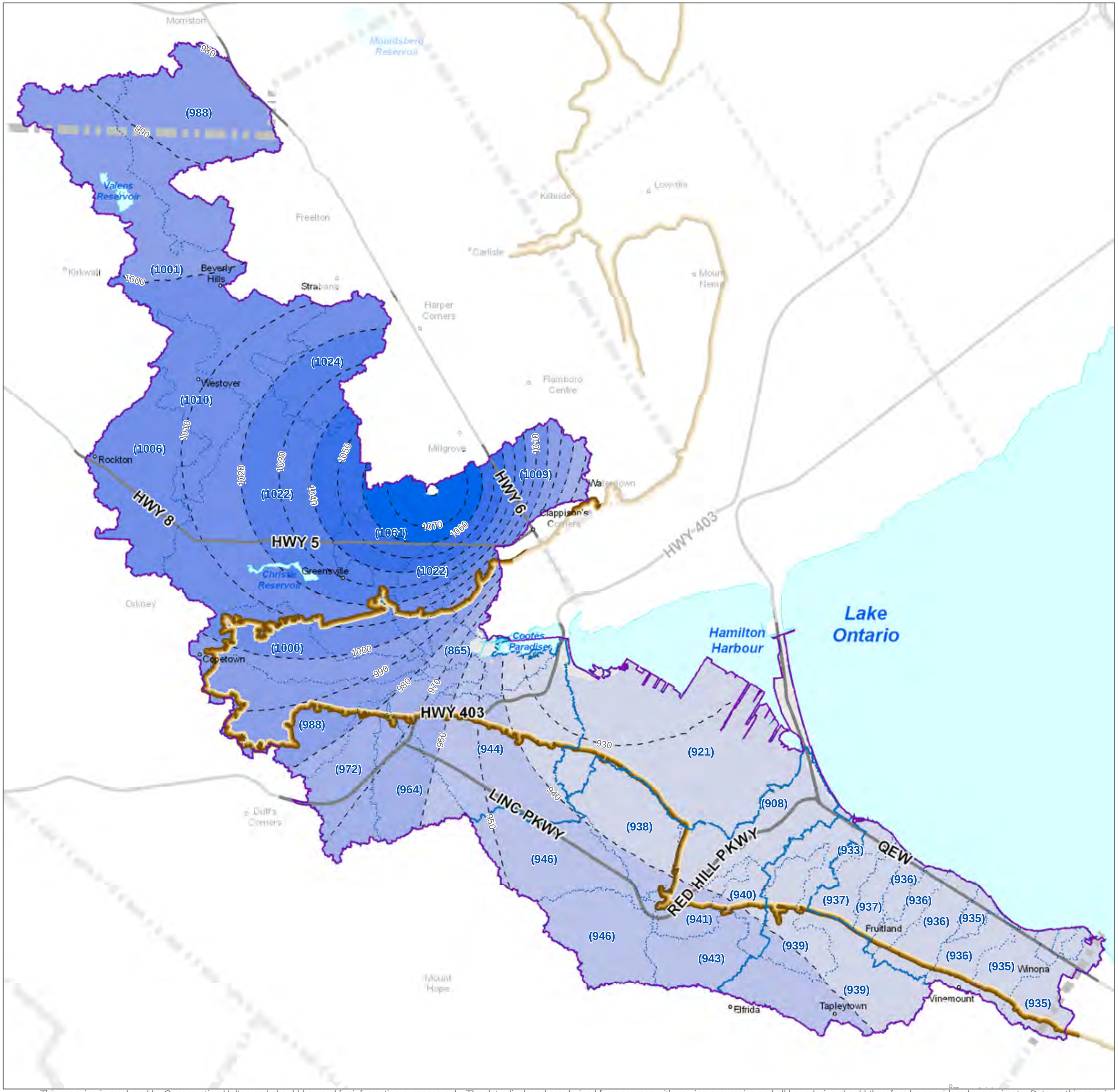
Figure 2.13

Precipitation



Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual Precipitation (mm)

- Contours (10 mm interval)
- < 920
- 920 - 940
- 940 - 960
- 960 - 980
- 980 - 1000
- 1000 - 1020
- 1020 - 1040
- 1040 - 1060
- 1060 - 1080

Note : Label is Average Annual Precipitation (mm) for the entire Subwatershed.

Source : Halton Region / City of Hamilton / Earthfx PRMS Model (2010).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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Ontario

Figure 2.14

Actual Evapotranspiration

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual AET (mm)

- < 360
- 360 - 400
- 400 - 440
- 440 - 480
- 480 - 520
- 520 - 560
- 560 - 600
- 600 - 640
- 640 - 680
- 680 - 720

Note : Label is Average Annual AET (mm) for the entire Subwatershed.

Source : Halton Region / City of Hamilton / Earthfx PRMS Model (2010).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

DRINKING WATER SOURCE PROTECTION
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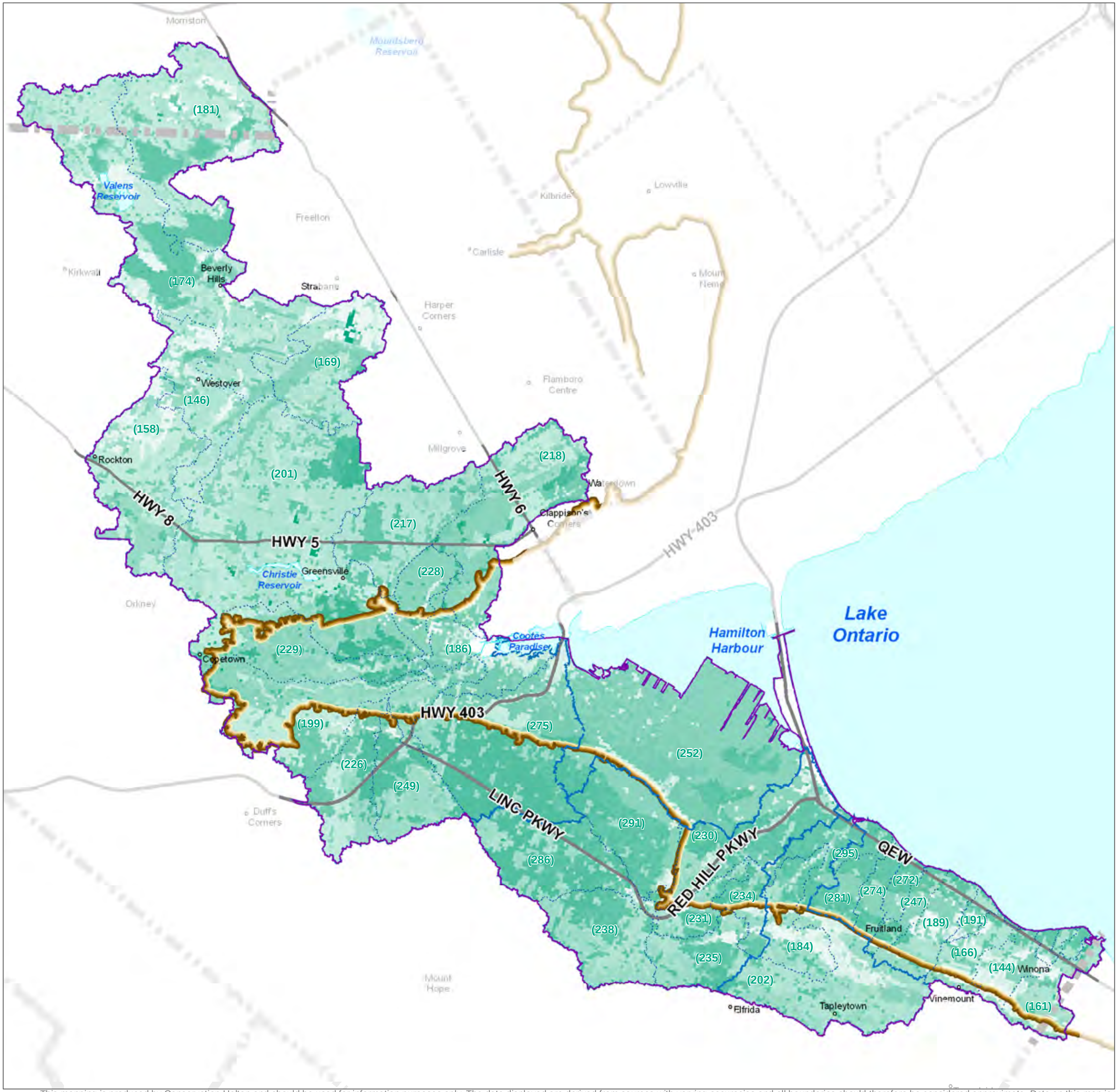
Figure 2.15

Runoff



Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual Runoff (mm)

- < 20
- 20 - 60
- 60 - 100
- 100 - 140
- 140 - 180
- 180 - 220
- 220 - 260
- 260 - 300
- 300 - 340
- 340 - 380
- 380 - 420
- 420 - 460
- 460 - 500

Note : Label is Average Annual Runoff (mm) for the entire Subwatershed.

Source : Halton Region / City of Hamilton / Earthfx PRMS Model (2010).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

N W E S

0 1 2 4 6

Kilometers

1:200,000

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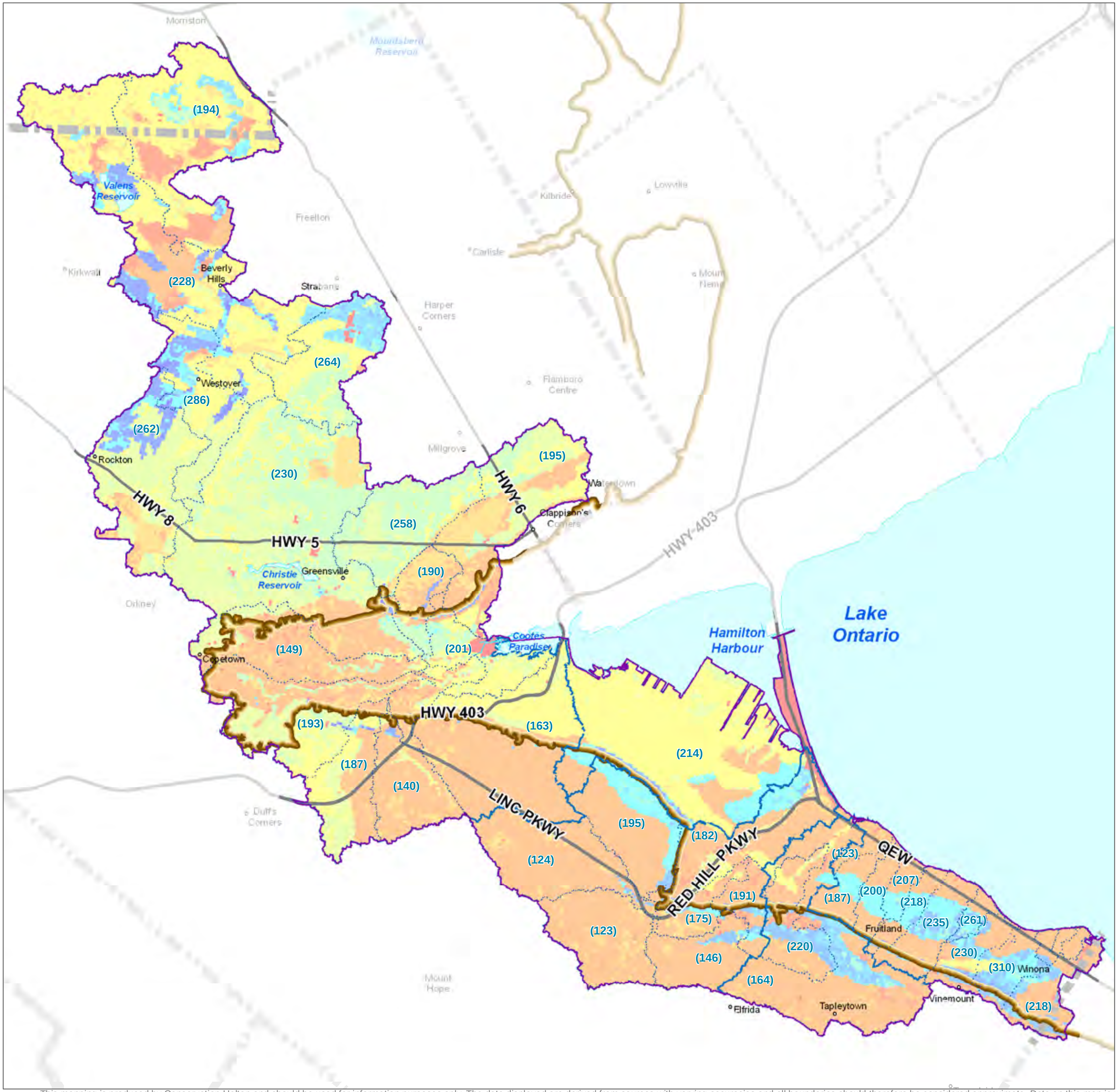
Figure 2.16

Recharge



Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual Recharge (mm)

- < 50
- 50 - 100
- 100 - 140
- 140 - 180
- 180 - 220
- 220 - 260
- 260 - 300
- 300 - 340
- 340 - 380
- 380 - 420
- 420 - 460
- 460 - 500
- 500 - 540

Note : Label is Average Annual Recharge (mm) for the entire Subwatershed.

Source : Halton Region / City of Hamilton / Earthfx PRMS Model (2010).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

N W E S

0 1 2 4 6
Kilometers
1:200,000

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The following **Tables 2.2** and **2.3** are summaries of the average annual water budget components based on the PRMS simulation for the Halton Region SPA and the Hamilton Region SPA subwatersheds, respectively. The summarized water budget components are:

P - Precipitation, (mm);

AET - Actual Evapotranspiration, (mm);

R - Recharge, (mm); and

RO - Surface Runoff, (mm).

Table 2.2: Halton Region SPA Annual Water Budget Components

Watershed	Subwatershed	Area [km^2]	P [mm]	AET [mm]	R [mm]	RO [mm]
Sixteen Mile Creek	East Branch	29.64	921	612	118	201
	East Branch Lisgar	25.88	909	576	121	219
	Lower Middle Branch	42.32	914	606	137	178
	Lower Middle Tributary	7.18	907	622	125	169
	Main Branch	24.67	888	544	151	199
	Middle East Branch	41.65	924	619	119	197
	Middle Branch	54.96	929	560	221	154
	Morrison-Wedgewood Diversion	16.05	867	502	147	223
	Upper West Branch	72.87	943	519	299	129
	West Branch	57.21	929	584	133	218
		372.42	**922**	**570**	**177**	**181**
Bronte Creek	Flamboro Creek	9.42	978	532	321	127
	Indian Creek	40.81	937	637	128	180
	Kilbride Creek	41.23	960	526	308	129
	Limestone Creek	36.60	954	552	275	130
	Lower Main Branch	35.33	940	563	218	162
	Lowville Creek	10.07	950	629	112	215
	Mount Nemo Creek	4.51	941	648	112	188
	Mountsberg Creek	55.08	966	577	249	145
	Strabane Creek	18.43	994	577	250	170
	Upper Main Branch	52.72	987	585	249	157
	Willoughby Creek	12.20	962	599	166	201
		316.39	**962**	**577**	**233**	**155**
Grindstone	201	22.73	1029	593	252	187
	204	6.66	1068	603	253	214
	210	8.02	1019	597	248	177
	214	8.07	1005	610	220	180
	215	14.64	966	600	183	188
	218	1.68	955	533	133	293
	220	8.19	944	630	111	209
	222	2.52	944	543	225	180
	224	5.68	932	589	200	148
	228	8.07	944	588	180	182
	230	1.65	908	550	202	161
	232 (Alternate)	2.45	947	576	164	212
		90.37	**989**	**596**	**209**	**189**

Table 2.2: Halton Region SPA Annual Water Budget Components

Watershed	Subwatershed	Area [km²]	P [mm]	AET [mm]	R [mm]	RO [mm]
North Shore Group 1	407 Diversion	5.23	928	566	119	248
	Cootes Paradise (Halton) *	0.71	81	51	11	19
	Falcon Creek	5.42	921	564	187	175
	Indian Creek	6.07	907	533	211	167
	North Cootes Paradise (232)	6.27	939	608	179	157
	Upper Hager Creek	4.23	921	500	218	207
	Upper Rambo Creek	6.29	923	487	176	263
	West Aldershot (East)	4.36	902	508	196	203
	West Aldershot (West)	0.18	798	500	180	124
		38.76	**920**	**541**	**183**	**201**
North Shore Group 2	Appleby Creek	14.08	928	505	197	229
	Beach Strip East Side *	0.70	78	40	16	22
	Beach Strip West Side *	0.26	0	0	0	0
	Lower Hager Creek	1.80	911	489	191	236
	Lower Rambo Creek	3.42	923	493	189	245
	Roseland Creek	9.40	925	495	164	270
	Sheldon Creek	17.67	925	523	197	208
	Shoreacres Creek	14.00	929	510	197	225
	Tuck Creek	10.45	930	530	154	250
		71.79	**926**	**512**	**186**	**233**
North Shore Group 3	Fourteen Mile Creek	34.76	908	550	157	207
	McCraney Creek	12.21	882	483	155	248
		46.98	**901**	**532**	**157**	**218**
North Shore Group 4	Ford Plant Special Area	0.55	843	325	298	221
	Joshua's Creek	21.62	863	545	153	173
	Lower Morrison Creek	5.92	847	414	216	220
	Lower Wedgewood Creek	5.49	841	421	217	208
		33.58	**856**	**498**	**177**	**187**
Halton Watershed		**970.29**	**937**	**564**	**198**	**180**

Note: * - PRMS model did not fully encompass this subwatershed, and therefore the data is incomplete. Data not used in averages.

Table 2.3: Hamilton Region SPA Annual Water Budget Components

Watershed	Subwatershed	Area [km²]	P [mm]	AET [mm]	R [mm]	RO [mm]
Spencer Creek	Ancaster Creek	14.01	972	563	187	226
	Borer's Creek	19.48	1009	600	195	218
	Chedoke Creek	25.06	944	510	163	275
	Flamborough Creek	13.30	1024	594	264	169
	Fletcher Creek	25.12	988	618	194	181
	Logie's Creek	13.28	1061	589	258	217
	Lower Spencer Creek	7.39	865	482	201	186
	Middle Spencer Creek	49.68	1022	595	230	201
	Spring Creek	13.11	1000	627	149	229
	Sulphur Creek	16.90	988	600	193	199
	Sydenham Creek	5.27	1022	608	190	228
	Tiffany Creek	9.08	964	580	140	249

Table 2.3: Hamilton Region SPA Annual Water Budget Components

Watershed	Subwatershed	Area [km^2]	P [mm]	AET [mm]	R [mm]	RO [mm]
	Upper Spencer Creek	35.92	1001	603	228	174
	West Spencer Creek	18.11	1006	590	262	158
	Westover Creek	10.89	1010	581	286	146
		276.59	**997**	**586**	**212**	**202**
Red Hill Creek	Green Hill	11.64	938	454	195	291
	Hannon Creek	10.97	946	589	123	238
	Lower Davis Creek	3.75	940	517	191	234
	Montgomery Creek	3.75	941	539	175	231
	Red Hill Valley *	13.28	908	499	182	230
	Upper Davis Creek	7.25	943	566	146	235
	Upper Ottawa	13.83	946	539	124	286
		64.46	**943**	**533**	**152**	**262**
Stoney Creek	Battlefield Creek	7.47	939	538	220	184
	Stoney Creek	21.03	939	577	164	202
		28.50	**939**	**567**	**179**	**197**
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
		37.46	**935**	**508**	**221**	**210**
Urban Hamilton Beach Strip *		2.34	59	34	8	17
Urban Hamilton City Core		36.52	921	458	214	252
Cootes Paradise (Hamilton) *		1.16	72	44	14	13
Hamilton Watershed		**447.04**	**966**	**555**	**202**	**213**

Note: * - PRMS model did not fully encompass this subwatershed, and therefore the data is incomplete. Data not used in averages.

In summary, the PRMS model simulation provided consistent and calibrated estimates of groundwater recharge across the Halton-Hamilton SPR. The PRMS recharge estimate provides a finer spatial distribution than a recharge estimate based on surficial geology only.

The daily PRMS simulated values of the water budget components data were also averaged on a monthly basis over the 8-year simulation period (from 1989 to 1997) to determine monthly average rates of the water budget components for the study period.

The following **Tables 2.4** through **2.13** summarize in detail the water budget components for all the watersheds and subwatersheds comprising the Halton-Hamilton SPR. **Figures 2.17** through **2.26** present monthly average water budget components distribution for all the Halton-Hamilton SPR watersheds.

HALTON REGION SPA WATERSHEDS WATER BUDGET SUMMARIES

Sixteen Mile Creek watershed and its subwatersheds

The average annual precipitation for the Sixteen Mile Creek watershed is 922 mm. The average actual evapotranspiration within this watershed is about 62 percent of the total precipitation and its annual values range between 503 mm and 622 mm. The average total runoff is about 19 percent of the total precipitation, and the average recharge is about 19 percent of the total precipitation.

The Morrison-Wedgewood Diversion subwatershed appears to be the most heavily urbanized subwatershed in the watershed, and as a result it is characterized by the highest annual surface runoff of 223 mm and rather low annual recharge of 147 mm. The highest annual recharge of 299 mm occurs in the headwaters of Sixteen Mile Creek in the Upper West Branch subwatershed. **Table 2.4** is a summary of precipitation, actual evapotranspiration, recharge and runoff monthly distributed data for the Sixteen Mile Creek watershed.

Table 2.4: Sixteen Mile Creek and Subwatershed Monthly Water Budget Components

Subwatershed		East Branch	East Branch Lisgar	Lower Middle Branch	Lower Middle Tributary	Main Branch	Middle East Branch	Middle Branch	Morrison-Wedgewood Diversion	Upper West Branch	West Branch	**Sixteen Mile Creek Total**
Catchment [km^2]		29.64	25.88	42.32	7.18	24.67	41.65	54.96	16.05	72.87	57.21	**372.42**
Precipitation [mm]	Jan	90	85	83	83	79	90	88	78	86	84	**86**
	Feb	57	55	55	54	52	57	57	50	56	56	**56**
	Mar	62	59	59	59	56	62	62	55	62	60	**60**
	Apr	94	89	88	88	83	94	93	81	92	89	**90**
	May	82	82	84	82	82	82	83	78	87	86	**84**
	Jun	63	66	67	66	67	64	66	65	70	69	**67**
	Jul	87	88	89	88	87	88	89	84	94	92	**90**
	Aug	85	82	81	82	79	85	84	79	83	81	**82**
	Sep	70	71	72	72	73	70	71	72	74	73	**72**
	Oct	79	81	83	82	84	79	80	83	83	83	**82**
	Nov	86	85	85	85	82	87	87	81	89	86	**86**
	Dec	68	66	67	66	64	68	68	62	69	68	**67**
	Annual	**921**	**909**	**914**	**907**	**888**	**924**	**929**	**867**	**943**	**929**	**922**
Actual Evapotranspiration [mm]	Jan	8	7	8	8	8	8	7	8	7	7	**7**
	Feb	13	12	13	13	13	13	12	12	11	12	**12**
	Mar	33	31	32	33	31	33	31	29	28	31	**31**
	Apr	56	52	54	56	49	56	52	45	50	52	**52**
	May	94	87	92	94	81	95	84	73	74	87	**85**
	Jun	115	107	112	116	96	116	97	89	84	108	**102**
	Jul	103	98	103	106	90	104	92	83	87	101	**96**
	Aug	81	77	80	82	72	83	76	66	72	78	**77**
	Sep	51	48	51	52	47	51	49	43	48	50	**49**
	Oct	36	34	36	37	34	36	36	32	36	35	**35**
	Nov	16	15	15	16	15	16	15	15	15	15	**15**
	Dec	9	8	9	9	9	9	8	8	8	8	**8**
	Annual	**612**	**577**	**606**	**622**	**544**	**619**	**560**	**503**	**519**	**584**	**570**
Recharge [mm]	Jan	14	14	17	15	19	14	24	18	31	15	**20**
	Feb	12	13	14	13	16	11	19	16	24	13	**16**
	Mar	20	22	24	22	23	20	36	22	48	23	**29**
	Apr	30	27	29	28	26	31	42	24	51	29	**35**
	May	8	9	11	10	11	8	13	11	18	11	**12**
	Jun	0	0	0	0	2	0	3	2	5	1	**2**
	Jul	0	0	1	0	2	0	5	3	8	1	**3**
	Aug	0	0	1	0	3	0	6	4	9	1	**3**
	Sep	0	0	1	0	3	0	5	4	9	1	**3**
	Oct	1	2	3	1	7	1	12	8	21	3	**8**
	Nov	14	16	19	17	20	15	31	19	43	19	**25**
	Dec	17	17	19	18	19	18	25	18	30	18	**21**
	Annual	**118**	**121**	**138**	**125**	**151**	**119**	**221**	**147**	**299**	**133**	**177**
Runoff [mm]	Jan	37	38	34	34	31	35	25	30	16	37	**30**
	Feb	28	30	27	26	23	28	20	22	13	31	**24**
	Mar	42	36	32	33	29	43	31	28	24	37	**33**
	Apr	18	18	15	14	18	19	17	20	17	19	**18**
	May	7	11	7	6	11	7	6	14	7	11	**8**
	Jun	3	6	4	3	7	3	2	10	3	6	**4**
	Jul	9	12	8	7	11	9	7	15	6	11	**9**
	Aug	12	13	8	8	12	11	8	17	6	11	**10**
	Sep	7	10	7	7	11	7	6	15	5	10	**8**
	Oct	10	14	11	10	16	9	8	19	9	14	**11**
	Nov	16	18	14	13	18	16	14	20	14	18	**16**
	Dec	11	13	12	10	13	11	9	13	9	14	**11**
	Annual	**201**	**219**	**178**	**169**	**199**	**197**	**154**	**223**	**129**	**218**	**181**

Figure 2.17 presents the monthly distribution of average water budget components within the Sixteen Mile Creek watershed. The most recharge occurs between November and April when it oscillates around 20 mm with April being the month of the highest recharge rate.

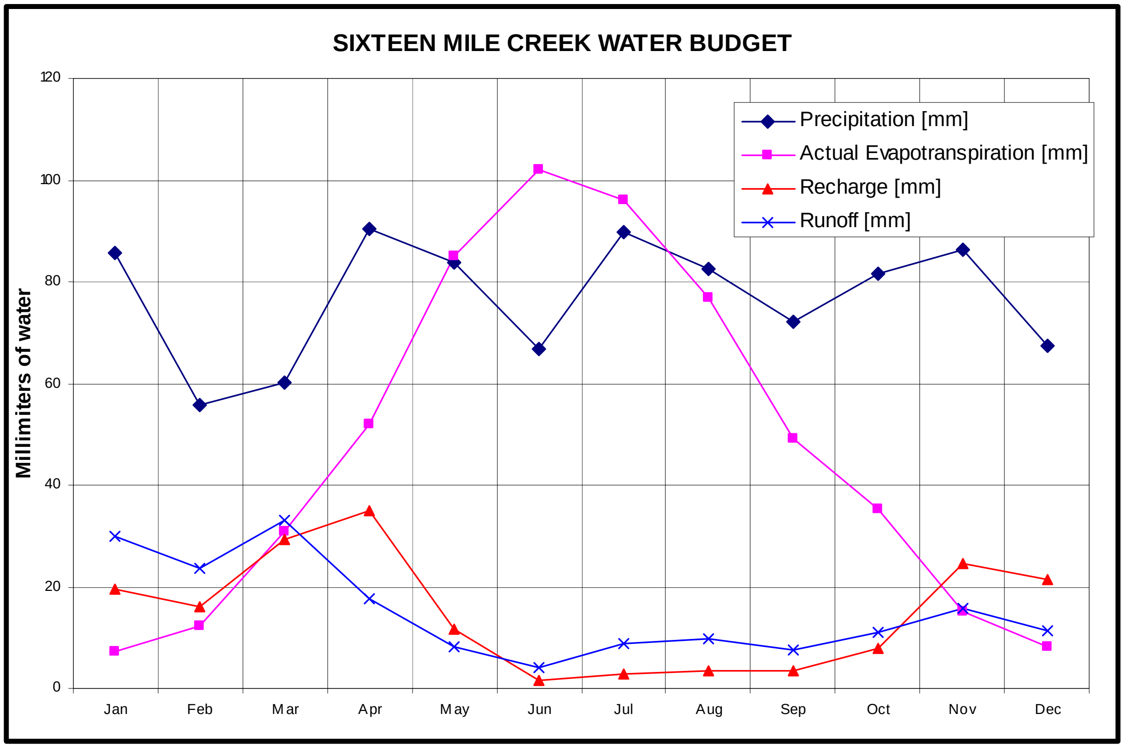

Figure 2.17 Sixteen Mile Creek Watershed Monthly Water Budget Components Distribution

Bronte Creek

The water budget components in the Bronte Creek watershed and its subwatersheds are summarized in **Table 2.5**. The average annual precipitation for the Bronte Creek watershed is 962 mm. The average actual evapotranspiration within this watershed is about 60 percent of the total precipitation and its annual values range between 532 mm and 648 mm. The average total runoff is about 16 percent of the total precipitation, and the average recharge is about 24 percent of the total precipitation.

In general, the Bronte Creek sub watersheds below the Escarpment and close to the edge of the Escarpment are characterized by higher surface runoff and lower recharge than average. The highest surface runoff occurs in the Mount Nemo Creek subwatershed, where the topography plays a major role in the increased runoff and reduced recharge. The highest groundwater recharge occurs in the Flamboro Creek subwatershed at 320 mm annually.

Table 2.5: Bronte Creek and Subwatershed Monthly Water Budget Components

Subwatershed		Flamboro Creek	Indian Creek	Kilbride Creek	Limestone Creek	Lower Main Branch	Lowville Creek	Mount Nemo Creek	Mountsberg Creek	Strabane Creek	Upper Main Branch	Willoughby Creek	**Bronte Creek Total**
Catchment [km^2]		9.42	40.81	41.23	36.60	35.33	10.07	4.51	55.08	18.43	52.72	12.20	**316.39**
Precipitation [mm]	Jan	87	83	86	85	82	83	82	86	88	87	84	**85**
	Feb	60	57	57	58	58	59	58	57	59	59	60	**58**
	Mar	63	61	62	62	60	61	60	63	64	64	62	**62**
	Apr	91	88	91	90	87	88	87	92	93	92	89	**90**
	May	94	88	90	90	90	91	91	91	95	94	93	**91**
	Jun	74	70	73	72	71	72	71	73	76	75	73	**73**
	Jul	100	94	98	97	95	96	95	99	104	102	98	**98**
	Aug	79	80	81	80	79	79	79	81	80	80	78	**80**
	Sep	78	75	76	76	76	76	75	77	80	79	77	**77**
	Oct	89	85	86	87	87	88	87	86	90	89	89	**87**
	Nov	89	86	89	88	86	86	85	90	92	91	87	**89**
	Dec	73	69	70	70	70	70	70	71	73	73	72	**71**
	Annual	**978**	**937**	**960**	**954**	**940**	**950**	**941**	**966**	**994**	**987**	**962**	**962**
Actual Evapotranspiration [mm]	Jan	7	8	7	7	8	7	8	7	7	7	7	**7**
	Feb	11	14	11	12	13	12	14	11	11	11	12	**12**
	Mar	29	33	29	31	32	32	34	29	29	30	32	**30**
	Apr	51	56	50	52	52	55	57	52	52	52	54	**52**
	May	78	95	75	80	84	94	97	83	83	85	89	**84**
	Jun	86	119	85	91	97	120	123	101	100	103	108	**101**
	Jul	89	111	90	92	94	113	114	103	104	105	104	**101**
	Aug	70	84	72	74	74	84	85	80	80	80	79	**78**
	Sep	50	54	49	51	50	53	55	51	52	52	53	**51**
	Oct	38	38	36	37	37	36	38	37	38	38	37	**37**
	Nov	15	16	15	16	16	15	16	15	15	15	15	**15**
	Dec	8	9	8	8	9	8	9	8	8	8	8	**8**
	Annual	**532**	**637**	**526**	**552**	**564**	**629**	**648**	**577**	**577**	**585**	**599**	**577**
Recharge [mm]	Jan	35	14	32	30	27	11	12	26	27	28	19	**26**
	Feb	30	13	27	24	23	8	10	24	23	26	16	**22**
	Mar	52	23	50	44	33	18	19	43	43	44	28	**39**
	Apr	49	29	48	46	34	29	28	42	39	40	32	**39**
	May	21	11	19	18	15	12	12	17	18	18	14	**16**
	Jun	5	0	6	4	2	0	0	3	4	3	1	**3**
	Jul	8	1	9	7	4	0	0	5	5	3	2	**4**
	Aug	7	1	8	7	4	0	0	4	4	3	2	**4**
	Sep	11	1	11	8	5	0	0	7	7	6	3	**6**
	Oct	25	2	23	20	13	1	0	15	16	14	7	**14**
	Nov	47	17	44	39	32	16	15	36	36	37	23	**34**
	Dec	32	16	30	28	25	17	15	27	28	29	19	**26**
	Annual	**320**	**127**	**308**	**275**	**218**	**112**	**112**	**249**	**250**	**249**	**166**	**233**
Runoff [mm]	Jan	18	34	16	20	25	36	33	20	23	22	32	**23**
	Feb	17	29	14	17	22	35	31	18	23	22	32	**21**
	Mar	22	34	24	23	26	44	39	32	38	34	37	**31**
	Apr	13	15	15	14	15	23	19	17	17	15	18	**16**
	May	8	8	8	7	10	10	8	7	9	9	11	**8**
	Jun	3	3	3	3	5	4	3	3	3	3	4	**3**
	Jul	6	7	7	6	9	8	7	6	8	8	9	**7**
	Aug	5	7	5	5	8	8	7	5	5	5	8	**6**
	Sep	4	6	5	5	7	7	6	4	5	5	7	**5**
	Oct	9	10	9	9	12	12	10	9	11	10	13	**10**
	Nov	12	14	14	12	14	15	13	14	16	14	17	**14**
	Dec	9	13	9	9	10	14	12	10	12	10	14	**11**
	Annual	**127**	**180**	**129**	**130**	**162**	**215**	**188**	**145**	**170**	**157**	**201**	**155**

Figure 2.18 presents the monthly distribution of the total annual precipitation, total annual actual evapotranspiration, total recharge and the total runoff within the Bronte Creek watershed. Recharge appears to be the highest in March and April, and the lowest between June and September.

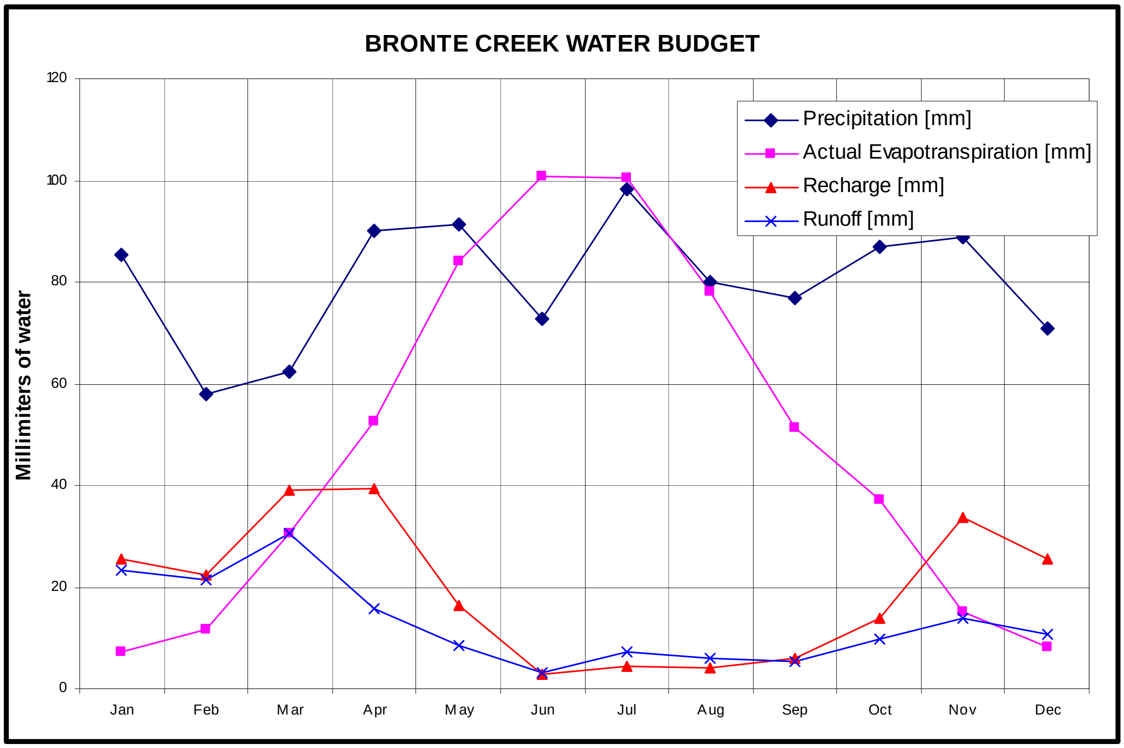

Figure 2.18 Bronte Creek Watershed Monthly Water Budget Components Distribution

Grindstone Creek

Table 2.6 is a summary of the water budget elements in the Grindstone Creek watershed and its subwatersheds. The average annual precipitation in the watershed is 989 mm. Annual average actual evapotranspiration in the Grindstone Creek watershed is 596 mm, which is about 60 percent of the total precipitation. The average annual total runoff is about 19 percent of the total precipitation, and the average annual recharge is about 21 percent of the total precipitation.

The annual surface runoff varies from 148 mm to 293 mm for the Grindstone Creek subwatersheds. Subwatershed 218 is characterized by the highest annual surface runoff and low annual recharge as it is mostly occupied by developed residential and commercial areas. The highest groundwater recharge occurs in the 204 subwatershed, which is located above the Escarpment. It is dominated by rural land uses and has relatively low relief.

Table 2.6: Grindstone Creek and Subwatershed Monthly Water Budget Components

Subwatershed		201	204	210	214	215	218	220	222	224	228	230	232 (Alternate)	**Grindstone Creek Total**
Catchment [km^2]		22.73	6.66	8.02	8.07	14.64	1.68	8.19	2.52	5.68	8.07	1.65	2.45	**90.37**
Precipitation [mm]	Jan	93	99	92	90	84	82	81	79	78	78	72	78	**87**
	Feb	65	67	64	63	61	61	59	61	60	62	61	63	**63**
	Mar	68	71	67	66	62	62	60	61	60	62	60	63	**65**
	Apr	94	97	93	92	88	87	86	86	85	86	83	87	**90**
	May	100	104	100	98	94	94	92	94	92	96	94	97	**97**
	Jun	77	79	76	75	73	73	72	73	72	73	71	73	**75**
	Jul	106	111	105	103	98	97	96	95	93	94	88	94	**101**
	Aug	76	75	76	77	78	78	79	77	78	75	73	74	**77**
	Sep	83	86	82	80	77	76	76	74	74	73	70	73	**79**
	Oct	96	100	95	94	90	89	88	88	87	88	85	89	**92**
	Nov	92	95	91	90	87	86	85	85	84	85	82	86	**89**
	Dec	79	83	78	77	72	72	70	71	69	71	68	72	**75**
	Annual	**1029**	**1068**	**1019**	**1005**	**966**	**955**	**944**	**944**	**932**	**944**	**908**	**947**	**989**
Actual Evapotranspiration [mm]	Jan	7	6	7	7	7	7	8	8	9	9	7	8	**7**
	Feb	11	11	12	12	12	11	13	13	14	14	13	13	**12**
	Mar	30	30	31	32	32	28	33	31	34	33	32	32	**31**
	Apr	54	54	54	55	55	47	56	50	54	53	53	53	**54**
	May	90	91	91	93	90	78	94	79	87	87	88	86	**90**
	Jun	106	111	110	113	108	97	118	93	103	105	97	103	**108**
	Jul	105	109	105	107	103	93	111	90	97	98	85	96	**103**
	Aug	76	77	75	77	78	70	83	69	75	74	65	73	**76**
	Sep	53	54	52	53	53	47	54	49	52	51	48	50	**52**
	Oct	39	39	39	39	38	33	37	36	38	38	37	37	**38**
	Nov	15	15	15	15	16	15	16	16	17	17	15	16	**16**
	Dec	8	8	8	8	8	8	9	9	10	10	9	9	**8**
	Annual	**593**	**603**	**598**	**610**	**600**	**533**	**630**	**543**	**589**	**588**	**550**	**576**	**596**
Recharge [mm]	Jan	30	23	31	27	23	16	13	27	25	21	29	19	**25**
	Feb	24	19	23	20	18	13	11	22	22	21	25	19	**20**
	Mar	41	38	39	34	30	22	22	32	28	29	29	26	**33**
	Apr	38	43	38	37	31	25	26	34	31	31	30	29	**34**
	May	20	22	20	19	15	13	11	18	16	17	15	16	**17**
	Jun	1	2	1	1	1	1	0	4	4	3	0	2	**1**
	Jul	1	0	0	0	2	1	0	5	4	3	0	2	**1**
	Aug	3	3	2	2	2	1	0	5	4	3	2	2	**2**
	Sep	6	7	5	3	3	1	0	5	5	3	1	2	**4**
	Oct	14	14	12	10	8	4	1	14	11	8	8	7	**10**
	Nov	41	45	40	35	27	19	13	33	27	24	34	22	**32**
	Dec	35	39	37	32	23	17	13	26	23	19	29	18	**28**
	Annual	**252**	**253**	**248**	**220**	**183**	**133**	**111**	**225**	**199**	**180**	**202**	**164**	**209**
Runoff [mm]	Jan	26	30	26	28	29	39	34	23	22	27	22	30	**28**
	Feb	29	30	30	33	32	40	34	25	23	28	26	32	**30**
	Mar	46	61	42	41	35	39	36	27	23	30	27	34	**39**
	Apr	17	24	14	15	16	25	17	16	13	16	13	18	**16**
	May	9	9	9	9	10	21	11	12	9	11	10	14	**10**
	Jun	3	3	4	3	4	13	6	7	5	6	6	7	**4**
	Jul	8	9	8	8	8	20	10	11	8	11	8	13	**9**
	Aug	5	4	5	6	7	17	10	10	8	9	7	10	**7**
	Sep	5	5	5	5	6	15	8	8	6	8	7	9	**6**
	Oct	11	11	10	10	12	22	14	14	11	14	13	16	**12**
	Nov	15	14	12	12	15	24	16	14	11	14	14	17	**14**
	Dec	13	14	12	12	14	19	14	11	9	10	10	12	**13**
	Annual	**187**	**214**	**177**	**180**	**188**	**293**	**209**	**180**	**148**	**182**	**161**	**212**	**189**

Figure 2.19 presents the monthly distribution of average water budget components within the Grindstone Creek watershed.

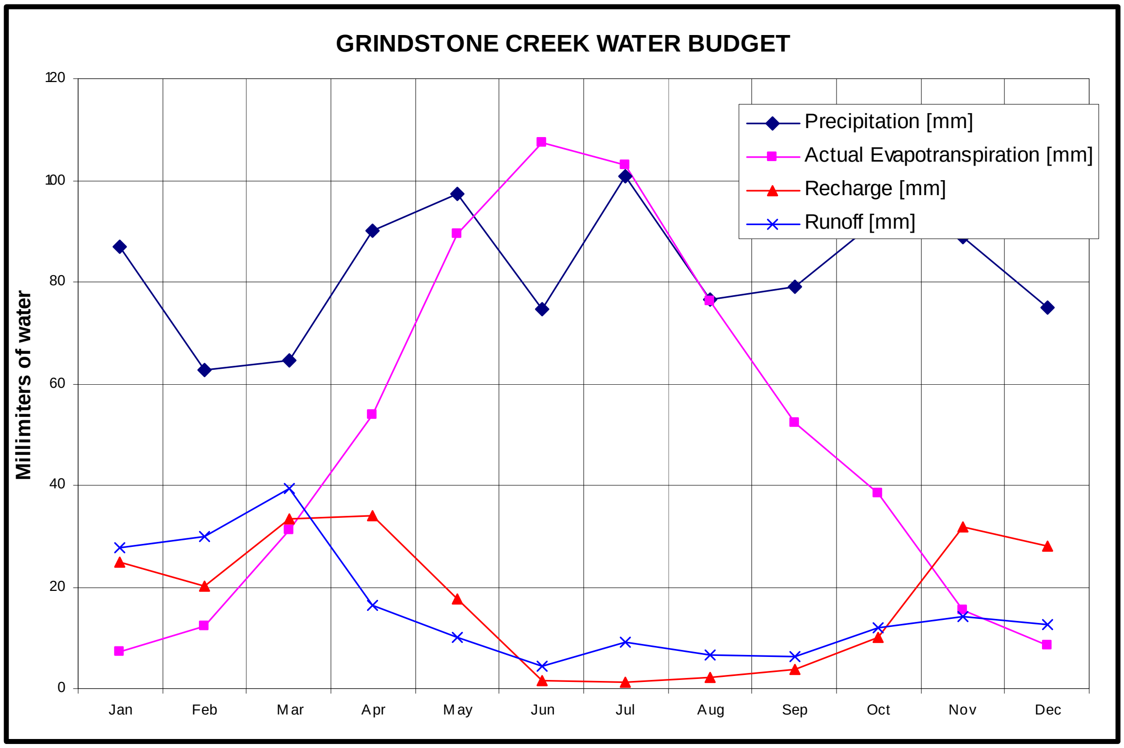

Figure 2.19 Grindstone Creek Watershed Monthly Water Budget Components Distribution

North Shore Group 1

The average annual precipitation within the North Shore Group 1 watersheds is about 920 mm. The average actual evapotranspiration is about 59 percent of the total precipitation and its annual values range between 487 mm and 609 mm. The average total runoff is about 22 percent of the total precipitation, and the average recharge is about 19 percent of the total precipitation.

The North Shore Group watersheds are mostly urbanized. Most of the watersheds have relatively high surface runoff, which varies from 158 mm to 263 mm (results for West Aldershot (West) subwatershed are excluded from analysis due to its size and biased results). Groundwater recharge in these watersheds is comparatively low. Water budgets of these watersheds are summarized in **Table 2.7**. The highest surface runoff, 263 mm, occurs in the Upper Rambo Creek.

Table 2.7: North Shore Group 1 Monthly Water Budget Components

Subwatershed		407 Diversion	Falcon Creek	Indian Creek	North Cootes Paradise (232)	Upper Hager Creek	Upper Rambo Creek	West Aldershot (East)	West Aldershot (West)	**North Shore Group 1 Total**
Catchment [km^2]		5.23	5.42	6.07	6.27	4.23	6.29	4.36	0.18	**38.76**
Precipitation [mm]	Jan	79	78	78	78	77	79	79	74	**78**
	Feb	58	58	58	56	62	57	57	59	**58**
	Mar	58	58	58	57	62	58	58	59	**59**
	Apr	84	84	84	82	86	84	84	82	**84**
	May	90	90	90	88	96	89	89	91	**90**
	Jun	71	71	71	69	73	71	71	70	**71**
	Jul	94	93	93	92	93	94	94	89	**93**
	Aug	80	79	79	79	73	81	80	75	**78**
	Sep	75	74	74	73	73	74	74	71	**73**
	Oct	87	86	86	85	88	86	86	85	**86**
	Nov	83	82	82	81	85	82	83	82	**83**
	Dec	68	68	68	67	71	68	68	67	**68**
	Annual	**928**	**921**	**921**	**907**	**939**	**922**	**923**	**903**	**920**
Actual Evapotranspiration [mm]	Jan	8	8	8	8	9	8	8	8	**8**
	Feb	13	14	14	14	14	13	12	13	**13**
	Mar	31	32	32	32	34	30	29	30	**31**
	Apr	51	52	52	50	55	47	45	48	**50**
	May	84	85	85	79	92	73	71	79	**81**
	Jun	104	99	99	90	111	83	83	89	**95**
	Jul	97	92	92	85	101	80	79	79	**88**
	Aug	74	71	71	67	75	63	62	60	**68**
	Sep	49	50	50	47	52	45	44	44	**47**
	Oct	34	37	37	36	39	34	32	35	**35**
	Nov	15	16	16	16	17	16	15	15	**16**
	Dec	9	9	9	9	10	9	9	9	**9**
	Annual	**566**	**564**	**564**	**533**	**609**	**500**	**487**	**508**	**541**
Recharge [mm]	Jan	16	28	28	31	22	31	25	31	**26**
	Feb	15	23	23	26	19	26	23	27	**22**
	Mar	21	26	26	27	28	27	23	27	**26**
	Apr	23	27	27	27	33	26	23	27	**27**
	May	11	14	14	15	17	16	14	15	**15**
	Jun	1	2	2	3	2	5	3	1	**2**
	Jul	1	2	2	4	2	6	4	0	**3**
	Aug	1	4	4	5	2	7	4	2	**3**
	Sep	1	3	3	4	2	6	4	1	**3**
	Oct	2	8	8	12	7	14	10	7	**8**
	Nov	14	26	26	29	26	28	22	31	**25**
	Dec	15	25	25	27	21	27	22	28	**23**
	Annual	**119**	**187**	**187**	**211**	**179**	**218**	**176**	**196**	**183**
Runoff [mm]	Jan	35	24	24	22	23	25	32	26	**27**
	Feb	31	23	23	19	28	21	26	23	**24**
	Mar	31	23	23	19	32	21	26	22	**25**
	Apr	21	15	15	14	14	18	23	16	**17**
	May	17	11	11	12	8	16	20	16	**14**
	Jun	12	8	8	8	4	12	15	11	**10**
	Jul	16	11	11	11	8	16	21	15	**14**
	Aug	16	11	11	12	6	16	20	14	**13**
	Sep	13	9	9	10	5	13	17	12	**11**
	Oct	20	14	14	15	11	19	24	18	**17**
	Nov	20	14	14	14	11	18	23	17	**17**
	Dec	17	13	13	12	8	14	18	13	**13**
	Annual	**248**	**175**	**175**	**167**	**158**	**207**	**263**	**204**	**201**

Figure 2.20 presents the monthly distribution of the total annual precipitation, total annual actual evapotranspiration, total recharge and the total runoff in the North Shore Group 1 watershed. The group is characterized by lower actual evapotranspiration and more evenly distributed runoff.

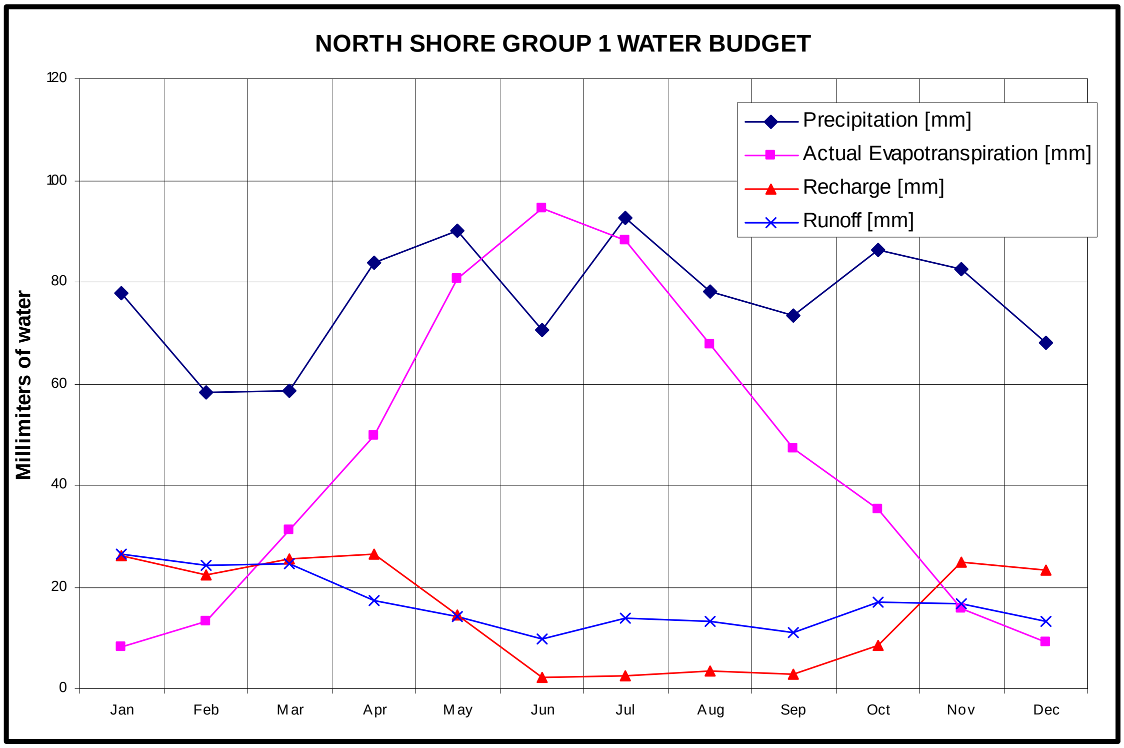

Figure 2.20 North Shore Group 1 Monthly Water Budget Components Distribution

North Shore Group 2

The average annual precipitation in the North Shore Group 2 watersheds is 926 mm. The average actual evapotranspiration within these watersheds equals about 55 percent of the total precipitation and its annual values range between 489 mm and 530 mm. The average total runoff is about 25 percent of the total precipitation, and the average recharge is about 20 percent of the total precipitation. The North Shore Group 2 watersheds are mostly urbanized. Most of these watersheds have high surface runoff, which varies from 208 mm to 270 mm. Water budgets of these watersheds are presented in **Table 2.8**.

Table 2.8: North Shore Group 2 Monthly Water Budget Components

Subwatershed		Appleby Creek	Lower Hager Creek	Lower Rambo Creek	Roseland Creek	Sheldon Creek	Shoreacres Creek	Tuck Creek	**North Shore Group 2 Total**
Catchment [km^2]		14.08	1.80	3.42	9.40	17.67	14.00	10.45	**71.79**
Precipitation [mm]	Jan	80	78	79	79	80	80	80	**80**
	Feb	57	57	57	58	57	58	58	**57**
	Mar	59	57	58	58	59	59	59	**59**
	Apr	85	83	84	84	85	85	85	**85**
	May	89	88	89	90	89	90	90	**89**
	Jun	71	70	71	71	70	71	71	**71**
	Jul	93	92	93	94	93	94	94	**93**
	Aug	79	79	80	80	79	79	80	**79**
	Sep	75	73	74	74	74	75	75	**74**
	Oct	87	85	86	87	86	87	87	**87**
	Nov	84	82	83	83	84	84	84	**84**
	Dec	68	67	68	68	68	68	69	**68**
	Annual	**928**	**911**	**923**	**925**	**925**	**929**	**930**	**926**
Actual Evapotranspiration [mm]	Jan	8	8	8	7	8	8	7	**8**
	Feb	12	12	12	12	13	12	12	**12**
	Mar	29	28	29	28	30	30	30	**30**
	Apr	46	45	46	45	48	47	48	**47**
	May	73	74	74	72	76	74	78	**74**
	Jun	86	85	85	86	89	87	94	**88**
	Jul	83	79	80	82	86	84	89	**85**
	Aug	66	60	61	63	69	66	69	**66**
	Sep	45	43	43	44	47	46	47	**46**
	Oct	33	33	33	32	34	33	33	**33**
	Nov	15	15	15	15	15	15	15	**15**
	Dec	9	8	9	8	9	9	8	**9**
	Annual	**505**	**489**	**493**	**495**	**523**	**510**	**530**	**512**
Recharge [mm]	Jan	26	33	33	25	25	26	20	**25**
	Feb	22	26	26	22	24	22	19	**22**
	Mar	27	25	24	23	28	26	23	**26**
	Apr	26	25	25	23	27	26	24	**25**
	May	15	14	14	13	14	15	13	**14**
	Jun	4	0	1	2	4	4	2	**3**
	Jul	6	0	0	2	6	5	3	**4**
	Aug	6	3	3	3	5	6	3	**5**
	Sep	6	1	1	2	6	5	3	**4**
	Oct	13	7	7	7	13	12	7	**11**
	Nov	25	28	27	21	25	26	20	**24**
	Dec	22	29	27	21	21	23	19	**22**
	Annual	**197**	**191**	**189**	**164**	**198**	**198**	**154**	**186**
Runoff [mm]	Jan	30	27	29	33	30	29	34	**31**
	Feb	24	22	23	27	23	24	28	**25**
	Mar	27	23	25	27	25	27	30	**27**
	Apr	21	19	20	23	18	21	22	**20**
	May	17	19	19	21	15	17	18	**17**
	Jun	11	14	14	15	9	11	12	**12**
	Jul	16	19	20	21	14	16	17	**17**
	Aug	15	18	18	20	13	15	16	**16**
	Sep	13	16	16	17	12	13	14	**14**
	Oct	19	21	22	24	17	19	21	**20**
	Nov	20	20	21	24	19	20	21	**20**
	Dec	15	17	18	19	13	15	17	**15**
	Annual	**229**	**236**	**245**	**270**	**208**	**225**	**250**	**233**

Figure 2.21 presents the monthly distribution of the total annual precipitation, total annual actual evapotranspiration, total recharge and the total runoff. Similarly to the North Shore Group 1 the North Shore Group 2 is characterized by lower than average evapotranspiration within the Halton Region SPA and evenly distributed runoff, which is higher than average for the Halton Region SPA.

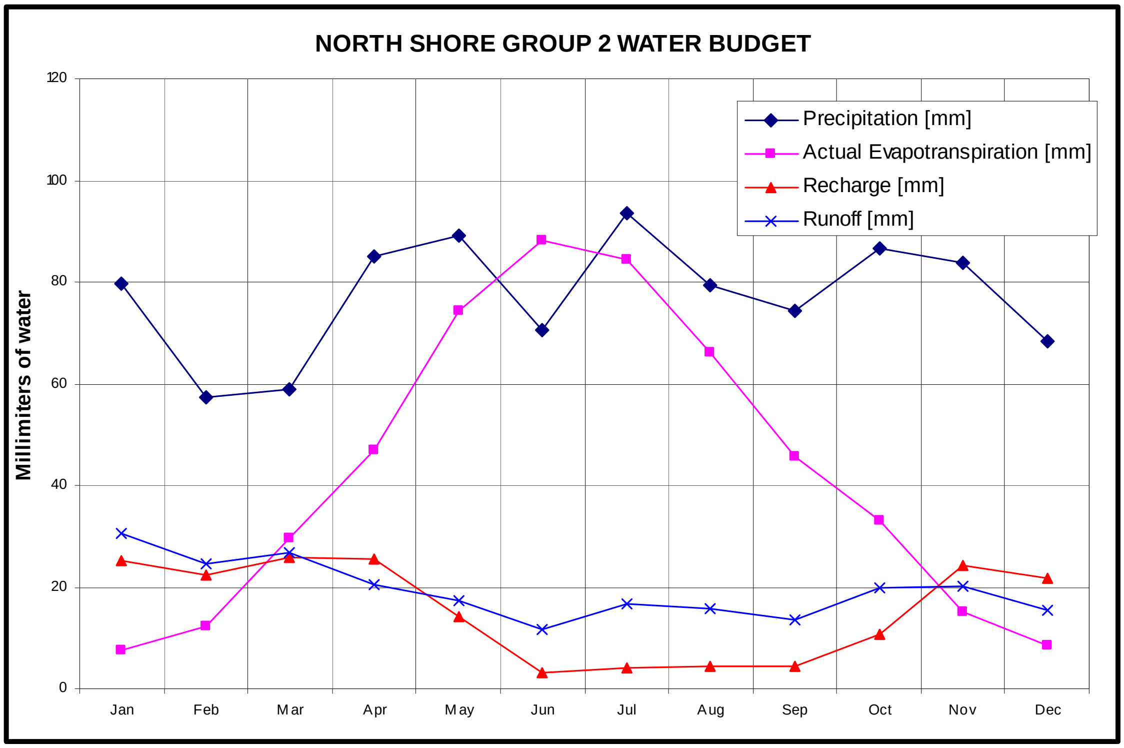

Figure 2.21 North Shore Group 2 Monthly Water Budget Components Distribution

North Shore Group 3 and 4

The long-term annual total precipitation in the North Shore Groups 3 and 4 watersheds is 883 mm (**Table 2.9**). The actual evapotranspiration is about 59 percent of the total of precipitation. The average runoff is about 23 percent and the recharge is at about 18 percent of the total precipitation.

The lower evapotranspiration is due to the urbanization of the area and increased runoff. Surface runoff in these watersheds varies from 173 mm in the Joshua's Creek watershed to 248 mm in the McCraney Creek watershed.

Table 2.9: North Shore Groups 3 and 4 Monthly Water Budget Components

Subwatershed/ Watershed		Fourteen Mile Creek	McCraney Creek		Ford Plant Special Area	Joshua's Creek	Lower Morrison Creek	Lower Wedgewood Creek	**North Shore Group 3 & 4 Total**
Catchment [km^2]		34.76	12.21		0.55	21.62	5.92	5.49	**80.56**
Precipitation [mm]	Jan	80	78		76	78	76	76	**79**
	Feb	55	52		47	49	48	47	**52**
	Mar	58	56		53	54	53	52	**56**
	Apr	84	82		78	81	78	78	**82**
	May	85	81		75	78	76	75	**81**
	Jun	69	66		63	64	63	62	**66**
	Jul	90	86		80	83	81	80	**86**
	Aug	79	79		78	79	78	78	**79**
	Sep	74	73		71	72	71	71	**73**
	Oct	85	84		83	83	83	82	**84**
	Nov	83	82		79	81	79	79	**82**
	Dec	66	64		60	62	61	60	**64**
	Annual	**908**	**882**		**843**	**863**	**847**	**841**	**883**
Actual Evapotranspiration [mm]	Jan	8	7		7	8	7	7	**8**
	Feb	13	12		11	13	11	11	**12**
	Mar	31	28		23	31	26	26	**30**
	Apr	50	44		32	49	40	40	**47**
	May	81	70		42	81	60	61	**76**
	Jun	98	84		43	98	68	69	**91**
	Jul	92	79		46	90	63	64	**85**
	Aug	72	63		42	71	53	54	**67**
	Sep	48	42		32	46	37	37	**45**
	Oct	34	31		27	34	29	30	**33**
	Nov	15	15		14	15	14	14	**15**
	Dec	9	8		8	9	8	8	**8**
	Annual	**550**	**483**		**325**	**545**	**415**	**421**	**518**
Recharge [mm]	Jan	20	21		39	20	32	32	**22**
	Feb	18	18		27	17	24	24	**18**
	Mar	24	23		33	23	27	28	**24**
	Apr	26	24		27	25	26	27	**25**
	May	12	12		18	11	14	14	**12**
	Jun	2	2		8	2	3	3	**2**
	Jul	3	3		14	3	5	5	**3**
	Aug	3	3		17	3	6	6	**4**
	Sep	3	3		15	3	7	6	**4**
	Oct	7	8		30	7	15	15	**9**
	Nov	20	20		41	20	33	33	**22**
	Dec	19	19		29	19	25	25	**20**
	Annual	**157**	**155**		**298**	**153**	**216**	**217**	**165**
Runoff [mm]	Jan	31	33		19	27	24	23	**29**
	Feb	24	24		14	19	18	16	**21**
	Mar	28	29		18	25	22	21	**26**
	Apr	18	22		21	15	19	18	**18**
	May	13	17		17	10	16	15	**13**
	Jun	8	12		13	6	12	12	**9**
	Jul	13	18		19	10	17	16	**13**
	Aug	13	19		22	13	20	19	**14**
	Sep	11	17		19	11	17	17	**13**
	Oct	16	22		23	14	21	20	**17**
	Nov	18	23		22	14	20	19	**18**
	Dec	14	16		13	10	14	13	**13**
	Annual	**207**	**248**		**221**	**173**	**220**	**208**	**205**

Figure 2.22 presents the monthly distribution of the total annual precipitation, total annual actual evapotranspiration, total recharge and the total runoff.

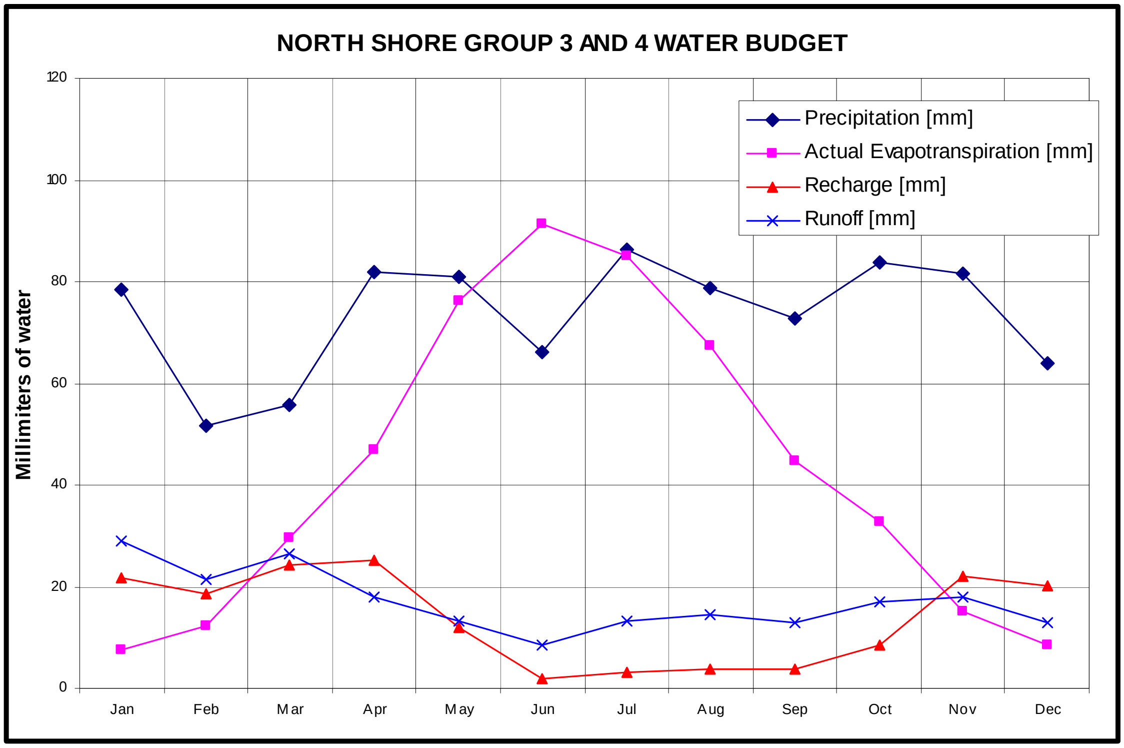

Figure 2.22 North Shore Groups 3 and 4 Monthly Water Budget Components Distribution

HAMILTON REGION SPA WATERSHEDS WATER BUDGET SUMMARIES

Spencer Creek

Table 2.10 shows water budget components of the Spencer Creek watershed and its subwatersheds. The modeled period average annual precipitation is 997 mm. The actual evapotranspiration was calculated at 59 percent, the total runoff at 20 percent and recharge at 21 percent of the total precipitation. The Chedoke Creek subwatershed has the highest surface runoff of 275 mm and rather lower than average recharge for the Spencer Creek watershed at 163 mm of the total precipitation.

Table 2.10: Spencer Creek Watershed Monthly Water Budget Components

Subwatershed/ Watershed		Ancaster Creek	Borer's Creek	Chedoke Creek	Flamborough Creek	Fletcher Creek	Logie's Creek	Lower Spencer Creek	Middle Spencer Creek	Spring Creek	Sulphur Creek	Sydenham Creek	Tiffany Creek	Upper Spencer Creek	West Spencer Creek	Westover Creek	**Spencer Creek Total**
Catchment [km^2]		14.0	19.5	25.1	13.3	25.1	13.3	7.4	49.7	13.1	16.9	5.3	9.1	35.9	18.1	10.9	**276.6**
Precipitation [mm]	Jan	83	90	77	92	87	98	72	92	88	86	91	82	88	89	90	**88**
	Feb	62	64	62	64	57	67	57	64	63	62	65	62	58	61	61	**62**
	Mar	64	66	62	67	64	70	57	67	66	65	67	63	64	65	66	**65**
	Apr	89	92	87	94	93	96	79	93	92	91	93	89	94	93	93	**92**
	May	97	100	96	100	94	104	88	100	98	97	101	96	96	97	98	**98**
	Jun	74	76	73	77	76	78	67	77	76	75	77	74	77	77	77	**76**
	Jul	98	103	93	106	104	110	86	106	102	101	105	97	106	105	105	**103**
	Aug	76	75	75	77	82	75	67	77	77	77	75	76	81	79	79	**77**
	Sep	77	80	73	82	80	86	67	82	80	79	82	76	81	81	81	**80**
	Oct	90	94	88	95	87	99	81	95	93	91	96	90	89	91	92	**92**
	Nov	88	91	86	92	92	95	78	92	90	90	92	87	93	92	92	**91**
	Dec	73	77	71	78	71	82	66	78	76	75	79	73	73	75	75	**75**
	Annual	**972**	**1009**	**944**	**1024**	**988**	**1061**	**865**	**1022**	**1000**	**988**	**1022**	**964**	**1001**	**1006**	**1010**	**997**
Actual Evapotranspiration [mm]	Jan	7	7	6	7	7	7	6	7	8	7	8	7	7	7	7	**7**
	Feb	12	12	11	11	11	11	11	12	13	12	13	12	11	12	12	**11**
	Mar	30	31	27	30	30	30	27	31	32	31	32	30	29	31	30	**30**
	Apr	51	53	46	55	54	52	45	54	55	53	53	51	53	53	53	**52**
	May	85	89	76	90	90	88	74	90	93	91	89	86	86	87	84	**87**
	Jun	104	111	94	104	112	108	86	109	117	112	111	108	108	105	101	**107**
	Jul	98	107	89	105	114	106	79	104	111	106	108	103	111	103	103	**104**
	Aug	72	77	65	77	86	75	59	75	82	78	80	77	84	76	77	**77**
	Sep	49	52	44	53	55	52	42	52	54	52	53	50	54	53	52	**52**
	Oct	35	38	31	40	38	38	32	39	38	37	38	34	38	39	39	**37**
	Nov	15	15	14	15	15	15	14	15	16	15	16	15	15	15	15	**15**
	Dec	8	8	7	8	8	8	8	8	9	8	9	8	8	8	8	**8**
	Annual	**563**	**600**	**510**	**594**	**619**	**589**	**482**	**595**	**628**	**600**	**608**	**580**	**603**	**590**	**581**	**586**
Recharge [mm]	Jan	22	23	19	32	21	25	28	26	15	19	23	14	23	29	32	**23**
	Feb	17	17	19	26	17	20	24	20	10	13	18	12	20	24	28	**19**
	Mar	28	30	26	45	33	39	30	36	20	26	31	22	38	41	48	**33**
	Apr	34	35	28	39	38	42	29	39	34	41	33	30	41	39	41	**37**
	May	17	18	16	20	15	23	16	20	17	19	18	15	18	20	21	**18**
	Jun	1	1	1	1	2	2	1	1	1	1	2	1	3	4	4	**2**
	Jul	1	1	1	2	1	0	1	0	0	0	2	0	3	4	6	**1**
	Aug	2	1	1	3	1	3	2	3	1	2	2	1	3	5	5	**2**
	Sep	3	3	1	6	4	6	2	5	1	3	3	1	6	8	9	**4**
	Oct	8	8	6	15	8	14	9	11	5	9	8	4	13	16	18	**10**
	Nov	31	30	24	42	29	45	32	38	25	34	28	21	33	40	41	**33**
	Dec	24	27	21	34	25	39	27	33	20	25	24	18	27	33	33	**28**
	Annual	**187**	**195**	**163**	**264**	**194**	**258**	**201**	**231**	**149**	**193**	**190**	**140**	**228**	**262**	**286**	**212**
Runoff [mm]	Jan	32	32	36	24	26	30	23	30	35	30	33	36	25	26	21	**29**
	Feb	35	37	39	26	26	32	26	32	36	31	37	41	25	28	22	**31**
	Mar	40	45	37	40	45	56	27	45	51	45	46	45	43	35	32	**43**
	Apr	21	18	22	16	19	21	16	19	29	27	18	21	18	13	13	**19**
	May	14	12	21	9	9	11	14	10	11	9	14	15	9	8	8	**11**
	Jun	8	6	13	3	3	5	8	4	5	4	6	8	3	3	3	**5**
	Jul	13	12	20	7	7	11	13	10	11	9	14	14	8	7	7	**11**
	Aug	10	8	16	4	5	6	10	6	7	6	8	11	4	4	4	**7**
	Sep	9	7	14	5	5	7	9	6	6	5	8	10	5	4	4	**7**
	Oct	15	13	22	10	10	12	15	12	12	10	14	16	9	9	9	**12**
	Nov	16	15	22	14	16	13	15	14	15	12	17	18	15	12	13	**15**
	Dec	13	14	14	12	12	13	11	13	12	11	14	14	11	11	10	**12**
	Annual	**226**	**218**	**275**	**169**	**181**	**217**	**186**	**201**	**228**	**199**	**228**	**249**	**175**	**158**	**147**	**202**

Figure 2.23 presents the monthly distribution of average water budget components within the Spencer Creek watershed.

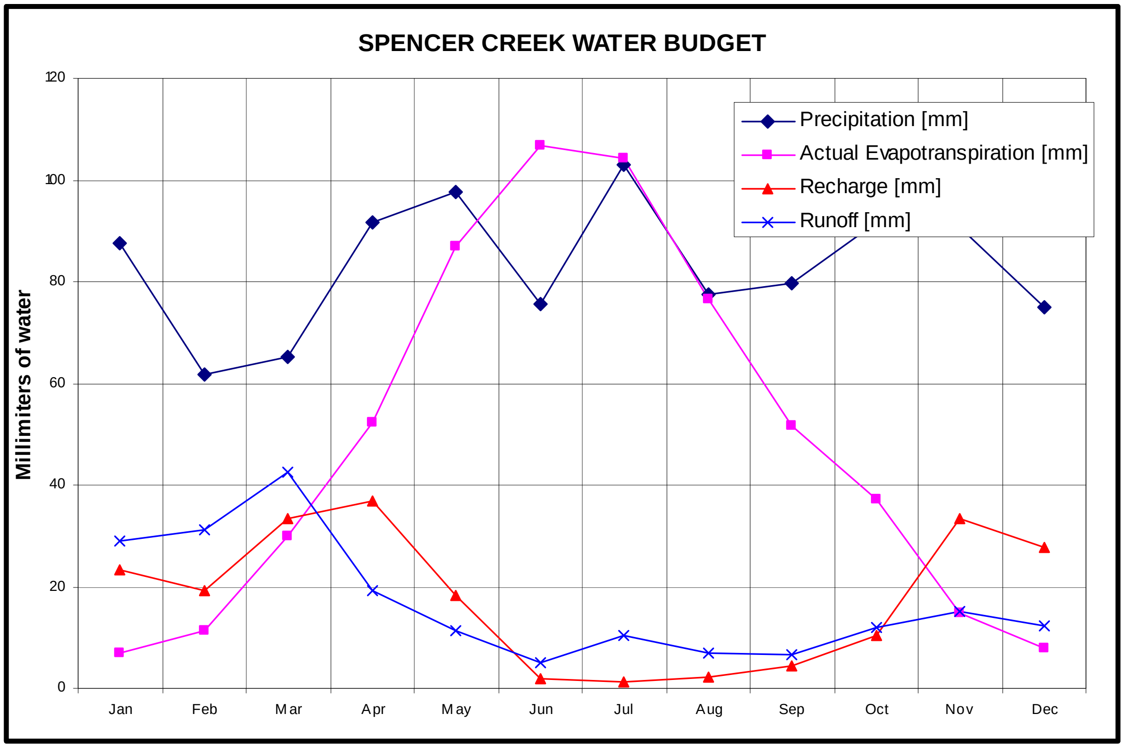

Figure 2.23 Spencer Creek Watershed Monthly Water Budget Components Distribution

Red Hill Creek

Water budget components of the Red Hill Creek watershed and its subwatersheds are presented in **Table 2.11**. The modeled period average annual precipitation is 935 mm. As the Red Hill Creek watershed is the most urbanized watershed in the Hamilton Region SPA, it is characterized by a high total runoff at 262 mm (28 percent of precipitation). The Green Hill subwatershed has the highest total runoff. Actual evapotranspiration in the Red Hill Creek watershed varies from 454 mm to 590 mm and on average is about 56 percent of the total precipitation. The average recharge in the Red Hill watershed is about 16 percent of the total precipitation.

The Red Hill Valley subwatershed data is incomplete and, therefore it was not used to obtain the watershed water budget components average monthly or annual values.

Table 2.11: Red Hill Creek Watershed Monthly Water Budget Components

Subwatershed/ Watershed		Green Hill	Hannon Creek	Lower Davis Creek	Montgomery Creek	Red Hill Valley*	Upper Davis Creek	Upper Ottawa	**Red Hill Creek Total**
Catchment [km^2]		11.64	10.97	3.75	3.75	13.28	7.25	13.83	**64.46**
Precipitation [mm]	Jan	77	79	79	79	76	79	79	**79**
	Feb	61	60	60	60	58	60	61	**60**
	Mar	62	62	61	61	59	61	62	**62**
	Apr	86	87	86	87	83	87	87	**87**
	May	94	94	93	93	90	93	95	**94**
	Jun	73	73	72	73	70	73	73	**73**
	Jul	93	95	94	94	91	95	94	**94**
	Aug	76	77	77	77	74	77	76	**76**
	Sep	73	74	74	74	71	74	74	**74**
	Oct	88	88	87	88	85	88	88	**88**
	Nov	85	86	85	86	82	86	86	**86**
	Dec	70	71	70	70	68	70	71	**71**
	Annual	**938**	**946**	**940**	**941**	**908**	**943**	**946**	**943**
Actual Evapotranspiration [mm]	Jan	6	7	7	7	7	7	7	**7**
	Feb	11	12	11	12	11	12	11	**11**
	Mar	26	31	29	29	28	30	28	**29**
	Apr	42	52	47	49	46	50	48	**47**
	May	65	87	75	79	73	83	79	**78**
	Jun	78	111	92	98	87	105	100	**97**
	Jul	77	105	90	94	84	100	95	**93**
	Aug	59	77	69	71	64	75	71	**70**
	Sep	41	50	46	47	44	49	46	**46**
	Oct	29	34	32	33	32	34	32	**32**
	Nov	14	15	14	14	14	15	14	**14**
	Dec	8	8	8	8	8	8	8	**8**
	Annual	**454**	**590**	**517**	**539**	**499**	**566**	**539**	**533**
Recharge [mm]	Jan	21	13	21	19	23	15	13	**16**
	Feb	23	13	21	20	22	16	14	**17**
	Mar	28	22	29	27	27	24	21	**24**
	Apr	26	27	30	29	27	28	26	**27**
	May	18	13	16	16	15	15	14	**15**
	Jun	5	0	4	3	3	2	1	**2**
	Jul	5	0	4	3	3	2	0	**2**
	Aug	5	0	4	3	3	1	0	**2**
	Sep	5	0	5	3	4	2	0	**2**
	Oct	13	2	12	9	10	5	3	**6**
	Nov	26	17	26	24	25	20	17	**21**
	Dec	20	16	21	20	22	17	16	**18**
	Annual	**195**	**123**	**192**	**175**	**182**	**146**	**124**	**152**
Runoff [mm]	Jan	36	38	31	33	31	37	41	**37**
	Feb	37	41	31	34	28	38	44	**39**
	Mar	33	38	32	32	28	36	40	**36**
	Apr	23	17	20	19	19	18	22	**20**
	May	23	15	17	16	17	15	20	**18**
	Jun	15	8	10	9	11	8	12	**11**
	Jul	23	13	15	15	16	13	19	**17**
	Aug	19	11	13	13	14	12	16	**14**
	Sep	17	10	12	11	12	11	14	**13**
	Oct	25	16	19	18	19	17	21	**20**
	Nov	26	18	20	19	21	19	23	**21**
	Dec	16	12	13	13	14	13	15	**14**
	Annual	**291**	**238**	**234**	**231**	**230**	**235**	**287**	**262**

Figure 2.24 presents the monthly distribution of average water budget components within the Red Hill Creek watershed.

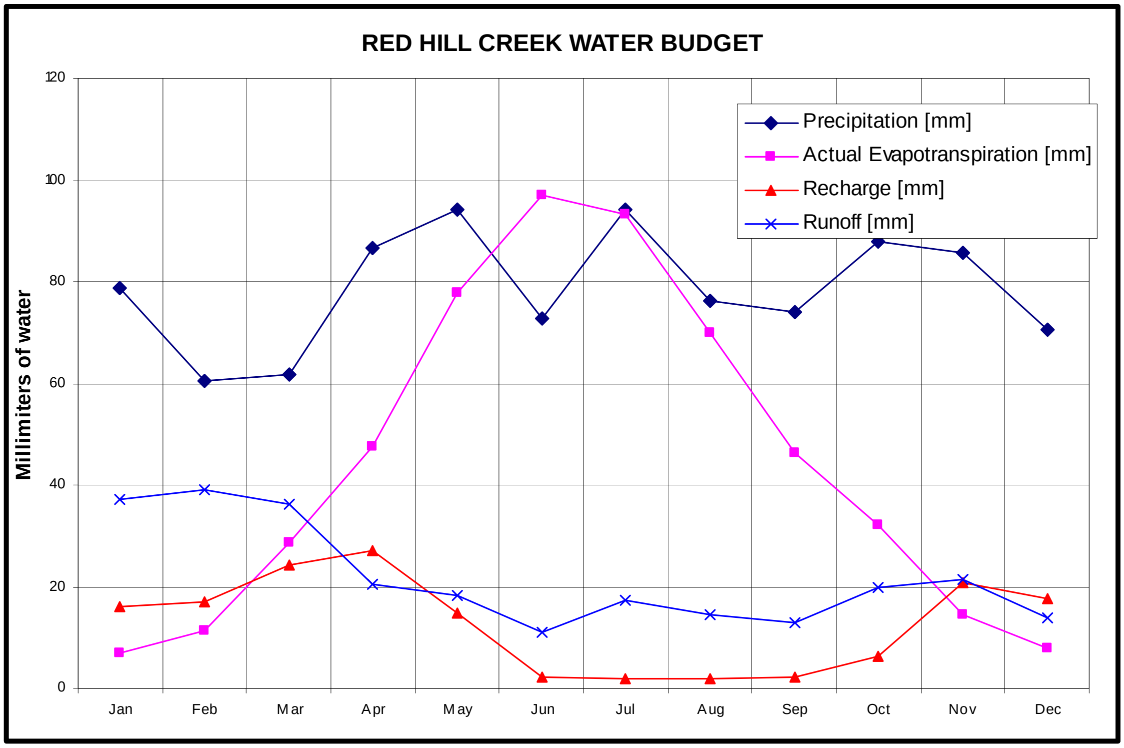

Figure 2.24 Red Hill Creek Watershed Monthly Water Budget Components Distribution

Stoney Creek

The Stoney Creek watershed has two (2) subwatersheds: Battlefield Creek and Stoney Creek. The average annual precipitation for the modeled period equals 939 mm. The average actual evapotranspiration across the watershed is about 60 percent of the total precipitation. The average total runoff and recharge are about 21 and 19 percent, respectively. **Table 2.12** summarizes the water budget components. The land uses in the watershed above the Escarpment are dominantly rural. However, below the Escarpment they are mostly urban. Hence the more developed Stoney-Battlefield subwatershed has slightly higher evapotranspiration.

Table 2.12: Stoney Creek Watershed Monthly Water Budget Components

Subwatershed/ Watershed		Battlefield Creek	Stoney Creek	**Stoney Creek Total**
Catchment [km^2]		7.47	21.03	**28.50**
Precipitation [mm]	Jan	79	80	**79**
	Feb	59	59	**59**
	Mar	61	61	**61**
	Apr	86	87	**87**
	May	93	92	**92**
	Jun	72	72	**72**
	Jul	94	94	**94**
	Aug	77	78	**78**
	Sep	74	74	**74**
	Oct	87	87	**87**
	Nov	85	86	**85**
	Dec	70	70	**70**
	Annual	**939**	**939**	**939**
Actual Evapotranspiration [mm]	Jan	7	8	**7**
	Feb	12	13	**12**
	Mar	30	31	**31**
	Apr	49	52	**51**
	May	79	85	**83**
	Jun	94	105	**102**
	Jul	91	100	**98**
	Aug	71	76	**75**
	Sep	48	50	**50**
	Oct	34	35	**35**
	Nov	15	15	**15**
	Dec	8	8	**8**
	Annual	**539**	**577**	**567**
Recharge [mm]	Jan	25	18	**20**
	Feb	24	19	**20**
	Mar	33	27	**28**
	Apr	32	28	**29**
	May	18	15	**15**
	Jun	4	2	**3**
	Jul	5	3	**3**
	Aug	5	2	**3**
	Sep	6	3	**3**
	Oct	14	7	**9**
	Nov	31	22	**24**
	Dec	24	19	**20**
	Annual	**220**	**164**	**179**
Runoff [mm]	Jan	27	32	**31**
	Feb	26	31	**29**
	Mar	28	32	**31**
	Apr	16	16	**16**
	May	12	12	**12**
	Jun	7	6	**6**
	Jul	11	11	**11**
	Aug	10	10	**10**
	Sep	9	9	**9**
	Oct	14	15	**14**
	Nov	16	17	**16**
	Dec	11	13	**12**
	Annual	**184**	**202**	**197**

Figure 2.25 presents the monthly distribution of average water budget components within the Stoney Creek watershed.

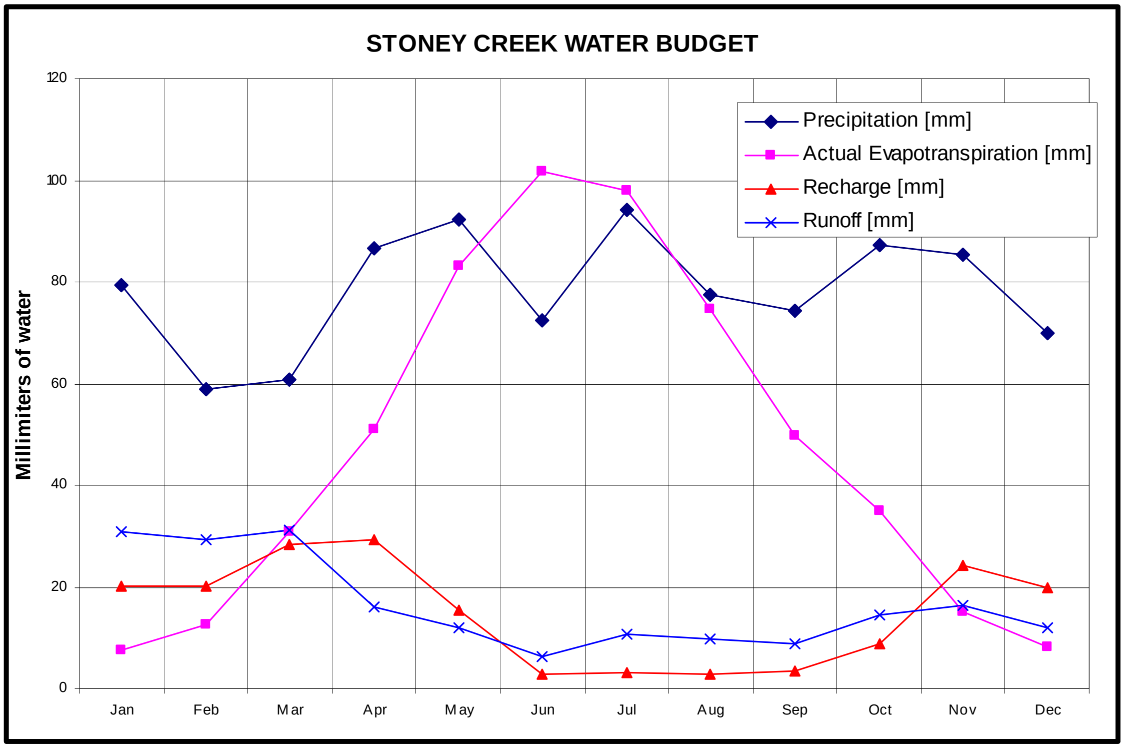

Figure 2.25 Stoney Creek Watershed Monthly Water Budget Components Distribution

Stoney Creek Watercourses

The Stoney Creek Watercourses is a group of 14 watersheds. Most of the watersheds are located below the Escarpment. WC 1, 2, 4, 5, 7, 9 and 12 have contributing areas that receive runoff from above the Escarpment. The Stoney Creek watercourses drain directly into Lake Ontario along approximately 10 km of shoreline. In the Stoney Creek Watercourses the annual total precipitation for the modeled period is 935 mm. The surface runoff, actual ET and groundwater recharge values are 209 mm (22 percent), 508 mm (54 percent) and 221 mm (24 percent), respectively (see **Table 2.13**).

Table 2.13: Stoney Creek Watercourses Watershed Monthly Water Budget Components

Subwatershed/ Watershed		WC 0	WC 1	WC 2	WC 3	WC 4	WC 5	WC 6	WC 7	WC 8	WC 9	WC 10	WC 10.1	WC 11	WC 12	**Stoney Creek Watercourses Total**
Catchment [km^2]		1.64	3.58	2.97	2.10	2.81	6.18	1.52	4.32	0.10	4.51	0.80	0.48	0.69	5.76	**37.46**
Precipitation [mm]	Jan	79	79	79	79	80	80	80	80	80	80	80	80	80	80	**80**
	Feb	59	59	59	59	59	58	58	58	58	58	58	58	57	58	**58**
	Mar	60	61	61	60	61	60	60	60	60	60	60	60	60	60	**60**
	Apr	86	86	86	86	86	86	86	86	86	86	86	86	86	86	**86**
	May	92	92	92	92	91	91	91	91	91	91	90	90	90	90	**91**
	Jun	72	72	72	72	72	72	72	72	72	72	72	72	72	72	**72**
	Jul	94	94	94	94	94	94	94	94	94	94	94	94	94	94	**94**
	Aug	77	78	78	78	78	78	78	78	78	78	78	78	78	78	**78**
	Sep	74	74	74	74	74	74	74	74	74	74	74	74	74	75	**74**
	Oct	87	87	87	87	87	87	87	87	87	87	86	86	86	86	**87**
	Nov	85	85	85	85	85	85	85	85	85	85	85	85	85	85	**85**
	Dec	69	70	70	69	69	69	69	69	69	69	69	69	69	69	**69**
	Annual	**933**	**937**	**937**	**936**	**936**	**936**	**935**	**936**	**934**	**935**	**934**	**933**	**933**	**935**	**935**
Actual Evapotranspiration [mm]	Jan	7	6	6	6	6	7	7	7	6	7	7	7	7	7	**7**
	Feb	11	11	11	11	11	12	12	12	10	12	12	12	12	12	**12**
	Mar	28	26	27	27	27	30	29	31	27	29	29	31	30	31	**29**
	Apr	47	43	43	42	44	48	46	50	46	46	48	51	49	51	**47**
	May	77	68	67	65	68	75	69	80	74	68	77	86	82	82	**73**
	Jun	95	82	80	77	81	88	79	96	89	77	95	110	104	99	**88**
	Jul	90	81	79	77	80	87	80	93	87	79	92	103	99	96	**86**
	Aug	68	63	62	60	63	68	64	72	68	64	70	77	74	75	**67**
	Sep	45	42	42	42	43	46	45	48	44	45	46	49	47	50	**45**
	Oct	31	29	29	30	30	33	33	34	31	33	32	34	33	35	**32**
	Nov	14	13	14	14	14	14	15	14	14	14	15	15	15	14	**14**
	Dec	8	7	7	8	7	8	8	8	7	8	8	8	8	8	**8**
	Annual	**519**	**471**	**465**	**459**	**473**	**516**	**485**	**544**	**503**	**483**	**531**	**583**	**561**	**559**	**508**
Recharge [mm]	Jan	15	22	24	25	26	28	32	27	11	37	19	14	14	24	**26**
	Feb	18	23	24	26	25	26	31	25	15	34	22	18	17	22	**25**
	Mar	22	28	28	29	30	33	35	35	18	42	26	23	22	32	**32**
	Apr	22	26	27	26	28	31	30	33	18	37	25	24	23	34	**30**
	May	11	15	16	16	17	18	19	17	9	21	13	11	11	17	**17**
	Jun	0	4	5	5	6	6	7	5	0	8	2	0	0	4	**5**
	Jul	0	5	6	6	7	7	9	6	0	10	3	0	0	6	**6**
	Aug	0	4	5	6	6	7	8	5	0	10	2	0	0	5	**6**
	Sep	0	5	6	6	7	8	9	6	0	11	3	0	0	6	**6**
	Oct	2	12	13	14	16	17	21	16	2	27	8	1	1	15	**15**
	Nov	15	24	26	26	28	31	34	31	11	43	20	12	12	30	**29**
	Dec	17	21	22	22	24	25	27	25	13	31	19	15	15	24	**24**
	Annual	**123**	**187**	**200**	**207**	**219**	**235**	**261**	**230**	**97**	**310**	**162**	**117**	**116**	**218**	**221**
Runoff [mm]	Jan	43	36	35	34	31	26	25	25	49	18	37	40	41	26	**29**
	Feb	34	30	29	28	27	23	20	22	39	15	28	30	32	23	**24**
	Mar	33	31	30	28	28	25	21	24	39	16	29	31	33	27	**26**
	Apr	24	25	24	24	22	17	17	15	29	14	21	19	21	15	**19**
	May	22	22	22	22	20	13	15	11	24	11	18	16	19	9	**15**
	Jun	14	14	14	14	12	7	9	6	14	6	11	9	11	4	**9**
	Jul	21	21	21	21	19	12	14	10	22	10	17	15	18	8	**14**
	Aug	18	18	18	18	16	11	12	9	19	9	15	13	16	7	**13**
	Sep	16	17	16	17	15	10	11	8	18	9	14	12	14	7	**12**
	Oct	24	24	24	24	21	15	17	13	27	13	20	18	20	12	**17**
	Nov	27	26	25	26	23	17	19	15	35	15	22	21	23	14	**19**
	Dec	19	17	17	17	15	11	12	9	24	9	14	13	14	9	**12**
	Annual	**295**	**281**	**274**	**272**	**247**	**188**	**191**	**166**	**337**	**144**	**245**	**239**	**262**	**162**	**209**

Figure 2.26 presents the monthly distribution of average water budget components within the Stoney Creek Watercourses watershed. The watershed is characterized by higher than average runoff with the Halton-Hamilton SPR.

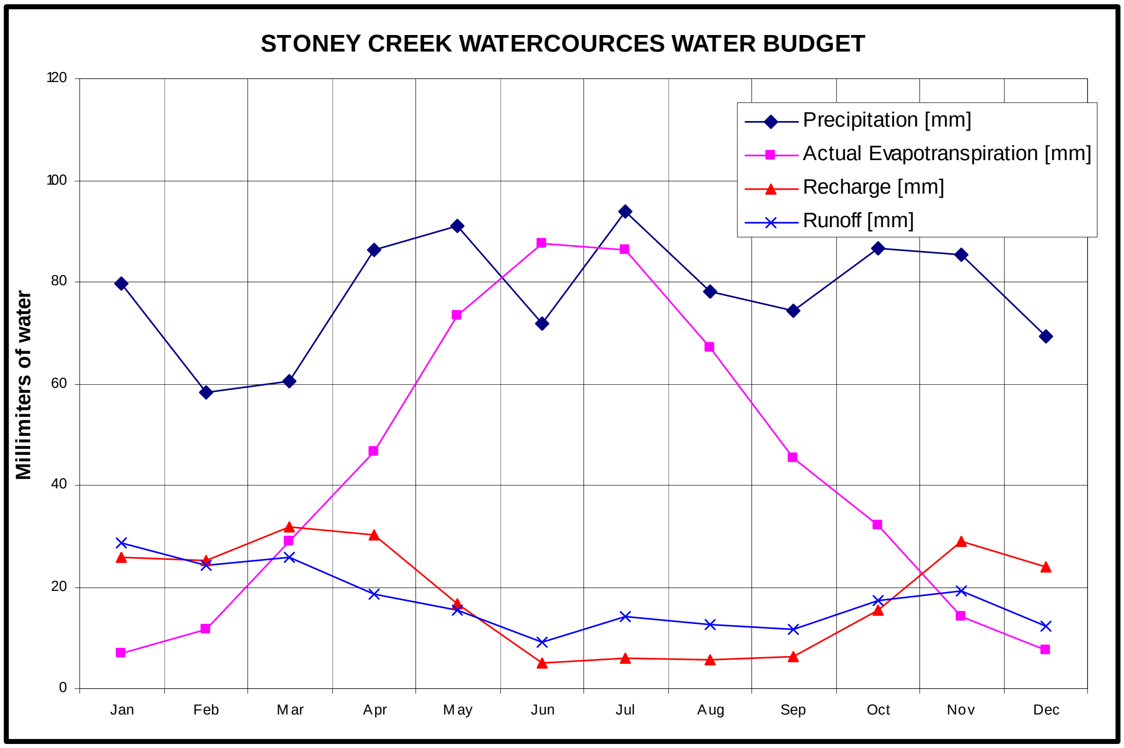

Figure 2.26 Stoney Creek Watercourses Monthly Water Budget Components Distribution

2.2.6 Streamflow

The streamflow data is required for the surface water supply estimates of all the Halton-Hamilton SPR subwatersheds. The calibrated surface water PRMS model was used to estimate the streamflows in the Halton-Hamilton SPR subwatersheds. To obtain the streamflow data on a subwatershed basis the PRMS model was ran for each of the sub-watersheds separately. The streamflow data was summarized and the monthly median flows were calculated for each of the subwatersheds.

The water supply for each subwatershed was calculated as monthly median streamflow rate (i.e. monthly 50th percentile) for each month over the modelled period. For the downstream subwatersheds, cumulative flow rates (m^3/s) were calculated by summarizing the modeled subwatershed flow and the upstream subwatersheds flow contribution.

The streamflow data is further discussed in the surface water supply **section 5.1**.

3 GROUNDWATER FLOW MODELS

3.1 Background and Model Selection

Use of a properly built and calibrated three-dimensional groundwater flow model is considered the best science-based method for estimating the lateral flows between subwatersheds for the water quantity stress assessment. As mentioned previously, Earthfx was retained by Halton Region and the City of Hamilton to develop groundwater models for their municipal jurisdictions. The Halton model includes the portion of the Halton Region lands within the Halton Region SPA. The Hamilton model covers only the portion of the Hamilton Region SPA north of the Dundas Valley.

In 2007 Halton Region and the City of Hamilton retained Earthfx to complete groundwater models for the two regions, including delineating WHPAs and assigning vulnerability scores within WHPAs.

The groundwater flow model used in this study was the USGS MODFLOW-96 code. MODFLOW simulates groundwater flow within an aquifer using a block-centered finite-difference approach. Layers can be simulated as confined, unconfined, or a combination of both. Flows from external stresses such as flow to wells, areal recharge, flow to drains, and flow through riverbeds can also be simulated. This code is recognized worldwide and has been extensively tested and verified in similar settings to the Halton-Hamilton SPR. The MODFLOW code is extremely well-suited for modelling regional and local-scale flow in multi-layered aquifer systems and can easily account for irregular boundaries, complex stratigraphy, and spatial variations in hydrogeologic properties. We acknowledge that applying a porous medium equivalent model may be questioned for modelling fractured bedrock aquifers, but considering the size of the models and limited information on the local and/or regional scale about groundwater fracture flow in the area it is reasonable to use MODFLOW code. The version of MODFLOW used is documented in McDonald and Harbaugh (1988) and Harbaugh and McDonald (1996). Best practices for groundwater modelling and professional judgment were followed when applying and calibrating the numerical models as outlined in the ASTM (2000) standards for groundwater flow modelling.

The study made extensive use of VIEWLOG (VIEWLOG Systems Inc., Version 3.9) to view, analyze, and manage hydrogeologic data. VIEWLOG allows a direct link to the extensive relational database that was constructed for the project. Along with the ability to facilitate geologic data analysis and spatial data management, VIEWLOG has an add-on module with pre-and post-processing functions for MODFLOW and MODPATH. The MODFLOW module was used to facilitate model construction and model calibration as well as interpretation and presentation of model results.

A post-processing program, Zone Budget (Harbaugh, 1990), was used to calculate groundwater budgets based on groundwater flow model results. The program determines simulated groundwater inflows and outflows across pre-defined zones (Q_{IN} and Q_{OUT}) as well as simulated groundwater discharge to surface water bodies (Q_D). Simulated discharge from the groundwater flow model was compared against estimated baseflows determined through hydrograph separation (Earthfx, 2008).

The results of the groundwater flow models are used for the estimates of groundwater supply and reserve for the WQSA.

The following **section 3.2** and **section 3.3** are summaries of the Halton and Hamilton modelling, respectively.

3.2 Halton Region Model

The three-dimensional numerical groundwater model used for the Halton Region SPA watershed Tier 1 WQSA was built upon earlier work completed by Earthfx (2005). The details of the groundwater flow model setup (i.e., hydrostratigraphy, hydraulic properties, boundary conditions, and stresses on the system) are available in the Earthfx (2010) report in **Appendix A**.

The MODFLOW code is well suited for the Halton watershed to simulate the:

- groundwater flow conditions in multi-layered aquifer systems with irregular boundaries;
- complex stratigraphy;
- spatial variations in hydraulic properties, and
- stresses on the system.

Following the model development and set-up the MODFLOW groundwater flow model was run as a steady state simulation (no storage considered).

3.2.1 Model Development

Hydrostratigraphic and Model Layers

Following a detailed review of the Halton Region SPA topography, physiography, bedrock geology and overburden geology conceptual stratigraphic model layers were created. An understanding of the complex geology of the area was critical in creating the three-dimensional hydrostratigraphic layers of the model. The aquifer layers may differ from the stratigraphic layers: for example, the bedrock stratigraphic layer beneath the Milton and Campbellville wells is Queenston Formation; however, from a hydrostratigraphic perspective, the Queenston Formation includes both an upper weathered aquifer and a deeper, unweathered aquitard.

The MODFLOW code requires continuous model layers across the entire model domain. To comply with this requirement it was necessary to match the interpreted geologic layers in the western part of the model (the Niagara Escarpment) with the interpreted overburden geologic layers in the eastern part of the model. The interpreted hydrostratigraphic layers for the Halton Region SPA model area (both above and below the Niagara Escarpment) are listed in **Table 3.1** below. The table also identifies which layers are considered to be aquifers and which are aquitards.

Table 3.1: Halton Model Hydrostratigraphic Layer Summary

Layer No.	West part of Study Area (above Niagara Escarpment)			East part of Study Area (below Niagara Escarpment)	
	Hydrostratigraphic Unit	Type		Hydrostratigraphic Unit	Type
1	Recent Deposits (where present)	Poor Aquifer		Recent Deposits	Poor Aquifer
2	Halton Till (where present)	Aquitard		Halton Till	Aquitard
3	Upper Sediments	Poor Aquifer		Oak Ridges Aquifer Complex (ORAC)	Aquifer
4	Wentworth Till	Aquitard		Upper Newmarket Till	Aquitard
5	Inter-till Sediments	Aquifer		Inter-till Sediments (ITS)	Aquifer
6	Port Stanley Till	Aquitard		Lower Till	Aquitard
7	Guelph Fm./Weathered Bedrock	Aquifer		Thorncliffe Aquifer Complex (TAC)	Aquifer
8	Eramosa/Upper Amabel	Aquitard		Sunnybrook Diamict	Aquitard
9	Amabel Production Zone	Aquifer		Scarborough Aquifer Complex (SAC)	Aquifer
VL*	Lower Amabel to Cabot Head	Aquitard			
10	Whirlpool Fm.	Poor Aquifer		Weathered Queenston Fm.	Poor Aquifer

* - MODFLOW virtual layer

Using the hydrostratigraphic layers a groundwater flow model was constructed by converting the hydrostratigraphic layers into numerical flow model layers. Each of these layers was assigned a set of hydrologic parameters, e.g., hydraulic conductivity, vertical conductance, porosity, etc. **Figures 48** through **51** of **Appendix A** show hydraulic conductivity distribution for model layers 3, 5, 7 and 9. MODFLOW requires continuous, non-zero layer thickness throughout the model domain. It should be noted that some of the hydrostratigraphic layers are not continuous, e.g., aquifers pinching out. To address the non-zero thickness requirement, a pinch out zone was represented as a thin model layer with the physical properties of the next layer above or below the missing layer.

Grid design

MODFLOW uses the finite-difference method to calculate flows with an aquifer and requires that the study area be subdivided vertically into several layers, where each layer can represent a hydrogeologic unit. The study area is also subdivided horizontally into a grid of small rectangular cells. In general, a better representation of the spatial change in water levels is achieved by using smaller cells in areas of steep groundwater gradients. Aquifer properties, such as top and bottom elevations for each layer, hydraulic conductivity, and recharge and discharge rates, are assigned to each cell.

The finite-difference grid design used to represent the model area started with square cells, each 50 metres on a side. The grid was refined in the vicinity of the Milton and Campbellville wellfields to provide better grid resolution around the wells and in the bedrock valley system. The Halton Region model grid consists of 885 rows by 890 columns with 10 layers. The hydrostratigraphic layers were adjusted to assure continuous, non-zero layer thickness throughout the model domain. To illustrate layer continuity a southwest-northeast section through model layers in the Campbellville and Kelso wellfields is presented in **Figure 22** of **Appendix A.**

Model Boundaries

MODFLOW requires an appropriate set of boundary conditions to simulate interactions of the groundwater flow model with physical surrounding hydrologic systems. Boundary conditions are specified for cells that lie along lines corresponding to the physical boundaries.

MODFLOW can represent three general types of conditions along the physical boundaries of the model. All three boundary condition types, constant head, no-flow, and head-dependent discharge boundaries, were employed in the numerical model to represent natural hydrologic boundaries. The natural hydrologic boundaries were generally well outside the likely area to be affected by municipal pumping, therefore they did not influence the groundwater flow patterns in the vicinity of any of the municipal wells.

A constant-head boundary set at 75.2 masl was used to represent the Lake Ontario shoreline. A no-flow boundary condition was applied along the lateral boundary of the model area as shown on **Figure 8** in **Appendix A**. It was assumed that flow across the external boundaries near the major streams was expected to be small. A no-flow boundary condition was applied at the base of the lowest model layer, which represents the deep unweathered bedrock layers.

Streams and rivers were simulated using two different types of head-dependent discharge boundaries, referred to in MODFLOW terminology as “rivers” and “drains” (McDonald and Harbaugh, 1988). MODFLOW drains were used to simulate discharge to the headwater tributaries of the streams (Strahler Class 1, 2, and 3). The key assumption regarding drains is that leakage occurs in only one direction, from the aquifer to the drain (**Figures 46 A** and **46 B** in **Appendix A**). MODFLOW river boundaries were used to simulate discharge to the lower reaches of major streams (Strahler Class 4 and above). The key assumption regarding MODFLOW rivers is that leakage can occur in either direction when the aquifer head is above the bottom elevation of the streambed (**Figures 46 C** and **46 D** in **Appendix A**).

All the river and stream boundaries were assigned to the upper most active layer of the model. Streambed conductance values were assigned to all streams and rivers based on an assumed hydraulic conductivity values in the range of silt to silty-fine sand (1.0×10^{-6} m/s) by default and streambed thickness of 1 metre for drains and 2 metre for rivers. If any cell had a lower hydraulic conductivity than the base value of 1×10^{-6} m/s, then the drain segment was assigned a value of 0.2 times the cell value. Elevations of streams and rivers were assigned based on the Digital Elevation Model (DEM) for the study area.

Wetland areas and lakes were also treated as MODFLOW drains. Each cell underlying the wetland was assigned a drain conductance calculated using a length and width equal to the length and width of the MODFLOW cell and a hydraulic conductivity value set to 1.0×10^{-7} m/s unless the wetland was located on a lower permeability unit. **Figure 47** in **Appendix A** shows the locations of all MODFLOW river and drain cells representing the streams, lakes, and wetlands in the study area.

Recharge

As discussed earlier in section 2.2, the average annual recharge was estimated using the PRMS model. Recharge was assigned to each model cell simulated using the RECHARGE module of the

MODFLOW code. If a layer went "dry" during simulation (i.e., the simulated head fell below the layer bottom), recharge was passed to the underlying layer.

Municipal Well Pumping

Simulated pumping rates for the Kelso, Walkers Line and Campbellville municipal wells were assigned based on the rates suggested by the Halton Region as representative of actual rates rather than the maximum permitted wellfield rates (Halton Region does not plan on increasing the pumping rates from the three systems). Allocation of pumping to individual wells is shown in **Table 2** in **Appendix A**. Extraction of groundwater for other users was not simulated.

3.2.2 Model Calibration

Model calibration is an iterative process necessary to obtain best combination of input parameters assuring acceptable comparison between the simulated and observed water levels and groundwater discharges (calibration targets). Calibration of the groundwater flow model was performed using a systematic trial-and-error process in which results of successive model runs were used to improve the initial estimates of model parameters (primarily hydraulic conductivity and vertical anisotropy). Spatial analysis of residuals (i.e., the difference between simulated and observed values) helped to highlight areas where the model was or was not performing well. Statistical tests, in which the observed and simulated groundwater heads and baseflow estimates were compared, helped determine whether the calibration met the required goodness-of-fit criterion.

Maps showing the final calibrated hydraulic conductivity distribution for model layers 3, 5, 7 and 9 (**Table 3.1**) are shown in **Figures 48** through **51** of **Appendix A**, respectively. The zones of higher hydraulic conductivity in Layer 7 (**Figure 50**, **Appendix A**) represent the bedrock valley infill. The high conductivity zone in Layer 9 was interpreted by Earthfx as the zone where the Lower Amabel subcrops above the Niagara Escarpment (**Figure 51**, **Appendix A**).

Water Level Calibration

The primary targets for regional water level calibration were the observed static water levels obtained from the MOE Water Well Information System (WWIS) database. It should be noted that the geostatistical analysis of the variance in the MOE WWIS data for the modeled area indicated a variogram nugget of 4 $m^{2,}$ suggesting an intrinsic local-scale standard error of approximately ±2 m. Trying to achieve a calibration at a greater accuracy than the intrinsic error in the static water level data is not justified. Accordingly, the focus of the regional calibration to the MOE WWIS data was on matching head and flow patterns on a broader scale.

Three calibration statistics were used to assess and demonstrate model accuracy: the mean error (ME), mean absolute error (MAE), and root mean squared error (RMSE). These are given by Anderson and Woessner (1992) as:

$$\text{Mean Error} = \frac{1}{n}\sum_{1}^{n}(h_O - h_S)_i$$

$$\text{Mean Absolute Error} = \frac{1}{n}\sum_{1}^{n}\left|(h_O - h_S)_i\right|$$

$$\text{Root Mean Squared Error} = \sqrt{\frac{1}{n}\sum_{1}^{n}(h_O - h_S)_i^2}$$

where: h_o - Observed hydraulic head;
h_s - Simulated hydraulic head at the same point; and
n - Number of wells.

Calibration statistics comparing the 3205 observed MOE water levels to the simulated heads are presented in **Table 3.2** below.

Table 3.2: Halton Model Water Level Calibration Statistics

Model Result By Aquifer/Layer	Number of Wells	ME [m]	MAE [m]	RMSE [m]	Range in Observations [m]	RMSE as Percent of Range
Layer 3 - Upper Sediments/ORAC	585	-1.32	4.58	5.88	215	2.7
Layer 5 - Inter-Till Sediments /INS	118	-0.12	4.85	6.5	170	3.8
Layer 7- Guelph Fm./TAC	54	-7.32	8.63	9.89	110	9.0
Layer 9 - SAC	1424	-2.89	5.5	7.46	260	2.9
Layer 9 - Amabel Production Zone	827	-4.47	6.12	7.85	140	5.6

The magnitude of the absolute error ranges from very small (-0.12 m) to -7.3 m. The negative sign on the ME value indicates that simulated values are, on average, higher than the observed values (the model over-predicts water levels). The range of the MAE (4.6 to 8.6 m) and RMSE (5.9 to 9.9 m) provide good estimates of the average magnitude of the difference between the observed and simulated values.

Values for MAE and RMSE are often compared to the overall response of the model (Anderson and Woessner, 1992); in this case, the range in observed heads over the study area. The total range of observations varies from 110 m to 260 m, depending on the particular aquifer. Accordingly, RMSE ranged from 2.7 percent of the range for Layer 3 to 9.0 percent for Layer 7. The statistics for Layer 7 are influenced to a large extent by the sparsity of data within that unit. The MODFLOW mass balance error for the model was quite reasonable at less than 2 percent.

Figures 52 through **55** in **Appendix A** show the simulated water levels for model layers 3, 5, 7 and 9. The observed heads for these layers are also posted on the figures as dots plotted using the same colour scale. Most of the coloured dots blend into the colour fill for the simulated water levels indicating a good match. The poorest match is in Layer 7 in the northwest corner of the model near Morriston where predicted water levels are much higher than observed. Layer 7 is also characterized by the poorest calibration statistics as summarized in **Table 3.2** above.

Simulated water levels show more depression in the vicinity of the streams, indicative of groundwater discharge to the streams. The difference between the interpolated and simulated heads in these areas is most likely due to the observed water level data sparsity.

Figures 56 through **58** in **Appendix A** show scatterplots of the observed static water levels versus simulated heads in each aquifer layer. Ideally, all data points should fall on the 45° line shown on the graph. The scatterplots show that most data points fall within bands defined by ±5 to 6 m, except for Layer 7 (±8.6 m). The model generally tends to over-predict rather than under-predict heads over most of the area except in the north-central part of the study. The match to the observed heads in Layer 9 in the Campbellville and Milton area is quite good and shows little bias.

Simulated Groundwater Discharge to Streams

Another important flow model calibration target is to match annual average simulated baseflow to estimated baseflow at the Environment Canada streamflow gauges. The summary of the HYDAT stations used in the calibration process is presented in **Table 18** of **Appendix A**. The table compares the model estimate of the groundwater discharge to the calculated baseflow at the four key gauges with catchment covering most of the model area. Excellent matches were achieved at the Bronte Creek at Carlisle and Oakville (16 Mile) Creek at Milton gauges (gauges near to the wellfields) but poorer matches were achieved at the East Oakville at Omagh and Grindstone Creek gauges (both of which are quite far from the wellfields).

It is possible that the poor match at East Oakville Creek is due, in part, to the specifying of a no-flow condition along the Oakville Creek watershed boundary (the north eastern boundary of the model, as shown in **Figure 8** of **Appendix A**). Some groundwater flow may be lost to the Credit watershed in the upper part of the East Oakville Creek subwatershed and to Joshua's Creek in the lower part of the subwatershed.

3.2.3 Model Results

A reasonably calibrated flow model can be used to determine water levels in an area, groundwater flow directions, discharge to streams and rivers, etc. Maps showing the simulated heads in the Halton model layers 3, 5, 7, and 9, are presented in **Figures 52** through **55** in **Appendix A**. White areas on the figures denote "dry" cells, that is, places where the simulated water level lies below the base of the model layer. This occurs primarily in areas where there is severe topographic change, such as along the Niagara Escarpment, where water levels likely drop into the deeper layers which outcrop at the surface. The shaded areas appear patchier for the upper layers because the interpreted geologic units tend to be discontinuous and/or are unsaturated.

Based on the results of the calibrated flow model, Zone Budget post-processing simulations were carried out to obtain lateral flows into subwatersheds as part of the water supply for water quantity stress assessment.

3.3 City of Hamilton Model

The three-dimensional numerical groundwater model used for the Hamilton Region SPA watershed Tier 1 WQSA was built upon earlier work completed by SNC-Lavalin Engineers and Constructors Incorporated in association with Charlsworth and Associates (SNC-Lavalin and Charlesworth, 2006) and work completed for Halton Region (Earthfx, 2005). The details of the groundwater flow model setup (i.e., hydrostratigraphy, hydraulic properties, boundary conditions, and stresses on the system) are available in the Earthfx (2010) report in **Appendix B**.

3.3.1 Model Development

Hydrostratigraphic and Model Layers

Similarly to the Halton model development following a detailed review of the Hamilton Region SPA topography, physiography, bedrock geology and overburden geology conceptual stratigraphic model layers were created. An understanding of the complex geology of the area was critical in creating the three-dimensional hydrostratigraphic layers of the model. The aquifer layers may differ from the stratigraphic layers.

For detailed stratigraphic model layer development and hydrostratigraphic layer development please see **Appendix B section 3.0**. The interpreted hydrostratigraphic layers for the Hamilton model area are listed in **Table 3.3** below. The table also identifies which layers are considered to be aquifers and which are aquitards.

Table 3.3: Hamilton Model Hydrostratigraphic Layer Summary

Layer No.	**Study Area**	
	Hydrostratigraphic Unit	Type
1	Surficial Deposits	Variable
2	Upper Till	Aquitard
3	Basal Sand	Aquifer
4	Weathered Bedrock	Aquifer
5	Eramosa	Aquitard
6	Upper Amabel/Gasport	Aquitard
7	Middle Amabel	Aquifer
8	Lower Amabel/Gasport	Aquitard
9	Reynales to weathered Queenston	Aquitard/Aquifer
10	Unweathered Queenston	Aquitard

Using the hydrostratigraphic layers a groundwater flow model was constructed by converting the hydrostratigraphic layers into numerical flow model layers. Each of these layers was assigned a set of hydrologic parameters, e.g., hydraulic conductivity, vertical conductance, porosity, etc. **Figures 48** through **51** of **Appendix A** show hydraulic conductivity distribution for model layers 3, 5, 7 and 9. MODFLOW requires continuous, non-zero layer thickness throughout the model domain. It should be noted that some of the hydrostratigraphic layers are not continuous, e.g., aquifers pinching out. To address the non-zero thickness requirement, a pinch out zone was represented as a thin model layer with the physical properties of the next layer above or below the missing layer.

Grid design

MODFLOW uses the finite-difference method to calculate flows with an aquifer and requires that the study area be subdivided vertically into several layers, where each layer can represent a hydrogeologic unit. The study area is also subdivided horizontally into a grid of small rectangular cells. In general, a better representation of the spatial change in water levels is achieved by using smaller cells in areas of steep groundwater gradients (see **Figure 42** and **Figure 43** in **Appendix B**). Aquifer properties, such as top and bottom elevations for each layer, hydraulic conductivity, and recharge and discharge rates, are assigned to each cell.

The Hamilton Region model grid consists of 699 rows by 683 columns with 10 layers. The hydrostratigraphic layers were adjusted to assure continuous, non-zero layer thickness throughout the model domain.

Model Boundaries

MODFLOW requires an appropriate set of boundary conditions to simulate interactions of the groundwater flow model with physical surrounding hydrologic systems. Boundary conditions are specified for cells that lie along lines corresponding to the physical boundaries.

Constant head, no-flow, and head-dependent discharge boundaries, were employed in the numerical model to represent natural hydrologic boundaries. The natural hydrologic boundaries were generally well outside the likely area to be affected by municipal pumping, therefore they did not influence the groundwater flow patterns in the vicinity of any of the municipal wells. Although a constant head boundary is close to the Greensville municipal well it is downgradient of the well and it does not affect the results for use in Water Budget and WQSA.

To resolve some problems with model stability a constant head boundary was applied at a setback of 500 metres along the face of the Escarpment. This boundary vastly improved model stability and has no effect on model results.

A no-flow boundary condition was applied at the base of the lowest model layer, which represents the deep unweathered bedrock layers.

Streams and rivers were simulated using two different types of head-dependent discharge boundaries, referred to in MODFLOW terminology as “rivers” and “drains” (McDonald and Harbaugh, 1988). MODFLOW drains were used to simulate discharge to the headwater tributaries of the streams (Strahler Class 1, 2, and 3). Drains allow for leakage in only one direction, from the aquifer to the drain (**Figures 44 A** and **44 B** in **Appendix B**). MODFLOW river boundaries were used to simulate discharge to the lower reaches of major streams (Strahler Class 4 and above). The key assumption regarding MODFLOW rivers is that leakage can occur in either direction when the aquifer head is above the bottom elevation of the streambed (**Figures 44 C** and **44 D** in **Appendix A**).

All the river and stream boundaries were assigned to the upper most active layer of the model. Streambed conductance values were assigned to all streams and rivers based on an assumed hydraulic conductivity values in the range of silt to silty-fine sand ($5.0x10^{-6}$ m/s). Elevations of streams and rivers were assigned based on the Digital Elevation Model (DEM) for the study area.

Wetland areas were treated as MODFLOW drains under an assumption that that most of the wetlands are discharge zones. **Figure 45** in **Appendix B** shows the locations of all MODFLOW river and drain cells.

Recharge

As discussed earlier in **section 2.2**, the average annual recharge was estimated using the PRMS model, which encompasses both SPAs. Recharge was assigned to each model cell simulated using the RECHARGE module of the MODFLOW code. If a layer went "dry" during simulation (i.e., the simulated head fell below the layer bottom), recharge was passed to the underlying layer.

Municipal Well Pumping

Simulated pumping rates for the Greensville and Freelton municipal wells were set to the maximum permitted rates. The simulated pumping rates for Carlisle were set to lower than permitted rates as the model indicated that the Carlisle wells cannot be pumped simultaneously at maximum permitted rates. This was supported by operational data. For details about the simulating pumping rates and schedule please see **section 4.6** and **Table 7** in **Appendix B**

3.3.2 Model Calibration

Calibration of the groundwater flow model was performed using a systematic trial-and-error process in which results of successive model runs were used to improve the initial estimates of model parameters. Calibration targets were the observed water levels from the MOE WWIS database in the overburden and bedrock and the estimates of groundwater discharges to streams based on the Environment Canada HYDAT streamflow gauges with long term record. In addition to matching the water level and baseflow data Earthfx conducted visual comparison to assure that the flow patterns and potentiometric surfaces were properly represented.

Section 5 of **Appendix B** report fully addresses the calibration process and the calibration results.

Mean Error (ME) Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) calibration statistics were used to assess and demonstrate model accuracy. These statistics were defined in the Halton model calibration section and are also defined in the Earthfx report in Appendix B section 5.3.

The following **Table 3.4** presents a summary of the calibration statistics:

Table 3.4: Hamilton Model Water Level Calibration Statistics

Model Result By Aquifer/Layer	Number of Wells	ME [m]	MAE [m]	RMSE [m]	Range in Observations [m]	RMSE as Percent of Range
Layer 2 – Overburden Heads	1985	-1.17	5.27	6.88	150	4.6
Layer 7 – Bedrock Heads	6472	-1.80	4.06	5.69	160	3.7

The results of the simulated discharges to streams are addressed in **section 5.4** of **Appendix B** report and are summarized in **Table 19** and **Figure 61** of **Appendix B**. Generally, the match between the simulated and observed baseflows is good except for Fairchild Creek near Brantford, which is outside of our study area.

3.3.3 Model Results

The Hamilton flow model can be used to determine water levels in an area, groundwater flow directions, discharge to streams and rivers, etc. Maps showing the simulated heads in the Hamilton model layers 2 and 7, are presented in **Figures 56** and **Figure 57** in **Appendix A,** respectively. White areas on the figures denote "dry" cells, that is, places where the simulated water level lies below the base of the model layer.

Based on the results of the calibrated Hamilton flow model, Zone Budget post-processing simulations were carried out to obtain lateral flows into subwatersheds as part of the water supply for water quantity stress assessment.

4 WATER DEMAND

The next step in the Water Quantity Stress Assessment is to estimate the demand on the water supplies. The following subsections summarize the sources of the water demand estimates and the final consumptive water demands and assumptions used in the estimates.

4.1 Water Demand Data Sources

Groundwater and surface water demands are estimated separately for all subwatersheds within the Halton Region SPA and the Hamilton Region SPA. The groundwater water demand is estimated on an annual basis and on a monthly basis. The surface water demand is estimated on monthly basis only. Data sources used to estimate water demand include:

3. Permitted sources:
    - Permit To Take Water (PTTW) database from the Ministry of the Environment (MOE);
    - Actual water takings (PTTW Water Taking Reporting System, Halton Region Agricultural Survey, Halton-Hamilton SPR collection); and
    - Actual municipal water takings and projected future municipal water takings obtained from Halton Region and the City of Hamilton.
4. Non-permitted sources:
    - Domestic water takings based on population estimates (present 2006 and future 2031); and
    - Agricultural water takings based on the Statistics Canada Census of Agriculture (2006).

The 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 water source and not returned back to the same source in a reasonable time. For example, water taken from a stream/aquifer and not returned back to the same stream/aquifer will be considered as consumptive with respect to the source. In the Halton Region SPA the Kelso and Walkers Line municipal wells extract groundwater from aquifers of the Upper West Branch subwatershed and then the water is discharged as waste water treatment effluent into the West Branch subwatershed of Sixteen Mile Creek, therefore, the consumptive factor for these water takings is 100 percent with respect to the source and the subwatershed.

If the water is returned to the same source within the same subwatershed, the MOE proposed specific consumptive factors as given in **Table 4.1**.

Table 4.1: Consumptive Use Factors

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 Form	0.9	Institutional	Schools	0.25
Agriculture	Tender Fruit	0.8	Miscellaneous	Dams and Reservoirs	0.1
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 - Industrial	0.25	Water Supply	Communal	0.2
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			

It should be noted that the proposed consumptive use factor for Dams and Reservoirs of 0.1 was changed to 0 in the Halton-Hamilton SPR water quantity stress assessment. It was assumed that there is no consumptive taking through dams and reservoirs as the “taking” occurs only during the months when there is an abundance of water and any increase in evaporation from the larger surface area of open body of water was accounted for through the PRMS surface water model.

The PTTW Database summarizes all the permits into ten (10) different categories by general purposes and then the permits are subdivided into specific sub-purpose categories. The ten (10) categories and their appropriate specific purpose takings are summarized in **Table 4.1**.

To address seasonality of the water demands a monthly use factor was used. **Table 4.2** (GRCA, 2005) is a summary of the monthly use factors for all specific purpose water takings as summarized in the MOE PTTW Database.

Table 4.2: Monthly Demand Adjustment Factors

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural	Field and Pasture Crops	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Fruit Orchards	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Market Gardens/Flowers	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Nursery	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Other-Agricultural	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Sod Farm	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Tender Fruit	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Tobacco	0	0	0	0	0	0	1	1	0	0	0	0
Commercial	Aquaculture	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Bottled Water	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Golf Course Irrigation	0	0	0	0	1	1	1	1	1	0	0	0
Commercial	Mall/Business	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Other-Commercial	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Snowmaking	1	1	0	0	0	0	0	0	0	0	0	1
Construction	Other-Construction	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Road Building	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Construction	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Other-Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Pits and Quarries	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Aggregate Washing	0	0	0	0	1	1	1	1	1	1	1	0
Industrial	Cooling Water	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Food Processing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Manufacturing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other-Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other-Industrial	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Pipeline Testing	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Other-Institutional	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Schools	1	1	1	1	1	1	0	0	1	1	1	1
Miscellaneous	Damsand Reservoirs	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Heat Pumps	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Other-Miscellaneous	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Pumping Test	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Wildlife Conservation	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Other-Recreational	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Wetlands	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Groundwater	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Other-Remediation	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Campgrounds	0	0	0	0	1	1	1	1	1	0	0	0
Water Supply	Communal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Municipal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Other-Water Supply	1	1	1	1	1	1	1	1	1	1	1	1

Note: 0 – indicates that on average no water taking occurs for a specific purpose
1 – indicates that on average water taking occurs for a specific purpose

Consumptive factors were used for all permitted and non-permitted use categories.

The sources and methodology of the permitted and non-permitted water demand estimates are summarized in the following subsections 4.2 through 4.5.

4.2 PTTW Demand

The MOE PTTW Management Database is an important component of the Water Budget and Water Quantity Stress Assessment. Section 34 of the Ontario Water Resources Act (OWRA) requires anyone taking more than a total of 50,000 litres/day of water with the exception of water taking for domestic use, livestock watering and water taking for firefighting, to obtain a Permit from a Director appointed by the Minister of the Environment. The MOE PTTW Management Database is a summary of water takings requiring a permit from the MOE and contains information such as: the locations of water takings, the water use category, water sources and the maximum permitted water taking values. The PTTW Management Database (Version 1, August 2006) used in the Tier 1 Water Budget analysis was improved by:

1. obtaining hard copies of all the available permits;
2. scanning the hard copies to pdf format;
3. linking the pdf copies to the individual database records;
4. reviewing / correcting the following information in the database
    a. water handling practices;
    b. multiple source permits distribution of takings;
    c. groundwater versus surface water taking classification;
    d. maximum takings for each source;
    e. spatial locations of the sources, and
5. adding 36 new permits.

In total, 194 hard copy permits were collected, reviewed, scanned to pdf and linked to records within the database.

For this assessment permits with an expiry date of March 21, 2003 or later were classified as 'active'.

The updated PTTW database was examined to identify, and exclude from analysis, any temporary permits issued for activities such as construction dewatering and well testing. The permits that had duplicate entries or were replaced by newer permits, revoked, or voluntarily surrendered were also excluded. After an initial PTTW Database review the total number of permits within Halton-Hamilton SPR was narrowed down to 131 permits. The total number of active permits and sources (surface water plus groundwater) in the Halton Region SPA is 81 and 157, respectively. The total number of active permits and sources (surface water plus groundwater) in the Hamilton Region SPA is 50 and 88, respectively. Hence, some of the permits allow water taking from more than one source.

Missing and additional information (e.g., number of days of water taking, demand proportion, consumptive subwatershed and consumptive unit) was added to the PTTW database by taking into consideration the specific use and conditions for each permit. The source of water takings were adjusted to better reflect the actual conditions. For example, a primarily groundwater fed pond was changed from a surface water source to a groundwater source.

In the Halton Region SPA there are 67 surface water-based water takings/sources included in 37 permits, and 90 groundwater-based water takings/sources accounting for 52 permits. Eight (8) permits have both groundwater and surface water sources. **Table 4.3** provides a summary of the number of permits by general purpose in the Halton Region SPA.

Table 4.3: Summary of Halton Region SPA PsTTW – Number of Active Permits

Source	Agriculture	Commercial	Dewatering	Industrial	Remediation	Miscellaneous	Recreational	Water Supply	Total
Surface Water	15	11	0	1	0	2	0	0	**29**
Groundwater	18	4	4	1	2	0	0	15	**44**
Surface Water and Groundwater	1	7	0	0	0	0	0	0	**8**
Total	**34**	**22**	**4**	**2**	**2**	**2**	**0**	**15**	**81**

Notes: Miscellaneous include recreation, ecological, and flow augmentation.
Lake-based permits are excluded.

In the Hamilton Region SPA there are 27 surface water-based water takings/sources included in 17 permits, and 61 groundwater-based water takings/sources included in 35 permits. There are two (2) permits which include both groundwater and surface water sources. **Table 4.4** provides a summary of the number of permits by general purpose in the Hamilton Region SPA.

Table 4.4: Summary of Hamilton Region SPA PsTTW – Number of Active Permits

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**

Notes: Miscellaneous include flow augmentation and snowmaking permits.
Lake-based permits are excluded.

Figure 4.1 and **Figure 4.2** show the locations of all groundwater and surface water active permit sources in the Halton Region SPA and Hamilton Region SPA, respectively.

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 4.1

Permit To Take Water (PTTW) Source Location

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment

Roads

- Highway
- Regional
- Hydrography
- Waterbody

Active Permit To Take Water (PTTW)

SourceType

- Groundwater
- Surface Water
- Municipal Intake

Source : Ministry of Environment, Permit To Take Water Database (2006), with updates (2008).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

0 1 2 4 6

Kilometers

1:200,000

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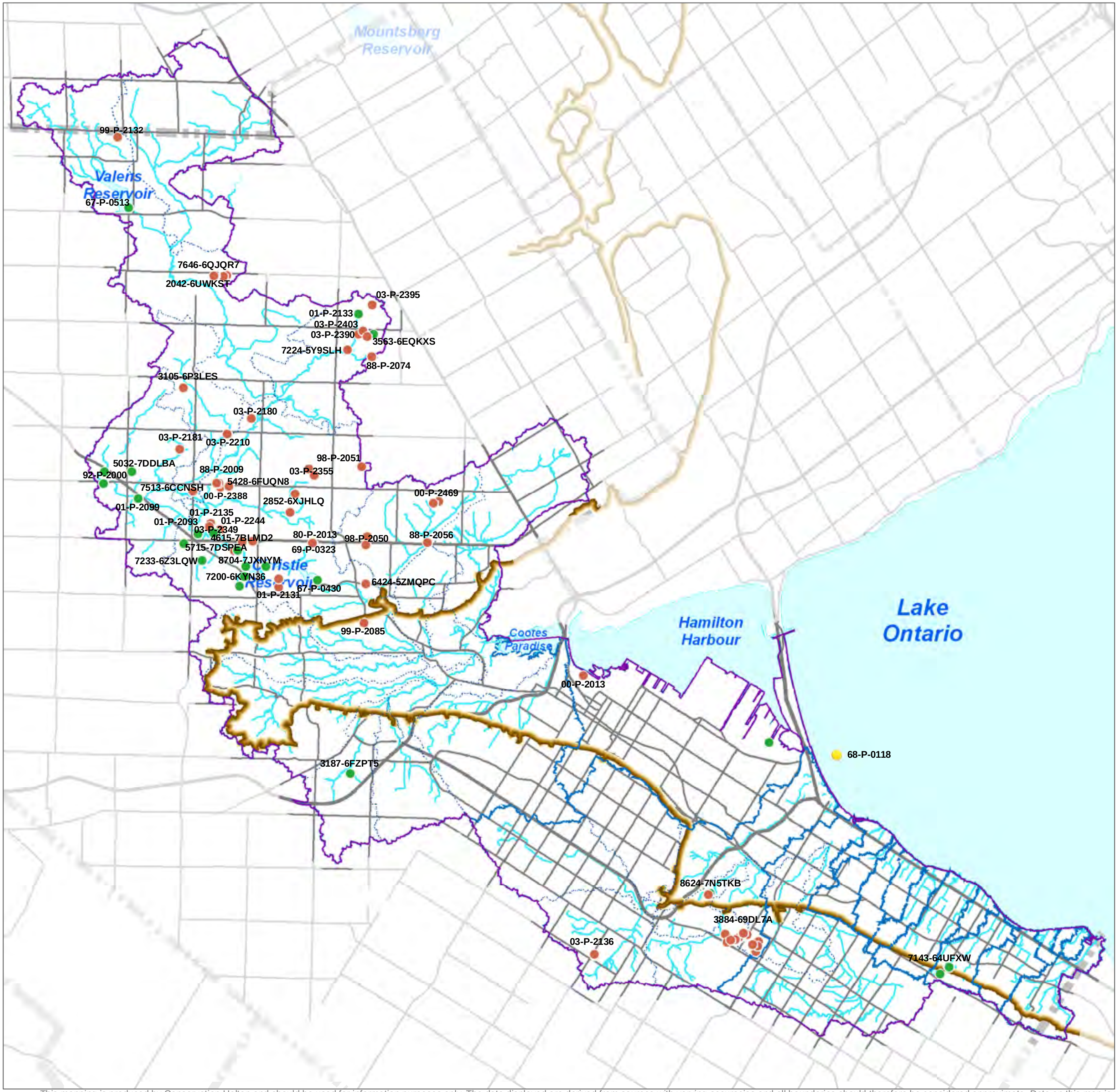

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 4.2

Permit To Take Water (PTTW) Source Location

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment

Roads

- Highway
- Regional
- Hydrography
- Waterbody

Active Permit To Take Water (PTTW)

SourceType

- Groundwater
- Surface Water
- Municipal Intake

Source : Ministry of Environment, Permit To Take Water Database (2006), with updates (2008).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

N W E S

0 1 2 4 6

Kilometers

1:200,000

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4.2.1 PTTW Maximum Permitted Water Takings

The PTTW Database was further analyzed to summarize the total permitted water takings. The maximum permitted water taking summary was completed based on a subwatershed basis for the nine (9) different categories. It should be noted that none of the current permits within the Halton-Hamilton SPR were categorized as institutional.

Tables 4.5 and **4.6** below provide summaries of the maximum permitted annual total surface water (SW) and groundwater (GW) water takings in cubic metres at a subwatershed scale based on the PTTW database.

Table 4.5: Halton Region SPA Summary of the PTTW Maximum Permitted Annual Water Takings

Watershed	Subwatershed	Agricultural		Commercial		Dewatering		Industrial		Misc.		Remediation		Water Supply		Total	
		SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW
Sixteen Mile Creek	Lower Middle Branch			1,738,139												**1,738,139**	**0**
	Lower Middle Tributary			1,319,136												**1,319,136**	**0**
	Main Branch			10,950,000												**10,950,000**	**0**
	Middle East Branch	4,048	1,961	19,650												**23,698**	**1,961**
	Middle Branch	40,800		240,000	278,276		2,064,440									**280,800**	**2,342,716**
	Upper West Branch						25,530,845			850,356					5,167,936	**850,356**	**30,698,781**
	West Branch	51,846		2,223,391	204,244										48,253	**2,275,237**	**252,497**
Bronte Creek	Flamboro Creek	19,572	20,000	909,650											1,572,268	**929,222**	**1,592,268**
	Kilbride Creek		150,000												117,833	**0**	**267,833**
	Limestone Creek	75,695		368,226	9,008										1,160,700	**443,921**	**1,169,708**
	Lower Main Branch	14,731	83,685					383,688							238,893	**398,419**	**322,578**
	Lowville Creek			250,792	882,935											**250,792**	**882,935**
	Mountsberg Creek	27,000		262,395	101,632										238,893	**289,395**	**340,525**
	Strabane Creek														80,127	**0**	**80,127**
	Upper Main Branch	34,377	238,172		21,170										525,666	**34,377**	**785,007**
	Willoughby Creek			344,845			2,646,396									**344,845**	**2,646,396**
Grindstone	201	11,250	83,025													**11,250**	**83,025**
	204		976,213													**0**	**976,213**
	210	80,080	61,956													**80,080**	**61,956**
	214	11,250	11,250													**11,250**	**11,250**
	215	15,260	307,955													**15,260**	**307,955**
	220			26,035	80,859											**26,035**	**80,859**
North Shore Group 1	407 Diversion			663,390											23,893	**663,390**	**23,893**
North Shore Group 2	Appleby Creek			238,032												**238,032**	**0**
	Shoreacres Creek												20,075			**0**	**20,075**
	Tuck Creek												65,153			**0**	**65,153**
North Shore Group 3	Fourteen Mile Creek				190,764				20,809							**0**	**211,573**
Halton Watershed		**385,910**	**1,934,217**	**19,553,681**	**1,768,888**	**0**	**30,241,681**	**383,688**	**20,809**	**850,356**	**0**	**0**	**85,228**	**0**	**9,174,460**	**21,173,635**	**43,225,283**

Notes:
1. All values are in m^3.
2. Water Supply includes municipal, communal and campgrounds.
3. Great Lake-based water takings are excluded.

Table 4.6: Hamilton Region SPA Summary of the PTTW Maximum Permitted Annual Water Takings

Watershed	Subwatershed	Agricultural		Commercial		Dewatering		Industrial		Misc.		Remediation		Water Supply		Total	
		SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW
Spencer Creek	Ancaster Creek			327,240												**327,240**	**0**
	Flamborough Creek	27,300	637,710		68,080				71,398						48,190	**27,300**	**825,378**
	Logie's Creek		234,096				18,410,809									**0**	**18,644,905**
	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**
	Upper Spencer Creek				597,344										406,325	**0**	**1,003,670**
	West Spencer Creek	199,364	104,350													**199,364**	**104,350**
	Westover Creek		104,350		75,123						450					**0**	**179,923**
Red Hill Creek	Hannon Creek								35,173							**0**	**35,173**
	Lower Davis Creek												3,365,373			**0**	**3,365,373**
	Montgomery Creek				303,698											**0**	**303,698**
	Upper Davis Creek												231,264			**0**	**231,264**
Stoney Creek Watercourses	WC 7	204,450														**204,450**	**0**
Urban Hamilton City Core													36,792			**0**	**36,792**
Hamilton Watershed		**1,889,185**	**2,305,294**	**543,992**	**1,641,999**	**0**	**35,003,779**	**0**	**364,328**	**0**	**450**	**0**	**3,596,637**	**0**	**646,140**	**2,433,177**	**43,558,627**

Notes:
1. All values are in m^3.
2. Water Supply includes municipal, communal and campgrounds.
3. Great Lake-based water takings are excluded.

Figure 4.3 shows that in the Halton watershed, the maximum permitted surface water and groundwater takings are 33 percent and 67 percent, respectively.

Halton Region SPA Surface Water Takings

The biggest permitted surface water takings are for commercial purposes, which account for 92 percent of the total permitted takings. The remaining eight (8) percent are for agricultural takings (two (2) percent), industrial takings (two (2) percent) and miscellaneous takings (four (4) percent).

Halton Region SPA Groundwater Takings

The major permitted groundwater takings are for dewatering and water supply purposes, which account for 71 percent and 21 percent of the total permitted groundwater takings respectively. The remaining eight (8) percent are for agricultural takings (four (4) percent), commercial takings (four (4) percent) and industrial takings (a fraction of one (1) percent).

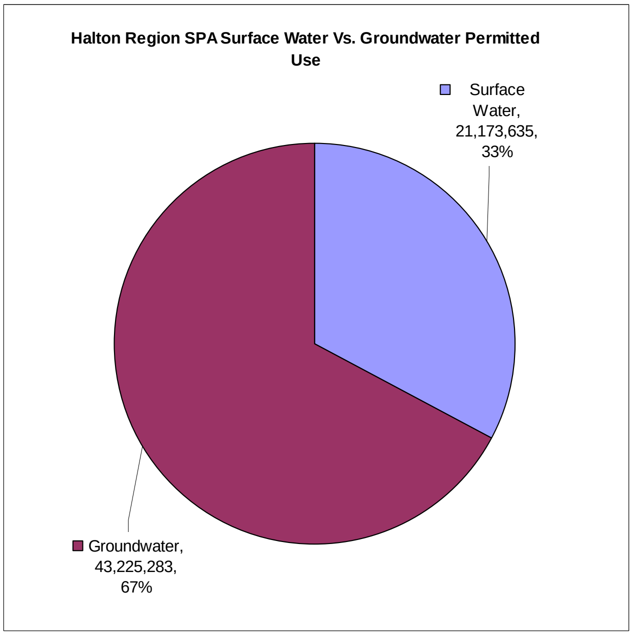


Figure 4-3: Halton Region SPA Permitted Takings

Figure 4.4 shows that in the Hamilton watershed, the maximum permitted surface water and groundwater takings are five (5) and 95 percent, respectively.

Hamilton Region SPA Surface Water Takings

The permitted surface water takings in the Hamilton Region SPA are for two purposes only: agricultural, which accounts for 78 percent of the total permitted, and commercial, which accounts for the remaining 22 percent of the permitted takings.

Hamilton Region SPA Groundwater Takings

Similarly to Halton Region SPA, the majority of the permitted groundwater takings are for dewatering purposes, which account for 81 percent of the total permitted groundwater takings. The remaining 19 percent of takings are for remediation (eight (8) percent), agricultural (five (5) percent), commercial (four (4) percent), industrial (one (1) percent), water supply (one (1) percent) and miscellaneous (a fraction of one (1) percent) purposes.

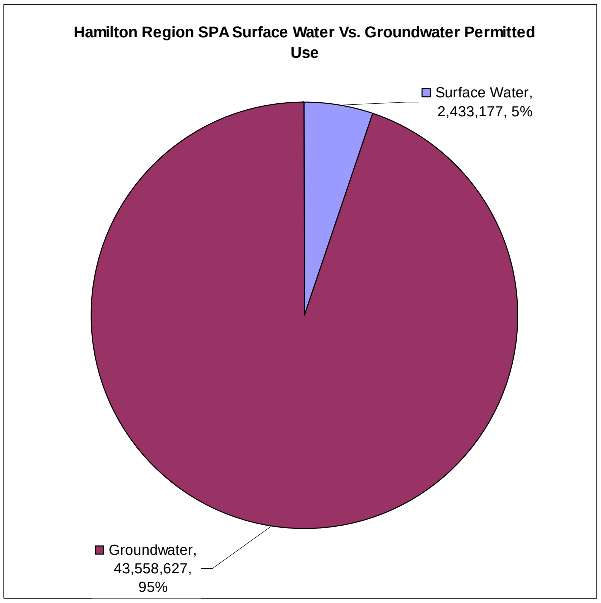


Figure 4-4: Hamilton Region SPA Permitted Takings

4.2.2 PTTW Actual Water Takings

The 131 database records for active permits in Halton-Hamilton SPR were further analyzed to assess the consumptive permitted takings by subwatershed.

A very significant step in the water budget and water quantity stress assessment was the collection of the actual water taking data from PTTW holders. A total of 29 permit holders from within the Halton Region SPA and 24 permit holders from the Hamilton Region SPA reported their actual water takings directly for this assessment.

The volume of actual water takings is a primary factor for an accurate water quantity stress assessment. Specifically, the actual water takings were collected for the following:

- 10 golf course irrigation permits (eight (8) in the Halton region SPA and two (2) in the Hamilton Region SPA); it should be noted that there are 24 PTTWs classified as commercial for golf course irrigation takings (18 in the Halton Region SPA and six (6) in the Hamilton Region SPA);
- Seven (7) quarry dewatering permits(1) (four (4) in the Halton Region SPA and three (3) in the Hamilton Region SPA);
- 11 agricultural water taking permits (one (1) in the Halton Region SPA and ten (10) in the Hamilton Region SPA);
- All six (6) municipal well supply systems accounting for seven (7) permits. The actual municipal water takings are discussed in Section 4.3 of this report;
- 10 communal and campground water supply system permits (seven (7) in the Halton Region SPA and three (3) in the Hamilton Region SPA);
- Three (3) industrial food processing type permits (Hamilton Region SPA) and two (2) other industrial type permits (Halton Region SPA);
- Two (2) permits classified as miscellaneous (one in each SPA); and
- One (1) remediation type permit (Hamilton Region SPA).

Quarry dewatering, commercial takings and municipal water supply takings are the largest water use sectors; the collection of the actual water taking data for these sectors improved the reliability of the water quantity stress assessment. It should be noted all seven (7) quarry dewatering permits have reported the actual water taking data.

(1) – some of the data sources for the actual water taking data: Conestoga-Rovers & Associates, March 2008. 2007 Annual Monitoring Report for Dufferin Milton Quarry; Golder Associates, February 2008. Technical Support Document for Renewal of PTTW No. 98-P-2051; Golder Associates, February 2008. Technical Support Document for Renewal of PTTW No. 98-P-2050

4.2.3 PTTW Average Consumptive Water Takings

The estimation of actual consumptive water demand required a detailed analysis of each permit in the PTTW database. Permit holders usually apply and get permits for more volume of water than their actual requirements and to improve the stress assessment a considerable effort was made to better represent water takings in the subwatersheds.

Four (4) methods to estimate the actual permitted water takings were utilized:

- Use of actual reported water takings;
- Use of the maximum permitted water taking per minute and the average hours of taking as reported in the PTTW Database;
- Use of the maximum daily water taking as reported in the PTTW Database; and
- Use of the actual water taking data to estimate average water taking from the same sector.

Consumptive water demands for specific uses were estimated using the appropriate consumptive factors given in **Table 4.1**.

As stated in the previous section there are 24 golf course irrigation permits out of which seven (7) have reported high quality actual water taking data. To estimate the average water taking data of the remaining 17 permits the actual takings were averaged on monthly bases and compared to their maximum allowed water takings. **Table 4.7** summarizes the monthly factors used to estimate water takings for golf courses for which actual water taking rates were not available.

Table 4.7: Actual Water Taking to Maximum Permitted Water Taking Factors for the Golf Industry

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Golf Course Irrigation	0	0	0	0	0.347	0.373	0.382	0.253	0.19	0	0	0

It should be noted that the monthly demand adjustment factor (see **Table 4.2**) in the PTTW Database for golf course irrigation for the month of May was changed from zero (0) to one (1) based on the reported actual water taking data for golf courses.

The quarry dewatering consumptive factor of 0.25 was used for all operations as our understanding of the proportion of the water taking that is actually groundwater is poor. The reported amount of water pumped from quarries is the sum of the groundwater flow into the quarries, direct precipitation, surface water drainage, etc. Furthermore, all quarry takings differ based on their depth, size, rock formation hydrogeologic properties, water handling (use for processing, recharging back into the bedrock aquifer, etc.). Thus a factor of 0.25 is expected to be reasonable.

Table 4.8 and **Table 4.9** provide summaries of the consumptive annual water takings based on the PTTW database at a subwatershed scale for Halton Region SPA and Hamilton Region SPA, respectively.

Figure 4.5 and **Figure 4.6** illustrate the distribution of the permitted total groundwater consumptive water takings based on general purpose in Halton Region SPA and Hamilton Region SPA, respectively.

The drinking water supply consumptive taking in the Halton Region SPA accounts for 67 percent of the total. The next most significant groundwater consumptive taking is for dewatering, which accounts for about 25 percent. Permits categorized as dewatering within the Halton-Hamilton SPR are for quarry dewatering only. Other consumptive takings are for commercial, agricultural and remediation purposes and they account for four (4), three (3) and one (1) percent of the total taking.

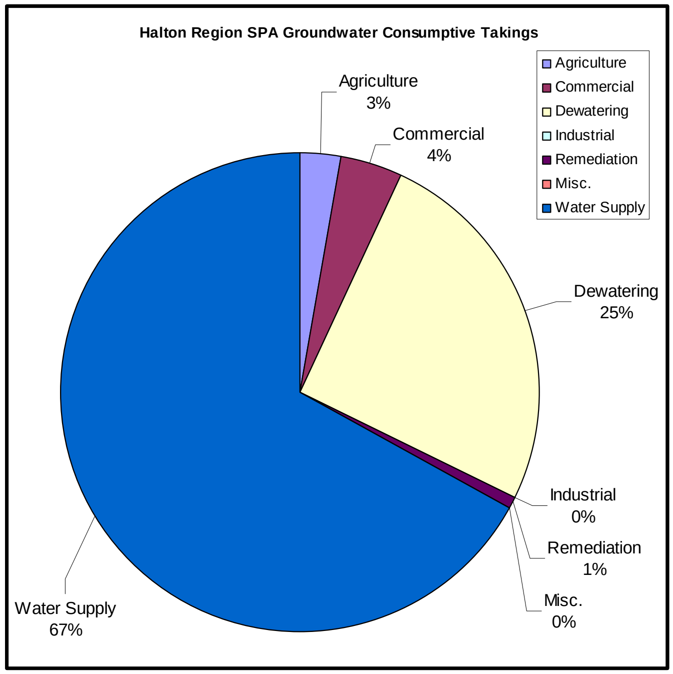


Figure 4-5: Halton Region SPA Permitted Groundwater Consumptive Taking by General Purpose

Contrary to the situation in the Halton Region SPA, water supply taking is one of the smallest takings at two (2) percent. The largest groundwater taking within the Hamilton Region SPA is for dewatering purposes at about 56 percent of the total permitted taking (**Figure 4.6**). Agricultural groundwater takings are also significant at 21 percent of the total. The remediation, commercial and industrial groundwater takings are at ten (10), eight (8) and three (3) percent, respectively. Miscellaneous takings are just a fraction of one (1) percent.

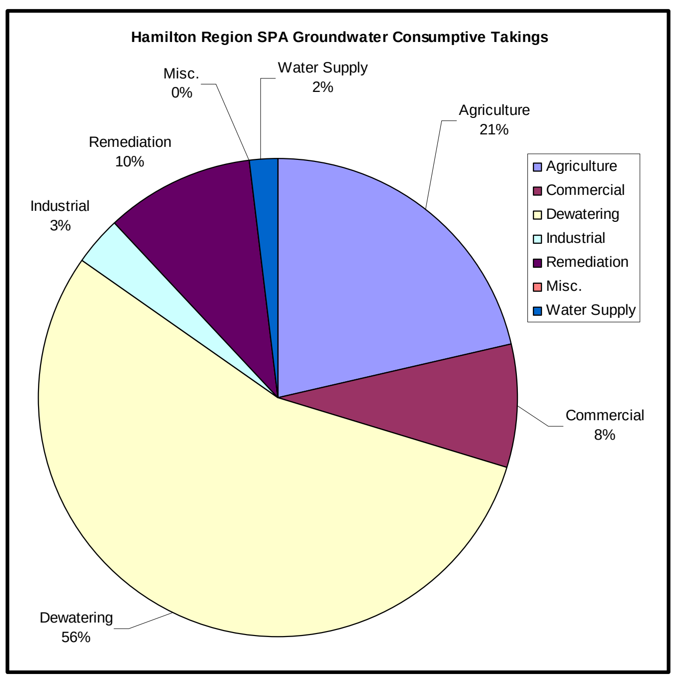


Figure 4-6: Hamilton Region SPA Permitted Groundwater Consumptive Taking by General Purpose

Table 4.8: Halton Region SPA Summary of the Consumptive Annual Water Takings Based on PTTW Database

Watershed	Subwatershed	Agricultural		Commercial		Dewatering		Industrial		Misc.		Remediation		Water Supply		Total	
		SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW
Sixteen Mile Creek	Lower Middle Branch			184,793												**184,793**	**0**
	Lower Middle Tributary			40,746												**40,746**	**0**
	Main Branch			23,117												**23,117**	**0**
	Middle East Branch	2,631	523	16,098												**18,730**	**523**
	Middle Branch	15,232		139,654	28,186		122,443									**154,886**	**150,629**
	Upper West Branch						687,673			12,871					2,843,265	**12,871**	**3,530,938**
	West Branch	10,888		309,635	24,903										2,561	**320,523**	**27,464**
Bronte Creek	Flamboro Creek	11,749	4,608	113,667											84,547	**125,416**	**89,155**
	Kilbride Creek		9,677												27,245	**0**	**36,922**
	Limestone Creek	16,082		53,983	197										520,371	**70,065**	**520,569**
	Lower Main Branch	6,187	2,933					9,513							9,954	**15,700**	**12,886**
	Lowville Creek			8,992	26,976											**8,992**	**26,976**
	Mountsberg Creek	11,059		37,428	68,918										9,954	**48,488**	**78,871**
	Strabane Creek														4,346	**0**	**4,346**
	Upper Main Branch	20,624	30,817		21,170										44,464	**20,624**	**96,452**
	Willoughby Creek			49,727			538,122									**49,727**	**538,122**
Grindstone	201	9,422	18,639													**9,422**	**18,639**
	204		34,211													**0**	**34,211**
	210	9,173	20,094													**9,173**	**20,094**
	214	11,032	9,422													**11,032**	**9,422**
	215	9,428	19,820													**9,428**	**19,820**
	220			3,734	11,403											**3,734**	**11,403**
North Shore Group 1	407 Diversion			28,753											1,935	**28,753**	**1,935**
North Shore Group 2	Appleby Creek			29,352												**29,352**	**0**
	Shoreacres Creek												10,038			**0**	**10,038**
	Tuck Creek												32,576			**0**	**32,576**
North Shore Group 3	Fourteen Mile Creek				35,957				763							**0**	**36,720**
Halton Watershed		**133,508**	**150,744**	**1,039,679**	**217,709**	**0**	**1,348,238**	**9,513**	**763**	**12,871**	**0**	**0**	**42,614**	**0**	**3,548,642**	**1,195,571**	**5,308,709**

1. All values are in m^3.
2. Misc. includes aesthetic, recreation, ecological, and flow augmentation.
3. Lake-Ontario based water takings are excluded.

Table 4.9: Hamilton Region SPA Summary of the Consumptive Annual Water Takings Based on PTTW Database

Watershed	Subwatershed	Agricultural		Commercial		Dewatering		Industrial		Misc.		Remediation		Water Supply		Total	
		SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW
Spencer Creek	Ancaster Creek			47,974												**47,974**	**0**
	Flamborough Creek	11,466	135,399		19,189				2,373						1,531	**11,466**	**158,492**
	Logie's Creek		17,160				475,646									**0**	**492,806**
	Middle Spencer Creek	191,337	292,263	31,086	59,167		773,167		65,195						26,500	**222,423**	**1,216,293**
	Upper Spencer Creek				59,734										16,179	**0**	**75,914**
	West Spencer Creek	101,549	21,999													**101,549**	**21,999**
	Westover Creek		21,999		12,957						456					**0**	**35,412**
Red Hill Creek	Hannon Creek								8,614							**0**	**8,614**
	Lower Davis Creek												210,570			**0**	**210,570**
	Montgomery Creek				40,272											**0**	**40,272**
	Upper Davis Creek												18,847			**0**	**18,847**
Stoney Creek Watercourses	WC 7	34,144														**34,144**	**0**
Urban Hamilton City Core													18,396			**0**	**18,396**
Hamilton Watershed		**338,496**	**488,820**	**79,060**	**191,320**	**0**	**1,248,813**	**0**	**76,182**	**0**	**456**	**0**	**247,813**	**0**	**44,211**	**417,556**	**2,297,615**

1. All values are in m^3.
2. Misc. includes aesthetic, recreation, ecological, and flow augmentation.
3. Lake-Ontario based water takings are excluded.

4.3 Present and Future Municipal Well System Demand

4.3.1 Present Municipal Well System Demand

In accordance with the Technical Rules year 2007 is the study year for the Halton-Hamilton SPR; therefore, the reported actual water taking data for 2007 was used in the demand calculation.

Table 4.10 provides the summary of the municipal groundwater taking permits.

Table 4.10: Municipal Groundwater Taking Permits in Halton-Hamilton SPR

Municipality	Wellfield and Water Well Number	PTTW Permit Number	PTTW [m^3/yr]	Subwatershed
Halton Region	Walkers Line Well 1	87-P-3046	955,570	Limestone Creek (Bronte Creek watershed)
	Kelso Wells 3 to 6	87-P-3046	4,976,775	Upper West Branch (Sixteen Mile Creek watershed)
	Campbellville Wells 1 & 2A	8361-6Q3KPE	191,161	
City of Hamilton	Freelton Well 1	03-P-2246	320,470	Upper Main Branch (Bronte Creek watershed)
	Carlisle Wells 1 & 2	75-P-2072	310,615	Flamboro Creek (Bronte Creek watershed)
	Carlisle Well 3R	6550-6BTJ4L	788,400	
	Carlisle Well 5	4150-6C4L9B	473,040	
	Greensville	6424-5ZMQPC	71,905	Middle Spencer Creek (Spencer Creek watershed)

1. The combined permitted water taking for Walkers Line Wells (1 and 2) is 1,160,700 m^3/yr. Well 2 is no longer in use (has been capped).
2. Town of Milton water supply system takes water from the Walkers Line and Kelso wells listed above, and also receives some supply from the lake based system. The service population and water usage reported above is for the groundwater system only (serving the older part of the Town).

Actual water takings were provided by Halton Region and the City of Hamilton, as summarized in **Table 4.11**.

Table 4.11: Summary of Actual Municipal Groundwater Use in Halton-Hamilton SPR

HH SPR	Water Supply System	Actual Water Use [m^3]		
		2005	2006	2007
Halton	Kelso	2,795,912	2,738,389	2,840,895
	Walkers Line	597,216	416,980	520,372
	Campbellville	16,505	20,682	11,848
	Freelton	120,064	127,827	157,294
	Carlisle	346,849	339,847	422,735
Hamilton	Greensville	17,460	13,790	12,781

Notes: Greensville system data between 2003 and 2006 are estimates only; year 2007 is actual metered data.

Monthly variation in municipal water use is summarized in **Table 4.12** below, based on the actual water takings in 2007.

Table 4.12: Monthly Actual Municipal Groundwater Use in Halton-Hamilton SPR

Well System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kelso	217,654	200,186	217,667	217,951	229,076	289,169	295,748	278,552	251,300	222,483	219,264	201,845
Walkers Line	39,342	32,937	33,119	47,792	51,619	52,518	55,148	54,792	43,675	37,646	23,855	47,928
Campbellville	1,265	893	856	834	979	1,274	1,333	1,251	940	732	704	787
Freelton	10,651	9,392	12,116	10,638	13,446	18,321	21,302	19,139	16,088	8,750	8,692	8,761
Carlisle	12,821	11,642	13,915	17,207	38,061	64,790	75,695	69,796	53,309	25,896	18,892	20,714
Greensville	846	821	864	986	1,082	1,484	1,485	1,490	1,393	764	771	795

Note: All values are in m^3.

As previously discussed Kelso and Walkers Line water takings have consumptive factor of 1.0 because the water taken from the groundwater aquifers is not returned back to the same sources.

For the Campbellville, Freelton, Carlisle and Greensville groundwater takings, a consumptive factor of 0.2 is used as the water taken from the groundwater aquifers is assumed to be returning back to the same aquifers by the septic systems at these localities.

Table 4.13 is a summary of the total actual annual water takings and consumptive water takings by municipal groundwater systems in 2007.

Table 4.13: Total and Consumptive Water Use by Municipal Well Supply Systems in Hamilton-Halton SPR

Water Supply System	Total Water Use	Consumptive Water Use
	[m^3]	**[m^3]**
Kelso	2,840,895	2,840,895
Walkers Line	520,372	520,372
Campbellville	11,848	2,370
Freelton	157,294	31,459
Carlisle	422,735	84,547
Halton Watershed	**3,953,144**	**3,479,643**
Greensville	12,781	2,556
Hamilton Watershed	**12,781**	**2,556**
Halton-Hamilton SPR	**3,965,925**	**3,482,199**

Table 4.14 below is a summary of the monthly distribution of consumptive municipal groundwater use.

Table 4.14: Monthly Consumptive Municipal Groundwater Use

Well System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kelso	217,654	200,186	217,667	217,951	229,076	289,169	295,748	278,552	251,300	222,483	219,264	201,845
Walkers Line	39,342	32,937	33,119	47,792	51,619	52,518	55,148	54,792	43,675	37,646	23,855	47,928
Campbellville	253	179	171	167	196	255	267	250	188	146	141	157
Freelton	2,130	1,878	2,423	2,128	2,689	3,664	4,260	3,828	3,218	1,750	1,738	1,752
Carlisle	2,564	2,328	2,783	3,441	7,612	12,958	15,139	13,959	10,662	5,179	3,778	4,143
Greensville	169	164	173	197	216	297	297	298	279	153	154	159

Note: All values are in m^3.

4.3.2 Future Municipal Well System Demand

For the Kelso and Walkers Line municipal wells future demand scenario, Halton Region has confirmed that all future population growth in the area will be served by the lake-based system. Furthermore, the Campbellville well supply will not grow. Therefore, estimates of municipal groundwater demand in Halton Region as of 2031 will remain the same.

Future Freelton municipal system demand was estimated using long-term average built-out demand as provided by the City of Hamilton. At the time of this report preparation there was no available data as to the future demand of the Carlisle municipal system. Based on the communication with the City of Hamilton staff the Greensville future water demand will remain unchanged.

Table 4.15 below is a summary of the monthly consumptive future municipal well system takings.

Table 4.15: Future (2031) Monthly Consumptive Municipal Groundwater Use

Well System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kelso	217,654	200,186	217,667	217,951	229,076	289,169	295,748	278,552	251,300	222,483	219,264	201,845
Walkers Line	39,342	32,937	33,119	47,792	51,619	52,518	55,148	54,792	43,675	37,646	23,855	47,928
Campbellville	253	179	171	167	196	255	267	250	188	146	141	157
Freelton	3,195	2,818	3,635	3,191	4,034	5,496	6,391	5,742	4,826	2,625	2,608	2,628
Carlisle	2,564	2,328	2,783	3,441	7,612	12,958	15,139	13,959	10,662	5,179	3,778	4,143
Greensville	169	164	173	197	216	297	297	298	279	153	154	159

Note: All values are in m^3.

4.4 Non-Permitted Water Takings

4.4.1 Present and Future Domestic Water Demands

The Statistics Canada 2006 Census GeoSuite product was used to determine the current (2006) population for private non-permitted water users. This dataset contains a single record for every census block. The census block boundary file was purchased from Statistics Canada, and the

GeoSuite population values were joined, then area-weighted to the catchment boundaries and subsequently aggregated to the subwatershed boundaries.

The key sources of information for the population forecasts to 2031 were the Region of Halton's and the City of Hamilton's projected traffic zones. These figures were also generated in consultation with the Region of Peel, Wellington County and Niagara Region. In addition, the population figures found in the Province's Places to Grow were also reviewed. A similar approach was used to spatially distribute the forecasted population as identified above for the existing population.

Table 4.16 provides population information for each watershed/subwatershed of Halton Region SPA. Current and future population values are based on an area weighting of the available datasets.

Table 4.16: Population Served by Municipal and Private Systems in Halton Region SPA

Watershed/ Group	Subwatershed	Population (2006)			Population (2031)		
		Mun.	Private	Total	Mun.	Private	Total
Sixteen Mile Creek	East Branch	5,982	1,146	7,127	5,669	401	6,071
	East Branch Lisgar	41,897	842	42,739	48,939	1,452	50,391
	Lower Middle Branch	23,682	568	24,250	79,685	52	79,738
	Lower Middle Tributary	-	149	149	4,971	6	4,976
	Main Branch	29,096	196	29,292	44,648	49	44,697
	Middle East Branch	-	1,221	1,221	2,639	1,050	3,690
	Middle Branch	20	1,317	1,337	51	1,284	1,335
	Morrison-Wedgewood Div.	31,253	65	31,318	56,319	-	56,319
	Upper West Branch[1]	80	2,263	2,343	65	2,044	2,108
	West Branch	21,589	783	22,373	84,519	379	84,898
	Total	**153,598**	**8,550**	**162,149**	**327,505**	**6,717**	**334,222**
Bronte Creek	Flamboro Creek[1]	449	425	874	179	834	1,013
	Indian Creek (Bronte)	27	1,109	1,136	41,148	610	41,758
	Kilbride Creek	-	1,437	1,437	-	1,512	1,512
	Limestone Creek[1]	-	1,059	1,059	-	1,172	1,172
	Lower Main Branch	9,816	1,061	10,877	15,454	1,234	16,688
	Lowville Creek	-	459	459	-	496	496
	Mount Nemo Creek	-	109	109	-	81	81
	Mountsberg Creek	55	1,954	2,008	38	2,627	2,664
	Strabane Creek	122	562	685	30	693	723
	Upper Main Branch[1]	2,335	2,749	5,084	578	3,215	3,793
	Willoughby Creek	-	520	520	-	478	478
	Total	**12,804**	**11,444**	**24,248**	**57,426**	**12,952**	**70,378**
Grindstone Creek	201	-	1,375	1,375	-	1,430	1,430
	204	-	303	303	-	283	283
	210	-	694	694	-	418	418
	214	7	860	867	9	578	587
	215	21	666	688	24	881	905
	218	3,390	70	3,460	4,052	16	4,068
	220	902	803	1,705	4,086	519	4,605
	222	1,689	100	1,789	1,514	237	1,751
	224	481	98	578	2,227	1,563	3,790
	228	1,972	717	2,689	2,039	1,192	3,232
	230	675	45	719	797	-	797
	232 (alternate)	429	46	475	474	261	735
	Total	**9,565**	**5,777**	**15,343**	**15,222**	**7,377**	**22,599**
North Shore	407 Diversion	7,676	428	8,104	6,575	163	6,739

Table 4.16: Population Served by Municipal and Private Systems in Halton Region SPA

Watershed/ Group	Subwatershed	Population (2006)			Population (2031)		
		Mun.	Private	Total	Mun.	Private	Total
Group 1	Cootes Paradise (Halton)	9	55	65	2	13	14
	Falcon Creek	3,397	117	3,514	6,281	1,287	7,567
	Indian Creek	5,464	268	5,732	7,104	675	7,780
	North Cootes Paradise	415	141	556	572	202	773
	Upper Hager Creek	4,496	51	4,547	4,561	153	4,714
	Upper Rambo Creek	11,222	-	11,222	11,025	-	11,025
	West Aldershot (East)	5,705	-	5,705	9,510	-	9,510
	West Aldershot (West)	-	-	-	119	-	119
	Total	**38,384**	**1,061**	**39,445**	**45,749**	**2,493**	**48,242**
North Shore Group 2	Appleby Creek	22,632	43	22,675	26,406	51	26,458
	Beach Strip East Side	271	2	273	109	-	109
	Beach Strip West Side	28	1	29	28	-	28
	Lower Hager Creek	9,569	-	9,569	12,645	-	12,645
	Lower Rambo Creek	11,032	-	11,032	14,904	-	14,904
	Roseland Creek	20,918	5	20,924	20,892	7	20,899
	Sheldon Creek	22,494	60	22,554	28,245	209	28,455
	Shoreacres Creek	17,291	50	17,340	17,740	107	17,847
	Tuck Creek	18,093	72	18,165	17,379	100	17,479
	Total	**122,327**	**234**	**122,561**	**138,350**	**475**	**138,825**
North Shore Group 3	Fourteen Mile Creek	37,269	799	38,067	46,452	101	46,553
	McCraney Creek	24,998	11	25,009	24,543	-	24,543
	Total	**62,266**	**810**	**63,076**	**70,995**	**101**	**71,096**
North Shore Group 4	Ford Plant Special Area	-	-	-	-	-	-
	Joshua's Creek	9,471	389	9,860	27,366	101	27,467
	Lower Morrison Creek	7,584	-	7,584	17,258	-	17,258
	Lower Wedgewood Creek	6,323	-	6,323	5,383	-	5,383
	Total	**23,379**	**389**	**23,767**	**50,006**	**101**	**50,006**
Halton Watershed		**422,324**	**28,265**	**450,589**	**705,253**	**30,216**	**735,469**

Note: [1] Subwatershed contains municipal wellfield

Based on the above table 93.7 percent of the residents in the Halton watershed rely on municipal water systems. The municipal water supplies are based on either a groundwater source (municipal wells) or a surface water source (Lake Ontario). The current estimated population served by municipal wells is about 28,210 or 6.3 percent of the total population.

Consequently, approximately 28,265 people or 6.3 percent of the total population get their drinking water from private water systems (domestic wells). In total about 56,475 people, or 12.5 percent of the total population in the Halton watershed, rely on groundwater sources.

Table 4.17 is a summary of current and forecast populations to be served by municipal water systems and private water system within each watershed/subwatershed of Hamilton Region SPA.

Table 4.17: Population Served by Municipal and Private Systems in Hamilton Region SPA

Watershed/ Group	Subwatershed	Population (2006)			Population (2031)		
		Mun.	Private	Total	Mun.	Private	Total
Spencer Creek	Ancaster Creek	10,980	892	11,872	11,910	716	12,626
	Borer's Creek	8,117	1,009	9,126	9,367	5,476	14,843
	Chedoke Creek	73,067	265	73,332	82,454	2	82,457
	Flamborough Creek	-	428	428	-	713	713
	Fletcher Creek	-	577	577	-	745	745
	Logie's Creek	5	898	903	-	1,515	1,515
	Lower Spencer Creek	8,421	141	8,562	11,774	156	11,930
	Middle Spencer Creek[1]	8,220	3,609	11,829	6,105	3,919	10,024
	Spring Creek	4,173	995	5,168	5,879	3,140	9,019
	Sulphur Creek	5,004	611	5,615	4,938	2,126	7,064
	Sydenham Creek	3,486	175	3,661	2,488	528	3,015
	Tiffany Creek	9,808	82	9,890	14,699	63	14,762
	Upper Spencer Creek	-	1,183	1,183	-	1,529	1,529
	West Spencer Creek	-	600	600	-	966	966
	Westover Creek	-	275	275	-	755	755
	Total	**131,281**	**11,740**	**143,021**	**149,613**	**22,348**	**171,961**
Red Hill Creek	Green Hill	43,275	-	43,275	43,141	-	43,141
	Hannon Creek	9,695	180	9,875	12,280	67	12,347
	Lower Davis Creek	7,141	217	7,358	9,170	-	9,170
	Montgomery Creek	7,318	-	7,318	8,176	-	8,176
	Red Hill Valley	23,059	11	23,070	24,046	-	24,046
	Upper Davis Creek	11,007	85	11,091	17,351	-	17,351
	Upper Ottawa	36,427	48	36,475	44,392	7	44,399
	Total	**137,921**	**541**	**138,461**	**158,555**	**74**	**158,629**
Stoney Creek	Battlefield Creek	7,530	262	7,792	11,080	235	11,315
	Stoney Creek	13,088	817	13,905	17,620	6,890	24,510
	Total	**20,618**	**1,079**	**21,697**	**28,700**	**7,125**	**35,825**
Stoney Creek Watercourses	WC 0	2,620	1	2,621	2,207	-	2,207
	WC 1	8,319	2	8,321	9,937	2	9,939
	WC 2	5,960	1	5,961	6,946	3	6,949
	WC 3	4,480	59	4,538	3,010	-	3,010
	WC 4	5,038	5	5,043	4,018	12	4,031
	WC 5	2,425	259	2,684	6,251	1,284	7,535
	WC 6	493	-	493	1,591	-	1,591
	WC 7	563	162	726	3,811	1,175	4,986
	WC 8	68	-	68	107	-	107
	WC 9	2,251	104	2,355	4,009	336	4,345
	WC 10	698	32	730	897	-	897
	WC 10.1	503	-	503	531	-	531
	WC 11	1,093	-	1,094	767	-	767
	WC 12	651	473	1,124	2,748	893	3,641
	Total	**35,162**	**1,098**	**36,260**	**46,830**	**3,540**	**50,370**
Urban Hamilton Beach Strip		1,085	6	1,091	1,981	-	1,981
Urban Hamilton City Core		107,525	20	107,544	123,430	-	123,430
Cootes Paradise (Hamilton)		5	115	120	149	362	511
Hamilton Watershed		**433,597**	**14,598**	**448,195**	**509,259**	**33,449**	**542,708**

Note: [1] Subwatershed contains municipal wellfield

Based on the above table 96.7 percent of the residents in the Hamilton watershed rely on municipal water systems. The municipal water supplies are based on either a groundwater source (municipal well in Greensville) or a surface water source (Lake Ontario). The current estimated population served by municipal wells is about 127 persons (0.03 percent of population in watershed).

Consequently, approximately 14,598 people or 3.3 percent of the total population get their drinking water from private water systems (domestic wells). In total 14,725 people, or roughly 3.3 percent of the total population in the Hamilton watershed, rely on groundwater sources.

An estimation of present (2006) private domestic water takings is based on the summaries of population not being served by a municipal water supply system. It was assumed that the population outside of municipally serviced areas uses private domestic groundwater sources. Existing and projected domestic water use was based on a conservatively estimated per capita consumption rate of 335 L/d/capita. This value was an average for residential water use in 2001 from municipal supply systems across Canada (Environment Canada, 2007).

A consumptive factor of 0.2 was applied to non-municipal domestic water takings. It was assumed that all the private systems are groundwater takings and that groundwater after use is being returned back through septic beds to the same source. **Tables 4.18** and **4.19** provide the present and future projected estimates of the total and consumptive domestic water demands for each watershed/ subwatershed within the Halton Region SPA and Hamilton Region SPA, respectively.

Table 4.18: Halton Region SPA Present and Future Non-Municipal Annual Domestic Water Demand

Watershed	Subwatershed	Domestic Water Use (Total) in m^3		Domestic Water Use (Consumptive) in m^3	
		Year 2006	Year 2031	Year 2006	Year 2031
Sixteen Mile Creek	East Branch	140,194	49,102	28,039	9,820
	East Branch Lisgar	103,030	177,660	20,606	35,532
	Lower Middle Branch	69,544	6,363	13,909	1,273
	Lower Middle Tributary	18,272	679	3,654	136
	Main Branch	23,951	5,945	4,790	1,189
	Middle East Branch	149,419	128,536	29,884	25,707
	Middle Branch	161,112	157,103	32,222	31,421
	Morrison-Wedgewood Diversion	7,924	0	1,585	0
	Upper West Branch	276,919	250,062	55,384	50,012
	West Branch	95,834	46,434	19,167	9,287
	Total	**1,046,198**	**821,884**	**209,240**	**164,377**
Bronte Creek	Flamboro Creek	52,050	102,086	10,410	20,417
	Indian Creek	135,672	74,639	27,134	14,928
	Kilbride Creek	175,768	184,967	35,154	36,993
	Limestone Creek	129,571	143,448	25,914	28,690
	Lower Main Branch	129,820	150,977	25,964	30,195
	Lowville Creek	56,220	60,719	11,244	12,144
	Mount Nemo Creek	13,343	9,861	2,669	1,972
	Mountsberg Creek	239,072	321,377	47,814	64,275
	Strabane Creek	68,826	84,823	13,765	16,965
	Upper Main Branch	336,352	393,418	67,270	78,684
	Willoughby Creek	63,609	58,471	12,722	11,694
	Total	**1,400,303**	**1,584,786**	**280,061**	**316,957**

Table 4.18: Halton Region SPA Present and Future Non-Municipal Annual Domestic Water Demand

Watershed	Subwatershed	Domestic Water Use (Total) in m^3		Domestic Water Use (Consumptive) in m^3	
		Year 2006	Year 2031	Year 2006	Year 2031
Grindstone	201	168,278	174,939	33,656	34,988
	204	37,103	34,661	7,421	6,932
	210	84,942	51,100	16,988	10,220
	214	105,171	70,741	21,034	14,148
	215	81,532	107,766	16,306	21,553
	218	8,604	1,910	1,721	382
	220	98,252	63,542	19,650	12,708
	222	12,252	28,960	2,450	5,792
	224	11,943	191,231	2,389	38,246
	228	87,751	145,908	17,550	29,182
	230	5,470	0	1,094	0
	232 (Alternate)	5,610	31,936	1,122	6,387
	Total	**706,910**	**902,693**	**141,382**	**180,539**
North Shore Group 1	407 Diversion	52,344	19,961	10,469	3,992
	Cootes Paradise (Halton)	6,787	1,570	1,357	314
	Falcon Creek	14,303	157,467	2,861	31,493
	Indian Creek	32,848	82,643	6,570	16,529
	North Cootes Paradise (232)	17,275	24,664	3,455	4,933
	Upper Hager Creek	6,247	18,695	1,249	3,739
	Upper Rambo Creek	0	0	0	0
	West Aldershot (East)	0	0	0	0
	West Aldershot (West)	0	0	0	0
	Total	**129,805**	**305,000**	**25,961**	**61,000**
North Shore Group 2	Appleby Creek	5,258	6,271	1,052	1,254
	Beach Strip East Side	304	0	61	0
	Beach Strip West Side	143	0	29	0
	Lower Hager Creek	0	0	0	0
	Lower Rambo Creek	0	0	0	0
	Roseland Creek	650	883	130	177
	Sheldon Creek	7,348	25,597	1,470	5,119
	Shoreacres Creek	6,062	13,108	1,212	2,622
	Tuck Creek	8,857	12,235	1,771	2,447
	Total	28,622	58,094	5,724	11,619
North Shore Group 3	Fourteen Mile Creek	97,736	12,343	19,547	2,469
	McCraney Creek	1,339	0	268	0
	Total	**99,075**	**12,343**	**19,815**	**2,469**
North Shore Group 4	Ford Plant Special Area	0	0	0	0
	Joshua's Creek	47,575	12,358	9,515	2,472
	Lower Morrison Creek	0	0	0	0
	Lower Wedgewood Creek	0	0	0	0
	Total	**47,575**	**12,358**	**9,515**	**2,472**
Halton Watershed		**3,458,489**	**3,697,157**	**691,698**	**739,431**

Table 4.19: Hamilton Region SPA Present and Future Non-Municipal Annual Domestic Water Demand

Watershed	Subwatershed	Domestic Water Use (Total) in m^3		Domestic Water Use (Consumptive) in m^3	
		Year 2006	Year 2031	Year 2006	Year 2031
Spencer Creek	Ancaster Creek	109,096	87,614	21,819	17,523
	Borer's Creek	123,514	670,008	24,703	134,002
	Chedoke Creek	32,468	304	6,494	61
	Flamborough Creek	52,370	87,242	10,474	17,448
	Fletcher Creek	70,601	91,157	14,120	18,231
	Logie's Creek	109,878	185,374	21,976	37,075
	Lower Spencer Creek	17,256	19,028	3,451	3,806
	Middle Spencer Creek	441,596	479,575	88,319	95,915
	Spring Creek	121,749	384,253	24,350	76,851
	Sulphur Creek	74,808	260,145	14,962	52,029
	Sydenham Creek	21,389	64,558	4,278	12,912
	Tiffany Creek	10,042	7,677	2,008	1,535
	Upper Spencer Creek	144,751	187,072	28,950	37,414
	West Spencer Creek	73,409	118,223	14,682	23,645
	Westover Creek	33,589	92,330	6,718	18,466
	Total	**1,436,435**	**2,734,472**	**287,287**	**546,894**
Red Hill Creek	Green Hill	0	0	0	0
	Hannon Creek	22,034	8,229	4,407	1,646
	Lower Davis Creek	26,498	0	5,300	0
	Montgomery Creek	0	0	0	0
	Red Hill Valley	1,368	0	274	0
	Upper Davis Creek	10,360	0	2,072	0
	Upper Ottawa	5,902	882	1,180	176
	Total	**66,162**	**9,111**	**13,232**	**1,822**
Stoney Creek	Battlefield Creek	32,046	28,777	6,409	5,755
	Stoney Creek	99,970	843,050	19,994	168,610
	Total	**132,015**	**871,828**	**26,403**	**174,366**
Stoney Creek Watercourses	WC 0	127	0	25	0
	WC 1	227	193	45	39
	WC 2	147	361	29	72
	WC 3	7,177	0	1,435	0
	WC 4	623	1,522	125	304
	WC 5	31,671	157,057	6,334	31,411
	WC 6	0	0	0	0
	WC 7	19,861	143,732	3,972	28,746
	WC 8	0	0	0	0
	WC 9	12,720	41,053	2,544	8,211
	WC 10	3,882	0	776	0
	WC 10.1	0	0	0	0
	WC 11	44	0	9	0
	WC 12	57,879	109,266	11,576	21,853
	Total	**134,356**	**433,131**	**26,871**	**86,626**
Urban Hamilton Beach Strip		752	0	150	0
Urban Hamilton City Core		2,393	0	479	0
Cootes Paradise (Hamilton)		14,051	44,287	2,810	8,857
Hamilton Watershed		**1,786,165**	**4,092,830**	**357,233**	**818,566**

4.4.2 Agricultural Water Demand

Two datasets are used to estimate the consumptive agricultural water use:

(1) Census of Agriculture; and
(2) Agricultural permits from the MOE PTTW database.

The two datasets were summarized on subwatershed basis and the consumptive water takings were compared. The higher of the two values for each subwatershed was used as the consumptive agricultural water taking for further analyses.

The methodology outlined in by de Loe (2005) was generally used to process the Census of Agriculture data into estimates of agricultural water use.

In order to protect the information associated with any individual or agricultural operation, Statistics Canada enforces a number of confidentiality rules as outlined in the Statistics Act (1970) when providing data obtained under the Census of Agriculture. These rules dictate that:

- a minimum number of sixteen (16) farms within any single reporting area is required,
- a minimum number of three (3) parameters must be reported within a single reporting area.

Should either of these conditions not be met, suppression of the data associated with that particular area or parameter would occur and be represented within the data as an ‘x’. A further method of protecting farm operator confidentiality occurs as random rounding where a reported value is either rounded up or down to a multiple of five (5).

Rather than purchasing the Census of Agriculture data using the standard boundary definition, the Halton-Hamilton SP team provided the Source Protection Region subwatershed boundaries to Statistics Canada to summarize the data. The inherent errors associated with an area weighting method, where areas outside the watershed may erroneously be incorporated and areas inside the watershed may be excluded were avoided and the most accurate results possible were attained by following this approach.

The Census of Agriculture data underwent the water use calculation methodology of de Loe (2005) with some minor adjustments. Approximately 850 variables are provided within the Census of Agriculture. Of these, approximately 150 are used within the de Loe methodology to calculate agricultural water use. For example, farm variables such as the number of cows, chicken, sheep, etc. are multiplied by their water use coefficient or water use factor, to arrive at the total water use per subwatershed for that variable. For crop type variables, such as sod, tomatoes, wheat, etc. the total area of a crop is multiplied by the percent area irrigated by the number of irrigation events per season and by the volume of water applied per irrigation event to arrive at the total agricultural water use. These coefficients were originally published in a report by Ecologistics (1993).

Once the calculation of water use for each variable is completed, they were summed into the following groups:

- Livestock
- Field Crops
- Fruit Crops

- Vegetables
- Specialty Crops
- Summer Crops
- All Irrigation
- Summer Irrigation
- Total Water Use

From the above list of water use totals, seasonal water use was calculated by subtracting summer water use from the year-round total, dividing the resulting value by the twelve months of the year, and then by apportioning growing season water use over the summer months.

The total water use for each subwatershed was then compared to the total water use as calculated from the PTTW assessment discussed in section 4.1. The greater of the two values for an individual subwatershed replaced the lesser, and was subsequently carried forward in the calculation of total water demand for that subwatershed.

Groundwater versus surface water agricultural use was calculated based on proximity of agricultural land to potential water sources. This method is not totally accurate because it is possible that animals requiring groundwater are classified based on the farm location as surface water dependent. However, it is believed that the method is acceptable at the scale of this assessment. Agricultural lands that were within three hundred (300) meters of third order streams or water bodies were assigned to surface water sources, while agricultural lands that were within 200 meters of a water supply well as recorded in the MOE's Water Well Information System (WWIS) database with a spatial accuracy less than 100 meters were assigned to groundwater sources. Third order streams are those that are formed by the convergences of two or more second order streams and are generally considered to contain enough water to act as a source of water for agriculture. The ordering of streams is determined such that 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.

These groundwater/surface water agricultural lands were then summed to obtain a percentage split of agricultural land within each individual subwatershed.

The percentage of surface water and groundwater agricultural lands was then multiplied by the total agricultural water use to obtain groundwater and surface water totals. This methodology results in subwatersheds with a high density of streams and few water supply wells relying more heavily on surface water, while subwatersheds with fewer streams would tend towards more groundwater use. Finally, the groundwater/surface water totals for each subwatershed were multiplied by a factor of 0.8 to obtain the consumptive values used in the subwatershed stress assessment.

Tables 4.20 and **4.21** provide the estimated consumptive agricultural water demands based on the de Loe methodology at the watershed and subwatershed evaluation scales within the Halton Region SPA and the Hamilton Region SPA, respectively.

Table 4.20: Halton Region SPA Estimated Annual Consumptive Agricultural Water Demand

Watershed	Watershed Name	Agricultural Water Taking		
		Surface Water [m^3]	Groundwater [m^3]	Total [m^3]
Sixteen Mile Creek	East Branch	58,705	32,717	91,422
	East Branch Lisgar	41,964	69,673	111,637
	Lower Middle Branch	174,818	49,565	224,382
	Lower Middle Tributary	26,903	14,489	41,393
	Main Branch	14,731	9,892	24,623
	Middle East Branch	106,194	47,276	153,470
	Middle Branch	102,828	73,289	176,117
	Morrison-Wedgewood Diversion	2,151	8,365	10,516
	Upper West Branch	35,053	62,094	97,146
	West Branch	41,994	20,731	62,725
	Total	**605,340**	**388,091**	**993,431**
Bronte Creek	Flamboro Creek	9,022	34,562	43,583
	Indian Creek	33,597	19,570	53,167
	Kilbride Creek	34,901	35,414	70,315
	Limestone Creek	43,597	29,857	73,454
	Lower Main Branch	53,807	17,520	71,327
	Lowville Creek	6,621	8,964	15,586
	Mount Nemo Creek	3,639	2,236	5,875
	Mountsberg Creek	102,254	83,616	185,870
	Strabane Creek	10,179	21,298	31,477
	Upper Main Branch	56,434	86,511	142,945
	Willoughby Creek	8,086	11,660	19,746
	Total	**362,138**	**351,206**	**713,345**
Grindstone Creek	201	71,510	72,584	144,094
	204	25,177	11,973	37,150
	210	42,845	32,082	74,927
	214	33,591	11,790	45,382
	215	24,938	65,766	90,704
	218	2,053	287	2,340
	220	10,419	9,013	19,432
	222	2,528	30	2,558
	224	7,792	3,418	11,210
	228	11,637	1,822	13,459
	230	2,126	0	2,126
	232 (Alternate)	2,789	947	3,737
	Total	**237,406**	**209,714**	**447,120**
North Shore Group 1	407 Diversion	1,128	2,966	4,094
	Cootes Paradise (Halton)	0	0	0
	Falcon Creek	13,029	4,901	17,930
	Indian Creek	8,010	191	8,202
	North Cootes Paradise (232)	2,709	425	3,134
	Upper Hager Creek	16,632	960	17,591
	Upper Rambo Creek	0	0	0
	West Aldershot (East)	403	0	403
	West Aldershot (West)	0	0	0
	Total	**41,911**	**9,444**	**51,354**
North Shore Group 2	Appleby Creek	14,895	2,405	17,299
	Beach Strip East Side	0	0	0
	Beach Strip West Side	0	0	0

Table 4.20: Halton Region SPA Estimated Annual Consumptive Agricultural Water Demand

Watershed	Watershed Name	Agricultural Water Taking		
		Surface Water [m^3]	Groundwater [m^3]	Total [m^3]
	Lower Hager Creek	0	0	0
	Lower Rambo Creek	0	0	0
	Roseland Creek	170	964	1,134
	Sheldon Creek	25,675	4,392	30,066
	Shoreacres Creek	14,319	2,731	17,050
	Tuck Creek	27,296	1,052	28,348
	Total	**82,354**	**11,544**	**93,898**
North Shore Group 3	Fourteen Mile Creek	15,195	9,073	24,269
	McCraney Creek	1,419	323	1,742
Total	Total	**16,614**	**9,396**	**26,010**
North Shore Group 4	Ford Plant Special Area	0	0	0
	Joshua's Creek	13,878	12,242	26,120
	Lower Morrison Creek	0	0	0
	Lower Wedgewood Creek	0	0	0
	Total	**13,878**	**12,242**	**26,120**
Halton Watershed		**1,359,641**	**991,637**	**2,351,278**

Based on this approach the highest agricultural water use is in the Sixteen Mile Creek watershed although, taking into account the surface area of the watershed, the Grindstone Creek watershed has a higher concentration of agricultural water takings. As expected the agricultural taking are not very significant in the North Shore Group watersheds as these are heavily urbanized.

Table 4.21: Hamilton Region SPA Estimated Annual Consumptive Agricultural Water Demand

Watershed	Watershed Name	Agricultural Water Taking		
		Surface Water [m^3]	Groundwater [m^3]	Total [m^3]
Spencer Creek	Ancaster Creek	12,794	2,803	15,597
	Borer's Creek	54,143	79,350	133,493
	Chedoke Creek	3,653	5,261	8,914
	Flamborough Creek	24,195	44,844	69,038
	Fletcher Creek	7,097	21,750	28,846
	Logie's Creek	23,767	58,613	82,380
	Lower Spencer Creek	1,759	757	2,516
	Middle Spencer Creek	105,970	114,053	220,022
	Spring Creek	34,133	2,433	36,566
	Sulphur Creek	27,699	4,776	32,475
	Sydenham Creek	9,464	25,138	34,602
	Tiffany Creek	9,592	1,313	10,905
	Upper Spencer Creek	27,896	35,846	63,742
	West Spencer Creek	53,751	44,713	98,464
	Westover Creek	12,792	58,921	71,714
	Total	**408,704**	**500,569**	**909,274**
Red Hill Creek	Green Hill	139	7	146
	Hannon Creek	9,393	794	10,186

Table 4.21: Hamilton Region SPA Estimated Annual Consumptive Agricultural Water Demand

Watershed	Watershed Name	Agricultural Water Taking		
		Surface Water [m^3]	Groundwater [m^3]	Total [m^3]
	Lower Davis Creek	1,181	377	1,558
	Montgomery Creek	2,267	156	2,422
	Red Hill Valley	7,216	785	8,001
	Upper Davis Creek	3,008	472	3,480
	Upper Ottawa	469	295	764
	Total	**23,672**	**2,885**	**26,557**
Stoney Creek	Battlefield Creek	10,544	4,705	15,249
	Stoney Creek	25,564	5,103	30,667
	Total	**36,109**	**9,807**	**45,916**
Stoney Creek Watercourses	WC 0	0	0	0
	WC 1	660	105	765
	WC 2	279	121	400
	WC 3	0	0	0
	WC 4	248	420	668
	WC 5	7,880	5,867	13,746
	WC 6	3,943	574	4,517
	WC 7	9,321	6,809	16,130
	WC 8	3	0	3
	WC 9	19,400	20,106	39,506
	WC 10	0	6,138	6,138
	WC 10.1	937	370	1,307
	WC 11	442	62	505
	WC 12	31,292	28,964	60,256
	Total	**74,405**	**69,535**	**143,940**
Urban Hamilton Beach Strip		0	0	0
Urban Hamilton City Core		0	0	0
Cootes Paradise (Hamilton)		0	0	0
Hamilton Watershed		**542,890**	**582,797**	**1,125,686**

In Hamilton Region SPA the most agricultural water users are located in the Spencer Creek watershed. Almost nine tenths of all the agricultural takings are located in the Spencer Creek watershed.

4.5 Consumptive Water Demands

4.5.1 Annual Consumptive Water Demand

As per Rule 33 of Part III.3 of the Technical Rules an annual Water Quantity Stress Assessment is required only for groundwater. This is due to the fact that the groundwater supply is not as sensitive to seasonal changes as surface water. As previously stated the total consumptive water demand is a sum of permitted and non-permitted uses. The total annual consumptive groundwater demands and their constituting elements for the existing conditions are given in **Table 4.22** for Halton Region SPA and in **Table 4.23** for Hamilton Region SPA.

Table 4.22: Halton Region SPA Annual Consumptive Groundwater Demand

Watershed	Subwatershed	Private Domestic	Agricultural	Municipal/ Communal	PTTW*	Total	Total**
		[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[mm]
Sixteen Mile Creek	East Branch	28,039	32,717	0	0	60,755	2.0
	East Branch Lisgar	20,606	69,673	0	0	90,279	3.5
	Lower Middle Branch	13,909	49,565	0	0	63,473	1.5
	Lower Middle Tributary	3,654	14,489	0	0	18,144	2.5
	Main Branch	4,790	9,892	0	0	14,682	0.6
	Middle East Branch	29,884	47,276	0	0	77,160	1.9
	Middle Branch	32,222	73,289	0	150,629	256,141	4.7
	Morrison-Wedgewood Diversion	1,585	8,365	0	0	9,950	0.6
	Upper West Branch	55,384	62,094	2,843,265	687,673	3,648,415	50.1
	West Branch	19,167	20,731	2,561	24,903	67,362	1.2
	Total	**209,240**	**388,091**	**2,845,826**	**863,204**	**4,306,361**	**11.6**
Bronte Creek	Flamboro Creek	10,410	34,562	84,547	0	129,519	13.7
	Indian Creek	27,134	19,570	0	0	46,704	1.1
	Kilbride Creek	35,154	35,414	27,245	0	97,813	2.4
	Limestone Creek	25,914	29,857	520,371	197	576,340	15.7
	Lower Main Branch	25,964	17,520	9,954	0	53,438	1.5
	Lowville Creek	11,244	8,964	0	26,976	47,184	4.7
	Mount Nemo Creek	2,669	2,236	0	0	4,905	1.1
	Mountsberg Creek	47,814	83,616	9,954	68,918	210,301	3.8
	Strabane Creek	13,765	21,298	4,346	0	39,409	2.1
	Upper Main Branch	67,270	86,511	44,464	21,170	219,415	4.2
	Willoughby Creek	12,722	11,660	0	538,122	562,504	46.1
	Total	**280,061**	**351,206**	**700,881**	**655,383**	**1,987,531**	**6.3**
Grindstone	201	33,656	72,584	0	0	106,239	4.7
	204	7,421	34,211	0	0	41,631	6.3
	210	16,988	32,082	0	0	49,071	6.1
	214	21,034	11,790	0	0	32,825	4.1
	215	16,306	65,766	0	0	82,072	5.6
	218	1,721	287	0	0	2,008	1.2
	220	19,650	9,013	0	11,403	40,067	4.9
	222	2,450	30	0	0	2,480	1.0
	224	2,389	3,418	0	0	5,807	1.0
	228	17,550	1,822	0	0	19,372	2.4
	230	1,094	0	0	0	1,094	0.7
	232 (Alternate)	1,122	947	0	0	2,069	0.8
	Total	**141,382**	**231,952**	**0**	**11,403**	**384,737**	**4.3**
North Shore Group 1	407 Diversion	10,469	2,966	1,935	0	15,370	2.9
	Cootes Paradise (Halton)	1,357	0	0	0	1,357	1.9
	Falcon Creek	2,861	4,901	0	0	7,762	1.4
	Indian Creek	6,570	191	0	0	6,761	1.1
	North Cootes Paradise (232)	3,455	425	0	0	3,880	0.6
	Upper Hager Creek	1,249	960	0	0	2,209	0.5
	Upper Rambo Creek	0	0	0	0	0	0.0
	West Aldershot (East)	0	0	0	0	0	0.0
	West Aldershot (West)	0	0	0	0	0	0.0
	Total	**25,961**	**9,444**	**1,935**	**0**	**37,339**	**1.0**
North Shore Group 2	Appleby Creek	1,052	2,405	0	0	3,456	0.2
	Beach Strip East Side	61	0	0	0	61	0.1
	Beach Strip West Side	29	0	0	0	29	0.1
	Lower Hager Creek	0	0	0	0	0	0.0
	Lower Rambo Creek	0	0	0	0	0	0.0
	Roseland Creek	130	964	0	0	1,094	0.1

Table 4.22: Halton Region SPA Annual Consumptive Groundwater Demand

Watershed	Subwatershed	Private Domestic	Agricultural	Municipal/ Communal	PTTW*	Total	Total**
		[m³]	[m³]	[m³]	[m³]	[m³]	[mm]
	Sheldon Creek	1,470	4,392	0	0	5,861	0.3
	Shoreacres Creek	1,212	2,731	0	10,038	13,981	1.0
	Tuck Creek	1,771	1,052	0	32,576	35,400	3.4
	Total	**5,724**	**11,544**	**0**	**42,614**	**59,882**	**0.8**
North Shore Group 3	Fourteen Mile Creek	19,547	9,073	0	36,720	65,340	1.9
	McCraney Creek	268	323	0	0	591	0.0
	Total	**19,815**	**9,396**	**0**	**36,720**	**65,931**	**1.4**
North Shore Group 4	Ford Plant Special Area	0	0	0	0	0	0.0
	Joshua's Creek	9,515	12,242	0	0	21,757	1.0
	Lower Morrison Creek	0	0	0	0	0	0.0
	Lower Wedgewood Creek	0	0	0	0	0	0.0
	Total	**9,515**	**12,242**	**0**	**0**	**21,757**	**0.6**
Halton Watershed		**691,698**	**1,013,874**	**3,548,642**	**1,609,324**	**6,863,537**	**7.1**

Note: * - PTTW consumptive demand excluding agricultural and municipal takings, which are reported in their specific columns;
** - total as millimitres of water per unit area.

Sixteen Mile Creek watershed is characterized by the highest consumptive groundwater demand within the Halton Region SPA.

Table 4.23: Hamilton Region SPA Annual Consumptive Groundwater Demand

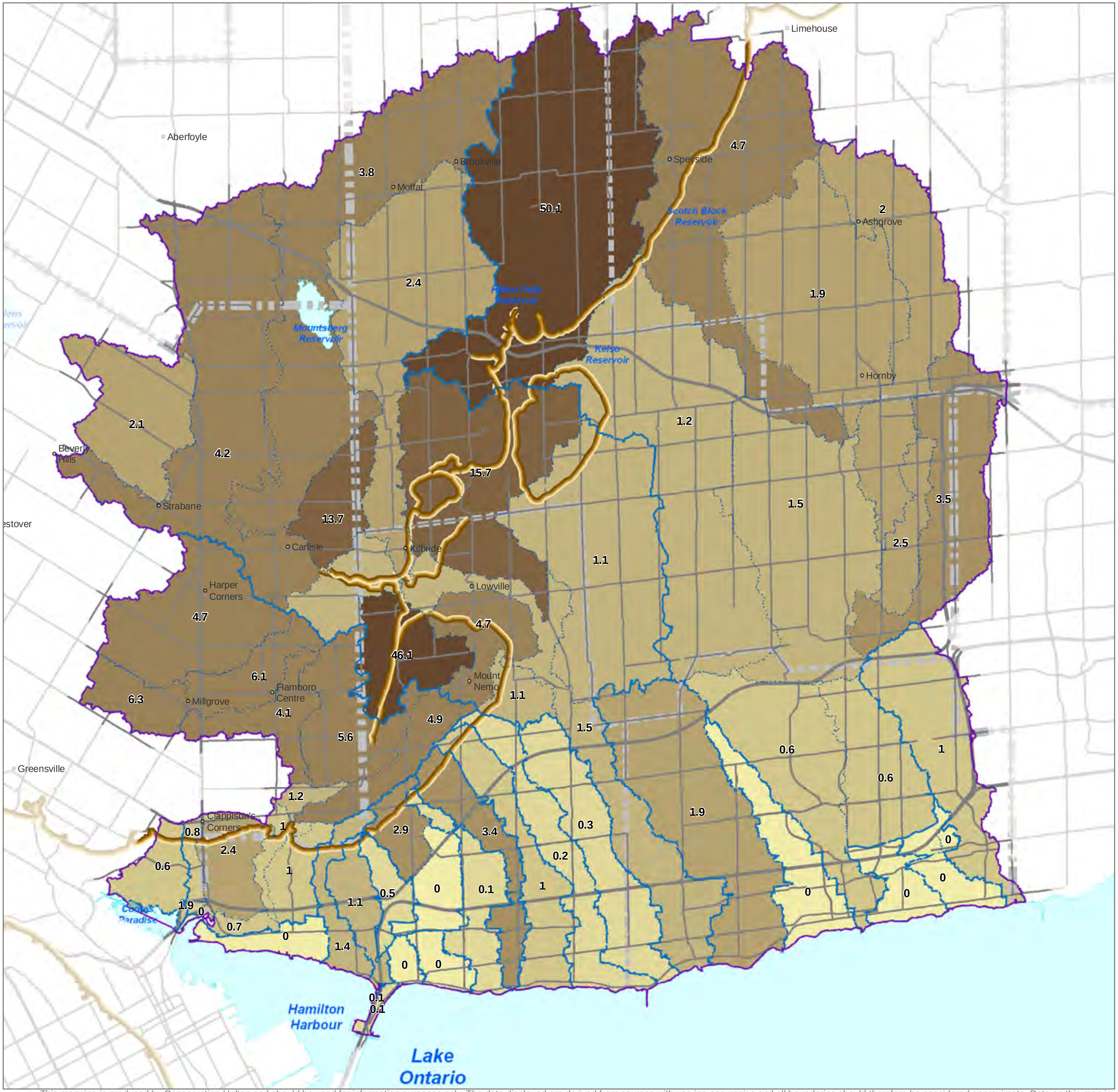
Watershed	Subwatershed	Private Domestic	Agricultural	Municipal/ Communal	PTTW*	Total	Total**
		[m³]	[m³]	[m³]	[m³]	[m³]	[mm]
Spencer Creek	Ancaster Creek	21,819	2,803	0	0	24,622	1.8
	Borer's Creek	24,703	79,350	0	0	104,053	5.3
	Chedoke Creek	6,494	5,261	0	0	11,754	0.5
	Flamborough Creek	10,474	135,399	1,531	21,562	168,966	12.7
	Fletcher Creek	14,120	21,750	0	0	35,870	1.4
	Logie's Creek	21,976	58,613	0	475,647	556,236	41.9
	Lower Spencer Creek	3,451	757	0	0	4,208	0.6
	Middle Spencer Creek	88,319	292,263	26,500	897,530	1,304,612	26.3
	Spring Creek	24,350	2,433	0	0	26,783	2.0
	Sulphur Creek	14,962	4,776	0	0	19,738	1.2
	Sydenham Creek	4,278	25,138	0	0	29,415	5.6
	Tiffany Creek	2,008	1,313	0	0	3,321	0.4
	Upper Spencer Creek	28,950	35,846	16,179	59,734	140,710	3.9
	West Spencer Creek	14,682	44,713	0	0	59,395	3.3
	Westover Creek	6,718	58,921	0	13,413	79,052	7.3
	Total	**287,303**	**769,335**	**44,211**	**1,467,886**	**2,568,735**	**9.3**
Red Hill Creek	Green Hill	0	7	0	0	7	0.0
	Hannon Creek	4,407	794	0	8,614	13,815	1.3
	Lower Davis Creek	5,300	377	0	210,570	216,246	57.6
	Montgomery Creek	0	156	0	40,272	156	10.8
	Red Hill Valley	274	785	0	0	1,059	0.1
	Upper Davis Creek	2,072	472	0	18,847	21,391	3.0
	Upper Ottawa	1,180	295	0	0	1,476	0.1
	Total	**13,232**	**2,885**	**0**	**238,031**	**254,148**	**3.9**
Stoney Creek	Battlefield Creek	6,409	4,705	0	0	11,114	1.5
	Stoney Creek	19,994	5,103	0	0	25,097	1.2
	Total	**26,403**	**9,807**	**0**	**0**	**36,210**	**1.3**

Table 4.23: Hamilton Region SPA Annual Consumptive Groundwater Demand

Watershed	Subwatershed	Private Domestic	Agricultural	Municipal/ Communal	PTTW*	Total	Total**
		[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
	Total	**26,871**	**69,535**	**0**	**0**	**96,406**	**2.6**
Urban Hamilton Beach Strip		150	0		0	150	0.1
Urban Hamilton City Core		479	0		18,396	18,875	0.5
Cootes Paradise (Hamilton)		2,810	0		0	2,810	2.4
Hamilton Watershed		**357,249**	**851,562**	**44,211**	**1,764,585**	**3,017,607**	**6.7**

Note: * - PTTW consumptive demand excluding agricultural and municipal takings, which are reported in their specific columns;
** - total as millimitres of water per unit area.

Figures 4.7 and **Figure 4.8** illustrate the consumptive groundwater demand in millimeters of water on subwatershed basis in the Halton Region SPA and Hamilton Region SPA, respectively.



DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 4.7

Groundwater Demand (mm/yr)

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment

Roads
- Highway
- Regional
- Waterbody

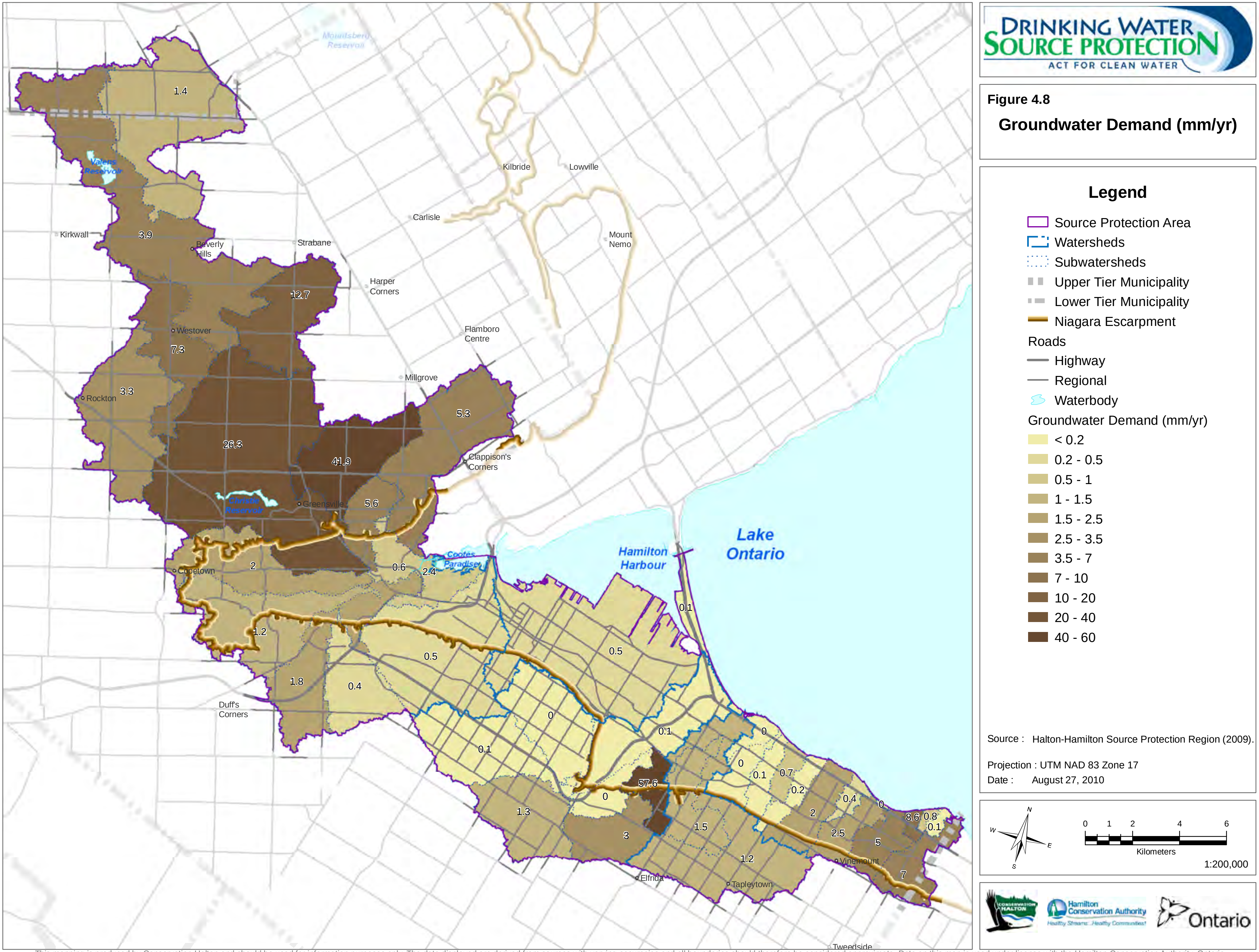
Groundwater Demand (mm/yr)
- < 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2.5
- 2.5 - 3.5
- 3.5 - 7
- 7 - 10
- 10 - 20
- 20 - 40
- 40 - 60

Source : Halton-Hamilton Source Protection Region (2009).

Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

Conservation Halton
Hamilton Conservation Authority — Healthy Streams...Healthy Communities!
Ontario



This mapping is produced by Conservation Halton and should be used for information purposes only. The data displayed are derived from sources with varying accuracies and all boundaries should therefore be considered approximate. Data on this map is used under license with the Hamilton Conservation Authority, Ontario Ministry of Natural Resources, Halton Region, City of Hamilton, Ministry of Environment, Ontario Geological Survey, Natural Resources Canada, Teranet Enterprises Inc. and other agencies. Copyright 2009.

4.5.2 Monthly Consumptive Groundwater Demand

Monthly consumptive groundwater demands were estimated using the following:

- Actual monthly distributed water taking data;
- Estimated values based on the actual water taking data from the same sector (e.g., golf course irrigation as explained in section 4.2.3);
- Estimates for permitted takings using the PTTW Database monthly use factors and suggested number of days of taking;
- Estimates of agricultural water taking based on the de Loe method as explained in section 4.4.2; and
- Estimates of private domestic takings based on the municipal water taking distribution.

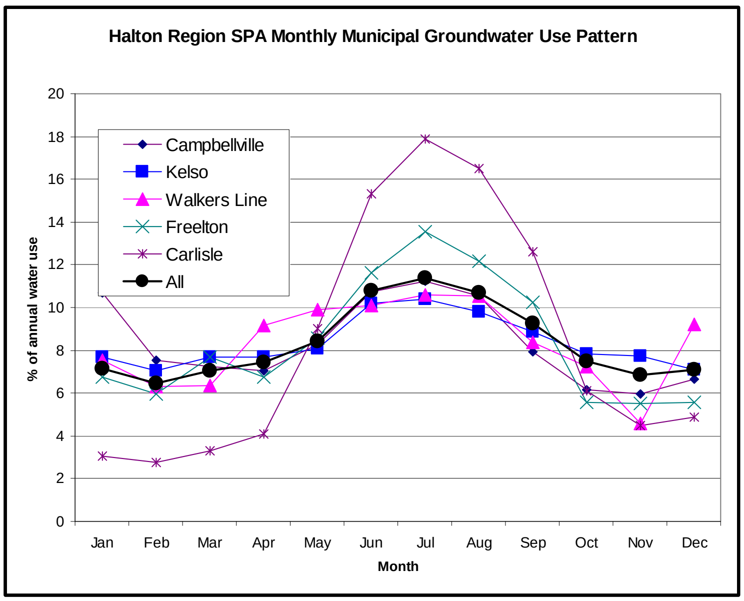


Figure 4-9: Halton Region SPA Monthly Municipal Groundwater Use Percentage Distribution

There is no known research and/or monitoring on monthly use patterns by owners of private well systems available. In Ontario there is no requirement to collect data on and monitor small-scale private systems - other than some private communal systems. To account for seasonality of the private domestic water takings or well based communal systems, such as lawn and garden watering in the summer, filling up swimming pools in the spring, car washing, etc., it was assumed they vary seasonally according to the same general pattern of water use experienced in municipal water supply systems. Existing monthly groundwater use ratio (as percent of the total annual water use) for the private domestic groundwater demands was estimated using the average of the actual monthly water takings of all municipal groundwater supply systems within each SPA. The monthly water taking distribution in percent of annual takings is presented in **Figure 4.9** for the Halton Region SPA.

On average the highest groundwater taking occurs in June, July and August.

Similarly to Halton Region SPA the municipal taking data was summarized on monthly basis for the Hamilton Region SPA.

Figure 4.10 illustrates the Greensville monthly water taking distribution. The monthly percent of annual water use was applied to the domestic takings to obtain the seasonal groundwater taking distribution.

Similarly to Halton municipal takings the Greensville takings are the highest from June through September and they are considerably lower during the winter months.

The percent distribution of the municipal takings was applied to the annual private domestic taking to obtain a monthly water taking distribution accounting for the seasonal changes.

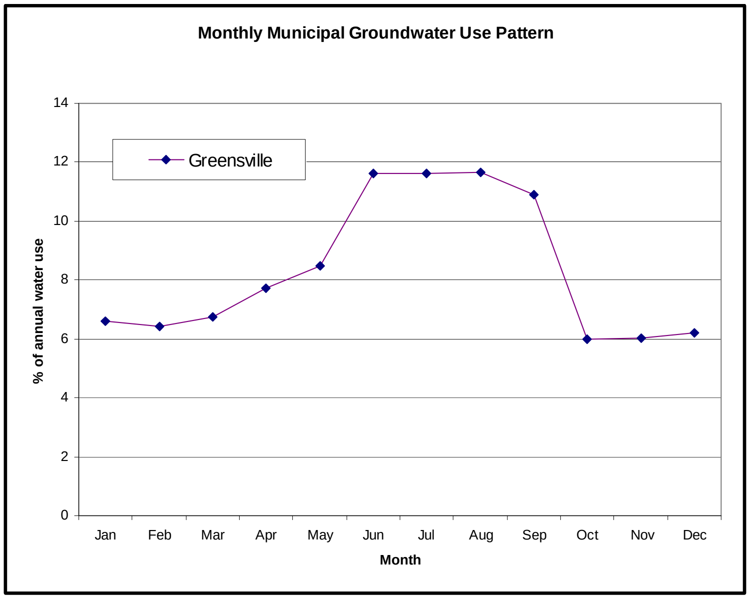


Figure 4-10: Hamilton Region SPA Monthly Municipal Groundwater Use Percentage Distribution

Tables 4.24 and **4.25** provide the watershed/subwatershed-based monthly consumptive permitted groundwater demands for the existing conditions for the Halton Region SPA and the Hamilton Region SPA, respectively.

Table 4.24: Halton Region SPA Monthly Consumptive Groundwater Demand

Watershed	Subwatershed	Jan [m³]	Feb [m³]	Mar [m³]	Apr [m³]	May [m³]	Jun [m³]	Jul [m³]	Aug [m³]	Sep [m³]	Oct [m³]	Nov [m³]	Dec [m³]	Total [m³]
Sixteen Mile Creek	East Branch	3,062	2,873	3,033	3,152	4,416	9,648	11,932	8,862	4,578	3,160	2,989	3,050	**60,755**
	East Branch Lisgar	3,664	3,525	3,643	3,730	6,080	16,495	21,219	14,815	6,104	3,736	3,610	3,655	**90,279**
	Lower Middle Branch	2,065	1,971	2,050	2,109	4,064	12,800	16,779	11,379	4,056	2,113	2,028	2,059	**63,473**
	Lower Middle Tributary	717	692	713	729	1,211	3,362	4,341	3,013	1,211	730	708	716	**18,144**
	Main Branch	634	602	629	649	1,013	2,588	3,294	2,339	1,030	651	621	632	**14,682**
	Middle East Branch	3,359	3,157	3,328	3,455	5,360	13,518	17,149	12,247	5,496	3,463	3,281	3,346	**77,160**
	Middle Branch	10,511	12,156	15,660	15,867	21,300	30,756	33,221	35,382	28,356	21,354	15,665	15,912	**256,141**
	Morrison-Wedgewood Diversion	360	350	359	365	648	1,923	2,505	1,714	644	366	356	360	**9,950**
	Upper West Branch	278,007	230,525	300,290	284,309	303,850	348,014	364,380	362,726	339,118	289,043	277,726	270,427	**3,648,415**
	West Branch	2,395	2,368	2,388	2,508	8,799	11,966	13,334	9,702	6,418	2,601	2,459	2,424	**67,362**
	Total	304,775	258,218	332,094	316,874	356,743	451,070	488,155	462,180	397,011	327,216	309,444	302,581	**4,306,361**
Bronte Creek	Flamboro Creek	4,345	4,039	4,553	5,255	10,624	21,279	25,869	21,423	13,685	6,996	5,532	5,919	**129,519**
	Indian Creek	2,950	2,767	2,922	3,037	3,669	5,997	6,939	5,695	3,865	3,045	2,879	2,939	**46,704**
	Kilbride Creek	4,694	4,499	4,991	5,861	7,792	15,131	17,427	13,798	8,617	5,576	4,812	4,615	**97,813**
	Limestone Creek	41,849	35,268	35,598	50,382	55,557	62,099	67,209	63,546	47,805	40,284	26,311	50,432	**576,340**
	Lower Main Branch	3,252	3,076	3,225	3,335	4,118	7,171	8,456	6,745	4,294	3,342	3,184	3,240	**53,438**
	Lowville Creek	1,052	976	1,040	1,088	7,552	9,636	10,492	7,304	4,883	1,091	1,022	1,047	**47,184**
	Mount Nemo Creek	253	235	250	261	361	764	938	706	378	262	246	252	**4,905**
	Mountsberg Creek	11,865	11,542	11,816	12,018	15,957	30,522	37,028	28,044	15,893	12,031	11,740	11,844	**210,301**
	Strabane Creek	2,016	1,923	2,002	2,230	2,986	5,787	7,075	5,454	3,124	2,358	2,214	2,241	**39,409**
	Upper Main Branch	12,988	12,321	13,264	13,247	17,301	29,973	35,668	28,487	18,340	12,990	12,383	12,453	**219,415**
	Willoughby Creek	55,049	38,185	44,177	91,740	81,668	29,826	31,668	65,006	47,375	10,368	30,900	36,542	**562,504**
	Total	140,311	114,832	123,838	188,456	207,584	218,185	248,770	246,208	168,258	98,342	101,222	131,524	**1,987,531**
Grindstone	201	4,535	4,308	4,501	4,643	7,300	18,852	24,036	17,024	7,419	4,653	4,447	4,521	**106,239**
	204	872	821	864	895	1,358	3,334	17,949	17,900	1,392	897	852	868	**48,004**
	210	2,129	2,014	2,112	2,184	3,394	8,622	11,978	11,867	3,463	2,188	2,085	2,122	**54,156**
	214	1,948	1,806	1,926	2,015	2,539	4,501	7,101	6,965	2,689	2,021	1,893	1,939	**37,344**
	215	4,012	3,902	3,995	4,064	5,789	13,408	16,858	12,183	5,817	4,069	3,969	4,005	**82,072**
	218	134	122	132	139	164	240	267	233	177	140	129	133	**2,008**
	220	1,744	1,611	1,723	1,807	4,803	6,579	7,281	5,492	3,788	1,812	1,692	1,735	**40,067**
	222	176	159	173	184	208	270	286	268	228	184	169	175	**2,480**
	224	300	284	298	308	423	905	1,116	832	437	309	294	299	**5,807**
	228	1,320	1,202	1,302	1,376	1,598	2,237	2,445	2,187	1,737	1,381	1,274	1,313	**19,372**
	230	78	71	77	81	92	118	124	117	101	82	75	78	**1,094**
	232 (Alternate)	116	108	115	120	156	300	362	280	164	120	113	116	**2,069**
	Total	17,363	16,409	17,218	17,817	27,826	59,366	73,251	53,684	27,411	17,856	16,994	17,303	**362,499**
North Shore Group 1	407 Diversion	1,136	1,065	1,125	1,169	1,283	1,581	1,666	1,565	1,368	1,172	1,108	1,131	**15,370**
	Cootes Paradise (Halton)	97	88	95	101	114	146	154	145	125	101	93	96	**1,357**
	Falcon Creek	581	562	578	590	637	789	846	773	659	591	574	580	**7,762**

Table 4.24: Halton Region SPA Monthly Consumptive Groundwater Demand

Watershed	Subwatershed	Jan [m^3]	Feb [m^3]	Mar [m^3]	Apr [m^3]	May [m^3]	Jun [m^3]	Jul [m^3]	Aug [m^3]	Sep [m^3]	Oct [m^3]	Nov [m^3]	Dec [m^3]	Total [m^3]
	Indian Creek	483	439	476	504	569	727	767	722	623	506	466	480	**6,761**
	North Cootes Paradise (232)	262	239	259	274	319	453	498	442	346	274	253	261	**3,880**
	Upper Hagar Creek	163	155	162	167	183	229	244	225	193	167	160	162	**2,209**
	Upper Rambo Creek	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	West Aldershot (East)	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	West Aldershot (West)	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Total	2,722	2,547	2,695	2,805	3,105	3,925	4,174	3,873	3,313	2,813	2,654	2,711	**37,339**
North Shore Group 2	Appleby Creek	260	253	259	263	283	349	375	342	291	264	257	260	**3,456**
	Beach Strip East Side	4	4	4	5	5	7	7	7	6	5	4	4	**61**
	Beach Strip West Side	2	2	2	2	2	3	3	3	3	2	2	2	**29**
	Lower Hagar Creek	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Lower Rambo Creek	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Roseland Creek	84	83	83	84	89	109	117	106	90	84	83	83	**1,094**
	Sheldon Creek	443	433	441	448	479	589	633	576	489	448	439	442	**5,861**
	Shoreacres Creek	1,133	1,125	1,132	1,137	1,159	1,235	1,264	1,226	1,168	1,137	1,130	1,133	**13,981**
	Tuck Creek	2,922	2,910	2,920	2,928	2,949	3,009	3,028	3,005	2,963	2,928	2,917	2,921	**35,400**
	Total	4,848	4,809	4,842	4,866	4,966	5,301	5,428	5,264	5,010	4,868	4,833	4,846	**59,882**
North Shore Group 3	Fourteen Mile Creek	1,728	1,596	1,709	1,788	10,345	12,754	13,693	9,719	6,827	1,789	1,677	1,715	**65,340**
	McCraney Creek	29	27	28	29	42	96	120	88	44	30	28	29	**591**
	Total	1,757	1,623	1,737	1,817	10,388	12,850	13,814	9,808	6,871	1,819	1,705	1,744	**65,931**
North Shore Group 4	Ford Plant Special Area	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Joshua's Creek	1,040	976	1,030	1,071	1,555	3,589	4,484	3,279	1,607	1,073	1,015	1,036	**21,757**
	Lower Morrison Creek	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Lower Wedgewood Creek	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Total	1,040	976	1,030	1,071	1,555	3,589	4,484	3,279	1,607	1,073	1,015	1,036	**21,757**
Halton Watershed		**472,816**	**399,414**	**483,456**	**533,707**	**612,167**	**754,287**	**838,076**	**784,297**	**609,480**	**453,987**	**437,868**	**461,744**	**6,841,300**

Table 4.25: Hamilton Region SPA Monthly Consumptive Groundwater Demand

Watershed	Subwatershed	Jan [m^3]	Feb [m^3]	Mar [m^3]	Apr [m^3]	May [m^3]	Jun [m^3]	Jul [m^3]	Aug [m^3]	Sep [m^3]	Oct [m^3]	Nov [m^3]	Dec [m^3]	Total [m^3]
Spencer Creek	Ancaster Creek	1,494	1,451	1,524	1,733	2,007	3,199	3,435	3,123	2,530	1,354	1,367	1,407	**24,622**
	Borer's Creek	4,369	4,321	4,403	4,640	7,133	18,578	23,525	16,798	7,579	4,211	4,225	4,270	**104,053**
	Chedoke Creek	523	510	532	594	849	2,002	2,442	1,845	993	482	485	497	**11,754**
	Flamborough Creek	2,455	2,435	2,470	3,192	11,469	19,869	56,897	53,294	13,249	5,542	2,414	2,414	**175,699**
	Fletcher Creek	1,800	1,772	1,820	1,955	2,625	5,673	6,881	5,242	2,930	1,710	1,718	1,744	**35,870**
	Logie's Creek	37,665	44,089	28,536	43,788	55,105	66,486	37,953	44,387	41,117	56,512	49,266	51,330	**556,236**
	Lower Spencer Creek	242	235	247	280	335	580	644	559	417	220	222	228	**4,208**
	Middle Spencer Creek	44,995	57,036	77,705	68,632	137,617	144,239	179,789	159,041	122,768	94,274	103,105	128,361	**1,317,563**

Table 4.25: Hamilton Region SPA Monthly Consumptive Groundwater Demand

Watershed	Subwatershed	Jan [m^3]	Feb [m^3]	Mar [m^3]	Apr [m^3]	May [m^3]	Jun [m^3]	Jul [m^3]	Aug [m^3]	Sep [m^3]	Oct [m^3]	Nov [m^3]	Dec [m^3]	Total [m^3]
	Spring Creek	1,655	1,607	1,688	1,922	2,200	3,405	3,610	3,341	2,785	1,499	1,513	1,558	**26,783**
	Sulphur Creek	1,075	1,046	1,096	1,239	1,538	2,870	3,271	2,732	1,889	979	988	1,015	**19,738**
	Sydenham Creek	1,459	1,450	1,464	1,505	2,085	4,748	5,921	4,325	2,152	1,431	1,434	1,441	**29,415**
	Tiffany Creek	156	152	159	178	245	545	654	506	290	143	144	148	**3,321**
	Upper Spencer Creek	9,576	9,565	9,635	9,933	11,149	16,719	18,582	15,854	11,891	9,254	9,221	9,331	**140,710**
	West Spencer Creek	1,810	1,782	1,831	1,971	3,800	12,204	15,886	12,710	4,042	1,717	1,725	1,752	**61,229**
	Westover Creek	1,719	1,706	1,728	1,792	6,939	17,474	22,235	14,774	5,639	1,676	1,679	1,692	**79,052**
	Total	110,994	129,158	134,837	143,354	245,096	318,590	381,726	338,531	220,272	181,004	179,505	207,188	**2,590,253**
Red Hill Creek	Green Hill	0	0	0	0	0	1	2	1	0	0	0	0	**7**
	Hannon Creek	1,031	1,023	1,037	1,080	1,139	1,400	1,457	1,381	1,245	1,003	1,006	1,014	**13,815**
	Lower Davis Creek	18,492	12,618	21,211	20,513	15,045	16,833	23,080	22,943	22,648	22,532	10,346	9,985	**216,246**
	Montgomery Creek	4	4	4	4	9	33	44	29	9	4	4	4	**156**
	Red Hill Valley	40	39	40	43	71	200	256	180	76	38	38	39	**1,059**
	Upper Davis Creek	1,937	1,911	1,916	1,937	1,784	1,854	1,904	1,772	1,647	1,560	1,520	1,649	**21,391**
	Upper Ottawa	86	84	88	99	118	200	222	193	146	79	79	82	**1,476**
	Total	21,590	15,678	24,297	23,676	18,167	20,522	26,964	26,500	25,771	25,217	12,994	12,772	**254,148**
Stoney Creek	Battlefield Creek	553	540	562	623	828	1,754	2,090	1,635	973	512	516	527	**11,114**
	Stoney Creek	1,463	1,424	1,491	1,682	2,003	3,417	3,782	3,293	2,477	1,335	1,346	1,383	**25,097**
	Total	2,016	1,964	2,052	2,306	2,831	5,170	5,872	4,928	3,451	1,847	1,862	1,911	**36,210**
Stoney Creek Watercourses	WC 0	2	2	2	2	2	3	3	3	3	2	2	2	**25**
	WC 1	10	10	10	10	12	18	21	17	13	10	10	10	**150**
	WC 2	10	10	10	10	12	18	21	17	12	10	10	10	**150**
	WC 3	95	92	97	111	122	167	167	167	156	86	87	89	**1,435**
	WC 4	36	36	36	37	43	67	76	63	45	35	35	36	**545**
	WC 5	807	794	815	876	984	1,462	1,592	1,418	1,134	766	770	781	**12,201**
	WC 6	38	38	38	38	44	71	84	66	43	38	38	38	**574**
	WC 7	713	705	718	756	856	1,305	1,455	1,252	948	687	689	697	**10,781**
	WC 8	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	WC 9	1,041	1,036	1,044	1,069	1,566	3,855	4,879	3,485	1,595	1,024	1,026	1,031	**22,650**
	WC 10	318	316	319	326	478	1,177	1,489	1,064	487	313	313	315	**6,914**
	WC 10.1	16	16	16	16	25	65	84	59	24	16	16	16	**370**
	WC 11	3	3	3	3	5	12	15	11	5	3	3	3	**71**
	WC 12	2,023	2,000	2,039	2,150	2,925	6,472	7,948	5,942	3,161	1,949	1,955	1,977	**40,540**
	Total	5,110	5,058	5,147	5,405	7,073	14,692	17,834	13,566	7,628	4,938	4,953	5,003	**96,406**
Urban Hamilton Beach Strip		10	10	10	12	13	17	17	18	16	9	9	9	**150**
Urban Hamilton City Core		1,565	1,564	1,565	1,570	1,574	1,589	1,589	1,589	1,585	1,562	1,562	1,563	**18,875**
Cootes Paradise (Hamilton)		186	180	190	217	238	326	327	328	306	168	170	175	**2,810**
Hamilton Watershed		**141,471**	**153,611**	**168,098**	**176,539**	**274,990**	**360,907**	**434,329**	**385,459**	**259,029**	**214,745**	**201,055**	**228,621**	**2,998,854**

4.5.3 Monthly Consumptive Surface Water Demand

Surface water consumptive demand is calculated as an average monthly rate of water takings for each subwatershed.

It should be noted that for some of the permitted takings if there is insufficient data the water taking is the maximum permitted value. For the permitted water takings, monthly consumptive surface water uses were estimated using the monthly use factor available in the PTTW Management Database with some minor adjustments. Consumptive water demand estimation for the permitted water takings in detail is explained in Section 4.1.3. Monthly consumptive agricultural water uses were estimated by seasonal water demand by crops and plants. Seasonal variation in total agricultural water use depends on how crop irrigation demand will vary over the growing season (May through September).

To avoid double counting of agricultural water uses the maximum of the monthly consumptive permitted water takings and monthly consumptive agricultural water uses is used as the total consumptive monthly water demands for each subwatershed. **Tables 4.26** and **4.27** show the total monthly consumptive water demands in cubic metres per second (m^3/s) for each subwatershed in the Halton Region SPA and Hamilton Region SPA, respectively. The consumptive demand is higher in the summer months, June, July and August and lower in the winter months.

Table 4.26: Halton Region SPA Monthly Consumptive Surface Water 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]
Sixteen Mile Creek	East Branch	0.0007	0.0008	0.0007	0.0007	0.0014	0.0046	0.0059	0.0039	0.0014	0.0007	0.0007	0.0007
	East Branch Lisgar	0.0005	0.0005	0.0005	0.0005	0.0010	0.0033	0.0042	0.0028	0.0010	0.0005	0.0005	0.0005
	Lower Middle Branch	0.0014	0.0016	0.0014	0.0015	0.0227	0.0315	0.0358	0.0237	0.0121	0.0014	0.0015	0.0014
	Lower Middle Tributary	0.0022	0.0024	0.0022	0.0023	0.0016	0.0021	0.0027	0.0018	0.0016	0.0022	0.0023	0.0022
	Main Branch	0.0002	0.0002	0.0002	0.0002	0.0008	0.0090	0.0021	0.0010	0.0003	0.0002	0.0002	0.0002
	Middle East Branch	0.0010	0.0011	0.0010	0.0011	0.0036	0.0102	0.0127	0.0088	0.0036	0.0010	0.0011	0.0010
	Middle Branch	0.0013	0.0014	0.0013	0.0021	0.0082	0.0271	0.0197	0.0190	0.0036	0.0042	0.0026	0.0013
	Morrison-Wedgewood Diversion	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000
	Upper West Branch	0.0029	0.0007	0.0003	0.0003	0.0008	0.0030	0.0039	0.0025	0.0008	0.0003	0.0006	0.0020
	West Branch	0.0007	0.0007	0.0007	0.0013	0.0126	0.0308	0.0405	0.0231	0.0147	0.0063	0.0007	0.0007
Bronte Creek	Flamboro Creek	0.0001	0.0001	0.0001	0.0020	0.0109	0.0126	0.0138	0.0057	0.0018	0.0010	0.0010	0.0001
	Indian Creek	0.0007	0.0007	0.0007	0.0007	0.0009	0.0020	0.0025	0.0018	0.0009	0.0007	0.0007	0.0007
	Kilbride Creek	0.0004	0.0004	0.0004	0.0004	0.0008	0.0028	0.0036	0.0024	0.0008	0.0004	0.0004	0.0004
	Limestone Creek	0.0004	0.0004	0.0004	0.0004	0.0055	0.0088	0.0099	0.0065	0.0035	0.0004	0.0004	0.0004
	Lower Main Branch	0.0010	0.0010	0.0010	0.0010	0.0016	0.0045	0.0057	0.0039	0.0016	0.0010	0.0010	0.0010
	Lowville Creek	0.0001	0.0001	0.0001	0.0001	0.0009	0.0014	0.0015	0.0010	0.0006	0.0001	0.0001	0.0001
	Mount Nemo 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
	Mountsberg Creek	0.0010	0.0011	0.0010	0.0010	0.0054	0.0122	0.0147	0.0097	0.0040	0.0010	0.0010	0.0010
	Strabane Creek	0.0002	0.0002	0.0002	0.0002	0.0003	0.0007	0.0009	0.0006	0.0003	0.0002	0.0002	0.0002
	Upper Main Branch	0.0009	0.0010	0.0009	0.0009	0.0014	0.0040	0.0049	0.0039	0.0014	0.0009	0.0009	0.0009
	Willoughby Creek	0.0001	0.0001	0.0001	0.0001	0.0044	0.0053	0.0054	0.0036	0.0025	0.0001	0.0001	0.0001
Grindstone	201	0.0008	0.0009	0.0008	0.0008	0.0016	0.0058	0.0074	0.0049	0.0016	0.0008	0.0008	0.0008
	204	0.0003	0.0003	0.0003	0.0003	0.0006	0.0021	0.0026	0.0018	0.0006	0.0003	0.0003	0.0003
	210	0.0005	0.0005	0.0005	0.0005	0.0010	0.0035	0.0045	0.0030	0.0010	0.0005	0.0005	0.0005
	214	0.0005	0.0005	0.0005	0.0005	0.0008	0.0025	0.0031	0.0021	0.0008	0.0005	0.0005	0.0005
	215	0.0004	0.0004	0.0004	0.0004	0.0006	0.0017	0.0021	0.0018	0.0006	0.0004	0.0004	0.0004
	218	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000
	220	0.0001	0.0002	0.0001	0.0002	0.0006	0.0011	0.0013	0.0009	0.0004	0.0001	0.0002	0.0001
	222	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002	0.0002	0.0001	0.0000	0.0000	0.0000
	224	0.0001	0.0001	0.0001	0.0001	0.0002	0.0006	0.0007	0.0005	0.0002	0.0001	0.0001	0.0001
	228	0.0002	0.0002	0.0002	0.0002	0.0003	0.0009	0.0011	0.0007	0.0003	0.0002	0.0002	0.0002
	230	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000
	232 (Alternate)	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0003	0.0002	0.0001	0.0000	0.0000	0.0000
North Shore Group 1	407 Diversion	0.0000	0.0000	0.0000	0.0000	0.0024	0.0027	0.0027	0.0018	0.0014	0.0000	0.0000	0.0000
	Cootes Paradise (Halton)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Falcon Creek	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004

Table 4.26: Halton Region SPA Monthly Consumptive Surface Water 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]
	Indian Creek	0.0002	0.0003	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002
	North Cootes Paradise (232)	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0003	0.0002	0.0001	0.0000	0.0000	0.0000
	Upper Hager Creek	0.0005	0.0005	0.0005	0.0005	0.0005	0.0006	0.0007	0.0006	0.0005	0.0005	0.0005	0.0005
	Upper Rambo Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	West Aldershot (East)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	West Aldershot (West)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
North Shore Group 2	Appleby Creek	0.0004	0.0005	0.0004	0.0004	0.0029	0.0033	0.0033	0.0023	0.0019	0.0004	0.0004	0.0004
	Beach Strip East Side	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Beach Strip West Side	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Lower Hager Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Lower Rambo Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Roseland Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Sheldon Creek	0.0007	0.0008	0.0007	0.0008	0.0008	0.0010	0.0010	0.0009	0.0008	0.0007	0.0008	0.0007
	Shoreacres Creek	0.0004	0.0005	0.0004	0.0004	0.0004	0.0005	0.0006	0.0005	0.0004	0.0004	0.0004	0.0004
	Tuck Creek	0.0008	0.0009	0.0008	0.0008	0.0008	0.0010	0.0011	0.0010	0.0008	0.0008	0.0008	0.0008
North Shore Group 3	Fourteen Mile Creek	0.0002	0.0002	0.0002	0.0002	0.0003	0.0012	0.0016	0.0010	0.0003	0.0002	0.0002	0.0002
	McCraney 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
North Shore Group 4	Ford Plant Special Area	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Joshua's Creek	0.0002	0.0002	0.0002	0.0002	0.0003	0.0011	0.0014	0.0010	0.0003	0.0002	0.0002	0.0002
	Lower Morrison Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Lower Wedgewood Creek	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.27: Hamilton Region SPA Monthly Consumptive Surface Water 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	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
	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
	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
	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
	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
	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
	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

Table 4.27: Hamilton Region SPA Monthly Consumptive Surface Water 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]
	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
	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
	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
	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
	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
	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
Red Hill Creek	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
	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
	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
	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
	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
	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
	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
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
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
Urban Hamilton Beach Strip		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	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
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

5 WATER SUPPLY

5.1 Surface Water Supply

Surface water quantity stress assessment is completed on a monthly basis; therefore, monthly water supply data is required. The calibrated PRMS surface water model was the method used to estimate the surface water supply (see section 2.2.6). The PRMS model assumptions, model development, calibration and the water budget results are discussed in Section 2.2 and in 2010 Earthfx reports for Halton Region and Hamilton (**Appendix A** and **Appendix B**).

The simulated monthly median streamflows include precipitation received, baseflow and runoff from one subwatershed to the next. The values are equivalent to the water available for all uses within the subwatershed/watershed.

Tables 5.1 and **5.2** present monthly median streamflows simulated by the PRMS model for the Halton Region SPA and the Hamilton Region SPA, respectively.

Table 5.1: Halton Region SPA Surface Water Supply (Median Streamflow, Estimated by the PRMS Model)

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]
Sixteen Mile Creek	East Branch	0.205	0.171	0.282	0.320	0.197	0.058	0.013	0.004	0.005	0.016	0.115	0.155
	East Branch Lisgar	0.179	0.143	0.257	0.263	0.180	0.061	0.014	0.004	0.006	0.020	0.115	0.141
	Lower Middle Branch	1.598	1.259	2.206	2.589	1.566	0.519	0.198	0.156	0.171	0.332	1.155	1.345
	Lower Middle Tributary	0.050	0.038	0.072	0.075	0.048	0.015	0.004	0.001	0.001	0.004	0.032	0.039
	Main Branch	3.277	2.544	4.410	5.317	3.228	1.177	0.588	0.496	0.575	1.031	2.677	2.923
	Middle East Branch	0.276	0.229	0.379	0.482	0.282	0.084	0.019	0.006	0.006	0.022	0.169	0.218
	Middle Branch	0.569	0.430	0.755	0.979	0.551	0.200	0.118	0.125	0.132	0.223	0.504	0.539
	Morrison-Wedgewood Diversion	0.130	0.111	0.166	0.163	0.114	0.048	0.027	0.025	0.029	0.048	0.096	0.101
	Upper West Branch	0.939	0.685	1.074	1.647	0.927	0.384	0.278	0.262	0.303	0.506	0.968	0.974
	West Branch	1.339	1.008	1.725	2.292	1.363	0.538	0.326	0.286	0.338	0.583	1.271	1.310
Bronte Creek	Flamboro Creek	0.126	0.102	0.157	0.208	0.127	0.054	0.037	0.025	0.040	0.072	0.136	0.135
	Indian Creek	0.257	0.213	0.437	0.459	0.288	0.092	0.029	0.012	0.013	0.035	0.187	0.191
	Kilbride Creek	0.527	0.417	0.642	0.899	0.546	0.234	0.176	0.136	0.182	0.309	0.565	0.566
	Limestone Creek	0.448	0.326	0.571	0.740	0.436	0.177	0.125	0.094	0.131	0.227	0.431	0.437
	Lower Main Branch	3.384	2.693	4.366	5.487	3.435	1.335	0.783	0.523	0.772	1.444	3.177	3.301
	Lowville Creek	0.055	0.037	0.094	0.112	0.071	0.023	0.006	0.001	0.001	0.006	0.043	0.046
	Mount Nemo Creek	0.024	0.018	0.045	0.049	0.030	0.009	0.002	0.001	0.000	0.002	0.018	0.018
	Mountsberg Creek	0.605	0.489	0.728	1.040	0.639	0.247	0.142	0.097	0.142	0.266	0.595	0.630
	Strabane Creek	0.210	0.161	0.248	0.326	0.215	0.087	0.051	0.031	0.050	0.095	0.202	0.213
	Upper Main Branch	0.826	1.270	1.492	2.011	1.882	0.964	0.422	0.238	0.268	0.475	1.047	1.421
	Willoughby Creek	0.104	0.075	0.145	0.165	0.104	0.036	0.017	0.009	0.014	0.032	0.082	0.085
Grindstone	201	0.315	0.218	0.326	0.392	0.268	0.101	0.034	0.014	0.044	0.078	0.274	0.306
	204	0.393	0.273	0.407	0.509	0.354	0.135	0.043	0.018	0.057	0.100	0.360	0.408
	210	0.115	0.079	0.112	0.137	0.096	0.036	0.010	0.004	0.013	0.023	0.093	0.109
	214	0.611	0.422	0.616	0.775	0.540	0.203	0.062	0.024	0.079	0.141	0.533	0.609
	215	0.153	0.115	0.182	0.200	0.134	0.048	0.019	0.010	0.017	0.036	0.114	0.122
	218	0.775	0.547	0.816	0.994	0.688	0.256	0.082	0.034	0.097	0.180	0.656	0.742
	220	0.046	0.037	0.083	0.084	0.054	0.017	0.005	0.001	0.001	0.004	0.029	0.031
	222	0.851	0.607	0.936	1.118	0.769	0.286	0.094	0.040	0.104	0.196	0.709	0.799
	224	0.060	0.048	0.076	0.074	0.051	0.023	0.014	0.009	0.012	0.023	0.045	0.047
	228	0.071	0.065	0.105	0.109	0.076	0.032	0.017	0.009	0.012	0.025	0.057	0.058
	230	1.024	0.757	1.173	1.354	0.933	0.355	0.131	0.061	0.132	0.253	0.844	0.938
	232 (Alternate)	0.021	0.019	0.031	0.031	0.022	0.009	0.005	0.002	0.003	0.006	0.016	0.017
North Shore Group 1	407 Diversion	0.038	0.031	0.060	0.051	0.035	0.012	0.004	0.002	0.002	0.005	0.020	0.024
	Cootes Paradise (Halton)	0.001	0.002	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.002
	Falcon Creek	0.065	0.049	0.075	0.066	0.046	0.018	0.008	0.006	0.008	0.014	0.042	0.048

Table 5.1: Halton Region SPA Surface Water Supply (Median Streamflow, Estimated by the PRMS Model)

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]
	Indian Creek	0.237	0.192	0.268	0.236	0.177	0.078	0.046	0.033	0.039	0.075	0.154	0.173
	North Cootes Paradise (232)	0.062	0.049	0.077	0.089	0.060	0.022	0.009	0.004	0.006	0.014	0.048	0.049
	Upper Hager Creek	0.158	0.130	0.186	0.163	0.123	0.054	0.032	0.023	0.025	0.050	0.102	0.115
	Upper Rambo Creek	0.104	0.087	0.129	0.113	0.084	0.035	0.018	0.013	0.013	0.028	0.064	0.073
	West Aldershot (East)	0.056	0.050	0.058	0.054	0.040	0.014	0.004	0.002	0.004	0.007	0.039	0.045
	West Aldershot (West)	0.002	0.002	0.002	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.002	0.002
North Shore Group 2	Appleby Creek	0.150	0.132	0.202	0.164	0.126	0.059	0.043	0.033	0.036	0.068	0.116	0.122
	Beach Strip East Side	0.006	0.006	0.007	0.007	0.005	0.002	0.001	0.000	0.000	0.001	0.004	0.004
	Beach Strip West Side	0.002	0.002	0.003	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.001	0.002
	Lower Hager Creek	0.024	0.021	0.022	0.020	0.016	0.006	0.001	0.001	0.002	0.003	0.015	0.019
	Lower Rambo Creek	0.046	0.040	0.042	0.039	0.030	0.011	0.003	0.003	0.004	0.007	0.028	0.036
	Roseland Creek	0.097	0.086	0.104	0.095	0.076	0.030	0.014	0.009	0.012	0.023	0.062	0.074
	Sheldon Creek	0.185	0.167	0.235	0.204	0.155	0.071	0.051	0.039	0.045	0.084	0.142	0.149
	Shoreacres Creek	0.154	0.131	0.197	0.167	0.126	0.058	0.040	0.031	0.034	0.065	0.118	0.126
	Tuck Creek	0.093	0.081	0.129	0.111	0.081	0.032	0.017	0.012	0.013	0.026	0.063	0.071
North Shore Group 3	Fourteen Mile Creek	0.308	0.253	0.439	0.380	0.273	0.106	0.056	0.045	0.054	0.095	0.217	0.239
	McCraney Creek	0.109	0.101	0.131	0.124	0.092	0.038	0.020	0.017	0.020	0.038	0.080	0.087
North Shore Group 4	Ford Plant Special Area	0.008	0.007	0.008	0.007	0.005	0.003	0.003	0.003	0.004	0.006	0.008	0.007
	Joshua's Creek	0.184	0.150	0.228	0.223	0.154	0.060	0.033	0.030	0.037	0.060	0.129	0.144
	Lower Morrison Creek	0.076	0.061	0.077	0.068	0.052	0.024	0.015	0.014	0.019	0.031	0.061	0.064
	Lower Wedgewood Creek	0.079	0.063	0.078	0.070	0.053	0.024	0.016	0.016	0.020	0.034	0.064	0.065

Table 5.2: Hamilton Region SPA Surface Water Supply (Median Streamflow, Estimated by the PRMS Model)

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]
Spencer Creek	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
	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
	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
	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
	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
	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
	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
	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

Table 5.2: Hamilton Region SPA Surface Water Supply (Median Streamflow, Estimated by the PRMS Model)

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]
	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
	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
	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
	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
	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
Red Hill Creek	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
	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
	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
	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
	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
	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
	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
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
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
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
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

5.2 Groundwater Supply

Groundwater supply is the total available groundwater for all uses. The Technical Rules interpret the groundwater supply as the sum of the recharge of water to aquifers and the lateral flows into the subwatersheds. It should be noted that the Water Quantity Stress Assessment is completed for each subwatershed, which are delineated based on the surface water drainage areas. Surface watersheds and ground watersheds are not equivalent and therefore, there are lateral groundwater inflows into subwatersheds. It should also be noted that there may be more than one aquifer in a subwatershed and groundwater from all aquifers is considered available for use.

To estimate the groundwater supplies, the average annual recharge distribution was summarized based on the results of the surface water PRMS model.

The lateral groundwater flow into each subwatershed was obtained from the groundwater flow models. As the City of Hamilton groundwater flow model does not cover the entire Hamilton Region SPA; the subwatersheds outside of the modeled area (south of the Dundas Valley) are missing the lateral flow input data (see **Figure 41** in **Appendix B** for the Hamilton model extents). In these subwatersheds the groundwater supply is only recharge.

5.2.1 Recharge – PRMS Model (Earthfx, 2010)

The average annual recharge distribution (**Figures 2.12** and **2.16**) was obtained from the Regions of Halton and the City of Hamilton groundwater flow models.

Tables 5.3 and **5.4** provide the average annual recharge (PRMS - Earthfx, 2010) at the watershed/ subwatershed scale for the Halton Region SPA and Hamilton Region SPA, respectively.

Table 5.3: Halton Region SPA Average Annual Groundwater Recharge

Watershed	Subwatershed	Area [km^2]	Recharge [m^3/year]	Recharge [mm/year]
Sixteen Mile Creek	East Branch	29.64	3,484,746	118
	East Branch Lisgar	25.88	3,129,616	121
	Lower Middle Branch	42.32	5,817,538	137
	Lower Middle Tributary	7.18	896,696	125
	Main Branch	24.67	3,723,314	151
	Middle East Branch	41.65	4,937,882	119
	Middle Branch	54.96	12,131,836	221
	Morrison-Wedgewood Diversion	16.05	2,365,974	147
	Upper West Branch[1]	72.87	21,755,110	299
	West Branch	57.21	7,618,982	133
	Total	**372.42**	**65,861,694**	**177**
Bronte Creek	Flamboro Creek[1]	9.42	3,020,950	321
	Indian Creek	40.81	5,209,716	128
	Kilbride Creek	41.23	12,716,202	308
	Limestone Creek[1]	36.60	10,076,707	275
	Lower Main Branch	35.33	7,713,487	218
	Lowville Creek	10.07	1,130,558	112
	Mount Nemo Creek	4.51	505,679	112
	Mountsberg Creek	55.08	13,738,768	249

Table 5.3: Halton Region SPA Average Annual Groundwater Recharge

Watershed	Subwatershed	Area [km²]	Recharge [m³/year]	Recharge [mm/year]
	Strabane Creek	18.43	4,606,423	250
	Upper Main Branch[1]	52.72	13,110,902	249
	Willoughby Creek	12.20	2,023,278	166
	Total	**316.39**	**73,852,669**	**233**
Grindstone	201	22.73	5,726,429	252
	204	6.66	1,683,802	253
	210	8.02	1,989,132	248
	214	8.07	1,776,427	220
	215	14.64	2,674,623	183
	218	1.68	223,881	133
	220	8.19	905,246	111
	222	2.52	567,100	225
	224	5.68	1,134,383	200
	228	8.07	1,453,046	180
	230	1.65	334,122	202
	232 (Alternate)	2.45	402,284	164
	Total	**90.37**	**18,870,477**	**209**
North Shore Group 1	407 Diversion	5.23	622,079	119
	Cootes Paradise (Halton)	0.71	8,012	11
	Falcon Creek	5.42	1,010,947	187
	Indian Creek	6.07	1,279,583	211
	North Cootes Paradise (232)	6.27	1,122,529	179
	Upper Hager Creek	4.23	923,878	218
	Upper Rambo Creek	6.29	1,105,587	176
	West Aldershot (East)	4.36	854,760	196
	West Aldershot (West)	0.18	31,547	180
	Total	**38.76**	**6,958,923**	**180**
North Shore Group 2	Appleby Creek	14.08	2,774,996	197
	Beach Strip East Side	0.70	11,225	16
	Beach Strip West Side	0.26	0	0
	Lower Hager Creek	1.80	343,844	191
	Lower Rambo Creek	3.42	645,948	189
	Roseland Creek	9.40	1,541,155	164
	Sheldon Creek	17.67	3,489,155	197
	Shoreacres Creek	14.00	2,765,214	197
	Tuck Creek	10.45	1,608,243	154
	Total	**71.79**	**13,179,780**	**184**
North Shore Group 3	Fourteen Mile Creek	34.76	5,463,554	157
	McCraney Creek	12.21	1,896,705	155
	Total	**46.98**	**7,360,258**	**157**
North Shore Group 4	Ford Plant Special Area	0.55	162,823	298
	Joshua's Creek	21.62	3,314,604	153
	Lower Morrison Creek	5.92	1,279,279	216
	Lower Wedgewood Creek	5.49	1,192,192	217
	Total	**33.58**	**5,948,899**	**177**
Halton Watershed		**970.29**	**192,032,700**	**188**

[1] Subwatershed contains municipal wellfield

Table 5.4: Hamilton Region SPA Average Annual Groundwater Recharge

Watershed	Subwatershed	Area [km^2]	Recharge [m^3/year]	Recharge [mm/year]
Spencer Creek	Ancaster Creek	14.01	2,619,382	187
	Borer's Creek	19.48	3,791,210	195
	Chedoke Creek	25.06	4,081,872	163
	Flamborough Creek	13.30	3,507,640	264
	Fletcher Creek	25.12	4,863,018	194
	Logie's Creek	13.28	3,428,136	258
	Lower Spencer Creek	7.39	1,483,693	201
	Middle Spencer Creek[1]	49.68	11,450,049	230
	Spring Creek	13.11	1,948,387	149
	Sulphur Creek	16.90	3,256,709	193
	Sydenham Creek	5.27	1,001,072	190
	Tiffany Creek	9.08	1,272,248	140
	Upper Spencer Creek	35.92	8,175,785	228
	West Spencer Creek	18.11	4,743,354	262
	Westover Creek	10.89	3,115,949	286
	Total	**276.59**	**58,738,504**	**212**
Red Hill Creek	Green Hill	11.64	2,265,511	195
	Hannon Creek	10.97	1,349,395	123
	Lower Davis Creek	3.75	718,464	191
	Montgomery Creek	3.75	653,852	175
	Red Hill Valley	13.28	2,420,963	182
	Upper Davis Creek	7.25	1,056,850	146
	Upper Ottawa	13.83	1,719,166	124
	Total	**64.46**	**10,184,202**	**158**
Stoney Creek	Battlefield Creek	7.47	1,641,777	220
	Stoney Creek	21.03	3,449,496	164
	Total	**28.50**	**5,091,273**	**179**
Stoney Creek Watercourses	WC 0	1.64	202,014	123
	WC 1	3.58	670,763	187
	WC 2	2.97	595,588	200
	WC 3	2.10	434,373	207
	WC 4	2.81	614,247	218
	WC 5	6.18	1,452,032	235
	WC 6	1.52	395,210	261
	WC 7	4.32	991,298	230
	WC 8	0.10	9,270	97
	WC 9	4.51	1,398,211	310
	WC 10	0.80	130,146	162
	WC 10.1	0.48	55,514	117
	WC 11	0.69	79,378	116
	WC 12	5.76	1,255,790	218
	Total	**37.46**	**8,283,834**	**221**
Urban Hamilton Beach Strip		2.34	18,831	8
Urban Hamilton City Core		36.52	7,798,816	214
Cootes Paradise (Hamilton)		1.16	16,737	14
Hamilton Watershed		**447.04**	**90,132,197**	**202**

[1] Subwatershed contains municipal wellfield

5.2.2 Groundwater Lateral Flows

As explained in **section 3.0** of this report the Halton Region and the City of Hamilton groundwater flow models were used to estimate the lateral flows through the boundaries of the subwatersheds within the model domains. The lateral flows are summarized in the following **section 5.2.3** in **Tables 5.5** and **5.6** for the Halton Region SPA and the Hamilton Region SPA, respectively. It should be noted that as per the Technical Rules the summary of the lateral flows includes only the lateral flows into the subwatersheds. It is considered that any groundwater lateral flow into a subwatershed is available for taking; therefore, the groundwater lateral flows out of a subwatershed are not deducted from the total.

5.2.3 Total Groundwater Supply

The groundwater supply is calculated for each of the subwatersheds in the Halton-Hamilton SPR, and is defined as the sum of the recharge to aquifers and the lateral flows into specific subwatershed. **Table 5.5** is a summary of the recharge, lateral inflows and the total groundwater supplies for each subwatershed/watershed in the Halton Region SPA.

Table 5.5: Halton Region SPA Groundwater Supply Summary

Watershed	Subwatershed	Recharge	Lateral Inflow	Q_{SUPPLY}
		[m³/sec]	[m³/sec]	[m³/sec]
Sixteen Mile Creek	East Branch	0.1104	0.06816	0.1786
	East Branch Lisgar	0.0992	0.02388	0.1231
	Lower Middle Branch	0.1843	0.04960	0.2340
	Lower Middle Tributary	0.0284	0.01849	0.0469
	Main Branch	0.1180	0.07439	0.1924
	Middle East Branch	0.1565	0.05745	0.2139
	Middle Branch	0.3844	0.15349	0.5379
	Morrison-Wedgewood Diversion	0.0750	0.01673	0.0917
	Upper West Branch[1]	0.6894	0.18043	0.8698
	West Branch	0.2414	0.12938	0.3708
		2.0870		
Bronte Creek	Flamboro Creek[2]	0.0957	0.02051	0.1162
	Indian Creek	0.1651	0.04387	0.2090
	Kilbride Creek	0.4030	0.06713	0.4701
	Limestone Creek[3]	0.3193	0.04850	0.3678
	Lower Main Branch	0.2444	0.16900	0.4134
	Lowville Creek	0.0358	0.01665	0.0525
	Mount Nemo Creek	0.0160	0.01556	0.0316
	Mountsberg Creek	0.4354	0.05829	0.4936
	Strabane Creek	0.1460	0.00559	0.1516
	Upper Main Branch[4]	0.4155	0.07421	0.4897
	Willoughby Creek	0.0641	0.01921	0.0833
		2.3402		
Grindstone	201	0.1815	0.02441	0.2059
	204	0.0534	0.00838	0.0617
	210	0.0630	0.01931	0.0823
	214	0.0563	0.03875	0.0950
	215	0.0848	0.02619	0.1109

Table 5.5: Halton Region SPA Groundwater Supply Summary

Watershed	Subwatershed	Recharge	Lateral Inflow	Q_{SUPPLY}
		[m^3/sec]	[m^3/sec]	[m^3/sec]
	218	0.0071	0.00833	0.0154
	220	0.0287	0.00582	0.0345
	222	0.0180	0.01900	0.0370
	224	0.0359	0.02334	0.0593
	228	0.0460	0.02144	0.0675
	230	0.0106	0.01903	0.0296
	232 (Alternate)	0.0127	0.02504	0.0378
		0.5980		
North Shore Group 1	407 Diversion	0.0197	0.01569	0.0354
	Cootes Paradise (Halton)	0.0003	0.00418	0.0044
	Falcon Creek	0.0320	0.02835	0.0604
	Indian Creek	0.0405	0.04390	0.0844
	North Cootes Paradise (232)	0.0356	0.01338	0.0489
	Upper Hager Creek	0.0293	0.03095	0.0602
	Upper Rambo Creek	0.0350	0.02551	0.0605
	West Aldershot (East)	0.0271	0.01283	0.0399
	West Aldershot (West)	0.0010	0.00000	0.0010
		0.2205		
North Shore Group 2	Appleby Creek	0.0879	0.03994	0.1279
	Beach Strip East Side	0.0004	0.00216	0.0025
	Beach Strip West Side	0.0000	0.00052	0.0005
	Lower Hager Creek	0.0109	0.00442	0.0153
	Lower Rambo Creek	0.0205	0.00818	0.0286
	Roseland Creek	0.0488	0.03605	0.0849
	Sheldon Creek	0.1106	0.03843	0.1490
	Shoreacres Creek	0.0876	0.03789	0.1255
	Tuck Creek	0.0510	0.03848	0.0894
		0.4176		
North Shore Group 3	Fourteen Mile Creek	0.1731	0.04481	0.2179
	McCraney Creek	0.0601	0.02507	0.0852
		0.2332		
North Shore Group 4	Ford Plant Special Area	0.0052	0.00224	0.0074
	Joshua's Creek	0.1050	0.02874	0.1338
	Lower Morrison Creek	0.0405	0.02081	0.0613
	Lower Wedgewood Creek	0.0378	0.02721	0.0650
		0.1885		
Halton Watershed		**6.0851**		

The Hamilton Region groundwater flow model domain does not cover the entire Hamilton Region SPA and therefore lateral flows for some of the watersheds are unavailable.

Table 5.6 is a summary of the recharge and lateral inflows into subwatersheds/watersheds and the total groundwater supplies in the Hamilton Region SPA.

Table 5.6: Hamilton Region SPA Groundwater Supply Summary

Watershed	Subwatershed	Recharge [m³/sec]	Lateral Inflow [m³/sec]	Q_{SUPPLY} [m³/sec]
Spencer Creek	Ancaster Creek	0.0830		0.0830
	Borer's Creek	0.1201	0.0032	0.1233
	Chedoke Creek	0.1293		0.1293
	Flamborough Creek	0.1112	0.0034	0.1146
	Fletcher Creek	0.1541	0.0052	0.1593
	Logie's Creek	0.1086	0.0002	0.1088
	Lower Spencer Creek	0.0470	0.0018	0.0489
	Middle Spencer Creek[1]	0.3628	0.0797	0.4426
	Spring Creek	0.0617		0.0617
	Sulphur Creek	0.1032		0.1032
	Sydenham Creek	0.0317	0.0137	0.0454
	Tiffany Creek	0.0403		0.0403
	Upper Spencer Creek	0.2591	0.0020	0.2610
	West Spencer Creek	0.1503	0.0686	0.2189
	Westover Creek	0.0987	0.0000	0.0987
		1.8613		
Red Hill Creek	Green Hill	0.0718		0.0718
	Hannon Creek	0.0428		0.0428
	Lower Davis Creek	0.0228		0.0228
	Montgomery Creek	0.0207		0.0207
	Red Hill Valley	0.0767		0.0767
	Upper Davis Creek	0.0335		0.0335
	Upper Ottawa	0.0545		0.0545
		0.3227		
Stoney Creek	Battlefield Creek	0.0520		0.0520
	Stoney Creek	0.1093		0.1093
		0.1613		
Stoney Creek Watercourses	WC 0	0.0064		0.0064
	WC 1	0.0213		0.0213
	WC 2	0.0189		0.0189
	WC 3	0.0138		0.0138
	WC 4	0.0195		0.0195
	WC 5	0.0460		0.0460
	WC 6	0.0125		0.0125
	WC 7	0.0314		0.0314
	WC 8	0.0003		0.0003
	WC 9	0.0443		0.0443
	WC 10	0.0041		0.0041
	WC 10.1	0.0018		0.0018
	WC 11	0.0025		0.0025
	WC 12	0.0398		0.0398
		0.2625		
Urban Hamilton Beach Strip		0.0006		0.0006
Urban Hamilton City Core		0.2471		0.2471
Cootes Paradise (Hamilton)		0.0005	0.0043	0.0048
Hamilton Watershed		**2.8561**		

Figures 5.1 and **5.2** illustrate graphically the total annual groundwater supplies in mm for the Halton Region SPA and Hamilton Region SPA, respectively.

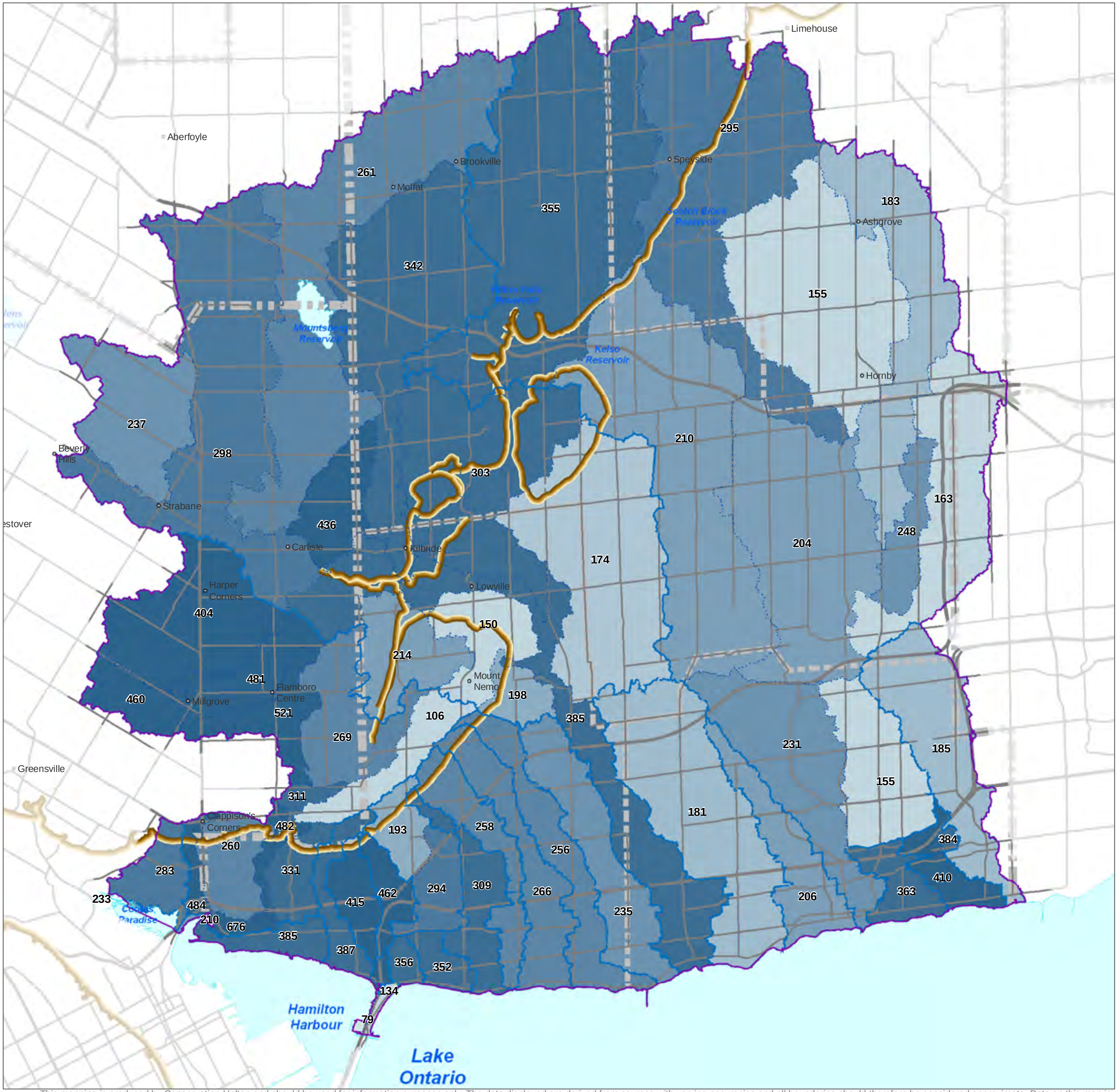


Figure 5.1

Groundwater Supply (mm/yr)

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment

Roads

- Highway
- Regional
- Waterbody

Groundwater Supply (mm/yr)

- < 80
- 80 - 170
- 170 - 180
- 180 - 190
- 190 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 400
- 400 - 675

Source : Halton-Hamilton Source Protection Region (2009).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

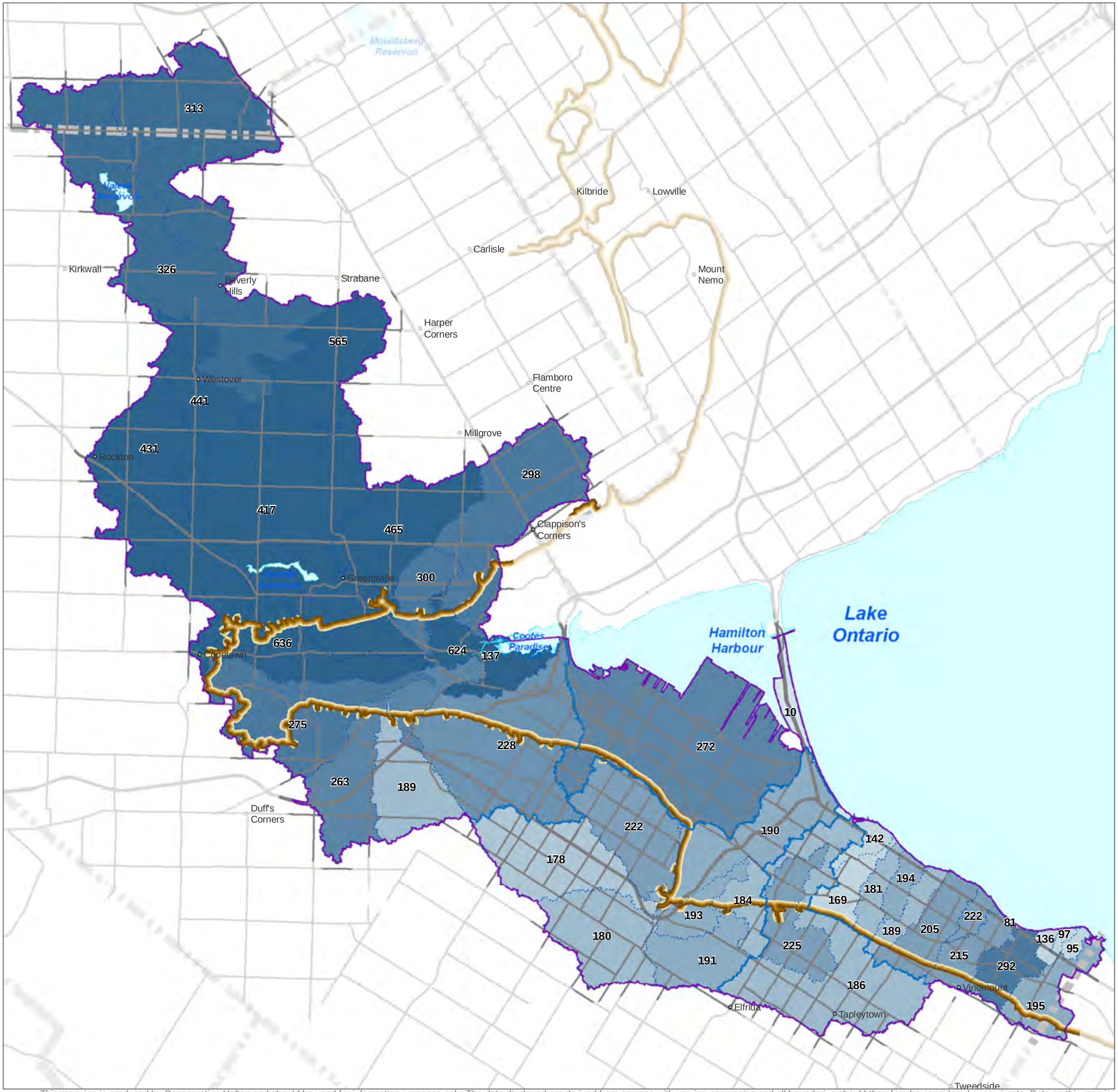
0 1 2 4 6 Kilometers

1:200,000

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 5.2

Groundwater Supply (mm/yr)



Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment

Roads

- Highway
- Regional
- Waterbody

Groundwater Supply (mm/yr)

- < 15
- 15 - 170
- 170 - 180
- 180 - 190
- 190 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 400
- 400 - 635

Source : Halton-Hamilton Source Protection Region (2009).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

N W E S

0 1 2 4 6
Kilometers

1:200,000

Conservation Halton
Hamilton Conservation Authority
Healthy Streams...Healthy Communities!
Ontario

6 WATER RESERVE

6.1 Surface Water Reserve

The Water Reserve for the Tier 1 analysis is a statistical measure of low flow to support other water uses within the watershed including:

- ecosystem requirements, and
- other anthropogenic uses not accounted for in the demand estimates.

Since a majority of the subwatersheds in the Halton and Hamilton watersheds do not have measured continuous streamflows, the estimated 10th percentile streamflows based on the results of the PRMS model was used for the surface water stress assessment. The 10th percentile streamflow was determined on a monthly basis and it is described as the streamflow value that is exceeded 90 % of the time.

Tables 6.1 and **6.2** on the following pages present monthly 10th percentile streamflows (water reserve) simulated by the PRMS model for the Halton Region SPA and Hamilton Region SPA, respectively. A specific month's water reserve is calculated as the monthly 10th percentile streamflow rate for that month, considering all months over the modeled period (1989 to 1997).

It should be noted that some of the 10th percentile flows within the Halton-Hamilton SPR are quite large compared with the median flows, e.g., Main Branch subwatershed of Sixteen Mile Creek, Lower Main Branch subwatershed of Bronte Creek, and Lower Spencer Creek subwatershed of Spencer Creek. This results in a small difference between the average monthly median flows and the 10th percentile flows. This leaves a limited amount of water available for taking, especially during the summer months (June through August).

Table 6.1: Halton Region SPA Surface Water Reserve (10th Percentile Streamflow, PRMS)

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]
Sixteen Mile Creek	East Branch	0.069	0.086	0.127	0.153	0.119	0.028	0.006	0.002	0.002	0.008	0.029	0.086
	East Branch Lisgar	0.062	0.070	0.116	0.131	0.108	0.026	0.006	0.002	0.002	0.006	0.044	0.080
	Lower Middle Branch	0.616	0.711	1.091	1.381	0.966	0.270	0.098	0.085	0.072	0.153	0.508	0.801
	Lower Middle Tributary	0.019	0.020	0.034	0.037	0.031	0.007	0.002	0.000	0.001	0.002	0.011	0.022
	Main Branch	1.337	1.490	2.330	3.022	2.005	0.642	0.288	0.271	0.246	0.464	1.403	1.773
	Middle East Branch	0.095	0.117	0.166	0.228	0.173	0.040	0.009	0.003	0.003	0.011	0.042	0.123
	Middle Branch	0.247	0.288	0.436	0.592	0.343	0.119	0.058	0.070	0.055	0.103	0.282	0.338
	Morrison-Wedgewood Diversion	0.054	0.059	0.096	0.084	0.067	0.022	0.013	0.013	0.014	0.022	0.051	0.057
	Upper West Branch	0.432	0.470	0.722	1.078	0.592	0.241	0.135	0.146	0.131	0.227	0.614	0.619
	West Branch	0.580	0.630	0.996	1.414	0.862	0.315	0.159	0.159	0.144	0.261	0.763	0.820
Bronte Creek	Flamboro Creek	0.059	0.068	0.110	0.136	0.082	0.034	0.017	0.015	0.018	0.032	0.088	0.087
	Indian Creek	0.090	0.104	0.186	0.233	0.184	0.050	0.016	0.007	0.006	0.015	0.085	0.122
	Kilbride Creek	0.250	0.283	0.452	0.587	0.352	0.147	0.081	0.077	0.079	0.141	0.365	0.355
	Limestone Creek	0.195	0.224	0.358	0.472	0.285	0.109	0.057	0.056	0.056	0.104	0.287	0.281
	Lower Main Branch	1.494	1.714	2.765	3.369	2.210	0.810	0.364	0.303	0.342	0.622	1.918	2.079
	Lowville Creek	0.018	0.020	0.033	0.055	0.043	0.011	0.003	0.001	0.000	0.001	0.020	0.030
	Mount Nemo Creek	0.008	0.008	0.016	0.023	0.019	0.005	0.001	0.000	0.000	0.001	0.007	0.011
	Mountsberg Creek	0.276	0.329	0.517	0.657	0.421	0.157	0.069	0.054	0.064	0.115	0.356	0.389
	Strabane Creek	0.096	0.104	0.176	0.204	0.141	0.057	0.025	0.017	0.023	0.041	0.124	0.133
	Upper Main Branch	0.379	0.708	1.029	1.314	1.197	0.625	0.235	0.126	0.132	0.202	0.578	0.874
	Willoughby Creek	0.038	0.045	0.073	0.096	0.065	0.021	0.008	0.006	0.006	0.012	0.049	0.055
Grindstone	201	0.147	0.136	0.215	0.231	0.172	0.058	0.015	0.008	0.025	0.036	0.147	0.201
	204	0.184	0.170	0.270	0.300	0.227	0.077	0.019	0.009	0.033	0.048	0.191	0.267
	210	0.053	0.050	0.075	0.080	0.061	0.020	0.005	0.001	0.009	0.010	0.048	0.069
	214	0.283	0.262	0.409	0.455	0.345	0.115	0.028	0.012	0.047	0.066	0.281	0.395
	215	0.063	0.067	0.099	0.112	0.084	0.027	0.010	0.006	0.009	0.013	0.062	0.080
	218	0.351	0.334	0.516	0.577	0.437	0.145	0.038	0.018	0.057	0.080	0.347	0.481
	220	0.014	0.018	0.032	0.043	0.033	0.009	0.002	0.001	0.000	0.001	0.011	0.017
	222	0.379	0.366	0.568	0.641	0.487	0.161	0.044	0.021	0.060	0.086	0.373	0.515
	224	0.027	0.028	0.043	0.040	0.032	0.012	0.007	0.005	0.004	0.009	0.025	0.028
	228	0.030	0.035	0.060	0.058	0.047	0.017	0.008	0.005	0.005	0.009	0.030	0.035
	230	0.455	0.449	0.702	0.769	0.588	0.198	0.061	0.032	0.071	0.107	0.445	0.599
	232 (Alternate)	0.008	0.010	0.017	0.016	0.014	0.005	0.002	0.001	0.001	0.002	0.008	0.010

Table 6.1: Halton Region SPA Surface Water Reserve (10th Percentile Streamflow, PRMS)

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]
North Shore Group 1	407 Diversion	0.014	0.014	0.028	0.026	0.020	0.006	0.002	0.001	0.001	0.002	0.009	0.012
	Cootes Paradise (Halton)	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
	Falcon Creek	0.029	0.028	0.042	0.035	0.027	0.010	0.004	0.003	0.004	0.005	0.021	0.029
	Indian Creek	0.106	0.105	0.167	0.126	0.103	0.040	0.022	0.018	0.015	0.027	0.084	0.100
	North Cootes Paradise (232)	0.026	0.029	0.044	0.049	0.038	0.013	0.005	0.002	0.003	0.005	0.023	0.030
	Upper Hager Creek	0.069	0.069	0.113	0.087	0.072	0.027	0.015	0.013	0.010	0.019	0.056	0.064
	Upper Rambo Creek	0.043	0.044	0.075	0.059	0.049	0.018	0.009	0.007	0.005	0.010	0.033	0.039
	West Aldershot (East)	0.027	0.028	0.041	0.029	0.024	0.007	0.002	0.000	0.003	0.002	0.019	0.026
	West Aldershot (West)	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001
North Shore Group 2	Appleby Creek	0.069	0.075	0.121	0.086	0.073	0.030	0.020	0.018	0.015	0.027	0.069	0.071
	Beach Strip East Side	0.003	0.003	0.005	0.004	0.003	0.001	0.000	0.000	0.000	0.000	0.001	0.002
	Beach Strip West Side	0.001	0.001	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
	Lower Hager Creek	0.011	0.011	0.015	0.011	0.009	0.003	0.001	0.000	0.001	0.001	0.007	0.010
	Lower Rambo Creek	0.022	0.021	0.029	0.020	0.017	0.006	0.002	0.001	0.003	0.002	0.013	0.020
	Roseland Creek	0.043	0.045	0.071	0.051	0.043	0.016	0.007	0.005	0.005	0.008	0.031	0.040
	Sheldon Creek	0.080	0.093	0.155	0.110	0.090	0.037	0.023	0.021	0.019	0.034	0.084	0.088
	Shoreacres Creek	0.072	0.075	0.117	0.086	0.074	0.031	0.019	0.017	0.014	0.025	0.068	0.074
	Tuck Creek	0.038	0.041	0.071	0.057	0.047	0.017	0.008	0.006	0.005	0.010	0.033	0.040
North Shore Group 3	Fourteen Mile Creek	0.127	0.140	0.238	0.199	0.159	0.053	0.028	0.023	0.025	0.041	0.111	0.135
	McCraney Creek	0.045	0.051	0.081	0.065	0.053	0.018	0.010	0.008	0.009	0.016	0.042	0.049
North Shore Group 4	Ford Plant Special Area	0.004	0.004	0.005	0.004	0.003	0.001	0.001	0.002	0.002	0.003	0.005	0.005
	Joshua's Creek	0.082	0.085	0.137	0.119	0.095	0.029	0.017	0.015	0.017	0.027	0.062	0.082
	Lower Morrison Creek	0.036	0.040	0.050	0.037	0.030	0.011	0.007	0.007	0.009	0.013	0.033	0.040
	Lower Wedgewood Creek	0.037	0.041	0.050	0.039	0.030	0.011	0.007	0.008	0.010	0.014	0.035	0.041

Table 6.2: Hamilton Region SPA Surface Water Reserve (10th Percentile Streamflow, PRMS)

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	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
Red Hill Creek	Green Hill	0.05	0.06	0.09	0.07	0.07	0.03	0.02	0.01	0.01	0.02	0.06	0.06
	Hannon Creek	0.02	0.03	0.04	0.06	0.05	0.01	0.00	0.00	0.00	0.00	0.02	0.03
	Lower Davis Creek	0.03	0.04	0.06	0.07	0.06	0.02	0.01	0.01	0.01	0.01	0.04	0.05
	Montgomery Creek	0.01	0.02	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.02
	Red Hill Valley	0.20	0.24	0.39	0.38	0.33	0.12	0.05	0.03	0.03	0.06	0.23	0.27
	Upper Davis Creek	0.02	0.02	0.04	0.04	0.04	0.01	0.00	0.00	0.00	0.01	0.02	0.03
	Upper Ottawa	0.03	0.03	0.06	0.07	0.06	0.02	0.01	0.00	0.00	0.00	0.03	0.04
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
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

Table 6.2: Hamilton Region SPA Surface Water Reserve (10th Percentile Streamflow, PRMS)

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]
	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
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
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
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

6.2 Groundwater Reserve

A groundwater reserve of ten percent (10 percent) of the total groundwater supply was set aside for users not accounted for in the groundwater demand estimate. **Tables 6.3** and **6.4** provide the estimated groundwater reserves based on the groundwater flow models results for the Halton Region SPA and the Hamilton Region SPA, respectively.

Table 6.3: Halton Region SPA Groundwater Reserve

Watershed	Subwatershed	Area [km^2]	Groundwater Reserve [m^3/s]
Sixteen Mile Creek	East Branch	29.64	0.0179
	East Branch Lisgar	25.88	0.0123
	Lower Middle Branch	42.32	0.0234
	Lower Middle Tributary	7.18	0.0047
	Main Branch	24.67	0.0192
	Middle East Branch	41.65	0.0214
	Middle Branch	54.96	0.0538
	Morrison-Wedgewood Diversion	16.05	0.0092
	Upper West Branch	72.87	0.0870
	West Branch	57.21	0.0371
Bronte Creek	Flamboro Creek	9.42	0.0116
	Indian Creek	40.81	0.0209
	Kilbride Creek	41.23	0.0470
	Limestone Creek	36.60	0.0368
	Lower Main Branch	35.33	0.0413
	Lowville Creek	10.07	0.0052
	Mount Nemo Creek	4.51	0.0032
	Mountsberg Creek	55.08	0.0494
	Strabane Creek	18.43	0.0152
	Upper Main Branch	52.72	0.0490
	Willoughby Creek	12.20	0.0083
Grindstone	201	22.73	0.0206
	204	6.66	0.0062
	210	8.02	0.0082
	214	8.07	0.0095
	215	14.64	0.0111
	218	1.68	0.0015
	220	8.19	0.0035
	222	2.52	0.0037
	224	5.68	0.0059
	228	8.07	0.0067
	230	1.65	0.0030
	232 (Alternate)	2.45	0.0038
North Shore Group 1	407 Diversion	5.23	0.0035
	Cootes Paradise (Halton)	0.71	0.0004
	Falcon Creek	5.42	0.0060
	Indian Creek	6.07	0.0084
	North Cootes Paradise (232)	6.27	0.0049
	Upper Hager Creek	4.23	0.0060
	Upper Rambo Creek	6.29	0.0061
	West Aldershot (East)	4.36	0.0040
	West Aldershot (West)	0.18	0.0001

Table 6.3: Halton Region SPA Groundwater Reserve

Watershed	Subwatershed	Area [km^2]	Groundwater Reserve [m^3/s]
North Shore Group 2	Appleby Creek	14.08	0.0128
	Beach Strip East Side	0.70	0.0003
	Beach Strip West Side	0.26	0.0001
	Lower Hager Creek	1.80	0.0015
	Lower Rambo Creek	3.42	0.0029
	Roseland Creek	9.40	0.0085
	Sheldon Creek	17.67	0.0149
	Shoreacres Creek	14.00	0.0126
	Tuck Creek	10.45	0.0089
North Shore Group 3	Fourteen Mile Creek	34.76	0.0218
	McCraney Creek	12.21	0.0085
North Shore Group 4	Ford Plant Special Area	0.55	0.0007
	Joshua's Creek	21.62	0.0134
	Lower Morrison Creek	5.92	0.0061
	Lower Wedgewood Creek	5.49	0.0065
		33.58	

Table 6.4: Hamilton Region SPA Groundwater Reserve

Watershed	Subwatershed	Area $[km^2]$	Groundwater Reserve $[m^3/s]$
Spencer Creek	Ancaster Creek	14.01	0.0083
	Borer's Creek	19.48	0.0123
	Chedoke Creek	25.06	0.0129
	Flamborough Creek	13.30	0.0115
	Fletcher Creek	25.12	0.0159
	Logie's Creek	13.28	0.0109
	Lower Spencer Creek	7.39	0.0049
	Middle Spencer Creek	49.68	0.0443
	Spring Creek	13.11	0.0062
	Sulphur Creek	16.90	0.0103
	Sydenham Creek	5.27	0.0045
	Tiffany Creek	9.08	0.0040
	Upper Spencer Creek	35.92	0.0261
	West Spencer Creek	18.11	0.0219
	Westover Creek	10.89	0.0099
Red Hill Creek	Green Hill	11.64	0.0072
	Hannon Creek	10.97	0.0043
	Lower Davis Creek	3.75	0.0023
	Montgomery Creek	3.75	0.0021
	Red Hill Valley	13.28	0.0077
	Upper Davis Creek	7.25	0.0033
	Upper Ottawa	13.83	0.0054
Stoney Creek	Battlefield Creek	7.47	0.0052
	Stoney Creek	21.03	0.0109
Stoney Creek Watercourses	WC 0	1.64	0.0006
	WC 1	3.58	0.0021
	WC 2	2.97	0.0019
	WC 3	2.10	0.0014
	WC 4	2.81	0.0019
	WC 5	6.18	0.0046
	WC 6	1.52	0.0013
	WC 7	4.32	0.0031
	WC 8	0.10	0.0000
	WC 9	4.51	0.0044
	WC 10	0.80	0.0004
	WC 10.1	0.48	0.0002
	WC 11	0.69	0.0003
	WC 12	5.76	0.0040
Urban Hamilton Beach Strip		2.34	0.0001
Urban Hamilton City Core		36.52	0.0247
Cootes Paradise (Hamilton)		1.16	0.0005

Monthly groundwater stress calculations were completed using the annual groundwater reserve divided by 12.

7 WATER QUANTITY STRESS ASSESSMENT

The main objective of the Water Quantity Stress Assessment is to identify areas with municipal drinking water sources which may not be able to meet current or future water demands. To achieve this objective, the WQSA is to be carried out using three-tier approach.

As explained in **section 1.4** the Tier 1 level of stress assessment is a screening process which requires estimating of the percentage of the consumptive water demand to the available water supply. This percentage is referred to as Percent Water Demand in the Technical Rules. Assessment areas where the Percent Water Demand is determined as moderate or significant and which contain municipal drinking water systems will require next tier (Tier 2) of water budget and WQSA refinement.

7.1 Surface Water Stress Assessment

Section 1.4.2 explains the methodology of the surface water stress assessment. The parameters used for the assessment at a subwatershed scale are monthly averages of:

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

The consumptive surface water demand was summarized in **section 4.5.3** in **Tables 4.26** and **4.27.** The surface water supplies are summarized in **section 5.1** in **Tables 5.1** and **5.2** and the surface water reserves are discussed in **section 6.1** and are summarized in **Tables 6.1** and **6.2** for the Halton Region SPA and the Hamilton Region SPA, respectively.

Tables 7.1 and **7.2** present the results of the surface water percent water demand and the WQSA stress levels assigned by comparing the largest monthly percent demands of the subwatersheds with the threshold criteria presented in **Table 1.5** in **section 1.4.2**.

There are 12 subwatersheds within the Halton Region SPA with significant stress levels and 7 (seven) with moderate stress levels assigned. It is quite apparent that most of the surface water stresses occur in subwatersheds outside urban areas, where agricultural, commercial (golf course takings) and industrial takings are substantially higher. Only the 407 Diversion subwatershed, which is located within an urban area of the North Shore Group 1 watershed, has a significant surface water stress level.

In the Hamilton Region SPA there are five (5) subwatersheds with significant stress levels and nine (9) with moderate stresses. Similarly to the Halton watershed the stresses mostly occur outside urbanized areas.

There are many subwatersheds within Halton-Hamilton SPR with stress levels of more than 100 percent. This could be a result of:

- for permitted water takings without actual water taking data, the estimates are too high; although PsTTW have maximum amount of water assigned in most cases it is impossible to tell how much water is actually taken. It should be noted that most PsTTW terms and conditions state that if the permitted water taking causes negative impacts the permit holder should cease water taking immediately and mitigate the impacts. This could not be addressed in the water demand estimate and would definitely lower any excess stresses;

- the actual takings are higher than the available water supply, meaning that the total taking in a subwatershed is higher than the difference of the average monthly median flow and the 10th percentile flow. This suggests that the water taking depletes the water reserved for surface water body natural functions and other users; however, because many creeks within the Halton-Hamilton SPR have very low flows, or in some cases are ephemeral or intermittent, the estimated available water can be minimal.
- an assumption was made for agricultural takings to assign a source of water to the takings. Our assumption that farms within 300 m of a stream take water from that stream may not be true in all cases and may add stress to the results of our calculation of stress level.

The surface water percent demand and stress levels are presented graphically in **Figures 7.1** and **7.2** within the Halton Region SPA and the Hamilton Region SPA, respectively.

Tuck Creek watershed within the Halton Region SPA and Stoney Creek Watercourse 11 watershed within the Hamilton Region SPA have reported stress levels at 18.3 percent in August and 18.8 percent in July, respectively. There is no streamflow data available to re-calibrate the PRMS for a better water supply estimate. The only water demands in both watersheds are non-permitted agricultural takings estimated using the de Loe method. This method was used in an unbiased manner across the entire Halton-Hamilton SPR. There are no municipal drinking water systems within these subwatersheds; therefore, it is believed that there is no reason to upgrade the surface water stress level of these subwatersheds to moderate.

Table 7.1: Halton Region SPA Surface Water Percent Demand and Stress Levels

Watershed	Subwatershed	Percent Water Demand [%]												Stress Level
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Sixteen Mile Creek	East Branch	0.5	0.9	0.5	0.4	1.8	14.9	83.7	170.6	55.0	9.4	0.8	1.0	Significant
	East Branch Lisgar	0.4	0.7	0.3	0.4	1.3	9.3	53.1	149.2	25.7	3.7	0.7	0.8	Significant
	Lower Middle Branch	0.1	0.3	0.1	0.1	3.8	12.7	35.7	33.1	12.2	0.8	0.2	0.3	Moderate
	Lower Middle Tributary	7.1	12.9	5.8	6.0	9.1	28.0	143.2	302.9	268.0	116.7	11.0	13.5	Significant
	Main Branch	0.0	0.0	0.0	0.0	0.1	1.7	0.7	0.5	0.1	0.0	0.0	0.0	Low
	Midddle East Branch	0.6	1.0	0.5	0.4	3.3	23.1	122.5	266.3	129.0	9.5	0.8	1.1	Significant
	Middle Branch	0.4	1.0	0.4	0.5	4.0	33.8	32.8	34.4	4.8	3.5	1.2	0.6	Moderate
	Morrison-Wedgewood Diversion	0.0	0.1	0.0	0.0	0.1	0.7	1.5	1.2	0.3	0.1	0.1	0.1	Low
	Upper West Branch	0.6	0.3	0.1	0.1	0.2	2.1	2.7	2.2	0.5	0.1	0.2	0.6	Low
	West Branch	0.1	0.2	0.1	0.2	2.5	13.8	24.4	18.1	7.6	2.0	0.1	0.1	Moderate
Bronte Creek	Flamboro Creek	0.2	0.3	0.2	2.8	24.3	62.1	69.5	57.2	8.2	2.6	2.0	0.2	Significant
	Indian Creek	0.4	0.7	0.3	0.3	0.9	4.8	19.9	35.0	13.2	3.2	0.7	0.9	Moderate
	Kilbride Creek	0.1	0.3	0.2	0.1	0.4	3.2	3.8	4.1	0.8	0.2	0.2	0.2	Low
	Limestone Creek	0.1	0.4	0.2	0.1	3.6	13.1	14.7	17.3	4.7	0.3	0.3	0.2	Low
	Lower Main Branch	0.1	0.1	0.1	0.0	0.1	0.9	1.4	1.8	0.4	0.1	0.1	0.1	Low
	Lowville Creek	0.2	0.4	0.1	0.1	3.3	11.9	49.4	144.8	288.3	1.4	0.3	0.4	Significant
	Mount Nemo Creek	0.2	0.4	0.1	0.2	0.8	6.5	32.1	85.0	82.4	3.5	0.4	0.5	Significant
	Mountsberg Creek	0.3	0.7	0.5	0.3	2.5	13.4	20.2	22.7	5.2	0.6	0.4	0.4	Moderate
	Strabane Creek	0.1	0.3	0.2	0.1	0.3	2.4	3.4	4.5	0.9	0.3	0.2	0.2	Low
	Upper Main Branch	0.2	0.2	0.2	0.1	0.2	1.2	2.7	3.4	1.0	0.3	0.2	0.2	Low
	Willoughby Creek	0.1	0.3	0.1	0.1	11.2	33.5	59.9	103.1	33.0	0.4	0.3	0.3	Significant
Grindstone Creek	201	0.5	1.0	0.7	0.5	1.7	13.4	38.9	82.3	8.4	1.9	0.6	0.7	Significant
	204	0.1	0.3	0.2	0.1	0.5	3.6	11.1	20.9	2.4	0.5	0.2	0.2	Moderate
	210	0.7	1.7	1.2	0.8	2.8	21.9	81.8	142.0	22.7	3.6	1.1	1.2	Significant
	214	0.1	0.3	0.2	0.2	0.4	2.8	9.1	17.2	2.6	0.6	0.2	0.2	Low
	215	0.5	0.9	0.5	0.5	1.2	8.2	23.6	46.3	7.9	1.8	0.8	1.0	Moderate
	218	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.8	0.1	0.0	0.0	0.0	Low
	220	0.5	0.9	0.3	0.4	2.8	12.9	56.8	176.8	107.8	6.2	0.9	1.1	Significant
	222	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.8	0.1	0.0	0.0	0.0	Low
	224	0.3	0.6	0.3	0.3	1.0	5.5	9.9	12.0	2.6	0.8	0.6	0.6	Low
	228	0.4	0.6	0.4	0.3	1.0	5.8	11.7	15.9	3.9	1.1	0.6	0.7	Low
	230	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.1	0.0	0.0	0.0	Low
	232 (Alternate)	0.3	0.5	0.3	0.3	0.8	5.0	10.7	14.6	4.0	1.0	0.5	0.6	Low

Table 7.1: Halton Region SPA Surface Water Percent Demand and Stress Levels

Watershed	Subwatershed	Percent Water Demand [%]												Stress Level
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
North Shore Group 1	407 Diversion	0.1	0.2	0.1	0.1	17.0	47.7	134.9	199.8	139.9	1.0	0.3	0.3	**Significant**
	Cootes Paradise (Halton)	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**
	Falcon Creek	1.0	1.9	1.1	1.2	2.1	5.9	11.5	16.5	9.0	4.0	1.8	1.9	**Low**
	Indian Creek	0.2	0.3	0.2	0.2	0.3	0.8	1.3	1.9	1.0	0.5	0.3	0.3	**Low**
	North Cootes Paradise (232)	0.1	0.2	0.1	0.1	0.3	2.0	5.7	8.5	2.1	0.4	0.2	0.2	**Low**
	Upper Hager Creek	0.5	0.9	0.7	0.7	1.0	2.4	4.0	5.7	3.3	1.5	1.1	0.9	**Low**
	Upper Rambo Creek	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**
	West Aldershot (East)	0.0	0.1	0.1	0.0	0.1	0.2	0.7	0.8	0.8	0.2	0.1	0.1	**Low**
	West Aldershot (West)	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**
North Shore Group 2	Appleby Creek	0.5	0.8	0.5	0.6	5.5	11.5	14.2	15.3	8.9	1.1	0.9	0.8	**Low**
	Beach Strip East Side	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**
	Beach Strip West Side	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**
	Lower Hager Creek	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**
	Lower Rambo Creek	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**
	Roseland Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	**Low**
	Sheldon Creek	0.7	1.1	0.9	0.8	1.2	2.8	3.7	5.0	3.0	1.5	1.3	1.2	**Low**
	Shoreacres Creek	0.5	0.8	0.5	0.5	0.8	2.0	2.7	3.6	2.2	1.0	0.9	0.8	**Low**
	Tuck Creek	1.5	2.1	1.4	1.5	2.4	6.9	12.4	18.3	11.2	4.9	2.7	2.5	**Low**
North Shore Group 3	Fourteen Mile Creek	0.1	0.2	0.1	0.1	0.3	2.3	5.6	4.7	1.2	0.3	0.2	0.2	**Low**
	McCraney Creek	0.0	0.0	0.0	0.0	0.1	0.6	1.5	1.2	0.3	0.1	0.0	0.0	**Low**
North Shore Group 4	Ford Plant Special Area	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**
	Joshua's Creek	0.1	0.3	0.2	0.2	0.5	3.6	8.6	6.6	1.6	0.5	0.2	0.2	**Low**
	Lower Morrison Creek	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**
	Lower Wedgewood Creek	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**

Table 7.2: Hamilton Region SPA Surface Water Percent Demand and Stress Levels

Watershed	Subwatershed	Percent Water Demand [%]												Stress Level
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
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
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
Stoney Creek	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
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

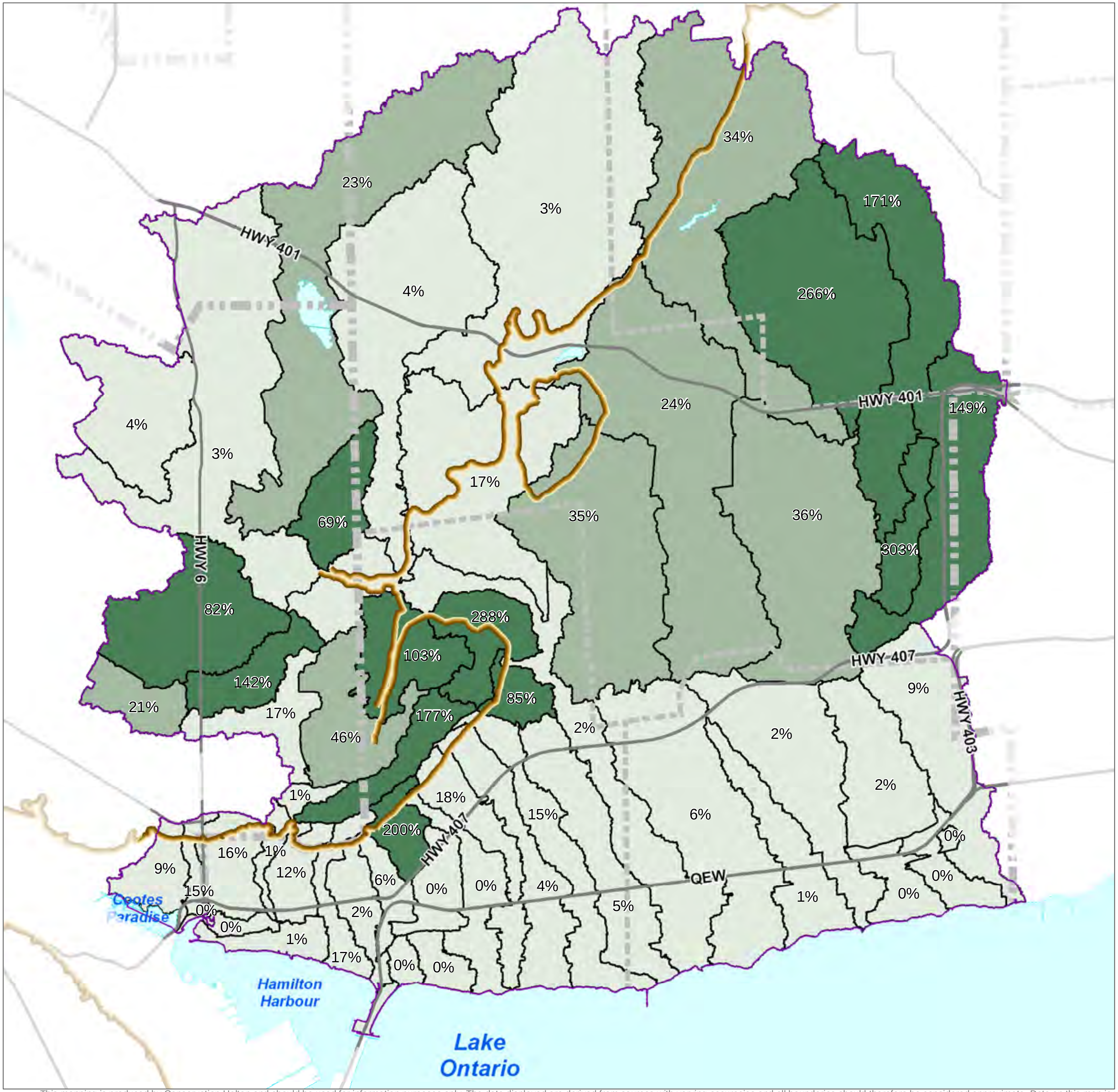
Table 7.2: Hamilton Region SPA Surface Water Percent Demand and Stress Levels

Watershed	Subwatershed	Percent Water Demand [%]												Stress Level
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	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**
Urban Hamilton Beach Strip		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**
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**
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**

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 7.1

Monthly Surface Water Stress Assessment



Legend

- Source Protection Area
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Monthly Surface Water Stress

- Significant
- Moderate
- Low

Label indicates the Percent Water Demand for the entire Subwatershed.

Source : Halton - Hamilton Source Protection
Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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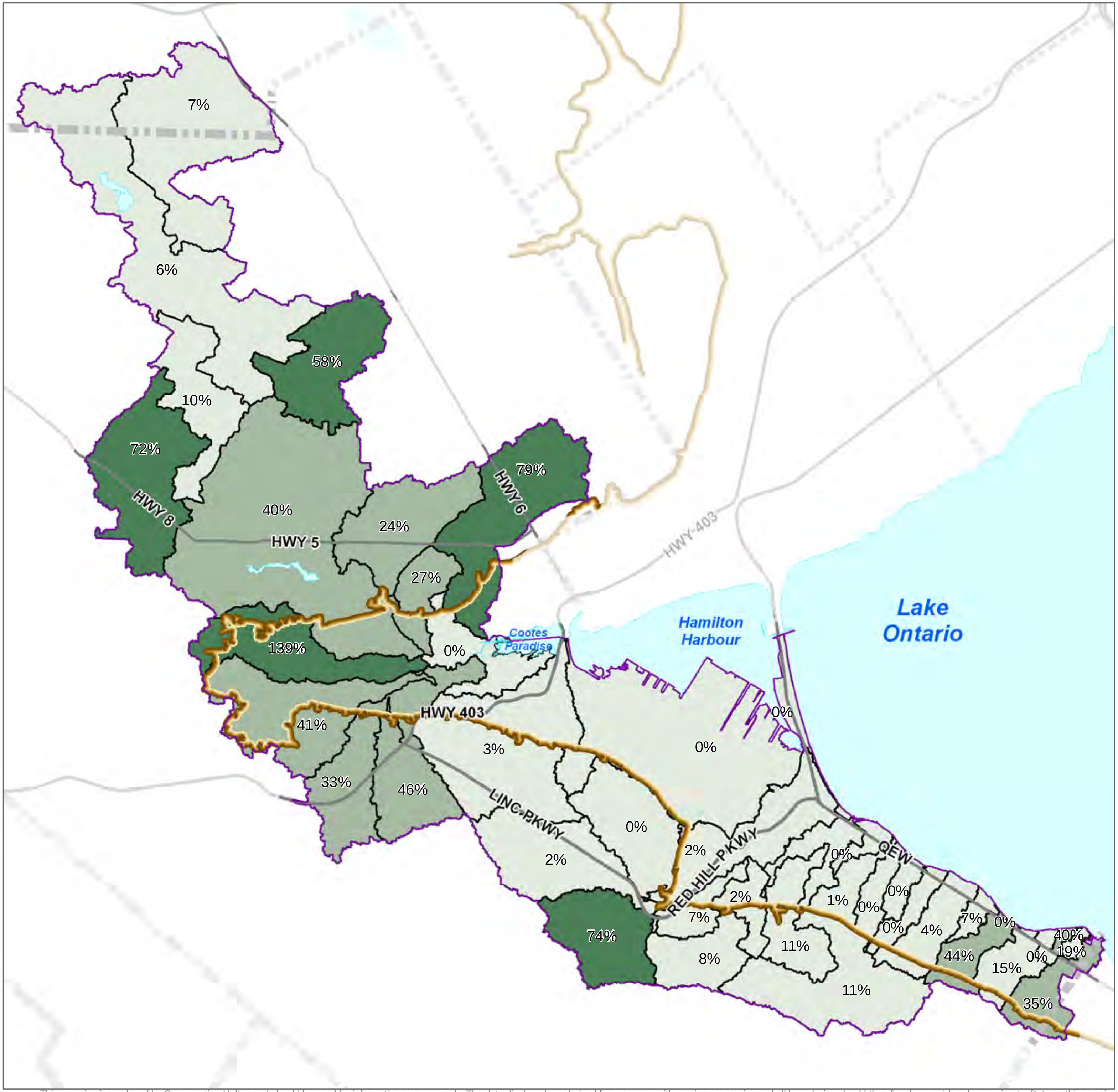

Figure 7.2

Monthly Surface Water Stress Assessment

Legend

- Source Protection Area
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Monthly Surface Water Stress

- Significant
- Moderate
- Low

Label indicates the Percent Water Demand for the entire Subwatershed.

Source : Halton - Hamilton Source Protection
Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

7.2 Groundwater Stress Assessment

7.2.1 Present Conditions Annual Stress Assessment

Using the percent demand equation as identified in section 1.4.1 the annual groundwater quantity stress assessment was carried out for present (2007) conditions using groundwater demand, supply and reserve values as summarized in sections 4.0 through 6.0. **Tables 7.3** and **7.4** provide the evaluation of the present annual Percent Groundwater Demand and groundwater quantity stress level for each subwatershed in the Halton Region SPA and the Hamilton Region SPA, respectively.

Table 7.3: Halton Region SPA Annual Groundwater Stress Assessment – Present 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
Sixteen Mile Creek	East Branch	0.1104	0.0019	0.0682	0.1786	0.0179	1.2	Low
	East Branch Lisgar	0.0992	0.0029	0.0239	0.1231	0.0123	2.6	Low
	Lower Middle Branch	0.1843	0.0020	0.0496	0.2340	0.0234	1.0	Low
	Lower Middle Tributary	0.0284	0.0006	0.0185	0.0469	0.0047	1.4	Low
	Main Branch	0.1180	0.0005	0.0744	0.1924	0.0192	0.3	Low
	Middle East Branch	0.1565	0.0024	0.0575	0.2139	0.0214	1.3	Low
	Middle Branch	0.3844	0.0081	0.1535	0.5379	0.0538	1.7	Low
	Morrison-Wedgewood Diversion	0.0750	0.0003	0.0167	0.0917	0.0092	0.4	Low
	Upper West Branch[1]	0.6894	0.1156	0.1804	0.8698	0.0870	14.8	**Moderate**
	West Branch	0.2414	0.0021	0.1294	0.3708	0.0371	0.6	Low
Bronte Creek	Flamboro Creek[2]	0.0957	0.0041	0.0205	0.1162	0.0116	3.9	Low
	Indian Creek	0.1651	0.0015	0.0439	0.2090	0.0209	0.8	Low
	Kilbride Creek	0.4030	0.0031	0.0671	0.4701	0.0470	0.7	Low
	Limestone Creek[3]	0.3193	0.0183	0.0485	0.3678	0.0368	5.5	Low
	Lower Main Branch	0.2444	0.0017	0.1690	0.4134	0.0413	0.5	Low
	Lowville Creek	0.0358	0.0015	0.0166	0.0525	0.0052	3.2	Low
	Mount Nemo Creek	0.0160	0.0002	0.0156	0.0316	0.0032	0.5	Low
	Mountsberg Creek	0.4354	0.0067	0.0583	0.4936	0.0494	1.5	Low
	Strabane Creek	0.1460	0.0012	0.0056	0.1516	0.0152	0.9	Low
	Upper Main Branch[4]	0.4155	0.0070	0.0742	0.4897	0.0490	1.6	Low
	Willoughby Creek	0.0641	0.0178	0.0192	0.0833	0.0083	23.8	**Moderate**
Grindstone	201	0.1815	0.0034	0.0244	0.2059	0.0206	1.8	Low
	204	0.0534	0.0013	0.0084	0.0617	0.0062	2.4	Low
	210	0.0630	0.0016	0.0193	0.0823	0.0082	2.1	Low
	214	0.0563	0.0010	0.0388	0.0950	0.0095	1.2	Low
	215	0.0848	0.0026	0.0262	0.1109	0.0111	2.6	Low
	218	0.0071	0.0001	0.0083	0.0154	0.0015	0.5	Low
	220	0.0287	0.0013	0.0058	0.0345	0.0035	4.1	Low
	222	0.0180	0.0001	0.0190	0.0370	0.0037	0.2	Low
	224	0.0359	0.0002	0.0233	0.0593	0.0059	0.3	Low
	228	0.0460	0.0006	0.0214	0.0675	0.0067	1.0	Low
	230	0.0106	0.0000	0.0190	0.0296	0.0030	0.1	Low
	232 (Alternate)	0.0127	0.0001	0.0250	0.0378	0.0038	0.2	Low
North Shore Group 1	407 Diversion	0.0197	0.0005	0.0157	0.0354	0.0035	1.5	Low
	Cootes Paradise (Halton)	0.0003	0.0000	0.0042	0.0044	0.0004	1.1	Low
	Falcon Creek	0.0320	0.0002	0.0284	0.0604	0.0060	0.5	Low
	Indian Creek	0.0405	0.0002	0.0439	0.0844	0.0084	0.3	Low
	North Cootes Paradise (232)	0.0356	0.0001	0.0134	0.0489	0.0049	0.3	Low
	Upper Hager Creek	0.0293	0.0001	0.0310	0.0602	0.0060	0.1	Low
	Upper Rambo Creek	0.0350	0.0000	0.0255	0.0605	0.0061	0.0	Low
	West Aldershot (East)	0.0271	0.0000	0.0128	0.0399	0.0040	0.0	Low

Table 7.3: Halton Region SPA Annual Groundwater Stress Assessment – Present 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
	West Aldershot (West)	0.0010	0.0000	0.0000	0.0010	0.0001	0.0	Low
North Shore Group 2	Appleby Creek	0.0879	0.0001	0.0399	0.1279	0.0128	0.1	Low
	Beach Strip East Side	0.0004	0.0000	0.0022	0.0025	0.0003	0.1	Low
	Beach Strip West Side	0.0000	0.0000	0.0005	0.0005	0.0001	0.2	Low
	Lower Hager Creek	0.0109	0.0000	0.0044	0.0153	0.0015	0.0	Low
	Lower Rambo Creek	0.0205	0.0000	0.0082	0.0286	0.0029	0.0	Low
	Roseland Creek	0.0488	0.0000	0.0360	0.0849	0.0085	0.0	Low
	Sheldon Creek	0.1106	0.0002	0.0384	0.1490	0.0149	0.1	Low
	Shoreacres Creek	0.0876	0.0004	0.0379	0.1255	0.0126	0.4	Low
	Tuck Creek	0.0510	0.0011	0.0385	0.0894	0.0089	1.4	Low
North Shore Group 3	Fourteen Mile Creek	0.1731	0.0021	0.0448	0.2179	0.0218	1.1	Low
	McCraney Creek	0.0601	0.0000	0.0251	0.0852	0.0085	0.0	Low
North Shore Group 4	Ford Plant Special Area	0.0052	0.0000	0.0022	0.0074	0.0007	0.0	Low
	Joshua's Creek	0.1050	0.0007	0.0287	0.1338	0.0134	0.6	Low
	Lower Morrison Creek	0.0405	0.0000	0.0208	0.0613	0.0061	0.0	Low
	Lower Wedgewood Creek	0.0378	0.0000	0.0272	0.0650	0.0065	0.0	Low

Notes:
[1] - Contains Kelso and Campbellville municipal wells
[2] - Contains Carlisle municipal wells
[3] - Contains Walkers Line municipal well
[4] - Contains Freelton municipal well

Table 7.4: Hamilton Region SPA Groundwater Annual Stress Assessment – Present 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
Spencer Creek	Ancaster Creek	0.0830	0.0008		0.0830	0.0083	1.0	Low
	Borer's Creek	0.1201	0.0033	0.0032	0.1233	0.0123	3.0	Low
	Chedoke Creek	0.1293	0.0004		0.1293	0.0129	0.3	Low
	Flamborough Creek	0.1112	0.0054	0.0034	0.1146	0.0115	5.2	Low
	Fletcher Creek	0.1541	0.0011	0.0052	0.1593	0.0159	0.8	Low
	Logie's Creek	0.1086	0.0176	0.0002	0.1088	0.0109	18.0	**Moderate**
	Lower Spencer Creek	0.0470	0.0001	0.0018	0.0489	0.0049	0.3	Low
	Middle Spencer Creek[1]	0.3628	0.0413	0.0797	0.4426	0.0443	10.4	**Moderate**
	Spring Creek	0.0617	0.0008		0.0617	0.0062	1.5	Low
	Sulphur Creek	0.1032	0.0006		0.1032	0.0103	0.7	Low
	Sydenham Creek	0.0317	0.0009	0.0137	0.0454	0.0045	2.3	Low
	Tiffany Creek	0.0403	0.0001		0.0403	0.0040	0.3	Low
	Upper Spencer Creek	0.2591	0.0045	0.0020	0.2610	0.0261	1.9	Low
	West Spencer Creek	0.1503	0.0019	0.0686	0.2189	0.0219	1.0	Low
	Westover Creek	0.0987	0.0025		0.0987	0.0099	2.8	Low
Red Hill Creek	Green Hill	0.0718	0.0000		0.0718	0.0072	0.0	Low
	Hannon Creek	0.0428	0.0004		0.0428	0.0043	1.1	Low
	Lower Davis Creek	0.0228	0.0069		0.0228	0.0023	33.4	**Significant**
	Montgomery Creek	0.0207	0.0013		0.0207	0.0021	6.9	Low
	Red Hill Valley	0.0767	0.0000		0.0767	0.0077	0.0	Low
	Upper Davis Creek	0.0335	0.0007		0.0335	0.0033	2.2	Low
	Upper Ottawa	0.0545	0.0000		0.0545	0.0054	0.1	Low

Table 7.4: Hamilton Region SPA Groundwater Annual Stress Assessment – Present 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
Stoney Creek	Battlefield Creek	0.0520	0.0004		0.0520	0.0052	0.8	Low
	Stoney Creek	0.1093	0.0008		0.1093	0.0109	0.8	Low
Stoney Creek Watercourses	WC 0	0.0064	0.0000		0.0064	0.0006	0.0	Low
	WC 1	0.0213	0.0000		0.0213	0.0021	0.0	Low
	WC 2	0.0189	0.0000		0.0189	0.0019	0.0	Low
	WC 3	0.0138	0.0000		0.0138	0.0014	0.4	Low
	WC 4	0.0195	0.0000		0.0195	0.0019	0.1	Low
	WC 5	0.0460	0.0004		0.0460	0.0046	0.9	Low
	WC 6	0.0125	0.0000		0.0125	0.0013	0.2	Low
	WC 7	0.0314	0.0003		0.0314	0.0031	1.2	Low
	WC 8	0.0003	0.0000		0.0003	0.0000	0.0	Low
	WC 9	0.0443	0.0007		0.0443	0.0044	1.8	Low
	WC 10	0.0041	0.0002		0.0041	0.0004	5.9	Low
	WC 10.1	0.0018	0.0000		0.0018	0.0002	0.7	Low
	WC 11	0.0025	0.0000		0.0025	0.0003	0.1	Low
	WC 12	0.0398	0.0013		0.0398	0.0040	3.6	Low
Urban Hamilton Beach Strip		0.0006	0.0000		0.0006	0.0001	0.9	Low
Urban Hamilton City Core		0.2471	0.0006		0.2471	0.0247	0.3	Low
Cootes Paradise (Hamilton)		0.0005	0.0001	0.0043	0.0048	0.0005	2.0	Low

Notes:
[1] - Contains Greensville municipal well

The above percent groundwater demand and the stress levels for all the subwatersheds within the Halton-Hamilton SPR are presented graphically in **Figures 7.3** and **7.4**.

Within the Halton Region SPA there are two subwatersheds exhibiting moderate groundwater quantity stresses (percent demand > 10 percent):

- Upper West Branch of Sixteen Mile Creek, and
- Willoughby Creek within the Bronte Creek watershed.

The Upper West Branch subwatershed contains two groundwater based municipal drinking water systems: Campbellville and Kelso.

Within the Hamilton Region SPA the Lower Davis Creek subwatershed within the Red Hill Creek watershed has significant stress levels. The Logie's Creek subwatershed of Spencer Creek has a moderate stress level and Middle Spencer Creek subwatershed exhibits moderate stress level. The Middle Spencer Creek subwatershed contains the Greensville groundwater municipal supply.

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 7.3

Annual Groundwater Stress Assessment - Present Conditions

Legend

- Source Protection Area
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual Groundwater Stress

- Moderate
- Low

Label indicates the Percent Water Demand for the entire Subwatershed.

Source : Halton - Hamilton Source Protection
Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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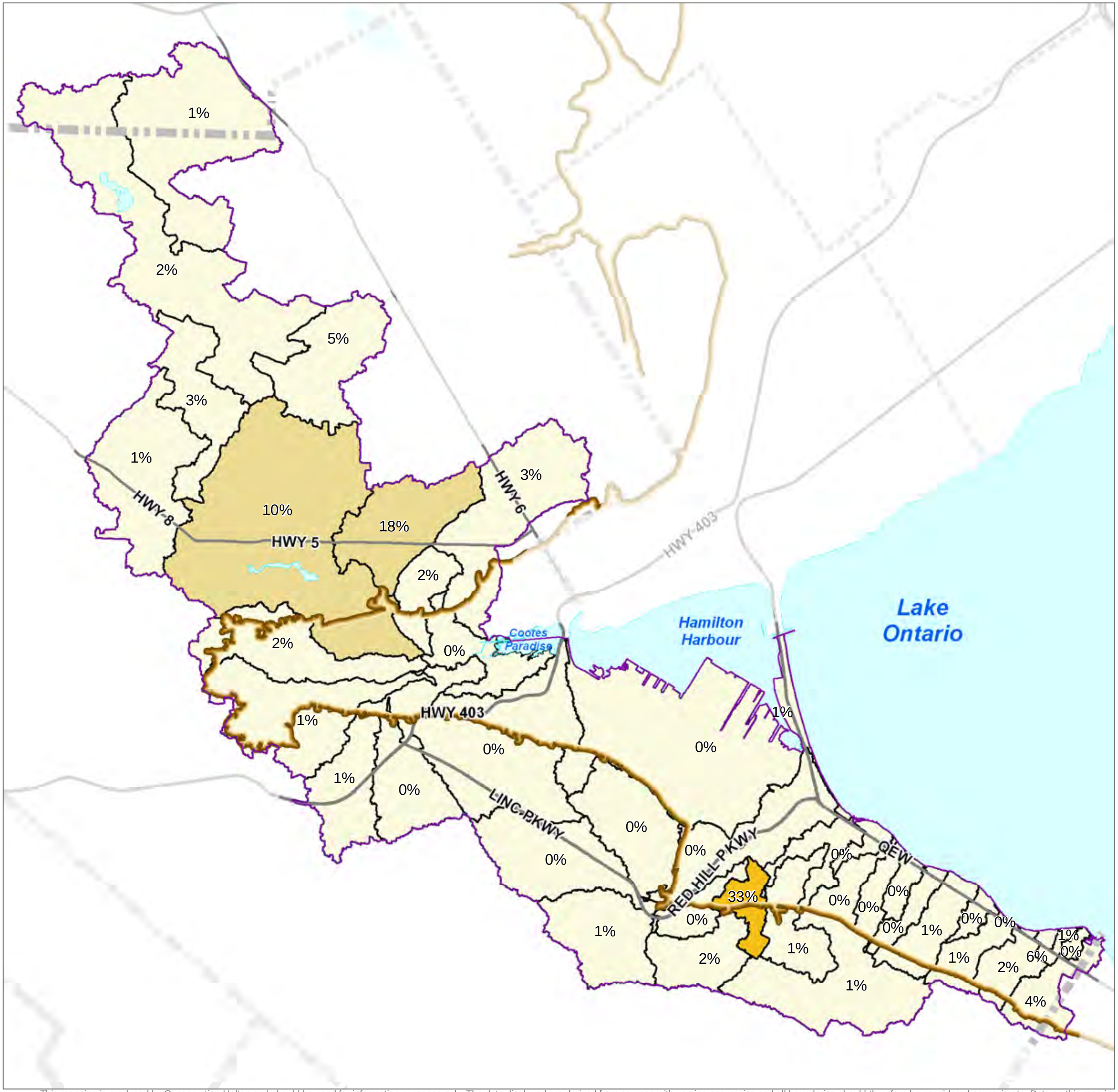

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 7.4

Annual Groundwater Stress Assessment - Present Conditions

Legend

- Source Protection Area
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Annual Groundwater Stress

- Significant
- Moderate
- Low

Label indicates the Percent Water Demand for the entire Subwatershed.

Source : Halton - Hamilton Source Protection
Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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7.2.2 Future Conditions Annual Stress Assessment

Similarly to the current percent demand calculation process, the future demand uses the same percent demand equation as identified in section 1.4.1. The future (2031) conditions stress assessment is completed using an estimate of future demand and the same water supply and reserve values as the present conditions assessment. The future demand estimate addresses the future municipal takings and the private domestic estimates based on population projections for the year 2031. The future municipal and private domestic demands were addressed in sections 4.3.2 and 4.4.1, respectively.

Tables 7.5 and **7.6** below provide the evaluation of the future annual Percent Groundwater Demand and groundwater quantity stress level for each subwatershed in the Halton Region SPA and the Hamilton Region SPA, respectively.

Table 7.5: Halton Region SPA Groundwater Annual Stress Assessment – Future Conditions

Watershed	Subwatershed	Recharge	Demand	Lateral Inflow	Q_{SUPPLY}	$Q_{RESERVE}$	Percent Water Demand	Stress Level
		[m^3/sec]	[m^3/sec]	[m^3/sec]	[m^3/sec]	[m^3/sec]		
Sixteen Mile Creek	East Branch	0.1104	0.0013	0.0682	0.1786	0.0179	0.8	Low
	East Branch Lisgar	0.0992	0.0033	0.0239	0.1231	0.0123	3.0	Low
	Lower Middle Branch	0.1843	0.0016	0.0496	0.2340	0.0234	0.8	Low
	Lower Middle Tributary	0.0284	0.0005	0.0185	0.0469	0.0047	1.1	Low
	Main Branch	0.1180	0.0004	0.0744	0.1924	0.0192	0.2	Low
	Middle East Branch	0.1565	0.0023	0.0575	0.2139	0.0214	1.2	Low
	Middle Branch	0.3844	0.0081	0.1535	0.5379	0.0538	1.7	Low
	Morrison-Wedgewood Diversion	0.0750	0.0003	0.0167	0.0917	0.0092	0.3	Low
	Upper West Branch	0.6894	0.1154	0.1804	0.8698	0.0870	**14.7**	**Moderate**
	West Branch	0.2414	0.0018	0.1294	0.3708	0.0371	0.5	Low
Bronte Creek	Flamboro Creek	0.0957	0.0044	0.0205	0.1162	0.0116	4.2	Low
	Indian Creek	0.1651	0.0011	0.0439	0.2090	0.0209	0.6	Low
	Kilbride Creek	0.4030	0.0032	0.0671	0.4701	0.0470	0.8	Low
	Limestone Creek	0.3193	0.0184	0.0485	0.3678	0.0368	5.5	Low
	Lower Main Branch	0.2444	0.0019	0.1690	0.4134	0.0413	0.5	Low
	Lowville Creek	0.0358	0.0015	0.0166	0.0525	0.0052	3.2	Low
	Mount Nemo Creek	0.0160	0.0001	0.0156	0.0316	0.0032	0.5	Low
	Mountsberg Creek	0.4354	0.0073	0.0583	0.4936	0.0494	1.6	Low
	Strabane Creek	0.1460	0.0014	0.0056	0.1516	0.0152	1.0	Low
	Upper Main Branch	0.4155	0.0079	0.0742	0.4897	0.0490	1.8	Low
	Willoughby Creek	0.0641	0.0178	0.0192	0.0833	0.0083	**23.7**	**Moderate**
Grindstone	201	0.1815	0.0034	0.0244	0.2059	0.0206	1.8	Low
	204	0.0534	0.0013	0.0084	0.0617	0.0062	2.3	Low
	210	0.0630	0.0013	0.0193	0.0823	0.0082	1.8	Low
	214	0.0563	0.0008	0.0388	0.0950	0.0095	1.0	Low
	215	0.0848	0.0028	0.0262	0.1109	0.0111	2.8	Low
	218	0.0071	0.0000	0.0083	0.0154	0.0015	0.2	Low
	220	0.0287	0.0010	0.0058	0.0345	0.0035	3.4	Low
	222	0.0180	0.0002	0.0190	0.0370	0.0037	0.6	Low
	224	0.0359	0.0013	0.0233	0.0593	0.0059	2.5	Low
	228	0.0460	0.0010	0.0214	0.0675	0.0067	1.6	Low
	230	0.0106	0.0000	0.0190	0.0296	0.0030	0.0	Low
	232 (Alternate)	0.0127	0.0002	0.0250	0.0378	0.0038	0.7	Low
North Shore	407 Diversion	0.0197	0.0002	0.0157	0.0354	0.0035	0.8	Low

Table 7.5: Halton Region SPA Groundwater Annual 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
Group 1	Cootes Paradise (Halton)	0.0003	0.0000	0.0042	0.0044	0.0004	0.2	Low
	Falcon Creek	0.0320	0.0012	0.0284	0.0604	0.0060	2.1	Low
	Indian Creek	0.0405	0.0005	0.0439	0.0844	0.0084	0.7	Low
	North Cootes Paradise (232)	0.0356	0.0002	0.0134	0.0489	0.0049	0.4	Low
	Upper Hager Creek	0.0293	0.0001	0.0310	0.0602	0.0060	0.3	Low
	Upper Rambo Creek	0.0350	0.0000	0.0255	0.0605	0.0061	0.0	Low
	West Aldershot (East)	0.0271	0.0000	0.0128	0.0399	0.0040	0.0	Low
	West Aldershot (West)	0.0010	0.0000	0.0000	0.0010	0.0001	0.0	Low
North Shore Group 2	Appleby Creek	0.0879	0.0001	0.0399	0.1279	0.0128	0.1	Low
	Beach Strip East Side	0.0004	0.0000	0.0022	0.0025	0.0003	0.0	Low
	Beach Strip West Side	0.0000	0.0000	0.0005	0.0005	0.0001	0.0	Low
	Lower Hager Creek	0.0109	0.0000	0.0044	0.0153	0.0015	0.0	Low
	Lower Rambo Creek	0.0205	0.0000	0.0082	0.0286	0.0029	0.0	Low
	Roseland Creek	0.0488	0.0000	0.0360	0.0849	0.0085	0.0	Low
	Sheldon Creek	0.1106	0.0003	0.0384	0.1490	0.0149	0.2	Low
	Shoreacres Creek	0.0876	0.0005	0.0379	0.1255	0.0126	0.4	Low
	Tuck Creek	0.0510	0.0011	0.0385	0.0894	0.0089	1.4	Low
North Shore Group 3	Fourteen Mile Creek	0.1731	0.0015	0.0448	0.2179	0.0218	0.8	Low
	McCraney Creek	0.0601	0.0000	0.0251	0.0852	0.0085	0.0	Low
North Shore Group 4	Ford Plant Special Area	0.0052	0.0000	0.0022	0.0074	0.0007	0.0	Low
	Joshua's Creek	0.1050	0.0005	0.0287	0.1338	0.0134	0.4	Low
	Lower Morrison Creek	0.0405	0.0000	0.0208	0.0613	0.0061	0.0	Low
	Lower Wedgewood Creek	0.0378	0.0000	0.0272	0.0650	0.0065	0.0	Low

Table 7.6: Hamilton Region SPA Groundwater Annual 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	Ancaster Creek	0.0830	0.0006		0.0830	0.0083	0.9	Low
	Borer's Creek	0.1201	0.0068	0.0032	0.1233	0.0123	6.1	Low
	Chedoke Creek	0.1293	0.0002		0.1293	0.0129	0.1	Low
	Flamborough Creek	0.1112	0.0056	0.0034	0.1146	0.0115	5.4	Low
	Fletcher Creek	0.1541	0.0013	0.0052	0.1593	0.0159	0.9	Low
	Logie's Creek	0.1086	0.0181	0.0002	0.1088	0.0109	**18.5**	**Moderate**
	Lower Spencer Creek	0.0470	0.0001	0.0018	0.0489	0.0049	0.3	Low
	Middle Spencer Creek	0.3628	0.0416	0.0797	0.4426	0.0443	**10.5**	**Moderate**
	Spring Creek	0.0617	0.0025		0.0617	0.0062	4.5	Low
	Sulphur Creek	0.1032	0.0018		0.1032	0.0103	1.9	Low
	Sydenham Creek	0.0317	0.0012	0.0137	0.0454	0.0045	2.9	Low
	Tiffany Creek	0.0403	0.0001		0.0403	0.0040	0.2	Low
	Upper Spencer Creek	0.2591	0.0049	0.0020	0.2610	0.0261	2.1	Low
	West Spencer Creek	0.1503	0.0022	0.0686	0.2189	0.0219	1.1	Low
	Westover Creek	0.0987	0.0029		0.0987	0.0099	3.2	Low
Red Hill Creek	Green Hill	0.0718	0.0000		0.0718	0.0072	0.0	Low
	Hannon Creek	0.0428	0.0004		0.0428	0.0043	0.9	Low
	Lower Davis Creek	0.0228	0.0067		0.0228	0.0023	**32.6**	**Significant**

Table 7.6: Hamilton Region SPA Groundwater Annual 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
	Montgomery Creek	0.0207	0.0013		0.0207	0.0021	6.9	Low
	Red Hill Valley	0.0767	0.0000		0.0767	0.0077	0.0	Low
	Upper Davis Creek	0.0335	0.0006		0.0335	0.0033	2.0	Low
	Upper Ottawa	0.0545	0.0000		0.0545	0.0054	0.0	Low
Stoney Creek	Battlefield Creek	0.0520	0.0003		0.0520	0.0052	0.7	Low
	Stoney Creek	0.1093	0.0055		0.1093	0.0109	5.6	Low
Stoney Creek Watercourses	WC 0	0.0064	0.0000		0.0064	0.0006	0.0	Low
	WC 1	0.0213	0.0000		0.0213	0.0021	0.0	Low
	WC 2	0.0189	0.0000		0.0189	0.0019	0.0	Low
	WC 3	0.0138	0.0000		0.0138	0.0014	0.0	Low
	WC 4	0.0195	0.0000		0.0195	0.0019	0.1	Low
	WC 5	0.0460	0.0012		0.0460	0.0046	2.9	Low
	WC 6	0.0125	0.0000		0.0125	0.0013	0.2	Low
	WC 7	0.0314	0.0011		0.0314	0.0031	4.0	Low
	WC 8	0.0003	0.0000		0.0003	0.0000	0.0	Low
	WC 9	0.0443	0.0009		0.0443	0.0044	2.3	Low
	WC 10	0.0041	0.0002		0.0041	0.0004	5.2	Low
	WC 10.1	0.0018	0.0000		0.0018	0.0002	0.7	Low
	WC 11	0.0025	0.0000		0.0025	0.0003	0.1	Low
	WC 12	0.0398	0.0016		0.0398	0.0040	4.5	Low
Urban Hamilton Beach Strip		0.0006	0.0000		0.0006	0.0001	0.0	Low
Urban Hamilton City Core		0.2471	0.0006		0.2471	0.0247	0.3	Low
Cootes Paradise (Hamilton)		0.0005	0.0003	0.0043	0.0048	0.0005	6.4	Low

The results of the future annual stress assessment are similar to the present stress assessment results:

1. Within the Halton Region SPA there are two subwatersheds exhibiting moderate groundwater quantity stresses (percent demand > 10):

- Upper West Branch of Sixteen Mile Creek, and
- Willoughby Creek subwatershed within the Bronte Creek watershed.

2. Within the Hamilton Region SPA there are two subwatersheds exhibiting moderate quantity stresses:

- Logie's Creek of Spencer Creek, and
- Middle Spencer Creek.

And one subwatershed with a significant stress level:

- Lower Davies Creek of Red Hill Creek.

The Middle Spencer Creek subwatershed contains a groundwater municipal system located in Greensville.

7.2.3 Present Conditions Monthly Stress Assessment

In addition to the annual WQSA, a monthly water demand assessment was completed to look at seasonal variability in water taking. The monthly Percent Water Demand is calculated with the same equation used for the annual Percent Water Demand, but using different threshold values. It should be noted that the monthly groundwater supply is the annual groundwater supply divided by 12.

Based on the results of the assessment there are three (3) subwatersheds exhibiting moderate monthly stress levels. The Willoughby Creek subwatershed of Bronte Creek within the Halton Region SPA and the Logie's Creek subwatershed of Spencer Creek and Lower Davis Creek of Red Hill Creek within the Hamilton Region SPA. These three (3) subwatersheds were also identified as stressed in the annual stress assessment.

There are no significantly stressed subwatersheds based on the present conditions monthly groundwater stress assessment.

Tables 7.7 and **7.8** provide the results of the monthly Percent Water Demand assessment and groundwater quantity stress level for each subwatershed.

Figures 7.5 and **7.6** present maps of the maximum monthly Percent Water Demand and the stress levels across the Halton Region SPA and the Hamilton Region SPA, respectively.

Figure 7.5

Monthly Groundwater Stress Assessment - Present Conditions

Legend

- Source Protection Area
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

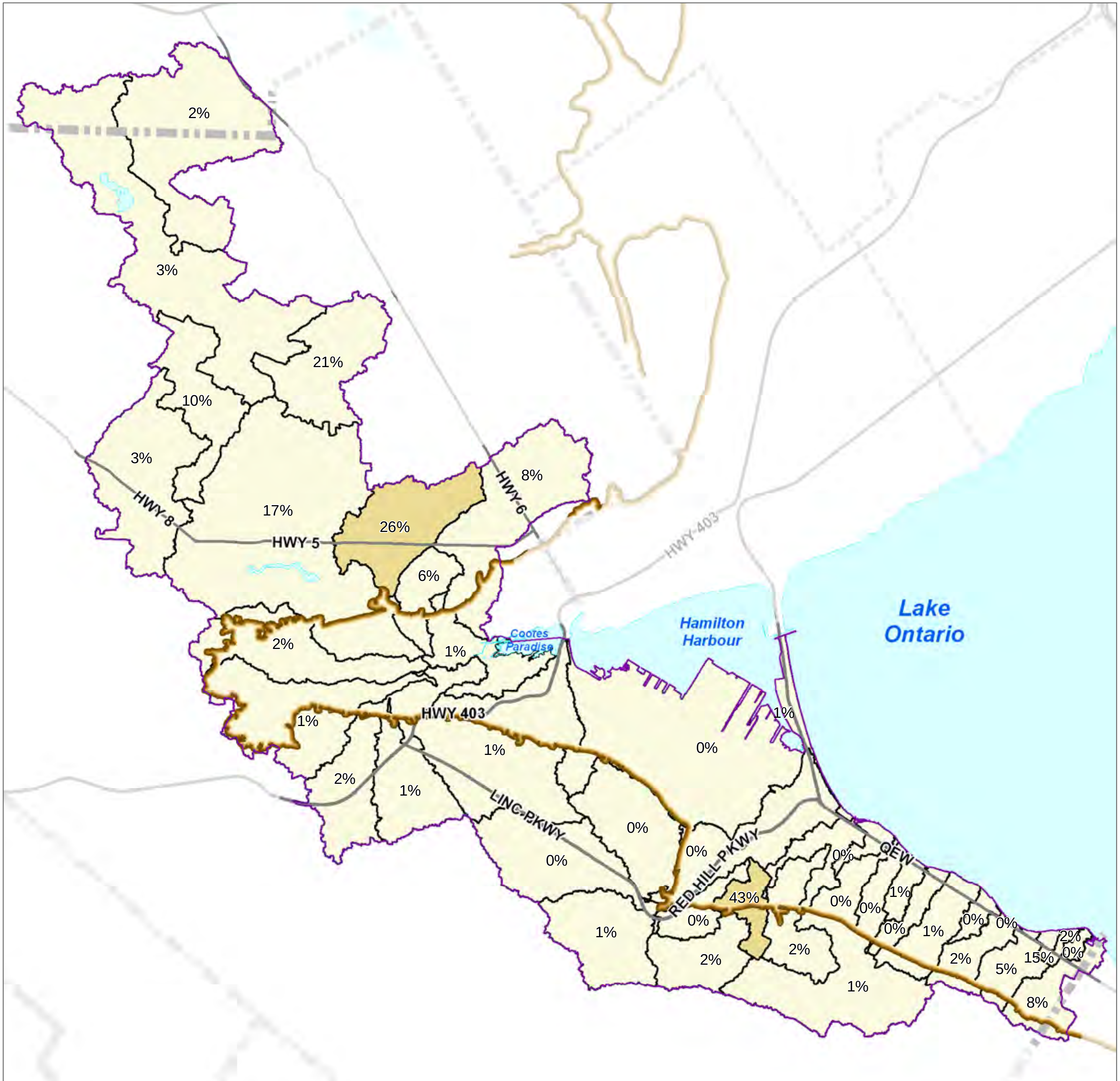
Monthly Groundwater Stress

- Moderate
- Low

Label indicates the Percent Water Demand for the entire Subwatershed.

Source : Halton - Hamilton Source Protection
Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000



DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Figure 7.6

Monthly Groundwater Stress Assessment - Present Conditions

Legend

- Source Protection Area
- Upper Tier Municipality
- Lower Tier Municipality
- Niagara Escarpment
- Highway
- Waterbody

Monthly Groundwater Stress

- Moderate
- Low

Label indicates the Percent Water Demand for the entire Subwatershed.

Source : Halton - Hamilton Source Protection
Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

0 1 2 4 6
Kilometers
1:200,000

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Table 7.7: Halton Region SPA Groundwater Monthly Stress Assessment – Present Conditions

Watershed	Subwatershed	Percent Water Demand [%]												Stress Level
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Sixteen Mile Creek	East Branch	0.7	0.7	0.7	0.7	1.0	2.3	2.8	2.1	1.1	0.7	0.7	0.7	**Low**
	East Branch Lisgar	1.3	1.2	1.3	1.3	2.1	5.7	7.3	5.1	2.1	1.3	1.2	1.3	**Low**
	Lower Middle Branch	0.4	0.4	0.4	0.4	0.7	2.3	3.0	2.1	0.7	0.4	0.4	0.4	**Low**
	Lower Middle Tributary	0.6	0.6	0.6	0.7	1.1	3.0	3.9	2.7	1.1	0.7	0.6	0.6	**Low**
	Main Branch	0.1	0.1	0.1	0.1	0.2	0.6	0.7	0.5	0.2	0.1	0.1	0.1	**Low**
	Middle East Branch	0.7	0.6	0.7	0.7	1.1	2.7	3.4	2.4	1.1	0.7	0.6	0.7	**Low**
	Middle Branch	0.8	1.0	1.2	1.2	1.7	2.4	2.6	2.8	2.2	1.7	1.2	1.2	**Low**
	Morrison-Wedgewood Diversion	0.2	0.2	0.2	0.2	0.3	0.9	1.2	0.8	0.3	0.2	0.2	0.2	**Low**
	Upper West Branch	13.5	11.2	14.6	13.8	14.8	16.9	17.7	17.6	16.5	14.0	13.5	13.1	**Low**
	West Branch	0.3	0.3	0.3	0.3	1.0	1.4	1.5	1.1	0.7	0.3	0.3	0.3	**Low**
Bronte Creek	Flamboro Creek	1.6	1.5	1.7	1.9	3.9	7.7	9.4	7.8	5.0	2.5	2.0	2.2	**Low**
	Indian Creek	0.6	0.6	0.6	0.6	0.7	1.2	1.4	1.2	0.8	0.6	0.6	0.6	**Low**
	Kilbride Creek	0.4	0.4	0.4	0.5	0.7	1.4	1.6	1.2	0.8	0.5	0.4	0.4	**Low**
	Limestone Creek	4.8	4.1	4.1	5.8	6.4	7.1	7.7	7.3	5.5	4.6	3.0	5.8	**Low**
	Lower Main Branch	0.3	0.3	0.3	0.3	0.4	0.7	0.9	0.7	0.4	0.3	0.3	0.3	**Low**
	Lowville Creek	0.8	0.8	0.8	0.9	6.1	7.8	8.4	5.9	3.9	0.9	0.8	0.8	**Low**
	Mount Nemo Creek	0.3	0.3	0.3	0.3	0.5	1.0	1.3	0.9	0.5	0.4	0.3	0.3	**Low**
	Mountsberg Creek	1.0	1.0	1.0	1.0	1.4	2.6	3.2	2.4	1.4	1.0	1.0	1.0	**Low**
	Strabane Creek	0.6	0.5	0.6	0.6	0.8	1.6	2.0	1.5	0.9	0.7	0.6	0.6	**Low**
	Upper Main Branch	1.1	1.1	1.1	1.1	1.5	2.6	3.1	2.5	1.6	1.1	1.1	1.1	**Low**
	Willoughby Creek	27.9	19.4	22.4	**46.5**	**41.4**	15.1	16.1	33.0	24.0	5.3	15.7	18.5	**Moderate**
Grindstone	201	0.9	0.9	0.9	1.0	1.5	3.9	4.9	3.5	1.5	1.0	0.9	0.9	**Low**
	204	0.6	0.6	0.6	0.6	0.9	2.3	12.3	12.2	1.0	0.6	0.6	0.6	**Low**
	210	1.1	1.0	1.1	1.1	1.7	4.4	6.1	6.1	1.8	1.1	1.1	1.1	**Low**
	214	0.9	0.8	0.9	0.9	1.1	2.0	3.2	3.1	1.2	0.9	0.8	0.9	**Low**
	215	1.5	1.5	1.5	1.5	2.2	5.1	6.4	4.6	2.2	1.5	1.5	1.5	**Low**
	218	0.4	0.3	0.4	0.4	0.4	0.7	0.7	0.6	0.5	0.4	0.4	0.4	**Low**
	220	2.1	2.0	2.1	2.2	5.9	8.1	8.9	6.7	4.6	2.2	2.1	2.1	**Low**
	222	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	**Low**
	224	0.2	0.2	0.2	0.2	0.3	0.6	0.8	0.6	0.3	0.2	0.2	0.2	**Low**
	228	0.8	0.8	0.8	0.9	1.0	1.4	1.5	1.4	1.1	0.9	0.8	0.8	**Low**
	230	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**
	232 (Alternate)	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.3	0.2	0.1	0.1	0.1	**Low**
North Shore Group 1	407 Diversion	1.4	1.3	1.3	1.4	1.5	1.9	2.0	1.9	1.6	1.4	1.3	1.4	**Low**
	Cootes Paradise (Halton)	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**
	Falcon Creek	0.4	0.4	0.4	0.4	0.4	0.6	0.6	0.5	0.5	0.4	0.4	0.4	**Low**
	Indian Creek	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.2	0.2	**Low**

Table 7.7: Halton Region SPA Groundwater Monthly Stress Assessment – Present Conditions

Watershed	Subwatershed	Percent Water Demand [%]												Stress Level
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	North Cootes Paradise (232)	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.4	0.3	0.2	0.2	0.2	**Low**
	Upper Hager Creek	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**
	Upper Rambo Creek	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**
	West Aldershot (East)	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**
	West Aldershot (West)	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**
North Shore Group 2	Appleby Creek	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**Low**
	Beach Strip East Side	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**Low**
	Beach Strip West Side	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	**Low**
	Lower Hager Creek	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**
	Lower Rambo Creek	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**
	Roseland Creek	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**
	Sheldon Creek	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**
	Shoreacres Creek	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	**Low**
	Tuck Creek	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	**Low**
North Shore Group 3	Fourteen Mile Creek	0.3	0.3	0.3	0.3	2.0	2.5	2.7	1.9	1.3	0.3	0.3	0.3	**Low**
	McCraney Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	**Low**
North Shore Group 4	Ford Plant Special Area	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**
	Joshua's Creek	0.3	0.3	0.3	0.3	0.5	1.1	1.4	1.0	0.5	0.3	0.3	0.3	**Low**
	Lower Morrison Creek	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**
	Lower Wedgewood Creek	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**

Table 7.8: Hamilton Region SPA Groundwater Monthly Stress Assessment – Present Conditions

Watershed	Subwatershed	Percent Water Demand [%]												Stress Level
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Spencer Creek	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**
	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**
	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**
	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**
	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**
	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**
	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**
	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**
	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**
	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**

Table 7.8: Hamilton Region SPA Groundwater Monthly Stress Assessment – Present Conditions

Watershed	Subwatershed	Percent Water Demand [%]												Stress Level
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	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**
	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**
	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**
	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**
Red Hill Creek	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**
	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**
	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**
	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**
	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**
	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**
	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**
Stoney Creek	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**
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**
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**
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**
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**

7.2.4 Future Conditions Monthly Stress Assessment

The future (2031) conditions monthly stress assessment is completed using an estimate of future demand and the water supply and reserve values used for the present conditions monthly assessment. This follows the requirements of the Province. The future monthly demand estimates address the future municipal takings and the private domestic monthly estimates based on population projections for the year 2031. The future municipal and private domestic demands were discussed in **sections 4.3.2** and **4.4.1**, respectively.

Tables 7.9 and **7.10** provide the results of the future monthly Percent Groundwater Demand and groundwater quantity stress level for each subwatershed using the results.

The future monthly stress assessment results are consistent with the present monthly stress assessment. The only three (3) subwatersheds with moderate stresses are:

- Willoughby Creek (Bronte Creek watershed) in the Halton Region SPA; and
- Logie's Creek (Spencer Creek watershed) and Lower Davis Creek (Red Hill Creek watershed) in the Hamilton Region SPA.

Table 7.9: Halton Region SPA Monthly Groundwater Stress Assessment – Future Conditions

Watershed	Subwatershed	Jan [%]	Feb [%]	Mar [%]	Apr [%]	May [%]	Jun [%]	Jul [%]	Aug [%]	Sep [%]	Oct [%]	Nov [%]	Dec [%]	Stress Level
Sixteen Mile Creek	East Branch	0.4	0.4	0.4	0.4	0.7	1.8	2.3	1.6	0.7	0.4	0.4	0.4	**Low**
	East Branch Lisgar	1.6	1.5	1.6	1.7	2.5	6.2	7.9	5.6	2.6	1.7	1.6	1.6	**Low**
	Lower Middle Branch	0.2	0.2	0.2	0.2	0.5	2.1	2.8	1.8	0.5	0.2	0.2	0.2	**Low**
	Lower Middle Tributary	0.4	0.4	0.4	0.4	0.8	2.7	3.6	2.4	0.8	0.4	0.4	0.4	**Low**
	Main Branch	0.1	0.1	0.1	0.1	0.2	0.5	0.6	0.4	0.2	0.1	0.1	0.1	**Low**
	Middle East Branch	0.6	0.6	0.6	0.6	1.0	2.6	3.3	2.3	1.0	0.6	0.6	0.6	**Low**
	Middle Branch	0.8	1.0	1.2	1.2	1.7	2.4	2.6	2.8	2.2	1.7	1.2	1.2	**Low**
	Morrison-Wedgewood Diversion	0.1	0.1	0.1	0.1	0.2	0.8	1.1	0.7	0.2	0.1	0.1	0.1	**Low**
	Upper West Branch	13.5	11.2	14.6	13.8	14.7	16.9	17.7	17.6	16.4	14.0	13.5	13.1	**Low**
	West Branch	0.2	0.2	0.2	0.2	0.9	1.2	1.4	1.0	0.6	0.2	0.2	0.2	**Low**
Bronte Creek	Flamboro Creek	1.8	1.7	1.9	2.2	4.2	8.1	9.8	8.2	5.3	2.8	2.3	2.4	**Low**
	Indian Creek	0.4	0.4	0.4	0.4	0.5	0.9	1.1	0.9	0.6	0.4	0.4	0.4	**Low**
	Kilbride Creek	0.4	0.4	0.5	0.5	0.7	1.4	1.6	1.3	0.8	0.5	0.5	0.4	**Low**
	Limestone Creek	4.8	4.1	4.1	5.8	6.4	7.2	7.8	7.3	5.5	4.7	3.0	5.8	**Low**
	Lower Main Branch	0.4	0.4	0.4	0.4	0.5	0.8	0.9	0.7	0.5	0.4	0.4	0.4	**Low**
	Lowville Creek	0.9	0.8	0.9	0.9	6.1	7.8	8.5	6.0	4.0	0.9	0.9	0.9	**Low**
	Mount Nemo Creek	0.3	0.3	0.3	0.3	0.4	0.9	1.1	0.8	0.4	0.3	0.3	0.3	**Low**
	Mountsberg Creek	1.1	1.1	1.1	1.2	1.5	2.8	3.4	2.6	1.5	1.2	1.1	1.1	**Low**
	Strabane Creek	0.6	0.6	0.6	0.7	0.9	1.7	2.1	1.7	1.0	0.8	0.7	0.7	**Low**
	Upper Main Branch	1.3	1.2	1.3	1.3	1.7	2.9	3.4	2.8	1.8	1.3	1.2	1.2	**Low**
	Willoughby Creek	**27.9**	19.3	22.4	**46.5**	**41.4**	15.1	16.0	**32.9**	24.0	5.2	15.6	18.5	**Moderate**
Grindstone	201	1.0	0.9	0.9	1.0	1.5	3.9	5.0	3.5	1.5	1.0	0.9	0.9	**Low**
	204	0.6	0.5	0.6	0.6	0.9	2.2	12.2	12.2	0.9	0.6	0.6	0.6	**Low**
	210	1.1	1.0	1.1	1.1	1.7	4.4	6.1	6.1	1.8	1.1	1.1	1.1	**Low**
	214	0.9	0.8	0.9	0.9	1.1	2.0	3.2	3.1	1.2	0.9	0.8	0.9	**Low**
	215	1.5	1.5	1.5	1.5	2.2	5.1	6.4	4.6	2.2	1.5	1.5	1.5	**Low**
	218	0.4	0.3	0.4	0.4	0.4	0.7	0.7	0.6	0.5	0.4	0.4	0.4	**Low**
	220	2.1	2.0	2.1	2.2	5.9	8.1	8.9	6.7	4.6	2.2	2.1	2.1	**Low**
	222	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	**Low**
	224	0.2	0.2	0.2	0.2	0.3	0.6	0.8	0.6	0.3	0.2	0.2	0.2	**Low**
	228	0.8	0.8	0.8	0.9	1.0	1.4	1.5	1.4	1.1	0.9	0.8	0.8	**Low**
	230	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**
	232 (Alternate)	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.3	0.2	0.1	0.1	0.1	**Low**
North Shore Group 1	407 Diversion	0.7	0.7	0.7	0.7	0.8	0.9	1.0	0.9	0.8	0.7	0.7	0.7	**Low**
	Cootes Paradise (Halton)	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**
	Falcon Creek	1.8	1.7	1.8	1.9	2.1	2.7	2.9	2.7	2.3	1.9	1.8	1.8	**Low**
	Indian Creek	0.6	0.5	0.6	0.6	0.7	0.9	0.9	0.9	0.8	0.6	0.6	0.6	**Low**

Table 7.9: Halton Region SPA Monthly Groundwater Stress Assessment – Future Conditions

Watershed	Subwatershed	Jan [%]	Feb [%]	Mar [%]	Apr [%]	May [%]	Jun [%]	Jul [%]	Aug [%]	Sep [%]	Oct [%]	Nov [%]	Dec [%]	Stress Level
	North Cootes Paradise (232)	0.3	0.3	0.3	0.3	0.4	0.5	0.6	0.5	0.4	0.3	0.3	0.3	**Low**
	Upper Hager Creek	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.3	0.3	0.2	0.2	0.2	**Low**
	Upper Rambo Creek	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**
	West Aldershot (East)	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**
	West Aldershot (West)	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**
North Shore Group 2	Appleby Creek	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**Low**
	Beach Strip East Side	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**
	Beach Strip West Side	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**
	Lower Hager Creek	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**
	Lower Rambo Creek	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**
	Roseland Creek	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**
	Sheldon Creek	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2	**Low**
	Shoreacres Creek	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4	**Low**
	Tuck Creek	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.4	1.4	1.4	1.4	**Low**
North Shore Group 3	Fourteen Mile Creek	0.1	0.1	0.1	0.1	1.7	2.1	2.3	1.5	1.0	0.1	0.1	0.1	**Low**
	McCraney Creek	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**
North Shore Group 4	Ford Plant Special Area	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**
	Joshua's Creek	0.2	0.2	0.2	0.2	0.3	0.9	1.2	0.8	0.3	0.2	0.2	0.2	**Low**
	Lower Morrison Creek	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**
	Lower Wedgewood Creek	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**

Table 7.10: Hamilton Region SPA Monthly Groundwater Stress Assessment – Future Conditions

Watershed	Subwatershed	Jan [%]	Feb [%]	Mar [%]	Apr [%]	May [%]	Jun [%]	Jul [%]	Aug [%]	Sep [%]	Oct [%]	Nov [%]	Dec [%]	Stress Level
Spencer Creek	Ancaster Creek	0.6	0.6	0.6	0.7	0.8	1.4	1.5	1.3	1.0	0.6	0.6	0.6	**Low**
	Borer's Creek	4.0	3.9	4.0	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	0.0	0.0	0.1	0.4	0.6	0.4	0.1	0.0	0.0	0.0	**Low**
	Flamborough Creek	1.1	1.1	1.1	1.4	4.5	7.7	21.4	20.0	5.2	2.2	1.0	1.0	**Low**
	Fletcher Creek	0.5	0.5	0.6	0.6	0.8	1.6	2.0	1.5	0.9	0.5	0.5	0.5	**Low**
	Logie's Creek	15.0	17.5	11.5	17.4	21.9	**26.5**	15.4	17.9	16.6	22.3	19.5	20.3	**Moderate**
	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**
	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**
	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**
	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**
	Sydenham Creek	1.9	1.9	1.9	2.0	2.6	5.3	6.4	5.0	2.9	1.8	1.8	1.8	**Low**

Table 7.10: Hamilton Region SPA Monthly Groundwater Stress Assessment – Future Conditions

Watershed	Subwatershed	Jan [%]	Feb [%]	Mar [%]	Apr [%]	May [%]	Jun [%]	Jul [%]	Aug [%]	Sep [%]	Oct [%]	Nov [%]	Dec [%]	Stress Level
	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
	Upper Spencer Creek	1.7	1.7	1.7	1.8	2.0	3.0	3.3	2.8	2.1	1.6	1.6	1.6	Low
	West Spencer Creek	0.5	0.5	0.5	0.5	0.9	2.6	3.3	2.7	1.0	0.4	0.4	0.4	Low
	Westover Creek	1.1	1.1	1.1	1.2	3.4	8.1	10.1	6.9	3.0	1.0	1.0	1.0	Low
Red Hill Creek	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
	Hannon Creek	0.8	0.8	0.8	0.9	0.9	1.1	1.1	1.0	0.9	0.8	0.8	0.8	Low
	Lower Davis Creek	**33.7**	22.8	**38.7**	**37.3**	**27.1**	**30.1**	**41.7**	**41.4**	**41.0**	**41.2**	18.6	17.9	**Moderate**
	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
	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
	Upper Davis Creek	2.3	2.2	2.2	2.2	2.0	2.0	2.1	1.9	1.8	1.8	1.8	1.9	Low
	Upper Ottawa	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
Stoney Creek	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	8.0	8.1	8.0	7.2	4.0	4.0	4.1	Low
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	0.1	0.1	0.1	0.0	0.0	0.0	0.0	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	0.1	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	4.0	4.1	4.0	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	4.0	5.6	5.8	5.6	4.9	2.9	2.9	3.0	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	1.4	1.3	1.4	1.4	2.0	4.3	5.3	4.0	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	10.0	4.1	2.7	2.7	2.7	Low
	WC 10.1	0.4	0.4	0.4	0.4	0.6	1.6	2.0	1.4	0.6	0.4	0.4	0.4	Low
	WC 11	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.1	0.0	0.0	0.0	Low
	WC 12	2.9	2.8	2.9	3.1	4.0	8.1	9.7	7.6	4.5	2.7	2.7	2.8	Low
Urban Hamilton Beach Strip		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
Urban Hamilton		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
Cootes Paradise (Hamilton)		5.1	5.0	5.2	6.0	6.5	9.0	9.0	9.0	8.4	4.6	4.7	4.8	Low

7.3 Conclusions and Recommendations

The surface water stress analysis has indentified significant and/or moderate stress in several subwatersheds in the Halton-Hamilton SPR watersheds.

The following **Tables 7.11** and **7.12** summarize all the surface water stress levels identified through the WQSA within the Halton Region SPA and the Hamilton Region SPA, respectively.

Table 7.11: Halton Region SPA Surface Water Stress Levels

Watershed	Subwatershed	Area [km^2]	Stress Level	Maximum Monthly Percent Water Demand
Sixteen Mile Creek	East Branch	29.64	Significant	171
	East Branch Lisgar	25.88	Significant	149
	Lower Middle Branch	42.32	Moderate	36
	Lower Middle Tributary	7.18	Significant	303
	Middle East Branch	41.65	Significant	266
	Middle Branch	54.96	Moderate	34
	West Branch	57.21	Moderate	24
Bronte Creek	Flamboro Creek	9.42	Significant	69
	Indian Creek	40.81	Moderate	35
	Lowville Creek	10.07	Significant	288
	Mount Nemo Creek	4.51	Significant	85
	Mountsberg Creek	55.08	Moderate	23
	Willoughby Creek	12.20	Significant	103
Grindstone Creek	201	22.73	Significant	82
	204	6.66	Moderate	21
	210	8.02	Significant	142
	215	14.64	Moderate	46
	220	8.19	Significant	177
North Shore Group 1	407 Diversion	5.23	Significant	200

Table 7.12: Hamilton Region SPA Surface Water Stress Levels

Watershed	Subwatershed	Area [km^2]	Stress Level	Maximum Monthly Percent Water Demand
Spencer Creek	Ancaster Creek	14.01	Moderate	33
	Borer's Creek	19.48	Significant	79
	Flamborough Creek	13.30	Significant	58
	Logie's Creek	13.28	Moderate	24
	Middle Spencer Creek	49.68	Moderate	40
	Spring Creek	13.11	Significant	139
	Sulphur Creek	16.90	Moderate	41
	Sydenham Creek	5.27	Moderate	27
	Tiffany Creek	9.08	Moderate	46
	West Spencer Creek	18.11	Significant	79
Red Hill Creek	Hannon Creek	10.97	Significant	74
Stoney Creek Watercourses	WC 7	4.32	Moderate	44
	WC 10.1	0.48	Moderate	40
	WC 12	5.76	Moderate	35

The results of the surface water quantity analysis showed significant stress level in 17 subwatersheds and moderate level in 16 subwatersheds. As there are no surface drinking water intakes in these subwatersheds, they do not warrant a Tier 2 level of stress assessment. If any of these subwatersheds experience development pressure a more detailed water budget and water quantity stress assessment should be considered.

In the Halton watershed the only surface water drinking water sources are located in Lake Ontario; therefore none of the subwatersheds under surface water stress require Tier 2 Water Budget and WQSA.

The groundwater stress assessment identified four (4) subwatersheds across the Halton-Hamilton SPR that exhibit either annual or monthly stress levels.

The following **Table 7.13** summarizes the groundwater stresses:

Table 7.13: Halton-Hamilton SPR Groundwater Stress Level Summary

SPA	Watershed	Subwatershed	Present Conditions Stress Level		Future Conditions Stress Level	
			Annual	Monthly	Annual	Monthly
Halton	**Sixteen Mile Creek**	Upper West Branch	Moderate	Low	Moderate	Low
	Bronte Creek	Willoughby Creek	Moderate	Moderate	Moderate	Moderate
Hamilton	**Spencer Creek**	Logie's Creek	Moderate	Moderate	Moderate	Moderate
		Middle Spencer Creek	Moderate	Low	Moderate	Low
	Red Hill Creek	Lower Davies Creek	Significant	Moderate	Significant	Moderate

Of the five (5) subwatersheds with groundwater stresses the Upper West Branch of Sixteen Mile Creek and the Middle Spencer Creek subwatersheds contain municipal drinking water system. Tier 2 level of WQSA are required for these subwatersheds.

8 TIER 2 WATER BUDGET

Subwatersheds that contain municipal drinking water systems and that are assigned a moderate or significant degree of stress at the Tier 1 stress assessment level require a Tier 2 water budget analysis. The main purpose of the 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. This includes use of numerical modelling for groundwater systems and use of continuous surface water flow modelling tools to estimate the amount of water supply and reserve. Another main component of the Tier 2 assessment is a detailed review of the consumptive water demand.

The Halton-Hamilton SPR used numerical modelling of groundwater systems and surface water flows for best estimates of groundwater and surface water supplies and a detailed water taking review was completed for the best to date water demand estimate.

There are two (2) subwatersheds recommended for the Tier 2 groundwater stress assessment:

- Upper Middle Branch of Sixteen Mile Creek within the Halton region SPA; and
- Middle Spencer Creek of the Spencer Creek watershed within the Hamilton Region SPA.

8.1 Upper West Branch Assessment

The Upper West Branch subwatershed includes two (2) groundwater municipal well fields: Kelso and Campbellville.

Figure 8.1 is a map showing the Upper West Branch subwatershed.

The water supply used for the WQSA equals to the sum of recharge and lateral flow into a subwatershed. The PRMS model fully encompasses the Upper West Branch subwatershed and no additional data are available to improve the model output. Therefore, the recharge estimate will stay constant.

The limitation of the groundwater flow model developed for the Halton area, which includes the Upper West Branch subwatershed was that the northern boundary of the subwatershed was also the model's boundary with an assigned no flow conditions. Therefore, no lateral flow was estimated through the boundary. It should be noted that the length of the no flow boundary constitutes only about 10 percent of the total Upper West Branch subwatershed's boundary. Also, just north of the subwatershed's northern boundary lays a local groundwater divide associated with the Black Creek drainage. The location of the groundwater divide limits the amount of lateral flow through this boundary into the Upper West Branch subwatershed.

The peer review team decided that a sensitivity analysis would be performed on the WQSA components before the groundwater flow model was altered to try to capture the full amount of lateral flows into the subwatershed.

The consumptive demands were estimated carefully and there is no available data to better the consumptive demand estimate.

Thus, the only element of the water budget which could improve the WQSA at this point is the lateral flow into the subwatershed.

8.1.1 Sensitivity Analysis

To estimate the groundwater quantity stress at the Tier 2 level it was assumed that:

Scenario 1 - lateral flows into the subwatershed would be double the Tier 1 estimated value based on the groundwater flow modelling; and

Scenario 2 - lateral flows into the subwatershed would equal the recharge estimate.

The first scenario is a rather conservative approach of estimating the lateral flows into the subwatershed. Based on the results of the percent demand of this scenario the second scenario was used. The second scenario is an obvious overestimate of the lateral flows into a subwatershed; therefore, if the percent demand is over the 10 percent threshold the Upper West Branch subwatershed is definitely stressed.

The summary of consumptive water demand, water supply and reserve estimates and the results of the stress assessment analysis are summarized in the following **Table 8.1**.

Table 8.1: Upper West Branch Subwatershed Groundwater Stress Level Summary

Tier Level	Consumptive Demand	Recharge	Lateral Flow	Supply	Reserve	Percent Demand
	[m^3/sec]	[m^3/sec]	[m^3/sec]	[m^3/sec]	[m^3/sec]	
Tier 1	0.1156	0.6405	0.1804	0.8209	0.0821	**15.6**
Tier 2	0.1156	0.6405	0.3608 *	1.0013	0.1001	**12.8**
	0.1156	0.6405	0.6405 **	1.281	0.1281	**10.02**

Note: * - Double of the Tier 1 lateral flow estimate;
** - Lateral flow equal to recharge estimate.

In scenario 1, where the lateral flow equals double the Tier 1 lateral flow estimate (based on the groundwater flow modelling) the percent demand is 12.8 %.

In scenario 2, where the amount of the groundwater inflow into the subwatershed equals the amount of recharge within the subwatershed, the percent demand value is marginally above 10 percent, and therefore classified as moderate stress level.

Based on the best available science-based data to date the Upper West Branch subwatershed is moderately stressed in terms of groundwater quantity at the Tier 2 level and requires a Tier 3 Water Budget and Local Area Risk Assessment analysis.

No drought scenarios were completed at the Tier 2 WQSA level as the subwatershed appears to be stressed for the existing system average conditions scenario and the Tier 3 water budget analysis is required. Transient groundwater flow modelling will be completed for the subwatershed Tier 3 water budget study. The transient flow modeling will be used to complete the drought scenarios.

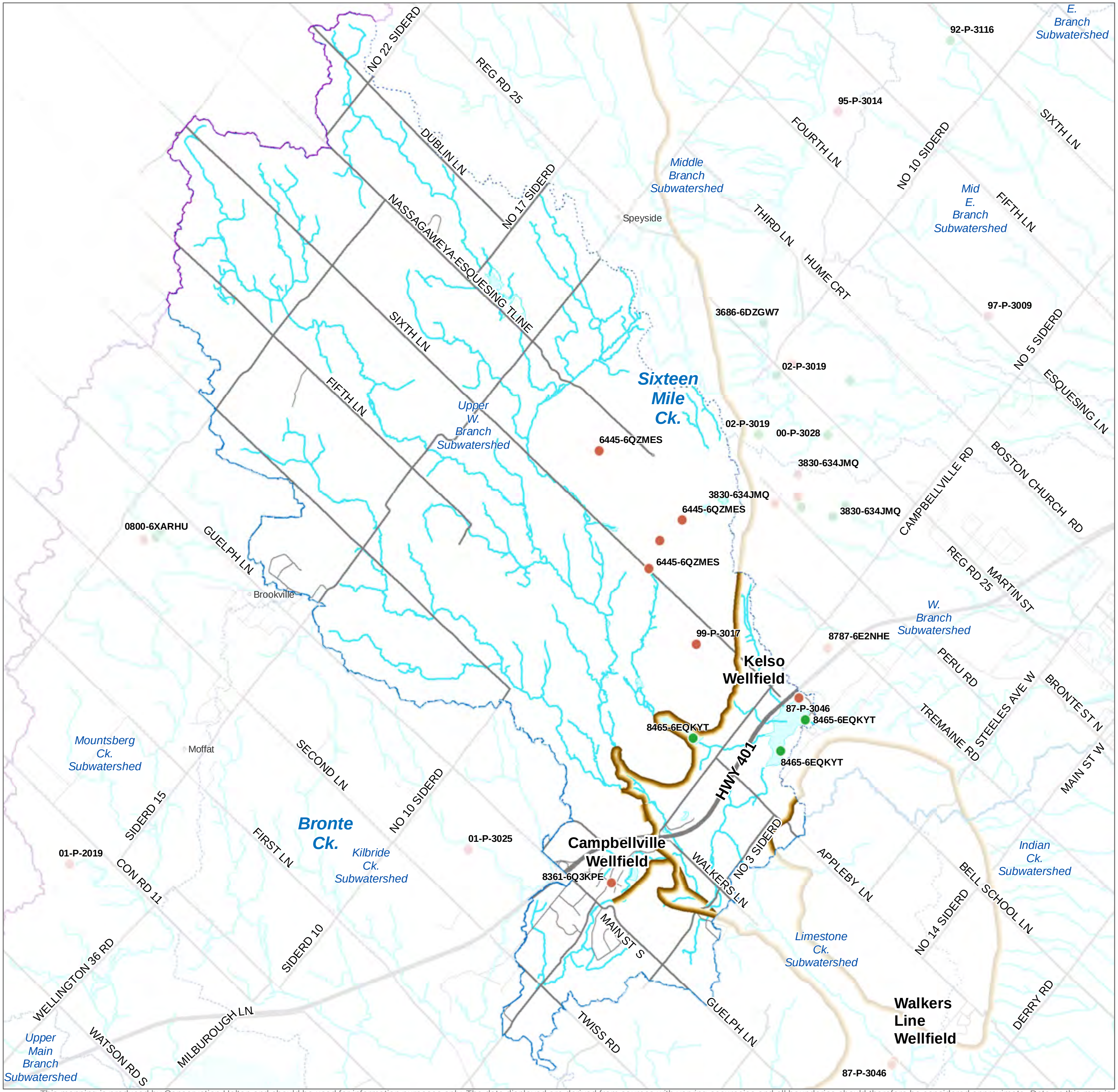

Figure 8.1

Upper West Branch Tier 2 Study Area

Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Niagara Escarpment
- Roads
  - Highway
  - Regional
  - Local
- Hydrography
- Waterbody
- Permit To Take Water (PTTW)
  - Groundwater Sources
  - Surface Water Sources

Source : Ministry of Environment, Permit To Take Water Database (2006), with updates (2008).

Projection : UTM NAD 83 Zone 17

Date : August 27, 2010

N W E S

0 0.4 0.8 1.6 2.4 Kilometers

1:81,000

8.2 Middle Spencer Creek Assessment

The Middle Spencer Creek subwatershed includes one (1) groundwater municipal well field in Greensville.

Figure 8.2 is a map showing the Middle Spencer Creek subwatershed and the location of the Greensville wellfield and locations of permitted water takings in the area. It is clearly seen that the municipal wellfield is located away from any major water users in the subwatershed.

The water supply used for the WQSA is a sum of recharge and lateral flow into the subwatershed. The PRMS model fully encompasses the Middle Spencer Creek subwatershed and no additional data are available to improve the model output. Therefore, the recharge estimate will stay constant.

The limitation of the groundwater flow model developed for the Hamilton area, which includes the Middle Spencer Creek subwatershed is that the southern boundary of the model crops the below the Niagara Escarpment part of the subwatershed. Therefore, no lateral flow was estimated through the boundary of the cropped portion of the subwatershed. The length of the cropped boundary is about 20 percent of the total Middle Spencer Creek subwatershed's boundary. The cropped area lies below the Escarpment and is believed to be a discharge zone. Therefore, no lateral flow into the Middle Spencer Creek subwatershed from that portion of the subwatershed is expected.

The consumptive demands were estimated carefully and there is no available data to better the consumptive demand estimate at this time.

Following the above discussion there are no WQSA components that could be improved at this time for a better estimate of the hydrologic stresses in the area. Therefore, a Tier 3 water budget is recommended to further understand the local conditions.

To further support the proposed Tier 3 study our technical team investigated the location of the Greensville municipal well and the area contributing water to the well. Although, the stress assessments are done on subwatershed basis the surficial drainage boundaries very often do not align with the groundwater ones. It appears that the area contributing water to the Greensville well extends to the north of the well into the neighboring Logie's Creek subwatershed, which has been identified as under moderate annual and monthly stress level.

No drought scenarios were completed at the Tier 2 WQSA level as the subwatershed appears to be stressed for the existing system average conditions scenario and the Tier 3 water budget is required. Transient groundwater flow modelling will be completed for the subwatershed Tier 3 water budget study. The transient flow modeling will be used to complete the drought scenarios.

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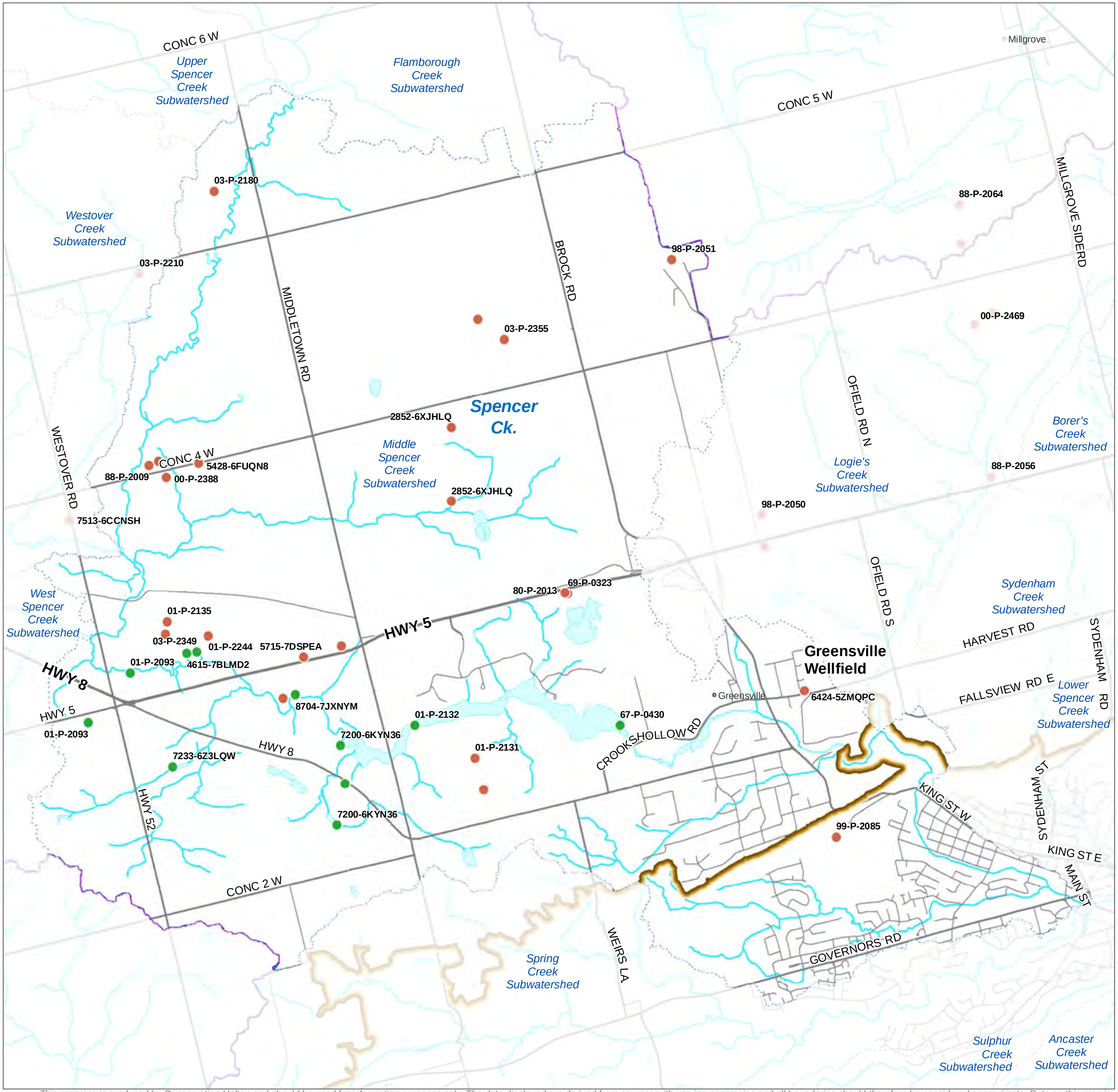
Figure 8.2

Middle Spencer Creek Tier 2 Study Area



Legend

- Source Protection Area
- Watersheds
- Subwatersheds
- Niagara Escarpment
- Roads
  - Highway
  - Regional
  - Local
- Hydrography
- Waterbody
- Permit To Take Water (PTTW)
  - Groundwater Sources
  - Surface Water Sources

Source : Ministry of Environment, Permit To Take Water Database (2006), with updates (2008).
Projection : UTM NAD 83 Zone 17
Date : August 27, 2010

N W E S

0 0.25 0.5 1 1.5
Kilometers
1:52,000

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9 UNCERTAINTY

For each stress assessment scale an assessment and rating of the uncertainty is required as either 'high' or 'low'.

The evaluation of the uncertainty for the spatial scale (subwatershed) stress assessment consists of the following two steps:

i. Uncertainty in supply: uncertainty due to measured and estimated hydrologic parameters (i.e., recharge, interflow, streamflow) that are contributing to the final percent water demand score.

ii. Uncertainty in demand: uncertainty in the consumptive water demand estimate that is contributing to the final Percent Water Demand score.

9.1 Uncertainty in Surface Water Supply and Demand Estimations

9.1.1 Uncertainty in Surface Water Supply Estimation

The surface water supply was estimated based on the PRMS distributed hydrologic model results. Therefore, the uncertainties of the surface water supply estimation are related to the uncertainties of the PRMS conceptual model and the measured data used to develop and calibrate the model.

All hydrologic models are simplifications of actual hydrologic responses within a natural system. The performance of a model is checked through a calibration process using measured data.

The Halton-Hamilton SPR PRMS model uses land use data, land elevation, topography, soil and climate data as inputs to represent the physical and natural system. The certainty of the model is related to these inputs. The certainty of the model is also related to the conceptual model e.g.: how well it represents the natural physical environment.

Climate Data

The uncertainty in the climate data use in the Halton-Hamilton PRMS model can be summarized as follows:

1. Climate data in a watershed have temporal and spatial variations, although are represented at 9 stations within the model domain only;
2. Climate data used for the PRMS model represents eight (8) years of daily averages;
3. The model used computed potential ET data based on the solar radiation from one weather station only;
4. Climate data measurement inaccuracies; and
5. The interpolation method of the climate data between the stations is a simple mathematical method, which does not simulate actual climate changes.

As a result there is a level of uncertainty in the climate data. Cumming Coburn Limited (2000) estimated approximately ±10 percent uncertainty with the precipitation measurement. This uncertainty is higher, about ±20 percent, in winter.

Overall climate data uncertainty is low. It is believed that the inherent errors of climate data tends to average out over the long period of data collection and have less impact on the results.

Measures Taken to Reduce Level of Uncertainty in the Model

Climate data (precipitation and temperature) from outside of the Halton-Hamilton SPR was used to better represent the variations in the data along the SPR boundary.

The model results were verified with the measured streamflow as explained in Section 2.2.4. There are varying degrees of uncertainty of streamflow measurement, but in general the uncertainty of the measured data is low. The model is well calibrated and produces lots of information about the hydrologic responses in the watersheds, which might not be possible through measurement or field data collection. The PRMS model simulated surface runoff with reasonable accuracy; therefore, its results can be relied upon for the water budget components and the WQSA.

9.1.2 Uncertainty in Surface Water Consumptive Water Demand Estimation

The surface water demand was estimated from the PTTW database and Census of Agricultural data. For permits with no actual water taking data reported the maximum water taking values reported in the PTTW database were used to estimate water demand, which might eventually provide overestimation of water quantity stress.

The estimate of the agricultural taking based on the Census of Agricultural data using de Loe method has its limitations and multiple assumptions adding to the uncertainty. Although, proactive approaches were used to minimize the uncertainty, e.g., providing Halton-Hamilton SPR boundaries to Statistics Canada to summarize the data and avoid inherent errors associated with an area weighting method, where areas outside the watershed could erroneously be incorporated and areas inside the watershed could be excluded.

9.2 Uncertainty in Groundwater Supply and Demand Estimations

9.2.1 Uncertainty in Groundwater Supply Estimation

Generally, the uncertainty associated with the estimated recharge generated by the surface water model is considered high, if not coupled with a groundwater flow model. The surface water models are calibrated with observed streamflows while the groundwater flow models are calibrated with observed baseflows as well as measured groundwater elevations. If the groundwater flow model is calibrated with the groundwater elevations and baseflows it is thought the simulated results from the groundwater model are less uncertain.

The groundwater supply estimation is based on a numerical groundwater flow model. Any model is always a simplified representation of a natural system. There are uncertainties associated with:

1. Using a numerical code to approximate solution of the groundwater flow equations;
2. Representation of the natural system: there is recognition that we never know enough about the spatial complexities of the physical system and temporal variations of the stresses on the system to incorporate all the details into a numerical model. Representation of fractures and hydraulic conductivities are good examples of spatial complexities, while the assumption of steady-state for the stresses is mostly a constraint on temporal variations; and
3. Measured data: numerical models simulate the physical conditions irrespective of the quality of the input data. The results are non-unique (i.e., the same output can be obtained with different sets of input information). The groundwater measured data can be summarized in three (3) categories:
    - Actual water takings;
    - Groundwater levels; and
    - Aquifer properties.

    The uncertainty of actual water takings for the municipal wells is low as the systems are being monitored by properly trained municipal staff. The other available actual groundwater takings such as quarry dewatering have rather high uncertainty due to unknown groundwater portion of the monitored discharge.

    The measured groundwater level data can be divided into low uncertainty data such as the PGMN well data, which is of high quality and high uncertainty data such as the MOE WWIS used for the groundwater flow calibration.

    Measured aquifer properties are usually of high quality (low uncertainty), but caution should be always exercised in extrapolating the data in model development.

The above listed problems do not negate the use of numerical models as tools to understand natural systems. The issue is that there is a need to recognize the limitations of these models and the results should be interpreted carefully. However, even with these limitations, the numerical models are often the only way to represent the complex natural systems and simulate the future conditions.

Both the Halton Region’s and the City of Hamilton’s groundwater flow models and the PRMS surface water model were developed at regional scales. As a result, the lateral flows and recharge distribution are good and consistent estimates of the groundwater supply.

To lower the uncertainty associated with the Halton and Hamilton groundwater flow models they were calibrated using data obtained from municipal monitoring networks and other high-quality sources that have less uncertainty.

Part of a quality assurance and quality control, the PRMS model and the two groundwater flow models are undergoing a peer review process by a third party. The initial comments of the peer reviewers indicate that the models are reasonable regional models, which provide good estimates of the surface water and groundwater supplies.

9.2.2 Uncertainty in Groundwater Consumptive Water Demand Estimation

The following factors contribute to the uncertainty of the consumptive water demand:

1. **Permitted water takings**

   The PTTW database used in this analysis was received in March 2007 and may not be complete. Active permits were considered to be those issued on or after March 21, 2003. Actual water takings were not available for all the permitted operations, and the water demand based on the maximum permitted water takings are subject to various levels of uncertainty. The use of maximum water takings probably overestimates the water quantity stress.

2. **Non-permitted water takers**

   Water takings less than 50,000 litres/day do not require permits and these takings introduce uncertainty in the total consumptive demand. Not knowing the locations of such takings may underestimate the water quantity stress level.

3. **Consumptive factor**

   Consumptive use factors are used for the specific purposes of the water takings. Certainty in the consumptive water use is not warranted as these factors are general in nature and can vary for similar types of uses in different hydrogeologic settings.

4. **Monthly use adjustment**

   Monthly demands are adjusted based on the GRCA (2005) findings for typical active months for each specific purpose of the water takings. These are approximations only and a field survey and/or obtaining of actual consumptive water takings would be very beneficial.

Uncertainty Summary
There are a number of factors that contribute to uncertainty in the analysis presented in this report. It is important to note, however, these factors are in no way unique to this body of work. Rather, they should be used as cautionary notes when using the information outside the purposes of this report.

10 CONCLUSIONS

The objective of the WQSA analysis is to identify subwatersheds where the sustainability of water supplies is questionable and to identify the causes of the limited sustainability. The Technical Rules require a tiered approach for water budget evaluation and WQSA:

(1) Conceptual Water Budget;
(2) Tier 1 Water Budget and WQSA;
(3) Tier 2 Water Budget and WQSA; and
(4) Tier 3 Water Budget and Local Area Risk Assessment.

This report represents a significant amount of work involving the collection, organization, assessment, and evaluation of a wide range of technical information from a number of different data information sources.

Water Budget

The water budget elements were calculated using the PRMS surface water model and averaged over the 8-year simulation period to determine annual rates of recharge, actual evapotranspiration and total runoff.

The PRMS model simulation provided consistent and calibrated estimates of groundwater recharge across the Halton-Hamilton SPR.

Water Demand

Water demand used in the WQSA is a consumptive use.

In the Halton Region SPA the total consumptive groundwater use is mainly for water supply (61 percent), dewatering (20 percent), agriculture (15 percent) and the remaining four (4) percent are for other uses. In the Hamilton Region SPA the total consumptive groundwater use is more evenly distributed. The largest consumptive water demand is for dewatering at 42 percent followed by agricultural demand at 28 percent, water supply at 13 percent, remediation at eight (8) percent, commercial at six (6) percent and industrial demand at three (3) percent.

The total consumptive surface water demand is mainly related to agricultural and commercial sectors. In the Halton Region SPA the agricultural demand is about 56 percent and the commercial demand is about 43 percent. The remaining one (1) percent is for other uses. In the Hamilton Region SPA the agricultural demand is about 90 percent and the commercial demand is about 10 percent.

There are no inland surface water municipal takings within the Halton-Hamilton SPR; therefore, there is no need for further investigation of the surface water demand for a refinement of the stress levels.

Water Supply

Surface water and groundwater supplies were estimated using numerical surface water and groundwater flow models.

The surface water PRMS model was calibrated using HYDAT station streamflow data. The water supply for each subwatershed was calculated as monthly median streamflow rate (i.e., monthly 50th percentile flow) for each month over the modelled period. For the downstream subwatersheds, cumulative flow rates (m^3/s) were calculated through routing flows from the upstream subwatersheds.

Groundwater supplies were defined as the sum of recharge and lateral flows into a subwatershed. The average annual recharge distribution was obtained from the continuous surface water PRMS model. The lateral groundwater flows into each subwatershed were obtained from the groundwater flow models.

The calibrated PRMS surface water model and groundwater MODFLOW models provided reasonable estimates of surface water and groundwater supplies used for the Halton-Hamilton SPR WQSAs.

Water Reserve

Since a majority of the subwatersheds in the Halton watershed do not have measured continuous streamflows, this report used the estimated 10th percentile monthly streamflows based on the results of the PRMS model.

The groundwater reserve was estimated as ten percent (10%) of the total groundwater supply.

Tier 1 Stress Assessment

The results of the surface water stress assessment showed significant stress levels in 17 subwatersheds and moderate levels in 16 subwatersheds in the Halton-Hamilton SPR. As there are no surface drinking water intakes in these subwatersheds, they do not warrant a Tier 2 level of stress assessment. If any of these subwatersheds experience development pressure a more detailed water budget and water quantity stress assessment should be considered.

The groundwater stress assessment identified five (5) subwatersheds across the Halton-Hamilton SPR that exhibit either annual or monthly stress levels.

Of the five (5) subwatersheds with groundwater quantity stresses the Upper West Branch subwatershed of Sixteen Mile Creek and the Middle Spencer Creek subwatershed contain municipal drinking water systems. Tier 2 level WQSAs were required for these subwatersheds.

The results of the Tier 1 stress assessment are summarized in the **Table 11.2** below:

Table 10.1: Tier 1 Level WQSA Summary

Watershed	Subwatershed	Municipal Wellfield(s)	Stress Levels					
			Surface Water		Groundwater			
			Monthly		Monthly		Annual	
			Moderate	Significant	Moderate	Significant	Moderate	Significant
Halton Region SPA								
Sixteen Mile Creek	East Branch			X				
	East Branch Lisgar			X				
	Lower Middle Branch		X					
	Lower Middle Tributary			X				
	Middle East Branch			X				
	Middle Branch		X					
	Upper West Branch	Kelso and Campbellville					X	
	West Branch		X					
Bronte Creek	Flamboro Creek	Carlisle		X				
	Indian Creek		X					
	Lowville Creek			X				
	Mount Nemo Creek			X				
	Mountsberg Creek		X					
	Willoughby Creek			X	X		X	
Grindstone Creek	201			X				
	204		X					
	210			X				
	215		X					
	220			X				
North Shore Group 1	407 Diversion			X				
Hamilton Region SPA								
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					

Tier 2 Stress Assessment

The Tier 2 WQSA for the Upper West Branch subwatershed of Sixteen Mile Creek confirmed the potential of moderate hydrologic groundwater stress under current demand conditions.

The Tier 2 WQSA for the Middle Spencer Creek subwatershed confirmed the potential of moderate hydrologic groundwater stress under current demand conditions.

Tier 3 Water Budgets and Local Area Risk Assessments are required for the Upper West Branch of Sixteen Mile Creek and the Middle Spencer Creek subwatersheds.

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APPENDIX A

Vulnerability Analysis for the Milton and Campbellville Wellfields Report, Regional Municipality of Halton, Ontario, Earthfx, April 2010

Bound Separately

APPENDIX B

Vulnerability Assessment and Scoring of Wellhead Protection Areas Report, City of Hamilton, Ontario, Earthfx, April 2010

Bound Separately