Drinking Water Source Protection
ACT FOR CLEAN WATER
Trent Conservation Coalition
Source Protection Region

Approved

Ganaraska Assessment Report

Volume 1 of 2

Approved October 1, 2014

Updated September 1, 2023

Ganaraska Region Source Protection Area

Ontario
Made possible through the support of the Government of Ontario

www.trentsourceprotection.on.ca

This Assessment Report was prepared on behalf of the Trent Conservation Coalition Source Protection Committee under the Clean Water Act, 2006.

TRENT CONSERVATION COALITION SOURCE PROTECTION COMMITTEE

Membership as of date of Plan Approval (October 23, 2014)

Jim Hunt (Chair)

Municipal
Dave Burton, *KHSPA municipalities*
Rob Franklin (Bruce Craig to June 2011), *GRSPA municipalities*
Dave Golem, *CVSPA municipalities*
Rosemary Kelleher-MacLennan, *LTSPA municipalities*
Gerald McGregor, *KHSPA municipalities*
Mary Smith, *OPSPA municipalities*
Richard Straka, *OPSPA municipalities*

Commercial/Industrial
Monica Berdin, *Recreation/Tourism*
Edgar Cornish, *Agriculture*
Kerry Doughty, *Aggregate/Mining*
Robert Lake, *Economic Development*
Glenn Milne, *Agriculture*
Bev Spencer, *Agriculture*
Dave Workman (Rick Johnson to June 2009), *Commercial/Industrial*

Other Interests
Alanna Boulton, *Trent-Severn Waterway*
William Cornfield, *Drinking Water Expert*
Roberta Drew, *Public -Rural*
Michael Gibbs (Matt Taft to September 2010), *Public - Urban*
Terry Rees, *Waterfront Landowner*
Wayne Stiver, *Drinking Water Expert*
Alix Taylor (Mary Jane Conboy to March 2010), *Environmental Non-Governmental Organization*

First Nations
Darla Blodgett, *Hiawatha First Nation*
Pam Crowe (to June 2013), *Alderville First Nation*
Mae Whetung (Tracey Taylor to July 2008, Wanita Dokis to November 2008), *Curve Lake First Nation*

The Trent Conservation Coalition Source Protection Committee is a locally based committee, comprised of 28 representatives from municipal governments, First Nations, the commercial/industrial/agriculture sectors, and other interests. The Committee's ultimate role is to develop a Source Protection Plan that establishes policies for preventing, reducing, or eliminating threats to sources of drinking water. In developing the plan, the committee members are committed to the following:

- *Basing policies on the best available science and, where there is uncertainty, being mindful of the precautionary approach*
- *Considering and incorporating voluntarily contributed local and traditional knowledge*
- *Ensuring that public concerns are heard and taken into consideration*
- *Consulting with all stakeholders and, in particular, with impacted landowners/businesses*
- *Considering all economic impacts*
- *Making decisions that are fair and reasonable through an open and transparent process*
- *Advocating ongoing provincial funding to provide financial assistance to property/business owners, municipalities, agencies, and others for stewardship and other implementation measures.*

Liaison
Anne Alexander (Tom Cathcart: acting) (to 2013), *Health Unit/Department*
Wendy Lavender (Debbie Scanlon to January 2009, Wendy Lavender to June 2011, Claire Mitchell 2011 to 2012), *Ministry of the Environment, Conservation and Parks ~~and Climate Change~~*
Glenda Rodgers (Jim Kelleher to September 2010), *Source Protection Authority*

Current Membership (as of August 11, 2022)

Municipal
Lori Burtt, *OPSPA municipalities*
Bonnie Clark, *OPSPA municipalities*
Brent Devolin, *KHSPA municipalities*
Doug Elmslie, *KHSPA municipalities*
Rob Franklin, *GRSPA municipalities*
Rosemary Kelleher-MacLennan, *LTSPA municipalities*
George Offshack, *CVSPA municipalities*

Commercial/Industrial
Cyndy Broughton, *Recreation/Tourism*
Jessica Ferri, *Aggregate/Mining*
Robert Lake, *Economic Development*
Faye Langmaid, *Economic Development*
Glenn Milne, *Agriculture*
Bev Spencer, *Agriculture*
Dave Workman, *Commercial/Industrial*

Other Interests
Alanna Boulton, *Trent-Severn Waterway*
Rene Gagnon, *Drinking Water Expert*
Michael Gibbs, *Public/Urban*
Alexander Hukowich, *Drinking Water Expert*
Terry Rees, *Waterfront Landowner*
Richard Straka, *Public/Rural*
Alix Taylor, *Environmental Non- Governmental Organization*

First Nations
Darla Blodgett, *Hiawatha First Nation*
Kristin Muskratt, *First Nation Youth Representative*
Tracey Taylor, *Curve Lake First Nation*

Liaison
Julie Ingram, *Health Unit*
Mary Wooding, *Ministry of the Environment, Conservation and Parks*
Rhonda Bateman, *Source Protection Authority*2010), *Source Protection Authority*

ACKNOWLEDGEMENTS

The Committee would like to thank staff of the following organizations for their contributions in preparing this Assessment Report.

Conservation Authorities

- Crowe Valley Conservation Authority
- Ganaraska Region Conservation Authority
- Kawartha Conservation
- Lower Trent Conservation
- Otonabee Conservation.

Consultants & Others

- EarthFX Inc.
- GENIVAR (formerly Jagger Hims Ltd.)
- AECOM Canada Ltd.
- University of Guelph
- Lake Ontario Collaborative
- Dr. Ray Dewey
- Stantec Consulting Ltd.
- IBI Group
- Harden Environmental Services Ltd.
- Greenland International Consulting Ltd.
- Intera Engineering Ltd.
- Bruce W. Kitchen, P. Eng., Consultant, Peterborough Utilities Services Inc.
- Trent University
- Conservation Authorities Moraine Coalition
- Trent-Severn Waterway
- Ministry of the Environment, Conservation and Parks ~~and Climate Change~~
- Ministry of Natural Resources and Forestry
- Conservation Ontario

Municipalities

The following municipalities are located, either in part or entirely, within the Ganaraska Region Source Protection Area. There has been ongoing communication with municipalities throughout the source protection planning process. Many have been involved with the development of the Ganaraska Assessment Report.

- Township of Alnwick/Haldimand
- Township of Cavan Monaghan
- Municipality of Clarington
- Town of Cobourg
- Regional Municipality of Durham
- Township of Hamilton
- City of Kawartha Lakes
- County of Northumberland
- Township of Otonabee-South Monaghan
- County of Peterborough
- Municipality of Port Hope.

TRENT CONSERVATION COALITION SOURCE PROTECTION REGION

The Trent Conservation Coalition Source Protection Region extends across the Trent and Ganaraska River watersheds, covering a 14,500 square kilometre area stretching from Algonquin Park to the Bay of Quinte and Lake Ontario. Five conservation authorities within this region have worked with the source protection committee, local municipalities, and other stakeholders to facilitate the development of the Trent and Ganaraska Source Protection Plans.

Crowe Valley Conservation Authority

Ganaraska Region Conservation Authority

Kawartha Region Conservation Authority

Lower Trent Region Conservation Authority

Otonabee Region Conservation Authority

PREFACE

This Assessment Report was prepared to satisfy the requirements of the *Clean Water Act* on behalf of the Trent Conservation Coalition Source Protection Committee. The report is made up of two volumes: Volume 1 (Text) and Volume 2 (Maps). While some figures have been included in the text for illustrative purposes, the complete map set is in Volume 2.

This report applies to the Ganaraska Region Source Protection Area. A separate report has been prepared for the four source protection areas in the Trent Conservation Coalition Source Protection Region that drain primarily to the Trent River - Crowe Valley, Kawartha-Haliburton, Lower Trent, and Otonabee-Peterborough - which are referred to collectively as the "Trent source protection areas". The water budget for a small portion of the Ganaraska Region Source Protection Area, which flows into the Trent River system via Rice Lake, is discussed in the Trent Assessment Report.

The purpose of the Assessment Report is to assess the quality and quantity of municipal drinking water supplies. The Assessment Report identifies significant threats including potential future threats that could impact drinking water sources.

> ***Technical Rules***
>
> *The Technical Rules sets out the requirements for the Assessment Report. The Technical Rules is available at https://www.ontario.ca/page/2021-technical-rules-under-clean-water-act ~~on the Ministry of the Environment and~~*

The Ganaraska Assessment Report was developed from a number of technical reports that have been completed in accordance with the *Clean Water Act* using the best available data (prepared by the Ganaraska Region Conservation Authority, conservation authorities of the Trent Conservation Coalition, municipalities, and consultants). The requirements for preparing the technical reports and the Assessment Report content are set out in detail in the *Technical Rules: Assessment Report*, which was originally developed by the Ministry of the Environment and Climate Change. A list of background reports is found in Appendix D.

Public Consultation

The draft Proposed Ganaraska Assessment Report was made available for public consultation from June 2 to July 9, 2010. It was posted on the Trent Conservation Coalition website (www.trentsourceprotection.on.ca), and public meetings were held in each of the source protection areas in order to seek input from the public. The comments received from the public were considered by the Source Protection Committee, and the draft Proposed Ganaraska Assessment Report was revised as appropriate. Following the revisions, the Proposed Ganaraska Assessment Report was posted for a second round of public consultation (September 10 to October 10, 2010) and submitted to the Source Protection Authorities established under the *Clean Water Act*. The Source Protection Authorities were responsible for submitting the Proposed Ganaraska Assessment Report to the Ministry of the Environment and Climate Change for review. The Proposed Ganaraska Assessment Report was submitted on October 29, 2010.

During the winter of 2010-11, the Proposed Ganaraska Assessment Report was updated to reflect new information received since the October submission. Further, recommended revisions to ensure compliance with the Technical Rules (Nov 2009) were received from the Ministry of the Environment and Climate Change in April

2011. The amended document addresses these comments from the Ministry of the Environment and Climate Change. The Draft Amended Proposed Ganaraska Assessment Report was submitted for public consultation from May 4 to June 3, 2011. No comments were received in reference to the document posted. The Amended Proposed Ganaraska Assessment Report was submitted to the Ganaraska Region Source Protection Authority and then forwarded to the Ministry of the Environment and Climate Change for review and consideration in June 2011. The Ganaraska Assessment Report was approved by the Ministry of the Environment and Climate Change in October 2011.

In 2013, additional modeling work was carried out to identify significant drinking water threats to the three Lake Ontario drinking water systems. Updates to the Ganaraska Assessment Report occurred in 2013, and public consultation occurred from November 18 to December 20, 2013. The Updated Ganaraska Assessment Report ~~will be~~was submitted to the Ministry of the Environment and Climate Change for review and ~~consideration~~ approval in March 2014.

In 2023, the Source Protection Committee engaged in public consultation as part of the Section 36 Amendments to the Ganaraska Assessment Report and Ganaraska Source Protection Plan.

Source Protection Plan

This Assessment Report will be used as a foundation for preparing the Ganaraska Source Protection Plan. The purpose of the Ganaraska Source Protection Plan is to eliminate or reduce the significant threats to municipal drinking water sources that are identified in the Assessment Report. The plan can apply various types of policies including outreach and education, incentive programs, risk management plans, or even prohibition of certain activities.

EXECUTIVE SUMMARY

The Ganaraska Assessment Report is a summary of the technical studies undertaken in the Ganaraska Region Source Protection Area to meet the requirements of the *Clean Water Act* and *Technical Rules: Assessment Report*.

The report includes the following elements:

- A watershed characterization that characterizes human and physical geography, drinking water systems, terrestrial and aquatic ecology, and regional water quality
- A water budget and water quantity stress assessment
- An assessment of groundwater and surface water vulnerability
- An evaluation of existing source water quality issues associated with municipal drinking water systems
- A water quality threats assessment
- Great Lakes considerations
- Potential climate change implications
- A discussion of cross-boundary considerations (with other source protection areas and regions)
- A list of data gaps and next steps.

The main findings of the Ganaraska Assessment Report are summarized below.

WATERSHED CHARACTERIZATION

The Ganaraska Region Source Protection Area covers 930 square kilometres (km^2) of land that extends from the Wilmot Creek watershed in the west to the Cobourg Creek watershed in the east, and from the crest of the Oak Ridges Moraine and Rice Lake in the north to Lake Ontario in the south. The major watersheds include Wilmot Creek, Graham Creek, the Ganaraska River, Gages Creek, and Cobourg Creek, all of which originate on the Oak Ridges Moraine. All of the watersheds within the Source Protection Area drain directly to Lake Ontario, except for 107 km^2 of land in the northeast corner that drains to Rice Lake, which is a part of the larger Trent River watershed.

Groundwater and surface water flows are controlled by geologic characteristics that are Paleozoic in origin. Varying depths of unconsolidated glacial sediments overlay the limestone bedrock. The Oak Ridges Moraine significantly contributes baseflow to the major watersheds within the Source Protection Area. The natural surface water flows are only marginally controlled by dams and weirs for the purpose of flood control, recreation, and maintenance of aquatic habitat. As a result of geological characteristics and settlement patterns, agriculture and development are predominant in the south end of the Source Protection Area within the South Slope and Lake Iroquois Plain physiographic regions. Forests dominate the northern end of the Source Protection Area and the stream valleys.

Natural vegetative cover includes about 44 km^2 of wetlands and 340 km^2 of woodlands. Vegetated riparian areas (including vegetated lands within 120 metres of streams, rivers, lakes, and wetlands) cover about 209 km^2.

The majority of the population lives in the Village of Newcastle (within the Municipality of Clarington), the Municipality of Port Hope (Ward 1), and the Town of Cobourg. An important source of drinking water is private water supply wells, however municipal drinking water systems provide water from three groundwater wellfields and three Lake Ontario intakes.

WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

A water budget and water quantity stress assessment analysis was completed for the five major watersheds and three groupings of watersheds that drain to Lake Ontario. The portion of the Ganaraska Region Source Protection Area that drains to Rice Lake, located within the Trent River watershed, was analysed in the Trent River conceptual water budget, and in the Trent River Tier 1 water budget and water quantity stress assessment.

The Ganaraska Region Source Protection Area analysis included a conceptual water budget, a Tier 1 water budget, and a water quantity stress assessment. The conceptual water budget described all available data and provided an initial overview of water movement at a coarse spatial scale. This included a description of the physical setting and provided an initial evaluation of each watershed's water budget. The Tier 1 water budget expanded on the findings of the conceptual water budget by calculating water budgets using more detailed modeling. The water quantity stress assessment assigned water quantity stress levels to the eight studied watersheds in the Ganaraska Region Source Protection Area. The uncertainty associated with the Tier 1 water budget and water quantity stress levels was also evaluated.

Of the eight watersheds studied, two were found to have moderate surface water stress: the Gages Creek watershed and the Wilmot Creek watershed. Given that no municipal drinking water sources are present in the Gages Creek watershed, a Tier 2 analysis was not required for the purpose of drinking water source protection.

The Wilmot Creek watershed exhibited moderate surface water stress related to anthropogenic impacts, and given that the Orono Drinking Water System was defined as groundwater under the direct influence of surface water (GUDI), the Tier 1 water budget assessment recommended that the Wilmot Creek watershed proceed to a Tier 2 study. However, subsequent to the Tier 1 water budget assessment, the Orono Drinking Water System has been proven to be a non-GUDI system. This designation has been accepted by the Ministry of the Environment, Conservation and Parks ~~and Climate Change~~. Due to this information, a Tier 2 analysis for the Orono Drinking Water System will not be reported in the Ganaraska Assessment Report.

As a result of the Tier 1 water budget and water quantity stress assessment, it was concluded that there are no water quantity stresses to municipal water supplies in the Ganaraska Region Source Protection Area.

VULNERABILITY ASSESSMENT

Surface Water Systems

There are three municipal surface water intakes in the Ganaraska Region Source Protection Area. These are the following:

- Cobourg Surface Water Supply (hereafter referred to as Cobourg Water Treatment Plant)
- Port Hope Surface Water Supply (hereafter referred to as Municipality of Port Hope Water Treatment Plant)
- Newcastle Surface Water Supply (hereafter referred to as Newcastle Drinking Water System).

The surface water intakes in the Ganaraska Region Source Protection Area are all located in Lake Ontario and have been classified as Type A intakes (per the *Clean Water Act* definitions). Intake Protection Zones 1 and 2 were delineated for each municipal surface water system. An Intake Protection Zone 3 has been delineated based on a modeled spill from a fuel pipeline. Intake Protection Zone 1 was delineated using a circle with a radius of 1 kilometre around the intake crib. Intake Protection Zone 2 was delineated in Lake Ontario using lake based models. The modeled time of travel distance in Lake Ontario was calculated to the outlet of tributaries, and the remainder of the two-hour travel time distance (residual time of travel) was mapped upstream into the tributaries and transport pathways.

Vulnerability scores were assigned to Intake Protection Zone 1 and 2 based on an area vulnerability factor that reflects the physical setting of the zone, and a source vulnerability factor that reflects the characteristics of the intake and the water quality. Vulnerability scores are highest in Intake Protection Zone 1. Intake Protection Zones and their vulnerability scores are illustrated on a series of maps in Volume 2.

Groundwater Systems

There are three municipal well systems in the Ganaraska Region Source Protection Area. These are the following:

- Creighton Heights Well Supply (hereafter referred to as Creighton Heights Water Supply System) in the Township of Hamilton
- Camborne Well Supply (hereafter referred to as Camborne Water Supply System) in the Township of Hamilton
- Orono Well Supply (hereafter referred to as Orono Drinking Water System) in the Regional Municipality of Durham.

The Wellhead Protection Area (WHPA) was delineated for each of the systems using computer based three-dimensional groundwater flow models (Visual MODFLOW). The total area within the WHPAs for the Ganaraska Region Source Protection Area is 108.5 km^2. The vulnerability for the aquifers related to the municipal wells was assessed using two methods. The Surface to Aquifer Advection Time (SAAT) was used for the Creighton Heights and Camborne Water Supply Systems, and the Aquifer Vulnerability Index (AVI) was used for the Orono Drinking

Water System. Vulnerability scores were assigned to each area in the respective WHPAs based on its time of travel and vulnerability. Wellhead Protection Areas and their vulnerability scores are illustrated on a series of maps in Volume 2.

LANDSCAPE-SCALE GROUNDWATER ANALYSES

Groundwater Vulnerability

Groundwater vulnerability was assessed at a landscape scale across the entire Trent Conservation Coalition Source Protection Region. The analysis focused on the uppermost aquifer from which the majority of domestic wells draw their water. The analysis was based on databases of well records that included spatial and geological data for thousands of wells in the Source Protection Region. The analysis was performed using VIEWLOG (a borehole data management and visualization software package) and a Geographic Information System (GIS). Because of the significant variation in groundwater vulnerability and data availability across the Source Protection Region, a combination of the Intrinsic Susceptibility Index and Aquifer Vulnerability Index methods was used to assign vulnerability. In general, the aquifers in the Precambrian area (north) were found to be highly vulnerable, and the vulnerability of the aquifers in the Paleozoic (south) was more variable. Maps of the landscape-scale vulnerability and highly vulnerable aquifers (areas with a vulnerability score of 6) are provided in Volume 2.

Significant Groundwater Recharge Areas

Significant groundwater recharge areas in the Trent Conservation Coalition Source Protection Region were delineated using the water budget surplus method (areas where the annual recharge volume is at least 55% of the annual water budget surplus). The delineation process consisted of an analysis of climate, estimation of recharge rates, and calculation of the water budget surplus and threshold recharge volume. ~~Significant groundwater recharge areas were assigned a vulnerability score of 6, 4, or 2 using the landscape-scale groundwater vulnerability analysis discussed above.~~ Maps of the significant groundwater recharge areas ~~and vulnerability scores~~ are provided in Volume 2.

DRINKING WATER ISSUES

Drinking water issues exist where the concentration of a contaminant in a well or at a surface water intake related to a drinking water system may indicate a deterioration of the quality of the water for use as a source of drinking water. Only issues that are the result of anthropogenic (human) activity are of significance under the *Clean Water Act*. No drinking water issues were identified in the Ganaraska Region Source Protection Area.

DRINKING WATER THREATS

Areas within each vulnerable area and the relevant circumstances where an activity or condition is or would be a significant, moderate, or low drinking water threat are illustrated on a series of maps in Volume 2.

No significant drinking water threats were identified by using the scoring approaches for IPZ-1 and IPZ-2. An Intake Protection Zone 3 has been delineated based on a modeled spill from a fuel pipeline. Through modeling this activity has been shown to produce concentrations of benzene above Ontario Drinking Water Standards at all three Lake Ontario intakes. Therefore the modeled spill has been defined as a prescribed significant drinking water threat~~ and identified as a local threat by the Trent Conservation Source Protection Committee~~.

In 2013, additional modeling was undertaken which identified significant drinking water threats: marina gasoline storage tank ruptures (fuel spill) impacting the Cobourg and Newcastle surface water supplies; and wastewater treatment plant disinfection failures impacting the Cobourg, Newcastle, and Port Hope surface water supplies.

The number of significant threats located in wellhead protection areas and the total number of parcels on which these threats are located are summarized in the table below.

There were no conditions resulting from past activities identified as significant drinking water threats.

Summary of Wellhead Protection Area Significant Drinking Water Threats in the Ganaraska Region Source Protection Area

Prescribed Drinking Water Threats	Total No. Significant Threats	Total No. of Affected Parcels
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*	0	0
The establishment, operation or maintenance of a system that collects, stores, transmits, treats, or disposes of sewage	~~13~~10	~~13~~10
The application of agricultural source material to land	1	1
The storage of agricultural source material	0	0
The management of agricultural source material	0	0
The application of non-agricultural source material to land	0	0
The handling and storage of non-agricultural source material	0	0
The application of commercial fertilizer to land	0	0
The handling and storage of commercial fertilizer	0	0
The application of pesticide to land	~~1~~0	~~(1)~~0
The handling and storage of pesticide	0	0
The application of road salt	0	0
The handling and storage of road salt	0	0
The storage of snow	0	0
The handling and storage of fuel	~~8~~1	(~~8~~1)
The handling and storage of a dense non-aqueous phase liquid	~~1~~3	~~1~~3
The handling and storage of an organic solvent	0	0
The management of runoff that contains chemicals used in the de-icing of aircraft	0	0
The use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard	0	0
TOTAL NOTE: SOME PARCELS HAVE MORE THAN ONE SIGNIFICANT THREAT. BRACKETS DENOTE ADDITIONAL THREATS ON THE SAME PARCEL.	**~~24~~15**	**~~15~~14**

ADDITIONAL CONTENT

Great Lakes Considerations

A discussion is included on how the Ganaraska Assessment Report considered the *Great Lakes Water Quality Agreement*, the *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem*, and the *Great Lakes Charter*. The *Clean Water Act* allows for the Minister of the Environment, Conservation and Parks ~~and Climate Change~~ to establish targets relating to the use of the Great Lakes as a source of drinking water for any of the source protection areas that contribute water to the Great Lakes. If targets are set, policies and steps would need to be established to achieve these targets. No targets have been set to date.

Potential Climate Change Implications

Contents of the Ganaraska Assessment Report that include projections or analyses of historical climate data have the potential to be affected by climate change. Secondary impacts are expected as a result of the changes in climate (e.g., a decrease in surplus water due to an increase in evapotranspiration). The potential impacts of climate change on the findings of the Ganaraska Assessment Report in the next 25 years include increases in sizes of some of the vulnerability zones, increases in numbers of significant water quality threats, and increases in water quantity stress levels.

Cross-Boundary Considerations

The Ganaraska Assessment Report identifies a number of matters that affect other source protection areas and regions. These include, but are not limited to, an Intake Protection Zone that extends into the Central Lake Ontario Source Protection Area. The Intake Protection Zone 3 of the Hastings Municipal Water Supply System extends into the Ganaraska Region Source Protection Area from the Lower Trent Source Protection Area. Regional considerations such as significant groundwater recharge areas and highly vulnerable aquifers that share boundaries with neighbouring source protection areas should also be included in cross-boundary considerations.

Data Gaps

Key data gaps identified in the Ganaraska Assessment Report include the following:

- Identification of water quality issues for drinking water systems in highly vulnerable aquifers and significant groundwater recharge areas.

NEXT STEPS

The approved Ganaraska Assessment Report ~~will be used as a~~is the foundation for preparing the ~~local~~ Ganaraska Source Protection Plan. The purpose of the Ganaraska Source Protection Plan is to eliminate or reduce significant threats to municipal drinking water sources that are identified in the Ganaraska Assessment Report. The plan ~~will be~~is developed by the Source Protection Committee in consultation with municipalities, conservation authorities, property and business owners, farmers, industry, health officials, community groups, ~~First Nations~~Indigenous Communities, and others working together to develop a fair, practical, and implementable Ganaraska Source Protection Plan. The plan could uses various types of policies ranging from outreach and education to incentive plans, to risk management plans, or and even prohibition of certain activities. Public input and consultation will play is an important tool a significant role throughout the process.

The Ganaraska Source Protection Plan was must be submitted to the Minister of the Environment and Climate Change inby August 20, 2012.

A Section 36 amendment occurred since the original approval of the Ganaraska Assessment Report and Ganaraska Source Protection Plan with submission for approval by the Ministry of Environment, Conservation and Parks in 2023.

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CHAPTER 1: INTRODUCTION

This Ganaraska Assessment Report has been prepared as a component of the source protection planning process on behalf of the Trent Conservation Coalition Source Protection Region by its Source Protection Committee in accordance with the Ontario *Clean Water Act, 2006 S.15 (1).*

1.1 CLEAN WATER ACT, 2006

The *Clean Water Act* was passed by the Ontario government to establish a framework for drinking water source protection across the province. Source protection planning is the first line of defense in a multi-barrier approach to the provision of safe drinking water that aims to prevent the contamination and overuse of lakes, rivers, and groundwater. This is achieved by evaluating threats to these water sources and establishing policies to minimize or eliminate them. The Act mandates existing conservation authorities to perform the powers of source protection authorities for the purpose of source protection planning in a source protection area. The Act assigns responsibilities, prescribes research and technical studies, and provides regulation in support of the development and implementation of Source Protection Plans. Regulations under the Act include *Service of Documents (Ontario Regulation (O. Reg.) 231/07), Source Protection Areas and Regions (O. Reg. 284/07), General Regulations (O. Reg. 287/07),* and *Source Protection Committees (O. Reg. 288/07).*

The multi-barrier approach to the provision of safe drinking water includes source protection, treatment, distribution, and testing.

1.1.1 SOURCE PROTECTION AUTHORITIES

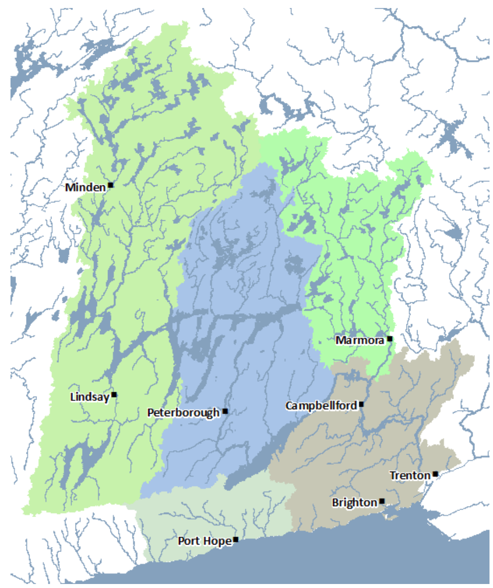
Source protection authorities are administrative bodies mandated to satisfy the requirements of the Act in a source protection area. They are generally composed of the conservation authority boards of directors, which are made up of representatives appointed by councils of the municipalities in the conservation authority. Where the jurisdiction of a source protection authority has been expanded to include areas outside of the jurisdiction of a conservation authority, the source protection authority includes additional representation from the municipalities included by the boundary expansion.

1.1.2 SOURCE PROTECTION AREAS AND REGIONS

Source protection areas are the areas of focus for a source protection authority and are defined in *O. Reg. 284/07* of the Act. In most cases a source protection area is the same as the conservation authority jurisdiction as defined in the *Conservation Authorities Act.* However, where desirable for the purpose of source protection, watersheds located outside of conservation authority jurisdiction have been included in that jurisdiction or established as independent source protection areas. In some parts of the province the Act has consolidated several adjacent source protection areas into source protection regions. Within these consolidated areas, the administration of the source protection planning process is centralized with a lead source protection authority subject to an agreement among the source protection authorities in the region.

1.2 TRENT CONSERVATION COALITION SOURCE PROTECTION REGION

The Trent Conservation Coalition Source Protection Region (hereafter, the Region) has been established in accordance with the Act as a partnership among the Crowe Valley, Ganaraska Region, Kawartha-Haliburton, Lower Trent, and Otonabee-Peterborough Source Protection Authorities, with Lower Trent as the lead Source Protection Authority. The Region covers an area of approximately 14,500 square kilometres (km^2) and includes the entire Trent River watershed and two additional watersheds. The Ganaraska Region Source Protection Area drains into Lake Ontario (except for a small portion that drains into Rice Lake) and the southern portion of the Lower Trent Source Protection Area drains into both Lake Ontario and the Bay of Quinte. The Region also includes land outside of Conservation Authority jurisdiction. The boundaries of the Region and its source protection areas are illustrated on Map 1-1.



The five Source Protection Areas of the Trent Conservation Coalition Source Protection Region

1.2.1 LANDS OUTSIDE OF CONSERVATION AUTHORITY JURISDICTION

The Kawartha-Haliburton, Otonabee-Peterborough, and Lower Trent Source Protection Areas have been defined by *O. Reg. 284/07* of the Act to include areas outside of conservation authority jurisdiction. Specifically, the Kawartha Region and Otonabee Region Conservation Authority boundaries have been expanded for purposes of source protection planning to include the headwaters of the Trent River, which includes parts of Haliburton and Peterborough Counties. The Lower Trent Source Protection Area encompasses a small portion of the Township of Havelock-Belmont-Methuen, which is not within the jurisdiction of any conservation authority.

1.2.2 TRENT-SEVERN WATERWAY

The Trent-Severn Waterway is a system of rivers, lakes, canals, locks, and water control structures that forms a navigable route through the Region and the adjacent South Georgian Bay Lake Simcoe Source Protection Region. It extends from Georgian Bay at Port Severn to the Bay of Quinte at Trenton and is a central feature of both source protection regions. Many of the major watercourses in the Region form the navigation channel of the waterway. Additionally, waterbodies and watercourses act as reservoirs helping to regulate water supply. The waterway is owned by the crown and operated by Parks Canada. Their management decisions can have a significant impact on water flows and levels throughout the Region.

1.2.3 LAKE ONTARIO

Although a portion of the Ganaraska Region Source Protection Area drains to the Trent River watershed, the majority of its watersheds drain directly to Lake Ontario. Together, the five Great Lakes and their connecting rivers form the largest fresh surface water system on the earth. The Great Lakes are a shared water source supplying drinking water to millions of people in Ontario and eight Great Lakes States, as well as to downstream Quebec communities on the St. Lawrence River. More than 85% of Ontario's population rely on the waters of the Great Lakes Basin as their source of drinking water. Specifically within the Ganaraska Region Source Protection Area, 66% of the population obtain their drinking water from Lake Ontario, therefore making the protection of this large water source a focus of the source protection planning process.

1.3 OVERVIEW OF SOURCE PROTECTION PLANNING PROCESS

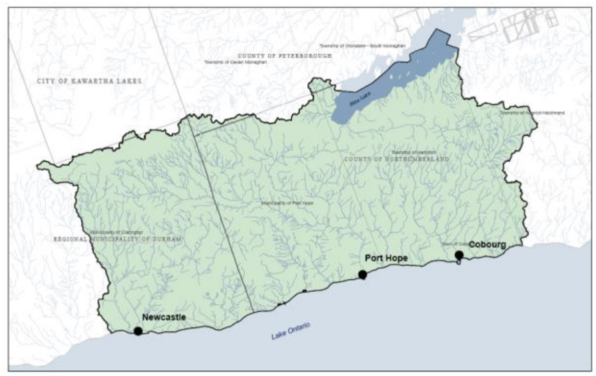
Source protection planning under the Act requires the development of a Terms of Reference, Assessment Report, and Source Protection Plan. The Terms of Reference outlines the work plan, timeline, and responsibilities for the development of the Assessment Report and lists the drinking water systems that are within its scope. A *Terms of Reference* for each source protection area in the Region ~~has~~ was ~~been~~ completed, publicly reviewed, approved by the Minister of the Environment and Climate Change in 2009, and is available on the Trent Conservation Coalition website. The Assessment Report is a technical document developed in accordance with the Terms of Reference and regulations that identifies and evaluates threats to drinking water quality and quantity. The Assessment Report accomplishes this by compiling all relevant data on the applicable source protection areas and by applying scientific methodologies to assess the vulnerability of the municipal drinking water systems that are located in the areas. The Act also contains provisions to include non-municipal drinking water systems in prescribed circumstances.

The Source Protection Plan will build on the findings of the Assessment Report by establishing policies to reduce or eliminate significant threats to water quality or stresses to drinking water quantity and will identify who is responsible for taking action, setting timelines, and establishing performance measures for plan implementation. Where possible, the Source Protection Plan will build on work currently underway and will recognize or reinforce existing management practices relevant to drinking water source protection.

1.4 SCOPE AND PURPOSE OF THE ASSESSMENT REPORT

This Assessment Report has been developed for the Ganaraska Region Source Protection Area, which primarily drains to Lake Ontario. An Assessment Report has been created for the Crowe Valley, Kawartha-Haliburton, Lower Trent, and Otonabee-Peterborough Source Protection Areas (the Trent Assessment Report). These source protection areas have been grouped to maintain a focus on the Trent River watershed and to preserve linkages to the Trent-Severn Waterway. Where technical studies performed in fulfillment of the Act have considered all five source protection areas, the Trent Assessment Report will be cross-referenced as appropriate. The Ganaraska Region Source Protection Area is illustrated on Map 1-2.

This report has been prepared in accordance with *O. Reg. 287/07* of the Act, the *Technical Rules* published by the Ministry of the Environment, Conservation and Parks ~~and Climate Change~~, and the *Terms of Reference* for the Ganaraska Region Source Protection Area. The *Technical Rules* and *O. Reg. 287/07* identify the specific contents of the Assessment Report and establish standards for technical work undertaken in fulfillment of the Act. This report will bring together the results of the technical studies required by the Act and *Technical Rules* including a watershed characterization, water budgets, vulnerability assessments, issues identifications, and threats assessments. It will provide a scientific basis for the development of policies in a Source Protection Plan.



The Ganaraska Region Source Protection Area

1.5 PARTICIPANTS IN THE PROCESS

Source protection planning is a multi-stakeholder process that seeks to involve everyone that may be affected by the Source Protection Plan. Participants include the provincial government, conservation authorities, municipalities, First Nations, landowners, businesses, the public, and other stakeholders. Participants in the process are represented by the Source Protection Committee. The public has multiple opportunities to provide input through a defined public consultation process.

1.5.1 SOURCE PROTECTION COMMITTEE

The Act assigns the responsibility for developing the Assessment Report and Source Protection Plan to a Source Protection Committee made up of individuals selected to represent municipal, economic, general public, and First Nations interests across the Region. The composition and operation of the Committee are prescribed under *O. Reg. 288/07* of the Act. The Chair was originally appointed by the Minister of the Environment and Climate Change on August 20, 2007 and the Committee was established in November 2007 following an open public process. In addition to the Chair, there are twenty-four members: seven municipal representatives, seven representatives from the economic/industrial sector, seven members representing other interests, and three First Nations representatives. Three non-voting liaison members also sit on the Committee to represent the

Ministry of the Environment, Conservation and Parks and Climate Change, source protection authorities in the Region, and Health Units/Departments.

1.5.2 PUBLIC CONSULTATION

The Source Protection Committee is required to consult broadly across the watershed at three key stages during the preparation of the Terms of Reference, Assessment Report, and Source Protection Plan. Consultation on the Ganaraska Assessment Report occurred in June and July 2010 upon the completion of the Draft Proposed Ganaraska Assessment Report and again in September and October 2010 when the Proposed Ganaraska Assessment Report was submitted to the Ganaraska Region Source Protection Authority. Public consultation on the Draft Amended Proposed Ganaraska Assessment Report occurred in May and June 2011 prior to submission to the Source Protection Authority and the Ministry of the Environment and Climate Change in June 2011. In November and December 2013, public consultation on updates to the Ganaraska Assessment Report occurred in regards to Lake Ontario modeled threats.

Additional public consultation is required when there are amendments to the Assessment Report. This can occur where there are changes to a municipal drinking water system, such as a new well coming online. In these circumstances the committee must consult with the affected public as part of the Section 34 Amendment process. Furthermore, periodically amendments to the Assessment Report may be required because of technical rule changes or outdated information and these amendments can be addressed as part of the Section 36 Amendment process, which also requires public consultation.

1.6 PROJECT TIMELINE

The Act establishes timelines for the source protection planning process. The Assessment Report is was to be submitted to the Ministry of the Environment and Climate Change within one year of the approval of the Terms of Reference. The Source Protection Plan is was to be submitted to the Minister of the Environment and Climate Change within five years of the appointment of the Source Protection Committee chair. Since the *Terms of Reference* for the source protection areas in the Region were approved in early 2009, the Act requires the Proposed Assessment Reports to be submitted by early 2010. However, an extension to October 29, 2010 was granted by the Ministry of the Environment and Climate Change (see Appendix A). This deadline extension does did not affect the August 20, 2012 deadline for the submission of the Source Protection Plan.

After submission of the Proposed Assessment Report, a work plan was accepted by the Ministry of the Environment and Climate Change detailing tasks to be completed in a future update/amendment to the Proposed Assessment Report. This Amended Proposed Ganaraska Assessment Report was submitted to the Ministry in June 2011. The Trent Conservation Coalition Source Protection Committee received notice from the Ministry of the Environment and Climate Change in October 2011 advising that the Trent Assessment Report was approved. The approval process was considered complete with the posting of an Information Notice on the Environmental Bill of Rights Registry in January 2012, as required under Section 18 of the *Clean Water Act.* The timeline for the completion of the components of the source protection planning process is illustrated in Table 1-1.

Table 1-1: Timeline for Source Protection Products

	2005	2006	2007	2008	2009	2010	2011	2012
Watershed Studies								
Municipal Technical Studies								
Terms of Reference								
Assessment Reports								
Source Protection Plans								
Clean Water Act, July 3, 2007								

CHAPTER 2: WATERSHED CHARACTERIZATION

A watershed is the area of land that drains to a particular body of water. A watershed characterization is a documentation of various aspects of a watershed for the purpose of obtaining a general understanding of its features and functions. The following characterization of the Ganaraska Region Source Protection Area has been prepared in accordance with the *Clean Water Act*, *2006*, *O. Reg. 287/07*, and Part II of *Technical Rules: Assessment Report* (2008). This watershed characterization draws from a document prepared before the publication of the technical rules entitled Watershed Characterization Report: Ganaraska Region Source Protection Area (Ganaraska Region Conservation Authority, 2008) and has expanded on it where required to satisfy the legislation.

2.1 OVERVIEW OF THE GANARASKA REGION SOURCE PROTECTION AREA

The Ganaraska Region Source Protection Area covers 930 km^2 of land that extends from the Wilmot Creek watershed in the west to the Cobourg Creek watershed in the east, and from the crest of the Oak Ridges Moraine and Rice Lake in the north to Lake Ontario in the south. The major watersheds include Wilmot Creek, Graham Creek, the Ganaraska River, Gages Creek and Cobourg Creek. In addition, four groups of smaller watersheds drain to either Lake Ontario or Rice Lake. The Ganaraska Region Source Protection Area boundary and its watersheds are shown on Maps 2-1 and 2-2, respectively.

All of the watersheds within the Source Protection Area drain to Lake Ontario except for 107 km^2 of land in the northeast corner that drains to Rice Lake, which is a part of the larger Trent River watershed. The watersheds are primarily coldwater systems, but there are a few warm water stream reaches scattered throughout. The largest watershed is the Ganaraska River (278 km^2) that is renowned for its trout and salmon fishery. The Source Protection Area also includes the Ganaraska Forest, which is the largest continuous forest in the built-up area of southern Ontario. Local residents and visitors from across Ontario, Canada, and the United States use the Ganaraska Forest for its motorized and non-motorized recreational opportunities. It also hosts the widely acclaimed Ganaraska Forest Centre, which provides a unique outdoor education experience in the heart of the Ganaraska Forest to elementary and secondary school students.

Groundwater and surface water flows are controlled by geological characteristics that are Paleozoic in origin. Varying depths of unconsolidated glacier sediments overlay the limestone bedrock. The Oak Ridges Moraine significantly contributes baseflow to the major watersheds in the Source Protection Area. The natural surface water flows are marginally controlled by dams and weirs for the purpose of flood control, recreation, and maintenance of aquatic habitat. As a result of geological characteristics and settlement patterns, agriculture and development are predominant in the south end of the Source Protection Area within the South Slope and Lake Iroquois Plain physiographic regions. Forests dominate the northern end of the Source Protection Area and in stream valleys.

The majority of the population lives in the Village of Newcastle (in the Municipality of Clarington), the Municipality of Port Hope (Ward 1), and the Town of Cobourg. Smaller settlements exist throughout the rural landscape and include larger communities such as Orono, Kendal, Garden Hill, Welcome, Bewdley, Gore’s Landing, Harwood, Coldsprings, Camborne, and Baltimore. A large portion of the population obtain drinking water from private water supply wells, however municipal drinking water systems provide water from three groundwater wellfields and three Lake Ontario intakes.

2.2 GEOGRAPHY AND LAND USE

2.2.1 PHYSICAL GEOGRAPHY

The prominent physiographic regions in the Ganaraska Region Source Protection Area are the Oak Ridges Moraine, the Peterborough Drumlin Field, the South Slope, and the Lake Iroquois Plain. Physiographic regions are shown on Map 2-3 and the percent coverage of each physiographic region is identified in Table 2-1. Physical characteristics of each watershed, including physiographic characteristics, are summarized in Table 2-2.

The Oak Riges Moraine was once severely deforested (top). Today, after a massive restoration effort, the Oak Ridges Moraine within the Ganaraska Region Source Protection Area is reforested (bottom). Restoration was undertaken to control erosion and downstream flooding problems associated with the deforested, sandy soils. Photo Source: Ganaraska Region Conservation Authority.

The Oak Ridges Moraine is defined as an interlobate moraine and occupies the northern portions of the source protection area. This region is characterized by high relief, hummocky terrain, tills capped with sand hills, and coarse outwash. In the western part of the source protection area, the Oak Ridges Moraine is partly capped by a thin layer of the clay-rich Halton Till. Sands are comprised predominantly of limestone, which is a soil-building material, and is fairly high in phosphorus and low in potash content. The till contains lime components that make it highly impervious to water and difficult to excavate.

The Peterborough Drumlin Field occupies the northeast corner of the source protection area. Many geological units in this physiographic region are similar to those found in the Oak Ridges Moraine including a dense, silty till that is likely equivalent to the Newmarket Till (Earthfx Incorporated, 2006). The region is characterized by a series of southwest-trending drumlins composed mainly of till materials. In many parts of the Peterborough Drumlin Field, clay soils dominate the lowlands between the drumlins (Morrison Environmental Ltd., 2004). These clay soils influence the drainage systems in the Rice Lake area, limiting the potential for both recharge and discharge in the low-lying areas between the drumlins.

On the southern slope of the interlobate moraine lies the South Slope, which is a gently sloping area of land found north of the low-lying Lake Iroquois Plain (Chapman & Putnam, 1966). The surficial soils are predominantly sandy till materials in the east and clay-rich materials in the west. The till is calcareous and contains a large portion of fine and silty material. The northwestern portion of the South Slope region is drumlinized, and the drumlins are scattered, long and thin, and point directly up toward the slope of the moraine. Streams flow directly and rapidly down the slope; this has resulted in sharp valleys being eroded into the tills. Numerous gullies have also been cut by intermittent drainage such that east-west side roads cross a succession of valleys.

The Lake Iroquois Plain is a plain of glaciolacustrine deposits located south of the former Glacial Lake Iroquois shoreline (Chapman & Putnam, 1984). The Lake Iroquois Plain can be divided into distinctive upper and lower parts as a result of the retreat of the glacial lake from north to south. The upper part has an irregular low relief and includes the former Lake Iroquois shore and nearshore deposits. In the former Lake Iroquois shore, sand and gravel were deposited in beaches, bars, and spits. Sand and gravel bars, as well as beach terraces, can also be observed in this area. The lower part contains deposits that grade into massive, laminated silts and clays to the south that define the lower lake plain area. In many parts of the source protection area, the abandoned Lake Iroquois shoreline is well defined by relief and beach material, but in certain areas its position can be inferred from the presence of lacustrine materials and elevation.

Table 2-1: Physiographic Regions

Physiographic Region	Area (km^2)	Land Coverage (%)
Oak Ridges Moraine	222	24
Peterborough Drumlin Field	45	5
South Slope	319	34
Lake Iroquois Plain	330	34

Data Source: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange
Calculations do not include the area under Rice Lake

Table 2-2: Physical Characteristics of the Ganaraska Region Source Protection Area Watersheds and Subwatersheds

Watershed	Subwatershed	Drainage Area (km^2)	Channel Length (km)	Total Fall (m)	Channel Average Slope (%)	Percent Land Cover			Physiographic Region(s)
						Wetlands	Meadows	Woodland	
Wilmot Creek									
	Total Watershed	98.8	29.3	191	0.65	1.5	8.0	23.4	Oak Ridges Moraine, South Slope, Lake Iroquois Plain
	Orono Creek	18.0	10.4	107	1.03				
	Hunter Creek	8.1	8.0	90	1.13				
	Stalker Creek	11.5	11.1	89	0.80				
	Foster Creek	9.6	8.2	48	0.59				
Graham Creek									
	Total Watershed	78.1	32.3	82	0.25	9.4	8.6	21.5	Oak Ridges Moraine, South Slope, Lake Iroquois Plain
	Mulligan Creek	14.9	8.8	68	0.77				
West Lake Ontario									
	Total Area	117.3				5.9	9.5	16.1	South Slope and Lake Iroquois Plain
	Lovekin Creek	7.2	112.5	16.6	0.01				
	Bouchette Point Creek	23.0	132.7	12.3	0.01				
	Port Granby Creek	13.3	8.1	52	0.64				
	Wesleyville Creek	8.3	5.2	64	1.23				
	Port Britain Creek	36.2	20.0	90	0.45				
	Brands Creek	9.4	7.4	54	0.74				
	Little's Creek	4.6	3.2	54	1.69				
Ganaraska River									
	Total Watershed	277.9	42.0	161	0.38	4.4	6.1	37.0	Oak Ridges Moraine, Peterborough Drumlin Field, South Slope, Lake Iroquois Plain
	North Ganaraska Branch	70.5	22.5	121	0.54				
Gages Creek									
	Total Watershed	48.6	25.2	147	0.58	2.2	7.2	7.4	Oak Ridges Moraine, South Slope, Lake Iroquois Plain
East of Gages Creek									
	Total Area	12.5				0	0.3	0.9	Lake Iroquois Plain
Cobourg Creek									
	Total Watershed	123.2	27.6	181	0.66	6.2	7.6	51.7	Oak Ridges Moraine, South Slope, Lake Iroquois Plain
	Baltimore Creek	45.3	8.8	62	0.70				
	West Branch	43.7	20.1	143	0.71				
Rice Lake North and West Shore									
	Total Area	107.5				3.4	4.9	13.7	Oak Ridges Moraine and Peterborough Drumlin Field
East Lake Ontario									
	Total Area	42.7				0.1	7.7	30.2	Oak Ridges Moraine, South Slope, Lake Iroquois Plain
	Midtown Creek	6.1	7.2	51	0.71				
	Brook Creek	15.5	5.9	28	0.47				
	Massey Creek	5.9	8.2	47	0.57				
	Spicer Creek	11.6	10	110	1.10				

Data Source: Drainage areas calculated using Arc Hydro, land cover calculated using Ecological Land Classification based on 2002 aerial photos, physiographic regions provided under license by member of the Ontario Geospatial Data Exchange.

2.2.2 HUMAN GEOGRAPHY: POPULATION AND LAND USE

2.2.2.1 AREAS OF SETTLEMENT

Areas of Settlement
Area[s] of land designated in an official plan for urban uses, including urban areas, urban policy areas, towns, villages, hamlets, rural clusters, rural settlement areas, urban systems, rural service centres or future urban use areas, or as otherwise prescribed (*Places to Grow Act*)

Areas of settlement, as defined in the *Places to Grow Act*, in the Ganaraska Region Source Protection Area are generally found along the shore of Lake Ontario with the exception of historic settlement areas that exist along historic rail or road corridors and the south shore of Rice Lake. A large proportion of residents live in rural residential areas, hamlets, and estate residential areas, which are identified and defined in municipal official plans. Areas of settlement in the source protection area are shown on Map 2-4.

Areas of commerce and industry are found alongside areas of settlement. There are over 100 manufacturers in the source protection area and most of them are located south of Highway 401. Major industrial operations include nuclear fuel bundling, uranium refining, custom vacuum forming and packing, food processing and packaging, manufacturing of steel, metal, paper, and wood products, robotics, conveyor apparatus, vinyl and urethane plastic auto interiors, industrial paints and lacquers, and prefabricated homes.

2.2.2.2 MUNICIPALITIES

There are 10 municipalities located within or partially within the Ganaraska Region Source Protection Area that have a total approximate population of 61,113 (Statistics Canada, 2006). Population density is greatest at the western end of the source protection area, which is closest to the Greater Toronto Area and south of Highway 401 in Ward 1 of the Municipality of Port Hope and the Town of Cobourg. In addition, increases in population may occur during summer months. Municipal boundaries, population (people per census consolidated subdivision), and population densities (people/km^2 in a census consolidated subdivision) are shown on Maps 2-5, 2-6, and 2-7, respectively. Municipal populations and population densities are listed in Table 2-3.

Table 2-3: Municipal Populations

Municipality	Tier	Area (km^2)	Population	Population Density (people/km^2)	Area (km^2) in GRSPA	Approximate Population in GRSPA
Lower and Single Tier Municipalities						
Township of Alnwick/Haldimand*	Lower	398	6,435	16	43	761
Township of Hamilton	Lower	256	10,972	42	284	10,972
Town of Cobourg	Lower	22	18,210	814	23	18,210
Municipality of Port Hope	Lower	279	16,390	59	272	16,358
Municipality of Clarington	Lower	611	77,820	127	295	14,637
Township of Cavan Monaghan*	Lower	306	8,828	29	7	79
Township of Otonabee-South Monaghan*	Lower	349	6,934	20	5	74
City of Kawartha Lakes	Single	3,060	74,561	13	1	22
Upper Tier Municipalities						
Regional Municipality of Durham	Upper	2,523	561,258	13	295	16,358
Northumberland County	Upper	1,903	80,963	13	621	46,301
Peterborough County	Upper	3,806	133,080	35	12	153

Data Source: Calculated from Statistics Canada, GeoSuite, 92-150-XCB, 2006 Census.
*Located only marginally within the Source Protection Area
Approximate Population in the GRSPA calculated from Statistics Canada, GeoSuite, 92-150-XCB, 2006 Census and clipped to the GRSPA boundary

2.2.2.3 FIRST NATIONS

There are no First Nation Reserves in the Ganaraska Region Source Protection Area.

2.2.2.4 FEDERAL LANDS

Lands within the Ganaraska Region Source Protection Area that are under the jurisdiction of the Government of Canada include Rice Lake, which is part of the Trent-Severn Waterway (managed by Parks Canada), and certain lands associated with historic low-level radioactive waste. A number of sites associated with low-level radioactive wastes are licensed by the Canadian Nuclear Safety Commission (CNSC). Federal lands in the Ganaraska Region Source Protection Area are shown on Map 2-8.

Historic Low-Level Radioactive Waste

Historic waste management practices have contaminated major on-land areas (ravines, large open land areas, and a municipal landfill site) and small-scale sites (individual properties and public roadways) in and around the former Town of Port Hope. Major waste deposits are also located at the Welcome Waste Management Facility in Ward 2 of the Municipality of Port Hope and at the Port Granby Waste Management Facility in Ward 4 of the Municipality of Clarington.

The federal government has accepted responsibility for the remediation of the lands contaminated with historic low-level radioactive waste. Atomic Energy of Canada Ltd. operates the Port Hope Area Initiative on behalf of the federal government, through a cost-recovery agreement with Natural Resources Canada, to carry out the remedial projects. Environmental assessments have recently been completed at both project sites (Port Hope Project and Port Granby Project) and clean-up/remediation programs are currently being developed to address all historic low-level radioactive waste contamination within the Ganaraka Region Source Protection Area. A number of properties will become federally owned as the cleanup/remediation programs proceed.

2.2.2.5 INTERACTIONS BETWEEN HUMAN AND PHYSICAL GEOGRAPHY

Soil fertility and access to water and trade routes were among the most significant influences on human settlement in the Ganaraska Region Source Protection Area. The original vegetation of the Oak Ridges Moraine consisted of mixed forests (pines and hardwoods). White Pines were harvested for the Royal Navy for the construction of ships and ship masts. Among the hardwoods, maple, beech, and oak were exploited for many local and regional uses. Following the exploitation of timber, most of the area was occupied by agriculture and, over time, the poorer farms were abandoned; this was due in part to the droughty and erosion-prone nature of the soils of the Oak Ridges Moraine (Chapman & Putnam, 1966).

When *The Ganaraska Report* (Richardson, 1944) was written, the land use on the Oak Ridges Moraine was 39% cropland, 36% pasture, 19% woodland, and 7% idle. After the Second World War, a decline in agriculture and the extension of reforestation resulted in a decline in rural population. Much of the land that had been taken out of agriculture was put into passive and recreational uses (e.g., Ganaraska Forest and Brimacombe Ski Hill) or used to create rural estate lots. Many of the remaining farms are actually rural residential areas where only a nominal amount of farming occurs and where other incomes support the resident farm families.

Agriculture within the Peterborough Drumlin Field tends to be suppressed due to the presence of stones, steep slopes, and wet, swampy lowlands (Chapman & Putnam, 1966). Currently, large farms do exist in some areas with high quality soil, however marginal farms have given way to hobby farming, rural residential settlement, and cottage development adjacent to Rice Lake.

The South Slope contains a variety of soils, and some of them have proved excellent for agriculture (Chapman & Putnam, 1966). These productive soils are developed on tills that tend to be sandy in nature. Grain, corn, and soybeans are the predominant crops grown on the South Slope. The South Slope has preserved its rural character because of the favourable farming conditions and the small historical farming communities found throughout.

The Lake Iroquois Plain is scattered with a number of drumlinized uplands that were once islands within Lake Iroquois (Chapman & Putnam, 1966). The drumlin soils are generally sandy and therefore not conducive to agriculture, however the lowlands between these drumlins support a great deal of agriculture. Between the end of the Second World War and the 1980s, tobacco production was significant in this area (Chapman & Putnam, 1966). Near Lake Ontario, soils become finer grained and more favourable for agriculture. The area closest to Lake Ontario is one of the oldest settled areas in all of Ontario and it remains a corridor between heavily urbanized areas (Toronto and Kingston). The Village of Newcastle, Ward 1 of the Municipality of Port Hope, and the Town of Cobourg have become manufacturing centres as well as service centres for the rural areas to the north. The area around the Village of Newcastle is currently a productive area for fruit trees.

2.3 OVERVIEW OF DRINKING WATER SYSTEMS

Drinking water systems in the Ganaraska Region Source Protection Area include municipal and non-municipal systems of various sizes that draw raw water from both groundwater and surface water sources. Drinking water systems are divided into eight classifications by the *Drinking-Water Systems Regulation (O. Reg. 170/03)* under

The Ontario Safe Drinking Water Act (herein referred to as the *Safe Drinking Water Act*), based on ownership, number of users, flow rate, annual operating period, and type of facility served. Source protection planning under the *Clean Water Act,* is focused on municipal residential drinking water systems, which include the "large municipal residential" and "small municipal residential" classifications. The remaining six classifications include non-municipal and non-residential drinking water systems. Approximately 30% of the population of the Source Protection Area rely on private wells and lake sources, which are not regulated under the *Safe Drinking Water Act*.

Municipal Residential Drinking Water Systems

Municipal residential drinking water systems are drinking water systems that serve major residential developments. Small municipal residential systems serve fewer than 101 private residences and large municipal residential systems serve more than 100 private residences.

2.3.1 MUNICIPAL RESIDENTIAL DRINKING WATER SYSTEMS

About 70% of the population in the Ganaraska Region Source Protection Area (43,321 people) obtain their drinking water from six municipal residential drinking water systems. These systems are discussed in more detail below, and their locations and approximate service areas are shown on Map 2-9.

2.3.1.1 SURFACE WATER SYSTEMS

There are three existing municipal residential surface water supply systems in the Ganaraska Region Source Protection Area that obtain their water from surface water sources (all of them from Lake Ontario). These systems serve about 40,538 people. Under the *Drinking-Water Systems Regulation* (*O. Reg. 170/03),* these systems are all classified as large municipal residential systems. These systems are discussed in more detail in Chapter 4.

2.3.1.2 GROUNDWATER SYSTEMS

There are three existing municipal residential groundwater supply systems in the Ganaraska Region Source Protection Area that obtain their water from groundwater sources. These systems serve about 2,783 people. Under the *Drinking-Water Systems Regulation (O. Reg. 170/03)*, two of these systems are classified as large municipal residential systems and one is classified as a small municipal residential system. These systems are discussed in detail in Chapter 5. There are no municipal residential drinking water systems in the Ganaraska Region Source Protection Area that are considered to be groundwater under the direct influence (GUDI) of surface water.

GUDI Wells

The *Drinking-Water Systems Regulation (O. Reg. 170/03)* under the *Safe Drinking Water Act*, defines specific circumstances under which a groundwater supply is considered to be groundwater under the direct influence of surface water. These wells are more susceptible to contamination than non-GUDI wells because they can be affected by short-term water quality issues associated with surface water sources.

2.3.2 OTHER DRINKING WATER SYSTEMS

There are about 42 drinking water systems in the Ganaraska Region Source Protection Area that are classified as municipal residential systems under the *Drinking-Water Systems Regulation (O. Reg. 170/03),* for example, trailer parks, campgrounds, subdivisions, community centres, schools, and public buildings. Estimates of the number of systems of each non-municipal and non-residential classification are given in Table 2-4. Details for many of these systems are given in Appendix B, and their locations are shown on Map 2-10. Note that these systems were identified from the Drinking Water Information System Database that only provides a partial listing of these systems. It is expected that the total number of non-municipal and non-residential systems is significantly greater.

Table 2-4: Drinking Water Systems and their Classifications

Safe Drinking Water Act Classification	Estimated No. Systems
Large municipal non-residential	1
Small municipal non-residential	7
Non-municipal year-round residential	5
Non-municipal seasonal residential	2
Large non-municipal non-residential	0
Small non-municipal non-residential	27

Data Sources: Ministry of the Environment and Climate Change Drinking Water Information System (March 19, 2009)

2.4 TERRESTRIAL AND AQUATIC CHARACTERISTICS

2.4.1 NATURAL VEGETATIVE COVER

Natural vegetative cover in the Ganaraska Region Source Protection Area primarily includes wetlands, woodlands, and vegetated riparian areas, however meadows and rare habitats such as tallgrass prairie also exist. Natural vegetative cover plays a critical role in protecting drinking water sources by trapping sediments and soils thereby altering or reducing contaminants, nutrients, and some pathogens before they reach water sources. Healthy watersheds include diverse vegetation that is well distributed across the landscape. Naturally vegetated watersheds are better able to keep soil, nutrients, pathogens, and contaminants on the landscape and out of drinking water sources. Natural vegetative cover in the Source Protection Area is summarized in Table 2-5 and shown on Map 2-11.

Table 2-5: Natural Vegetative Cover

Natural Vegetative Cover Type		Area (km^2)	Land Coverage (%)
Wetlands	Provincially Significant	20	2.1
	Other Wetlands	24	2.6
Woodlands		340	37
Vegetated Riparian Areas[1]		209	23

[1]Vegetated riparian areas include vegetated lands located within 120 m of lakes, wetlands, and watercourses

Data Source: Ecological Land Classification derived from 2002 aerial photography

2.4.1.1 WETLANDS

Wetlands found in the Ganaraska Region Source Protection Area primarily include swamps and marshes. These wetlands also include vulnerable coastal wetlands; two of the largest occur at the mouth of Wilmot Creek and Graham Creek. Wetlands perform a significant role in improving water quality by contributing to groundwater recharge, providing surface water discharge, augmenting low flows, and attenuating floods. Wetland vegetation traps and removes nutrients and pollutants from the water that flows through them. Wetlands also provide important habitat for many fish and wildlife species. Wetlands cover about 4.7% of the Source Protection Area

(44 km^2), which includes 18 Provincially Significant Wetlands that cover 20 km^2. Wetlands in the Ganaraska Region Source Protection Area are shown on Map 2-11.

2.4.1.2 WOODLANDS

Woodland cover in the Ganaraska Region Source Protection Area includes deciduous, coniferous and mixed forests, cultural woodlands, and plantations. Woodland vegetation prevents erosion by stabilizing soils and acting as a natural shelterbelt. This protects water quality by preventing sedimentation of watercourses. Woodland cover in the Ganaraska Region Source Protection Area is shown on Map 2-11. Many woodlands are located on private lands, however the larger woodlands such as the Ganaraska Forest, Northumberland County Forest, Orono Crown Lands, and Kendal Crown Lands are located on public lands.

2.4.1.3 RIPARIAN AREAS

Riparian areas are the transitional zones between aquatic and terrestrial habitats that are found along watercourses and waterbodies. Healthy riparian areas are vegetated and provide bank stability, reduce erosion, provide the shade necessary to moderate water temperature, and improve water quality by filtering out contaminants from runoff. Riparian areas also provide important habitat for many species of fish, mammals, birds, reptiles, amphibians, and insects, particularly during the early stages of their lifecycles. Vegetated riparian areas were delineated as vegetated lands located within 120 metres (m) of lakes, wetlands, and watercourses. Vegetated riparian areas in the Ganaraska Region Source Protection Area are shown on Map 2-12.

2.4.2 AQUATIC HABITATS

Aquatic habitats are the areas inhabited or potentially inhabited by aquatic species. The health and composition of aquatic communities depend on the availability of adequate food, shelter, water, and space to provide their required habitats. Aquatic species, including fish and macroinvertebrates, are often used as indicators of water quality because they have specific requirements and tolerances to various elements known to exist in water.

This section identifies the location and types of aquatic habitats in the Ganaraska Region Source Protection Area, including fisheries and aquatic macroinvertebrates. It further discusses the impacts of development on these aquatic communities. There is insufficient data to compare aquatic communities in the watershed to unimpacted reference sites.

2.4.2.1 FISHERIES

Location and Types of Habitats

The Ganaraska Region Source Protection Area includes Rice Lake, Lake Ontario, and many rivers and streams that provide habitat for a variety of cold, cool, and warm water fish species. Primarily cold and cool water fish species such as Brook Trout, Rainbow Trout, and Brown Trout are found throughout the Source Protection Area and therefore the rivers are managed as cold/cool water systems (e.g., *Fisheries Act*). However,

Atlantic Salmon are currently being stocked in Cobourg Creek in an effort to estabish a sustainable population in Lake Ontario. This native top predator fish once was common throughout the Lake Ontario Drainage Basin. Photo Source: Ganaraska Region Conservation Authority certain stream reaches or subwatersheds are considered warm water habitats based on stream temperatures. In addition, the mouths of the streams and rivers provide for a diverse fish assemblage, primarily due to the migratory nature of many species of fish and the presence of coastal wetlands on Wilmot Creek and Graham Creek.

Aquatic habitats can be classified using many variables including instream substrate size, channel morphology, and stream cover. However, stream temperature, which is best linked to water quality, can be used as an indicator to identify aquatic habitat types. Water temperature is a key factor contributing to the health of fish populations, as every fish species has a specific range of tolerance beyond which its health and survivability are threatened. As a result of this dependence on water temperature, thermal classifications of watercourses or waterbodies are often indicative of the types of species likely to inhabit a given aquatic habitat. Based on these thermal classifications, individual fish species may be categorized as cold water (< 19°C), cool water (19°C to 25°C), or warm water (> 25°C) (Department of Fisheries and Oceans, 2010). Stream segments characterized by stream temperatures in the Ganaraska Region Source Protection Area are shown on Map 2-13.

Impacts of Development

Impacts from development on fish habitats in the Ganaraska Region Source Protection Area include variation in stream temperature (usually in a particular stream reach), alterations to instream habitat, presence of stream barriers, and loss of riparian vegetation. These impacts are particularly evident south of Highway 401 and along Highway 35/115 where development and urbanization have resulted in the alteration of many watercourses, hardening of stream banks, and loss of riparian vegetation. Stormwater outfalls also have a significant impact on aquatic habitats in areas where they cause extreme variability in flows.

2.4.2.2 AQUATIC MACROINVERTEBRATES

Location and Types of Habitats

Aquatic macroinvertebrates, commonly referred to as benthic macroinvertebrates, are organisms that live in the bottom of watercourses. They serve many functions in the aquatic ecosystem including acting as both decomposers and as food for larger macroinvertebrates, birds, and fish. They are excellent indicators of aquatic health and can be used to assess long-term water quality. The Hilsenhoff Water Quality Index provides an indication of water quality and the likelihood of organic pollution based on the presence or absence of benthic macroinvertebrate species with specific pollution tolerances. The location of benthic macroinvertebrate sampling sites and the Hilsenhoff Water Quality Index value at each site are shown on Map 2-14. The Simpson's Species Biodiversity Index indicates the diversity of the benthic macroinvertebrate community. The location of benthic macroinvertebrate sampling sites and the Simpson's Species Biodiversity Index value at each site are shown on Map 2-15.

Impacts of Development

Analysis of benthic macroinvertebrate communities across the Ganaraska Region Source Protection Area indicated a range of water quality conditions and species diversity. Sites with good water quality are dominated by pollution-intolerant species of the taxa Ephemeroptera, Trichoptera, and Plecoptera, and demonstrate high species diversity and abundance. Such sites are typically found in the northern portion of the watershed where development and infrastructure is limited, human population density is very low, and there is an abundance of forest cover. Sites with moderate water quality are dominated by the presence of pollution-tolerant benthic macroinvertebrates. Areas in the southern portion of the Ganaraska Region Source Protection Area exhibit moderate water quality, particularly where agriculture is the dominant land use or where there is some level of urbanization, which includes transportation routes. Sites with poor water quality are dominated by pollution-tolerant species of the taxa Chironomidae, Simuliidae, and Isopoda, and show limited diversity and abundance. Generally, areas with poor water quality are located in the Town of Cobourg, Ward 1 of the Municipality of Port Hope, and the Village of Newcastle, along with other urbanized areas subject to the impacts of intensive development and transportations routes.

2.5 SURFACE WATER AND GROUNDWATER QUALITY

2.5.1 SURFACE WATER QUALITY

Quality water is arguably the most important factor in drinking water source protection. The quality of surface water determines the suitability of a source for human consumption. Conversely, water quality dictates the health and integrity of the ecosystem, which can influence potable water supplies. For example, in extreme cases, blooms of cyanobacteria caused by eutrophication can be toxic to living organisms because they can release toxins and create anoxic conditions (Carpenter et al., 1998). In light of current risks to water, constant monitoring is required in surface water systems and groundwater to evaluate the quality of water that is used by the environment and humans alike. Monitoring also ensures that raw water is appropriate for consumption and helps to determine treatment methods prior to distribution. Regardless of the assumed quality, raw surface water should not be consumed without proper treatment. This section is a summary of the available data that are suitable for a watershed-scale analysis of surface water quality in the Ganaraska Region Source Protection Area. Surface water quality data specific to individual Lake Ontario drinking water systems were analysed during the evaluation of drinking water issues (see Chapter 4).

Surface water quality data for the Ganaraska Region Source Protection Area are available from the Provincial Water Quality Monitoring Network and through programs administered by the Ganaraska Region Conservation Authority including the Ganaraska Region Water Quality Monitoring Network and the Municipal Salt Monitoring Program.

The Provincial Water Quality Monitoring Network has records from nine active monitoring stations across the Source Protection Area with data available as far back as 1964 at most stations. The Ganaraska Region Water Quality Monitoring Network, designed to sample water quality throughout the Ganaraska Region Conservation Authority, has water quality records from across the Source Protection Area from 2002 to 2007. Both networks have data on various water quality parameters. The Municipal Salt Monitoring Program was designed to understand chloride concentrations in local streams from winter road salting. The data available from the Provincial Water Quality Monitoring Network, Ganaraska Region Water Quality Monitoring Network, and Municipal Salt Monitoring Program are summarized in Tables 2-6, 2-7, and 2-8, respectively. Surface water quality monitoring sites are shown on Map 2-16.

2.5.1.1 INDICATOR PARAMETERS

There are many water quality parameters that can be used to characterize the quality of a surface water source. Indicator parameters reflect a range of land uses and aid in determining the relative watershed health. These parameters can be naturally occurring or can enter surface water through point and non-point sources or through groundwater discharge. A small group of parameters is often used to provide a representative overview of water quality in an area of interest. Seven indicator parameters have been selected to represent the water quality conditions that reflect the natural features and land uses in the Ganaraska Region Source Protection Area. These indicator parameters and their associated standards or guidelines are identified in Table 2-9.

Table 2-6: Provincial Water Quality Monitoring Network Stations and Available Data

Subwatershed	Station Name	Station ID	Years on Record
Cobourg Creek	Cobourg Creek at Telephone Road	6013300502	2002-present**
Cobourg Creek	Cobourg Creek at Fourth Street*	6013300102	1964-1996; 2002-present
Gages Creek	Gages Creek at County Road 2	6013000102	1964-1996; 2002-present**
Ganaraska River	Ganaraska River at Osaca	6012900202	1974; 2002-present**
Ganaraska River	Ganaraska River at Sylvan Glen	6012900502	2002-present**
Ganaraska River	Ganaraska River at Peter Street	6012900102	1965-1994; 1996; 2002-present
Graham Creek	Graham Creek at Mill Street	6011800102	1965-1994; 2002-present**
Wilmot Creek	Wilmot Creek at Squair Road	6011700202	1964-1990; 2002-present**
Wilmot Creek	Wilmot Creek at Regional Road 2	6011700302	1973-1994; 1996; 1997; 2002-present

Data Source: Provincial Water Quality Monitoring Network
*Data from the nearby King Street station has been combined with data from the Fourth Street Station
Turbidity sampling stopped in December 2006 at all stations **Metals sampling stopped in 2006

Table 2-7: Ganaraska Region Water Quality Monitoring Network Stations and Available Data

Watershed	Number of Stations	Data Record Analyzed
Wilmot Creek	15	2005 and 2006
Graham Creek	12	2002, 2003 and 2005
West Lake Ontario	16	2005 and 2006
Ganaraska River	38	2003, 2004 and 2005
Gages Creek	6	2003
Cobourg Creek	12	2002, 2003 and 2005
East of Gages Creek	2	2005, 2006 and 2007
East Lake Ontario	5	2002, 2005 and 2006
Rice Lake	8	2003, 2005 and 2007

Data Source: Ganaraska Region Water Quality Monitoring Network

Table 2-8: Municipal Salt Monitoring Stations and Available Data

Watershed	Number of Stations	Data Record Analyzed
Wilmot Creek	9	2006 and 2007
Graham Creek	0	…
West Lake Ontario	5	2007
Ganaraska River	11	2007
Gages Creek	5	2007
Cobourg Creek	14	2005 to 2007
East of Gages Creek	2	2007
East Lake Ontario	6	2005 to 2007
Rice Lake	3	2007

Data Source: Ganaraska Region Municipal Salt Monitoring Program

Table 2-9: Surface Water Indicator Parameters

Parameter	Standards		Source	Effects
	PWQO[1]	CEQG[2]		
Chloride (Cl^-)	None	250 mg/L	Chloride can occur naturally. Anthropogenic sources include sodium chloride (road salts), calcium chloride (industry and wastewater treatment, road salts), potassium chloride (fertilizers and road salts) and magnesium chloride (de-icing agent) (Mayer et al., 1999).	Toxic (acute and chronic) to aquatic organisms (depending on concentration).
Aluminum (Al)	75 µg/L	None	Natural sources include dissolution from rocks and ores. Anthropogenic sources include industrial wastes and discharge from water treatment plants (Ministry of the Environment and Climate Change, 1991).	Toxic to aquatic organisms (depending on pH of water) (Environment Canada, 1987).
Copper (Cu)	5 µg/L	None	Sources are primarily anthropogenic and include urban areas and landfills that contain household materials, auto parts, and construction materials.	Attached to soil particles, copper can be relatively immobile, yet is toxic to aquatic organisms at high concentrations (Ministry of the Environment and Climate Change, 1991).
Lead (Pb)	5 µg/L	None	Anthropogenic inputs of lead into the environment increased during the industrial revolution because of the combustion of fossil fuels. In the 1970s, lead was removed as a gasoline additive, decreasing its environmental inputs (Wetzel, 2001).	Toxic at relatively low concentrations, affecting the central nervous system of organisms.
Zinc (Zn)	30 µg/L	None	Anthropogenic sources are associated with urbanized and industrial areas.	An important micronutrient for cell function (Wetzel, 2001), but at high concentrations can be toxic to aquatic organisms.
Total Phosphorus (P)	0.03 mg/L	None	Natural inputs of phosphorus occur through physical methods (e.g., erosion) (Sharpley et al., 1996). Anthropogenic sources include fertilizers (organic and synthetic) and septic systems.	Essential to life processes but, in excess, can cause increased aquatic vegetative growth, including toxic cyanobacteria, and can cause anoxic conditions when vegetation decomposes. As a result, phosphorous can be indirectly toxic to humans and aquatic organisms (Carpenter et al., 1998).
Nitrate (NO_3^-)	None	2.9 mg/L	Natural inputs of nitrate occur through atmospheric deposition, and anthropogenic sources include wastewater discharge, septic systems, and agricultural land use.	The most stable and usable form of nitrogen, but can be toxic in high concentrations and cause rapid growth of aquatic vegetation.

*This guideline was set for the recreational use of water
[1]Provincial Water Quality Objective, Data Sources: Ministry of the Environment and Climate Change 1999
[2]Canadian Environmental Quality Guideline

2.5.1.2 SURFACE WATER QUALITY SUMMARY

The following subsections summarize the surface water quality data available in the Ganaraska Region Source Protection Area. The summary focuses on data from the Provincial Water Quality Monitoring Network stations and expands in detail with data from the Ganaraska Region Water Quality Monitoring Network and Municipal Salt Monitoring Program. Each subsection includes a brief discussion of the sampling results for the indicator parameters identified above, and provides a table that summarizes the historical Provincial Water Quality Monitoring Network exceedances and trends (for all data on record), and includes a statistical summary (including minimum, median, maximum, and percentiles) of the data available at each station for the period of 2004 to 2008, where available.

Chloride

Chloride data are available from the Provincial Water Quality Monitoring Network and the Municipal Salt Monitoring Program. Expected chloride concentration ranges and trends over time have been determined by analysing long-term Provincial Water Quality Monitoring Network data. These chloride trends and concentration ranges are summarized in Table 2-10.

Chloride concentrations have increased since the 1960s, 1970s, and 2000s at the Graham Creek, Ganaraska River at Osaca, Ganaraska River at Sylvan Glen, Ganaraska River at Peter Street, Gages Creek, and Cobourg Creek at Telephone Road Provincial Water Quality Monitoring Network stations. Chloride concentrations at the two Wilmot Creek stations also increased considerably during this timeframe; chloride trends at these stations are illustrated in Figure 2-1. The Wilmot Creek at Squair Road station, representing the Orono Creek tributary, has higher chloride concentrations than the downstream main stream station in Wilmot Creek at Regional Road 2. Given the concentrations measured through the Provincial Water Quality Monitoring Network, there is an indication that chloride concentrations in Wilmot Creek may soon reach the guideline of 250 milligrams per litre (mg/L) especially during peak snowmelt or salt application times.

Chloride concentrations sampled at the Cobourg Creek Fourth Street Provincial Water Quality Monitoring Network station have declined from 1965 to 2008. A possible explanation for a decline is improvements to the wastewater treatment plant that discharges to Cobourg Creek upstream of the Fourth Street station. A similar decline in chloride in Lake Ontario has been attributed to lower loadings from industrial and domestic sources from improved control/treatment of industrial and domestic effluents (Mayer et al., 1999).

Chloride data obtained through the Municipal Salt Monitoring Program provide data to explain an expected range of concentrations throughout the year and throughout local rivers and streams. In addition, this program provides chloride data on watersheds that are not sampled through the Provincial Water Quality Monitoring Network. Chloride data obtained through this program have shown elevated concentrations of chloride in the Ganaraska River, East Lake Ontario, and East of Gages Creek watersheds that may be related to urbanization and increased traffic density. Additional analysis was undertaken to see if there was a difference in chloride concentrations between months that receive snow or mixed precipitation and months that receive rain. This analysis revealed that there is a difference in chloride concentrations between these months (Table 2-11), and that chloride concentrations are higher from November through to April. Chloride data from the Municipal Salt Monitoring Program are summarized in Table 2-11.

Table 2-10: Summary of Chloride Data at Provincial Water Quality Monitoring Network Stations

Watershed	Station Name	Station ID	Years on Record	No. Samples on Record	CEQG Exceedances[1] 250 mg/L		Trend		Descriptive Statistics (mg/L)						
					%	#	Direction	p^2	Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Wilmot Creek	Squair Road	6011700202	65-90, 02-08	323	0.0	0	↑	<0.01	04-08	41	76	143	175	128	156
Wilmot Creek	Regional Road 2	6011700302	73-97, 02-08	300	0.0	0	↑	<0.01	04-08	41	20	51	60	48	52
Graham Creek	Mill Street	6011800102	65-94, 02-08	388	0.0	0	↑	<0.01	04-08	41	13	23	42	20	24
Ganaraska River	Osaca	6012900202	74, 02-08	73	0.0	0	↑	<0.01	04-08	41	8	10	16	10	12
Ganaraska River	Sylvan Glen	6012900502	02-08	55	0.0	0	↑	0.01	04-08	41	7	15	22	8	11
Ganaraska River	Peter Street	6012900102	65-96, 02-08	437	0.2	1	↑	<0.01	04-08	41	10	9	25	14	18
Gages Creek	County Road 2	6013000102	65-96, 02-08	394	0.0	0	↑	<0.01	04-08	41	9	15	24	13	19
Cobourg Creek	Telephone Road	6013300502	02-08	56	0.0	0	↑	0.02	04-08	42	14	19	35	17	20
Cobourg Creek	Fourth Street	6013300402	65-96, 02-08	402	0.2	1	↓	<0.01	04-08	42	12	28	55	25	31

Data source: Provincial Water Quality Monitoring Network

[1]Indicates the quantity of all samples on record that exceeded the Guidelines for Canadian Drinking Water Quality (aesthetic guideline)

[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends were considered statistically significant where $p<0.05$)

Table 2-11: Chloride Concentrations as Sampled through the Municipal Salt Monitoring Program

Watershed	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Higher Chloride Concentrations in Winter Months
Wilmot Creek (Orono Creek)	1	162	55	Yes
Graham Creek	NA	NA	NA	NA
West Lake Ontario	5	136	45	No
Ganaraska River	3	1,075	8	No
Gages Creek	4	196	11	No
Cobourg Creek	2	122	16	Yes
East of Gages Creek	14	244	47	N/A
East Lake Ontario	1	1,290	32	Yes
Rice Lake Watershed	7	17	10	No

Data source: Ganaraska Region Municipal Salt Monitoring Program

Chloride concentrations were then compared between months dominated by snow and snowmelt (November to April) and months dominated by rain (May to October) using the non-parametric Mann-Whitney U Test.

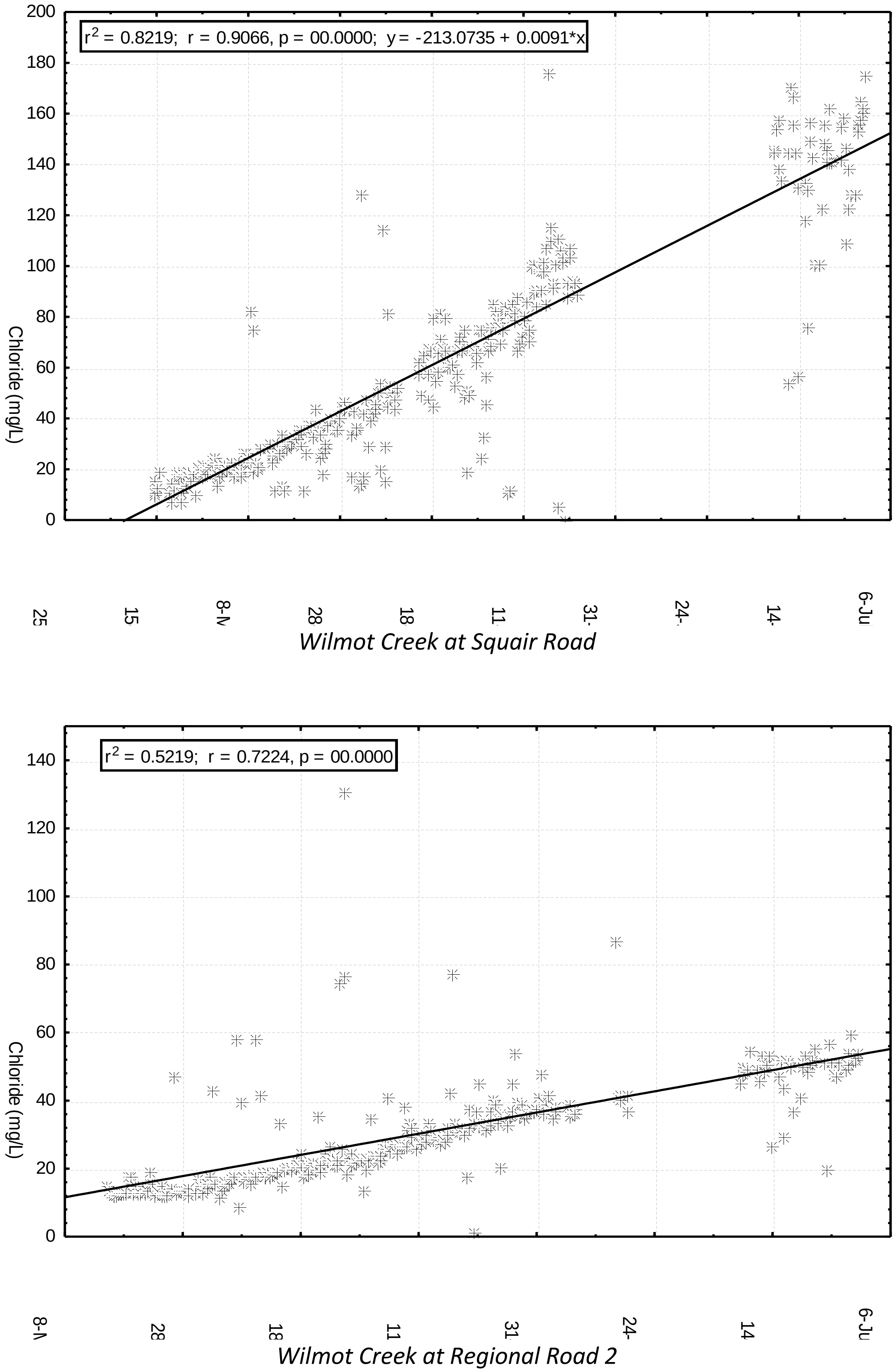


Figure 2-1: Chloride Trends at Wilmot Creek Provincial Water Quality Monitoring Network Stations

Metals

Metals are sampled through the Provincial Water Quality Monitoring Network. Data analysis was carried out for the entire data set although laboratory methods may have changed over time. Variations in laboratory methods may have altered data results due to changes in detection limits.

Aluminum

Aluminum concentrations occasionally exceeded the Provincial Water Quality Objective across the Source Protection Area. There is no observable trend at any of the Provincial Water Quality Monitoring Network stations, except at Wilmot Creek at Squair Road and Cobourg Creek at Telephone Road stations where there has been a decline in concentrations, and at the Gages Creek station where there has been an increase. Note that the Provincial Water Quality Objective for aluminum is based on samples that do not contain clay, yet water samples often contain a large amount of fine particulates (including clay) that originate from glacial deposits. Although aluminum concentrations are high, it is likely that the aluminum is bound to particulates and is not bioavailable (Aaron Todd, Ministry of the Environment and Climate Change, personal communication, January 27, 2007). Aluminum sampling data at Provincial Water Quality Monitoring Network stations are summarized in Table 2-12.

Copper

Copper concentrations at all Provincial Water Quality Monitoring Network stations in the Source Protection Area occasionally exceeded the Provincial Water Quality Objective prior to 2003. Since that time, copper concentrations have never exceeded the Provincial Water Quality Objective. The Provincial Water Quality Monitoring Network shows a declining trend in copper concentrations at all stations except for two where no trend is evident (Cobourg Creek at Telephone Road and Ganaraska River at Sylvan Glen). Copper sampling data at Provincial Water Quality Monitoring Network stations are summarized in Table 2-13.

Lead

Lead concentrations have occasionally exceeded the Provincial Water Quality Objective. The Provincial Water Quality Monitoring Network shows a declining trend in lead concentrations at all stations except for two where no trend is evident (Cobourg Creek at Telephone Road and Ganaraska River at Sylvan Glen). Note that lead measurements through the Provincial Water Quality Monitoring Network have a high detection limit and high uncertainty, so sampling results from this source are unreliable (Aaron Todd, Ministry of the Environment and Climate Change, personal communication, January 27, 2007). Lead sampling data at Provincial Water Quality Monitoring Network stations in the Source Protection Area are summarized in Table 2-14.

Zinc

Zinc concentrations have exceeded the Provincial Water Quality Objective only once since 2004 (Ganaraska River at Peter Street station). Prior to 2004, zinc concentrations rarely exceeded the provincial objective. The Provincial Water Quality Monitoring Network shows a declining trend in zinc concentrations at all of the stations. Zinc sampling data at Provincial Water Quality Monitoring Network stations in the Source Protection Area are summarized in Table 2-15.

Table 2-12: Summary of Aluminum Data at Provincial Water Quality Monitoring Network Stations

Watershed	Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (75 *ug*/L)		Trend		Descriptive Statistics (*ug*/L)						
									Years Analyzed	n	min[3]	median	max	Percentiles	
					%	#	Direction	p[2]						25th	75th
Wilmot Creek	Squair Road	6011700202	02-08	55	5	3	↓	<0.01	02-08	41	-6	11	301	5	18
Wilmot Creek	Regional Road 2	6011700302	80, 94, 96, 97, 02-08	66	14	9	none	0.83	02-08	41	6	25	384	15	31
Graham Creek	Mill Street	6011800102	80,94, 02-07	43	26	11	none	0.29	03-07	38	22	49	1,070	40	74
Ganaraska River	Osaca	6012900202	74, 02-07	40	13	5	none	0.17	03-07	38	14	38	765	29	57
Ganaraska River	Sylvan Glen	6012900502	02-07	39	18	7	none	0.13	03-07	38	27	45	1,040	34	67
Ganaraska River	Peter Street	6012900102	80, 95, 96, 02-08	67	16	11	none	0.13	02-08	42	21	46	1,730	33	62
Gages Creek	County Road 2	6013000102	80, 95, 96, 02-08	67	31	21	↑	<0.01	02-08	41	20	63	424	42	88
Cobourg Creek	Telephone Road	6013300502	02-07	39	13	5	↓	0.03	03-07	38	15	40	1,300	30	58
Cobourg Creek	Fourth Street	6013300402	80, 95, 96, 02-08	67	19	13	none	0.09	02-08	42	-0.1	43	224	30	66

Data source: Provincial Water Quality Monitoring Network
[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends were considered statistically significant where p<0.05)
[3]Negative values indicate concentrations below the analytical detection limit

Table 2-13: Summary of Copper Data at Provincial Water Quality Monitoring Network Stations

Watershed	Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (5 *ug*/L)		Trend		Descriptive Statistics (*ug*/L)						
									Years Analyzed	n	min[3]	median	max	Percentiles	
					%	#	Direction	p[2]						25th	75th
Wilmot Creek	Squair Road	6011700202	81-90, 02-08	159	18	29	↓	<0.01	04-08	41	0.2	0.7	2.9	0.4	1
Wilmot Creek	Regional Road 2	6011700302	80-97, 02-08	200	14	27	↓	<0.01	04-08	32	-0.1	0.5	1.7	0.4	0.9
Graham Creek	Mill Street	6011800102	80-94, 02-07	185	14	25	↓	<0.01	03-07	38	-0.1	0.6	3.6	0.3	0.9
Ganaraska River	Osaca	6012900202	74, 02-07	57	32	18	↓	<0.01	03-07	38	-0.4	0.3	2.4	0.1	0.5
Ganaraska River	Sylvan Glen	6012900502	02-07	39	0	0	none	0.5	03-07	41	-0.3	0.3	1.7	0.1	0.5
Ganaraska River	Peter Street	6012900102	75-78, 80-96, 02-08	246	21	51	↓	<0.01	04-08	38	-0.4	0.5	2.0	0.3	0.7
Gages Creek	County Road 2	6013000102	80-96, 02-08	209	17	35	↓	<0.01	04-08	41	-0.2	0.5	1.3	0.3	0.9
Cobourg Creek	Telephone Road	6013300502	02-07	39	0	0	none	0.7	03-07	38	-0.3	0.3	3.2	0.2	0.6
Cobourg Creek	Fourth Street	6013300402	80-96, 02-08	210	13	27	↓	<0.01	04-08	43	-1.3	0.7	2.7	0.3	1.1

Data source: Provincial Water Quality Monitoring Network
[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends were considered statistically significant where p<0.05)
[3]Negative values indicate concentrations below the analytical detection limit

Table 2-14: Summary of Lead Data at Provincial Water Quality Monitoring Network Stations

Watershed	Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (5 *ug/L*)		Trend		Descriptive Statistics (*ug/L*)						
									Years Analyzed	n	min[3]	median	max	Percentiles	
					%	#	Direction	p[2]						25th	75th
Wilmot Creek	Squair Road	6011700202	81-90, 02-08	158	0.6	1	↓	<0.01	04-08	41	-20	-0.4	7	-2	1.2
Wilmot Creek	Regional Road 2	6011700302	80-97, 02-08	209	0.4	1	↓	<0.01	04-08	41	-12	-0.3	10	-3	0.6
Graham Creek	Mill Street	6011800102	80-94, 02-07	185	0.5	1	↓	<0.01	03-07	38	-24	0.1	5	-2	2.5
Ganaraska River	Osaca	6012900202	74, 02-07	56	4	2	↓	<0.01	03-07	38	-10	-0.9	9	-3	2.3
Ganaraska River	Sylvan Glen	6012900502	02-07	39	15	6	none	<0.01	03-07	38	-13	0.2	11	-3	2.7
Ganaraska River	Peter Street	6012900102	75-78, 80-96, 02-08	224	0.4	1	↓	<0.01	04-08	41	-8	0.3	5	-3	2.4
Gages Creek	County Road 2	6013000102	80-96, 02-08	209	2	5	↓	<0.01	04-08	41	-17	-0.4	11	-2	3.1
Cobourg Creek	Telephone Road	6013300502	02-07	39	5	2	none	0.23	03-07	38	-10	0.04	6	-2	2.3
Cobourg Creek	Fourth Street	6013300402	80-96, 02-08	210	2	4	↓	<0.01	04-08	42	-8	1.3	11	-2	2.9

Data source: Provincial Water Quality Monitoring Network
[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends were considered statistically significant where $p<0.05$)
[3]Negative values indicate concentrations below the analytical detection limit

Table 2-15: Summary of Zinc Data at Provincial Water Quality Monitoring Network Stations

Watershed	Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (30 *ug/L*)		Trend		Descriptive Statistics (*ug/L*)						
									Years Analyzed	n	min[3]	median	max	Percentiles	
					%	#	Direction	p[2]						25th	75th
Wilmot Creek	Squair Road	6011700202	81-90, 02-08	159	1	2	↓	<0.01	04-08	41	-1.7	0.4	3	0.1	0.8
Wilmot Creek	Regional Road 2	6011700302	77, 80-97, 02-08	210	0	0	↓	<0.01	04-08	41	-2.0	0.3	4	-2.6	0.9
Graham Creek	Mill Street	6011800102	80-94, 02-07	185	2	3	↓	<0.01	03-07	38	-1.1	0.6	14	0.2	1.2
Ganaraska River	Osaca	6012900202	74, 02-07	56	4	2	↓	<0.01	03-07	38	-1.6	0.7	10	0.2	0.7
Ganaraska River	Sylvan Glen	6012900502	02-07	39	13	5	↓	<0.01	03-07	41	-1.1	0.4	9	-0.01	1.1
Ganaraska River	Peter Street	6012900102	75-78, 80-96, 02-08	224	0	0	↓	<0.01	04-08	38	-0.6	1.0	34	0.3	2.4
Gages Creek	County Road 2	6013000102	80-96, 02-08	209	2	5	↓	<0.01	04-08	41	-1.2	0.3	3	-17.0	0.8
Cobourg Creek	Telephone Road	6013300502	02-07	39	0	0	↓	<0.01	03-07	38	-1.0	0.4	13	-0.05	1.1
Cobourg Creek	Fourth Street	6013300402	80-96, 02-08	210	5	10	↓	<0.01	04-08	42	-1.8	1.4	10	0.7	2.4

Data source: Provincial Water Quality Monitoring Network
[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends were considered statistically significant where $p<0.05$)
[3]Negative values indicate concentrations below the analytical detection limit

Nutrients

Total Phosphorus

Total phosphorus is a measure of all forms of phosphorus present in water with concentrations varying greatly throughout the Source Protection Area. Total phosphorus concentrations have frequently exceeded the Provincial Water Quality Objective at all Provincial Water Quality Monitoring Network and Ganaraska Region Water Quality Monitoring Network stations. The high concentrations of phosphorus observed at the Cobourg Creek at Fourth Street station may be a result of effluent discharge from the wastewater treatment plant located upstream. Greenland International Consulting Ltd. (2004) has indicated that effluent from this plant results in a small increase in total phosphorus in Cobourg Creek in all seasons except autumn. However, there are observable declines in total phosphorus concentrations at all Provincial Water Quality Monitoring Network stations except at Ganaraska River at Sylvan Glen.

Since phosphorus can bind to soil particles, phosphorus in aquatic environments is often correlated with the turbidity of water. As a result, runoff can increase the concentration of total phosphorus in a watercourse. Provincial Water Quality Monitoring Network data indicate that 90% of the time turbidity in the Source Protection Area is low; this suggests that high phosphorus concentrations observed during low flows (when there is no runoff) may be caused by point or local sources. Conversely, high phosphorus concentrations observed during high flows (when there is more runoff) may be associated with non-point sources throughout the watershed.

Total phosphorus data at Provincial Water Quality Monitoring Network and Ganaraska Region Water Quality Monitoring Network stations are summarized in Tables 2-16 and 2-18, respectively.

Nitrate Nitrogen

Nitrate nitrogen is the concentration of nitrogen present in water in the form of the nitrate ion (NO_3^-). Nitrate nitrogen concentrations have been increasing at all Provincial Water Quality Monitoring Network stations except at Ganaraska River at Sylvan Glen, Ganaraska River at Osaca, and Cobourg Creek at Telephone Road where no trend is evident. Provincial Water Quality Monitoring Network data indicate that nitrate nitrogen occasionally exceeded the Canadian Environmental Quality Guideline; the station showing the most frequent exceedances of nitrate nitrogen is Wilmot Creek at Squair Road (17% of samples). However, Ganaraska Region Water Quality Monitoring Network data show more frequent exceedances. Watersheds sampled under this program have shown higher exceedances of nitrate nitrogen in the East of Gages Creek (71%), Wilmot Creek (18%), West Lake Ontario (17%), and Rice Lake (12%) watersheds. Nitrate nitrogen data at Provincial Water Quality Monitoring Network and Ganaraska Region Water Quality Monitoring Network stations are summarized in Tables 2-17 and 2-18, respectively.

Table 2-16: Summary of Total Phosphorus Data at Provincial Water Quality Monitoring Network Stations

Watershed	Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances (0.03 mg/L)[1]		Trend		Descriptive Statistics (mg/L)						
									Years Analyzed	n	min	median	max	Percentiles	
					%	#	Direction	p[2]						25th	75th
Wilmot Creek	Squair Road	6011700202	64-90, 02-08	338	17	57	↓	<0.01	04-08	41	0.002	0.01	0.08	0.01	0.02
Wilmot Creek	Regional Road 2	6011700302	73-97, 02-08	300	22	67	↓	<0.01	04-08	41	0.002	0.01	0.13	0.01	0.02
Graham Creek	Mill Street	6011800102	65-94, 02-08	389	30	118	↓	<0.01	04-08	41	0.004	0.02	0.12	0.01	0.02
Ganaraska River	Osaca	6012900202	74, 02-08	76	20	15	↓	<0.01	04-08	41	0.006	0.02	0.17	0.01	0.02
Ganaraska River	Sylvan Glen	6012900502	02-08	55	16	9	none	0.13	04-08	41	0.004	0.02	0.43	0.01	0.03
Ganaraska River	Peter Street	6012900102	65-96, 02-08	438	41	181	↓	<0.01	04-08	41	0.007	0.02	0.23	0.01	0.03
Gages Creek	County Road 2	6013000102	64-96, 02-08	399	50	199	↓	<0.01	04-08	41	0.003	0.02	0.15	0.01	0.03
Cobourg Creek	Telephone Road	6013300502	02-08	56	23	13	↓	0.04	04-08	42	0.005	0.02	0.11	0.01	0.03
Cobourg Creek	Fourth Street	6013300402	64-96, 02-08	406	85	345	↓	<0.01	04-08	42	0.002	0.02	0.09	0.02	0.03

Data source: Provincial Water Quality Monitoring Network
[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends were considered statistically significant where p<0.05)

Table 2-17: Summary of Nitrate Nitrogen Data at Provincial Water Quality Monitoring Network Stations

Watershed	Station Name	Station ID	Years on Record	No. Samples on Record	CEQG Exceedances[1] (2.9 mg/L)		Trend		Descriptive Statistics (mg/L)						
									Years Analyzed	n	min	median	max	Percentiles	
					%	#	Direction	p[2]						25th	75th
Wilmot Creek	Squair Road	6011700202	64-87, 02-08	235	17	39	↑	<0.01	04-08	41	1.6	2.9	3.5	2.6	3.0
Wilmot Creek	Regional Road 2	6011700302	73-97, 02-08	334	2	8	↑	<0.01	04-08	41	0.5	1.8	2.5	1.8	2.0
Graham Creek	Mill Street	6011800102	65-94, 02-08	427	0.2	1	↑	<0.01	04-08	41	0.5	0.9	2.3	0.8	1.0
Ganaraska River	Osaca	6012900202	74, 02-08	76	0	0	none	0.08	04-08	41	0.4	0.5	1.3	0.5	0.6
Ganaraska River	Sylvan Glen	6012900502	02-08	55	0	0	none	0.07	04-08	41	0.6	0.8	1.6	0.7	1.2
Ganaraska River	Peter Street	6012900102	66-96, 02-08	481	0.4	2	↑	<0.01	04-08	41	0.5	0.8	2.9	0.7	1.2
Gages Creek	County Road 2	6013000102	64, 66-96, 02-08	428	2	10	↑	<0.01	04-08	41	1.2	1.7	3.1	1.4	2.2
Cobourg Creek	Telephone Road	6013300502	02-08	56	0	0	none	0.09	04-08	42	0.8	1.1	2.4	1.0	1.4
Cobourg Creek	Fourth Street	6013300402	66-96, 02-08	431	2	7	↑	<0.01	04-08	42	0.7	1.1	2.2	0.9	1.4

Data source: Provincial Water Quality Monitoring Network
[1]Indicates the quantity of all samples on record that exceeded the Canadian Water Quality Guidelines for the Protection of Aquatic Life
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends were considered statistically significant where p<0.05)

Table 2-18: Summary of Total Phosphorus and Nitrate Nitrogen Data at Ganaraska Region Water Quality Monitoring Network Stations

Subwatershed	Total Phosphorus			Nitrate Nitrogen		
	PWQO Exceedances[1] (0.03 mg/L)		No. Samples on Record	CEQG Exceedances[2] (2.97 mg/L)		No. Samples on Record
	% Total	No. Samples		% Total	No. Samples	
Wilmot Creek	52	22	65	18	10	65
Graham Creek	21	11	66	0	0	66
West Lake Ontario	39	18	64	17	9	64
Ganaraska River	13	14	126	0	0	126
Gages Creek	47	10	30	0	0	30
Cobourg Creek	20	11	63	0	0	63
East of Gages Creek	50	6	18	71	7	18
East Lake Ontario	44	19	61	0	0	61
Rice Lake	30	21	92	12	10	92

Data source: Ganaraska Region Water Quality Monitoring Network [1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective [2]Indicates the quantity of all samples on record that exceeded the Canadian Water Quality Guideline for the Protection of Aquatic Life

2.5.2 GROUNDWATER QUALITY

Groundwater quality can be defined as the suitability of groundwater for a particular use based on physical, chemical, and biological characteristics. Parameters commonly analysed for groundwater quality are conventional (e.g., pH, temperature, hardness, conductivity, chloride, alkalinity, total organic carbon, etc.), fecal bacteria, nutrients, metals and minerals, and pesticides and herbicides. Concentrations are compared to numeric standards and guidelines to determine if the quality of groundwater is suitable for a particular use. This section is a summary of the available data that are suitable for a watershed-scale analysis of groundwater quality in the Ganaraska Region Source Protection Area. Groundwater quality data specific to individual drinking water systems were analysed during the evaluation of drinking water issues (see Chapter 5). The available data include limited groundwater quality data from the Provincial Groundwater Monitoring Network, the Ministry of the Environment and Climate Change Water Well Records Database, and several regional groundwater quality studies.

2.5.2.1 INDICATOR PARAMETERS

There are many parameters that can be used to characterize the quality of a groundwater source. A small group of parameters is often used to provide a representative overview of water quality in an area of interest. Groundwater quality data and studies summarized in the following sections evaluate water quality using indicator parameters that reflect the natural features and land uses in the Ganaraska Region Source Protection Area. Common groundwater indicator parameters are described in Table 2-19.

2.5.2.2 PROVINCIAL GROUNDWATER MONITORING NETWORK

The Provincial Groundwater Monitoring Network was established by the Ministry of the Environment and Climate Change in 2000 to collect and manage ambient (baseline) groundwater level and quality information from major aquifers located across Ontario (Ministry of the Environment and Climate Change, 2006). Seventeen monitoring wells at twelve sites were established in the Source Protection Area as part of the overall network, and they generally represent regional aquifers. Provincial Groundwater Monitoring Network wells in the Source Protection Area are described in Table 2-20 and their locations are shown on Map 2-17.

Table 2-19: Summary of Groundwater Indicator Parameters

Parameter	Source(s)	Guidelines[1]	Effects
Chloride (Cl^-)	Chloride is common in nature, generally as sodium chloride (NaCl), potassium chloride (KCl), and magnesium chloride. Natural sources include rocks and anthropogenic sources include road salting, agricultural runoff, industrial wastewater, and wastewater treatment plants. Chloride is a highly soluble and mobile ion which does not biodegrade, volatilize, easily precipitate, nor does it significantly absorb onto mineral surfaces. It travels readily through soils, enters groundwater and eventually discharges into surface water.	250 mg/L (AO)	Chloride is not usually harmful to humans. At concentrations above the aesthetic objective of 250 mg/L, chloride and sodium chloride impart undesirable tastes to water and may cause corrosion in water distribution systems. Calcium or magnesium chlorides are not usually detected by taste until levels of 1,000 mg/L are reached.
Hardness	Water hardness is naturally caused by dissolved polyvalent metal ions. In fresh waters the principal hardness-causing ions are calcium and magnesium. Other ions such as strontium, iron, barium, and manganese ions can also contribute groundwater hardness.	80 to 100 mg/L (OG)	Hard water does not have major health effects. On heating, hard water has a tendency to form scale deposits and can cause excessive scum with regular soaps. However, certain detergents are largely unaffected by hardness. Conversely, soft water may result in accelerated corrosion of water pipes. The operational guideline for hardness provides an acceptable balance between corrosion and scaling of pipes. Water supplies with hardness greater than 200 mg/L are considered poor but tolerable; more than 500 mg/L is unacceptable for domestic purposes.
Sulphate (SO_4^{2-})	Natural sources of sulphate include decomposing vegetation and rock or soil containing gypsum, barite, or other minerals. Sulphates are commonly discharged into the aquatic environment in wastes from industries that use sulphates and sulphuric acid, such as mining and smelting operations, pulp and paper mills, textile mills, and tanneries.	500 mg/L (AO)	The presence of sulphate above 150 mg/L may result in a noticeable taste. The taste threshold concentration depends on the associated metals present in the water. Above the aesthetic objective of 500 mg/L sulphate can have a laxative effect; however, regular users adapt and problems are usually only experienced by new consumers. High levels of sulphate may be associated with calcium, which is a major component of scale in boilers and heat exchangers. In addition, sulphate can be converted into sulphide by anaerobic bacteria creating odour problems and potentially accelerating corrosion. Sulphates can also form strong acids, which change the pH of water.
Iron	Iron is the fourth most abundant element, by weight, in the earth's crust. Iron in groundwater is normally present in the ferrous or bivalent form [Fe^{2+}] which is soluble. It is easily oxidized to ferric iron [Fe^{3+}] or insoluble iron when exposed to air. Ferrous (Fe^{2+}) and ferric (Fe^{3+}) ions are the primary forms of concern in the aquatic environment. Other forms may be present in either organic or inorganic wastewater. The ferrous form can persist in water void of dissolved oxygen and usually originates from groundwater or mines that are pumped or drained.	0.3 mg/L (AO)	Generally, there is a minimal taste of iron in drinking water at concentrations below 0.3 mg/L. At concentrations above 0.3 mg/L, iron can stain laundry and plumbing fixtures and produce a bitter, strong taste in water and beverages. The precipitation of excessive iron imparts a reddish-brown colour to water. Iron may also promote the growth of certain microorganisms, leading to the deposition of a slimy coating in water distribution pipes. Iron based coagulants such as ferric sulfate can be highly effective at removing particles from water, leaving very little residual iron in the treated water.
Sodium	Sodium is the most abundant of the alkali elements and constitutes 2.6 % of the Earth's crust. Compounds of sodium are widely distributed in nature. Weathering of salt deposits and contact of water with igneous rock provide natural sources of sodium in groundwater regimes.	200 mg/L (AO) 20 mg/L [2] (MAC)	The taste of drinking water is generally considered offensive at sodium concentrations above the aesthetic objective of 200 mg/L. To maintain a total daily sodium intake of 500 mg, as is widely prescribed for persons on a sodium restricted diet, a sodium concentration in drinking water no higher than 20 mg/L is required. Reduction of sodium content with current technologies to this level would be expensive. It is therefore recommended that sodium be included in routine monitoring programs, because levels may be of interest to those on a sodium reduced diet [2].

Parameter	Source(s)	Guidelines[1]	Effects
Nitrate, and Nitrite	The most common contaminant identified in groundwater is dissolved nitrogen in the form of nitrate (NO_3^-). Although nitrate is the main form in which nitrogen occurs in groundwater, dissolved nitrogen also occurs in the form of ammonium (NH_4^+), ammonia (NH_3), nitrite (NO_2^-), nitrogen (N_2), nitrous oxide (N_2O), and organic nitrogen. Nitrate (NO_3^-) and nitrite (NO_2^-) are naturally occurring ions that are ubiquitous in the environment. Both are products of the oxidation of nitrogen (which comprises roughly 78% of the atmosphere) by microorganisms in plants, soil or water and, to a lesser extent, by electrical discharges such as lightning. Nitrite is fairly rapidly oxidized to nitrate and is therefore seldom present in water in significant concentrations. Nitrite may occur in groundwater, however if chlorination is practised the nitrite will usually be oxidized to nitrate. In groundwater that is strongly oxidizing, nitrate is always the most stable form of dissolved nitrogen. Nitrogen can enter groundwater through municipal and industrial wastewater effluent, septic leachate, animal waste, and runoff from fertilized agricultural fields and lawns. Elevated concentrations of nitrate, particularly those greater than 3 mg/L, are usually the result of human activity.	NO_2 = 1 mg/L (as nitrogen) (MAC) NO_3 = 10 mg/L (as nitrogen) (MAC) NO_2+NO_3 = 10 mg/L (as nitrogen) (MAC)	Dissolved nitrogen in the form of nitrate is becoming increasingly widespread because of agricultural activities and disposable of sewage on or beneath the land surface. Its presence in undesirable concentrations is threatening large number of aquifers. Nitrites can react with hemoglobin in the blood of warm-blooded animals to produce methemoglobin; this destroys the ability of red blood cells to transport oxygen. This condition is serious in babies under three months, causing methemoglobinemia or "blue baby" syndrome. Nitrates can also cause digestive problems. High concentrations of nitrate can be toxic to fish and other organisms.
Organic Nitrogen	Organic nitrogen is the nitrogen that is incorporated in organic substances. Organic nitrogen is calculated by the difference between the total Kjeldahl nitrogen and ammonia nitrogen. A high level of organic nitrogen in groundwater indicates that contamination may be caused by septic tank leakage, septic failure, or sewage effluent contamination. This form of contamination in drinking water is often associated with some types of chlorine- worsened taste problems.	0.15 mg/L (OG)	Organic nitrogen compounds frequently contain amine groups which can react with chlorine and severely reduce its disinfectant power. Certain chlorinated organic nitrogen compounds may be responsible for taste problems that are associated with chlorophenol. Taste and odour problems are common with organic nitrogen levels greater than 0.15 mg/L.
Dissolved Organic Carbon (DOC)	Dissolved organic carbon (DOC) is present in all ecosystems. It occurs in forms that range in size from simple amino acids to complex high-molecular- weight DOC. Dissolved organic matter frequently measured as DOC, is an important component of the organic energy budget of temperate ecosystems. Storms are a primary mechanism of DOC above ground mobility and intrusion into groundwater because they produce increases in both DOC concentration and discharge. Nitrate concentrations in groundwater can decrease due to reduction if that groundwater contains high concentration of dissolved organic carbon.	5 mg/L (AO)	In water systems, a high concentration of dissolved organic carbon (DOC) is an indicator of possible water quality deterioration during storage and/or distribution due to the carbon being a growth nutrient for biofilm dwelling bacteria. In addition, a high DOC concentration in water supply and distribution systems would be considered as an indicator of potential chlorination by-product problems. Coagulant treatment or high pressure membrane treatment can be used to reduce DOC in drinking water systems.
Total Dissolved Solids (TDS)	Total Dissolved Solids (TDS) are the total amount of mobile charged ions, including inorganic substances such as minerals, salts, or metals dissolved in a given sample of water. The principal constituents of TDS are usually the cations calcium, magnesium, sodium, and potassium and the anions carbonate, bicarbonate, chloride, and sulphate.	500 mg/L (AO)	The presence of dissolved solids in water may affect its taste. The effects of TDS on drinking water quality depend on the levels of the individual components. Excessive hardness, taste, mineral deposition, or corrosion are common properties of highly mineralized water. TDS above 500 mg/L can result in excessive scaling in water pipes, water heaters, boilers, and household appliances such as tea kettles and steam irons. Drinking water supplies with TDS levels greater than 1,200 mg/L are unpalatable. The palatability of drinking water with a TDS level less than 500 mg/L is generally considered to be good. Drinking water with extremely low concentrations may also be unacceptable because of its flat, dull taste.

Data Sources: Ministry of the Environment and Climate Change 2003

(1) Maximum Acceptable Concentration (MAC), Aesthetic Objective (AO), and Operational Guideline (OG) values are from the Technical Support Document for Ontario Drinking Water Standards, Objectives, and Guidelines (Ministry of the Environment and Climate Change, 2003), produced in support of the Ontario Drinking-Water Quality Standards Regulation (O. Reg. 169/03 amended to O. Reg. 327/08) made under *the Safe Drinking Water Act.*

(2) The local Medical Officer of Health should be notified when concentrations exceed 20 mg/L so that information can be provided to the water user who may be on a sodium restricted diet.

Provincial Groundwater Quality Monitoring Network wells were sampled from 2002 to 2004 and 2006 to 2008 and analysed for most groundwater quality parameters in the *Ontario Drinking-Water Quality Standards Regulation (O. Reg. 169/03)*. Eleven parameters exceeded the operational guideline or aesthetic objective specified in the regulation. These parameters included total dissolved solids, organic nitrogen, sodium, hardness, and iron. Some wells exceeded standards for pH, alkalinity, aluminum, chloride, dissolved organic carbon, manganese, and zinc. Sodium was the only parameter with potential human health impacts that exceeded the standard (at 3 of the 13 wells sampled). The number of samples and the range of sampling results up to 2008 for the groundwater indicator parameters indicated above are listed in Table 2-21.

Table 2-20: Provincial Groundwater Quality Monitoring Network Wells

Well Identification Numbers		Watershed	Casing Inside Diameter (inches)	Well Depth (m)	Static Water Level (m)	Aquifer (relative location)	Number of Water Quality Sampling Events
MOECC[1] ID	Casing ID						
1901052	W113-1	Wilmot Creek	6.00	40.28	20.0	Deep	4
1901053	W138-1	Wilmot Creek	4.00	153.92	10.0	Very Deep	4
1902685	W139-1	Wilmot Creek	1.50	215.8	66.5	Very Deep	0
1902683	W189-2	Wilmot Creek	6.50	67.00	56.0	Deep	5
1900957 nw	W114-3	Wilmot Creek	6.00	12.09	2.0	Shallow	4
1900956 swm	W114-4	Wilmot Creek	1.50	15.12	3.4	Middle	3
1900956 swt	W114-2	Wilmot Creek	1.50	8.49	2.0	Shallow	4
1912085	W140-1	Graham Creek	6.25	11.79	6.8	Shallow	4
4513312	W207-1	Rice Lake Tributary	6.25	19.50	8.1	Middle	4
4513608	W348-1	Rice Lake Tributary	3.00	15.61	4.1	Middle	4
1901998	W208-1	Port Britain Creek	48.00	6.70	2.3	Shallow	0
1903467	W209-1	Ganaraska River	6.25	18.88	7.4	Middle	4
4513209-b	W259-3	Ganaraska River	2.00	19.67	2.0	Middle	4
4513209-a	W259-2	Ganaraska River	2.00	10.69	3.6	Shallow	4
4513610	W332-1	Ganaraska River	3.00	27.88	23.5	Deep	2
4513609	W351-1	Ganaraska River	3.00	21.46	16.4	Middle	5
4513604	W393-1	Cobourg Creek	3.00	21.56	1.3	Middle	4

Data source: Provincial Groundwater Quality Monitoring Network; Ganaraska Region Conservation Authority
[1]Ministry of the Environment and Climate Change

Table 2-21: Summary of Provincial Groundwater Monitoring Network Data

Well ID	Years on Record	Max No. Samples	Range of Water Quality Sampling Results								
			Hardness (mg/L as CaCO3)	Sodium (mg/L)	Iron (mg/L)	Sulphate (mg/L)	Chloride (mg/L)	Nitrate-N (mg/L)	Organic Nitrogen (mg/L)	DOC (mg/L)	TDS (mg/L)
W113-1	02, 06, 07, 08	4	77-173	2-332	0.1-1.3	26-27	5-7	0.01-0.05	<MDL	0.3-0.7	197-229
W138-1	02, 06, 07, 08	4	48-190	45-332	0.01-0.8	0.05-29	5-88	0.01-0.05	0.06-0.2	0.4-2	174-375
W189-2	02, 06, 07, 08	5	80-157	4-5	0.003-0.7	0.5-17	0.6-0.8	0.01-0.05	0.1-1	0.2-0.5	103-182
W114-3	02, 06, 07, 08	4	295-351	60-62	0.007-0.2	23-25	110-132	3.45-3.5	0.1-0.3	0.2-0.8	497-562
W114-4	02, 06, 07	3	329-344	58-63	0.01-0.5	24-30	130-140	0.007-0.3	0.2-1	0.2-4	500-627
W114-2	02, 06, 07, 08	4	307-351	54-58	0.002-0.07	24-27	100-123	2.6-3.2	0.05-0.1	0.2-4	491-572
W140-1	02, 07, 06, 08	4	404-540	174-345	0.0-2.0	25-28	370-728	1.6-1.7	0.05-0.1	0.7-1	1,210-1,930
W207-1	03,06,07,08	4	274-288	0.01-10	0.01-0.5	22-25	232-358	4.36-4.38	0.01-0.02	0.2-57	323-358
W348-1	03,06,07,08	4	107-172	0.02-79	0.002-0.3	3-75	3-6	<MDL	0.05-0.4	0.07-7	180-346
W209-1	03, 06, 07, 08	4	68-101	21-23	0.02-0.07	4-7	1.6-2	0.01-0.05	0.05-0.3	0.6-1	117-176
W259-3	06, 07, 08	4	276-585	48-87	0.01-0.3	14-49	100-381	0.01-0.3	0.05-0.2	0.6-4	423-1,280
W259-2	03, 06, 07, 08	4	416-475	30-66	0.01-0.3	12-43	192-310	0.01-0.2	0.1-2.5	1-7	731-962
W332-1	03, 06	2	NA	NA	NA	NA	NA	NA	0.05	1.6	565
W351-1	03,06,07,08	5	160-225	5-8	0.001-0.1	16-19	240-298	1.67-1.71	0.0-0.1	0.02-0.9	240-298
W393-1	04, 06, 07, 08	4	220-373	65-80	<0.01 – 4.0	10-16	75-100	<MDL	0.2 -0.8	3-4	494-599

2.5.2.3 MINISTRY OF THE ENVIRONMENT AND CLIMATE CHANGE WATER WELL RECORDS DATABASE

Qualitative information about groundwater quality is available from the Ministry of the Environment and Climate Change Water Well Records Database. The database contains well records provided by well drillers that include subjective comments about water quality encountered at wells such as "fresh", "salty", or "sulphurous." The subjective nature of the observations decreases the usefulness of the Water Well Records Database for determining the suitability of groundwater as a drinking water source.

2.5.2.4 REGIONAL GROUNDWATER STUDIES

Municipal Groundwater Study (Morrison Environmental Ltd., 2004)

In May 1999, the Ministry of the Environment and Climate Change initiated a series of studies designed to encourage the development of local groundwater protection strategies across Ontario. The Trent Conservation Coalition Municipal Groundwater Study was completed by Morrison Environmental Ltd. (2004). The Aquifer Characterization component of the study (Volume 1) uses the Water Well Records Database (discussed above) to evaluate groundwater quality in bedrock and overburden wells across most of the Trent Conservation Coalition Source Protection Region (with the exception of the Regional Municipality of Durham). Water quality observations from the Water Well Records Database compiled by the Municipal Groundwater Study in the Ganaraska Region Source Protection Area are illustrated in Figures 2-2 and 2-3.

The study observed that the vast majority of wells yielded fresh water. Specifically, wells screened in bedrock produced fresh water and wells screened in overburden occasionally had poor groundwater quality. The study concluded that groundwater in the Source Protection Area is naturally low in chloride, nitrate, and most metals, and occasionally exceeds the Ontario Drinking Water Standards for iron and manganese. (The occurrence of these metals is usually natural but can occasionally result from human activity and contamination.) The study also indicated that dissolved solids are the most common dissolved substances in Source Protection Area groundwater. Dissolved solids include common constituents such as calcium, sodium, iron, bicarbonate, and chloride; plant nutrients such as nitrogen and phosphorus; and trace elements such as selenium, chromium, and arsenic.

The Hydrogeology of Southern Ontario (Singer et al., 2003)

Singer et al. (2003) provided information related to the quality of groundwater in the Simcoe Group hydrogeologic unit that underlies a small area in the western part of the Ganaraska Region Source Protection Area. The parameters considered in the report include sodium, iron, chloride, sulphate, nitrate, total hardness, and total dissolved solids. The report indicated that most bedrock wells drilled in the Simcoe Group hydrogeologic unit usually yield fresh water, but they occasionally yield water with natural water quality problems such as high chloride, sulphate, hardness, or gas.

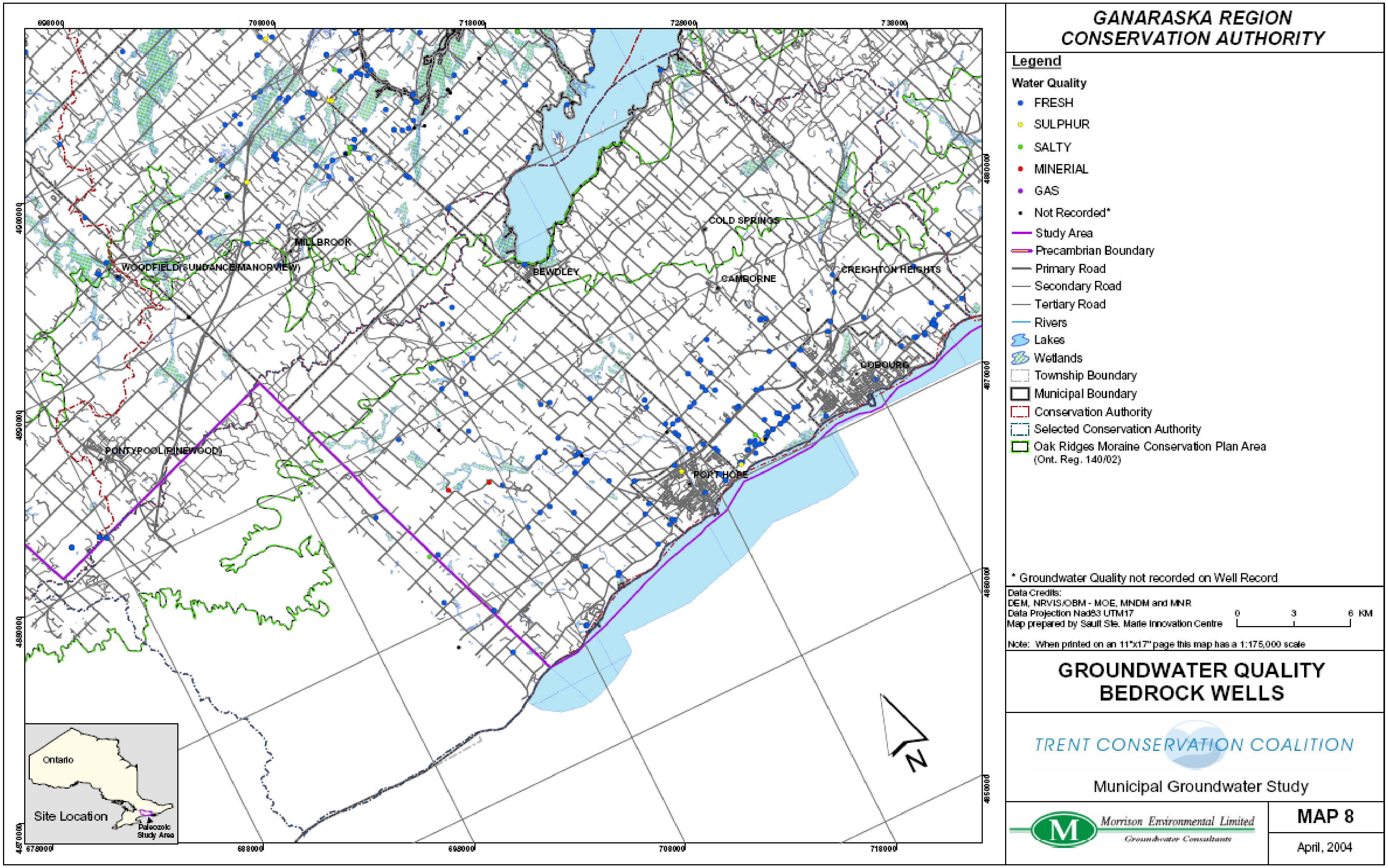


Figure 2-2: Groundwater Quality in Bedrock Wells (Morrison Environmental Ltd., 2004)

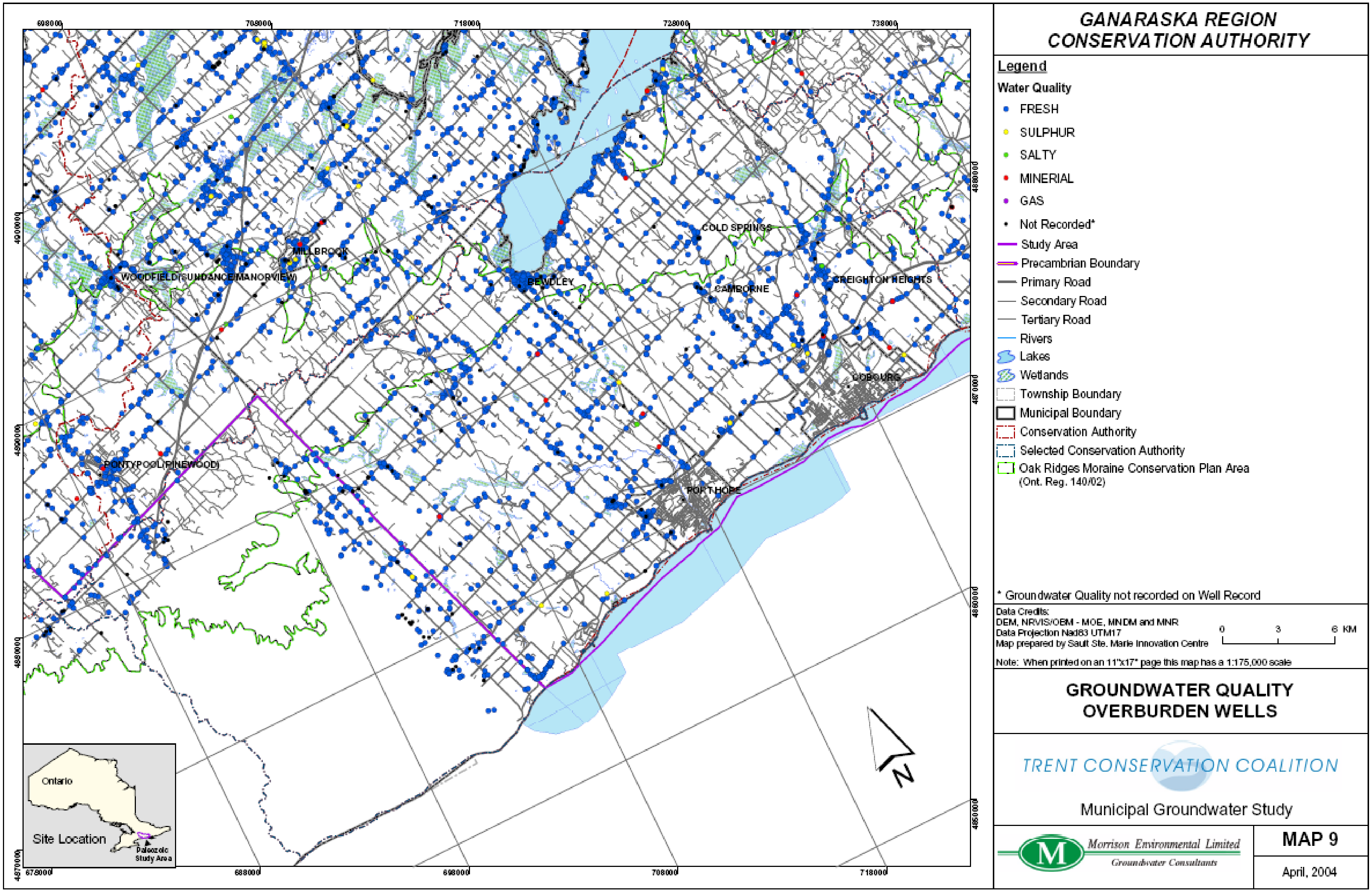


Figure 2-3: Groundwater Quality in Overburden Wells (Morrison Environmental Ltd., 2004)

2.5.2.5 WATER QUALITY OF MUNICIPAL WELLS

Groundwater quality data from municipal well records at the three wellfields in the Ganaraska Region Source Protection Area can increase the understanding of general regional groundwater quality. Data from these wellfields are reviewed and analysed in more detail in Chapter 5. The following sections provide a generalized overview of water quality from past wellfield sampling.

Camborne and Creighton Heights Wellfields (Township of Hamilton)

Groundwater quality data at the two municipal wellfields in the Township of Hamilton were initially evaluated in the Wellhead Protection component (Volume 2) of the Trent Conservation Coalition Municipal Groundwater Study (Morrison Environmental Ltd., 2004b). The study compared sampling results from the Camborne and Creighton Heights municipal wellfields to the Ontario Drinking Water Standards. The studies identified levels of lead at the Camborne municipal wellfield, iron and manganese at the Creighton Heights municipal wellfield, and hardness at both wellfields that exceeded the Ontario Drinking Water Standards. These results are typical of the natural groundwater quality of the area.

Groundwater quality was further summarized by Jagger Hims Ltd. (2007) as part of an update to increase the understanding of the municipal drinking water sources. At the Creighton Heights wellfield, hardness, turbidity, iron, and manganese were present in the raw water supply. At the Camborne wellfield, hardness, turbidity, and iron were present in the raw water supply. No volatile organic compounds, pesticides, or herbicides were detected in either water supply. Chloride and sodium concentrations at both wellfields showed variability, but it is expected that this is due to natural processes (Jagger Hims Ltd., 2007). These results are also typical of the natural groundwater quality of the area.

Orono Wellfield (Regional Municipality of Durham)

Groundwater quality data at the Orono municipal wellfield are available from a Wellhead Protection Program (Jagger Hims Ltd., 2003). Investigations indicate that inorganic chemistry at both supply wells is acceptable and typical for local groundwater. Pesticides and polychlorinated biphenyls (PCBs) sampled were below laboratory detection limits. Other water quality monitoring data from the Orono wellfield indicate typical natural groundwater quality of the area. These data sources include annual water quality reports and monitoring reports.

2.6 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Available information was used to complete the characterization of the Ganaraska Region Source Protection Area as required by the technical rules. Improvements to the characterization could be made with more data.

Non-Municipal Drinking Water Systems

The list of non-municipal drinking water systems is incomplete and should be revised when the provincial data set is updated. Additional information on locations of wells, pumping rates, number of users served, and locations of monitoring wells related to these systems would provide a more comprehensive overview.

Locations and Types of Aquatic Habitats

There are some limitations to the data available that indicate the locations and types of aquatic habitats. Stream temperature, Simpson's Diversity Index, and Hilsenhoff's Water Quality Index were used as indicators to identify the potential locations of aquatic habitats. As more information becomes available through provincial or local watershed studies, the report and mapping should be updated.

Surface Water Quality Data

The amount and quality of data available to characterize the surface water quality across the Ganaraska Region Source Protection Area vary. In some cases only historical data are available; sampling at these sites has been discontinued. In some areas only recent data are available. A long-term sampling program needs to be established and maintained.

Improvements to benthic macroinvertebrate surveys conducted will provide data that can be used to assess long-term water quality.

Groundwater Quality Data

Little data are available on groundwater quality. The Provincial Groundwater Monitoring Program was recently established to fill this gap. Continuation of this program will provide data to characterize the groundwater in the future.

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CHAPTER 3: WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

3.1 INTRODUCTION

A water budget is an accounting of the inputs and outputs of water in a hydrologic system. It quantifies the components of the hydrologic cycle and the human uses of water employing the available data and a water balance equation based on the law of conservation of mass. The results provide insight into how water moves in the watershed and are useful for the management of water quantity. A water quantity stress assessment examines percent groundwater and surface water demand against thresholds to determine if water systems are stressed.

3.1.1 CHAPTER LAYOUT

The following chapter is a description of the water budget process under the *Clean Water Act, 2006* as prescribed in Part III of the *Technical Rules* that follows a tiered approach. The first step is the conceptual water budget, which is a simple water budget performed at coarse spatial and temporal scales. The second step is the Tier 1 water budget, which assigns water quantity stress levels to each watershed in the Ganaraska Region Source Protection Area. Next, subwatersheds associated with municipal drinking water systems with a significant or moderate stress level in the Tier 1 water budget are the subject of the Tier 2 water budget, which either confirms or refutes the Tier 1 stress findings based on a more refined analysis. Lastly, subwatersheds with a significant or moderate stress level in the Tier 2 water budget are subject to a Tier 3 water budget, which delineates the vulnerable area that relates to existing or planned drinking water systems in the stressed subwatersheds.

Conceptual	→	Tier 1	→	Tier 2	→	Tier 3
All watersheds in study area		All watersheds in study area		Subwatersheds assigned a significant or moderate stress level in Tier 1 that contain a municipal drinking water system		Contributing area of municipal intakes and wells within subwatersheds assigned a significant or moderate stress level in Tier 2

3.1.2 STUDY AREA

The water budgets described in this chapter were developed for the Ganaraska Region Source Protection Area. The study area includes the larger watersheds of Wilmot Creek, Graham Creek, the Ganaraska River, Gages Creek, and Cobourg Creek. In addition, several small watersheds that drain to Lake Ontario were grouped into larger areas known as West Lake Ontario watersheds, East of Gages Creek watersheds, and East Lake Ontario watersheds (Map 3-1). The 107 km^2 of land that drains to Rice Lake in the Ganaraska Region Source Protection Area is part of the larger Rice Lake watershed that outlets into Lake Ontario via the Trent River and Bay of Quinte. As a result, water budget discussions and results associated with the watersheds that drain to Rice Lake are presented in the Trent Assessment Report.

3.1.3 WATER BUDGET PROCESS

Water budgets are developed by measuring or estimating the inputs and outputs of a hydrologic system. Inputs are the processes that add water to the system; these include precipitation and inflow from surface water and groundwater. Outputs are the processes that remove water from the system; these include evapotranspiration, the various uses of water by humans, and outflow from surface water and groundwater. The components of a water budget are illustrated in Figure 3.1-1. Many inputs and outputs can be measured directly or estimated using various techniques, but those that cannot be estimated are calculated using the water balance equation.

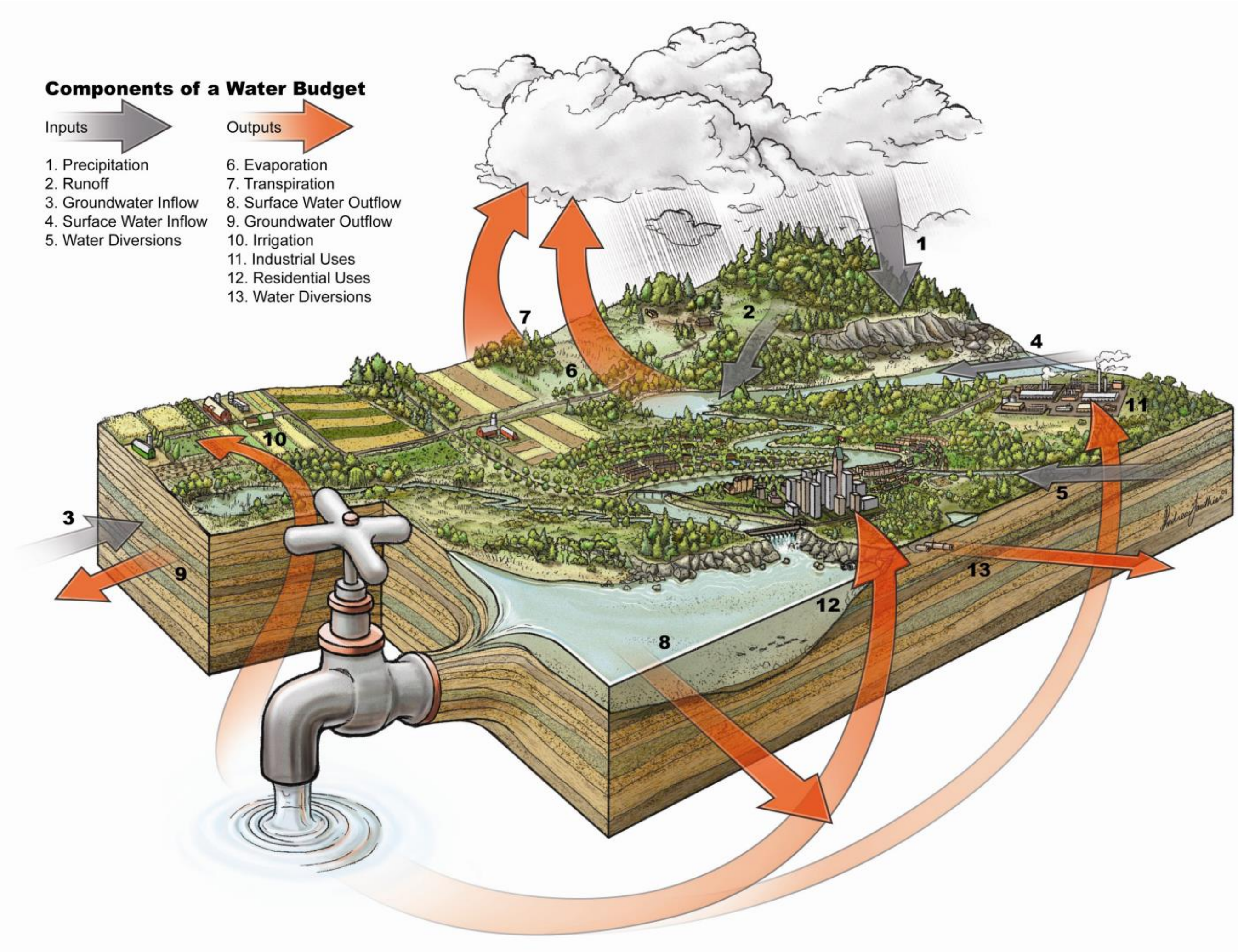


Figure 3.1-1: Components of a Water Budget

3.1.3.1 WATER BALANCE EQUATION

The water balance equation relates the inputs and outputs of a hydrologic system mathematically according to the law of conservation of mass. The water balance equation is given by:

$$(\text{Input}) - (\text{Output}) = (\text{Change in Storage})$$

Or, in finite difference form:

$$(\text{Input}) - (\text{Output}) = \Delta S/\Delta t$$

Where: ΔS = change in storage
Δt = time interval over which water budget is evaluated

This means that, in any given period of time, the difference between the amounts of water entering and leaving the watershed equals the change in the amount of water stored in the watershed. The terms in the equation can be expressed in units of volume (e.g., cubic metres (m^3)) or units of equivalent depth over the area of the watershed (e.g., millimetres (mm)).

Since there are several types of inputs and outputs, the above equation can be expanded to represent each input and output as a separate term. The expanded water budget equation can be given by:

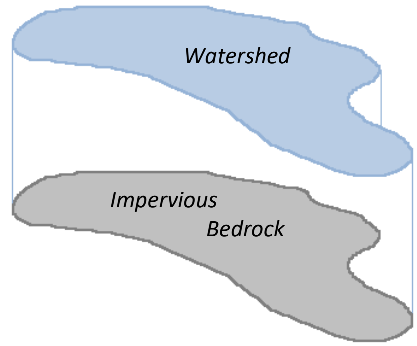
$$\underbrace{(P + G_{net})}_{\text{Inputs}} - \underbrace{(ET + Q_{net} + D_{net} + W_{net})}_{\text{Outputs}} = \Delta S$$

Where: P = precipitation
G_{net} = net groundwater in
ET = evapotranspiration
Q_{net} = net streamflow out
D_{net} = net diversions out
W_{net} = net human withdrawals
ΔS = change in storage

Except in very simple cases, the terms of this equation cannot be estimated without uncertainty. Thus it is useful to consider the terms as estimated long-term values and to include a residual term ("Residual") in the equation. The residual term includes the errors and uncertainties associated with estimating the water budget components and, in some cases, can include other terms of the water budget equation that cannot be measured or estimated by other means (e.g., the estimation of G_{net} in the absence of reliable groundwater flow models). The following equation was used as the basis for developing the water budgets presented in this section:

$$\underbrace{(P + G_{net})}_{\text{Estimated Inputs}} - \underbrace{(ET + Q_{net} + D_{net} + W_{net})}_{\text{Estimated Outputs}} \pm \Delta S = \text{Residual}$$

The water budget equation is applied to a fixed volume in space (control volume) that corresponds to the plan area of a watershed. The top and bottom surfaces of the control volume are the plan area of the watershed, and the sides are defined by projecting the watershed boundaries vertically down from the ground surface to an elevation where there are no transfers of groundwater to or from the stream (e.g., impervious bedrock). In this water budget, each watershed was taken as a separate control volume (i.e., the water budget equation was applied to each watershed).



*The water budget equation is applied to a **control volume** defined by a surface water divide projected vertically downwards to impervious bedrock.*

3.1.4 TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

The objective of the Tier 1 water budget and stress assessment was to screen watersheds directly draining to Lake Ontario within the Ganaraska Region Source Protection Area and identify those with significant or medium water quantity stress levels. The Tier 1 water budget describes the mathematical evaluation of watershed stress, whereas the conceptual understanding provides a more narrative description of the water budget in the Ganaraska Region Source Protection Area. The Tier 1 water budget was prepared provincial guidance modules and *Technical Rules*, which indicates that the stress assessment is evaluated by percent water demand: the ratio of the consumptive water demand to water supplies, minus water reserves. Through the comparison of thresholds and estimated percent water demand, each watershed (study unit) is assigned a surface and groundwater stress level.

3.2 CONCEPTUAL WATER BUDGET

The conceptual water budget is a simple water budget performed at coarse spatial and temporal scales. It gathers the information that will be required for subsequent steps of the water budget process and provides a general overview of water movement through a watershed. It also includes an assessment of watershed features that may impact the water budget calculation such as geology, physiography, and land cover. The following section is a summary of the Ganaraska Region Conservation Authority (2007) Conceptual Understanding - Water Budget Watersheds Draining to Lake Ontario, Final Draft Report, which was peer reviewed. The results of the review are summarized in Appendix C.

3.2.1 CLIMATE

Climate is a critical influence on the hydrology and hydrogeology of a region. This section is an assessment of the climatic parameters that are components of the water budget equation: precipitation, temperature, and evapotranspiration.

3.2.1.1 DATA SOURCES

Climate data in the Ganaraska Region Source Protection Area are available from climate stations operated by the Meteorological Service of Canada (Environment Canada) and the Ganaraska Region Conservation Authority. Climate stations in and near the source protection area that are operated by Environment Canada are listed in Table 3.2-1, and the Ganaraska Region Conservation Authority stations are listed in Table 3.2-2. Climate stations used in conceptual water budget calculations are shown on Map 3-2, and meteorologic zones on Map 3-3.

Table 3.2-1: Environment Canada Climate Stations

Station Name	Station Number	Beginning Year	Ending Year	Average Temperature (ºC)	Average Rainfall (mm)	Average Snowfall (cm)	Average Precipitation (mm)
Bowmanville Mostert	6150830	1966	2002	7.0	764.6	93.2	857.9
Campbellcroft Ganaraska	6151136	1979	1992	6.4	827.2	146	973.2
Camborne	6151090	1991	2002	7.3	771.0	135	906.0
Cobourg STP	6151689	1970	2006	7.0	765.8	106	871.7
Gores Landing	6152950	1943	1966	N/A	650.9	131.3	782.2
Gores Landing	6152951	1970	1982	6.8	687.1	177.4	864.6
Janetville	6153853	1981	2006	6.6	752.5	184.7	939.6
Campbellford	6151137	1915	1997	8.8	669.1	147	817.1
Millbrook	6155154	1975	1985	N/A	769.1	170.5	939.6
Oak Ridges	6155722	1918	1979	6.6	631.9	160.2	780.8
Orono	6155854	1923	1996	6.9	724.5	152.6	879.9
Oshawa Fire Hall #3	6155877	1976	1992	8.2	633.5	74.5	710.1
Oshawa WPCP	6155878	1969	2006	7.7	759.5	118.4	877.9
Peterborough A	6166418	1969	2006	6.0	682	162.0	840.3
Port Hope	6156670	1882	1993	7.1	679.7	150.3	833.8

Table 3.2-2: Ganaraska Region Conservation Authority Operated Climate Stations

Station Name	Watershed	Location	Year Established	Data Collected
GRCA Main Office	Ganaraska River	2216 County Road 28, Port Hope	2002	Rainfall, Air Temperature, Wind Speed and Direction, Relative Humidity
Cobourg Creek at 609 William Street*	Cobourg Creek	609 William Street, Cobourg	2003	Rainfall, Air Temperature
Wilmot Creek	Wilmot Creek	Concession Road 3, Village of Newcastle	1999	Rainfall
Ganaraska Forest Centre	Ganaraska River	10585 Cold Springs Camp Road, Campbellcroft	2001	Rainfall, Snowfall, Air Temperature, Wind Speed and Direction
Baltimore Creek	Cobourg Creek	4494 County Road 45 Baltimore	1999	Rainfall, Air Temperature, Wind Speed and Direction

* Replaced the Cobourg Pumphouse Climate Station that operated since 2000.

3.2.1.2 REGIONAL CLIMATE

Topography influences variation and distribution of local temperature and precipitation. The most significant factor affecting climate is the proximity of Lake Ontario. A definite moderating effect due to lake influence is seen in the immediate vicinity of the Lake Ontario shore, while the modification in climate diminishes as one ascends the northern inland slopes. On the Oak Ridges Moraine the climate is colder, exhibiting harsher winters and later springs than the rest of the source protection area.

The climate in the Ganaraska Region Source Protection Area is continental, with cold winters and warm summers. Climate data from several local Environment Canada climate stations indicate that precipitation in the Ganaraska Region Source Protection Area shows local variation. In the lakeshore region the mean annual precipitation varies from 755 to 830 mm, while on the northern upland slopes it varies from 875 to 900 mm. There is greater precipitation (up to 1,000 mm) on the Oak Ridges Moraine upland area than on the slope and low regions (Map 3-4).

According to the relevant climatic information (Table 3.2-3), the mean annual daily temperature in the Ganaraska Region Source Protection Area ranges from about 5.9 to 7.3 degrees Celsius (°C). January is the coldest month with mean daily temperatures in the -8 °C range. July is the warmest month with a mean daily temperature of approximately 20 °C. The mean annual precipitation ranges from about 830 millimetres per year (mm/yr) at Port Hope in the south to about 880 mm/yr in Orono in the west, but is wetter in the north. About 70 to 85% of precipitation falls as rain. Precipitation patterns vary across the Ganaraska Region Source Protection Area, with the September to December period generally being the wettest. Between December and March, most precipitation falls as snow, whereas in the months of November and April precipitation is mixed, with most being rain. Depending on location, either February or July is typically the driest month of the year. Figures 3.2-1 and 3.2-2 show the annual meteorological trends based on the records of two meteorological stations near the Ganaraska Region Source Protection Area.

Table 3.2-3: Precipitation and Temperature Data Summary (1971 to 2000) from Selected Weather Stations

	Campbellford*	Cobourg	Port Hope	Orono	Peterborough*
Elevation (masl)	146	79.2	80.8	148	191.4
Total Precipitation (mm)	836.7	871.1	832.0	879.9	840.3
Rain (mm)	684.1	765.8	709.0	724.5	682.0
Snow (mm)	149.3	106.0	122.0	152.6	162.0
Wettest Month (mm)	December, 82.1	September, 90.0	December, 80.5	September, 76.3	August, 83.2
Driest Month (mm)	July, 58.3	February, 54.0	July, 53.3	February, 63.8	February, 50.6
Mean Annual Temperature (°C)	N/A	7.1	7.3	6.8	5.9
Warmest Month (°C)	N/A	July, 19.6	July, 20.0	July, 20.1	July, 19.4
Coldest Month (°C)	N/A	January, -6.0	January, -5.8	January, -6.9	January, -8.9

* Stations located outside of the Ganaraska Region Source Protection Area, but near enough to have relevant data

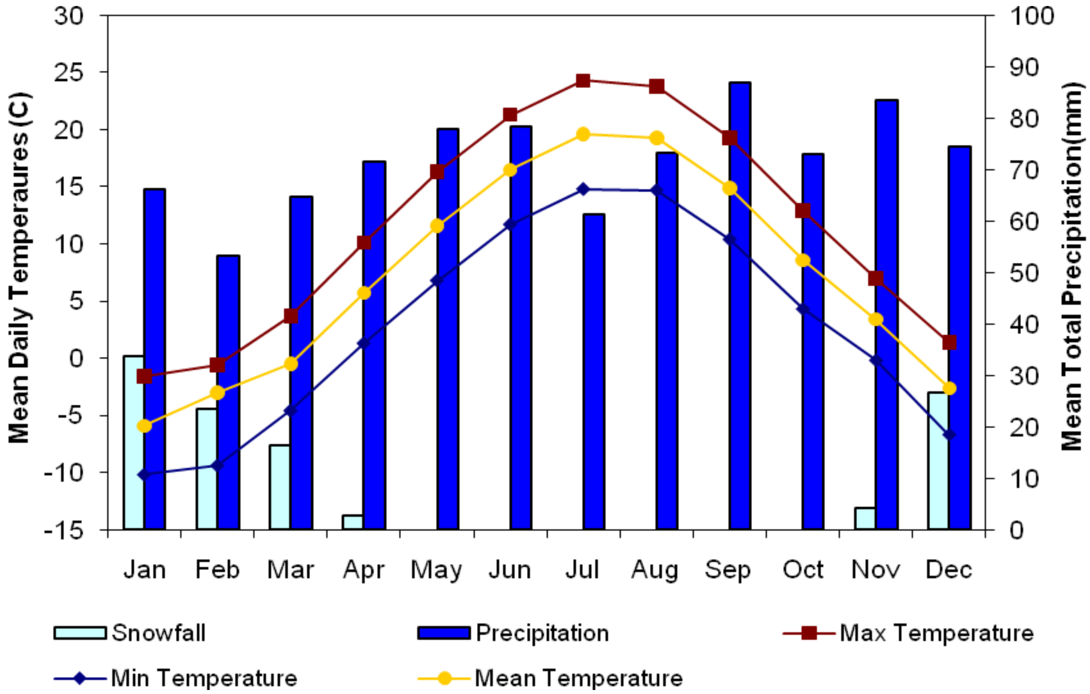


Figure 3.2-1: Cobourg STP Meteorological Station (6151689) 1970 to 2003

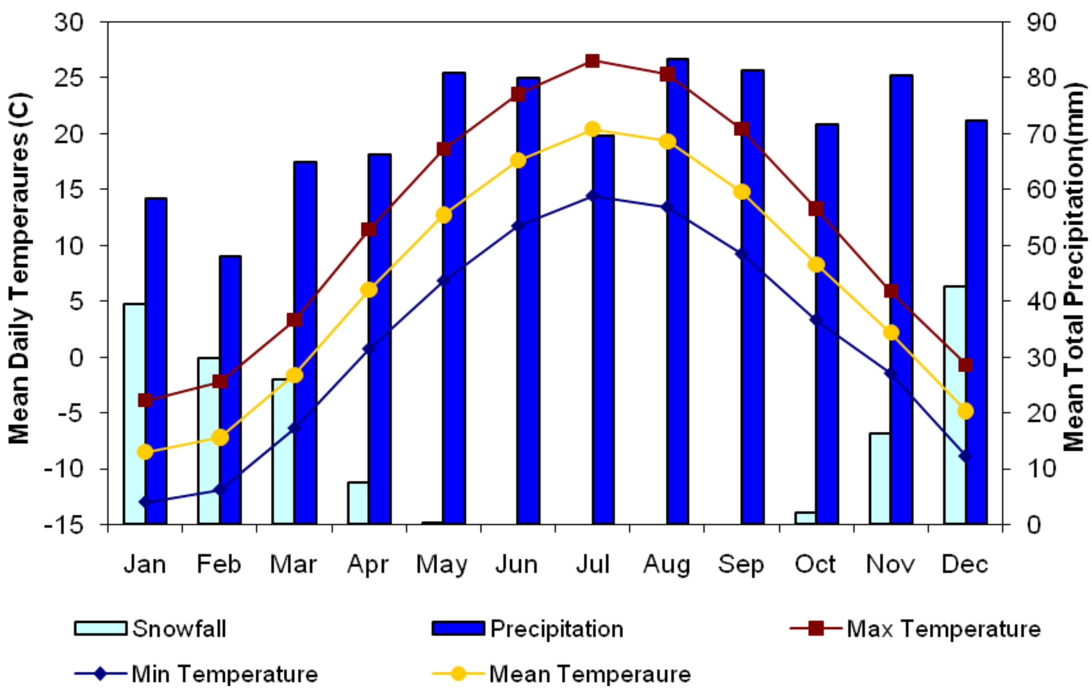


Figure 3.2-2: Peterborough, Trent University Meteorological Station (6166455) 1968 to 2000

3.2.1.3 EVAPOTRANSPIRATION

Evapotranspiration is the sum of water lost from an area by evaporation from the land surface and transpiration by plants. Evapotranspiration dominates the water balance and controls hydrologic phenomena such as soil moisture content, groundwater recharge, and stream flow.

The amount of evapotranspiration varies in the Ganaraska Source Protection Area due to differences in physiography and climate. In the source protection area most rainwater percolates into the soil; some recharges the groundwater (which generally cannot be used by plants), some discharges to streams as baseflow and interflow, and the remainder is held in storage in the soil as soil moisture, where it can be used by plants. Plants draw on the stored soil moisture through the process of evapotranspiration, whereby water passes through the plant to the atmosphere, largely in response to the drying properties of the overlying air.

There are no lake evaporation or evapotranspiration data available for the study area. Mean evapotranspiration was estimated using a spreadsheet model based on the Thornthwaite & Mather (1955) model. The model calculates potential evapotranspiration based on temperature, day length, and saturation vapour pressure. Potential evapotranspiration is a theoretical value that indicates the amount of evapotranspiration that would occur in the presence of ample water. Day length was estimated from the latitude of climate stations or hydrometric stations. Actual evapotranspiration was estimated from the potential evapotranspiration calculated by the model.

Mean potential evapotranspiration estimates for the watersheds of the Ganaraska Region Source Protection Area using the Thornthwaite and Mather model are presented in the results of the conceptual water budget. Model results indicated that evapotranspiration in the study area starts in April and reaches its maximum rate in July, and then declines until it reaches zero in December when the mean temperature drops below freezing. The estimates obtained from the model are in agreement with previous estimates. The Ministry of Natural Resources and Forestry (1984) estimated that mean annual evapotranspiration in southern Ontario varies from less than 500 mm to more than 600 mm (Singer et al., 2003).

3.2.2 GEOLOGY

3.2.2.1 BEDROCK GEOLOGY

The bedrock in the Ganaraska Region Source Protection Area is completely covered by a mantle of Quaternary deposits. The bedrock elevation ranges from about 50 to 80 metres above sea level (masl) along the shore of Lake Ontario to about 160 to 200 masl in the Oak Ridges Moraine (Map 3-5) (Earthfx Incorporated, 2006). The formations of bedrock underlying the majority of the area are categorized as belonging to the Lindsay Formation from the Simcoe Group of the Middle Ordovician Age. A small area of the source protection area within the Municipality of Clarington is underlain by bedrock belonging to the Whitby Formation from the Georgian Bay Group of the Upper Ordovician Age (Map 3-5). The calcareous Lindsay bedrock formations were not subjected to major tectonic changes and are consequently quite regular and even, although they dip slightly to the south to form part of a gentle syncline that extends well out under Lake Ontario. These fine-grained limestones are visible along the Lake Ontario shoreline at the outlets of the Ganaraska River and Gages Creek. The flat beds of limestone were not important in the creation of the present surface features and soil formations in the area.

Instead, the extensive glacial activity and resulting glacial deposits were the dominant factors in shaping the topography of the source protection area.

During the Pleistocene Epoch the massive ice formations and resulting meltwater of glacial lakes shaped many of the topographic features found in the source protection area. The glacial activity and resulting deposited materials have formed many physical features that affect the drainage patterns, soil formations, and the eventual land use practices. The joining of two massive ice lobes (Simcoe and Ontario ice lobes) was of particular importance in forming the Oak Ridges Interlobate Moraine. This kame type moraine is a dominant feature of the landscape, covering an area of approximately 104 km^2 at the northern portions of the Ganaraska Region Source Protection Area (Ministry of Natural Resources and Forestry, 1976).

3.2.2.2 TOPOGRAPHY

The topography of the area includes three distinct sections (Map 3-6). The most northern topography comprises the rolling and steep hills and the deeply cut river valleys of the Oak Ridges Moraine. Next is the South Slope, which is primarily a till plain with gently rolling hills interspersed with a number of drumlins that provide some topographic variation. Spillway channels from glacial meltwaters are also found on the South Slope; good examples are the valleys of Wilmot Creek and the Elizabethville tributary of the Ganaraska River. The third, most southerly section is the Iroquois Plain that was formed by a glacial lake that preceded the present Lake Ontario. The deposition of sand and clay particles from the glacial meltwaters of Lake Iroquois created a terrain similar in appearance to the South Slope, although different materials were deposited in the two sections.

The old beach line of the former Lake Iroquois is not a prominent feature of the landscape today, but beach line marks are evident in the Township of Hamilton, where an ancient drumlin was truncated by Lake Iroquois wave action, near Baltimore and along Highway 401 at the Ganaraska Region Source Protection Area eastern boundary. Similar phenomena are clearly visible here. The Lake Iroquois beach line runs from 6.4 to 11.3 km to the north of Lake Ontario and at an elevation of approximately 76.2 m above the shoreline of the present Lake Ontario (Ministry of Natural Resources and Forestry, 1976).

Many of the drumlins that can still be identified in the Iroquois Plain today were probably once conspicuous islands in the lake and others were undoubtedly long ago flattened or otherwise transformed by the lake waters. Other features resulting from deposits in Lake Iroquois included sand bars that now appear simply as sand deposits.

3.2.2.3 SURFICIAL GEOLOGY

During the approximately last 100,000 years of the Pleistocene Epoch the massive ice formations and resulting meltwaters of the glacial lakes shaped many of the surface features found in the Ganaraska Region Source Protection Area. The glacial activity and resulting deposits of materials have formed several physical features that in turn affected surficial geologic formations and soils and the eventual land use practices in the area. The topography of the source protection area includes three distinct sections as described above. From north to south, these are the Oak Ridges Moraine, South Slope, and Iroquois Plain topographic areas. Most of the surficial deposits within these physiographic regions range from sandy and gravely outwash and glaciolacustrine materials to silty and clayey tills (Map 3-7).

The thickness of the overburden in the Ganaraska Region Source Protection Area is between 10 and 70 m within the Iroquois Plain, 50 and 90 m within the South Slope, and reaches more than 180 m within the Oak Ridges Moraine (Map 3-8) (Ministry of Natural Resources and Forestry, 1976). The overburden consists of glacial, glaciofluvial, and glaciolacustrine deposits of Pleistocene age, and alluvial and swamp deposits of Recent age. According to Barnett (1992), the glacial deposits consist of two tills, the Halton Till and the undifferentiated till that was later identified as Newmarket Till or Bowmanville Till. The Halton Till is found in the western parts of the Ganaraska Region Source Protection Area south of the Oak Ridges Moraine. The Newmarket Till (Bowmanville Till), on the other hand, occurs in the eastern parts of the source protection area south of the moraine and also in the Iroquois Plain. The glacial till deposits are of calcareous material from limestone bedrock. However, the till deposits vary widely in texture as a result of reworking by wind and water action during the glaciations. The characteristics of these till units as well as their sequences are important to the groundwater and surface water flow of the region. Generally the Halton Till is considered an aquitard whereas the Newmarket Till (Bowmanville Till) is a leaky aquitard (Earthfx Incorporated, 2006).

Ice-contact deposits of sand and gravel occur within the moraine, and outwash deposits of sand and gravel occur along the southern flank of the moraine. Ice-contact stratified drift and outwash deposits also occur locally in the South Slope region and are generally comprised of older sediments exposed by erosion. Sand, silt, and clay deposits of glaciolacustrine origin occur in the Iroquois Plain.

3.2.3 PHYSIOGRAPHY

As described by Chapman & Putnam (1984), there are four prominent physiographic features found in the Ganaraska Region Source Protection Area (Map 3-9). These include, from north to south, the Peterborough Drumlin Field, Oak Ridges Moraine, South Slope, and Iroquois Plain. Details of the physiographic regions are found in Chapter 2.

3.2.4 SOILS

May different soils exist across the Source Protection Area (Map 3-10). The till deposits in some of the Oak Ridges Moraine areas are covered by 3 to 4.6 m of sand and sandy gravels and the present soils are mainly derived from the sand-gravel strata. The most typical soil of the Moraine area is the Pontypool Series consisting of sand and sandy loams with almost pure sands located on hilltops and more loamy soils in the drainage channels where they were formed during the period of glacial activity.

On the South Slope the soils were formed in about half a metre of sand deposits overlying the till plain and, because of this shallower depth, are not as thoroughly drained as the soils of Oak Ridges Moraine. Consequently, fewer nutrients were drained away during the formative periods leading to the development of typical loam types such as Dundonald sandy loam. However, there are still some patches of completely sandy soil on the higher reaches of the drumlins.

Little of the original till material of the Iroquois Plain was left unchanged by the glacial meltwater, and the soils are therefore different from those in the two more northerly sections. The general effect was for sandy loams to be created near to the beach line and for clay loams to form farther out in the ancient lake. The beach bars and spits of the ancient lakeshore also left areas of sandy soil. Tecumseth sandy loam and fine sandy loams are found in one such area close to the Village of Newcastle.

In hydrologic calculations, soils may be classified into four main groups (A, B, C, D) and three interpolated ones (AB, BC, CD). A is soil with high infiltration and transmission rates, and D is soil with very slow infiltration and transmission rates (Table 3.2-4). These hydrologic soil groups in the Ganaraska Region Source Protection Area are seen on Map 3-11.

Table 3.2-4: Hydrologic Soil Groups

Group	Infiltration rate	Description	Transmissivity	Soil types
A	High infiltration rates and low runoff potential even when thoroughly wetted	Chiefly deep, well to excessively drained sands or gravels.	High rate of water transmission (>0.75 cm/hr).	Sand, loamy sand, sandy loam.
B	Moderate infiltration rates when thoroughly wetted	Chiefly moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.	Moderate rate of water transmission (0.40-0.75 cm/hr).	Silt loam, loam.
C	Low infiltration rates when thoroughly wetted	Chiefly soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures.	Low rate of water transmission (0.15-0.40 cm/hr).	Sandy clay loam.
D	Very low infiltration rates and high runoff potential when thoroughly wetted	Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface or shallow soils over nearly impervious material.	Very low rate of water transmission (0-0.15 cm/hr).	Clay loam, silty clay loam, sandy clay, silty clay, clay.

Data Source: Soil Conservation Service (1986)

3.2.5 LAND COVER

Land cover, dictated by local geologic conditions, influences the distribution of surface runoff, infiltration, and evapotranspiration. By using Ecological Land Classification (ELC) for Southern Ontario, lands in the Ganaraska Region Source Protection Area can be classified according to land cover (Map 3-12, Table 3.2-5). However, limitations do exist with Ecological Land Classification mapping, including inaccurate classifications, therefore in-field verification must be conducted in areas of uncertainty.

In the Ganaraska Region Source Protection Area, based on 2002 Ecological Land Classification mapping, residential and urban areas occupy approximately 56 square kilometres (km^2) and 32 km^2 of land, respectively, representing 4.9% and 2.8% of the total land cover. Although residential areas are spread throughout the watersheds, urban areas are primarily concentrated along the shore of Lake Ontario, within the Iroquois Plain. Transportation corridors cover approximately 80 km^2 of land or a total of 7%. The combination of impermeable surfaces in residential and urban areas, and transportation corridors have the potential to alter and influence the natural hydrologic cycle, resulting in reduced infiltration, changes in evapotranspiration and increased surface runoff (Morrison Environmental Ltd., 2004a).

Agriculture dominates in the Ganaraska Region Source Protection Area covering an area of approximately 426 km^2 or 37% of total land cover. Depending on the season and land use practices associated with particular operations, surface water runoff, infiltration, and evapotranspiration rates can fluctuate either positively or negatively, therefore affecting the water budget of a particular area.

In terms of vegetative cover, forests (including plantations and woodland) occupy approximately 322 km^2 or 27% of the land cover. There are two major forests: the Ganaraska Forest (42 km^2), located in the northwest, and a portion of the Northumberland County Forest (21 km^2), located in the northeast (southeast of Rice Lake). Many forests, including the Ganaraska Forest have some form of protection, such as being a conservation area, and thus protect many hydrologic components.

Other vegetation types include meadows, prairies, savannahs, and thickets. In the Source Protection Area, these habitats cover approximately 125 km^2 or 11%. These areas aid in reducing surface water runoff allowing for increased ground infiltration and increased evapotranspiration rates through plant transpiration.

Wetlands, which contain less than 2 metres of water, include swamps, marshes, fens, and bogs. These can be broken down further into specific vegetation types using Ecological Land Classification methodology. Swamps and marshes that are commonly found in the Source Protection Area contribute greatly to infiltration with their close connection with groundwater. They also contribute to evapotranspiration rates depending on the amount of vegetation cover within these systems and the amount of surface water available for evaporation (Morrison Environmental Ltd., 2004a). As a result, wetlands play an important role in water fluxes and must be taken into consideration when calculating a watershed water budget.

Currently, Ecological Land Classification mapping suggests that there are approximately 40 km^2 of wetlands. This represents only 3.7% of land cover, which is well below the Great Lakes Area of Concern recommendation of 10%. However, many of the soils in the watersheds are sandy and therefore highly permeable and not conducive to holding water. Most of the wetland cover is in the form of forest and thicket swamps in lowland areas, although some relatively large cattail marshes are found at mouths of major creeks on Lake Ontario.

Open water, excluding Rice Lake, is found on approximately 10 km^2 of land, representing 0.9% of the total land surface in the Source Protection Area. This open water contributes to the water budget by means of evapotranspiration rates, but also allows for the investigation of infiltration rates. Since infiltration is difficult to measure accurately, it can be estimated by determining the baseflow at the up and downstream end of an open water feature (Morrison Environmental Ltd., 2004a).

Table 3.2-5: Approximate Land Cover Based on Ecological Land Classification

Land Cover	km^2	Percentage of Land [1]	Land Cover	km^2	Percentage of Land [1]
Open Beach/Bar	0.4	0.04	Shallow Marsh	2	0.2
Open Bluff	0.7	0.06	Fen	0.03	0.003
Shrub Bluff	0.6	0.05	Coniferous Swamp	17	1.5
Treed Bluff	0.4	0.04	Deciduous Swamp	1	0.1
Open Cliff	0.2	0.01	Mixed Swamp	9	0.8
Shrub Cliff	0.02	0.001	Thicket Swamp	5	0.4
Open Sand Barren	0.1	0.01	Floating-leaved Shallow Aquatic	0.1	0.01
Open Rock Barren	0.03	0.003	Submerged Shallow Aquatic	0.9	0.07
Deciduous Forest	70	6.1	Open Aquatic (excluding Rice Lake)	10	0.9
Coniferous Forest	70	5.2	Non-intensive Agriculture	86	7.5
Mixed Forest	79	6.9	Intensive Agriculture	340	29.6
Cultural Meadow	80	7.0	Manicured Open Space	7	0.6
Cultural Plantation	73	6.4	Residential	56	4.9
Cultural Savannah	9	0.8	Urban Area	32	2.8
Cultural Thicket	36	3.1	Aggregate	7	0.6
Cultural Woodland	30	2.6	Road/Railway	80	7.0
Meadow Marsh	5	0.4			

1 Land does not include Rice Lake or Lake Ontario

3.2.6 SURFACE WATER

Surface water refers to water on the ground's surface and includes lakes, rivers, and wetlands. The following sections describe the hydrology, control structures, and aquatic habitat of the Ganaraska Source Protection Area.

3.2.6.1 WATERSHEDS AND HYDROLOGY

Wilmot Creek Watershed

The Wilmot Creek watershed drains an area of about 98.8 km^2. Originating on the Oak Ridges Moraine at an elevation of about 331 masl, the creek flows southeasterly for about 21.2 km at an average slope of about 12 m/km, where it discharges to Lake Ontario. The watershed has a total fall of about 226 m with an average slope of about 1.4 m/km (Singer, 1981). The Wilmot Creek surface water system is composed of streams, ponds, and control structures. Its tributaries include Orono, Hunter, Stalker, and Foster Creeks, the latter of which is the most developed tributary of Wilmot Creek. The length of the main course of Wilmot Creek is 29.3 km. The length of the main branch and the first and second order tributaries is approximately 58 km whereas the total length of the main stem and all the tributaries is about 98 km (Singer, 1981). Characteristics of the major tributaries are listed in Table 3.2-6.

Table 3.2-6: Characteristics of Wilmot Creek Tributaries

Stream/Tributary	Drainage Area (km^2)	Total Fall (m)	Average Gradient (m/km)
Main Branch	42.8	191	6.5
Foster Creek	9.6	48	5.9
Hunter Creek	8.1	90	11.3
Orono Creek	18	107	10.3
Stalker Creek	11.5	89	8.0

Since 1965, flow data have been collected in the Wilmot Creek watershed. Table 3.2-7 describes the historic and current hydrometric stations in the Wilmot Creek watershed. There are two operational hydrometric stations, which are located on the main branch of Wilmot Creek at Concession Road 3 (02HD009) and Concession Road 7 (02HD021). Map 3-13 shows the locations of the two active hydrometric stations, as well as the Ganaraska Region Conservation Authority spot flow monitoring locations in the watershed. Another four seasonally operated hydrometric stations are present in the main branch near the Orono municipal wellfield. Water yields have been calculated for hydrometric station 02HD009 on the basis of stream flows, since it contains the most complete data to represent the Wilmot Creek watershed. Table 3.2-8 demonstrates the total mean annual runoff, the total mean annual precipitation, and the runoff to precipitation ratio for the hydrometric station.

Table 3.2-7: Hydrometric Stations in Wilmot Creek

Station	Location	Record Year	Drainage Area (km^2)	Status
02HD009	Concession Road 3	1965 to present	82.6	In Operation
02HD021	Concession Road 7	August 2005 to present	25.5	In Operation
GRCA Operated hydrometric stations (Wilmot 1, Wilmot 2, Durham 1, Wilmot 4)	Main Branch of Wilmot Creek between Concession Road 5 and Taunton Road	Summer 2004 to Summer 2009	N/A	In Operation (Seasonal)
GRCA short term hydrometric station	Foster Creek on Television Road	2000 to 2004	N/A	Discontinued

Table 3.2-8: Water Yield Ratio at Hydrometric Station 02HD009

Station Location	Drainage Area (km^2)	Mean Annual Runoff (mm)	Mean Annual Precipitation (mm)	Runoff/Precipitation Ratio
02HD009	82.6	368.8	872.1	42.3%

The source for the majority of baseflow in the Wilmot Creek watershed is the groundwater discharge zone of the Oak Ridges Interlobate Moraine in the northern portion of the watershed. An annual river flow hydrograph has been developed based upon the recorded daily flow rates taken at the two hydrometric stations. These flow rates were considered an acceptable description of the flow regime of the larger watershed. The highest average flows occur in early spring (March and April) and the lowest average flows occur from July to August (Figure 3.2-3).

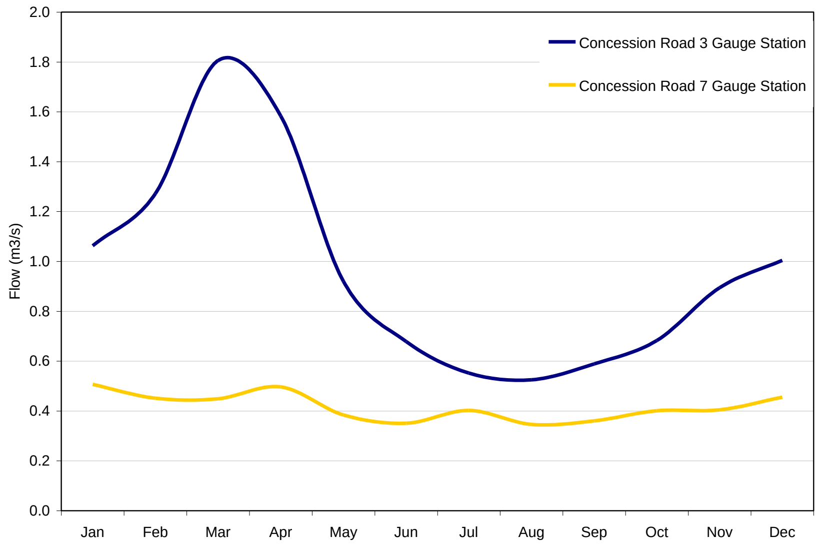


Figure 3.2-3: Annual Hydrograph for Wilmot Creek

Ganaraska River Watershed

The Ganaraska River has a triangular-shaped basin with a total area of 277.9 km^2. The surface water system is composed of streams, ponds, and control structures. The source of the main branch is in the Oak Ridges Moraine at an elevation of approximately 305 masl and the river flows southeasterly for 42 km to its outlet on Lake Ontario at the Municipality of Port Hope, Ward 1. A total of eight second order tributaries drain into the main river, of which the North Ganaraska is the largest one, joining the main branch at Canton. The characteristics of the major tributaries are listed in Table 3.2-9.

Table 3.2-9: Characteristics of the Ganaraska River Tributaries

Tributary	Drainage Area (km^2)	Main Channel Length (km)	Total Fall (m)	Average Gradient (m/km)
Main Branch	94.0	42.0	161	3.8
North Ganaraska River	70.5	22.5	121	5.4
Soper Creek	14.7	8.0	161	20.2
Burnham Branch	10.4	7.7	177	22.9
Cold Spring	12.7	11.8	192	16.2
Little Ganaraska	33.5	14.9	189	12.7
Quays Branch	20.6	12.7	121	9.5
Duck Pond	20.8	14.3	166	11.6

Starting in 1945, a total of five hydrometric stations have been operated in the Ganaraska River watershed (Table 3.2-10), however now only three stations are in operation. Map 3-13 shows the locations of the three active hydrometric stations, as well as the spot flow monitoring locations in the watershed.

Table 3.2-10: Historic and Current Hydrometric Stations in the Ganaraska River

Station	Location	Record year	Drainage Area (km^2)	Status
02HD001	Ganaraska River at Port Hope	1945 to 1951	N/A	Discontinued
02HD002	Ganaraska River Near Dale	1950 to 1975	N/A	Discontinued
02HD003	Bells Hill Road	1958 to Present	67.3	In Operation
02HD004	North Ganaraska branch Near Osaca	1958 to 1991, 1998 to Present	42.7	Discontinued and subsequently in operation
02HD012	Sylvan Glen Road	1976 to Present	232	In Operation

An annual river flow hydrograph has been developed based upon the recorded daily flow rates taken at the three hydrometric stations, all of which are above Dale Road (Figure 3.2-4). Since there are no major developments in the respective watershed area, these flow rates were considered an acceptable description of the flow regime of the larger watershed. Flows on the Ganaraska River are highest during the spring snowmelt. The majority of extreme flow events occur when ice cover conditions in the watershed provide a direct discharge for rainfall events.

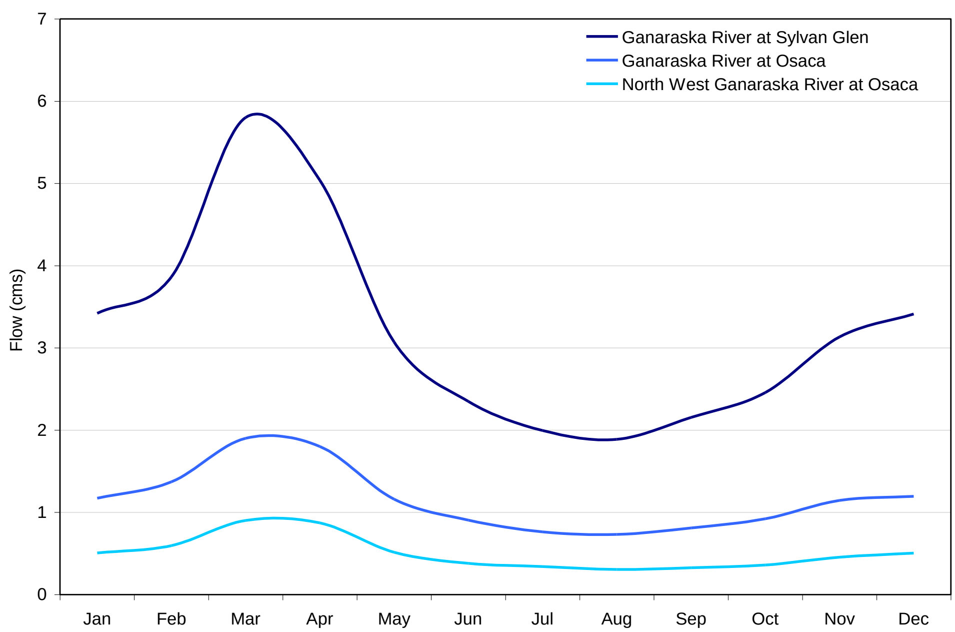


Figure 3.2-4: Annual Hydrograph for the Ganaraska River

Graham Creek Watershed

The Graham Creek watershed has a diamond-shaped basin with a total watershed length of 20.4 km and a drainage area of about 78 km^2. Its surface water system is composed of streams, ponds, and control structures. Graham Creek rises from west of Starkville at an elevation of approximately 205 masl. It flows in a northeast to southwest direction and empties into Lake Ontario. The watershed has a total fall of about 82 m with an average slope of about 2.5 m/km. The main channel follows a well-defined incised valley from Concession 3 in the

Municipality of Clarington south to Lake Ontario. There are two tributaries that drain into the main branch of Graham Creek. The characteristics of the tributaries are listed in Table 3.2-11.

Table 3.2-11: Characteristics of Graham Creek Tributaries

Stream/Tributary	Drainage Area (km^2)	Main Channel Length (km)	Total Fall (m)	Average Gradient (m/km)
Main Branch	55.7	27.1	82	2.5
Mulligan Creek	14.6	8.8	68	7.7
Crooked Creek	8.4	6.4	62	2.6

During the development of the water budget there were no stream hydrometric stations in the Graham Creek watershed, however a few spot flow measurements have been taken by Ganaraska Region Conservation Authority staff (Map 3-13).

Cobourg Creek Watershed and Midtown Creek Watershed

The Cobourg Creek watershed drains an area of 123.2 km^2 and the Midtown Creek watershed has a drainage area of 6.1 km^2. Both surface water systems are composed of streams, ponds, and control structures. Cobourg Creek rises on the Oak Ridges Moraine to the north at an elevation of approximately 330 masl. The stream flows from its origin in Concession 6 of the Township of Hamilton through till and sand plains to the outlet in Lake Ontario at Cobourg. Cobourg Creek has a total fall of about 181 m with an average slope of about 7.1 m/km. Two major tributaries drain into the Cobourg Creek. The Baltimore Creek is an eastern subwatershed of Cobourg Creek and has a drainage area of 45.3 km^2. The other tributary is the West Branch with a total drainage area of 43.7 km^2. The characteristics of major tributaries of Cobourg Creek are listed in Table 3.2-12.

Table 3.2-12: Characteristics of Cobourg Creek Tributaries

Stream/Tributary	Drainage Area (km^2)	Main Channel Length (km)	Total Fall (m)	Average Gradient (m/km)
Main Branch	133.8	27.6	181	6.6
West Branch	43.7	20.1	143	7.1
Baltimore Creek	45.3	8.8	62	7.0

Starting in 1982, flow data have been collected in the Cobourg Creek watershed from hydrometric stations. Table 3.2-13 describes the historic and current hydrometric stations in the Cobourg Creek watershed. Map 3-13 shows the locations of hydrometric stations and spot flow locations on Cobourg Creek.

Table 3.2-13: Hydrometric Stations in Cobourg Creek

Station	Location	Record Year	Drainage Area (km^2)	Status
02HD822	King Street Pump Station	1982 to 2003	N/A	Discontinued
02HD019	609 William Street	2003 to present	122	In Operation
02HD022	Telephone Road, 1 km west of County Road 18	2005 to present	34	In Operation
02HD020	4494 County Road 45, Baltimore	1999 to 2005	41	In Operation

An annual river flow hydrograph has been developed based upon the recorded daily flow rates taken at the three hydrometric stations, all of which are at or above William Street (Figure 3.2-5). These flow rates were considered an acceptable description of the flow regime of the larger watershed. Flows on Cobourg Creek are highest during the spring snowmelt. A higher flow at the William Street hydrometric station is representative of the large upstream drainage area.

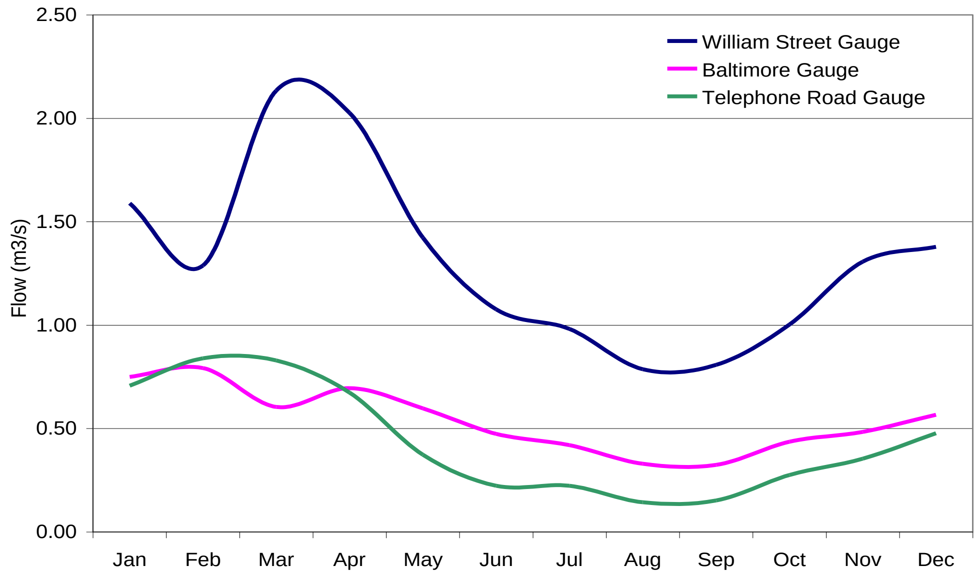


Figure 3.2-5: Annual Hydrograph for Cobourg Creek

Gages Creek Watershed

The Gages Creek watershed has a rectangular-shaped basin with a total drainage area of about 48.6 km^2. The creek follows a well-defined valley as it flows through the till plains in its upper reaches with a fairly steep weighted slope of 7.35 m/km. Its surface water system is composed of streams, ponds, and a few control structures. Gages Creek rises on the Oak Ridges Moraine in the Township of Hamilton at an elevation of approximately 320 masl. It flows in a north to south direction and empties into Lake Ontario in the eastern part of the Municipality of Port Hope, Ward 1. The length of its main channel is about 25.2 km and it has a total fall of about 147 m.

There are no active hydrometric stations in the Gages Creek watershed, however in 2004, temporary hydrometric stations were installed in the reach in the Dalewood Golf and Country Club. In addition, many spot flow measurements have been taken.

West Lake Ontario Watershed

The West Lake Ontario watershed has a triangular-shaped basin with a total area of about 117.3 km^2. Its surface water system is composed of streams, ponds, and control structures. The West Lake Ontario watershed is located southwest of the Ganaraska River watershed. It is composed of different streams that flow in a north to south direction and empty into Lake Ontario. Table 3.2-14 lists the major stream information in the West Lake Ontario watershed from west to east. All of these streams are located in the Lake Iroquois physiographic region, however the Port Britain watershed originates in the South Slope physiographic region. There are no active hydrometric stations in the West Lake Ontario watershed, however spot flow measurements have been taken (Map 3-13).

Table 3.2-14: Characteristics of Major Streams in the West Lake Ontario Watershed

Streams	Drainage Area (km^2)	Main Channel Length (km)	Total Fall (m)	Average Gradient (m/km)
Lovekin Creek	7.0	6.8	112	16.7
Bouchette Point Creek	22.9	10.8	133	12.3
Port Granby Creek	13.4	8.4	132	15.7
Chrysler Bluff Creek	1.3	2.5	70	28.1
Wesleyville Marsh Creek	2.1	2.7	85	31.5
Wesleyville Creek	8.4	5.4	115	21.3
Port Britain Creek	35.9	16.3	142	8.7
Brands Creek	9.6	6.3	77	12.3
Little's Creek	4.5	3.9	80	20.6

East of Gages Creek Watershed

The East of Gages Creek watershed has a square-shaped basin with a total area of 12.5 km^2. Its surface water system is composed of streams, ponds, and control structures. The East of Gages Creek watershed is located southeast of the Gages Creek watershed. It is composed of three unnamed streams that flow southerly to Lake Ontario. Table 3.2-15 lists the stream information in the East of Gages Creek watershed from west to east. There are no active hydrometric stations or spot flow measurements in the East of Gages Creek watershed.

Table 3.2-15: Characteristics of Streams in the East of Gages Creek Watershed

Stream	Drainage Area (km^2)	Main Channel Length (km)	Total Fall (m)	Average Gradient (m/km)
Hamilton Unnamed 9	3.2	3.7	50	13.8
Hamilton Unnamed 8	1.2	1.5	23	16.2
Hamilton Unnamed 7	6.9	5.0	63	12.8

Note: The stream naming system is produced by MNRF Peterborough District GIS.

East Lake Ontario Watershed

The East Lake Ontario watershed has a square-shaped basin with a total area of about 42.7 km^2. The East Lake Ontario watershed is located southeast of the Cobourg Creek watershed. Its surface water system is composed of small streams and ponds, which originate in the South Slope and Lake Iroquois physiographic regions and flow in a north to south direction to Lake Ontario. Table 3.2-16 lists the stream information in the East Lake Ontario watershed from west to east. There are no active hydrometric stations and only one spot flow measurement in the East Lake Ontario watershed (Map 3-13).

Table 3.2-16: Characteristics of Major Streams in the East Lake Ontario Watershed

Stream	Drainage Area (km^2)	Main Channel Length (km)	Total Fall (m)	Average Gradient (m/km)
Brook Creek	15.5	5.9	28	4.7
Massey Creek	5.9	8.2	47	5.7
Spicer Creek	11.6	10	110	11.0

3.2.6.2 CONTROL STRUCTURES

Many private water control structures and dams exist in the Ganaraska Region Source Protection Area. In addition, the Ganaraska Region Conservation Authority operates two dams for flood control purposes. Although these dams and water control structures exist, they do not significantly effect calculations used for water budgeting. Known water control structures are shown in Map 3-14.

A number of privately owned water control structures impound water for supply and recreation in the Ganaraska River watershed. Examination of 13 of these structures by Ganaraska Region Conservation Authority staff for general condition, use, location, and type showed that recreation, mainly swimming and fishing, was the most common reason for this type of water management. Farm ponds included in the group were of bypass and dugout construction, which have been recommended under assistance programs such as those sponsored by the Ministry of Agriculture, Food and Rural Affairs. Most of the agricultural ponds are used for stock watering and to a lesser extent for irrigation. There are many dams in the watershed with variable reservoir sizes and their effect on stream flows is considered to be influential only in local areas. The Ganaraska Region Conservation Authority operates the dam adjacent to the Garden Hill Conservation Area that supplies water for recreation and improved wildlife habitat.

Within the Cobourg Creek watershed, the two largest dams are Pratt's Dam located in the main branch and the Ball's Mill Dam located in Baltimore Creek. These dams have the potential to create minor negative effects on the flow of Cobourg Creek. The Orono Pond and dam is the only large control structure in the Wilmot Creek watershed, located on the Orono branch.

3.2.6.3 AQUATIC HABITAT

Most of the cold water streams in the Ganaraska Region Source Protection Area originate in the Oak Ridges Moraine and discharge into Lake Ontario or Rice Lake. Groundwater inputs into surface water are a dominant controlling factor of stream temperature (Power et al., 1999). Areas of groundwater discharge to a stream cause stream temperatures to be cooler than areas that do not experience discharge. Groundwater discharge areas provide places of refuge from warm temperatures, and coldwater fish tend to take advantage of these locations (Power et al., 1999). Water temperature and the presence or absence of groundwater discharge into a stream is an important factor in determining the presence or absence of fish species in a particular area of the stream (Power et al., 1999). For example, Brook Trout are generally found in the coldest reaches of Source Protection Area streams and utilize groundwater inputs for spawning.

Coldwater fish species require stream temperatures below 19 ^oC, cool water fish species between 19 ^oC and 25 ^oC, and warm water species above 25 ^oC. However, different life stages often require different temperatures. Although fish species can tolerate stream temperatures outside of their required range, the longer the stream temperature remains in an extreme stage, the more stress is applied to the individual fish or a particular fish species (Cushing & Allan, 2001).

Stream water temperatures were analysed and reported throughout the Source Protection Area. Summer water temperatures along main branches of the Source Protection Area rivers and streams show decreasing thermal regimes from warmer waters in lower reaches to colder waters in the headwaters. Based on the summer daily maximum thermal classification (Stoneman & Jones, 1996), the majority of sample sites in the Source Protection Area were classified as coldwater or cool water habitat, and they are illustrated on Map 3-15.

3.2.7 GROUNDWATER

Groundwater is water that is located beneath the ground surface in the spaces between soil particles or in fractures in rock. Groundwater used for drinking water supplies is withdrawn from aquifers. An aquifer is an underground layer of permeable material (high hydraulic conductivity) that can store and transmit useful quantities of water when tapped by a well. Aquifers typically consist of gravel, sand, sandstone, or highly fractured bedrock. Conversely, an aquitard is a layer of impermeable material (low hydraulic conductivity) that can store significant quantities of water but does not transmit it readily. (An aquitard is distinguished from an aquifer, which can neither store nor transmit water.) Aquitards typically consist of clay, silt, or unfractured bedrock. An aquifer that is overlain by an aquitard is known as a confined aquifer.

3.2.7.1 REGIONAL GROUNDWATER MOVEMENT

The understanding of the physiographic and geologic framework is important in identifying groundwater flow systems in the Ganaraska Region Source Protection Area. Water enters the groundwater flow regime through vertical infiltration of precipitation and snow melt to the shallow water table aquifer. Vertical infiltration of groundwater moves from shallow to deeper geologic units, and as lateral groundwater flow within these units. Based on the 3-D stratigraphic model produced by Sharpe et al. (1999), the geologic units identified in regional cross-sections were correlated to several aquifer and aquitard units (Earthfx Incorporated, 2006).

Table 3.2-17 provides a general description of typical stratigraphic and hydrostratigraphic units in the Ganaraska Region Source Protection Area watersheds, however local heterogeneities within the glacial overburden deposits could affect the sequence and thickness of these units. This is particularly noticeable in the Oak Ridges Moraine where alternation of till, sand, and gravel deposits creates more complicated stratigraphic units than what is provided in the table below. For example, based on data from the Ministry of the Environment and Climate Change Water Well Record Database on several well logs (in the area east of Wilmot Creek), the lower sediments package was found to be more complicated than what is provided in the table. This was also supported by data and well logs from drilling of several monitoring wells near the Orono municipal wellfield (Jagger Hims Ltd., 2003a). Data suggest that the Scarborough Formation does not exist in the area east of the Wilmot Creek watershed and more complicated lower unit(s) with different thicknesses and textures overlie the fractured bedrock unit.

Table 3.2-17: Stratigraphic/Hydrostratigraphic Units

Stratigraphic / Hydrostratigraphic Units Regional Model (Based on 5 layers)	Stratigraphic / Hydrostratigraphic Units Core Model (Based on 8 layers)	Stratigraphic / Hydrostratigraphic Units Ganaraska Region Source Protection Area Watersheds (Based on the Area Studies)	Description
Halton Till	Halton Till	Halton Till (Upper Glacial Unit)	Aquitard
Oak Ridges Moraine Complex	Oak Ridges Moraine Complex	Oak Ridges Moraine Complex	Aquifer
Newmarket Till	Newmarket Till	Bowmanville Till (Middle Glacial Unit)	Aquitard
Lower Sediments	Thorncliffe Formation	Clarke Deposits	Upper Aquifer
	Sunnybrook Formation	Port Hope Till	Aquitard
	Scarborough Formation	Scarborough Formation or Equivalent	Lower Aquifer
Bedrock	Fractured (Weathered) Bedrock	Fractured (Weathered) Bedrock	Aquifer
	Unweathered Bedrock	Unweathered Bedrock	Aquitard

Data Source: modified after Earthfx Incorporated (2006)

Table 3.2-17 was modified from a detailed geological correlation table provided in the Oak Ridges Moraine groundwater modeling document (Earthfx Incorporated, 2006). The names of the geologic and hydrostratigraphic units provided in the Ganaraska Region Source Protection Area watersheds were taken from specific studies completed in the area (e.g., Singer, 1981; Gwyn, 1976; Brookfield et al., 1982) as described in the geologic correlation table of the Oak Ridges Moraine groundwater modeling document (Earthfx Incorporated, 2006). Some of these geologic units were named after the local communities (Clarke and Port Hope) and are adopted in this report.

As described by Brennand et al. (1997), overburden deposits in the region play an important role in the regional drainage and recharge patterns; bedrock valleys do not necessarily control creek drainage and groundwater flows in the area. As in other regions of southern Ontario, the thickness of the overburden dictates the distribution of the overburden and bedrock aquifers and the specific importance of each type of deposit as a source of water supply. The till units have relatively low hydraulic conductivity and infiltration characteristics, and generally function as aquitards. Higher rates of infiltration generally occur in the more permeable sandy and coarse-grained deposits associated with the glacial lake and moraine sediments.

The physiographic regions (landforms) described above provide the framework for interpreting hydrostratigraphic conditions in the Ganaraska Region Source Protection Area watersheds. The regional hydrostratigraphic units observed include the following:

- Glacial Lake Deposits (Lake Iroquois Deposits) comprised of silt, sand, and gravel that form a discontinuous unconfined aquifer at surface
- Glacial till aquitard comprised of Halton Till (Upper Glacial Unit)
- Oak Ridges Moraine sediments consisting of ice-contact and outwash deposits that form an aquifer/aquitard complex

- Glacial till leaky aquitard comprised of Bowmanville Till (Middle Glacial Unit); this is equivalent to Newmarket Till found to the west of the Ganaraska Region Source Protection Area
- A complex and relatively thick-layered unit of Lower Sediments comprised of sand and gravel aquifer (Clarke Deposits), and aquitard of silt till and clayey silt (Port Hope Till), and a deep coarse sand and gravel aquifer; this could be equivalent to Scarborough Formation
- Fractured limestone and shale that form the bedrock aquifer
- Unweathered bedrock limestone of the Lindsay Formation from the Simcoe Group that forms an aquitard.

To examine the regional geology in depth, two regional geologic cross-sections were prepared using Viewlog software and Ganaraska Region Conservation Authority data (clipped data from the YPDT-CAMC regional data dated 2006) based on the Ministry of the Environment and Climate Change Water Well Record Database. The location of these cross-sections is shown in Figure 3.2-6. The water well locations with section offset distances of 250 m and 140 m, respectively, are also shown on Figures 3.2-7 and 3.2-8. Cross-section offset distance is the maximum distance away from the cross-section line on both (left and right) sides. The eight stratigraphic layers shown in these cross-sections resemble the hydrostratigraphic layers described above and correlate with the eight hydrostratigraphic layers of the core groundwater model for the Oak Ridges Moraine (Earthfx Incorporated, 2006). The simulated water table of the regional groundwater model is also shown in the cross-sections.

While stratigraphic data sets from the Ministry of the Environment and Climate Change Water Well Record Database are not of the highest quality, the data can be used to provide an indication of bedrock topography and the general hydrostratigraphic composition of the area. A review of the cross-sections indicates that the overburden consists of approximately 140 m of mostly sandy silt and till materials sloping south toward Lake Ontario (cross-section 1–1’). Cross-section 1-1’ reveals the presence of a till zone in the north (Halton Till) where the cross-section intersects the southern flank of the Oak Ridges Moraine. The cross-sections also show that the Bowmanville Till (Middle Glacial Unit) has a regional extent. In the south, southwestern parts of the watersheds, the recent Lake Iroquois Deposits (Proglacial Lake Deposits) cap the Bowmanville Till.

The Oak Ridges Moraine along the northern boundaries of the Ganaraska Region Source Protection Area acts as a topographic divide and as a source of baseflow for the Ganaraska River, Wilmot Creek, and other watersheds. A small number of wells have been drilled in the central parts of the moraine and a few of these wells are deep enough to provide a full picture of the geologic profile therein. Cross-section 2–2’ shows that several wells are screened in the Clarke Deposits that represent an important water supply aquifer.

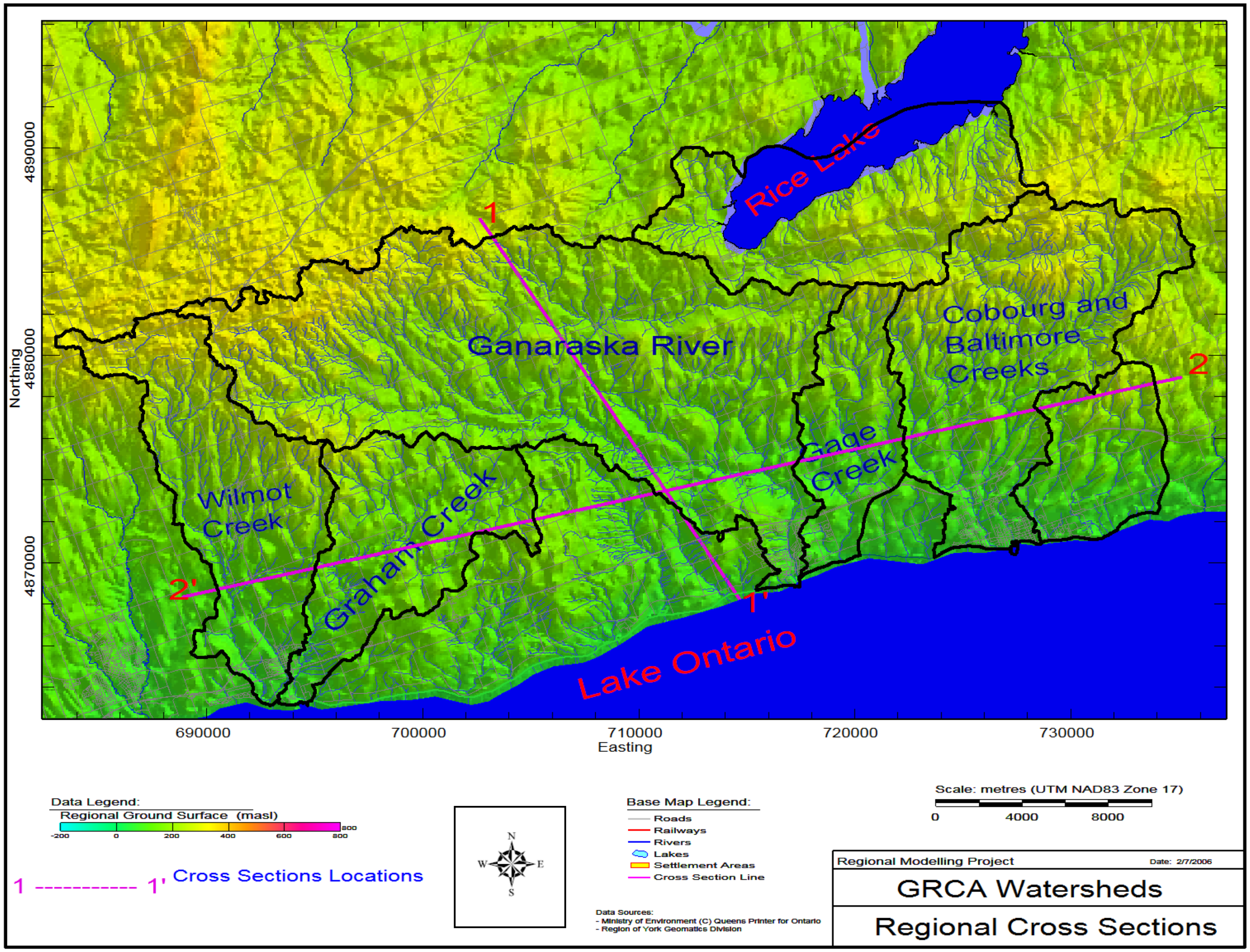


Figure 3.2-6: Cross-section 1 – 1' and 2 – 2' Location

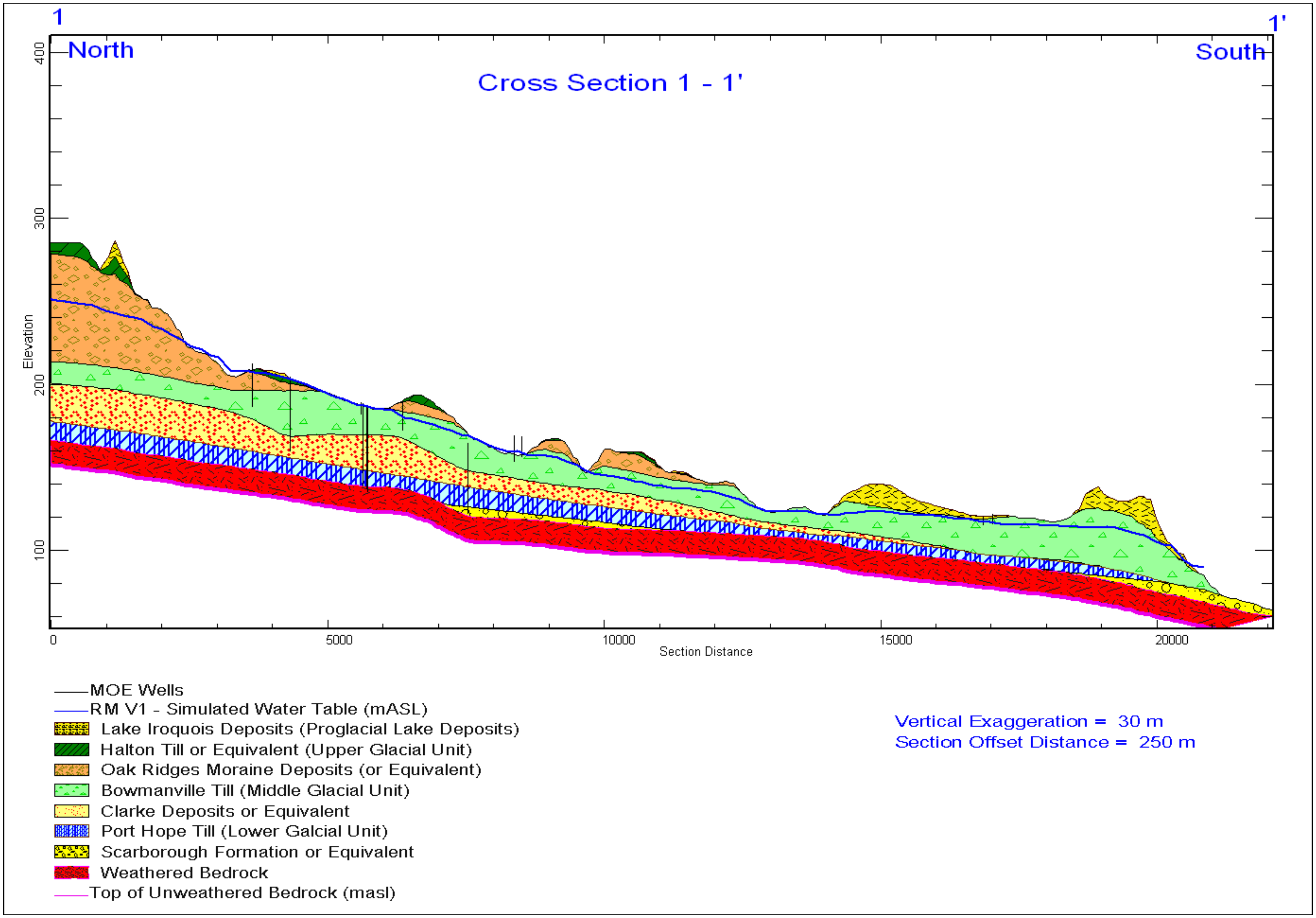


Figure 3.2-7: Cross-section 1 – 1'

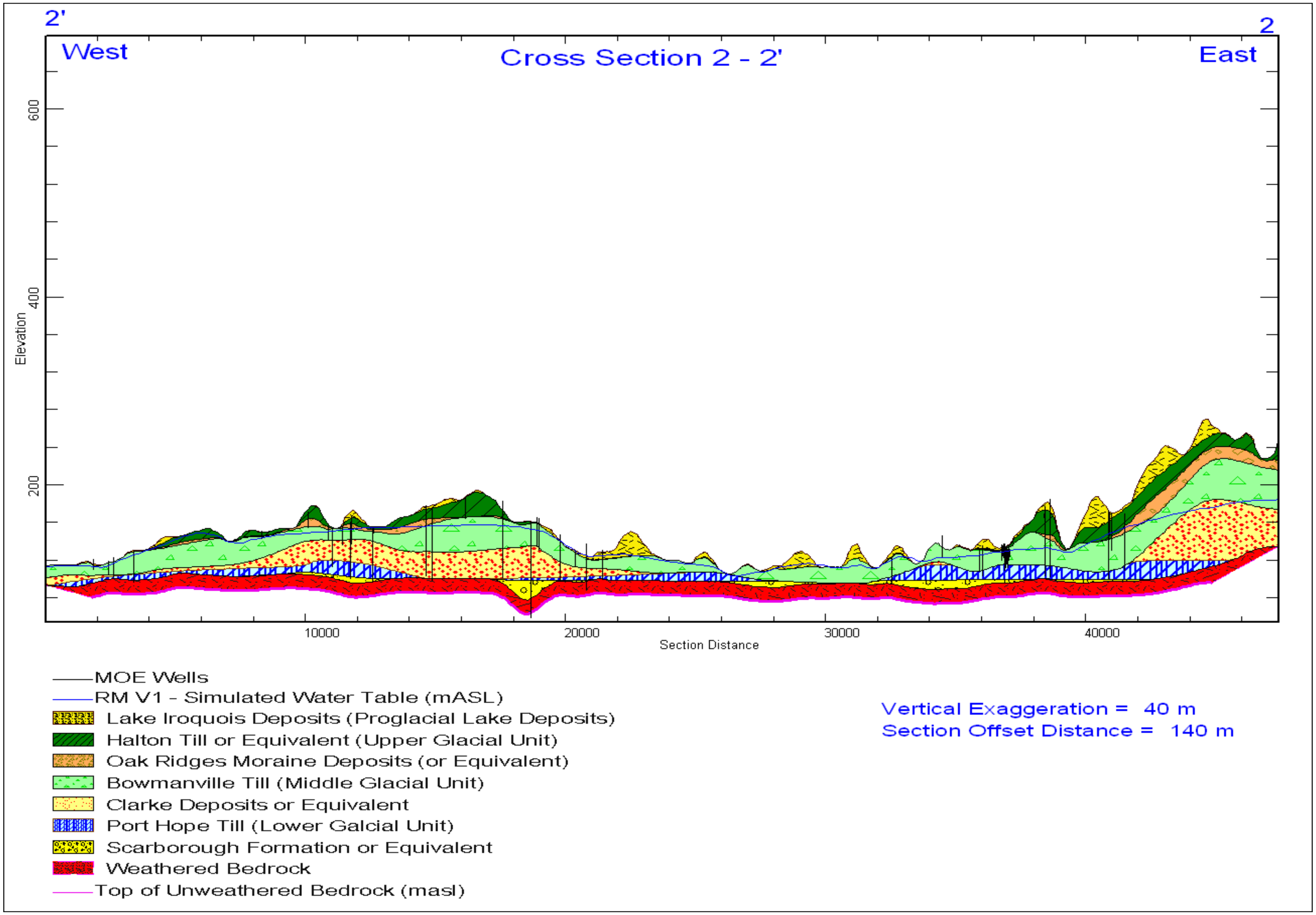


Figure 3.2-8: Cross-section 2 – 2'

3.2.7.2 GROUNDWATER RECHARGE AREAS

Recharge is the process by which groundwater is replenished and involves the vertical infiltration of water through the soil and subsoil deposits to the saturated zone. The major sources of recharge in the area are rain and snowmelt. The amount of groundwater recharge at a particular area mainly depends on surficial soil composition and topography. For example, hummocky areas in the north are important topographic features that allow water to infiltrate rather than ending up as surface runoff. Hummocky topography, which is mainly located in areas characterized by course and sandy surficial materials, act like sinks and provide important locations for rainfall and snowmelt to infiltrate. Generally, recharge in Ganaraska Region Source Protection Area watersheds is irregularly distributed in time and space based on specific climatic conditions and local geology.

The vertical movement of groundwater in the northern upland of the Moraine is normally downward. This part of the Moraine forms much of the recharge area in the Ganaraska Region Source Protection Area watersheds. The primary influence on the recharge distribution used in the Oak Ridges Moraine regional groundwater model was assumed to be surficial geology as mapped by the Geological Survey of Canada (Earthfx Incorporated, 2006). The spatial distribution of applied recharge to the regional model in the Source Protection Area is shown on Map 3-16. Recharge rates were highest over the Oak Ridges Moraine due to the sandy soils and hummocky topography (360 mm/yr) and lowest in areas covered with lake sediments or organic deposits (60 mm/yr). As indicated in the Trent Conservation Coalition Municipal Groundwater Study (Morrison Environmental Ltd., 2004a), recharge rates in the relatively permeable Glacial Lake and Oak Ridges Moraine deposits are estimated to be in the order of 250 to 350 mm/yr. Recharge rates in the till plains of the South Slope, and the glaciolacustrine clays and silts, were estimated to be 100 mm/yr or less.

The contribution of recharge depends on soil composition and topography. There are many factors affecting the distribution of recharge rates (Figure 3.2-9). These include the following:

- The presence of hummocky topography (Map 3-17) and thick overburden mainly in the northern part of the Source Protection Area. The higher topographic areas in the northern and northeastern parts of the Source Protection Area provide a significant groundwater recharge area.
- The presence of the course sand and gravel surficial materials in the north.
- The presence of sand and gravel bars as well as beach terraces of the Upper Lake Iroquois Plain provides for moderate recharge.
- The distribution of the silty and clayey till material in the central and southern portions of the watershed limits recharge.
- The Ganaraska Forest in the northern part of the Ganaraska River watershed plays a role in increasing groundwater recharge by providing shade, which in turn minimizes direct evaporation and lengthening snow melting periods.
- Similar to the Ganaraska Forest, the Northumberland County Forest in the headwaters of Cobourg Creek plays a role in increasing groundwater recharge.

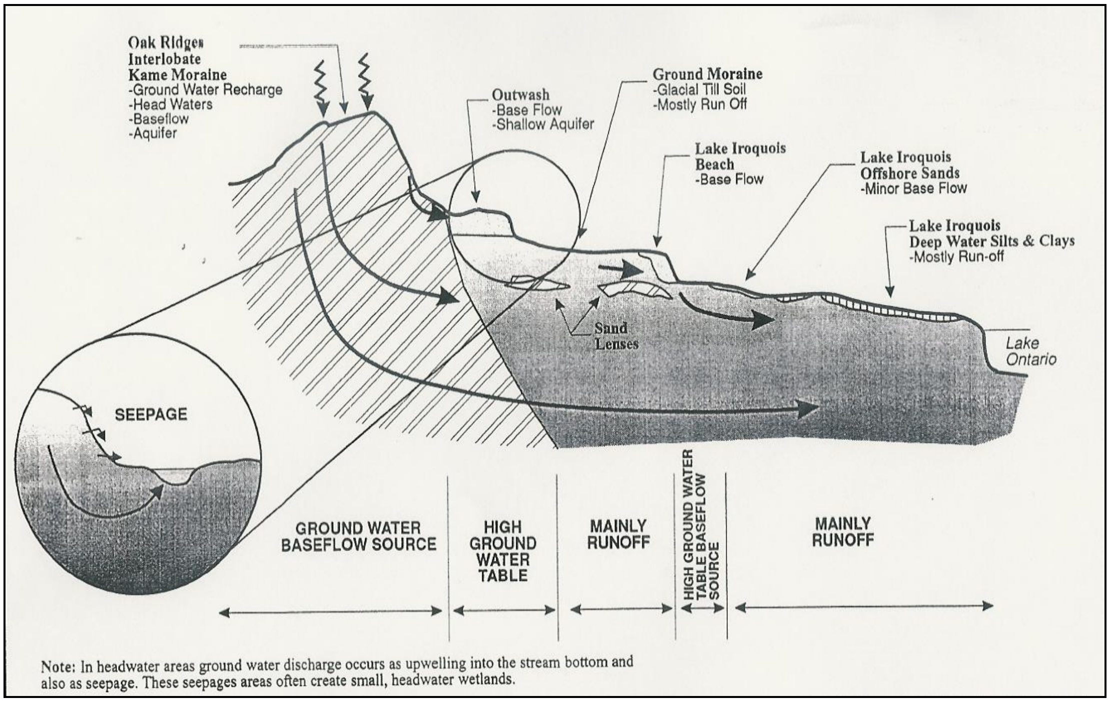


Figure 3.2-9: Functional Terrain Unit's Cross-section (Gartner Lee Ltd. et al., 1995)

3.2.7.3 GROUNDWATER FLOW DIRECTIONS

The movement of groundwater in the area is a subtle reflection of local topography and drainage as interpreted from the Ministry of the Environment and Climate Change Water Well Records. The lateral movement of groundwater in the shallow aquifers in the Source Protection Area occurs from topographic highs to topographic lows. The dominant regional groundwater flow direction is southerly, off the Oak Ridges Moraine toward the Lake Ontario basin with a westerly component in some local areas as inferred from Map 3-18. Map 3-18 shows the regional model simulated water level elevation of the first aquifer encountered across the Source Protection Area (simulated depth to water table). The map also shows the regional groundwater level contour elevations (in masl) calculated from the Ministry of the Environment and Climate Change Water Well Records database.

As groundwater flows downwards in an aquifer, its upper surface slopes in the direction of flow. This slope is known as the hydraulic gradient and is determined by measuring the water elevation in wells tapping the aquifer. For confined aquifers, the hydraulic gradient is the slope of the potentiometric surface. Map 3-19 shows the above-noted regional potentiometric surface, which represents groundwater levels in wells screened in confined aquifers in the Ganaraska Region Source Protection Area. For unconfined aquifers, it is the slope of the water table. Fluctuations of the water table were noted in the shallow aquifers (Singer, 1974). Generally the mean groundwater hydraulic gradient in the western part of the Source Protection Area is 0.015 (dimensionless) compared to a mean topographic gradient of 0.017 (Singer, 1981). This indicates that the water table in the area follows the topography, at least on a broad scale.

The deep regional aquifers are primarily recharged in the northern portion of the watersheds at the Oak Ridges Moraine. The deep groundwater then flows south to be intersected by streams, rivers, and Lake Ontario, or groundwater wells. The deep aquifers are generally under confined conditions, resulting in high groundwater pressure heads, and some wells in the western (Wilmot Creek) and eastern (Cobourg Creek) watersheds were found to be flowing artesian wells.

3.2.7.4 SURFACE WATER AND GROUNDWATER INTERACTIONS (GROUNDWATER DISCHARGE)

In many of the Ganaraska Region Source Protection Area watersheds, groundwater discharge tends to occur in the immediate vicinity of surface waterbodies. These discharge zones are often located within a short distance of the high water mark around surface water features, particularly in areas where there is a sharp topographic change associated with the stream bank or lakeshore. Another consideration in determining the significance of groundwater recharge and discharge areas is the hydraulic conductivity of the surficial materials, either soil or rock. In areas where the surface materials are less permeable, infiltration or discharge is restricted. Thus, areas of till or clay permit less infiltration and similarly less discharge.

A map of potential discharge areas within the Oak Ridges Moraine watersheds with an intensive discussion was provided by the YPDT-CAMC groundwater regional modeling initiatives (Earthfx Incorporated, 2006). Potential discharge locations in the watersheds were clipped from the regional YPDT-CAMC map and provided in Map 3-20. Potential discharge areas were identified by comparing the simulated water level elevation of the first aquifer encountered in the Ministry of the Environment and Climate Change Water Well Record Database and the ground surface topography as shown by the digital elevation model (DEM) of the watersheds. Whenever the elevation of the water table occurred above the ground surface elevation (i.e., the DEM) in any area, that area was flagged as a potential discharge location. This method is a preliminary stage investigation and needs to be verified with additional field observations or other methods. The colour scale in Map 3-20 refers to the possibility or likelihood of the event (i.e., high or low possibility of discharge condition in an area). Potential discharge areas can also be used to infer the depth to water table (shallow vs. deep water table) of the first aquifer encountered at different locations in local watersheds. This can only be valid with an assumption that all of the aquifers tapped by wells in the area are unconfined water table aquifers.

Potential discharge and spring areas in the Oak Ridges Moraine were investigated by Dyke et al. (1997) through the use of thermal air imagery that mapped groundwater discharge areas using the thermal difference between discharging groundwater (4 to 9 °C) versus air temperatures on a winter night (-6 to -15 °C). The results showed groundwater discharge conditions on the flank of the Oak Ridges Moraine as being responsible for flow in the headwaters of the majority of the streams, creeks, and rivers, including the Ganaraska River and its tributaries (Map 3-21).

Data collected from observation wells and analyzed in a number of hydrogeological studies conducted in the area (Funk, 1977; Singer, 1974 and 1981; Jagger Hims Ltd., 2003a and 2005; Conestoga-Rovers & Associates, 2004; CPG-Franz, 2004) have indicated that water table levels decline or rise in time mainly as a result of the net effect of groundwater recharge and discharge processes. The observed water table fluctuations at different monitoring wells in the area (including Provincial Groundwater Monitoring Network wells) could be described as having two peaks and two recession patterns, which is remarkably similar to the seasonal runoff variation process. The two peaks occur during the spring (high peak) and the fall (moderate peak). The two recessions occur during the winter (short-lived) and the summer (steeper initially and longer-lived).

Investigations of groundwater and surface water interactions have been completed in the Bowmanville, Soper, and Wilmot Creek drainage basins, just west of the Ganaraska River Watershed (Funk, 1977; Singer, 1981). Results at numerous monitoring wells throughout these drainage basins showed that away from the river valleys groundwater recharge conditions dominate the till plain and the lacustrine clay and sand plain, however flowing artesian wells were noted along the remnants of the Lake Iroquois shoreline (Funk, 1977; Singer, 1981). Flowing artesian wells are most often found in stream valleys with groundwater discharge to streams and rivers (Singer, 1981). This indicates that groundwater continues to discharge to surface water throughout these watersheds and, in particular, in the middle section where glacial lake deposits of sand and gravel are exposed to the surface. Several studies have noted that as the groundwater in the deep aquifers discharge to surface along the Lake Ontario shoreline, numerous groundwater fed marshes and streams have formed in the low lying areas along Lake Ontario (Singer, 1974). Therefore, whether through streams and rivers or directly from the ground, all groundwater in the watersheds ultimately finds its way to Lake Ontario.

Details of the Wilmot Creek watershed describe trends of groundwater discharge similar to other Oak Ridges Moraine headwater watersheds of the Ganaraska Region Source Protection Area. The area of highest groundwater discharge occurs in the headwater streams of the watershed. The headwater stream catchments contribute more than 50% of the net discharge. In these stream segments baseflow discharge originates at an elevation between 275 to 300 masl and increases towards the east (Hinton, 2005). Groundwater discharge is high to very high in the headwater tributaries and likely occurs both as flow through the sand and gravel streambeds and as discharge from groundwater seeps adjacent to the streams (Hinton, 2005). The high groundwater discharge in these streams is explained by high recharge in the coarse moraine and river sediments in the upslope areas and the drop in elevation along the south slope of the Oak Ridges Moraine that provides a natural drainage point for discharge.

In Wilmot Creek the second most important area of groundwater discharge (26%) occurs along the watershed's main valley below the former Lake Iroquois shoreline. Survey results indicated large increases in baseflow between Concessions 3 and 5 along Wilmot Creek, Orono, and Stalker Creeks near their confluences (Hinton, 2005). The drop in elevation from the till plain and the lower elevations of the valley compared to the adjacent lake sediments make the valley the preferred location of groundwater discharge. Although it is likely that some of the discharge originates from the surrounding area (particularly the sandy sediments from upper Lake Iroquois Plain), it is possible that some of the groundwater discharged in this area originates as recharge in the Oak Ridges Moraine and reaches the lower watershed as deeper groundwater flow. This is confirmed by the presence of Bowmanville Till in the surrounding area as an obstacle limiting local recharge.

Discharge areas in creeks not originating on the Oak Ridges Moraine are limited due to the fact that the permeability of overburden deposits decreases as one descends into the till and clay areas in the south portions of the watershed. In some areas overburden thickness is relatively thin. In these areas most discharge occurs as runoff with coldwater characteristics based on discharge from Lake Iroquois beach formations or where valley systems cut into higher-yielding aquifer units.

3.2.7.5 PROVINCIAL GROUNDWATER MONITORING NETWORK

A number of recent studies suggest that groundwater resources are under increasing stress from factors that affect both water quality and quantity (Ministry of the Environment and Climate Change, 1999). These studies have also recommended that the Ministry of the Environment and Climate Change implement long-term, integrated groundwater monitoring programs to address these issues. In 2001, the Ministry of the Environment and Climate Change initiated the development of a Provincial Groundwater Monitoring Network (PGMN) in partnership with a number of Conservation Authorities across the province. The Provincial Groundwater Monitoring Network consists of collecting water level and water quality data from a number of selected and instrumented monitoring wells within each Conservation Authority.

Provincial Groundwater Monitoring Network monitoring wells were selected to monitor ambient conditions in shallow and deeper aquifer systems. To date, 17 wells in the Ganaraska Region Conservation Authority have been incorporated into the network, 15 of which are instrumented with automated water level monitoring and telemetry equipment, and 2 are instrumented with automated water level monitoring and manual download equipment. The location of the Provincial Groundwater Monitoring Network wells is shown on Map 3-22 and details of the wells are discussed in Chapter 2. Data generated from this network provide supporting background information for such subjects as drought response, scientific modeling, water policy development, and land use planning.

3.2.8 WATER USE

Anthropogenic water uses (withdrawals or outputs) are an important part of any water budget. In some watersheds, significant losses of water can result from groundwater and/or surface water takings. In some cases this water is consumed (e.g., water bottling plant) and in other cases it is returned to the watershed (e.g., wastewater treatment plant). The water uses considered in this conceptual water budget include permitted uses (withdrawals taken under a Permit to Take Water), unserviced residential uses that do not require a permit, municipal water supplies, agricultural, commercial, industrial, dewatering, and ecological water needs.

Current water takings were evaluated using existing water use data and a variety of metrics and coefficient-based methods that estimate water use by means of enumeration data. Although it is likely that cumulative long-term water use has affected the current state of water resources, historical water use is not evaluated in this conceptual water budget because historical data were not readily available in existing inventories. Further, it is difficult to evaluate the effects of historical water use on water resources given the broad range of effects of climate change.

3.2.8.1 PERMITS TO TAKE WATER

Water users that take more than 50,000 litres per day (L/d) are required to obtain a Permit to Take Water (PTTW), with the exception of agricultural livestock uses. Individual domestic households and other common residential users are also not required to obtain a permit. The Ministry of the Environment and Climate Change maintains the Permit to Take Water database that contains a wealth of information, including permit holder, location, permitted purpose of water use, expiry date, maximum permitted rate of water taking, and maximum number of days per year taking. Due to the many limitations of the permit database, staff of the Ganaraska Region Conservation Authority filtered the data to ensure the best available data was utilized (Ganaraska Region Conservation Authority, 2007). The Permit to Take Water data and water well records indicate that surface water and groundwater are used for public, commercial, agricultural, industrial, irrigation, and domestic purposes. At the time of conceptual water budget preparation there were 67 active permitted water taking locations (Map 3-23) as well as historic expired surface water and groundwater permits.

Initial data analysis resulted in grouping the permitted water taking into five major use groups. These categories are agricultural, commercial, industrial, drinking water supply, and dewatering, shown in Table 3.2-18. Dewatering permits are normally issued for a shorter period or as temporary permits. The data analysis also revealed that several permits have more than one taking site. The multi-site permits are mainly surface water taking where the permit holders are allowed to take from different locations for reasons such as access, low flow conditions, and/or seasonal demands.

Table 3.2-18: Active Permits to Take Water

General Purpose	Number of Active Permits	Source of Water	Total Maximum Takings (L/day)[1]
Agriculture	5	Surface Water	6,889,836
	2	Groundwater	8,231,161
Commercial	7	Surface Water	16,941,704
	4	Groundwater	9,214,707
Industrial	2	Surface Water	2,359,230
	3	Groundwater	4,583,817
Water Supply	5	Surface Water (Lake Ontario)	119,978,600
	7	Groundwater	8,794,060
Dewatering	1	Surface Water	7,200,000

1 Data Source: Permit to Take Water Database

Provincial guidance recommends that estimates of water demand are key aspects of all tiers in the water budget and water quantity risk assessment (Ministry of the Environment and Climate Change, 2007). Water demand refers to the ratio of estimated consumptive water demand to the difference between groundwater or surface water source supply and water reserve (Ministry of the Environment and Climate Change, 2007). The water source supply refers to the total amount of water flowing through a surface water or groundwater system. Although the water demand estimation is initially conservative and becomes more refined through the process, the estimate of water demand always refers to consumptive water use. Consumptive water use is the net amount of water that is locally removed from a surface water or groundwater system and is not locally returned in a reasonable time period. However, calculations of consumptive water use are a difficult task and are only possible to estimate through assumptions and normalizations. The provincial recommended approach for estimating consumptive water demand will be used in the Tier 1 water budget.

3.2.8.2 PRIVATE WATER SYSTEMS

The majority of water wells in the Source Protection Area are private and used as domestic water supply sources. These domestic wells are located throughout the area, except where municipal water systems are available (Map 3-24). There are also some private surface water intake systems in the area (mainly small and non-Permit to Take Water systems). These systems serve much of the seasonal population in the area, however users of these systems likely use bottled water for drinking and cooking since most of these small surface water systems often do not incorporate treatment.

Many wells supply water to permanent residents and a small number of cottages and summer homes in rural areas. A few wells in the area are used for agricultural purposes, including livestock watering, irrigation, and domestic use on farms. In addition, a small number of wells are used for commercial and industrial purposes. Municipal/public water supplies are located in urban centres and larger rural communities as described below. There are also private surface water intake systems in the area used mainly for irrigation and livestock watering.

Singer et al. (2003) indicated that, within the Source Protection Area a total of 3,916 overburden wells have been identified compared to 864 bedrock wells, indicating that the overburden is more important as a source of private water supply wells. Of the overburden wells, 580 (14.8%) have no specific capacity data, 375 (9.6%) have specific capacities of less than 1.0 litre per minute per metre (L/min/m), 1,307 (33.4%) have specific capacities between 1.0 and 5.0 L/min/m, 615 (15.7%) have specific capacities between 5.0 and 10.0 L/min/m, 853 (21.8%) have specific capacities between 10.0 and 50.0 L/min/m, and 186 (4.7%) have specific capacities more than 50.0 L/min/m (Singer et al., 2003). Specific capacity is defined as the amount of water pumped from a well divided by the drawdown in the well and is a measure of well productivity.

Although most wells are domestic, the population served and volume pumped is small. Private wells are an integral component of the rural infrastructure, however the relatively widely dispersed nature of the wells suggests that the water taking by these systems has little impact on the overall hydrogeologic regime in the area. Morrison Environmental Ltd. (2004a) has provided a summary of water use from private wells in the Township of Hamilton and the Municipality of Port Hope (Table 3.2-19). It was estimated that a population of about 13,407 uses about 2,681 m^3/day (or an average consumption of about 200 L/day/ person (44 imperial gallons/min)). Compared to the province wide consumptions range of 270 to 450 L/day/person (Morrison Environmental Ltd., 2004b), these consumption values seem low. The percentage of the water returned from these private well usages was not estimated.

Table 3.2-19: Private Well Water Use Summary in the Township of Hamilton and Municipality of Port Hope

Municipality	Total Population[1]	Private Well Use	
		Estimated Population Using Private Wells*	Private Well Water Use (m^3/d)
Port Hope	15,605	3,887	777
Hamilton	10,140	9,520	1,904

Data Source: Morrison Environmental Ltd., 2004b

Note: Population using private wells is calculated as Total Municipal Population – Population Served by Municipal Groundwater and/or Surface Water System. Where no data were available and there were no known surface/groundwater systems, the entire population was assumed to be serviced by private wells.

[1] 2001 census population

3.2.8.3 MUNICIPAL WELLS

There are three municipal well systems within the Ganaraska Region Source Protection Area: Creighton Heights Water Supply System, Camborne Water Supply System, and Orono Drinking Water System. Map 3-25 shows the location of these wells. All of the municipal wells have active Permits to Take Water (Table 3.2-20). There are several aquifer characterization and wellhead protection studies that have been completed for these wells in addition to monitoring data and reports (Jagger Hims Ltd., 2003b and 2007; Morrison Environmental Ltd., 2004c and 2004d). Chapter 5 provides additional information about the three municipal wells.

Table 3.2-20: Municipal Groundwater System Water Takings

Name of Municipal Groundwater System	Camborne Water Supply System	Creighton Heights Water Supply System	Orono Drinking Water System
Maximum Daily Permitted (m^3/d)	Between 518.4 (both Wells Flowing Artesian) and 700 (both Wells Pumping)	1,468.8	1,309
Average Daily Flow (m^3/d) (2003 Data)	60	248	376
Maximum Daily Flow m^3/d) (2003 Data)	141	731	718

Note, all information obtained during the preparation of the conceptual water budget.

3.2.8.4 MUNICIPAL SURFACE WATER INTAKES

There are three municipal surface water intakes and water treatment plants within the Ganaraska Region Source Protection Area: Cobourg Water Treatment Plant, Municipality of Port Hope Water Treatment Plant, and Newcastle Drinking Water System (Map 3-25). These plants serve the larger urban centers and take water from Lake Ontario under a Permit to Take Water. Since water is pumped from Lake Ontario, the water demand from the intakes was not considered in the water budgets for the watersheds of the Ganaraska Region Source Protection Area. Chapter 4 provides additional information about the three Lake Ontario intakes.

3.2.8.5 AGRICULTURAL WATER USE

Based on the Permit to Take Water database the total maximum takings permitted to agricultural use in the Ganaraska Region Source Protection Area is 15,120,997 L/d. Data suggest that vegetable crop irrigation and livestock watering are the largest agricultural water uses. Other activities such as field irrigation and irrigation of nursery stock and related activities make up the remainder of the agricultural water use in the area.

Tobacco farming was once a major activity throughout most of the watersheds. Recommendations in the Ontario Department of Planning and Development (1957) irrigation water supply report were intended to improve management of small sub-watersheds for irrigation and were particularly directed towards correcting moisture deficiencies in the tobacco growing areas of central Hope Township (currently Ward 2, Municipality of Port Hope). However, only one tobacco farm remains in the Source Protection Area watershed today.

3.2.8.6 COMMERCIAL WATER USE

Commercial water use normally includes groundwater extraction for water bottling facilities, the operation of retail bait operations (where unchlorinated water is needed), resorts, hotels, motels, as well as surface water pumping for sport fishing/hunting clubs and farms, and golf courses irrigation. Commercial water uses in the Source Protection Area include several subcategories such as water bottling, golf course irrigation, and water used to maintain recreational facilities. Commercial water use occurs throughout the area and many operations do not take sufficient water to warrant a permit.

Some popular recreational activities are dependent on the availability of a body of water or flowing stream. These activities include swimming, boating, sailing, water skiing, skin diving, and fishing. The quality of water required for these activities is normally dependent upon sufficient quantity to sustain flows for replenishing water in reservoirs and for diluting pollutants entering streams. The majority of these water recreational activities are concentrated in Rice Lake area and other major on-line ponds. There are also some seasonal recreational activities dependent on water such as skiing at Oshawa Ski Club, which is located in the upper Ganaraska River watershed. The Club has active surface water taking permits to make snow during the operational season.

3.2.8.7 INDUSTRIAL WATER USE

Water used by industry varies with the product being manufactured or the commercial activity. The main industrial activities in the area are related to small manufacturing and food processing operations. There are many small industrial operations that take less than 50,000 L/day thus an accurate estimate of industrial/ commercial use is difficult. However based on the 2005 Permit to Take Water data there are five water-taking sites for industrial use in the area mainly for industrial support activities such as aggregate washing and food processing. In addition, many industries use water from municipal supplies such as Lake Ontario.

3.2.8.8 DEWATERING PERMITS

Water taking permits issued for dewatering are for construction and cooling purposes. Examples are permits issued for gas pipelines layout in high water table areas and cooling of the Cameco Corporation uranium conversion facility in Port Hope. Dewatering permits are normally issued for a shorter periods or are temporary, except the cooling permits where the process involves water circulation, where permits are normally issued for longer periods.

3.2.8.9 ECOLOGICAL WATER NEED

Water, either surface water or groundwater, plays an important ecological role in the natural environment. For instance, discharge of groundwater to surface water bodies is a significant component of baseflow in most perennial streams, which helps to lower surface water temperatures, and is integral to sustaining aquatic habitat in many watercourses. In areas with relatively high water tables, groundwater discharge also plays a role in maintaining wetlands. Groundwater discharge locations are important ecological areas. Most of the Source Protection Area watersheds are cold water fisheries habitats and groundwater discharge locations are an integral part of these habitats.

3.2.9 CONCEPTUAL WATER BUDGET RESULTS

Water budgets were calculated for each of the eight subwatersheds defined for the conceptual water budget. Since the conceptual water budget is intended to give a general overview of water movement through the watershed, the components of the water budget (i.e., inputs and outputs) were evaluated on the basis of long-term annual average conditions. Conceptual water budgets were calculated separately for the eight watersheds in the Ganaraska Region Source Protection Area that drain directly to Lake Ontario. These were developed using 35 years of data (1968 to 2003) and are presented in Table 3.2-21 and Figure 3.2-10. The results have not been subjected to statistical analysis, but they were used to inform the Tier 1 water budget process.

Table 3.2-21: Summary of Water Budget Calculations for Watersheds Draining to Lake Ontario

Watershed	Drainage Area (km^2)	Precipitation [(1)] (mm/yr)	ET [(2)] (mm/yr)	Infiltration [(3)] (mm/yr)	Runoff (mm/yr)
Wilmot Creek	99	880	586	165	129
Ganaraska River	278	870	590	162	118
Graham Creek	78	880	580	149	151
Cobourg Creek	134	859	550	187	122
Gages Creek	49	859	560	167	132
West Lake Ontario	118	859	570	155	134
East Lake Ontario	43	859	550	168	141
East of Gages Creek	13	859	560	153	146

Note: (1) Precipitation data were obtained from Peterborough (1968-2003), Cobourg (1970-2003) and Orono (1971-2000) Environment Canada Stations.

(2) Evapotranspiration (ET) was calculated as actual evapotranspiration using the Thornthwaite and Mather equation for watersheds with hydrometric stations and estimated for other watersheds.

(3) Infiltration was calculated based on surficial geology found in each physiographic region and adjusted to account for urban areas and land cover in each watershed.

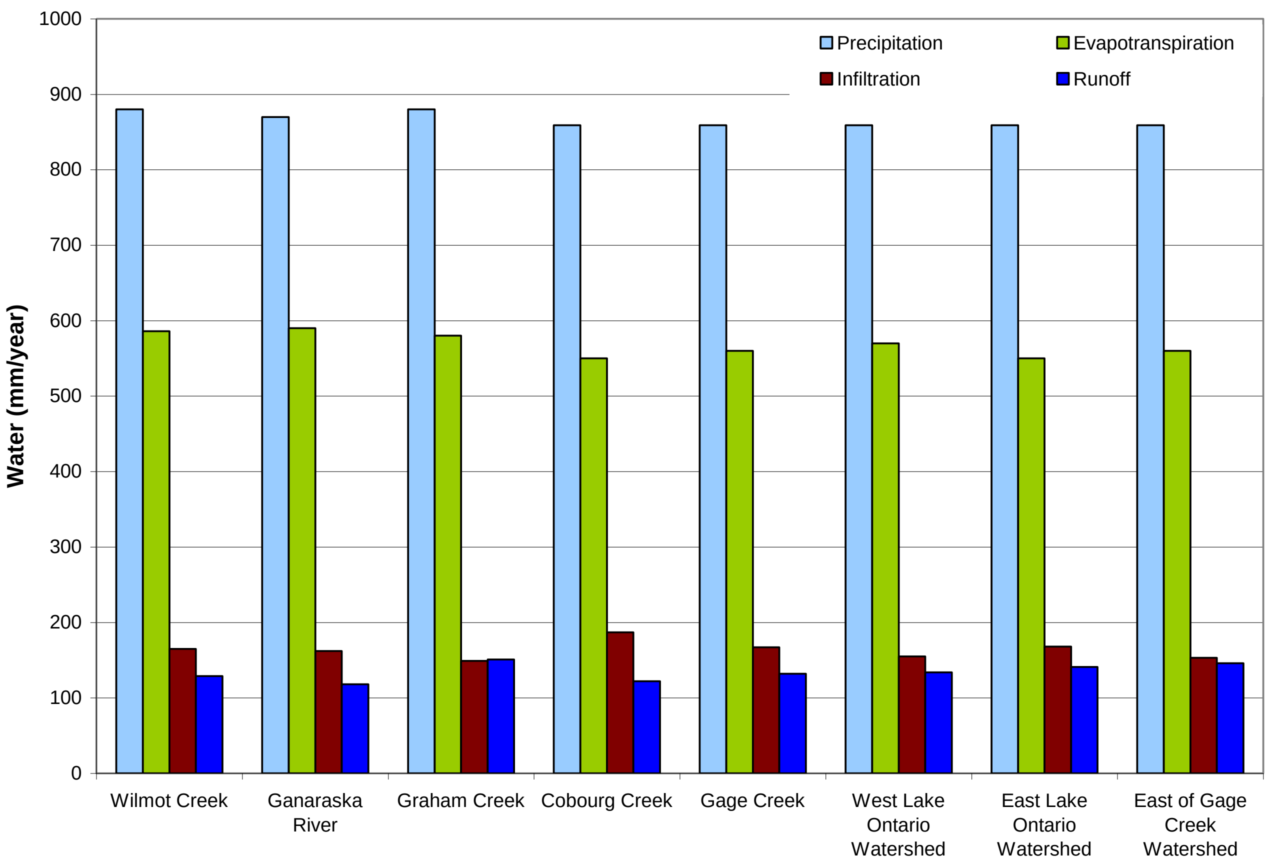


Figure 3.2-10: Calculated Water Budget for Watersheds Draining to Lake Ontario

3.2.10 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

The descriptions and mapping included in the conceptual water budget could be enhanced over time with collection of additional data. This includes the following:

Climate

- Additional climate stations in the Oak Ridges Moraine

Geology

- Edge matching of soils maps (including attribute classification between the soil maps of different counties)
- Stratigraphy and hydrostratigraphy

Land Cover

- Comprehensive list/location of active and abandoned pits and quarries
- Land cover data detailing anthropogenic use classifications due to limitations of Ecological Land Classification data

Surface Water

- Increased density of hydrometric stations in un-gauged watersheds

Groundwater

- Properly geo-referenced wells in the Water Well Information System
- Additional baseflow monitoring data
- Accurate, verified, geological stratification information for the Paleozoic Region
- Information on stream and lake temperatures, as related to groundwater discharge

Water use

- An improved data set or method for estimating agricultural water use
- An accurate survey of water wells and the coinciding use (residential, communal, commercial, industrial, etc
- A complete account of municipal and communal withdrawals
- A complete account of municipal wastewater treatment systems and the associated redistribution of water (including how discharge occurs to Lake Ontario)
- A means of accounting for commercial wells (i.e, restaurants, etc.) that are non-domestic and not accounted for in the Permit to Take Water database; these wells would use more water than domestic wells
- Estimates of water use efficiency for commercial users (i.e., restaurants, etc.)
- Estimates of water use efficiency for domestic users (in particular a means of estimating the amount of water redistributed through conventional septic systems)
- Actual water use data for permit holders under the Permit to Take Water Program

Aquatic Habitat

- Assessment of aquatic habitat dependent on seasonal biotic needs
- Assessment of aquatic habitat dependent on ecological water flow needs

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3.3 TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

The objective of the Tier 1 water budget and stress assessment was to screen watersheds directly draining to Lake Ontario within the Ganaraska Region Source Protection Area (Map 3-26) and identify those with significant or medium water quantity stress levels. The Tier 1 water budget described the mathematical evaluation of watershed water quantity stress, whereas the conceptual understanding provided a more narrative description of the water budget in the Ganaraska Region Source Protection Area. The Tier 1 water budget was prepared using provincial guidance (Ministry of the Environment and Climate Change, 2007) and *Technical Rules*, which indicate that the stress assessment is evaluated by percent water demand: the ratio of the consumptive water demand to water supplies, minus water reserves. Through the comparison of thresholds and estimated percent water demand each watershed (study unit) is assigned a surface and groundwater stress level in accordance with Part 111.3 of the *Technical Rules*.

The following section is a summary of the Ganaraska Region Conservation Authority (2010) Tier 1 Water Budget and Stress Assessment, Version 1.4, Draft Report, which was peer reviewed. The results of the review are summarized in Appendix C. Additionally Appendix E contains tables of all components of the water budget and stress assessment on a watershed basis.

3.3.1 SURFACE WATER AND GROUNDWATER STRESS ASSESSMENT METHODOLOGY

For each Ganaraska Region Source Protection Area watershed that drains to Lake Ontario, stress assessments were undertaken on surface water and groundwater independently and evaluated for two different land use scenarios: current scenario (scenario A, Table 1, *Technical Rules*) and future scenario (scenario B, Table 1, *Technical Rules*). The resulting assigned stress level is the maximum of the two scenarios.

3.3.1.1 SURFACE WATER CURRENT SCENARIO (SCENARIO A)

Water supply and water reserve were calculated based on monthly simulated stream flows and monitored flows. Water demands were distributed to each month considering the seasonal usage and typical peak demand situations in the summer. Then the percent water demands were calculated as a relative indicator for each month by using Equation 1 (Eq. 1). The largest monthly percent water demand was used to classify the stress level by comparing calculated values with surface water stress thresholds (Table 3.3-1).

$$\%\ \text{Water Demand} \quad \frac{Q_{\text{DEMAND (SW)}}}{Q_{\text{SUPPLY (SW)}} \qquad Q_{\text{RESERVE (SW)}}} \times 100 \qquad \text{... Eq. 1}$$

Table 3.3-1: Surface Water Stress Thresholds

Surface Water Quantity Stress Level Assignment	Scenario A and B Maximum Monthly Percent Water Demand
Significant	>= 50%
Moderate	> 20% but < 50%
Low	< 20%

3.3.1.2 GROUNDWATER UNDER CURRENT SCENARIO (SCENARIO A)

Following similar procedures as described in the surface water stress assessment, the percent water demand for groundwater was calculated using Equation 2 (Eq. 2). The stress level was determined by comparing results with groundwater stress thresholds listed in Table 3.3-2. Because groundwater sources and demand do not tend to demonstrate significant seasonal variability, annual supply values are deemed to be more appropriate for this exercise. However, peak monthly groundwater demand was also assessed to determine if the groundwater source could be temporarily overstressed in the specific months. The resulting groundwater stress level assigned is the maximum of the current (scenario A) and future (scenario B) assessment values for both annual and monthly conditions.

$$\% \text{ Water Demand} \quad \frac{Q_{\text{DEMAND (GW)}}}{Q_{\text{SUPPLY (GW)}} \qquad Q_{\text{RESERVE (GW)}}} \times 100 \qquad \text{...Eq.2}$$

Table 3.3-2: Groundwater Stress Thresholds

Groundwater Quantity Stress Level Assignment	Scenario A and B	
	Annual Percent Water Demand	Maximum Monthly Percent Water Demand
Significant	>= 25%	>= 50%
Moderate	< 25% but > 10%	< 50% but > 25%
Low	0 to 10%	0 to 25%

3.3.1.3 SURFACE WATER AND GROUNDWATER FUTURE SCENARIO (SCENARIO B)

The goal of the current scenario (scenario A) is to identify watersheds that are under stress as a result of existing water takings, while the goal of the future scenario (scenario B) is to identify watersheds that may become stressed as a result of future urbanization and/or additional drinking water requirements. The surface water percent water demand equation (Eq. 1) was also used in the future scenario. The stress level was determined by comparing results with the default surface water stress thresholds.

The equation (Eq. 2) of percent water demand for groundwater was also used for the future scenario. The stress level was classified by comparing results with the default stress thresholds.

3.3.2 ELEMENTS OF PERCENT WATER DEMAND EQUATION

3.3.2.1 WATER DEMAND AND USE EVALUATION

In the Tier 1 water budget and water quantity stress assessment approach (Ganaraska Region Conservation Authority, 2010) the estimation of monthly consumptive demand for surface water and groundwater is a critical element. This water demand can also be seen as an evaluation of water use, which is critical in describing anthropogenic effects on local watersheds during drought conditions.

Water demand needs to be calculated as the consumptive use, which refers to water taken from groundwater or surface water and not returned locally in a reasonable time period. From the calculation perspective, total consumptive demand estimation comprises the permitted water use estimation and non-permitted water use estimation, including non-permitted agricultural and non-permitted residential water use. The groundwater and surface water demands were calculated separately.

3.3.2.1.1 Permitted Water Use

The primary source of information for water demand estimation is the MOECC Permit to Take Water (PTTW) database, as summarized in Section 3.2.8. However, the Permit to Take Water database does not contain any direct information about the amount of water actually taken and no detailed information about when the water consumption occurs for each permitted use.

The new Permit to Take Water management database (2005) was developed by MOECC to supplement the old format PTTW database by accounting for multi-site permits, consumptive use and seasonal variability. Therefore, this new Permit to Take Water management database was selected as a basis for permitted water demand estimation. For the purpose of water demand estimation, the database was screened and updated by GRCA staff through the following steps:

- Screened the validity of all permits that expired before December 31, 2002. Expired permits, permitted takings from Lake Ontario, and temporary takings were not considered in water demand calculations.
- Updated database with new permits issued from 2005 to 2007
- Replaced maximum water taking rate by actual pumping rates where the actual records were available
- Reviewed all multiple sources and multiple factors in the permits
- Applied default monthly adjustments on Permit to Take Water and adjusted water taking figures by reviewing individual permits
- Applied default consumptive factors (Ganaraska Region Conservation Authority, 2010), except for those takings that removed water from original sources (watersheds) and did not return the water to the same watershed within a reasonable time period (e.g., water bottling).

Detailed information regarding the takings used in the modeling exercise can be found in Ganaraska Region Conservation Authority (2010).

3.3.2.1.2 Non-permitted Water Use

Non-permitted water use generally includes groundwater takings from private water supply wells in areas not serviced by municipal systems, and surface water takings from streams and ponds for agricultural uses. This was determined upon review of land use and local water use patterns. Information regarding non-permitted water use is found below.

3.3.2.1.3 Non-serviced Residential Water Demand

Water demand for non-serviced residential areas was calculated by combining population density with typical per capita water use rates. Statistics Canada Census data at the dissemination area level were used to estimate total population and non-serviced population by subtracting municipally serviced populations. When the non-serviced population distribution is generated, non-serviced residential demand can be calculated using the typical water usage rate of 335 litres per day per person. Upon review of local water use, it was determined that non-serviced residents primarily take their water from the groundwater system. The consumptive factor was designated to be 0.2 because major quantities of the removed water will be returned to the groundwater system through septic systems. The non-serviced water demand rates are presented in Table 3.3-3.

The total population for modeled watersheds was calculated by overlaying population dissemination area polygons on watershed polygons, broken down by area and aggregating numbers. The total 2006 population in the Ganaraska Region Source Protection Area, not including the Rice Lake watershed, was 57,580 with a population density of 69 people/km^2.

3.3.2.1.4 Serviced population

Existing urban areas are located in the Town of Cobourg, Ward 1 of the Municipality of Port Hope, the Village of Newcastle and Orono in the Municipality of Clarington, and Baltimore/Creighton Heights and Camborne in the Township of Hamilton. These urban areas rely on municipal water supply systems. There are six municipal drinking water treatment plants. Three plants take water from Lake Ontario and the other three systems withdraw water from municipal groundwater wells (Table 3.3-4). The serviced population data provided by municipalities were broken down by watershed by overlaying serviced areas on top of watershed population polygons (Table 3.3-3).

Table 3.3-3: Existing Residential Water Use

Watersheds	Area (km^2)	Total population	Serviced Population	Non-serviced Population	Percent Serviced	Non-serviced Residential Water Demand		Serviced Area
						m^3	mm	
Wilmot Creek	98.82	8,258	5,616	2,642	68	323,093	3.22	Orono, Village of Newcastle
Graham Creek	78.15	3,583	2,482	1,101	69	134,641	1.72	Village of Newcastle
West Lake Ontario	117.33	4,820	3,601	1,219	75	149,097	1.27	Village of Newcastle
Ganaraska River	277.95	11,032	6,687	4,346	61	531,367	1.91	Port Hope Ward 1
Gages Creek	48.63	4,667	3,565	1,101	76	134,674	2.77	Port Hope Ward 1
East of Gages Creek	12.53	785	553	232	70	28,310	2.26	Cobourg
Cobourg Creek	133.80*	19,620	14,832	4,788	76	585,440	4.38	Cobourg, Creighton Heights, Camborne
East Lake Ontario	42.71	4,814	3,923	891	81	108,985	2.55	Cobourg, Creighton Heights, Camborne
Total	811.30	57,580	41,259	16,321	72	1,995,609	2.46	N/A

* for the Tier 1 Water Budget analysis, Midtown Creek was included with Cobourg Creek

Table 3.3-4: Municipal Water Services

Municipal Water System	Source	Permit Number	Population Served[1]
Town of Cobourg	Lake Ontario	02-P-4065	18,500
Municipality of Port Hope	Lake Ontario	2240-6QQJ98	12,500
Village of Newcastle	Lake Ontario	00-P-3024	7,800
Creighton Heights	Groundwater	95-P-4019	1,100
Camborne	Groundwater	1711-6TVJ76	200
Orono	Groundwater	6401-6N3K79	1,783

[1] Note that these values were used at the time that calculations were conducted for the Tier 1 water budget and stress assessment

3.3.2.1.5 Non-permitted Agricultural Water Demand

The de Loë (2002) method was used to calculate non-permitted agricultural water use. This method estimates agricultural water use based on the Statistics Canada 2001 agricultural census data at the Census Consolidates Subdivision level. The consumptive factor was assumed to be 0.78 (de Loë, 2002). Considering the fact that land use has not experienced measurable changes in the past five years, the results from the de Loë (2002) method were used directly. This was done by overlaying the de Loë's layer on the watershed polygons and aggregating the data. Non-permitted agricultural water use was estimated by subtracting permitted takings for agricultural purposes (Table 3.3-5). Two assumptions were applied during the calculation. Non-permitted agricultural use was assumed to be exclusively surface water taking, and seasonal water use was assumed to occur in the summer (July and August).

Table 3.3-5: Surface Water Non-permitted Agricultural Water Use (m^3)

Watershed	January to June*	July	August	September to December*	Annual
Wilmot Creek	3,352	3,352	3,352	3,352	40,219
Graham Creek	2,736	22,945	22,945	2,736	73,252
West Lake Ontario	2,323	2,323	2,323	2,323	27,879
Ganaraska River	9,684	63,554	63,554	9,684	223,944
Gages Creek	2,719	11,943	11,943	2,719	51,072
East of Gages Creek	700	3,075	3,075	700	13,148
Cobourg Creek	6,503	43,098	43,098	6,503	151,223
East Lake Ontario	750	19,309	19,309	750	46,115

* These values represent water use per month

3.3.2.1.6 Future Water Demand

Future land use scenarios and water demand encompass future build out as defined in municipal official plans. Water demand needs to be adjusted by increasing (or decreasing) the municipal demand, taking into account population growth estimates. Municipal water supply strategies were used in assessing future demand. It was assumed that the non-municipal permitted demands will remain constant in the future. For future scenarios, water demand was estimated by taking into account the increase in population serviced by the groundwater source. The water demand for the municipal areas serviced by Lake Ontario was assumed to be constant. From a conservative perspective, the water demand increase from the non-municipal serviced areas was also considered in this study. In this case, 25.2%, 13.2%, 18%, and 50.8% were estimated to represent increases over 25 years in the Municipality of Port Hope, Municipality of Clarington rural areas, Orono and the Township of Hamilton, respectively. The increase rates for every watershed are area-weighted values (Table 3.3-6).

Table 3.3-6: Future Non-serviced Residential Water Use

Watersheds	Area (km^2)	Existing Non-serviced Population	Future Projected Population Increase Rate	Future Non-serviced Population	Non-serviced Residential Water Demand		Non-Serviced Area
					m^3	mm	
Wilmot Creek	98.82	2,642	13.32%	2,994	366,130	3.71	Clarington Rural
Graham Creek	78.15	1,101	13.20%	1,246	152,414	1.95	Clarington Rural
West Lake Ontario	117.33	1,219	20.75%	1,472	180,035	1.53	Clarington Rural, Municipality of Port Hope
Ganaraska River	277.95	4,346	23.49%	5,366	656,186	2.36	Clarington Rural, Municipality of Port Hope, Township of Hamilton
Gages Creek	48.63	1,101	25.17%	1,379	168,572	3.47	Municipality of Port Hope, Township of Hamilton
East of Gages Creek	12.53	232	25.17%	290	35,435	2.83	Municipality of Port Hope, Township of Hamilton
Cobourg Creek	133.80	4,788	50.79%	7,220	882,785	6.60	Township of Hamilton
East Lake Ontario	42.71	891	50.79%	1,344	164,338	3.85	Township of Hamilton
Total	809.92	16,321	N/A	21,312	2,605,895	3.22	N/A

3.3.3 WATER SUPPLY ESTIMATION

In any particular watershed the water supply estimation consists of two components: surface water supply, which is the water available as stream flow, and groundwater supply, which is the water available in the aquifers of that watershed. Water supply defines the total amount of water available or the surplus defined by a water budget. For the purpose of this study, the monthly water supply is defined as the monthly median flow or Q_{p50}. The Rice Lake tributaries are excluded from this analysis as they are part of the larger regulated Trent River watershed and should be considered in the context of its water budget.

3.3.3.1 SURFACE WATER SUPPLY STUDY APPROACH AND MODEL SCENARIOS

The following section describes the methods used to estimate surface water supply using a CANWET modeling approach for the eight watersheds within the Ganaraska Region Source Protection Area that drain to Lake Ontario (Ganaraska Region Conservation Authority, 2010). Of the eight watersheds, three are gauged with hydrometric stations and five watersheds are without hydrometric stations. For the gauged watersheds the CANWET model was calibrated at the hydrometric station. A comparison was then made between the modeled and the monitored (hydrometric data) stream monthly median flows (Q_{p50}).

For the ungauged watersheds the CANWET model was set up using the calibrated parameters of a neighbouring watershed with similar physiographic and land use features. The modeled simulated stream flow was then used to estimate Q_{p50} to determine the monthly surface water supply.

Current Scenario Modeling (Scenario A)

Current scenario A involves estimating surface water supply for the existing climate and current land use. The CANWET model was run for all eight watersheds using long-term climate data from 1976 to 1995 and the existing land use features. The simulated (ungauged) and monitored (gauged) stream flow data for the 20-year period were then used to estimate Q_{p50} to determine the monthly surface water supply.

Future Scenario Modeling (Scenario B)

Future scenario B involves estimating surface water supply for the existing climatic conditions and future land use. The CANWET model was run for all eight watersheds using climate data from 1976 to 1995 and the land use scenario expected as defined by build out within municipal official plans. The future scenario assumes full build-out of municipal official plan designated lands. The Q_{p50} was then estimated from the 20-year simulated stream flow to predict the future monthly water supply in all watersheds.

3.3.3.2 GROUNDWATER SUPPLY STUDY APPROACH AND MODELING SCENARIOS

Groundwater supply is generally calculated as the estimated annual recharge rate plus the estimated groundwater inflow into a watershed. However, in this modeling exercise groundwater supply is calculated as the estimated annual recharge rate plus/minus GW_{net} (GW_{net} is '– 'for flow in and '+'for flow out). The GW_{net} term is used in the original assessment (Ganaraska Region Conservation Authority, 2010) for the following reasons:

- CANWET can only simulate the GW_{net} for each watershed instead of a separate groundwater inflow and outflow. If the GW_{in} term is required, then a more complex groundwater model needs to be used. However, the use of a complex groundwater model will not change the stress level for groundwater in any of the watersheds.
- Using GW_{net} may result in an overestimation of groundwater stress. However when GW_{net} was used, the stress level for groundwater systems in the watersheds was defined as a "low" level with percent water demand far less than the threshold of "moderate" stress.

However to meet the requirements of the *Technical Rules* (Part I.1. Definition 2), which state "Groundwater supply is calculated as the estimated annual groundwater recharge rate plus the annual estimated groundwater inflow into the subwatershed", the GW_{net} term can not be used. Instead groundwater inflow (GW_{in}) must be used. The GW_{in} value of 179.78 was obtained from a recently completed groundwater flow model (3-D MODFLOW) for the Wilmot Creek watershed. This value was used to estimate groundwater inflow into the other 7 studied watersheds included in the Tier 1 water budget study (Ganaraska Region Conservation Authority, 2010).

The groundwater supply term for each watershed was recalculated by adding the groundwater inflow (GW_{in}) and groundwater recharge terms. For the Tier 1 analysis on groundwater supply, aquifer storage was not considered and the water supply terms for each watershed are assumed to be constant on an average annual basis.

In the current scenario (scenario A) the calibrated surface water model CANWET was used to estimate the annual average groundwater recharge. The calibrated models were run on both gauged and ungauged watersheds for the 20-year simulation period (1976 to 1995) and estimated annual groundwater recharge was then averaged to predict groundwater supply. For the gauged watersheds the observed stream flow was also partitioned into baseflow and surface flow using six approaches including digital filter, PART, base sliding, fixed base, local minimum, and modified United Kingdom Institute of Hydrology. The base sliding interval technique was found more appropriate for Ganaraska Region Source Protection Area watersheds. The baseflow separation results were compared with the model simulated results. The modeled groundwater recharge was slightly higher than estimated values using the baseflow separation technique, however they realistically represent the characteristics of the watersheds under study and therefore were used.

Current Scenario Modeling (Scenario A)

Current scenario A involves estimating groundwater recharge values using the existing climate data and current land use scenario. The CANWET model was run for all eight watersheds using long-term climate data from 1976 to 1995 and the existing land use features. The simulated annual groundwater recharge was then averaged to estimate the groundwater supply. The monthly groundwater supply is calculated simply by dividing the annual numbers by 12.

Future Scenario Modeling (Scenario B)

Future scenario B involves estimating groundwater supply using the existing climate data and the future land use scenario. The CANWET model was run for all eight watersheds using climate data from 1976 to 1995 and future land use features as defined by build out within municipal official plans. The simulated annual groundwater recharge was then averaged to estimate the groundwater supply under future conditions.

3.3.3.3 WATER SUPPLY ESTIMATION RESULTS

Water supply estimations were modeled for each of the eight watersheds or groupings of watersheds that flow to Lake Ontario. Estimations were modeled based on current land use and future land use. Results for each modeled watershed are found in Ganaraska Region Conservation Authority (2010).

Figure 3.3-1 and Table 3.3-7 describe an example of the elements of the water budget simulated by CANWET using long-term data for the Ganaraska River watershed under the existing land use scenario. Further modeling was completed to describe the elements of the water budget simulated by CANWET for the Ganaraska River watershed using long-term existing climate data under the projected future land use scenario. The future scenario results showed negligible increase/decrease in stream flow compared to the existing land use scenario (Ganaraska Region Conservation Authority, 2010). Additional detailed water supply estimation calculations are found in Ganaraska Region Conservation Authority (2010).

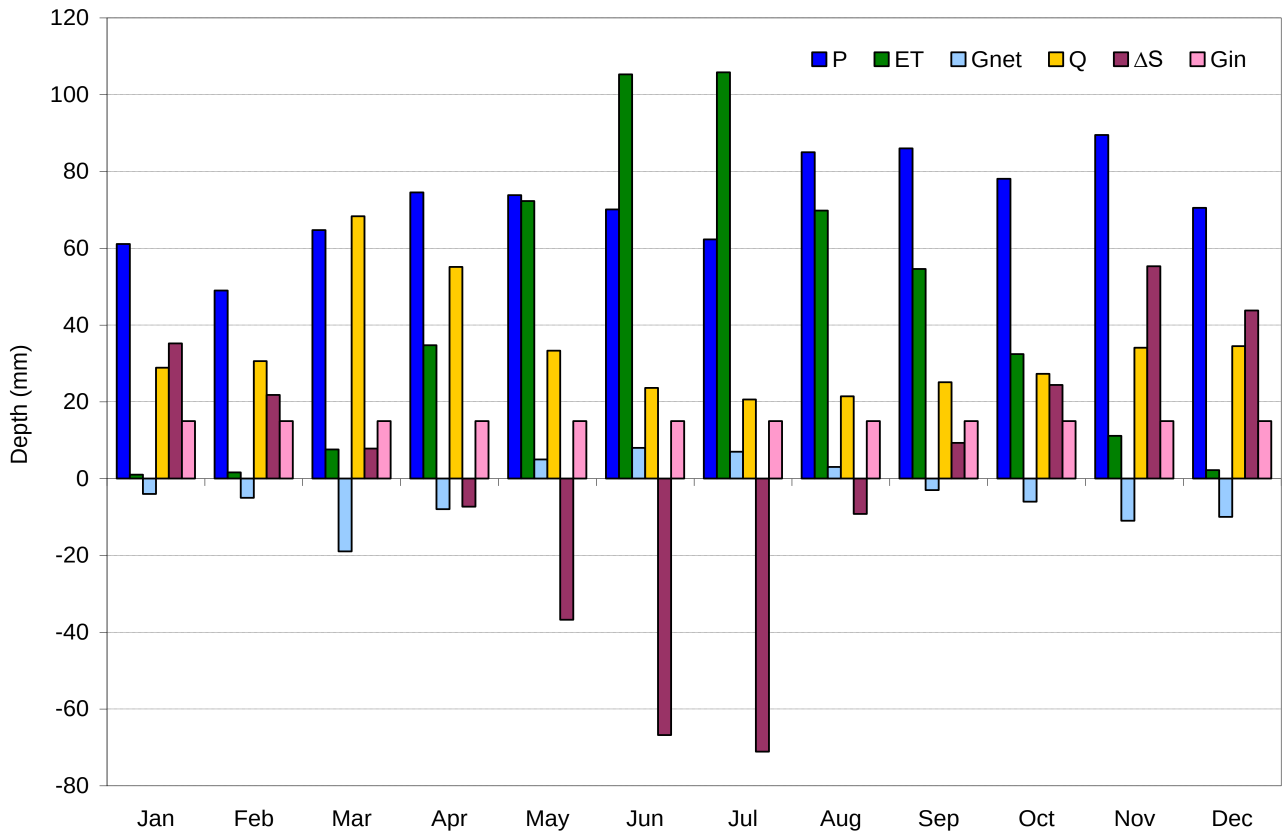

Figure 3.3-1: Water Budget Scenario A for the Ganaraska River

Table 3.3-7: Water Budget Scenario A for the Ganaraska River

Month	Precipitation (P) (mm)	Evapotranspiration (ET) (mm)	Net Groundwater Flow In and Out (G_{net}) (mm)	Groundwater Flow In (G_{in}) (mm) [1]	Stream Flow (Q) (mm)	Change in Storage (△S) (mm)
January	61.1	1.0	-4	14.98	28.9	35.2
February	49.0	1.6	-5	14.98	30.6	21.8
March	64.7	7.6	-19	14.98	68.3	7.8
April	74.5	34.7	-8	14.98	55.1	-7.3
May	73.8	72.3	5	14.98	33.3	-36.8
June	70.1	105.3	8	14.98	23.6	-66.8
July	62.3	105.8	7	14.98	20.6	-71.1
August	85.0	69.8	3	14.98	21.4	-9.2
September	86.0	54.6	-3	14.98	25.1	9.3
October	78.1	32.4	-6	14.98	27.3	24.4
November	89.5	11.1	-11	14.98	34.1	55.3
December	70.5	2.2	-10	14.98	34.5	43.8
Annual	864.6	498.4	-43	179.78	402.8	

[1] value obtained from Wilmot Creek Static MODFLOW Model

3.3.4 Q RESERVE VALUES

Reserving enough water to meet the needs of the ecology during low flow is essential in maintaining the aquatic environment. This is done by evaluating the ecological flow needs of a watercourse. During low flow conditions the viability of watercourse ecology may be compromised if flows dip below levels needed to maintain aquatic life. Significant research is being undertaken to define ecological flow needs for local watercourses. One set of methods used to consider the natural flow requirements of a stream is described in drinking water source protection guidance documents (Ministry of the Environment and Climate Change, 2007), which describe the calculation of the "water reserve" needed to maintain ecological health.

In order to maintain groundwater discharge and thereby maintain the ecology of a watershed, a minimum amount of groundwater must be maintained in the groundwater system during periods of low water conditions. Drinking water source protection documents define this minimum groundwater requirement as "groundwater reserve." The following sections describe how the drinking water source protection program has defined how the reserve flows are to be estimated for surface and groundwater systems.

3.3.4.1 SURFACE WATER RESERVE

Provincial guidance recommends two methods to estimate water reserve for surface water stress assessments. These methods include the calculation of lower decile flow (Q_{p90}) on a monthly basis and the calculation of reserve values using the Tessman method.

To select proper methods for gauged and ungauged watersheds, the two methods were applied on simulated stream flows and monitoring data over the period of 1976 to 1995 at two hydrometric stations (02HD012 in Ganaraska River and 02HD009 in Wilmot Creek). After comparison it was found that the monthly water reserve (based on simulated stream flows) is in better agreement with simulated low flows when using the Tessman method. Therefore, the Tessman method was believed to be more reliable in describing reserve flows for the following reasons:

- Q_{p90} is determined by one ranked position at lower decile after ranking stream flow from the largest value to the smallest value. It is less reliable when this method is used in simulated stream flows instead of observed stream flows.
- Since the Tessman method estimates water reserve based on mean values, the reserve values are not easily influenced by simulation errors.

However, when these two methods were applied on observed data, the monthly water reserves recommended by Q_{p90} were slightly higher than those by Tessman. This point is supported by the Wilmot Creek Ecological Flow Assessment Study (Bradford & Parish, 2005 and 2006). In the Wilmot Creek Ecological Flow Assessment Study, several low flow methods were compared based on flow data from the 3rd concession hydrometric station (02HD009). The study indicated that the Tessman method estimates for monthly low flow were outside the natural range of variability, falling well below the 10th percentile flow from October through December and April through May, and may be too low to ensure that natural stream functions can be sustained in Wilmot Creek. For that reason, in gauged watersheds where long-term monitoring data sets are available, the Q_{p90} method was used on the monitoring data. For ungauged watersheds, the Tessman method was applied on the simulated stream flows.

Reserve flow value calculations for all streams within the Ganaraska Region Source Protection Area are available (Ganaraska Region Conservation Authority, 2010). The Wilmot Creek results are shown in Tables 3.3-8 and 3.3-9 as an example.

Table 3.3-8: Wilmot Creek Scenario A Surface Water Reserve Calculation (Tessman Method)

Month	Water Supply (Q_{p50})		Water Reserve (Tessman)	
	m^3/s	mm/month	m^3/s	mm/month
January	0.82	25.73	0.39	12.34
February	0.89	27.83	0.46	14.37
March	1.89	59.15	0.82	25.88
April	1.52	47.70	0.66	20.56
May	0.89	27.82	0.39	12.34
June	0.63	19.61	0.39	12.34
July	0.52	16.32	0.39	12.34
August	0.51	16.00	0.39	12.34
September	0.64	19.94	0.39	12.34
October	0.72	22.56	0.39	12.34
November	0.96	30.11	0.40	12.46
December	0.95	29.84	0.39	12.34

Table 3.3-9: Wilmot Creek Scenario A Surface Water Reserve Calculation (Q_{p90})

Month	Water Supply (Q_{p50})		Water Reserve (Q_{p90})	
	m^3/s	mm/month	m^3/s	mm/month
January	0.82	25.73	0.40	12.60
February	0.89	27.83	0.44	13.83
March	1.89	59.15	1.15	35.96
April	1.52	47.70	1.08	33.92
May	0.89	27.82	0.70	22.02
June	0.63	19.61	0.49	15.31
July	0.52	16.32	0.35	10.89
August	0.51	16.00	0.43	13.61
September	0.64	19.94	0.43	13.43
October	0.72	22.56	0.57	17.92
November	0.96	30.11	0.65	20.46
December	0.95	29.84	0.61	19.30

3.3.4.2 GROUNDWATER RESERVE

Provincial guidance recommends that a simplified estimation method be applied for the Tier 1 water budget analysis whereby the groundwater reserve is estimated as 10% of the existing groundwater discharge. However, there is no theoretical basis for this value and it may be low considering that in the Ganaraska Region Source Protection Area watershed baseflow represents 70 to 80% of stream flow. Groundwater discharge to streams must be maintained to sustain baseflow. The required reserve was estimated and simplified as 10% of the average annual and monthly groundwater discharge.

Groundwater reserve value calculations for all watersheds within the Ganaraska Region Source Protection Area have been calculated using groundwater reserve values from the model and groundwater in values as noted above. The Wilmot Creek results are shown in Table 3.3-10 as an example.

Table 3.3-10: Wilmot Creek Scenario A Groundwater Reserve Calculation

Month	Water Supply (GW_r+GW_{in})		Water Reserve (10% supply)	
	m^3/s	mm/month	m^3/s	mm/month
January	1.52	39.37	0.15	3.94
February	1.52	39.37	0.15	3.94
March	1.52	39.37	0.15	3.94
April	1.52	39.37	0.15	3.94
May	1.52	39.37	0.15	3.94
June	1.52	39.37	0.15	3.94
July	1.52	39.37	0.15	3.94
August	1.52	39.37	0.15	3.94
September	1.52	39.37	0.15	3.94
October	1.52	39.37	0.15	3.94
November	1.52	39.37	0.15	3.94
December	1.52	39.37	0.15	3.94
Annual	18.24	472.38	1.82	47.24

3.3.4.3 UNCERTAINTIES IN WATER BUDGET CALCULATIONS AND THE STRESS ASSESSMENTS

Uncertainty is inherent to the water budget estimation and stress assessment process. The accuracy of estimates is reliant on the quality of input data, methodology, modeling, and the conceptual understanding of the watershed. Overall, the issues related to uncertainty, data, and knowledge gaps are complex and highly qualitative. There is a degree of uncertainty associated with every aspect of the water budget analyses. However, it is impossible to provide a quantitative assessment of this level of uncertainty. Rather one can only say, in very general terms, that the level is low, moderate, or high. However, uncertainty can be evaluated as low in watersheds where the following applies:

- A long-term historical record is available.
- High quality, dense monitoring data are provided.
- Complex numerical modeling is applied.
- Relative studies and research have been conducted to enhance the understanding of the water system.

According to provincial guidance the uncertainty becomes particularly important if a watershed has been assigned a low stress level and the percent water demand estimate is near the threshold of moderate stress. For that situation, estimates should be checked to make sure that they are conservative. The uncertainties coming from data limitation and conceptual understanding are shown in Table 3.3-11.

Table 3.3-11: Level of Uncertainty in Water Budget and Stress Assessment

Watershed	Groundwater Uncertainty	Surface Water Uncertainty
Wilmot Creek	Low	Low
Ganaraska River	Low	Low
Graham Creek	High	High
Cobourg Creek	Low	Low
Gages Creek	High	High
West Lake Ontario	High	High
East of Gages Creek	High	High
East Lake Ontario	High	High

3.3.5 STRESS ASSESSMENT SUMMARY

The surface water stress analysis indicated moderate stress for the Wilmot Creek watershed and the Gages Creek watershed (Map 3-27). All other watersheds demonstrated low surface water stress based on percent water demand (Map 3-27). Results of the current and future surface water stress assessment are found in Table 3.3-12.

Groundwater was shown to exist in adequate amounts and only low stresses were found associated with percent groundwater demand for all watersheds (Map 3-28). Results of the current and future groundwater stress assessment are found in Table 3.3-13.

Table 3.3-12: Summary of Surface Water Stress Assessment

Watershed	Annual Supply		Annual Reserve		Annual Water Demand	Existing and Future Maximum Monthly Water Demand (%)	Stress Level
	Existing (mm/yr)	Future (mm/yr)	Existing (mm/yr)	Future (mm/yr)	Existing and Future (mm/yr)		
Wilmot Creek	342.6	352.1	229.3	167.8	2.3	25.9	Moderate
Ganaraska River	397.4	397.3	284.7	183.1	2.3	18.7	Low
Graham Creek	355.8	355.7	151.7	151.7	2.1	10.5	Low
Cobourg Creek	480.2	480.6	234.1	232.6	1.7	5.0	Low
Gages Creek	468.5	478.2	231.7	233.7	13.3	48.0	Moderate
West Lake Ontario	395.0	390.7	185.2	189.6	1.7	15.3	Low
East of Gages Creek	355.7	378.1	180.5	189.4	1.1	5.8	Low
East Lake Ontario	479.8	482.5	232.5	233.9	1.3	7.9	Low

Table 3.3-13: Summary of Groundwater Stress Assessment

Watershed	Annual Supply		Annual Reserve		Annual Water Demand				Maximum Monthly Water Demand		Stress Level
	Existing (mm/yr)	Future (mm/yr)	Existing (mm/yr)	Future (mm/yr)	Existing (mm/yr)	Future (mm/yr)	Existing (%)	Future (%)	Existing (%)	Future (%)	
Wilmot Creek	472.38	464.48	47.24	46.45	4.4	4.5	1.02	1.07	1.63	1.69	Low
Ganaraska River	489.78	488.88	48.98	48.89	3.2	3.2	0.72	0.74	0.74	0.76	Low
Graham Creek	485.78	485.58	48.58	48.56	0.7	0.7	0.15	0.16	0.53	0.54	Low
Cobourg Creek	483.78	475.68	48.38	47.57	1.8	2.2	0.41	0.54	0.42	0.56	Low
Gages Creek	481.68	475.08	48.17	47.51	2.1	2.2	0.48	0.52	0.49	0.52	Low
West Lake Ontario	475.78	449.48	47.58	44.95	1.6	1.6	0.37	0.40	0.51	0.56	Low
East of Gages Creek	469.98	472.88	47.01	47.29	0.5	0.6	0.11	0.13	0.11	0.13	Low
East Lake Ontario	486.68	469.68	48.67	46.97	0.7	1.0	0.16	0.25	0.17	0.26	Low

The water budget components used in the stress assessment were derived from long-term (20-year) simulation runs of calibrated CANWET models and hydrometric data (Ganaraska Region Conservation Authority, 2010). The results from this information provided a number of insights:

1. The ability of the Oak Ridges Moraine to provide water recharge to the aquifers and subsequent baseflow (groundwater) discharge to local surface water systems is significant and provides sufficient groundwater quantities. (Baseflow index is around 0.8 for local watersheds.)
2. Lateral groundwater movement between watersheds within and from outside the Ganaraska Region Source Protection Area is significant.
3. The surface water stress calculations for both the Gages and Wilmot Creek watersheds are significantly altered by water taking in the respective watersheds.

Due to the fact that the Gages Creek watershed exhibits moderate surface water stress in the Tier 1 stress assessment, and that this stress is associated with anthropogenic impacts, but no municipal drinking water sources are present in the watershed, it is recommended that the Gages Creek watershed not proceed to a Tier 2 study.

Due to the fact that the Wilmot Creek watershed exhibits moderate surface water stress in the Tier 1 stress assessment, and that this stress is associated with anthropogenic impacts, and the Orono Drinking Water System was defined as a GUDI well, the Tier 1 assessment recommended that the Wilmot Creek watershed proceed to a Tier 2 study. The Tier 1 assessment acknowledges the connection between the surface water supply and the water being drawn into the supply wells. If a stress were to occur in the surface water it was felt that a corresponding stress might be present in the supply to the wells. Therefore it was concluded if a surface water stress was shown to occur in Wilmot Creek a Tier 2 analysis was appropriate given the creeks connection to the wells.

Subsequent to the Tier 1 assessment, the Orono Drinking Water System has been proven to be a non-GUDI system and this designation has been accepted by the Ministry of the Environment and Climate Change. Due to this information, a Tier 2 analysis for the Orono Drinking Water System will not be reported in the Ganaraska Assessment Report. The Ministry of the Environment and Climate Change letter regarding the removal of the GUDI status of the Orono wells is found in Appendix A to this report.

Due to the fact that the Ganaraska River watershed has a percent surface water demand of 18.7%, which is between 18 and 20%, but no municipal water supply system a source are present in the watershed. Based on the results of the Tier 1 water budget study, no Tier 2 analysis is required for the Ganaraska River watershed.

As a result of the Tier 1 water budget and water quantity stress assessment, it was concluded that there are no water quantity stresses to municipal water supplies in the Ganaraska Region Source Protection Area.

3.3.6 REFERENCES

Bradford, A & Parish, J. (2005). *Wilmot Creek Ecological Flow Assessment Study, Phase 1*. Prepared for the Ganaraska Region Conservation Authority. Guelph (ON).

Bradford, A & Parish, J. (2006). *Wilmot Creek Ecological Flow Assessment Study, Phase 2*. Prepared for the Ganaraska Region Conservation Authority. Guelph (ON).

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Ganaraska Region Conservation Authority. (August 2010). *Tier 1 Water Budget and Stress Assessment*. Version 1.4, Draft Report Port Hope (ON): Ganaraska Region Conservation Authority.

Ministry of the Environment and Climate Change. (2007). *Assessment Report: Draft Guidance Module 7 Water Budget and Water Quantity Risk Assessment*. Toronto: Ontario Ministry of the Environment and Climate Change.

CHAPTER 4: SURFACE WATER SYSTEMS: WATER QUALITY RISK ASSESSMENT

4.1 SUMMARY OF SURFACE WATER SYSTEMS

There are three municipal drinking water systems listed in the *Terms of Reference* for the Ganaraska Region Source Protection Area that draw water from a surface water source, which in all three cases is Lake Ontario. General information regarding these systems is provided in Table 4.1-1. Details regarding their intakes and water treatment systems are summarized in Table 4.1-2. The average rates at which these systems pump water from their surface water source are provided in Table 4.1-3. There are no monitoring ~~wells~~ locations related to the three municipal surface water systems.

Table 4.1-1: Summary of Municipal Residential Surface Water Systems

System Name [1]	Drinking Water System No.	Operating Authority	*Safe Drinking Water Act* Classification	Population Served [2]
Cobourg Water Treatment Plant	220000825	Lakefront Utility Service Inc.	Large Municipal Residential	18,500
Municipality of Port Hope Water Treatment Plant	260058006	Municipality of Port Hope	Large Municipal Residential	12,500
Newcastle Drinking Water System	220004787	Regional Municipality of Durham	Large Municipal Residential	10,038

[1] Official Drinking Water System name [2] Data Source: Ministry of the Environment and Climate Change

Table 4.1-2: Summary of Surface Water Intakes and Water Treatment Systems for Municipal Residential Surface Water Systems

System Name	Intake (s) [1]				Water Treatment System [1]			
	No. Intakes	Intake Distance from Shore (m)	Size (mm)	Approx. Depth to Crib (m)	Coagulant / Flocculation	Filtration	Disinfection	Other Available Treatment Details
Cobourg Water Treatment Plant	1	856	1,050	12	Aluminum sulphate	Granular activated carbon	Chlorine gas	Additional sodium hypochlorite re-chlorination facilities at booster pumping station and 2 elevated storage tanks.
Municipality of Port Hope Water Treatment Plant	1	880	900/762[2]	9	None	Ultrafiltration membrane system	Chlorine gas	The Zone 2 Jocelyn Street Reservoir and the Fox Road Elevated Tank dose sodium hypochlorite for disinfection.
Newcastle Drinking Water System	1	1,067	610	10	Polyaluminum chloride	Sand/anthracite dual media filters	Chlorine	Additional chlorination is applied at the Newtonville Pumping Station.

[1] Data Source: Water Plant Operators. [2] 900 mm is the onshore pipe diameter and 762 mm is the in-water diameter.

Table 4.1-3: Pumping Rates for Municipal Residential Surface Water Systems

System Name	Monthly Average Pumping Rates (m^3/day)												Average Annual Pumping Rate (m^3/day)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Cobourg Water Treatment Plant	9,829	10,260	9,950	10,358	10,445	11,564	11,309	11,231	10,414	9,861	9,152	8,729	10,258
Municipality of Port Hope Water Treatment Plant	6,102	6,079	6,058	6,296	6,990	7,550	7,369	7,684	7,253	6,465	6,355	5,939	6,140
Newcastle Drinking Water System	2,121	2,039	2,002	2,105	2,483	3,247	2,974	2,921	2,419	2,251	2,166	2,136	2,405

Data Source: Water Plant Operators

4.2 INTAKE PROTECTION ZONE: DELINEATION AND VULNERABILITY

Water drawn from surface water sources (rivers and lakes) is inherently vulnerable to contamination. Many factors affect the degree of vulnerability, including depth of the water intake, distance from shore, the land use and land cover, and slope of the area. This chapter provides a description of the delineation of intake protection zones and assignment of vulnerability scores for the three surface water intakes identified in the *Terms of Reference* for the Ganaraska Region Source Protection Area in accordance with Part VIII of the *Technical Rules*. These intakes are associated with the Cobourg Surface Water Supply System (hereafter referred to as the Cobourg Water Treatment Plant), the Port Hope Surface Water Supply System (hereafter referred to as the Municipality of Port Hope Water Treatment Plant), and the Newcastle Surface Water System (hereafter referred to as the Newcastle Drinking Water System)[1].

The vulnerability analysis (Intake Protection Zones 1 and 2) for the three intakes was completed under seven separate studies prepared by Stantec Consulting Ltd. from January 2007 to April 2010, which were peer reviewed. The vulnerability analysis (Intake Protection Zone 2) was further refined by the Ganaraska Region Conservation Authority in 2011, which was also peer reviewed. In 2022 work was undertaken by the Ganaraska Region Conservation Authority to update the Cobourg IPZ-2 as a result of increased residential development. The results of the peer reviews are summarized in Appendix C. An event based vulnerability analysis (Intake Protection Zone 3) was completed for the three intakes under a study prepared by the Lake Ontario Collaborative during the winter of 2010/2011 (Stantec Consulting Limited, 2011). In 2013, additional event based modeling was completed for the three intakes (Dewey, 2013). For a listing of the reports, please see Section 4.2.6. This chapter is a summary of the work presented in these studies.

4.2.1 INTAKE CLASSIFICATIONS

The *Terms of Reference* identifies three municipal surface water intakes in the Ganaraska Region Source Protection Area. The *Technical Rules* classifies surface water intakes according to the nature of the water source from which they draw water. Different methodologies are prescribed for the delineation of intake protection zones for each intake classification. The four intake classifications are as follows:

1. Type A: Intakes located in the Great Lakes
2. Type B: Intakes located in connecting channels
3. Type C: Intakes located in rivers where neither the flow nor direction of water at the intake is affected by a water impoundment structure
4. Type D: All other intakes (e.g., intakes located in inland lakes).

A **surface water intake** is the structure through which surface water (water from lakes and rivers) is drawn for drinking water.

Intake Protection Zones (IPZ) are the areas of land and water that surround municipal water intakes that may be vulnerable to contamination.

Connecting channels refer to the St. Lawrence, St. Mary's, St. Clair, Detroit, and Niagara rivers and the Welland Canal.

[1] Surface Water System names as per the Ganaraska Region Source Protection Area Terms of Reference. "Referred to names" as per Drinking Water System names from Annual Reports.

All of the intakes in the Ganaraska Region Source Protection Area are located in Lake Ontario and are therefore all classified as Type A intakes.

4.2.2 INTAKE PROTECTION ZONE DELINEATION

The *Technical Rules* sets out requirements for the delineation of intake protection zones for surface water intakes and for the assignment of vulnerability scores in these zones. The intake protection zones and vulnerability scores provide the basis for identifying potential water quality threats and assessing risks.

The following three intake protection zones must be identified for each surface water intake related to a drinking water system identified in the *Terms of Reference*:

- Intake Protection Zone 1: The primary protection area around the intake
- Intake Protection Zone 2: The secondary protective zone for the intake (generally defined based on a minimum 2-hour time of travel)
- Intake Protection Zone 3: The protection area that may contribute contaminants to the intake during extreme events.

Intake Protection Zones 1 and 2 were delineated for each of the surface water supplies. These are shown on Maps 4-1, 4-2, and 4-3 (Cobourg Water Treatment Plant, Newcastle Drinking Water System, and Municipality of Port Hope Water Treatment Plant, respectively). The delineation of each type of intake protection zone is described in the following sections. Note that the intake protection zones encompass many watercourses in the Ganaraska Region Source Protection Area as these watercourses contribute source water to the intakes.

Intake Protection Zone 2 for the Newcastle Drinking Water System extends outside of the Ganaraska Region Source Protection Area and the Trent Conservation Coalition Source Protection Region into the Central Lake Ontario Source Protection Area (along the shore of Lake Ontario), which is part of the CTC Source Protection Region.

An Intake Protection Zone 3 was also delineated for each of the surface water supplies. This zone is shown on Maps 4-10, 4-11 and 4-12 (Cobourg Water Treatment Plant, Newcastle Drinking Water System, and Municipality of Port Hope Water Treatment Plant, respectively). The delineation of Intake Protection Zone 3 is described in section 4.2.2.3.

4.2.2.1 INTAKE PROTECTION ZONE 1

Intake Protection Zone 1 (IPZ-1) is the area immediately adjacent to the intake. This zone is considered the most vulnerable due to its proximity to the intake. Contaminants of concern entering the area would experience little to no dilution before reaching the intake. The delineation of IPZ-1 for a Type A system is defined as a circle with a radius of 1 kilometre around the intake crib. Where the IPZ-1 abuts land, it is extended perpendicular to the shoreline in a way that combines the 120-metre setback from the lake and the area of the Ganaraska Region Conservation Authority regulation limit.

4.2.2.2 INTAKE PROTECTION ZONE 2

Time of travel is the length of time required for surface water to travel a specified distance within a surface waterbody.

Intake Protection Zone 2 (IPZ-2) acts as a secondary protective zone that extends upstream from IPZ-1 and includes a setback from the watercourse and waterbody on land. IPZ-2 is defined as the area within and around a surface waterbody that may contribute water to an intake within a time of travel determined by water treatment plant operators to be sufficient for responding to a contamination event. In the event of a spill or release of contaminants into this zone, water treatment plant operators will have minimal time to respond (e.g., shutting down the intake). Discussions with plant personnel at each of the three intakes indicated that there was no need to increase the time of travel beyond the minimum 2-hour time of travel prescribed by the *Technical Rules*.

The *Technical Rules* indicates that a minimum 2-hour time of travel should be used to delineate the IPZ-2, but does not specify a methodology for calculating the distance associated with the time of travel. The key task for delineating IPZ-2 was to obtain an accurate determination of the distance of the 2-hour time of travel in Lake Ontario, and where this area touched land, the remainder of the travel time distances (residual time of travel) up the tributaries and storm sewer systems (see 4.2.2.4 for further information on storm sewer systems). Two different modeling approaches were used in Lake Ontario as described below. Where the IPZ-2 abuts land, it was extended perpendicular to the shoreline in a way that combined the 120-metre setback from the lake and the area of the Ganaraska Region Conservation Authority regulation limit. A number of models and methods were used to determine IPZ-2 associated with tributary flows. These are described below.

4.2.2.2.1 Calculating Time of Travel Distance in Lake Ontario

Newcastle Lake Ontario Modeling Study

Within the Regional Municipality of Durham the Lake Ontario area of the 2-hour time of travel distance was determined by applying 10-year easterly and westerly wind events and 2-year tributary flow events with event durations of 3.5 days using the Princeton Ocean Model (POM), and the MIKE3 model applying the 2-hour time of travel (W.F. Baird and Associates Coastal Engineers Ltd., 2007). Particle tracking was used to define the IPZ-2. The boundaries of IPZ-2 were conservatively extended to the shoreline and to land to include sewersheds, transport pathways, and streams within the two hour time of travel. The Lake Ontario Collaborative modeling group made a professional judgment call that the time of travel in Lake Ontario, if extended perpendicular to the shoreline, would be equal to the east-west in-water travel time (the modeled circulation). This was due to the fact that the Lake modeling has high uncertainty and that this would define a conservative travel time to locations along the shoreline. With this approach the 2 hour time of travel is still defined by the IPZ-2 as mapped (i.e., the IPZ-2 does not represent a travel time greater than 2 hours, it is a conservative 2 hour estimate of travel time).

Initially utilizing the farthest lake extents of the IPZ-2, radial arms were measured from the intake point to each of the opposite extents of the in-water IPZ-2. Using the determined length of the radial arms, arcs were projected onshore. One arc projected from either side of the IPZ-2. Ideally arcs were projected with similar angles, however local study area conditions may in some cases require the use of increased or decreased angles on a specific arc. Once the radial arms were projected and arcs plotted, an extension line was plotted from the extents of the in-water IPZ-2 to a point on-shore. If the arcs already crossed shore and where therefore already extended inland, the extension line was not necessary. Ideally the extension line was either a tangential extension of IPZ-2 perimeter, or a line, which intersected the shoreline at approximately 90 degrees. This extension was approximate and may have been altered to accommodate local study area conditions. From that point an administratively set back representing the greater of the Ganaraska Region Conservation Authority regulated limit and 120 meters was used as the upland extent until connecting with the previously determined arcs. Table 4.2-1 describes the extent of IPZ-2 for the Newcastle Drinking Water System.

Cobourg and Port Hope Lake Ontario Modeling Studies

The in-water Lake Ontario IPZ-2 boundaries for the Cobourg and Port Hope Water Treatment Plants were determined separately by using two-dimensional (2D) horizontal Advanced Circulation (ADCIRC) hydrodynamic modeling, which modeled wind and wave influences (HCCL, 2007a and 2007b). Particle tracking was used to define the IPZ-2. The boundaries of IPZ-2 were conservatively extended to the shoreline and to land to include sewersheds, transport pathways, and streams within the two hour time of travel. The Lake Ontario Collaborative modeling group made a professional judgment call that the time of travel in Lake Ontario, if extended perpendicular to the shoreline, would be equal to the east-west in-water travel time (the modeled circulation). This was due to the fact that the Lake modeling has high uncertainty and that this would define a conservative travel time to locations along the shoreline. With this approach the 2 hour time of travel is still defined by the IPZ-2 as mapped (i.e., the IPZ-2 does not represent a travel time greater than 2 hours, it is a conservative 2 hour estimate of travel time).

Where the IPZ-2 intersected the shoreline, it was necessary to determine approximate times of travel to enable up-tributary extents to be plotted. Times of travel were determined by assuming the distance from the intake to the extent of the in-water IPZ-2 perimeter represented two hours. With this convention established, distances to the mouths of watercourses were then measured and taken as a proportion of the established two-hour time of travel. Residual times were then applied to available watercourse velocities to determine the distance the up-tributary IPZ-2 extended. The landward extent of the IPZ-2 was determined with consideration to the up-tributary extents. From that point an administratively set back representing the greater of the Ganaraska Region Conservation Authority regulated limit and 120 meters was used as the upland extent until connecting with the previously determined arcs. Table 4.2-1 describes the extent of the IPZ-2 for the Cobourg and Port Hope Water Treatment Plants.

Table 4.2-1: Extent of IPZ-2 in Lake Ontario

Intake	IPZ-2 Extents (m)		
	East	West	Offshore
Cobourg Water Treatment Plant	4,500	4,800	2,400
Newcastle Drinking Water System	2,000	4,000	1,500
Municipality of Port Hope Water Treatment Plant	7,300	5,100	2,500

4.2.2.2.2 Calculating Time of Travel Distance in Tributaries and Storm Sewer Systems

Modeling Approach

A tributary analysis was conducted for watercourses that discharge to the alongshore extent of the IPZ-2. The time of travel distance in Lake Ontario was calculated to the outlet of the tributary and the remainder of the 2-

hour travel time distance (residual time of travel) was mapped upstream into the tributaries and the storm sewer systems (see 4.2.2.4 for further information on sewer systems). The residual time of travel distance in the watercourses was based on bankfull flow velocities that generally correspond to the flows experienced in a 2-year event flow. The Ganaraska Region Conservation Authority provided Stantec Consulting Ltd. with mapping and modeled 2-year flow and velocity information for a number of the tributaries. Where this information was not available, conservative velocity estimates were used to determine tributary areas in the IPZ-2.

4.2.2.3 INTAKE PROTECTION ZONE 3 AND EVENT BASED MODELING

Intake Protection Zone 3 (IPZ-3) is an area that may contribute contaminants to an intake during extreme events. In the case of the intakes associated with the Cobourg Water Treatment Plant, Newcastle Drinking Water System, and Municipality of Port Hope Water Treatment Plant, an extreme event was modeled in 2011 to examine a spill from fuel pipelines that run across the Ganaraska Region Source Protection Area north of Highway 401. The methodology used in 2011 is described in Stantec Consulting Limited (2011).

In 2013, event based modeling was done to examine the potential threat of two additional extreme events. The first, marine gasoline storage tank ruptures (fuel spill) at the Cobourg Marina, Newcastle Marina, and Port Hope Harbour; the second, disinfection failures at the Cobourg Wastewater Treatment Plants 1 and 2, the Port Hope Wastewater Treatment Plant, the Newcastle Wastewater Treatment Plant, and the Port Darlington Wastewater Treatment Plant. These events were all located within the IPZ-2 for the intakes (with the exception of Port Darlington, which is located within the CTC Source Protection Region) and therefore did not require the delineation of IPZ-3s. The methodology used in 2013 is described in Dewey (2013).

Fuel Pipeline

Modeling was undertaken to determine if fuel spilled from oil pipelines that traverse the Ganaraska River, Cobourg Creek, Wilmot Creek, Bowmanville Creek[2] and Graham Creek, would reach the intakes of the Cobourg Water Treatment Plant, Newcastle Drinking Water System, and Municipality of Port Hope Water Treatment Plant and cause deterioration of the quality of raw water for drinking water purposes.

The modeled parameter of concern for these scenarios was benzene, and the Ontario Drinking Water Quality Standard for benzene is 0.005 mg/L. The fuel was modeled as gasoline (87 octane with 0.5-1% benzene added). A spill from the pipeline was modeled with the Lake Ontario version of MIKE-3. The simulation period for the model was April 15 to July 7, 2006 (note the simulation for the Bowmanville Creek spill was from May 30 to July 7, 2006). The wind forcing was the NOAA 2-D wind field with additional data from Pearson Airport. The daily flow in the rivers was obtained from the Canada Water Survey database. The pipeline flow was based on the daily average flow rate of 0.125 m^3/s, with the pipeline break being a 6 hour event. Therefore approximately 2,700 m^3 of fuel was spilled in the duration of the event, which corresponds to a flow rate of 4.5 m^3/hr of pure benzene.

The pipeline flow was mixed with the river flow and it was assumed that the benzene in the gasoline would fully mix in the river water. The temperature in the tributaries was set at 20˚C, as was the gasoline temperature in

[2] Bowmanville Creek is located within the CTC Source Protection Region; however, a fuel spill within Bowmanville Creek can impact the Newcastle Drinking Water System located within the Ganaraska Region Source Protection Area.

the pipeline. This combined flow was discharged from the mouth of the watercourse and modeled. This modeling provides a typical lake response and does not rely on selected directional events. Results of this modeling and the concentration of benzene at the intakes are shown in Table 4.2-2.

The modeled benzene concentrations at the intakes for the modeled fuel (gasoline with 0.5-1% benzene added) (see Table 4.2-2) are several orders of magnitude greater than the water quality deterioration benchmark of 0.005mg/L. Given this result, it is projected that this modeling appropriately represents spills from pipelines traversing the source protection area that carry fuel products with a comparable flow rate of benzene and that are located in the general area of the modeled pipeline. Thus, for the purposes of determining if a pipeline that crosses watercourses in the source protection area is to be considered a significant drinking water threat, the flow rate of benzene in the modeled scenario will be considered a benchmark (i.e. pipelines that deliver a flow rate of at least 4.5 m^3/hr of pure benzene would be considered a significant drinking water threat). The hatched areas on maps 4-13, 4-14, and 4-15 show the areas where pipeline activities are or would be significant drinking water threats. These are the areas that are located downstream or in very close proximity to the modeled stream crossings.

The streams crossed by the pipeline that are outside the IPZ-1 and IPZ-2 have been included in the IPZ-3 delineation for the Cobourg, Newcastle, and Port Hope drinking water systems. Where the IPZ-3 abuts land, it was extended perpendicular to the river bank in a way that combined the 120-metre setback from the bank and the area of the Ganaraska Region Conservation Authority regulation limit.

Travel time estimates for a series of streams using the HEC-RAS hydraulic model were undertaken to determine the probability of miscible constituents of a fuel spill reaching Lake Ontario. It was determined that all streams crossed by the pipeline between Niagara and the Ganaraska Region Conservation Authority jurisdiction (inclusive) would have travel times short enough to deliver the spilled fuel to the Lake Ontario intakes (where Lake Ontario currents could move this material to an intake). Due to this analysis Gages Creek (an un-modeled creek) has been included in the IPZ-3 delineation for the Cobourg and Port Hope drinking water systems.

Given the approach to defining an IPZ-3 the spill is a significant threat, and there is no need to calculate vulnerability scores, due to the vulnerability of the surface water intakes to the extreme event.

Table 4.2-2: Modeling Results of Fuel Pipeline Spill Scenarios

Intake	Spill Scenario	Pipeline Spill Location	Water Quality Deterioration Benchmark (mg/L)	Peak Concentration at the Intake (mg/L)	Significant Drinking Water Threat
Cobourg Water Treatment Plant	Ganaraska River pipeline break[1]	Within IPZ-1 and IPZ-2	0.005	1.0	Yes
	Cobourg Creek pipeline break[1]	IPZ-3		3.0	Yes
	Gages Creek pipeline break[2]	IPZ-3	0.005		Yes
Newcastle Drinking Water System	Wilmot Creek pipeline break[1]	IPZ-3	0.005	3.0	Yes
	Graham Creek pipeline break[1]	IPZ-3		3.0	Yes

Intake	Spill Scenario	Pipeline Spill Location	Water Quality Deterioration Benchmark (mg/L)	Peak Concentration at the Intake (mg/L)	Significant Drinking Water Threat
	Bowmanville Creek pipeline break [3]	Bowmanville IPZ [3]	0.005	1.0	Yes
Municipality of Port Hope Water Treatment Plant	Ganaraska River pipeline break[1]	Within IPZ-2 and IPZ-3	0.005	3.0	Yes
	Cobourg Creek pipeline break[1]	IPZ-3		1.0	Yes
	Gages Creek pipeline break[2]	IPZ-2	0.005		Yes

[1]Modelled scenario

[2]Un-modelled (interpolated) scenario

[3]Pipeline breaks in Bowmanville Creek (within CLOCA SPA) can be significant threats to the Newcastle drinking water intake

Gasoline Storage Tanks

Event based modeling was undertaken to determine if gasoline spilled from marine storage tanks located at the Cobourg Marina, Newcastle Marina, and Port Hope Harbour would reach the intakes of the Cobourg Water Treatment Plant, Newcastle Drinking Water System, and Municipality of Port Hope Water Treatment Plant and cause deterioration of the quality of raw water for drinking water purposes.

The modeled parameter of concern for the fuel spill scenarios was benzene. The gasoline modeled had a benzene content of 1.5% and the Ontario Drinking Water Quality Standard for benzene is 0.005 mg/L. The fuel spill was simulated with the calibrated Lake Ontario MIKE-3 model with a new 270 m nested grid that was developed to include all intakes from Ajax to Cobourg (Dewey, 2013). The simulation period for the model was May 1 to October 22, 2006. The wind forcing was the NOAA 2-D wind field with additional data from Pearson Airport. The daily flow in the rivers was obtained from the Canada Water Survey database.

The size of the fuel tanks and the spill rates modeled are included in Table 4.2-3. For the Port Hope Harbour fuel tank spill, three different spill rates were modeled. These spill rates were calculated based on the total tank volume spilling in 1 hour, 2 hours, and 3 hours, respectively. The modeling results indicated that the relationship between spill rate and peak concentration at the intakes appeared linear; therefore, peak concentrations for shorter or longer spill times can be calculated from linear ratios. Based on this result for the Port Hope scenario, the other fuel spill scenarios were only run for the 1 hour spill.

The Port Hope Harbour fuel spill flow was mixed with Ganaraska River flow. It was assumed that benzene in the gasoline would fully mix with the river water. This combined flow was discharged from the mouth of the watercourse and modeled in Lake Ontario. The Cobourg Marina and Newcastle Marina fuel spill flow was mixed with lake water. It was assumed that the benzene in the gasoline would fully mix with the lake water. Additionally, a decay rate was applied to the benzene in all scenarios. Results of this modeling and the concentration of benzene at the intakes are shown in Table 4.2-4.

Table 4.2-3: Modeling Conditions of Gasoline Storage Tank Spill Scenarios

Gasoline Tank Location	Fuel Tank Description	Spill Rate (m^3/s) 1 hour spill	Spill Rate (m^3/s) 2 hour spill	Spill Rate (m^3/s) 3 hour spill
Cobourg Marina	Below ground, 15,000 L	0.00416	-	-
Newcastle Marina	Below ground, 4,500 L	0.00125	-	-
Port Hope Harbour	Above ground, double walled tank. 3,785 L	0.00105	0.00052	0.00035

Table 4.2-4: Modeling Results of Gasoline Storage Tank Spill Scenarios

Intake	Gasoline Tank Storage Spill Scenario	Spill Location	Water Quality Deterioration Benchmark (mg/L)	Peak Concentration at the Intake (mg/L)	Significant Drinking Water Threat
Cobourg Water Treatment Plant	Cobourg Marina	Within IPZ 2	0.005	0.087	Yes
	Newcastle Marina	Within IPZ 2		1.0 E-5	No
	Port Hope Harbour	Within IPZ 2		0.0006	No
Newcastle Drinking Water System	Cobourg Marina	Within IPZ 2	0.005	1.0 E-8	No
	Newcastle Marina	Within IPZ 2		0.0077	Yes
	Port Hope Harbour	Within IPZ 2		5.0 E-8	No
Municipality of Port Hope Water Treatment Plant	Cobourg Marina	Within IPZ 2	0.005	1.9 E-5	No
	Newcastle Marina	Within IPZ 2		1.0 E-5	No
	Port Hope Harbour	Within IPZ 2		0.003	No

Wastewater Treatment Plant Disinfection Failure

Event based modeling was undertaken to determine if a disinfection failure at the Cobourg, Port Hope, Newcastle, and Port Darlington wastewater treatment plants releasing E. coli at a level of 1,000,000 counts/100 ml of effluent would reach the intakes of the Cobourg Water Treatment Plant, Newcastle Drinking Water System, and Municipality of Port Hope Water Treatment Plant and cause deterioration of the quality of raw water for drinking water purposes.

The modeled parameter of concern for these scenarios was E. coli and the recreational Provincial Water Quality Standard used in the simulation was 100 counts/100 ml of raw water. The disinfection failure outflow was simulated with the calibrated Lake Ontario MIKE-3 model with a new 270 m nested grid that was developed to include all intakes from Ajax to Cobourg (Dewey, 2013). The simulation period for the model was May 1 to October 22, 2006. The wind forcing was the NOAA 2-D wind field with additional data from Pearson Airport. The daily flow in the rivers was obtained from the Canada Water Survey database. The average flow rates of the wastewater treatment plants used in the model are provided in Table 4.2-5.

The Cobourg Wastewater Treatment Plant 1 disinfection failure discharge was mixed with Cobourg Creek flow and it was assumed that the E. coli in the discharge would fully mix with the creek water. This combined flow was discharged from the mouth of the watercourse and modeled. The Cobourg Plant 2, Port Hope, and Newcastle Wastewater Treatment Plant disinfection failure discharges were mixed with lake water and it was assumed that the E. coli in the discharge would fully mix in the lake water. Additionally a first order decay rate of 1.1 E-5/s was applied to the E. coli in all scenarios. Results of this modeling and the concentration of E. coli at the intakes are shown in Table 4.2-6.

Table 4.2-5: Modeling Parameters of Wastewater Treatment Plant Disinfection Failure Scenarios

Wastewater Treatment Plant	Average Flow Rate (m^3/s)
Cobourg Plant 1	0.0709
Cobourg Plant 2	0.0507
Newcastle	discharge velocity of 2 m/s assumed
Port Hope	0.129

Table 4.2-6: Modeling Results of Wastewater Treatment Plant Disinfection Failure Scenarios

Intake	Wastewater Treatment Plant Scenarios	Spill Location	Water Quality Deterioration Benchmark(count/100ml)	Maximum Concentration at the Intake (count#/100ml)	Significant Drinking Water Threat
Cobourg Water Treatment Plant	Cobourg Plant 1	Within IPZ 2	100	670	Yes
	Cobourg Plant 2	Within IPZ 2		207	Yes
	Newcastle	Within IPZ 2		0.04	No
	Port Hope	Within IPZ 2		27	No
Newcastle Drinking Water System	Cobourg Plant 1	Within IPZ 2	100	0.28	No
	Cobourg Plant 2	Within IPZ 2		0.66	No
	Newcastle	Within IPZ 2		565	Yes
	Port Hope	Within IPZ 2		1.9	No
	Port Darlington[3]	Outside GRSPA		146	Yes
Municipality of Port Hope Water Treatment Plant	Cobourg Plant 1	Within IPZ 2	100	20	No
	Cobourg Plant 2	Within IPZ 2		13	No
	Newcastle	Within IPZ 2		5.5	No
	Port Hope	Within IPZ 2		501	Yes

4.2.2.4 TRANSPORT PATHWAYS

Transport pathways are features of the landscape that provide the potential for contaminants to quickly reach an intake by short-circuiting the flow of water. The more transport pathways that exist within an intake protection zone, the higher the vulnerability of that zone to contamination. The *Technical Rules* sets out a mechanism by which IPZ-2s that extend onto land can be extended to include natural transport pathways (e.g., small tributary channels, fractured rock, and sand lenses) or man-made transport pathways (e.g., sewer discharge pipes, drainage ditches, paved areas, and tile drains).

Natural and man-made transport pathways in the Ganaraska Region Source Protection Area were identified during the data collection phase of the studies and through field reconnaissance. Transport pathways are identified in Table 4.2-7. The Intake Protection Zone 2 delineations were modified where necessary to

[3] Port Darlington Wastewater Treatment Plant is located within the CTC Source Protection Region; however, a disinfection failure can impact the Newcastle Drinking Water System located within the Ganaraska Region Source Protection Area. Note that the discharge point of the plant is not associated with an intake protection zone polygon, rather, the discharge point and the connected contaminant collector line shown on map 4-14 make up the IPZ-3 for that discharge point in relation to the Newcastle drinking water intake.

incorporate the selected transport pathways. Transport pathways were also considered during the assignment of the vulnerability scores.

For storm sewersheds, the *Technical Rules* require that the IPZ-2 must be delineated based on the time of travel distance (in this case two hours). IPZ-2s delineated for the Cobourg Water Treatment Plant, Newcastle Drinking Water System, and Municipality of Port Hope Water Treatment Plant were calculated to determine the extent of the storm sewersheds that are within the two-hour time of travel to the corresponding intake. Storm sewers networks were individually analyzed with consideration of design flow velocities and contributing areas to each network. This analysis resulted in the truncation of storm sewersheds within the IPZ-2s for the Cobourg Water Treatment Plant, Newcastle Drinking Water System, and Municipality of Port Hope Water Treatment Plant (Ganaraska Region Conservation Authority, 2011) when compared to the original IPZ-2s which considered the entire extent of the storm sewersheds (Stantec Consulting Ltd. studies).

Table 4.2-7: Transport Pathways

Intake	Description of Transport Pathways	Location	Source of Information
Cobourg Water Treatment Plant	Watercourses	Cobourg Creek, Midtown Creek, Brook Creek, Unnamed Creek 1, Massey Creek, Unnamed Creek 2, Covert Creek	Ganaraska Region Conservation Authority, Town of Cobourg, OMAFRA[1] Tile Drainage Area mapping
	Storm Drainage Areas	Town of Cobourg storm drainage network	
	Tile Drainage Area	Throughout drainage area	
Newcastle Drinking Water System	Watercourses	Wilmot Creek, Graham Creek, Lovekin Creek, Unnamed Creek 1, Unnamed Creek 2, Unnamed Creek 3	Ganaraska Region Conservation Authority, Municipality of Clarington, OMAFRA Tile Drainage Area mapping
	Storm Drainage Areas	Municipality of Clarington, Village of Newcastle storm drainage network	
	Tile Drainage Area	Throughout drainage area	
Municipality of Port Hope Water Treatment Plant	Watercourses	Ganaraska River, Brands Creek, Little's Creek, Gage Creek, Unnamed Creek 1, Unnamed Creek 2, Unnamed Creek 3	Ganaraska Region Conservation Authority, Municipality of Port Hope, OMAFRA Tile Drainage Area mapping
	Storm Drainage Areas, and roadside ditches	Municipality of Port Hope Ward 1, storm drainage network	
	Tile Drainage Area	Throughout drainage area	

[1]OMAFRA: Ontario Ministry of Agriculture, Food and Rural Affairs

4.2.3 VULNERABILITY ASSESSMENT

Any drinking water system using surface water as a source is inherently at risk of contamination. However, the degree of risk varies depending on many factors, such as hydrologic and environmental characteristics of the waterbody, the proximity of drinking water threats to the intake, and the existence of pathways that allow these contaminants to reach the intake.

The *Technical Rules* provides a detailed methodology for determining vulnerability scores for intake protection zones 1 and 2. There are two elements of vulnerability associated with intake protection zones, an area vulnerability factor and a source vulnerability factor. For the IPZ-3 a vulnerability score is not assigned given scores for a Type A system within an IPZ-3 are not applicable.

In 2021, the Technical Rules were updated to consider local characteristics within an intake protection zone. The intake protection zone vulnerability assessment was reviewed and it was determined that the initial vulnerability assessment evaluated the local characteristics appropriately. As a result, no changes were made to the vulnerability analysis for the surface water intakes.

4.2.3.1 VULNERABILITY FACTORS

Area Vulnerability Factor

The area vulnerability factor differs between IPZ-1 and IPZ-2 in that the closer the zone to the intake, the higher the factor. Thus, the area vulnerability factor for Intake Protection Zone 1 is the highest and is fixed at 10. For Intake Protection Zone 2, the factor can range between 7 and 9. Area vulnerability factors were assigned by examining the following:

- Percentage of the area that is composed of land
- Land cover, soil type, permeability, and slope of setbacks
- Hydrological and hydrogeological conditions in the area that contribute water to the area through transport pathways.

To quantify these factors a decision matrix was developed using ranges of characteristics for each of the three sub factors. The sub factors were assumed to have equal importance and therefore were weighted equally. Table 4.2-8 provides the decision matrix created by Stantec to calculate the area vulnerability factor. To calculate the area vulnerability factor score, the following equation was used based upon Table 4.2-8 results.

Area Vulnerability Factor = (% land sub factor + land characteristics sub factor + transport pathways sub factor) / 3

Table 4.2-8: Area Vulnerability Factor Decision Matrix

Sub Factor	Component	Criteria			Sub Factor Score
		7	8	9	
% Land	n/a[2]	< 33%	33% to 66%	> 66%	Based on area calculated within the IPZ-2
Land Characteristics	Land Cover	Mainly forest	Agriculture and/or mixed vegetated, and developed	Mainly developed	Each sub factor assigned a score based on environmental conditions = sum of components / 4
	Soil Type	Sandy	Silty Clay	Clay	
	Permeability	> 66%	33% to 66%	< 33%	
	Percent Slope	< 2%	2% to 5%	> 5%	
Transport Pathways	Storm Catchment Area	< 33%	33% to 66%	> 66%	Each sub factor assigned a score based upon the characteristics of IPZ-2 = sum of components / 3
	Number of storm outfalls, watercourses, and drains per 1,000 ha [1]	0 to 3	4 to 7	> 7	
	Percent tile drain	< 33%	33% to 66%	> 66%	

[1] The criteria used in the component value for the number of storm outfalls was developed by Stantec Consulting, and tested on over 50 water treatment plants through a trial an error process. [2] n/a no additional components outlined in the Technical Rules for the sub factor

Source Vulnerability Factor

The source vulnerability factor applies to the location of the intake in a particular waterbody. Type A intakes are considered to be susceptible to contamination. Their range of possible source vulnerability factors is from 0.5 to 0.7. Source vulnerability factors were assigned in consideration of the following:

- Depth of the intake
- Distance of the intake from land
- History of water quality concerns at the intake.

Table 4.2-9 provides the decision matrix that was used to calculate the source vulnerability factor. The three sub factors were assumed to have equal importance and were therefore weighted equally. To calculate the source vulnerability factor score, the following equation was used.

Source Vulnerability Factor = (offshore length sub factor + depth sub factor + water quality sub factor) / 3

Table 4.2-9: Source Vulnerability Factor Decision Matrix

Sub Factor	Criteria			Sub Factor Score
	0.5	0.6	0.7	
Intake Depth [1]	> 6.1 m	3.1 m to 6.0 m	0 m to 3.0 m	Choose score based on intake characteristics
Intake Offshore Length [2]	< 500 m	300 m to 500 m	< 300 m	Choose score based on intake characteristics
Recorded Water Quality Issues	Minimal number of parameter results measured above ODWQS[3] No additional concerns	Some parameter results measured above ODWQS along with operator concerns Watershed characterization reported concerns	Several parameter results measured above ODWQS Operator and/or municipal staff confirmation of raw water quality concerns	Choose most appropriate score based upon information received

[1] Criteria developed by Stantec Consulting using Ministry of the Environment and Climate Change (2008).
[2] Criteria developed by Stantec Consulting based on Michigan Department of Environmental Quality Water Bureau (2004).
[3] Ontario Drinking Water Quality Standards

4.2.3.2 VULNERABILITY SCORES FOR IPZ-1 AND IPZ-2

The vulnerability score for each intake protection zone is calculated by multiplying the area vulnerability factor and the source vulnerability factor. A higher vulnerability score indicates a higher vulnerability to contamination. Depending on the intake protection zone, the vulnerability score of a Type A intake can range from 5 to 7 (IPZ-1) or from 3.5 to 6.3 (IPZ-2). Source and area vulnerability factors were assigned to each of the intakes based on considerations of intake characteristics and zone characteristics such as runoff generation potential, transport pathways, distances to intakes, and raw water quality characteristics. The area vulnerability scores are shown in Table 4.2-10 and the source vulnerability scores are shown in Table 4.2-11. A summary of vulnerability factors and vulnerability scores assigned to each of the three intakes is listed in Tables 4.2-12 and 4.2-13 respectively. Vulnerability scores for each of the systems are also shown on maps 4-1, 4-2, and 4-3.

Table 4.2-10: Area Vulnerability Factor and Sub Factor Scores

Intake	% Land	Land Characteristics					Transport Pathways				Area Vulnerability Factor
		Land Cover	Soil Type	Permeability	% Slope	Sub Factor Score	Storm Catchment Area	# of storm outfalls, watercourses and drains per 1,000 ha	% title drain	Sub Factor Score	
Cobourg Water Treatment Plant	8	8	8	8	7	7.8	9	9	9	8.3	8
Newcastle Drinking Water System	8	8	8	7	8	7.8	7	9	7	7.7	8
Municipality of Port Hope Water Treatment Plant	8	8	8	7	8	7.8	7	9	7	7.7	8

Table 4.2-11: Source Vulnerability Factor and Sub Factor Scores

Intake	Intake Depth	Intake Offshore Length	Recorded Water Quality Issues	Source Vulnerability Factor
Cobourg Water Treatment Plant	0.5	0.5	0.5	0.5
Newcastle Drinking Water System	0.5	0.5	0.5	0.5
Municipality of Port Hope Water Treatment Plant	0.5	0.5	0.5	0.5

Table 4.2-12: Summary of Vulnerability Factors

Intake	IPZ-1 Area Vulnerability Factor (prescribed for Type A intakes)	IPZ-2 Area Vulnerability Factor (Range 7-9 for Type A intakes)	Source Vulnerability Factor (Range 0.5-0.7 for Type A intakes)
Cobourg Water Treatment Plant	10	8	0.5
Newcastle Drinking Water System	10	8	0.5
Municipality of Port Hope Water Treatment Plant	10	8	0.5

Table 4.2-13: Vulnerability Scores

Intake	IPZ-1	IPZ-2
Cobourg Water Treatment Plant	5	4
Newcastle Drinking Water System	5	4
Municipality of Port Hope Water Treatment Plant	5	4

4.2.4 UNCERTAINTY ANALYSIS

The final component of the vulnerability assessment for an intake is the assignment of an uncertainty rating. With all technical work such as field studies, desktop analysis, statistical analysis, and numerical modeling, there are inherent variations in the level of uncertainty. This level of uncertainty is affected by the quality of the original data, the precision and accuracy of field data, and the use of assumptions in calculations and modeling.

It is impossible to achieve 100% certainty in making decisions regarding any natural system, but it is important to try to identify the overall uncertainty in the vulnerability assessment process.

Determining the uncertainty rating involves undertaking the following:

- An evaluation of the uncertainty of the footprints of Intake Protection Zone 1 and Intake Protection Zone 2 associated with each intake.
- An evaluation of the uncertainty of the vulnerability score that is assigned to each zone.
- An evaluation of the uncertainty of modeling approach/results.
- The assignment of an overall uncertainty rating (high or low) for each zone.

In order to assign a low uncertainty rating to a zone, the following were considered. If these conditions were not met, the uncertainty rating was set at "high":

- High density of data (spatial and temporal) and high degree of confidence in the data
- Local studies and investigations completed that have resulted in high quality and relevance of data
- Findings using different approaches (methods/models) are consistent.
- Where models have been used, they are sufficiently calibrated and verified.

Where there is either a high uncertainty in the zone delineation, or a high uncertainty in assigning the relative vulnerability scoring for the area, then the uncertainty score should be set to "high". When a high uncertainty rating is applied, uncertainties are to be addressed in subsequent stages of the source protection planning process.

4.2.4.1 UNCERTAINTY OF INTAKE PROTECTION ZONES

The uncertainty ratings assigned to the intake protection zone delineations are discussed in the following sections.

4.2.4.1.1 Intake Protection Zone 1

There was a high degree of confidence associated with the delineation of Intake Protection Zone 1 for the three Lake Ontario intakes because the delineation is prescribed according to the *Technical Rules*. Therefore the uncertainty rating assigned to the delineation of the Intake Protection Zone 1 area for all intakes was set to "low" (Table 4.2-14).

4.2.4.1.2 Intake Protection Zone 2

IPZ-2 Delineated Using Lake Ontario Hydrodynamic Models

The uncertainty rating assigned to the delineation of Intake Protection Zone 2 for all three intakes where the modeling approach was used was set to "high" because of limitations in the models, limited availability of high quality observed data, and limitations in the ability to calibrate and validate the models being used (Table 4.2-14).

IPZ-2 Delineated Using Residual Time of Travel Distance in Tributaries and Transport Pathways

The overall uncertainty rating assigned to the delineation of Intake Protection Zone 2 for the travel times calculated for tributaries was set to "high". Although the travel time calculated for storm sewers would have a "low" uncertainty, the uncertainty associated with the travel times in tributaries has been set as "high". This was due to limitations in models, limited availability of high quality observed data, and limitations in the ability to calibrate and validate the models being used.

4.2.4.1.3 Intake Protection Zone 3

The uncertainty rating assigned to the delineation of Intake Protection Zone 3 for all three intakes where the modeling approach was used was set to "high" because of limitations in the models, limited availability of high quality observed data, and limitations in the ability to calibrate and validate the models being used.

4.2.4.1.4 Uncertainty of Vulnerability Scoring

Uncertainty in the vulnerability scoring includes the uncertainty of both the source vulnerability factors and area vulnerability factors. The uncertainty ratings assigned to the vulnerability scoring of each zone are summarized in Table 4.2-14.

Area Vulnerability Factors

The area vulnerability factors for Intake Protection Zone 1 are set with no variation (i.e., they must be 10), so there is no uncertainty in this number. For Intake Protection Zone 2, the range of area vulnerability factors is from 7 to 9. A component approach to the assignment of these factors and the limited range of options have lead to a "low" uncertainty for these factors as well (Table 4.2-14).

Source Vulnerability Factors

The source vulnerability factors for Type A intakes have one of three options (0.5, 0.6, or 0.7). The uncertainty associated with the selection of the appropriate source vulnerability factor is "low" for all three intakes (Table 4.2-14).

Table 4.2-14: Uncertainty Rating Details

Uncertainty Component	Consideration Factor	IPZ-1 Rating	IPZ-2 Rating
Delineation of the surface water intake protection zones	Data	Low	High
	Modeling	n/a	High
	QA/QC	Low	Low
	Calibration and validation	n/a	High
Overall		Low	High
The assessment of the **vulnerability** of the intake protection zones	Data	Low	Low
	QA/QC	Low	Low
	Accuracy of the vulnerability factors	Low	Low
Overall		Low	Low

n/a – (not applicable) modeling is not required for the delineation of IPZ-1.

4.2.4.1.5 Final Uncertainty Ratings

The final uncertainty ratings for the vulnerability scoring are listed in Table 4.2-15. The final ratings are assigned based on the highest uncertainty rating (for delineation or vulnerability scoring) for each zone.

Table 4.2-15: Final Uncertainty Ratings

System Name	Uncertainty Ratings								
	IPZ Delineation			Assignment of Vulnerability Scores			Final Uncertainty Rating		
	IPZ-1	IPZ-2	IPZ-3	IPZ-1	IPZ-2	IPZ-3	IPZ-1	IPZ-2	IPZ-3
Cobourg Water Treatment Plant	Low	High	High	Low	Low	N/A	Low	High	High
Newcastle Drinking Water System	Low	High	High	Low	Low	N/A	Low	High	High
Municipality of Port Hope Water Treatment Plant	Low	High	High	Low	Low	N/A	Low	High	High

4.2.5 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Investigation into the possibility of modeling other IPZ-3 situations should occur. These could include, but are not limited to spills from transportation corridors (road, rail and shipping lanes) and low level radioactive waste clean-up activities.

4.2.6 REFERENCES

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4.3 ISSUES ASSESSMENT

Drinking water issues exist where the concentration of a contaminant at a surface water intake related to a drinking water system may result in the deterioration of the quality of the water for use as a source of drinking water. The identification of drinking water issues for the three surface water intakes in the Ganaraska Region Source Protection Area was completed under one study by the Region of Peel summarizing data collected: Region of Peel, 2010 *Issues Evaluation for Newcastle WTP, Cobourg WTP and Port Hope WTP*. This section is a summary of this report.

4.3.1 DRINKING WATER ISSUES EVALUATION

The *Technical Rules* describes what constitutes a "drinking water issue" and the requirements to identify them for consideration in the Assessment Report, as part of the process to assess the significance of drinking water threats. A drinking water issue is typically related to the presence of a chemical or a bacteriological parameter in a drinking water supply at a concentration that is greater than the maximum acceptable concentration (MAC) published in the *Ontario Drinking Water Quality Standards*. The definition is expanded for the purposes of the Assessment Report to include parameters that may cause deterioration of the quality of water for use as a drinking water source. To this end, parameters that do not necessarily cause effects to human health are also considered.

Where possible and required, an attempt is to be made to identify the cause of a drinking water issue and link it to an identified threat. Threats that are identified as the cause of the drinking water issues are to be considered significant drinking water threats in accordance with the *Technical Rules*.

The following sections provide the background and details of the process followed in this study to evaluate data and to determine which parameters constitute drinking water issues for the municipal water supply systems under review.

4.3.1.1 ONTARIO DRINKING WATER QUALITY STANDARDS

The primary benchmark for review of water quality data is the *Ontario Drinking Water Quality Standards* (ODWQS). The ODWQS includes maximum acceptable concentrations (MAC) for health-related parameters as well as recommended maximum concentrations for parameters that affect the aesthetics or taste of the water, and those that are used as operational guidelines. The *Technical Rules* requires that the drinking water issues assessment considers the parameters listed in Schedules 1-3 of these standards, which include microbiological, chemical, and radiological parameters, and Table 4 of the *Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines*, which includes aesthetic objectives and operational guidelines for water treatment. For chemical parameters (primarily organic chemicals) that do not typically occur in nature, the benchmark used was the laboratory method detection limit (MDL) for groundwater supplies. Additional notes about selected parameters are included below.

4.3.2 METHODOLOGY

The steps followed in the evaluation of drinking water issues included the following:

Step 1: Assemble available data
Step 2: Review data and analysis
Step 3: Evaluate drinking water issues
Step 4: Identify contributing area for drinking water issues
Step 5: Prepare list of drinking water issues.

4.3.2.1 ASSEMBLE AVAILABLE DATA

Available water quality data for raw and treated water from the three municipal water supply systems and from monitoring associated with these water supply systems were reviewed to identify drinking water issues. The available data for each of the three municipal groundwater systems were identified through a review of the following data sources:

- Water Supply System Engineers' Reports (to describe treatment capacity)
- Permits to Take Water and accompanying technical reports
- Municipal water supply water quality data
- Monthly certificates of analysis
- Annual water supply water quality monitoring reports
- Microbial Control Plans (where available)
- Various background reports
- Interviews with plant operators.

4.3.2.2 DATA REVIEW AND ANALYSIS

The review of issues was based on the information provided in the available data and includes the following:

- The issues that were documented in available reports
- The issues and concerns that were identified by local System Operators, Health Departments/Units, and other stakeholders
- Chemical parameters in raw or treated water where concentrations consistently exceeded an identified benchmark
- Pathogenic parameters (bacteria) that were consistently present in raw or treated water
- Data and hydrographs of concentration versus time for parameters of interest showing an increasing trend that would likely reach an identified benchmark in the future.

4.3.2.3 WATER TREATMENT PLANT OPERATOR INTERVIEWS

As part of the process to identify and evaluate drinking water issues, the operators of the three municipal surface water supplies were provided the opportunity to review the information and to contribute to the decision process. In addition, the Certificate of Approval and ~~the most recent Ministry of the Environment and Climate Change~~ Drinking Water System Inspection Reports were reviewed to collect information on the treatment processes used in each water supply system.

4.3.2.4 EVALUATE DRINKING WATER ISSUES

In review of the data available, no issues were defined for the Cobourg surface water supply, the Newcastle surface water supply, or the Port Hope surface water supply.

4.3.2.5 IDENTIFY CONTRIBUTING AREA FOR DRINKING WATER ISSUES

In review of the data available, no issues were defined for the Cobourg surface water supply, the Newcastle surface water supply, or the Port Hope surface water supply, therefore no contributing area for issues was identified.

4.3.3 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Due to the requirements of the *Safe Drinking Water Act*, the Drinking Water Information System is heavily populated with treated water quality, and with a limited amount of raw water quality information. A more rigorous issues evaluation could be completed if enhanced raw water sampling and raw water quality testing were carried out.

As part of the ongoing work being undertaken by the Lake Ontario Collaborative, further evaluation of pathogens and chemicals in Lake Ontario will occur. This information will support the continued improvement of issue evaluations for the Cobourg, Newcastle, and Port Hope Water Treatment Systems.

4.3.4 REFERENCES

Region of Peel. (2010). *Issues Evaluation for Newcastle WTP, Cobourg WTP and Port Hope WTP*. Public Works File Number 07-1590. Brampton (ON).

4.4 THREATS ASSESSMENT

The assessment of drinking water threats is the final step of the water quality risk assessment. It identifies all of the activities and conditions that can be considered drinking water threats in each vulnerable area and evaluates the threats that are currently located in vulnerable areas. This section refers to the drinking water threats for surface water systems located in intake protection zones.

The assessment of drinking water threats in the intake protection zones in the Ganaraska Region Source Protection Areas has been completed by the Ganaraska Region Conservation Authority. This section is a summary of the assessment.

4.4.1 OVERVIEW OF REQUIREMENTS

The following four general requirements are set out by the regulations and *Technical Rules* for the completion of the assessment of drinking water threats for each vulnerable area. These requirements are addressed in the following subsections.

- List the activities and conditions that are drinking water threats or that would be drinking water threats if they were located in a vulnerable area in the future.
- Identify the circumstances that would make the identified activities threat a significant, moderate, or low threat (for conditions, the hazard rating for the condition and information that confirms that there is a condition is required).
- Mapping of the areas in each vulnerable area that identifies the circumstances under which the identified activities are or would be a significant, moderate, or low drinking water threat.
- Enumeration of the locations (number of parcels) at which a person is engaging in an activity that is a significant drinking water threat or where there is a condition that is a significant drinking water threat.

4.4.2 LISTING OF ACTIVITIES THAT ARE OR WOULD BE DRINKING WATER THREATS

Certain activities have the potential to impact the quality of source water when located in vulnerable areas. The activities that are drinking water threats within the meaning of the *Clean Water Act* include the following. Each of these three types of activities is identified below.

- Activities prescribed to be drinking water threats in paragraphs 19 and 20 of subsection 1.1(1) of *O. Reg. 287/07 (General)*
- ~~Activities identified as local threats by the Source Protection Committee~~
- Activities that contribute to drinking water issues.

4.4.2.1 ACTIVITIES PRESCRIBED TO BE DRINKING WATER THREATS

The activities prescribed to be drinking water threats are listed in Table 4.4-1. These include ~~19~~ 20 water quality threats and 2 water quantity threats. Water quantity threats (19 and 20) do not apply due to the fact that the water is drawn from Lake Ontario, with the water being returned to Lake Ontario. Water quality threats (1 to 19, ~~and~~ 21 and 22) are evaluated in this section.

Table 4.4-1: Activities Prescribed to be Drinking Water Threats

No.	Description of Activity
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage
3	The application of agricultural source material to land
4	The storage of agricultural source material
5	The management of agricultural source material
6	The application of non-agricultural source material to land
7	The handling and storage of non-agricultural source material
8	The application of commercial fertilizer to land
9	The handling and storage of commercial fertilizer
10	The application of pesticide to land
11	The handling and storage of pesticide
12	The application of road salt
13	The handling and storage of road salt
14	The storage of snow
15	The handling and storage of fuel
16	The handling and storage of a dense non-aqueous phase liquid
17	The handling and storage of an organic solvent
18	The management of runoff that contains chemicals used in the de-icing of aircraft
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body[1]
20	An activity that reduces the recharge of an aquifer[1]
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard
22	The establishment and operation of a liquid hydrocarbon pipeline (see Section 4.4.2.2)

Source: Paragraphs 19 and 20 of subsection 1.1(1) of *O. Reg. 287/07 (General)*
[1]Activity is a water quantity threat (evaluated in the water budget and water quantity threats assessment)

~~4.4.2.2 ACTIVITIES IDENTIFIED BY THE SOURCE PROTECTION COMMITTEE~~

~~An activity has been identified as a local threat in the Ganaraska Region Source Protection Area by the Source Protection Committee (Table 4.4-2 and Appendix A).~~

~~Table 4.4-2 Local Threat Description~~

~~Activity~~	~~Vulnerability Score Required to Produce a Drinking Water Threat~~		
	~~Significant Threat~~	~~Moderate Threat~~	~~Low Threat~~
	~~IPZ-1, 2, 3, WHPA-E~~	~~IPZ-1, 2, 3, WHPA-E~~	~~IPZ-1, 2, 3, WHPA-E~~
~~1. The conveyance of oil by way of a pipeline that would be designated as transmitting or distributing "liquid hydrocarbons", including "crude oil", "condensate", or "liquid petroleum products", and not including "natural gas liquids" or "liquefied petroleum gas", with the meaning of the Ontario Regulation 210/01 under the *Technical Standards and Safety Act*, or is subject to the *National Energy Board Act*.~~ ~~2. The rupture of a pipeline in an area where the pipeline crosses a body of open water and may result~~	~~10~~	~~7 - 9~~	~~4.8 – 6.4~~

~~in the presence of BTEX in surface water.~~			

~~4.4.2.3~~4.4.2.2 ACTIVITIES THAT CONTRIBUTE TO DRINKING WATER ISSUES

Activities that contribute to drinking water issues are considered drinking water threats. No drinking water issues were identified at surface water intakes in the Ganaraska Region Source Protection Area.

~~4.4.2.4~~4.4.2.3 CIRCUMSTANCES UNDER WHICH EACH ACTIVITY IS OR WOULD BE A SIGNIFICANT, MODERATE, OR LOW DRINKING WATER THREAT

The threat level for an activity depends on the type of activity, its location, and the circumstances of the activity. Threat levels for the activities prescribed to be drinking water threats are given in the *Tables of Drinking Water Threats* ~~prepared by the Ministry of the Environment and Climate Change~~. These tables list the range of vulnerability scores under which each activity prescribed to be a drinking water threat is a significant, moderate, or low threat in each type of vulnerable area under a variety of circumstances.

The circumstances that would make the activities prescribed to be drinking water threats significant, moderate, or low drinking water threats in the intake protection zones in the Ganaraska Region Source Protection Area are identified on maps of these areas by reference to the appropriate sections of the *Tables of Drinking Water Threats* (Section 4.4.2.5).

Circumstances for some of the activities listed in the *Tables of Drinking Water Threats* refer to values of percent managed lands, livestock density, and percent impervious surface area. These are intermediate calculations that support the assignment of threat levels for certain prescribed activities. These calculations are discussed below.

~~4.4.2.4.1~~4.4.2.3.1 Managed Lands

Some of the circumstances listed for chemical threats associated with the land application of agricultural and non-agricultural source material and the land application of commercial fertilizer refer to the percent managed lands. Managed lands are lands to which materials are applied as nutrients. (Nutrients are organics or chemicals that are applied on land, obtained from chemical fertilizers, manure, or biosolids.) These lands include crop land, hay and pasture land, golf courses, and gardens and lawns in urban areas. The percent managed land in a vulnerable area is the sum of agricultural and non-agricultural managed land in the vulnerable area divided by the total area of the vulnerable area (multiplied by 100).

Agricultural managed lands were identified from provincial land use and land cover data (from the Ministry of Natural Resources and Forestry). Non-agricultural managed lands associated with urban and settlement areas were identified from the provincial data, taking 50% of urban/settlement areas as non-agricultural managed lands. Golf courses were identified from parcel data obtained from the Municipal Property Assessment Corporation. Where a parcel of managed land was located partially within a vulnerable area, only the portion of the parcel within the vulnerable area was used in the percent managed land calculation. These methods were used for calculating managed lands in intake protection zones and wellhead protection areas.

The percent managed lands in intake protection zones with vulnerability scores greater than or equal to 4.~~5~~ 0 (the minimum score required for an activity to be considered a drinking water threat) are shown on Maps 4-4 through 4-6 for the intake protection zones of each of the water treatment plants.

4.4.2.4.24.4.2.3.2 Livestock Density

Some of the circumstances listed for chemical threats associated with the storage and land application of agricultural source material, the land application of non-agricultural source material, the land application of commercial fertilizer, and the use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard refer to the livestock density calculation. Livestock density is the number of farm animals grown (expressed as nutrient units), produced, or raised per unit area (expressed in acres). This is used as a surrogate measure of the potential for applying agricultural sourced nutrients in a vulnerable area

Livestock density was calculated for each vulnerable area using information from the 2006 agricultural census, which reported livestock density by census consolidated subdivision (CCS). An assumption was made that all livestock reported by CCS were uniformly distributed across the agricultural managed lands located in the CCS.

Livestock density was calculated by dividing the number of equivalent livestock (in nutrient units) reported in a CCS by the acreage of the agricultural managed lands in the CCS. The resulting livestock density value was assigned to the agricultural managed lands in the CCS. This approach was used because the large areal coverage of intake protection zones would make the use of orthophotos to identify livestock barns very cumbersome and time-consuming. There is also a lack of orthophotos coverage in the northern part of the Trent source protection areas. Furthermore, it is difficult to predict the livestock numbers in the Trent source protection region as the land use practices changes drastically with market conditions.

This calculation process was carried out for the entire source protection region and produced polygons of agricultural managed lands with corresponding livestock density attributes. These agricultural managed lands were then clipped to the vulnerable areas in the source protection region, and the livestock density of the agricultural managed lands polygons was assigned to the vulnerable areas in which they were located. The detailed steps of the methodology are listed below and were used for calculating livestock density in intake protection zones and wellhead protection areas.:

1. Identify the number of different types of livestock for each CCS using the census of agriculture (2006) data
2. Convert the number of livestock to equivalent nutrient units using the information provided in section 3.1 of the Nutrient Management Protocol
3. Determine the area of the agricultural managed lands (in acres) within the CCS
4. Calculate the livestock density applicable to the agricultural lands within the CCS by dividing the nutrient units (as per step 2) by the acreage of land used for the application of nutrients (as per step 3)
5. The above four steps were carried out for all the CCS within the source protection region, and livestock densities were assigned to all agricultural managed lands located within the source protection region.
6. The agricultural managed lands were then clipped to the relevant vulnerable areas in the source protection region (i.e., WHPA-EWHPA A, IPZ-1, IPZ-2, and IPZ-3a), and the livestock densities of the agricultural managed lands were assigned to the vulnerable areas.

Livestock density in intake protection zones with vulnerability scores greater than or equal to 4.5 (the minimum score required for an activity to be considered a drinking water threat) are shown on Maps 4-4 through 4-6 for the intake protection zones of each of the water treatment plants.

4.4.2.4.3 4.4.2.3.3 Percent Impervious Surface Area

Some of the circumstances listed for the application of road salt refer to the percent impervious surface area. Impervious surface area is the surface area of all highways and other impervious land surfaces used for vehicular traffic and parking, and all pedestrian paths. These surfaces can potentially receive salt application for de-icing purposes. Impervious surfaces were identified from Ontario Road Network road data and air photo interpretation and percent impervious surface was calculated based on the amount in the particular vulnerable area. These methods were used for calculating percent impervious surface area in intake protection zones and wellhead protection areas. The percent impervious surface area was calculated based by square kilometre by overlaying a 1 by 1 km grid over the vulnerable areas. Geographic information system tools were used to calculate the percent impervious surface area for each grid cell that intersected a vulnerable area.

Since the analysis was done for the entire Source Protection Region (rather than a single source protection area), the grid used for the calculation was centred on the centroid of the Source Protection Region. This is a slight variance from the *Technical Rules*, which indicates that the grid should be centred on the centroid of the Source Protection Area. Director's approval was obtained to support this approach (see Appendix A).

Impervious surface areas in intake protection zones with a vulnerability score greater than or equal to 4.5 (the minimum score required for an activity to be considered a drinking water threat) are shown on Maps 4-4 through 4-6 for the intake protection zones of each of the water treatment plants.

4.4.2.5 4.4.2.4 MAPPING OF AREAS AND CIRCUMSTANCES WHERE AN ACTIVITY IS OR WOULD BE A SIGNIFICANT, MODERATE, OR LOW DRINKING WATER THREAT

The areas that are or would be significant, moderate, or low pathogen threats in the intake protection zones in the Ganaraska Region Source Protection Area are shown on Maps 4-7 through 4-9. These areas are mapped separately for chemical threats and pathogen threats because the ranges of vulnerability scores that would result in a drinking water threat are different for these types of threats.

4.4.3 LISTING OF CONDITIONS THAT ARE DRINKING WATER THREATS

The *Technical Rules* requires that the list of drinking water threats shall include the following conditions that is known to exist in a vulnerable area and that result from a past activity:

1. The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or wellhead protection area.
2. The presence of a single mass of more than 100 litres of one or more dense non-aqueous phase liquid in surface water in a surface water intake protection zone.
3. The presence of a contaminant in groundwater in a highly vulnerable aquifer, significant recharge area or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, and is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in groundwater could result in the deterioration of the groundwater for use as a source of drinking water.

4. The presence of a contaminant in surface soil in a surface water intake protection zone if, the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a concentration that exceeds the surface soil standard for industrial/commercial/community property use set out for the contaminant in that Table and the presence of the contaminant in surface soil could result in the deterioration of the surface water for use as a source of drinking water.
5. The presence of a contaminant in sediment in an intake protection zone, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table and the presence of the contaminant in sediment could result in the deterioration of the surface water for use as a source of drinking water.
6. The presence of a contaminant in groundwater that is discharging into an intake protection zone, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, the concentration of the contaminant exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in groundwater could result in the deterioration of the surface water for use as a source of drinking water.

The above noted conditions that result from past activities are considered drinking water threats if located in vulnerable areas. Conditions are evaluated by calculating a risk score. The risk score is calculated by multiplying the vulnerability score of the vulnerable area in which the condition is located by a hazard rating. The hazard rating is higher where there is evidence that the condition is causing off-site contamination or if the condition is on a property where a well, intake, or monitoring well related to a drinking water system is located. The threat level of the condition is assigned based on its risk score; where the risk score is greater than or equal to 80, the condition is a significant threat; where it is between 61 and 79, it is a moderate threat; and where it is between 41 and 59, it is a low threat. A condition may also be a significant drinking water threat if it is associated with a drinking water issue or if there is evidence that it is causing off-site contamination.

No conditions have been identified in the intake protection zones in the Ganaraska Region Source Protection Area as vulnerability scores will preclude the definition of significant threats. Further evaluation of conditions in Intake Protection Zone 1 defined for each municipal water system in this Assessment Report is recommended. This information will support the continued improvement of threats assessment for the Cobourg, Newcastle, and Port Hope Water Treatment Systems.

4.4.4 ENUMERATION OF SIGNIFICANT THREATS

The vulnerability scores defined in Section 4.2.3 are too low to create prescribed significant drinking water threats within the IPZ-1 and IPZ-2 for the Cobourg, Newcastle, and Port Hope surface water supplies. As a result, no significant drinking water threats were identified by using the scoring approaches for IPZ-1 and IPZ-2. Significant drinking water threats are only possible through inclusion of an event based approach.

Modeling of a Fuel Pipeline Threat~~Local Threat~~

The ~~local~~ threat of a fuel pipeline ~~(described in Section 4.4.2.2)~~ could be a low drinking water threat within an IPZ-1, 2, 3 or WHPA-E with a vulnerability score of 4.8 to 6.4. In the case of the Ganaraska Region Source Protection Area, the Lake Ontario based IPZ-1 does have a vulnerability score of 5, making the ~~local~~ threat a potential low drinking water threat (Appendix A). ~~However, due to the location of the land portion of the IPZ-1 at river/creek mouths and bluff areas of the Lake Ontario shoreline, the regulatory regime would not permit placement of fuel pipelines in these areas and therefore the local threat is not considered as a low threat within the Ganaraska Region Source Protection Area IPZ-1s.~~

The modeled spill of gasoline from a pipeline ~~indicated~~ determined that this extreme event is a prescribed significant threat to drinking water within the Ganaraska Region Source Protection Area. Given the methodology of defining an IPZ-3 for Lake Ontario intakes using the modeling approach, there is no need to calculate vulnerability scores.

Modeling of~~ed~~ ~~Threats~~ Marine Gasoline Storage Tank Spill and Disinfection Failure at a Wastewater Treatment Plant

Given the methodology of defining a modeled threat, the modeled fuel spill of a marine gasoline storage tank (described in section 4.2.2.3) is a significant drinking water threat to the Cobourg and Newcastle surface water supplies. The circumstances that create a significant drinking water threat are found in Table 4.4-~~3~~2.

The disinfection failure of the modeled wastewater treatment plants (described in section 4.2.2.3) is a significant drinking water threat to the Cobourg, Newcastle and Port Hope surface water supplies. The circumstances that create a significant drinking water threat are found in Table 4.4-~~3~~2.

The location of significant drinking water threats within Intake Protection Zones of the Ganaraska Region Source Protection Area are shown on Maps 4-13 through 4-15.

Table 4.4-~~3~~2 Modeled Threat Description

Modeled Threat	Surface Water System	Reference Number	Circumstance
Marina Gasoline Storage Tank Spill	Cobourg Newcastle	187	1. The below grade handling of liquid fuel in relation to its storage at a facility as defined in section 1 of O. Reg. 213/01 (Fuel Oil) made under the *Technical Standards and Safety Act, 2000* or a facility as defined in section 1 of O. Reg. 217/01 (Liquid Fuels) made under the *Technical Standards and Safety Act, 2000*, but not including a bulk plant. 2. The quantity of liquid fuel stored is more than 2,500 litres. 3. A spill of the fuel may result in the presence of BTEX in groundwater or surface water.
Disinfection Failure at a Wastewater Treatment Plant	Cobourg Newcastle Port Hope	1959	1. The system is a wastewater treatment facility that discharges to surface water through a means other than a designed bypass. 2. A discharge may result in the presence of one or more pathogens in groundwater or surface water.

4.4.5 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

As part of the ongoing work being undertaken by the Lake Ontario Collaborative, further evaluation of pathogens and chemicals in Lake Ontario will occur. This includes the following:

- Continued pathogen study - Quantitative Microbial Risk Assessment
- Algal toxin monitoring
- Ongoing watershed pollutant loading studies.

Additionally, further evaluation of conditions in Intake Protection Zone 1 defined for each municipal water system in this Assessment Report is recommended. This information will support the continued improvement of threats assessment for the Cobourg, Newcastle, and Port Hope Water Treatment Systems.

CHAPTER 5: GROUNDWATER SYSTEMS: WATER QUALITY RISK ASSESSMENT

5.1 SUMMARY OF GROUNDWATER SYSTEMS

There are three municipal drinking water systems listed in the *Terms of Reference* for the Ganaraska Region Source Protection Area that draw water from groundwater sources. General information regarding these systems is provided in Table 5.1-1. Details regarding their wells and water treatment systems are summarized in Table 5.1-2. Municipal groundwater supply wells are identified in Map 5-1. The average rates at which these systems pump water from their aquifers are provided in Table 5.1-3. Monitoring locations (i.e., wells) related to the Orono Drinking Water System are shown in Map 5-2. There are no monitoring ~~wells~~ locations associated with the Township of Hamilton municipal groundwater systems.

Table 5.1-1: Summary of Municipal Residential Groundwater Systems

System Name[1]	Drinking Water System No.	Watershed	Operating Authority	*Safe Drinking Water Act* Classification	Population Served [2]
Creighton Heights Water Supply System	220008104	Cobourg Creek	Township of Hamilton	Large Municipal Residential	844
Camborne Water Supply System	220008113	Cobourg Creek	Township of Hamilton	Small Municipal Residential	146
Orono Drinking Water System	220004769	Wilmot Creek	Regional Municipality of Durham	Large Municipal Residential	1,793[3]

[1] Official Drinking Water System Name as per Annual Reports [2]Data Source: Ministry of the Environment and Climate Change [3]This population is the projected population. A more accurate population based on 2.25 persons/connected properties is 1,066 persons.

Table 5.1-2: Summary of Wells and Water Treatment Systems for Municipal Residential Groundwater Systems

System Name	Well(s)						Water Treatment System
	Location	No. Wells	Depths (m)			GUDI Status	Treatment Details
			1	2	3		
Creighton Heights Water Supply System	Baltimore	3	61.9	64.9	63.4	No	Treatment is in place to remove and control iron, manganese, methane, and ammonia concentrations.
Camborne Water Supply System	Camborne	2	68.3	68.9	NA	No	Treatment is in place to remove and control natural parameters such as manganese.
Orono Drinking Water System[1]	Orono	3	13.7	13.7	12.4	No	Treatment is in place to remove and control natural parameters such as hardness.

[1]The Orono Drinking Water System consists of tow production wells. Currently the third well is being brought online to replace one of the existing production wells.

Table 5.1-3: Pumping Rates for Municipal Residential Groundwater Systems

System Name	Monthly Average Pumping Rates (m^3/day)												Average Annual Pumping Rate (m^3/day)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Creighton Heights Water Supply System	300.1	294.8	275.6	265.1	338.1	410.4	444.1	416.1	375.1	312.5	325.4	334.1	340.9
Camborne Water Supply System	43.6	42.4	43.6	46.9	53.6	63.1	63.6	60.3	54.7	43.0	43.1	43.5	50.1
Orono Drinking Water System	315.4	303.7	305.3	307.0	368.4	435.6	395.4	385.8	378.4	326.1	341.8	314.3	348.2

Data Sources: Provided by Water Treatment Plant operating authorities.
Average pumping rates expressed as a total of all intakes in the system; calculated using the following years of data: Camborne Water Supply System (2002 to 2008), Creighton Heights Water Supply System (2001 to 2008), Orono Drinking Water System (2005 to 2008).

5.2 WELLHEAD PROTECTION AREAS: DELINEATION AND VULNERABILITY

The purpose of developing a wellhead protection area (WHPA) and determining vulnerability is to minimize the potential for contaminating groundwater resources by land-based activities. The WHPA is the area around the wellhead where land activities have the potential to affect the quality of water that flows into the well. We can best protect our groundwater resources by determining the area from which our well water comes, determine the time it takes for the water to travel to the well, and determine how vulnerable that water is to being contaminated from activities occurring at the ground surface. With these three pieces of information, appropriate land use policies can be developed to minimize contamination of groundwater as it travels toward a well. This chapter is a description of the delineation of wellhead protection areas and assignment of the degree of vulnerability (vulnerability score) for these wellhead protection areas identified in the *Terms of Reference* for the Ganaraska Region Source Protection Area in accordance with Part VIII of the *Technical Rules.*

__Time of travel (TOT)__ is the amount of time it takes for water to travel from a given point within the aquifer to the well.
__Groundwater Vulnerability__ is measure of how easy or difficult it is for a contaminant to move from the surface to an aquifer. It is a measure of the amount of protection afforded by the subsurface material above the aquifer to a surface-based contamination source.

Three municipal drinking water systems consisting of eight wells were studied in the Ganaraska Region Source Protection Area. This work was carried out by Genivar Consultants LP (formerly Jagger Hims Ltd.) and was peer reviewed. The results of the review are summarized in Appendix C. This chapter is a summary of the work presented in these studies.

5.2.1 OVERVIEW OF REQUIREMENTS

The three municipal water supply systems are designated as Type 1 systems as per *Ontario Regulation 170/03* made under the *Safe Drinking Water Act*, thus requiring wellhead protection area delineations. Studies prepared for each of the municipal well systems in the Ganaraska Region Source Protection Area are required to use a methodology in accordance with the *Technical Rules* to determine the time it takes groundwater to travel to a well (time of travel). A groundwater vulnerability assessment is required for groundwater that takes 25 years or less to travel to the well.

It is recognized that the opportunity to detect and mitigate groundwater concerns improves with longer times of travel and therefore protective measures within the 25-year travel time need not be equal. More stringent protective measures are warranted for areas closer to a well than those farther away. This leads to the requirement in the *Terms of Reference* to delineate four zones within the 25-year time of travel to allow for the distinction of protection levels according to time of travel from the well. A fifth zone is used to delineate times of travel associated with wells under the direct influence of surface water.

It is also recognized that the natural geological setting is the most significant controlling factor determining the vulnerability of groundwater resources. Groundwater vulnerability is largely determined by the type, thickness, and hydraulic properties of soils and rock. For example, groundwater is more vulnerable in areas with thin, sandy soils than in areas with thick, clayey soils overlying the aquifer. The *Terms of Reference* requires the use of the physical characteristics of the soil and rock to categorize groundwater vulnerability into three levels: high, medium, and low.

5.2.1.1 WELLHEAD PROTECTION AREA (WHPA) DELINEATION

The four areas of protection within the 25-year time of travel are called WHPA-A (wellhead protection area A) through WHPA-D. WHPA-A is defined by a fixed distance from the well, and the time of travel within the aquifer is used to define zones WHPA-B through WHPA-D. The wellhead protection areas are defined in Table 5.2-1.

Table 5.2-1: Definition of Wellhead Protection Areas

Zone	Definition
WHPA-A	A distance of 100 metres or less from a wellhead.
WHPA-B	A travel time of 2 years or less in the aquifer excluding WHPA-A.
WHPA-C	A travel time in the aquifer of 5 years or less and greater than 2 years.
WHPA-D	A travel time in the aquifer of 25 years or less and greater than 5 years.
WHPA-E*	The same as an IPZ-2 starting from either known point of seepage to groundwater or nearest point between well and surface water feature.

* No surface water/groundwater interactions that would require a WHPA-E have been found in the municipal wells under consideration and therefore no WHPA-Es have been defined.

The *Technical Rules* allows time of travel to be calculated using one or more of the following methods:

- A computer based three-dimensional groundwater flow model
- Two-dimensional analytical model
- Uniform flow method
- Calculated fixed radius method.

All of the time of travel calculations determined for the drinking water systems in the Ganaraska Region Source Protection Area used the computer based three-dimensional groundwater flow model method. The information required to calculate time of travel includes the following:

__Porosity__ is the percent open spaces or voids occurring between mineral grains or in fractures of bedrock. It is a measure of the potential volume of water that can be stored in the geologic material.

- Types of and thickness of geological layers
- Hydraulic properties of geological layers (porosity and hydraulic conductivity)
- Amount of groundwater recharge
- Interaction of groundwater with streams.

The extent of wellhead protection areas determined in the aquifer is then projected vertically to the ground surface. Therefore, the time of travel associated with WHPA-B through WHPA-D does not represent a time of travel from the ground surface to the well intake. The time of travel associated with WHPA-B through WHPA-D represents the time of travel within the aquifer.

__Groundwater under the Direct Influence of Surface Water (GUDI) –__ GUDI wells obtain a portion of their water from surface water seeping underground to the well from a nearby lake, river, or stream.

There are special rules for wells that are near enough to a surface water feature that surface water seeps into the well in a relatively short period of time. These wells are deemed to be under the influence of that surface water feature (GUDI wells). The *Technical Rules* requires the protection of the surface water feature that is influencing the source of a GUDI well by the definition of a WHPA-E. The area of a surface water feature that is protected is the same as an IPZ-2 for a surface water intake starting from either of the following:

a. The point of interaction between groundwater that is the source of raw water supply for the well and the surface water that is directly influencing that groundwater, or

b. The point in the surface waterbody influencing the raw water supply for the well that is closest in proximity to the well, if the point of interaction described in (a) is not known.

No surface water/groundwater interactions that would require a WHPA-E have been found in the municipal wells under consideration and therefore no WHPA-Es have been defined in the Ganaraska Region Source Protection Area.

5.2.1.2 GROUNDWATER VULNERABILITY ASSESSMENT

The vulnerability of a groundwater system is an expression of the relative ease through which an aquifer could become contaminated by activities on or beneath the ground surface. An aquifer that can easily become contaminated is considered to be highly vulnerable. The province has provided specific guidance on categorizing groundwater vulnerability as either “high”, “medium”, or “low” using one of the following assessment methods:

1. Intrinsic susceptibility index (ISI)
2. Aquifer vulnerability index (AVI)
3. Surfaces to aquifer advection time (SAAT)
4. Surfaces to well advection time (SWAT)
5. A method that in the opinion of the Director is equivalent or better than the methods permitted.

Groundwater vulnerability analysis takes into account the best available understanding of the natural geological layers in relation to the water supply aquifer. The surface to aquifer advection time (SAAT) analysis was used to define the vulnerability of the Creighton Heights and Camborne Water Supply Systems in the Ganaraska Region Source Protection Area. The SAAT analysis includes two elements, the time taken for water to travel from the ground surface to the water table (unsaturated zone advection time (UZAT)) and the time taken for water to travel through the water table to the water supply aquifer (water table to aquifer advection time (WAAT)). When assessing the results of the SAAT analysis, an area is considered to have high vulnerability if water takes less than 5 years to travel from the ground surface to the aquifer. Medium vulnerability occurs if water takes 5 years or more, but 25 years or less to travel from the ground surface to the aquifer. An area is considered to have low vulnerability if water takes more than 25 years to travel from the ground surface to the aquifer.

The analysis for the Orono Drinking Water System was carried out using the Aquifer Vulnerability Index (AVI) method. The method was undertaken using two data sources, the CAMC/YPDT regional hydrostratigraphic interpretation (Earthfx Incorporated, 2006), which defines the regional extent of aquifer and aquitard layers, and local individual high-quality well/borehole data in the vicinity of the municipal wells. The Aquifer Vulnerability Index was calculated for the municipal water supply aquifer from both data sets and combined to fully and comprehensively define the vulnerability for the entire Orono wellhead protection area. The results of this analysis were compared to an ISI evaluation of the vulnerability and shown to be a conservative definition of vulnerability for the Orono Drinking Water System. The vulnerability was considered high if the AVI score was less than 30, medium if the AVI score was greater than or equal to 30 but less than or equal to 80, and low if the AVI score was greater than 80.

Both the SAAT and AVI analysis include an opportunity to consider situations where man-made influences can increase the natural vulnerability.

Examples of man-made influences that may provide an opportunity (a transport pathway) that could result in an increased vulnerability to a water supply source include the following:

- Existing wells or boreholes (all types)
- Unused or abandoned wells
- Pits and quarries
- Mines
- Construction activities (such as deep building basements/parking garages)
- Storm water infiltration
- ~~Septicp systems~~Onsite sewage systems
- Storm sewer, sanitary sewer and water distribution system infrastructure.

An evaluation of potential transport pathways in the wellhead protection areas has been carried out in the Ganaraska Region Source Protection Area. Where transport pathways were determined to exist, the vulnerability of the pathway and a 30-metre radius around it was increased.

5.2.1.3 VULNERABILITY SCORES

In determining the vulnerability score, the travel time in the aquifer (expressed as WHPA-A through D) was combined with the measurement of how easy it is for water to travel from the ground surface to the aquifer (determined in the SAAT and AVI analysis). Geographic Information System (GIS) software used the matrix described in Table 5.2-2 to produce a vulnerability score map. The higher the vulnerability score, the more easily a land use or activity could affect the drinking water supply aquifer. Vulnerability scores range from 2 to 10. For example, areas in WHPA-B, where groundwater can travel to the well in less than 2 years (with a vulnerability of medium) would have a vulnerability score of 8.

Table 5.2-2: Vulnerability Scores within a Wellhead Protection Area

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

* For SAAT methods the score is 2, for the AVI method the score is either 4 or 2.

A higher vulnerability score will always be assigned to the immediate vicinity of the municipal well and to any areas where the aquifer is shown to be vulnerable. Any specific areas where geologic conditions would allow potential contaminants to reach the aquifer (i.e., natural or artificial recharge areas) will be reflected by a higher vulnerability score. The output from this step of the analysis is a map of vulnerability scores in the wellhead protection areas that will be used to assess the relative significance of drinking water threats.

5.2.1.4 UNCERTAINTY ANALYSIS

As part of the vulnerability analysis, an uncertainty rating is required, defined as either high or low. The rating must take into account the quantity and quality of available data, the technical methods used to determine the vulnerability scores, and the efforts taken to maintain a quality outcome. A quantitative process has been developed by Jagger Hims Ltd. (2007) to allow a consistent approach to be used for assigning an uncertainty rating for each vulnerable area. In most cases, the uncertainty rating was governed by the quantity and quality of information available on which the understanding of the groundwater flow system is based. In other cases, the natural system itself may justify a high uncertainty rating.

In the technical guidance provided originally by the Ministry of the Environment and Climate Change prior to the *Technical Rules*, the uncertainty rating was described as having a specific role in deciding the types of management activities needed to address the identified threats to groundwater. Although this role is not clearly described in the *Technical Rules*, it is apparent that the high or low uncertainty rating will play a similar role in the source protection planning process. For example, a moderate threat identified with a high uncertainty rating could be proposed for further evaluation or risk reduction, while a moderate threat with low uncertainty could be monitored.

In the course of this work, attempts have been made to make decisions and assumptions that would err on the conservative side. Some examples of these decisions are the following:

1. Use of maximum permitted pumping rates at steady-state continuous pumping that will result in substantially larger wellhead protection areas than would be obtained for pumping scenarios at typical average rates with cycled operation during peak periods of the day
2. Use of the SAAT method to determine groundwater vulnerability using the numerical model with conservative assumptions that would provide minimum travel times
3. Use of both regional geological and local well geological data in completion of the AVI method
4. Groundwater velocity estimates for granular aquifers are estimated using an assumed effective porosity that reflects the low range of observed values. This will result in slightly larger time of travel areas, hence a larger wellhead protection area.

5.2.2 DELINEATION OF WHPAS AND ASSESSMENT OF VULNERABILITY

Comprehensive studies have been completed for the three municipal groundwater systems in the Ganaraska Region Source Protection Area (Jagger Hims Ltd., 2003 and 2007 and 2009; Genivar Consultants LP, 2010). For each municipal system, a numerical groundwater flow model was constructed using Visual MODFLOW, and calibrated to match historical groundwater elevations and measured stream baseflow data. Hydrostratigraphic surfaces from regional studies completed by CAMC/YPDT (Earthfx Incorporated, 2006) were used to construct the models. These surfaces and aquifer properties were modified locally to reflect site-specific data.

The calibrated numerical groundwater flow model was applied to delineate time of travel-based capture areas that are up-gradient of the municipal wells in Creighton Heights, Camborne, and Orono. These capture areas have been delineated as WHPA-A through D as per the *Technical Rules*. The vulnerability of the water supply aquifers in these systems was evaluated by completing a SAAT particle tracking analysis with the numerical groundwater flow model and AVI methods. The SAAT analysis defines the minimum time for groundwater to infiltrate through the unsaturated overburden and down to the deep aquifer layers that provide the water supply. The AVI method defines the indices of advection for the target aquifer. From these two methods, vulnerability scores can be assigned for each wellhead protection area.

5.2.2.1 CREIGHTON HEIGHTS WATER SUPPLY SYSTEM

The wellhead protection areas and the vulnerability assessment for the Creighton Heights Water Supply System were completed in the Township of Hamilton's Phase 1 Study (Jagger Hims Ltd., 2007) following the approach described in Sections 5.2.1.1 to 5.2.1.4. The following sections describe the wellhead protection areas and the estimated vulnerability of the water supply aquifer.

Wellhead Protection Area Delineation

The wellhead protection area was delineated by Jagger Hims Ltd. (2007) using a three-dimensional groundwater flow model (Visual MODFLOW) and is shown on Map 5-3. The time of travel was estimated for each wellhead using a conservative estimate of the maximum pumping rate for each well or well system as allowed by the Permit to Take Water. If the actual pumping rates were used, a less conservative definition of the wellhead protection areas would have been delineated. The Creighton Heights Water Supply System Conditions of the Permit to Take Water do not allow for all supply wells to be pumped simultaneously. In order to determine the maximum extent of the time of travel zones, multiple modeling runs were preformed to consider the potential combination of pumping rates. The final time of travel zones are based on the maximum distances observed in all scenarios. This modeling was conducted just prior to the release of the *Technical Rules* and methods were selected based on insuring a conservative definition of the wellhead protection area.

The map shows WHPA-A through D (100 m, 2-year time of travel, 5-year time of travel, and 25-year time of travel). The 5-year time of travel (WHPA-C) starts approximately 750 metres north of the wells and is approximately 1,200 metres wide. The WHPA-D extends approximately 4,000 metres to the northeast. The wellhead protection area extends less than 250 metres to the south of the wellfield (down-gradient). The wellhead protection area is shown to extend north of the wells and then divert to the east. Particle tracking analysis typically showed that groundwater removed from the wells has been in the deep aquifer layer for more than 25 years. The majority of the water removed from the aquifer travels horizontally along connected pathways and is recharged from areas of higher topography to the north.

Groundwater Vulnerability Assessment

The groundwater vulnerability of the water supply aquifer of the Creighton Heights Water Supply System was determined through a SAAT analysis (Jagger Hims Ltd., 2007). The analysis has shown that the travel time from surface to the water supply aquifer north of Creighton Heights is greater than 65 years. Artesian pressure near the wells will minimize the likelihood that water from the surface in these locations will reach the underlying aquifer. The entire wellhead protection area has been determined to be of "low" vulnerability as the SAAT time was calculated to be greater than 25 years. This is reasonable based on the following:

- The relative thickness of sediment overlying the water supply aquifer
- The overall fine-grained nature of the soils overlying the water supply aquifer

- The observed hydraulic pressures in the aquifer, which are typically above the top of the aquifer (confined).

Private wells that penetrate water supply aquifers provide the most likely cause of increasing the vulnerability of the wellhead protection area for the Creighton Heights Water Supply System. There are two private wells contained in the Water Well Information System (WWIS) database that are shown to either penetrate the water supply aquifer or stop within 3 metres of the interpreted top of the Creighton Heights water supply aquifer. An increase in vulnerability is reasonable for areas in the wellhead protection area where wells are known to intersect the water supply aquifers. Map 5-3 shows the groundwater vulnerability of the Creighton Heights wellhead protection area and the extent of the 30-metre radius around each identified pathway private well for which an increase in vulnerability was considered. The groundwater vulnerability has been increased from “low” to “medium” in the vicinity of the two identified private wells.

Given the predominance of fine-grained soils near surface, the relative depth to the water supply aquifer, and the confined nature of the water supply aquifer, municipal services are not likely to provide a preferential pathway to the deep water supply aquifer. The residents using the Creighton Heights Water Supply System are serviced by private ~~septic~~ onsite sewage systems. These are typically shallow and are not likely to provide a preferential pathway to the deep water supply aquifer (Jagger Hims Ltd., 2007). No existing or former pits or quarries were identified in the WHPA-A through D of the Creighton Heights Water Supply System. The areas identified as having pits and quarries lie within the total contributing area for the wells that lie beyond WHPA-D (Jagger Hims Ltd., 2007). The *Technical Rules* provides consideration for increasing the groundwater vulnerability to account for transport pathways only in WHPA B through D.

Vulnerability Scores

A vulnerability score was determined for the WHPA of Creighton Heights using the methodology described in Section 5.2.1.3. Map 5-3 illustrates the distribution of the vulnerability scores for the Creighton Heights WHPA. The area beyond the WHPA-B (2-year time of travel) is assigned a very low vulnerability score of 2 (Table 5.2-3).

The aquifers that supply groundwater to the Creighton Heights Water Supply System are naturally protected from typical chemical and pathogen threats associated with human activities. The presence of potential pathways, particularly in the form of poorly constructed or unused private wells into the water supply aquifer is the greatest concern in terms of potential vulnerability. Despite these concerns, artesian conditions in the deep aquifer system will likely minimize the possibility that these potential pathways can deliver contaminants down to the water supply aquifer.

Most groundwater flow systems are vulnerable to dense non-aqueous phase liquid (DNAPL) contaminants and the Creighton Heights Water Supply System is no exception. Future planning policy should work to minimize the potential for land uses that could introduce these types of contaminants, particularly industrial solvents, into the groundwater system in the entire wellhead protection area and particularly within WHPA-A through C.

Table 5.2- 3: Vulnerability Scores for the Creighton Heights Water Supply System

System Name	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Creighton Heights Water Supply System	10	8 and 6	2	2

Uncertainty Analysis

The uncertainty rating associated with the wellhead protection area delineation and vulnerability analysis of the Creighton Heights Water Supply System was assessed using a quantitative process, which is outlined in Section 5.2.1.4. The uncertainty rating for the vulnerability assessment was determined through a matrix method defined by Jagger Hims Ltd. (2007). A confidence score out of 10 is determined through a qualitative assessment considering available data, methodology, quality assurance, and quality control procedures. Three components were considered together to determine uncertainty as low for scores greater than 6, and high for scores less than 6. The scoring system used in the table is qualitative and is intended to reflect relative degrees of uncertainty.

The uncertainty rating assigned for the Creighton Heights Water Supply System is low (Tables 5.2-4 and 5.2-5). The assumptions made in the course of the analysis, including the selection of hydraulic conductivity parameters, effective porosities, and maximum pumping rates are intended to be conservative and protective of the water supply. The calculated range of travel times in the SAAT analysis also provides confidence that there is substantial protection to the deeper aquifer system.

Table 5.2-4: Confidence Score for WHPA Delineation and Vulnerability Scores for the Creighton Heights Water Supply System

System Name	Confidence Scores								
	Available Data	WHPA Delineation				Vulnerability Scores			
	WHPA	WHPA-A	WHPA-B	WHPA-C	WHPA-D	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Creighton Heights Water Supply System	6.3	7.4	7.4	7.4	7.4	10	10	10	10

Table 5.2 5: Final Uncertainty Ratings for the Creighton Heights Water Supply System

System Name	Final Uncertainty Ratings			
	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Creighton Heights Water Supply System	Low	Low	Low	Low

5.2.2.2 CAMBORNE WATER SUPPLY SYSTEM

The wellhead protection area and the vulnerability assessment for the Camborne Water Supply System were completed in the Township of Hamilton's Phase 1 study (Jagger Hims Ltd., 2007) following the approach described in Sections 5.2.1.1 to 5.2.1.4. The following sections describe the wellhead protection area and the estimated vulnerability of the water supply aquifer.

Wellhead Protection Area Delineation

The wellhead protection area was delineated by Jagger Hims Ltd. (2007) using a three-dimensional groundwater flow model (Visual MODFLOW) and is shown on Map 5-4. The time of travel was estimated for each wellhead using a conservative estimate of the maximum pumping rate for each well or well system as allowed by the Permit to Take Water. If the actual pumping rates were used, a less conservative definition of the wellhead protection areas would have been delineated. The Camborne Water Supply System Conditions of the Permit to Take Water do not allow for all supply wells to be pumped simultaneously. In order to determine the maximum extent of the time of travel zones, multiple modeling runs were preformed to consider the potential combination of pumping rates. The final time of travel zones are based on the maximum distances observed in all scenarios. This modeling was conducted just prior to the release of the *Technical Rules* and methods were selected based on insuring a conservative definition of the wellhead protection area.

The map shows WHPA-A through D (100 m, 2-year time of travel, 5-year time of travel, and 25-year time of travel). The 5-year time of travel (WHPA-C) extends approximately 1,300 metres north of the wells and is approximately 400 metres wide. The WHPA-D extends approximately 3,500 metres to the northeast. The wellhead protection area extends less than 100 metres to the south of the wellfield (down-gradient). The wellhead protection area is shown to extend north of the wells and divert to the east. Particle tracking analysis typically showed that groundwater removed from the wells has been in the deep aquifer layer for more than 25 years. The majority of the water removed from the aquifer travels horizontally along connected pathways and is recharged from areas of higher topography to the north.

Groundwater Vulnerability Assessment

The groundwater vulnerability of the water supply aquifer of the Camborne Water Supply System was determined through a SAAT analysis (Jagger Hims Ltd., 2007). The analysis has shown that the travel time from surface to the water supply aquifer north of Camborne is greater than 96 years. Artesian pressure near the wells will minimize the likelihood that water from the surface in these locations will reach the underlying aquifer. The entire wellhead protection area has been determined to be of “low” vulnerability as the SAAT time was calculated to be greater than 25 years. This is reasonable based on the following:

- The relative thickness of sediment overlying the water supply aquifer
- The overall fine-grained nature of the soils overlying the water supply aquifer
- The observed hydraulic pressures in the aquifer, which are typically above the top of the aquifer (confined) and often higher than ground surface (flowing artesian).

Private wells that penetrate water supply aquifers provide the most likely cause of increasing the vulnerability of the wellhead protection area for the Camborne Water Supply System. There are no private wells contained in the Water Well Information System (WWIS) database that are shown to either penetrate the water supply aquifer or stop within 3 metres of the interpreted top of the Camborne water supply aquifer. Map 5-4 shows the groundwater vulnerability of the Camborne WHPA. The vulnerability has not been increased in the wellhead protection area as there are no identified transport pathways.

Given the predominance of fine-grained soils near surface, the relative depth to the water supply aquifer, and the confined nature of the water supply aquifer, municipal services are not likely to provide a preferential pathway to the deep water supply aquifer. The residents using the Camborne Water Supply System are serviced by private onsite sewage~~septic~~ systems. These are typically shallow and are not likely to provide a preferential pathway to the deep water supply aquifer (Jagger Hims Ltd., 2007). No existing or former pits or quarries were identified in the WHPA-A through D of the Camborne Water Supply System. The areas identified as having pits and quarries lie within the total contributing area for the wells that lie beyond WHPA-D (Jagger Hims Ltd., 2007). The *Technical Rules* provides consideration for increasing the groundwater vulnerability to account for transport pathways only in WHPA-B through D.

Vulnerability Scores

A vulnerability score was determined for the wellhead protection area of Camborne using the methodology described in Section 5.2.1.3. Map 5-4 illustrates the distribution of the vulnerability scores for the Camborne WHPA. The area beyond the WHPA-B (2-year time of travel) is assigned a very low vulnerability score of 2 (Table 5.2-6).

The deep aquifers that supply groundwater to the Camborne Water Supply System are naturally protected from typical chemical and pathogen threats associated with human activities. The presence of potential pathways, particularly in the form of poorly constructed or unused private wells into the water supply aquifer are the greatest concern in terms of potential vulnerability. Despite these concerns, flowing artesian conditions in the deep aquifer system will likely minimize the prospect that these potential pathways might deliver contaminants down to the water supply aquifer.

Most groundwater flow systems are vulnerable to dense non-aqueous phase liquid (DNAPL) contaminants and the Camborne Water Supply System is no exception. Future planning policy should work to minimize the potential for land uses that could introduce these types of contaminants, particularly industrial solvents, into the groundwater system in the entire wellhead protection area and particularly within WHPA-A through C.

Table 5.2-6: Vulnerability Scores for the Camborne Water Supply System

System Name	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Camborne Water Supply System	10	6	2	2

Uncertainty Analysis

The uncertainty rating associated with the WHPA delineation and vulnerability analysis of the Camborne Water Supply System, as with the Creighton Heights Water Supply System, was assessed using a quantitative process, outlined in Section 5.2.1.4. The uncertainty rating for the vulnerability assessment was determined through a matrix method defined by Jagger Hims Ltd. (2007). A confidence score out of 10 is determined through a qualitative assessment considering available data, methodology, quality assurance, and quality control procedures. Three components were considered together to determine uncertainty as low for scores greater than 6, and high for scores less than 6. The scoring system used in the table is qualitative and is intended to reflect relative degrees of uncertainty.

The uncertainty rating assigned for the Camborne Water Supply System is low (Tables 5.2-7 and 5.2-8). The assumptions made in the course of the analysis, including selection of hydraulic conductivity parameters, effective porosities, and maximum pumping rates are intended to be conservative and protective of the water supply. The calculated range of travel times in the SAAT analysis also provides confidence that there is substantial protection to the deeper aquifer system.

Table 5.2-7: Confidence Scores for WHPA Delineation and Vulnerability Scores for the Camborne Water Supply System

System Name	Confidence Scores								
	Available Data	WHPA Delineation				Vulnerability Scores			
	WHPA	WHPA-A	WHPA-B	WHPA-C	WHPA-D	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Camborne Water Supply System	6.3	7.4	7.4	7.4	7.4	10	10	10	10

Table 5.2 8: Final Uncertainty Ratings for the Camborne Water Supply System

System Name	Final Uncertainty Ratings			
	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Camborne Water Supply System	Low	Low	Low	Low

5.2.2.3 ORONO DRINKING WATER SYSTEM

The wellhead protection area and the vulnerability assessment for the Orono Drinking Water System are described in Genivar Consultants LP (2010) as part of a larger Drinking Water Threats Assessment completed for the Regional Municipality of Durham following the approach described in Section 5.2.1. The following sections describe the wellhead protection area and the estimated vulnerability of the water supply aquifer.

Wellhead Protection Area Delineation

The wellhead protection area was delineated by Jagger Hims Ltd. (2003) using a three-dimensional groundwater flow model (Visual MODFLOW) and is shown on Map 5-5. The modeling methods used the maximum permitted pumping rates (as of 2003) with MW3 at 1,308 m^3/day and MW4 at 655 m^3/day. If the actual pumping rates were used, a less conservative definition of the wellhead protection areas would have been delineated. This modeling was conducted prior to the release of the *Technical Rules* and methods were selected based on insuring a conservative definition of the wellhead protection area.

Municipal system wells (MW3, MW4, and MW5) are finished in an aquifer that is covered by an overlying glacial till deposit. This deposit has a relatively low hydraulic conductivity due to its higher silt and clay content and heterogeneous particle size distribution. The dominant groundwater flow direction is from topographic highs in the north to the south. The interpolated groundwater flow has a westerly component toward the Wilmot Creek valley. The wellhead protection area reflects this direction of flow.

The above-noted map shows WHPA-A through D (100 m, 2-year time of travel, 5-year time of travel, and 25-year time of travel). The 5-year time of travel (WHPA-C) extends approximately 1,400 metres north of the wells and is approximately 300 metres wide. The WHPA-D extends approximately 2,000 metres to the northeast. The WHPA extends less than 100 metres to the south of the wellfield (down-gradient). The wellhead protection area is shown to extend north of the wells and slope to the east.

Groundwater Vulnerability Assessment

The groundwater vulnerability of the water supply aquifer of the Orono Drinking Water System was determined through an AVI analysis (Genivar Consultants LP, 2010). A series of analyses were completed comparing the ISI and AVI methods. Review of the results showed that the analysis produced similar trends in vulnerability. The consultant chose to use an AVI analysis employing two data sources: first, the CAMC/YPDT regional hydrostratigraphic interpretation (Earthfx Incorporated, 2006), which defines the regional extent of aquifer and aquitard layers, and second, in the vicinity of the municipal wells, local individual high-quality well/borehole data. This approach conservatively defines the vulnerability of the Orono Drinking Water System. Through consideration of uncertainties associated with this analysis, and to ensure that a conservative level of protection is provided in the wellhead protection area, this zone has been redesignated as high vulnerability. The resultant vulnerability is shown on Map 5-5.

The vulnerability in the area closest to the municipal wells and corresponding to Wilmot Creek is designated as high. The vulnerability through the area roughly equivalent to the 5-year time of travel (WHPA-C) is medium. The vulnerability of the most northerly portion of the WHPA is low. This is consistent with available water quality data for the wells and the understanding of the regional aquifers and the groundwater flow system.

Vulnerability Scores

Vulnerability scores were determined for the wellhead protection area of Orono using the methodology described in Section 5.2.1.3. Map 5-5 illustrates the distribution of the vulnerability scores for the Orono wellhead protection area (WHPA). An area at the northern portion of the WHPA-D (25-year time of travel) is assigned a very low vulnerability score of 2 (Table 5.2-9). The majority of the areas in the WHPA-A through WHPA-C have a vulnerability score of 6 or higher.

Most groundwater flow systems are vulnerable to dense non-aqueous phase liquid (DNAPL) contaminants and the Orono Drinking Water System is no exception. Future planning policy should work to minimize the potential for land uses that could introduce these types of contaminants, particularly industrial solvents, into the groundwater system within the entire wellhead protection area.

Table 5.2-9: Vulnerability Scores for the Orono Drinking Water System

Water Supply System Name	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Orono Drinking Water System	10	10 and 8	6 and 4	4 and 2

Uncertainty Analysis

The uncertainty rating associated with the wellhead protection area delineation and vulnerability analysis of the Orono Drinking Water System, as with the Creighton Heights and Camborne Water Supply Systems, was assessed using a quantitative process, outlined in Section 5.2.1.4. The uncertainty rating for the vulnerability assessment was determined through a matrix method defined by Genivar Consultants LP (2010). A confidence score out of 10 is determined through the qualitative assessment considering available data, methodology, quality assurance, and quality control procedures. Three components were considered together to determine uncertainty as low for scores greater than 6 and high for scores less than 6. The scoring system used in the table is qualitative and is intended to reflect relative degrees of uncertainty.

The uncertainty rating assigned for the Orono Drinking Water System is low (Tables 5.2-10 and 5.2-11). The assumptions made in the course of the analysis, including the definition of wellhead protection areas, areas of vulnerability, and scoring are intended to be conservative and protective of the water supply.

Table 5.2-10: Confidence Scores for WHPA Delineation and Vulnerability Scores for the Orono Drinking Water System

System Name	Confidence Scores								
	Available Data	WHPA Delineation				Vulnerability Scores			
	WHPA	WHPA-A	WHPA-B	WHPA-C	WHPA-D	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Orono Drinking Water System	7.5	8.9	8.9	8.9	8.9	10	10	10	10

Table 5.2-11: Final Uncertainty Ratings for the Orono Drinking Water System

System Name	Final Uncertainty Ratings			
	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Orono Drinking Water System	Low	Low	Low	Low

5.2.3 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

As better information becomes available regarding the geological and hydrogeological properties in the vicinity of the municipal wells, the wellhead protection area delineations can be improved. These include the following:

- Additional geological picks using quality borehole information (e.g., Consultants' Reports) should be carried out on a continuous basis to improve the hydrostratigraphic surfaces in the Conservation Authorities Moraine Coalition geological model. This would enhance the 3-D geological model for the region, which is used for groundwater flow models and the delineation of wellhead protection areas.
- Additional baseflow measurements on streams in or near the municipal wellhead areas could be used to improve calibration of groundwater discharges predicted from the groundwater flow models.
- Additional improvement of the Wellhead Protection Area for the Orono Municipal Groundwater System should be carried out as enhanced geological modeling is completed.
- Additional improvements of Wellhead Protection Areas using modeling that reflects more representative pumping rates should occur. The pumping rates used are conservative and therefore the Wellhead Protection Areas are defined by a time of travel under higher pumping rates that then might be expected.

5.2.4 REFERENCES

Earthfx Incorporated. (2006). *Groundwater Modeling of the Oak Ridges Moraine Area*. YPDT-CAMC Technical Report #01-06. Toronto (ON).

Genivar Consultants LP. (2010). Assessment *of Drinking Water Threats, Municipal Groundwater Supplies, the Regional Municipality of Durham*, DRAFT. File # 960754.09. Newmarket (ON).

Jagger Hims Limited. (2003). *Community of Orono Wellhead Protection Area Program Numerical Model Development*. Newmarket (ON).

Jagger Hims Limited. (2007). *Groundwater Study Creighton Heights and Camborne Municipal Wellfields, Township of Hamilton*. Prepared for Township of Hamilton and Ganaraska Region Conservation Authority. File # 061851.00. Newmarket (ON).

Jagger Hims Limited. (2009). *Assessment of Drinking Water Threats, Creighton Heights and Camborne Municipal Wellfields, Township of Hamilton* (DRAFT). Prepared for Township of Hamilton and Ganaraska Region Conservation Authority. File # 061851.01. Newmarket (ON).

5.3 ISSUES ASSESSMENT

Drinking water issues exist where the concentration of a contaminant at a well related to a drinking water system may result in the deterioration of the quality of the water for use as a source of drinking water. The evaluation of drinking water issues for the municipal wells in the Ganaraska Region Source Protection Area was completed under the following two separate studies. This section is a summary of these reports:

- Assessment of Drinking Water Threats: Municipal Groundwater Supplies: The Regional Municipality of Durham (Genivar Consultants LP, 2010)
- Assessment of Drinking Water Threats, Creighton Heights and Camborne Municipal Wellfields, Township of Hamilton (Jagger Hims Ltd., 2009a).

5.3.1 DRINKING WATER ISSUES EVALUATION

The *Technical Rules* describes what constitutes a “drinking water issue” and the requirements to identify them for consideration in the Assessment Report, as part of the process to assess the significance of drinking water threats. A drinking water issue is typically related to the presence of a chemical or bacteriological parameter in a drinking water supply at a concentration that is greater than the maximum acceptable concentration (MAC) published in the *Ontario Drinking Water Quality Standards*. The definition is expanded for the purposes of the Assessment Report to include parameters that may cause deterioration of the quality of water for use as a drinking water source. To this end, parameters that do not necessarily cause effects to human health are also considered.

Where possible, an attempt is to be made to identify the cause of a drinking water issue and link it to an identified threat. Threats that are identified as the cause of the drinking water issues are to be considered significant drinking water threats in accordance with the *Technical Rules*.

The following sections provide the background and details of the process followed in this study to evaluate data and to determine which parameters constitute drinking water issues for the municipal water supply systems under review.

5.3.1.1 ONTARIO DRINKING WATER QUALITY STANDARDS

The primary benchmark for review of water quality data is the *Ontario Drinking Water Quality Standards* (ODWQS). The ODWQS includes maximum acceptable concentrations (MAC) for health-related parameters as well as recommended maximum concentrations for parameters that affect the aesthetics or taste of the water, and those that are used as operational guidelines. The *Technical Rules* requires that the drinking water issues assessment considers the parameters listed in Schedules 1 to 3 of these standards, which include microbiological, chemical, and radiological parameters, and Table 4 of the *Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines*, which includes aesthetic objectives and operational guidelines for water treatment. For chemical parameters (primarily organic chemicals) that do not typically occur in nature, the benchmark used was the laboratory method detection limit (MDL) for groundwater supplies.

5.3.2 METHODOLOGY

The steps followed in the evaluation of drinking water issues included:

Step 1: Assemble available data
Step 2: Review data and identify potential drinking water issues
Step 3: Evaluate drinking water issues
Step 4: Identify contributing area for drinking water issues
Step 5: Prepare list of drinking water issues.

5.3.2.1 ASSEMBLE AVAILABLE DATA

Available water quality data for raw and treated water from the three municipal water supply systems and from monitoring ~~wells~~ locations associated with these water supply systems were reviewed to identify drinking water issues. The available data for each of the three municipal groundwater systems were identified through a review of the following data sources:

- Water Supply System Engineers' Reports (to describe treatment capacity)
- Municipal groundwater study reports
- Permits to Take Water and accompanying technical reports
- Municipal water supply water quality data
- Monthly certificates of analysis
- Annual water supply water quality monitoring reports
- Microbial Control Plans (where available)
- Sentry Well Monitoring Reports
- Various background reports.

5.3.2.2 DATA REVIEW AND IDENTIFY POTENTIAL DRINKING WATER ISSUES

The preliminary list of potential drinking water issues for each water supply source was prepared in a table format. The list is intended to document all potential drinking water issues. The preliminary list of potential issues was prepared based on the information provided in the available data and includes the following:

- The potential issues that were documented in available reports
- The potential issues and concerns that were identified by local System Operators, Health Departments/Units, and other stakeholders
- Chemical parameters in raw or treated water where concentrations consistently exceeded an identified benchmark
- Pathogenic parameters (bacteria) that were consistently present in raw or treated water
- Data and hydrographs of concentration versus time for parameters of interest showing an increasing trend that would likely reach an identified benchmark in the future.

As part of the process to identify and evaluate potential drinking water issues, the operators of the three municipal groundwater supplies were provided the opportunity to review the information and to contribute to the decision process. In addition, the Certificate of Approval and ~~the most recent Ministry of the Environment and Climate Change~~ Drinking Water System Inspection Reports were reviewed to collect information on the treatment processes used in each water supply system.

5.3.2.3 EVALUATE DRINKING WATER ISSUES

The preliminary list of potential drinking water issues was prepared to allow for a qualitative evaluation of each potential issue, either chemical or pathogen, in terms of the requirements of the *Technical Rules*. A decision process was developed to provide a consistent methodology for reviewing data to identify drinking water issues. The decision process primarily focused on the review of parameter concentrations relative to the benchmarks described above, but also allowed for consideration of the quality of data. The reliability of the data was qualitatively evaluated in terms of the following:

- Whether or not there was sufficient data to confirm that the stated results are real
- Whether or not there was confirmed presence of the parameter based on the relative frequency of observations
- Whether quality control/quality assurance review of the data or operating conditions was in place that suggested that the values identified above the benchmark may not reflect the actual conditions.

For parameter concentrations that are not greater than the ODWQS, the water quality data have been reviewed to identify increasing trends that may indicate a future potential to change the water quality. The parameter could have potentially been elevated to a drinking water issue if the operational staff agreed that the identified condition would lead to the deterioration of water quality for use as a drinking water source. In cases where treatment is in place, the drinking water issue could have additionally been identified with the qualification that treatment is in place to provide primary protection to the consumer.

5.3.2.4 IDENTIFY CONTRIBUTING AREA FOR DRINKING WATER ISSUES

If a drinking water issue is identified, the *Technical Rules* requires identification of the area where drinking water threats may contribute to that drinking water issue. The parameters that are considered to be drinking water issues are used to review the available threats inventory data for the area surrounding each municipal water supply to identify potential sources of the observed issue. This review does not require that a threat be prioritized as significant, moderate, or low in accordance with the *Technical Rules*. Where a link is identified, mapping is prepared to identify the general area that is considered to contribute to the drinking water issues. In some cases, the linkages between the drinking water issue and identified threats will be readily apparent and a link can be directly correlated to a known threat activity or condition. In other cases, the cause of the issue may be a result of multiple threats or may not be linkable to a specific instance of an activity or condition. An example might be the presence of contaminants from fertilizer application that cannot be specifically linked to any one property. In the event that the available information is insufficient to confirm the source of the drinking water issue, an outline for a plan to obtain further information will be provided.

5.3.2.5 PREPARE LIST OF DRINKING WATER ISSUES

The final list of drinking water issues is prepared for each water supply source based on the above-noted evaluation. The list of drinking water issues will identify the parameter, the identifier for the well where the drinking water issue is observed, the coordinates for the contributing area for the drinking water issue, and the activities, historical conditions, or naturally occurring conditions that contribute to the drinking water issue.

5.3.3 RESULTS OF ISSUES EVALUATION

The results of the issues evaluation for each municipal groundwater supply system in the Ganaraska Region Source Protection Area are summarized in the following sections.

5.3.3.1 CREIGHTON HEIGHTS WATER SUPPLY SYSTEM

The following sections describe the issues evaluation undertaken for the Creighton Heights water supply in accordance with the *Technical Rules*.

Drinking Water Issues

Water quality data (raw and treated) for the Creighton Heights water supply were reviewed to identify bacteriological, chemical, or physical parameters that are currently in excess of the *Ontario Drinking Water Quality Standards*. The available data were also reviewed to identify potential trends that could indicate that an issue is developing that would require future treatment. The data review and consultation with the drinking water system operators did not identify any chemical or pathogen parameters that are currently exceeding or trending into the future that should be considered as drinking water issues (Jagger Hims Ltd., 2009a). Details of the drinking water issues evaluation for the three Creighton Heights supply wells (TW-1, TW-6, and TW-7) are provided in Table 5.3-1.

No drinking water issues have been identified for the Creighton Heights Water Supply System.

The raw water quality of Creighton Heights has consistently maintained a high quality standard and is typically suitable for human consumption without treatment. Several parameters that are commonly observed such as hardness, turbidity, iron, and manganese are naturally present in the raw water supply. Volatile organic compounds, pesticides, and herbicides have not been detected in the raw water quality tests.

Dissolved gases such as methane and ammonia are present in the raw water. These parameters are not present in sufficient quantities to render the water unsuitable for human consumption. The dissolved methane gas is removed by passing the water through a methane stripping system. Primary disinfection is provided by ultraviolet light. Additionally, the treatment method results in methane removal and ammonia is left in the water after processing. This ammonia reacts with sodium hypochlorite that is added for disinfection. The reaction produces a chloramine residual, which in turn reduces the potential to generate undesirable trihalomethane by-products in the disinfection process.

Table 5.3-1: Evaluation of Drinking Water Issues - Creighton Heights Wellfield - Wells TW-1, TW-6 and TW-7

Parameter	Water Type	Years of Record	Benchmark Exceedances		Data Reliability		Extrapolation		Natural Source	Anthropogenic Source	Rationale
			Exceeds Ontario Drinking Water Quality Standards	Above Detection Limit	Sufficient Data	Presence In Samples	Trend	Exceed within 50 years			
Pathogens											
Coliforms	Raw	2003/ 2008	Yes	No	Yes	Rarely (<5%)	↔	No	Unknown	Unknown	• Unknown Source • Treatment in Place • Effective Mitigation
Chemicals											
2,4,6-trichlorophenol	Treated	2003/ 2008	No	Yes	Yes	Occasionally (5-40%)	↔	No	No	Yes	• Will not exceed Ontario Drinking Water Quality Standards in 50 years
Chloride	Raw	2003/ 2008	No	Yes	Yes	Always (>90%)	↔	No	Yes	No	• Naturally Occurring
Colour	Raw	2003/ 2008	Yes	No	Yes	Always (>90%)	↑	Yes	Yes	No	• Treatment in Place • Effective Mitigation • Naturally Occurring
Hardness	Raw	2003/ 2008	Yes	No	Yes	Always (>90%)	↔	Yes	Yes	No	• Naturally Occurring
Iron	Raw	2003/ 2008	Yes	No	Yes	Always (>90%)	↑	Yes	Yes	No	• Naturally Occurring • Treatment in Place • Effective Mitigation
Manganese	Raw	2003/ 2008	Yes	No	Yes	Always (>90%)	↑	Yes	Yes	No	• Naturally Occurring • Treatment in Place • Effective Mitigation
Methane	Raw	2003/ 2008	No	Yes	Yes	Majority (40%-90%)	↔	No	Yes	No	• Naturally Occurring • Treatment in Place • Effective Mitigation
Sodium	Treated /Raw	2003/ 2008	No	Yes	Yes	Always (>90%)	↔	No	No	Yes	• Will not exceed Ontario Drinking Water Quality Standards in 50 years
Trihalomethane (THM)	Treated	2003/ 2008	No	Yes	Yes	Always (>90%)	↔	No	No	Yes	• By-product of Treatment Process
Turbidity	Raw	2003/ 2008	Yes	No	Yes	Always (>90%)	↔	Yes	No	Yes	• Will not affect use of water source

5.3.3.2 CAMBORNE WATER SUPPLY SYSTEM

The following sections describe the issues evaluation undertaken for the Creighton Heights water supply in accordance with the *Technical Rules*.

Drinking Water Issues

Water quality data (raw and treated) for the Camborne water supply were reviewed to identify bacteriological, chemical, or physical parameters which are currently in excess of the *Ontario Drinking Water Quality Standards*. The available data were also reviewed to identify potential trends that could indicate that an issue is developing that would require future treatment. The data review and consultation with the drinking water system operators did not identify any chemical or pathogen parameters that are currently exceeding or trending into the future that should be considered as drinking water issues (Jagger Hims Ltd., 2009a). Details of the drinking water issues evaluation for the two groundwater supply wells (PW-1A and PW-2A) are provided in Table 5.3-2.

No drinking water issues have been identified for the Camborne Water Supply System.

The water quality of Camborne has consistently maintained a high quality standard and is typically suitable for human consumption without treatment. Several parameters that are commonly observed, such as hardness and turbidity, are present in the raw water supply. Volatile organic compounds, pesticides, and herbicides have not been detected in the raw water quality tests.

5.3.3.3 ORONO DRINKING WATER SYSTEM

The following sections describe the issues evaluation undertaken for the Orono water supply in accordance with the *Technical Rules*.

Drinking Water Issues

Water quality data (raw and treated) for the Orono water supply were reviewed to identify bacteriological, chemical, or physical parameters which are currently in excess of the *Ontario Drinking Water Quality Standards*. The available data were also reviewed to identify potential trends that could indicate that an issue is developing that would require future treatment. The data review and consultation with the drinking water system operators did not identify any chemical or pathogen parameters that are currently or trending into the future that should be considered as drinking water issues (Genivar Consultants LP, 2010). Details of the drinking water issues evaluation for the three groundwater supply wells (MW3 and MW4) are provided in Table 5.3-3.

No drinking water issues have been identified for the Orono Drinking Water System.

Table 5.3-2: Evaluation of Drinking Water Issues - Camborne Wellfield – Wells PW-1A and PW-2A

Parameter	Water Type	Years of Record	Benchmark Exceedences		Data Reliability		Extrapolation		Natural Source	Anthropogenic Source	Rationale
			Exceeds Ontario Drinking Water Quality Standards	Above Detection Limit	Sufficient Data	Presence In Samples	Trend	Exceed within 50 years			
Chemicals											
Hardness	Raw	2003/ 2008	Yes	No	Yes	Always (>90%)	⇔	Yes	Yes	No	• Naturally Occurring • Will not affect the use of water source
Trihalomethane (THM)	Treated	2003/ 2008	No	Yes	Yes	Always (>90%)	⇔	No	No	Yes	• By-product of Treatment Process
Turbidity	Raw	2003/ 2008	Yes	No	Yes	Occasionally (>90%)	↓	Yes	Yes	No	• Naturally Occurring

Table 5.3-3: Evaluation of Drinking Water Issues – Orono Wellfield – Wells MW3 and MW4

Parameter	Water Type	Years of Record	Benchmark Exceedances		Data Reliability		Extrapolation		Natural Source	Anthropogenic Source	Rationale
			Exceeds Ontario Drinking Water Quality Standards	Above Detection Limit	Sufficient Data	Presence In Samples	Trend	Exceed within 50 years			
Pathogens											
Coliforms	Raw	2002/ 2008	Yes	No	Yes	Rarely (<5%)	↔	-	-	-	• Anomalous Circumstances • Unknown Source • Treatment in Place
Chemicals											
2,4,6-tribromophenol	Raw	2002/ 2008	No	Yes	Yes	-	↔	-	-	-	• Anomalous Circumstance
Bromodichloro methane	Treated	2002/ 2008	No	Yes	No	Rarely (<5%)	↔	-	No	Yes	• Anomalous Circumstance
Chloride	Raw	2002/ 2008	No	Yes	Yes	Always (>90%)	↑	No	-	-	• Source Unknown • Will not exceed Ontario Drinking Water Quality Standards in 50 years
Chloroform	Treated	2002/ 2008	No	Yes	Yes	Majority (40-90%)	↑	No	No	Yes	• Will not exceed Ontario Drinking Water Quality Standards in 50 years
Colour	Raw	2002/ 2008	Yes	No	Yes	Always (>90%)	↑	-	Yes	No	• Naturally Occurring • Will not affect use of water source
Dibromochloro methane	Treated	2002/ 2008	No	Yes	No	Rarely (<5%)	↔	-	No	Yes	• Anomalous Circumstance
Dioxins and Furans	Raw	2002/ 2008	No	Yes	No	Rarely (<5%)	↔	-	-	-	• Anomalous Circumstance • Unknown Source
Dissolved Organic Carbon	Raw	2002/ 2008	Yes	No	Yes	Always (>90%)	↑	No	Yes	No	• Naturally Occurring • Will not exceed Ontario Drinking Water Quality Standards
Hardness	Raw	2002/ 2008	Yes	No	Yes	Always (>90%)	↓	-	Yes	No	• Naturally Occurring • Treatment in Place
Methane	Raw	2002/ 2008	No	Yes	No	Rarely (<5%)	↔	-	-	-	• Unknown source • Anomalous Circumstance
Nitrilotriacetic acid (NTA)	Raw	2002/ 2008	No	Yes	No	Rarely (<5%)	↔	-	-	-	• Anomalous Circumstance
N-Nitrosodium methylamine	Treated	2002/ 2008	No	Yes	N o	Rarely (<5%)	↔	-	-	-	• Unknown Source • Anomalous Circumstance
Sodium	Treated/ Raw	2002/ 2008	No	Yes	Yes	Always (>90%)	↑	No	-	-	• Unknown Source • Will not exceed Ontario Drinking Water Quality Standards in 50 years
Total Dissolved Solids	Raw	2002/ 2008	Yes	No	Yes	Rarely (<5%)	↑	Yes	Yes	No	• Naturally Occurring
Trihalomethane (THM)	Treated	2002/ 2008	No	Yes	No	Rarely (<5%)	↔	-	No	Yes	• Anomalous Circumstance • By-product of Treatment Process

5.3.4 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Due to the requirements of the *Safe Drinking Water Act*, the Drinking Water Information System is heavily populated with treated water quality information, but with a limited amount of raw water quality information. More rigorous issues evaluation could be completed if enhanced raw water sampling and raw water quality tests were carried out. For several parameters there was insufficient data to undertake a trend analysis.

5.3.5 REFERENCES

Genivar Consultants LP. (2010). *Assessment of Drinking Water Threats, Municipal Groundwater Supplies, the Regional Municipality of Durham*, Draft. File # 960754.09. Newmarket (ON).

Jagger Hims Limited. (2003a). *Community of Orono Wellhead Protection Area Program Numerical Model Development*. Newmarket (ON).

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5.4 THREATS ASSESSMENT

The assessment of drinking water threats is the final step of the water quality risk assessment. It identifies all of the activities and conditions that can be considered drinking water threats in each vulnerable area and evaluates the threats that are currently located in vulnerable areas. This section refers to the drinking water threats for groundwater systems located in wellhead protection areas.

The assessment of drinking water threats in the wellhead protection areas in the Ganaraska Region Source Protection Area was completed in two separate studies that are listed below. This section is a summary of these reports:

- Assessment of Drinking Water Threats, Creighton Heights and Camborne Municipal Wellfields, Township of Hamilton (Jagger Hims Ltd., 2009)
- Assessment of Drinking Water Threats: Municipal Groundwater Supplies: The Regional Municipality of Durham (Genivar Consultants LP, 2010).

Drinking Water Threat *– An activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes any activity or condition that is prescribed by the regulations as a drinking water threat.*

5.4.1 METHODOLOGY

The following sections describe the approach taken to identify drinking water threats in the *Technical Rules*. These requirements include the following:

- Listing drinking water threats – activities
- Listing drinking water threats – conditions
- Identifying areas for significant, moderate, and low drinking water threats – activities
- Identifying areas for significant, moderate, and low drinking water threats – conditions
- Enumerating significant drinking water threats.

5.4.1.1 LISTING DRINKING WATER THREATS – ACTIVITIES

Ontario Regulation 385/08 of the *Clean Water Act* identifies activities that are prescribed as drinking water threats (Table 5.4-1). ~~The *Technical Rules* describes the requirements under which a Source Protection Committee can add activities to be considered locally as drinking water threats with the appropriate approval by the Director.~~

Table 5.4-1: List of Prescribed Drinking Water Threat Activities

No.	Description of Activity
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage
3	The application of agricultural source material to land
4	The storage of agricultural source material
5	The management of agricultural source material
6	The application of non-agricultural source material to land
7	The handling and storage of non-agricultural source material
8	The application of commercial fertilizer to land
9	The handling and storage of commercial fertilizer
10	The application of pesticide to land
11	The handling and storage of pesticide
12	The application of road salt
13	The handling and storage of road salt
14	The storage of snow
15	The handling and storage of fuel
16	The handling and storage of a dense non-aqueous phase liquid
17	The handling and storage of an organic solvent
18	The management of runoff that contains chemicals used in the de-icing of aircraft
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body[1]
20	An activity that reduces the recharge of an aquifer[1]
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard
22	The establishment and operation of a liquid hydrocarbon pipeline

Source: Paragraphs 19 and 20 of subsection 1.1(1) of *O. Reg. 287/07 (General)*
[1]Activity is a water quantity threat (evaluated in the water budget and water quantity threats assessment)

5.4.1.2 LISTING DRINKING WATER THREATS – CONDITIONS

The *Technical Rules* requires that the list of drinking water threats shall include the following conditions that is know to exist in a vulnerable area and that result from a past activity:

1. The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, ~~significant groundwater recharge area~~ or wellhead protection area.
2. The presence of a single mass of more than 100 litres of one or more dense non-aqueous phase liquid in surface water in a surface water intake protection zone.
3. The presence of a contaminant in groundwater in a highly vulnerable aquifer, ~~significant recharge area~~, or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, ~~and~~ is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in groundwater could result in the deterioration of the groundwater for use as a source of drinking water.
4. The presence of a contaminant in surface soil in a surface water intake protection zone if, the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a

concentration that exceeds the surface soil standard for industrial/commercial/community property use set out for the contaminant in that Table and the presence of the contaminant in surface soil could result in the deterioration of the surface water for use as a source of drinking water.

5. The presence of a contaminant in sediment in an intake protection zone, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table and the presence of the contaminant in sediment could result in the deterioration of the surface water for use as a source of drinking water.

6. The presence of a contaminant in groundwater that is discharging into an intake protection zone, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, the concentration of the contaminant exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in groundwater could result in the deterioration of the surface water for use as a source of drinking water.

Conditions are evaluated by calculating a risk score. The risk score is calculated by multiplying the vulnerability score of the vulnerable area in which the condition is located by a hazard rating. The hazard rating is higher where there is evidence that the condition is causing off-site contamination or if the condition is on a property where a well, intake, or monitoring well related to a drinking water system is located. The threat level of the condition is assigned based on its risk score: where the risk score is greater than or equal to 80 the condition is a significant threat; where it is between ~~61~~ 60 and 79 it is a moderate threat; where it is between ~~41~~ 40 and 59 it is a low threat.

The following information sources were originally consulted to determine if there were any conditions present in the wellhead protection areas delineated in the Trent source protection areas:

- Files provided by the Ministry of the Environment and Climate Change local offices pertaining to licenses and records of spills (Ministry of the Environment and Climate Change Data Hound Files)
- Records available from the Ministry of the Environment and Climate Change, Brownfields Environmental Site Registry
- Records from available technical studies and previous contaminant source inventories that identified situations that may qualify as conditions
- Interviews with municipal staff and the Ontario Clean Water Agency.

If conditions were present, a list would be prepared for each identified wellhead protection area. The list of conditions would include information regarding the identified chemical or pathogen threat and the uncertainty associated with each identified condition.

5.4.1.3 IDENTIFY AREAS FOR SIGNIFICANT, MODERATE, OR LOW THREATS - ACTIVITIES

When addressing activities that may constitute a significant threat, a different process than is used for a condition is employed, but this process is still based on the risk score approach. The Province has prepared a series of tables (*Tables of Drinking Water Threats*) that describe activity threats in terms of the circumstances in which they might occur. For each threat and corresponding circumstance, a rating of low, moderate, or significant is defined based on the vulnerability of the area in which the threat is found.

The assessment of activities (and their associated circumstances) that are prescribed as drinking water threats involves consideration of percent managed lands, livestock density, and percentage of imperviousness. Please refer to Section 4.4.2.4 for details on methods used in evaluating these parameters. Livestock density in each wellhead protection area with vulnerability scores greater than or equal to 4.5 (the minimum score required for an activity to be considered a drinking water threat) are shown on maps which are referred to in Section 5.4.2.

When calculating percent impervious surfaces in wellhead protection areas, WHPA-A and WHPA-B were combined to reflect a 2-year time of travel zone. Where the fixed radius of WHPA-A extends beyond WHPA-B that area was also calculated as part of the 2-year time of travel zone. The impervious area in WHPA-C (5 year time of travel) was calculated separately from WHPA-A and B. Percent impervious surface was not calculated for WHPA-D given the vulnerability scores in this area are too low to generate to create prescribed threat.

Prescribed Threats 1 to 18, 21 and 22~~1~~ are considered in the assessment of the three municipal groundwater systems. The activities and circumstances under which these threats are considered to be significant, moderate, or low to groundwater are described in ~~Tables 1 and 2 of~~ the *Tables of Drinking Water Threats* (~~Ministry of the Environment and Climate Change, November 2009~~). The *Tables of Drinking Water Threats* classifies the threats based on the observed vulnerability scores in the identified vulnerable area.

Maps based on the vulnerability scores have been prepared to illustrate where activities are or would be significant, moderate, or low threats. Individual maps have been prepared to clearly illustrate areas for pathogen, chemical, and DNAPL threats.

5.4.1.4 IDENTIFY AREAS FOR SIGNIFICANT, MODERATE, OR LOW THREATS - CONDITIONS

The *Technical Rules* provides guidance on how to classify conditions as significant, moderate, or low threats. The classification of a condition is based on a risk score calculated as A x B, where A is the hazard rating of the condition and B is the vulnerability score of the area determined in accordance with Part VII or VIII of the *Technical Rules*, as the case may be.

Prescribed threats are assigned a hazard rating (A) of 10 as per the *Technical Rules*. A condition is identified as a significant threat when the risk score of the area associated with the condition is equal to or greater than 80. A condition is also considered to be significant if the area associated with the condition contributes to a drinking water issue as described in the *Technical Rules*. A condition is a moderate drinking water threat where the risk score is equal to or greater than 60 but less than 80. A condition is a low drinking water threat where the risk score is greater than 40 but less than 60.

5.4.1.5 ENUMERATE SIGNIFICANT DRINKING WATER THREATS

The enumeration of “activities” or “conditions” that are or would be significant drinking water threats is limited to the wellhead protection areas. Information gathered from previous threats inventories, from windshield surveys, and from a review of aerial photography was used to compile the initial list of significant threats.

Professional judgment was applied to prepare the initial list of significant threats. Where insufficient information was available, a plan was developed to obtain the information. The uncertainty associated with the assessment of conditions and activities was reviewed, and where appropriate, efforts were made to reduce the uncertainty in accordance with the Section 88 property entry rules. In addition, professional judgment was used on whether to include or not include parcels on the fringe of the vulnerable areas, taking into consideration that a spatial uncertainty of 100m was ascribed to the assessment parcel data

5.4.2 RESULTS OF THREATS ASSESSMENT

The results of the issues evaluation and threats assessment for each municipal groundwater supply system in the Ganaraska Region Source Protection Area are summarized in the following subsections.

5.4.2.1 CREIGHTON HEIGHTS WATER SUPPLY SYSTEM

The following sections describe the threats assessment undertaken for the Creighton Heights Water Supply System in accordance with the *Technical Rules*.

Drinking Water Threats

An assessment of drinking water threats for the Creighton Heights Water Supply System was completed in accordance with the methodology described in Section 5.4.1. Table 5.4-1 documents the prescribed drinking water threats considered in the assessment. ~~No additional drinking water threats were identified for consideration in the Creighton Heights Water Supply System.~~

Drinking Water Threats due to Activities

The following section describes the drinking water threats due to activities in the categories of pathogens, chemicals, and DNAPL. Map 5-6 shows managed lands, livestock density, and percentages of impervious surfaces used in developing the lists of drinking water threats due to activities.

List and Areas of Significant, Moderate, and Low Pathogen Drinking Water Threats

Map 5-7 with its corresponding table can be used in conjunction with the vulnerability scores to identify the areas where activities associated with pathogen threats are or would be significant, moderate, or low for the Creighton Heights Water Supply System. Activities that are or would be significant drinking water threats for pathogens can be observed in the areas where the vulnerability score is 10.

List and Areas of Significant, Moderate, and Low Chemical Drinking Water Threats

Map 5-7 with its corresponding table illustrates where activities associated with chemical threats are or would be significant, moderate, or low drinking water threats for the Creighton Heights Water Supply System. Activities that are or would be significant drinking water threats for chemicals can be observed in the areas where the vulnerability score is 10. In 2017, the Ministry of Environment, Conservation and Parks added "the establishment and operation of a liquid hydrocarbon pipeline" as a prescribed drinking water threat. As a result, this threat is considered a low threat to the Creighton Heights Water Supply System, as the oil pipeline is located in the WHPA-B with a score of 6.

List and Areas of Significant DNAPL Drinking Water Threats

Map 5-7 illustrates WHPA-C (wellhead protection area C) where activities associated with DNAPL parameters are considered to be a significant drinking water threat for the Creighton Heights Water Supply System.

Summary of Significant Drinking Water Threats, Creighton Heights Water Supply System – Activities

The numbers of significant drinking water threats for the Creighton Heights Water Supply System have been determined using the methodology outlined above (Jagger Hims Ltd., 2009). A total of 6 activities on ~~4~~ 5 land parcels were identified that are considered to be significant drinking water threats. These include the following:

- Private Onsite sewage system at the water treatment plant
- Private Onsite sewage systems at two residences
- Private ~~with assumed~~ storage of home heating fuel ~~below~~ above grade at one residence
- ~~Potential for~~The handling and storage of dense non-aqueous phase liquids (DNAPL) at ~~one~~ three property in the WHPA-C.

Drinking Water Threats due to Conditions

No confirmed conditions that produce drinking water threats have been identified for the Creighton Heights Water Supply System.

Drinking Water Threats due to Issues

No drinking water issues were identified at the Creighton Heights Water Supply System (see Section 5.3).

Enumeration of Significant Drinking Water Threats

Table 5.4-2 documents the enumeration of existing activities that are considered to be significant drinking water threats in the wellhead protection areas for the Creighton Heights Water Supply System.

Table 5.4-2: Enumeration of Significant Threats for the Creighton Heights Water Supply System

Prescribed Drinking Water Threat		Vulnerability Score 10		WHPA B and C	
		Number of Threats	Number of Parcels	Number of Threats	Number of Parcels
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.				
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	~~3~~2	~~3~~2		
3	The application of agricultural source material to land.				
4	The storage of agricultural source material.				
5	The management of agricultural source material.				
6	The application of non-agricultural source material to land.				
7	The handling and storage of non-agricultural source material.				
8	The application of commercial fertilizer to land.				
9	The handling and storage of commercial fertilizer.				
10	The application of pesticide to land.				
11	The handling and storage of pesticide.				
12	The application of road salt.				
13	The handling and storage of road salt.				

14	The storage of snow.				
15	The handling and storage of fuel.	~~2~~1	(1)~~2~~		
16	The handling and storage of a dense non-aqueous phase liquid.			~~1~~3	~~1~~3
17	The handling and storage of an organic solvent.				
18	The management of runoff that contains chemicals used in the de-icing of aircraft.				
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard.				
22	The establishment and operation of a liquid hydrocarbon pipeline				
	Total	**~~5~~3**	**~~3~~2**	**~~1~~3**	**~~1~~3**
	Total Number of Significant Threats	**6**			
	Total Parcels with Significant Threats	**~~4~~5**			

Note: blank cells means no prescribed significant threats were found. Brackets around parcels means multiple activities were found at the same parcel.

5.4.2.2 CAMBORNE WATER SUPPLY SYSTEM

The following sections describe the threats assessment undertaken for the Camborne Water Supply System in accordance with the *Technical Rules*.

Drinking Water Threats

An assessment of drinking water threats for the Camborne Water Supply System was completed in accordance with the methodology described in Section 5.4.1. Table 5.4-1 documents the prescribed drinking water threats considered in the assessment. No additional drinking water threats were identified for consideration in the Camborne Water Supply System.

Drinking Water Threats due to Activities

The following section describes the drinking water threats due to activities in the categories of pathogens, chemicals, and DNAPL. Map 5-8 shows managed lands, livestock density, and percentages of impervious surfaces used in developing the lists of drinking water threats due to activities.

List and Areas of Significant, Moderate, and Low Pathogen Drinking Water Threats

Map 5-9 with its corresponding table can be used in conjunction with the vulnerability scores to identify the areas where activities associated with pathogen threats are or would be significant, moderate, or low for the Camborne Water Supply System. Activities that are or would be significant drinking water threats for pathogens can be observed in the areas where the vulnerability score is 10.

List and Areas of Significant, Moderate, and Low Chemical Drinking Water Threats

Map 5-9 with its corresponding table illustrates where activities associated with chemical threats are or would be low drinking water threats for the Camborne Water Supply System. Activities that are or would be significant drinking water threats for chemicals can be observed in the areas where the vulnerability score is 10.

List and Areas of Significant DNAPL Drinking Water Threats

Map 5-9 illustrates WHPA-C where activities associated with DNAPL parameters are considered to be a significant drinking water threat for the Camborne Water Supply System.

Summary of Significant Drinking Water Threats, Camborne Water Supply System - Activities

The numbers of significant drinking water threats for the Camborne Water Supply System have been determined using the methodology outlined above (Jagger Hims Ltd., 2009). A total of ~~16~~ 7 activities on ~~10~~ 7 land parcels were identified that are considered to be significant drinking water threats. These include the following:

- Private sewage system at the water treatment plant
- Private sewage systems at ~~nine~~ six residences
- ~~Assumed storage of home heating fuel below grade at six residences.~~

Drinking Water Threats due to Conditions

No confirmed conditions that produce drinking water threats have been identified for the Camborne Water Supply System.

Drinking Water Threats due to Issues

No drinking water issues were identified at the Camborne Water Supply System (see Section 5.3).

Enumeration of Significant Drinking Water Threats

Table 5.4-3 documents the enumeration of existing activities that are considered to be significant drinking water threats in the wellhead protection areas for the Camborne Water Supply System.

Table 5.4-3: Enumeration of Significant Threats for the Camborne Water Supply System

Prescribed Drinking Water Threat		Vulnerability Score 10		WHPA B and C	
		Number of Threats	Number of Parcels	Number of Threats	Number of Parcels
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.				
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	~~10~~7	~~10~~7		
3	The application of agricultural source material to land.				
4	The storage of agricultural source material.				
5	The management of agricultural source material.				
6	The application of non-agricultural source material to land.				
7	The handling and storage of non-agricultural source material.				
8	The application of commercial fertilizer to land.				
9	The handling and storage of commercial fertilizer.				
10	The application of pesticide to land.				
11	The handling and storage of pesticide.				
12	The application of road salt.				
13	The handling and storage of road salt.				
14	The storage of snow.				
15	The handling and storage of fuel.	~~6~~	~~6~~		
16	The handling and storage of a dense non-aqueous phase liquid.				
17	The handling and storage of an organic solvent.				
18	The management of runoff that contains chemicals used in the de-icing of aircraft.				
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard.				
22	The establishment and operation of a liquid hydrocarbon pipeline				
	Total	~~16~~7	~~10~~7		
	Total Number of Significant Threats	~~16~~7			
	Total Parcels with Significant Threats	~~10~~7			

Note: blank cells means no prescribed significant threats were found

5.4.2.3 ORONO DRINKING WATER SYSTEM

The following sections describe the threats assessment undertaken for the Orono Drinking Water System in accordance with the *Technical Rules*.

Drinking Water Threats

An assessment of drinking water threats for the Orono Drinking Water System was completed in accordance with the methodology described in Section 5.4.1. Table 5.4-1 documents the prescribed drinking water threats considered in the assessment. No additional drinking water threats were identified for consideration in the Orono Drinking Water System.

Drinking Water Threats due to Activities

The following section describes the drinking water threats due to activities in the categories of pathogens, chemicals, and DNAPL. Map 5-10 shows managed lands, livestock density, and percentages of impervious surfaces used in developing the lists of drinking water threats due to activities.

List and Areas of Significant, Moderate, and Low Pathogen Drinking Water Threats

Map 5-11 with its corresponding table can be used in conjunction with the vulnerability scores to identify the areas where activities associated with pathogen threats are or would be significant, moderate, or low for the Orono Drinking Water System. Activities that are or would be significant drinking water threats for pathogens can be observed in the areas where the vulnerability score is 10.

List and Areas of Significant, Moderate, and Low Chemical Drinking Water Threats

Map 5-11 with its corresponding table illustrates where activities associated with chemical threats are or would be low drinking water threats for the Orono Drinking Water System. Activities that are or would be significant drinking water threats for chemicals can be observed in the areas where the vulnerability score is 10 or 8.

List and Areas of Significant DNAPL Drinking Water Threats

Map 5-11 illustrates WHPA-C where activities associated with DNAPL parameters are considered to be a significant drinking water threat for the Orono Drinking Water System.

Summary of Significant Drinking Water Threats, Orono Drinking Water System - Activities

The numbers of significant drinking water threats for the Orono Drinking Water System have been determined using the methodology outlined above (Genivar Consultants LP, 2010). A total of ~~two~~ one activit~~i~~y~~es~~ on one land parcel ~~were~~ was identified that are considered to be significant drinking water threats. These include the following:

- Application of agricultural source materials to land at one property
- ~~Application of pesticide to land at one property.~~

Drinking Water Threats due to Conditions

No confirmed conditions that produce drinking water threats have been identified for the Orono Drinking Water System.

Drinking Water Threats due to Issues

No drinking water issues were identified at the Orono Drinking Water System (see Section 5.3).

Enumeration of Significant Drinking Water Threats

Table 5.4-4 documents the enumeration of existing activities that are considered to be significant drinking water threats in the wellhead protection areas for the Orono Drinking Water System.

Table 5.4-4: Enumeration of Significant Threats for the Orono Drinking Water System

Prescribed Drinking Water Threat		Vulnerability Score 10		WHPA B and C	
		Number of Threats	Number of Parcels	Number of Threats	Number of Parcels
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.				
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.				
3	The application of agricultural source material to land.	1	1		
4	The storage of agricultural source material.				
5	The management of agricultural source material.				
6	The application of non-agricultural source material to land.				
7	The handling and storage of non-agricultural source material.				
8	The application of commercial fertilizer to land.				
9	The handling and storage of commercial fertilizer.				
10	The application of pesticide to land.	~~1~~	~~1~~		
11	The handling and storage of pesticide.				
12	The application of road salt.				
13	The handling and storage of road salt.				
14	The storage of snow.				
15	The handling and storage of fuel.				
16	The handling and storage of a dense non-aqueous phase liquid.				
17	The handling and storage of an organic solvent.				
18	The management of runoff that contains chemicals used in the de-icing of aircraft.				
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard.				
22	The establishment and operation of a liquid hydrocarbon pipeline				
	Total	**~~2~~1**	**1**		
	Total Number of Significant Threats	~~2~~1			
	Total Parcels with Significant Threats	1			

5.4.3 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Transportation Corridors

Transportation corridors are of concern in some wellhead protection areas. The Source Protection Committee will consider the need to include site-specific transportation corridor threats (i.e., requesting to add local threats) in a future Assessment Report. An alternative is to use a more general policy to address transportation corridors in the Source Protection Plan.

Refinement to Enumeration of Threats

Further information could be collected from landowners regarding activities in vulnerable areas.

5.4.4 REFERENCES

Genivar Consultants LP. (2010). *Assessment of Drinking Water Threats, Municipal Groundwater Supplies, the Regional Municipality of Durham*, Draft. Newmarket (ON).

Jagger Hims Limited. (2009). *Assessment of Drinking Water Threats, Creighton Heights and Camborne Municipal Wellfields, Township of Hamilton* (Draft). Prepared for Township of Hamilton and Ganaraska Region Conservation Authority. File # 061851.01. Newmarket (ON).

Ministry of the Environment and Climate Change. (2009). Tables of Drinking Water Threats. http://www.ene.gov.on.ca/envision/env_reg/er/documents/2009/010-7573%202.pdf

CHAPTER 6: LANDSCAPE-SCALE GROUNDWATER ANALYSES

6.1 GROUNDWATER VULNERABILITY AND HIGHLY VULNERABLE AQUIFERS

The vulnerability of an aquifer to contamination depends on many factors, including its depth below the ground, its geological setting, and the presence of transport pathways. A groundwater vulnerability assessment is an evaluation of these features, and it produces a map of the relative vulnerability of the aquifers in an area of interest. The results are used to identify highly vulnerable aquifers ~~and to assign vulnerability scores to significant groundwater recharge areas (Section 6.2)~~. The assessment of groundwater vulnerability in the Trent Conservation Coalition Source Protection Region was completed by AECOM Canada Ltd. and is discussed in detail in the report:

- *Trent Conservation Coalition Groundwater Vulnerability Assessment – TCC Source Protection Region (December 2009)*.

This section is a summary of that report. Note that groundwater vulnerability was assessed at a landscape scale (including the entire Trent Conservation Coalition Source Protection Region) and at a local scale for each municipal groundwater system. This section refers to the regional assessment. (The local-scale assessment is discussed in Chapter 5).

6.1.1 METHODOLOGY

There are several methods that can be used to assess the vulnerability of aquifers to contamination. The *Technical Rules* lists the following four acceptable methods:

- *Intrinsic Susceptibility Index:* A score that reflects the static water level and the soil types and thickness above the aquifer in each well in the study area
- *Aquifer Vulnerability Index:* A score that reflects the relative amount of protection provided by physical features that overlie the aquifer
- *Surface to Aquifer Advection Time:* The time it takes water to travel from the ground surface to the top of the aquifer
- *Surface to Well Advection Time:* The time it takes water to travel from the ground surface to the well.

Groundwater vulnerability was assessed separately for the Paleozoic and Precambrian areas because of their differences in physiography and data availability. In the Paleozoic area, both the Intrinsic Susceptibility Index and Aquifer Vulnerability Index methods were used, and the final vulnerability mapping is a combination of the two methods. In the Precambrian area, only the Intrinsic Susceptibility Index was used. The selection of these methods was based on previous groundwater vulnerability mapping in the area (e.g., *Oak Ridges Moraine Conservation Plan*) and approaches used by other source protection regions.

The assessment was focused on the uppermost aquifer from which the majority of domestic wells draw their water. Deep aquifers were not considered because they are generally more protected by the geological layers above. The analysis was based on several databases of well records (consolidated in the Conservation Authorities Moraine Coalition database), which included spatial and geological data for thousands of wells in the Source Protection Region. The well records were screened to include only those wells that had sufficiently accurate location (±100m) and elevation (±7.5m) data. The analysis was performed using VIEWLOG (a borehole data management and visualization software package) and a geographic information system.

6.1.1.1 INTRINSIC SUSCEPTIBILITY INDEX

The Intrinsic Susceptibility Index is an approach that takes advantage of the existing provincial well records database to produce a score for individual wells in the database that reflects the type and thickness of the geologic layers above the wells and their static water levels. The index is calculated by summing the products of the thickness of each soil or rock layer above the groundwater level and its hydraulic conductivity (a property of soil or rock that describes how easily water can move through pore spaces or fractures).

The index was calculated for individual wells, and the results were interpolated between wells to produce a map of groundwater vulnerability for the entire Source Protection Region. The analysis was performed separately for the Paleozoic and Precambrian areas because their differences in physiography and well availability required different considerations. (There are considerably fewer well records in the Precambrian area.) The first step in the analysis was to select well records that were appropriate for the analysis.

6.1.1.1.1 Selection of Well Records

Since the focus of the assessment was on the uppermost aquifer, only well records that satisfied specific depth criteria were included in the analysis. A preliminary review of the geology in the Paleozoic area (using several north-south cross-sections generated in VIEWLOG) revealed that the depth to the uppermost aquifer varies considerably by physiographic setting (i.e., domestic wells on the Oak Ridges Moraine are generally deeper than those on its northern and southern flanks). To eliminate some of the errors that would result from mapping all of the Paleozoic wells similarly, shallow wells in this area were selected using different depth criteria for different physiographic settings; wells located on the Oak Ridges Moraine were included if they were less than 60 m deep, and wells on its northern and southern flanks were included if they were less than 20 m deep.

In the Precambrian area, the sparse coverage of well records made it necessary to exclude wells located in areas of exposed bedrock or thin overburden (less than 5 m deep). Wells were also excluded if they did not have screens installed or did not have top of screen elevation and static water level recorded. Wells with static water levels that were lower than the screen elevation (i.e., dry wells) were also excluded from the analysis (and where a well had multiple screen intervals, the shallowest screen was used for this purpose).

6.1.1.1.2 Shallow Water Table Mapping

The water level data at the selected wells were interpolated between wells using kriging (a method of interpolating values between two or more known data points). The wells included in the analysis were analysed statistically using a variogram (a statistical function that describes the spatial correlation of a data set). The results of the variogram analysis were used to determine how the kriging would weigh the data points based on their distance from one another. In some valley areas, the kriging generated water levels that appeared to be above the ground surface. In these areas the water level was assumed to be equal to ground surface elevation for vulnerability assessment purposes.

6.1.1.1.3 Identification of Uppermost Aquifer

The geological descriptions used in ~~the Ministry of the Environment and Climate Change~~Provincial well records are quite varied (i.e., not standardized) since they are based on the descriptions provided by well drillers. A methodology developed by the Geological Survey of Canada was used to identify the geologic layers in each well that were identified by the well drillers and to convert their “raw” geologic descriptions into standardized “three-material” descriptions. Where these data were not available for a well, the first material in the “three-material” descriptions was used to characterize the geologic materials at the well. The standardized descriptions were then used to identify the uppermost aquifer in each well. For wells that did not contain aquifer layers, it was assumed that the uppermost aquifer was located at the uppermost screen elevation. Layers were only considered aquifer layers if they were at least 1 m thick and partially saturated (i.e., where the static water level was greater than elevation at the bottom of the layer).

6.1.1.1.4 Calculation of Intrinsic Susceptibility Index

The final step was to determine the thickness of each geologic layer above the uppermost aquifer and to calculate the Intrinsic Susceptibility Index for each well. The uppermost aquifer at a well was considered confined if its static water level was at least 4 m above the top of the aquifer layer. For wells in confined aquifers, the index calculation included the geologic layers between the ground surface and the top of the aquifer. For wells in unconfined aquifers, the calculation included the geologic layers between the ground surface and the static water level or the top aquifer (whichever was less). Hydraulic conductivities (K-factors) for the geologic layers were obtained from provincial guidance (Module 3) for groundwater vulnerability assessment (Table 3.2 of Appendix 3). The index calculated at each well was assigned a groundwater vulnerability classification in accordance with the ranges provided in the *Technical Rules*, and these are listed in Table 6.1-1.

Table 6.1-1: Groundwater Vulnerability Classifications

Intrinsic Susceptibility Index *or* Aquifer Vulnerability Index	Groundwater Vulnerability
0 – 29	High
30 – 79	Medium
>80	Low

In the Precambrian area, a modified Intrinsic Susceptibility Index method was used to account for the sparse coverage of well records. Areas of exposed bedrock or shallow overburden (less than 5 m) were automatically assigned a vulnerability rating of “high.” Director’s approval was obtained to use this approach for areas of sparse well coverage or thin overburden (see Appendix A).

6.1.1.2 AQUIFER VULNERABILITY INDEX

The intrinsic groundwater vulnerability of the Paleozoic area was also assessed using the Aquifer Vulnerability Index. This method of analysis generally followed the same procedure as the Intrinsic Susceptibility Index with the exception that the index calculation included the geologic layers above the uppermost aquifer regardless of where the static water level was located. Further, since the Aquifer Vulnerability Index does not consider the static water level in wells, geologic layers were considered aquifer layers if they were at least 2 m thick, regardless of whether or not they were saturated. The index calculated at each well was assigned a groundwater vulnerability classification in accordance with the ranges provided in the *Technical Rules*, listed in Table 6.1-1.

6.1.2 DISCUSSION OF RESULTS

6.1.2.1 PALEOZOIC AREA

For the Paleozoic area, maps of groundwater vulnerability were prepared using both the Intrinsic Susceptibility Index and Aquifer Vulnerability Index methods. The Aquifer Vulnerability Index results were better able to identify known vulnerable areas along the centre of the Oak Ridges Moraine area and along the southern shoreline of Rice Lake, and the Intrinsic Susceptibility Index results were better able to identify known vulnerable areas in the rest of the Paleozoic area. The final map of groundwater vulnerability for the Paleozoic area is a combination of the results that were better able to identify known vulnerable areas: the Aquifer Vulnerability Index results were used in the Ministry of Natural Resources and Forestry-defined Oak Ridges Moraine planning area, and the Intrinsic Susceptibility Index results were used in the rest of the Paleozoic area.

6.1.2.2 PRECAMBRIAN AREA

For the Precambrian area, maps of groundwater vulnerability were prepared using the Intrinsic Susceptibility Index method. Since the coverage of data in the Precambrian area is generally sparse, the results were corrected by using surficial geology data (from the Ontario Geological Survey) and drift thickness data (from the Ontario Geological Survey) as additional input data for the interpolation. The results were also modified using professional judgment where appropriate.

6.1.2.3 TRANSPORT PATHWAYS

The maps of groundwater vulnerability were further modified to reflect the presence of transport pathways that could “short-circuit” the natural flow of groundwater. In accordance with the *Technical Rules*, the presence of a transport pathway can increase the groundwater vulnerability in an area from low to medium or from medium to high (the vulnerability remains high if there is a transport pathway in an area of high vulnerability). The transport pathways considered in the assessment were old wells, pits, and quarries. For wells, the vulnerability was increased within a 30 m buffer around all of the wells in the database that were more than 10 years old (i.e., newer wells are likely to be constructed to a higher standard). For pits and quarries, the vulnerability was increased in the pit and quarry locations identified in databases from the Ministries of Natural Resources and Northern Development, Mines, and Forestry.

6.1.3 UNCERTAINTY ANALYSIS

The uncertainty of the landscape-scale groundwater vulnerability assessment and the delineation and vulnerability assessment of highly vulnerable aquifers were evaluated, and a value of "high" or "low" uncertainty was determined for each of the following factors:

1. The distribution, variability, quality, and relevance of data used (Data)
2. The ability of the methods and models used to accurately reflect the flow processes in the system (Modeling)
3. The quality assurance and quality control procedures applied (QA/QC)
4. The extent and level of calibration and validation achieved for models used or calculations/assessments completed (Calibration)
5. For the groundwater vulnerability assessment, the accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of underlying hydrogeological features (Accuracy of Vulnerability Categories).

An overall uncertainty rating was determined for each part of the analysis based on the highest uncertainty assigned to the factors listed above. The uncertainty ratings assigned to the vulnerability assessment of highly vulnerable aquifers are identical to those assigned to the groundwater vulnerability assessment because highly vulnerable aquifers are extracted from the results of the groundwater vulnerability assessment. Uncertainty ratings are given in Table 6.1-2.

Table 6.1-2: Summary of Uncertainty for Groundwater Vulnerability Assessment

Sources of Uncertainty	Uncertainty Ratings		
	Groundwater Vulnerability Assessment	Delineation of Highly Vulnerable Aquifers	Vulnerability Assessment of Highly Vulnerable Aquifers
Data	High	High	High
Modeling	High	High	High
QA/QC	Low	Low	Low
Calibration and Validation	High	High	High
Accuracy of Vulnerability Categories	Low	N/A	N/A
Overall Uncertainty Rating	**High**	**High**	**High**

6.1.4 FINAL GROUNDWATER VULNERABILITY MAP

The final map of groundwater vulnerability is a combination of the results that were best able to identify the known vulnerable areas in the Paleozoic and Precambrian areas. For practical reasons, small discrete areas less than 0.01 km^2 were eliminated from the map, and these small areas were assigned groundwater vulnerability based on the most frequent values observed in the surrounding areas. The final map of groundwater vulnerability in the Ganaraska Region Source Protection Area is shown on Map 6-1. The areas with high groundwater vulnerability (i.e., "highly vulnerable aquifers") are shown on Map 6-2.

6.1.5 ASSIGNMENT OF VULNERABILITY SCORES

In accordance with the *Technical Rules*, areas delineated as highly vulnerable aquifers were all assigned a vulnerability score of 6. The highly vulnerable aquifers with assigned vulnerability scores are shown on Map 6-3.

6.1.6 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Improvement of landscape-based groundwater vulnerability assessment

The provincial borehole database, which is continuously updated, should be used to improve the landscape-based groundwater vulnerability assessment as more data become available, especially in the Canadian Shield area.

Edge mapping

Methodologies for mapping highly vulnerable aquifers should be further evaluated considering differences between the Ganaraska Source Protection Area and the Central Lake Ontario Source Protection Area (see Chapter 9 for additional information).

6.1.7 REFERENCES

AECOM. (2009). *Groundwater Vulnerability Assessment – TCC Source Protection Region*. Guelph, (ON).

Ministry of the Environment and Climate Change. (2006). *Assessment Report: Draft Guidance Module 3 Groundwater Vulnerability Analysis*. Toronto: Ontario Ministry of the Environment and Climate Change.

6.2 SIGNIFICANT GROUNDWATER RECHARGE AREAS

Groundwater recharge is a hydrologic process by which aquifers are replenished by the downward movement of water. The amount of groundwater recharge that occurs in a particular area depends on the climate, topography, and surficial geology of that area. Significant groundwater recharge areas are locations where these conditions favour groundwater recharge. The delineation of significant groundwater recharge areas in the Trent Conservation Coalition Source Protection Region was completed as a joint project of the Conservation Authorities Moraine Coalition and the Municipalities of York, Peel, Durham, and Toronto, documented in the following report. The report was peer reviewed, and the result of the review is summarized in Appendix C.

- *Trent Source Water Protection Study Recharge Study: Final Report (CAMC-YPDT, November 2009)*

This section is a summary of that report. Note that the study was completed at a regional scale and considered all five source protection areas in the Trent Conservation Coalition Source Protection Region.

6.2.1 METHODOLOGY

The *Technical Rules* defines significant groundwater recharge areas as areas with a hydrological connection to a surface waterbody or aquifer that is a source of water for a drinking water system that meets one of the following two criteria:

1. The annual recharge rate is at least 1.15 times the annual recharge rate of the area under consideration
2. The annual recharge volume is at least 55% of the annual water budget surplus (precipitation minus actual evapotranspiration) of the area under consideration.

Significant groundwater recharge areas in the Source Protection Region were delineated using the second (water budget surplus) method. The delineation process consisted of an analysis of climate, estimation of recharge rates, and calculation of the water budget surplus and threshold recharge volume.

6.2.2 CLIMATE ANALYSIS

Climate affects groundwater recharge because precipitation and evapotranspiration rates affect the amount of water that is available to recharge the groundwater system. Given the large size of the area under consideration, the variation in climate across the Source Protection Region was evaluated to determine the best approach to apply climate data across the area for the purpose of calculating the water budget surplus.

Data from 71 climate stations were used to illustrate the interpolated 30-year temperature (Figure 6.2-1) and precipitation (Figure 6.2-2) normals (averages) across the Source Protection Region. Given the significant variability observed in the precipitation and temperature normals across the region, it was deemed inappropriate to calculate the water budget surplus using a set of climate data from a single station. Thus, taking into account the location of climate stations in the watershed, the interpolated precipitation and temperature data, general physiography (South Slope, Oak Ridges Moraine, Peterborough Drumlin Field, and Canadian Shield), and the location of watershed boundaries, the Source Protection Region was divided into northern, central, and southern climate zones (Figure 6.2-3). For convenience, the climate zones were delineated to coincide with watershed boundaries. One climate station was selected to represent the climate of each zone:

Cobourg Sewage Treatment Plant for the southern zone, Peterborough Airport for the central zone, and Minden Forestry for the northern zone. The water budget surplus was calculated separately for each climate zone. The long-term precipitation and temperature normals for these stations are listed in Table 6.2-1.

Table 6.2-1: 30-Year Climate Normals (1971-2000)

Station	Area	Precipitation	Temperature
Cobourg STP	South	871.1	7.1
Peterborough	Central	840.3	5.9
Minden Forestry	North	1,044.7	5.2

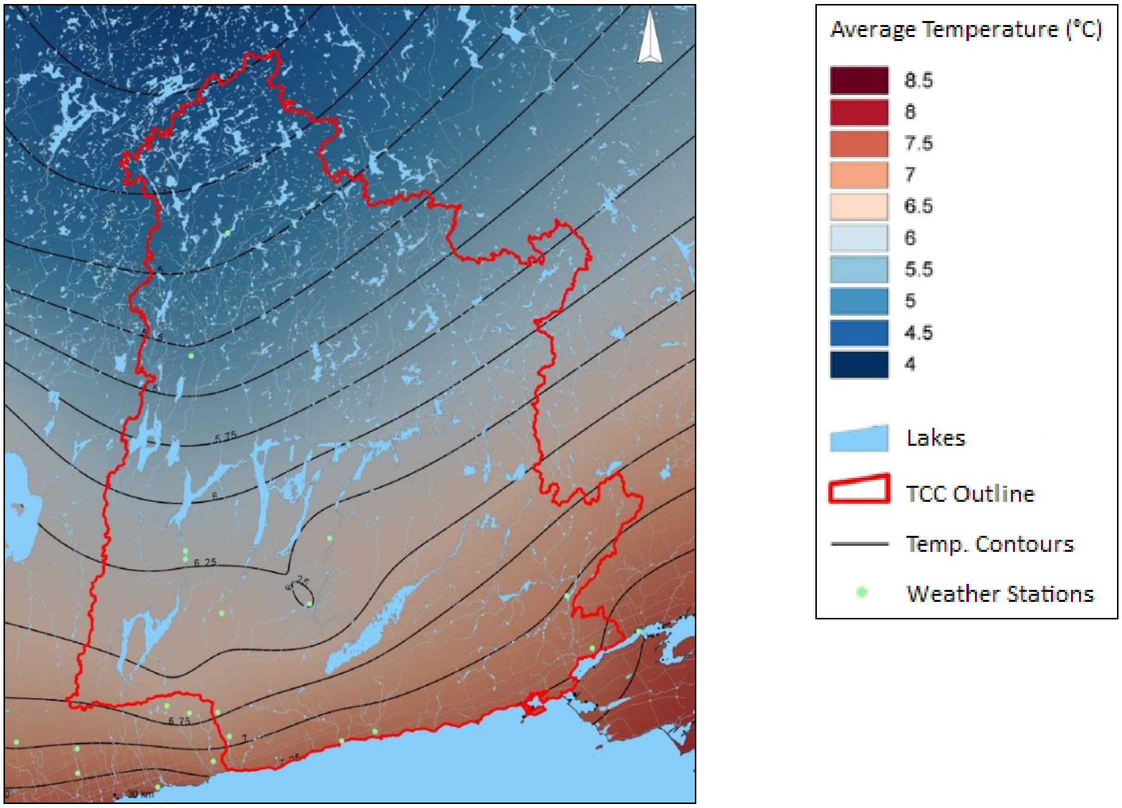

Figure 6.2-1: Temperature Normals (1971-2000)

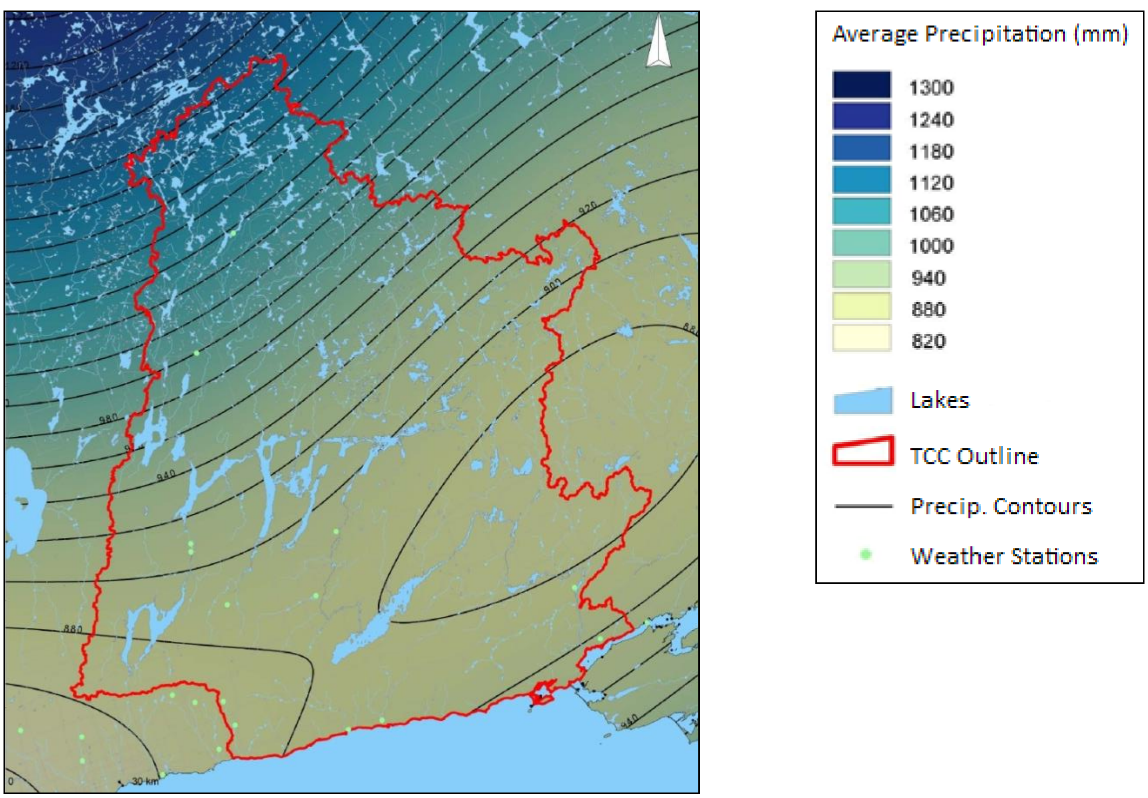

Figure 6.2-2: Precipitation Normals (1971-2000)

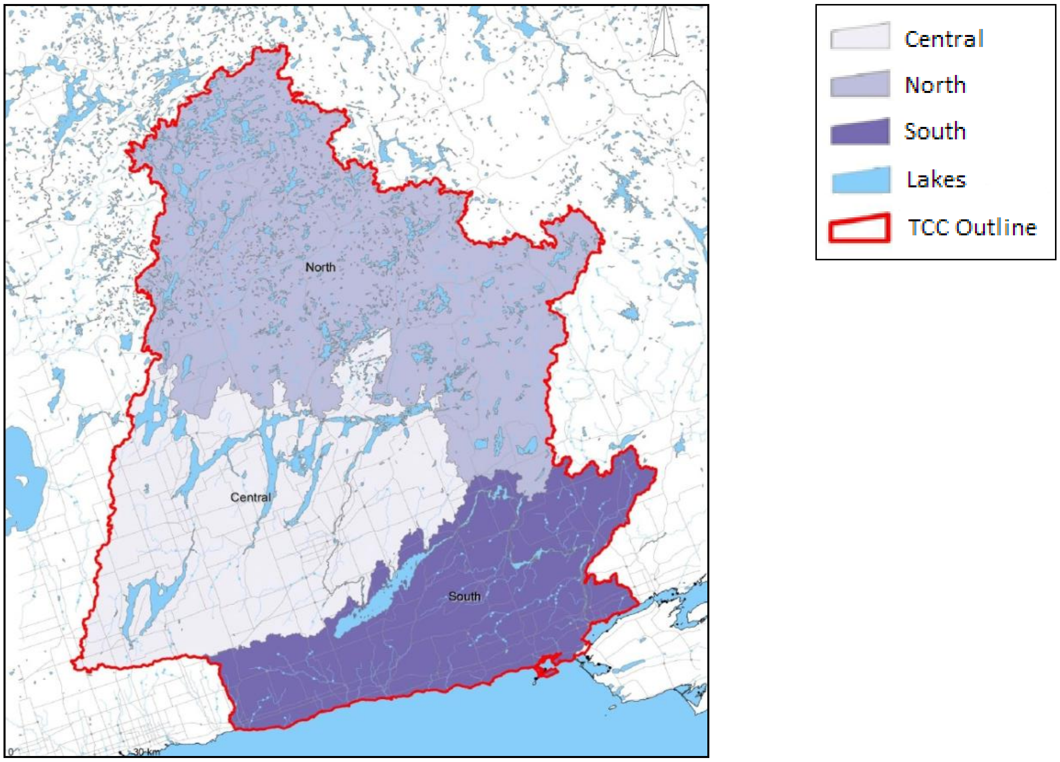

Figure 6.2-3: Climate Zones

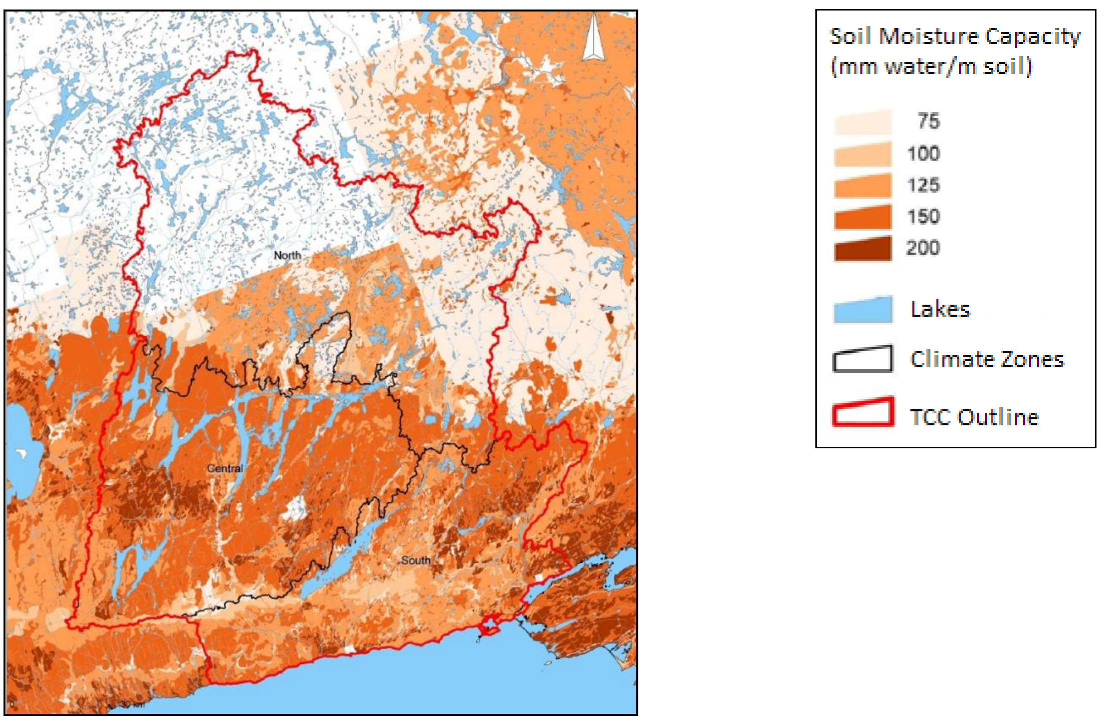

Figure 6.2-4: Soil Moisture Capacities

6.2.3 RECHARGE RATES

Recharge rates across most of the Paleozoic Area of the Trent Conservation Coalition Source Protection Region were estimated from a three-dimensional regional groundwater flow model developed by the Conservation Authorities Moraine Coalition. This model was created to help understand the hydrogeology of the Oak Ridges Moraine and surrounding area, and its geographic extent includes a southern portion of the Source Protection Region. Development of the model is discussed in Earthfx (2006). The model provided estimates of annual recharge rates for most of the Quaternary soil types in the Source Protection Region (listed in Table 6.2-2). These estimates were related to the surficial geology in the Source Protection Region using surficial geology mapping from the Ontario Geological Survey. This mapping covered the entire Source Protection Region with the exception of a large area (approximately 1,100 km^2) in the vicinity of Peterborough. This gap was filled in by transforming attributes from agricultural soil mapping produced by the Ministry of Agriculture, Food and Rural Affairs to equivalent Ontario Geological Survey mapping units. The attributes considered in the transformation included slope, stoniness, drainage, texture, hydrologic characteristics, and proximity to units on adjacent map sheets.

The recharge rate estimates were extrapolated across the parts of the Source Protection Region located outside the geographic extent of the model. The recharge rates for two soil types not located in the geographic extent of the model (kame and eolian) were estimated using professional judgment. Further, the recharge rates in the northern climate zone were multiplied by a factor of 1.25 to account for the higher precipitation and lower temperature observed in the area. (This combination would result in a higher water budget surplus.) However, since this area is mostly covered by Precambrian bedrock that provides very little groundwater recharge, it is recognized that the excess water in the north would likely only recharge into the limited sand and gravel deposits. Thus, the uniform increase in recharge rates did not affect the final delineation of significant groundwater recharge areas.

Table 6.2-2: Estimated Recharge Rates

Quaternary Soil Type	Estimated Annual Recharge Rate (mm/year)
Bedrock	60
Newmarket till	90
Halton till	90
Moraine sand/gravel	360
Glacio-fluvial sands	320
Glacio-lacustrine silts	60
Glacio-lacustrine sand	240
Organic peat	60
Miscellaneous recent alluvium	60
Kame*	320
Eolian*	220

*Soil type added to account for soil types that were not found in the CAMC-YPDT study area

6.2.4 WATER BUDGET SURPLUS

The water budget surplus is the difference between the precipitation and actual evapotranspiration in a given area over a particular time period; this value represents the amount of water that is available to recharge groundwater. The water budget surplus was calculated by subtracting the annual actual evapotranspiration from the precipitation normals in each of three climate zones. The water budget surplus calculation is summarized in Table 6.2-3.

Table 6.2-3: Water Budget Surplus Calculation

Climate Zone (Station)	Precipitation (mm/yr)	Actual Evapotranspiration (mm/year)	Water Budget Surplus (Precipitation - Actual Evapotranspiration) (mm/yr)
South (Cobourg STP)	871.1	518.2	353.7
Central (Peterborough A)	840.3	560.9	279.5
North (Minden Forestry)	1,044.7	559.1	485.6

The actual evaporation in each of the three climate zones was calculated using the Thornthwaite-Mather (1957) methodology. This is a water balance methodology that uses monthly temperature and precipitation normals and soil moisture storage values to estimate actual evapotranspiration. The methodology was run in each climate zone five times using the climate data from its representative climate station. The soil moisture capacity was increased incrementally in each run from a low of 75 millimetres of water per metre of soil (mm water/m soil) to a high of 200 mm water/m soil. (The values used were 75, 100, 125, 150, and 200 mm water/m soil.) This produced a range of actual monthly evapotranspiration values for various soil moisture capacities.

Soil moisture storage capacities were assigned to soil types in the Source Protection Region using agricultural soil classifications (rather than surficial geology classifications) because they were readily available in the literature. Agricultural soil classification mapping was available for most of the Source Protection Region, but the northern area was only partially mapped. Since Quaternary geology mapping in the unmapped portion showed that the northern area is fairly uniform, the soil classifications in the mapped portion of the northern climate zone were assumed to extend across the unmapped portion. Soil moisture capacities assigned to the soil types across the Source Protection Region are listed in Table 6.2-4. The soil moisture capacities across the Source Protection Region are shown in Figure 6.2-4, and the percent coverage of different soil moisture capacities in each of the three zones are listed in Table 6.2-5.

The actual evapotranspiration values calculated using the Thornthwaite-Mather routine were assigned to each soil type based on its soil moisture capacity. The actual evapotranspiration for each soil type was assumed to be equal to the actual evapotranspiration calculated by the Thornthwaite-Mather routine at the soil moisture capacity increment that was closest to the soil moisture capacity for that soil type given in the literature.

The actual evapotranspiration of each climate zone was calculated for each month by summing the products of the percent coverage of each soil type found in the area and its monthly actual evapotranspiration value (calculated using the Thornthwaite-Mather routine), and then summing the monthly values. The final actual evapotranspiration values for the three climate zones are listed in Table 6.2-5.

Table 6.2-4: Soil Moisture Capacities Assigned to Soils in the Source Protection Region

Soil Class	Soil Moisture Capacity (mm water/m soil)		Source (Comment)
	Literature	Thornthwaite-Mather	
Coarse sand & loamy sand	83	100	B.C. Water Factsheet[1]
Moderately coarse sandy loam	125	125	B.C. Water Factsheet[1]
Med. to moderately fine loam	175	150	B.C. Water Factsheet[1]
Silt loam	208	200	B.C. Water Factsheet[1]
Clay loam	200	200	B.C. Water Factsheet[1]
Silty clay	200	200	Estimated (same as silt/clay loam)
Clay	200	200	B.C. Water Factsheet[1]
Organic	175	150	Estimated (same as m. loam)
Bottom land	175	150	Estimated (same as organic/m. loam)
Rocky Phase	75	75	Estimated (lower than c. sand)
Rockland	50	75	Estimated (lower than c. sand)
Rock Outcrop	50	75	Estimated (lower than c. sand)
Bouldery	75	75	Estimated (lower than c. sand)
Rock	50	75	Estimated (lower than c. sand)
Gravelly sandy loam	75	75	Estimated (lower than c. sand)
Find sandy loam	142	150	B.C. Water Factsheet[1]
Gravelly sand	75	75	Estimated (lower than c. sand)
Silty clay loam	200	200	Estimated (same as silt/clay loam)
Loamy sand	100	100	B.C. Water Factsheet[1]

[1]B.C. Ministry of Agriculture, Food, and Fisheries (2001)

Table 6.2-5: Percent Coverage of Soil Moisture Capacities per Climate Zone

Soil Moisture Capacity (mm)	Percent Coverage per Climate Zone		
	South	Central	North
75	3.1	5.1	38.7
100	9.3	2.2	7.9
125	36.9	17.8	31
150	40.1	65	22.1
200	10.7	9.9	0.3

6.2.5 DELINEATION OF SIGNIFICANT RECHARGE AREAS

Significant groundwater recharge areas were delineated by calculating a threshold recharge rate above which an area would be considered a significant groundwater recharge area and comparing the recharge rates estimated across the Source Protection Region to this threshold value. In accordance with the selected approach, this threshold value was calculated as 55% of the water budget surplus for each climate zone.

In the northern climate zone, this threshold recharge value was divided by a factor of 1.25 to account for the higher precipitation and lower temperature (thus lower evapotranspiration) observed in this area (this combination would result in a higher water budget surplus). Professional judgment was used in the derivation of this factor (i.e. 1.25). However, since this area is mostly covered by Precambrian bedrock that provides very little groundwater recharge, it is recognized that the excess water in the north would likely only recharge into the limited sand and gravel deposits. Thus, any increase in the significant recharge area resulting from the lower threshold assigned for the recharge rates in the north was found to be very minimal.

The threshold values for each zone are listed in Table 6.2-6. Significant groundwater recharge areas in the Source Protection Region delineated using these threshold values are shown in Figure 6.2-5. Several methodologies were considered to refine the delineation of significant groundwater recharge areas shown in Figure 6.2-5; these are described in the following three sections.

Table 6.2-6: Significant Groundwater Recharge Area Thresholds

Climate Zone (Station)	Water Budget Surplus	SGRA Threshold[1] (mm/year)
South (Cobourg STP)	353.7	194.5
Central (Peterborough A)	279.5	153.7
North (Minden Forestry)	485.6	267.1

[1]Calculated as 55% of the water budget surplus

6.2.5.1 AREAS WITH A HYDRAULIC CONNECTION TO A DRINKING WATER SYSTEM

In accordance with the *Technical Rules*, only areas that have a hydraulic connection to a drinking water system can be considered significant groundwater recharge areas. However, since there are so many domestic wells across the Source Protection Region (also shown in Figure 6.2-5), very few of the significant groundwater recharge areas shown in Figure 6.2-5 would have to be removed to satisfy this requirement. In the northern part of the Source Protection Region there are areas with few domestic wells, but it was assumed that the numerous lakes in this area are built up with cottages that draw water from these lakes, and that the lakes are directly connected to the shallow groundwater flow systems that exist in the area. Thus, none of the significant groundwater recharge areas shown in Figure 6.2-5 were screened out to satisfy the technical rule that excludes areas that do not have a hydraulic connection to a drinking water system.

6.2.5.2 REMOVAL OF AREAS WITH SHALLOW GROUNDWATER

Areas with shallow groundwater, typically found in low lying valleys, are unlikely to contribute any significant groundwater recharge. Any recharge occurring in these lower lying areas would move laterally in the shallow groundwater system and discharge in adjacent streams and wetlands. Thus, areas where the water table was less than 2 m below the ground surface were removed from the delineation of significant groundwater recharge areas; this procedure resulted in the delineation shown in Figure 6.2-6.

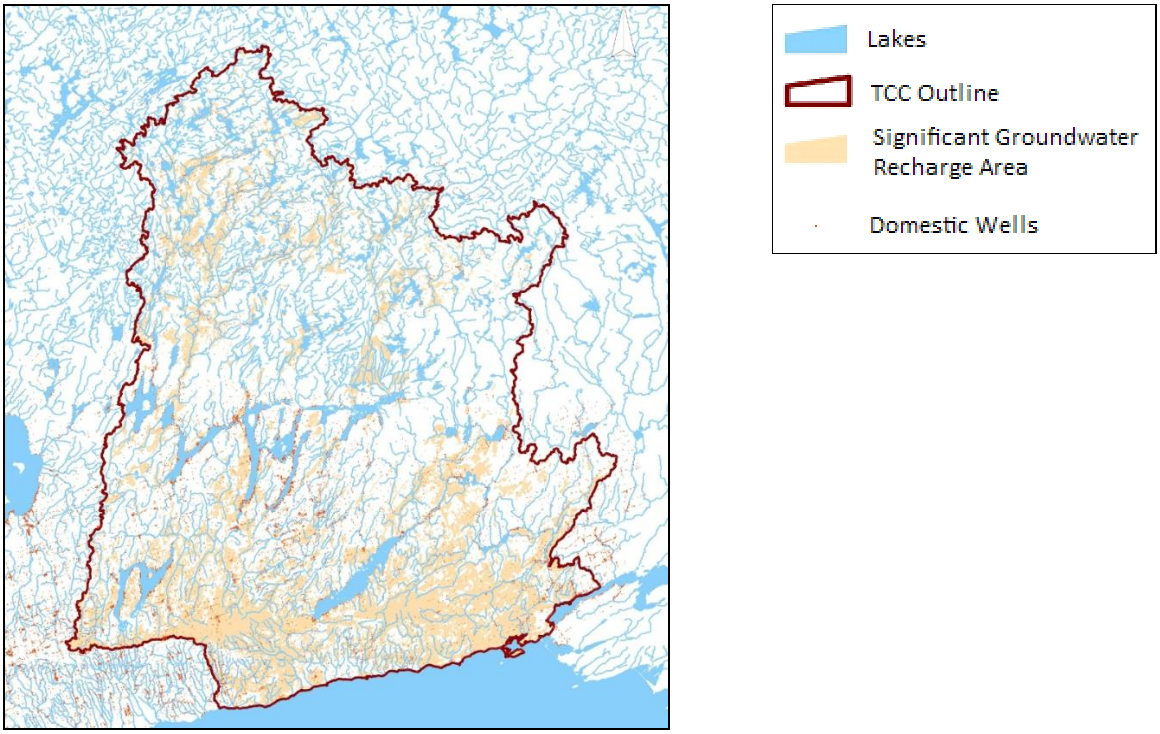

Figure 6.2-5: SGRA Delineation (annual recharge volume > 55% water budget surplus)

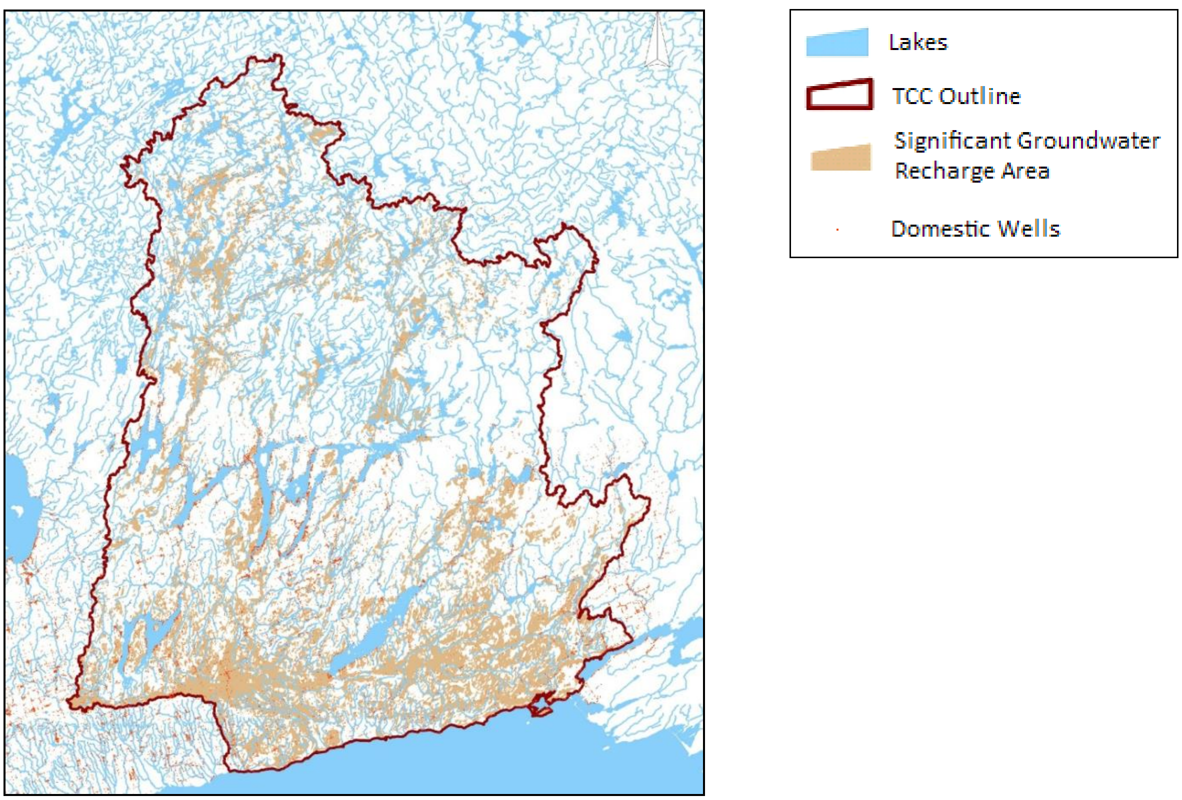

Figure 6.2-6: SGRA Delineation (annual recharge volume > 55% & shallow groundwater areas removed)

6.2.5.3 REMOVAL OF AREAS LESS THAN 0.01 KM^2

After removing areas with shallow groundwater, a number of small areas (less than 0.01 km^2) remained in the delineation shown in Figure 6.2-6. These areas were removed from the map in consideration of the resolution of the input data used in the delineation. The distribution of polygon sizes in the surficial geology mapping from the Ontario Geological Survey (generally at a scale of 1:50,000) was evaluated and it was observed that on the order of 1,000 out of some 23,000 polygons in the Source Protection Region (less than 5%) were smaller than 0.01 km^2 and that these small polygons were generally associated with bedrock outcrops or wetlands (although there was a limited number of other material types of this small size that were mapped). Further, the water table map that was used to remove areas with shallow groundwater areas was created with a grid cell size of 100 m x 100 m (i.e., 0.01 km^2). Given these map resolution issues, it was deemed appropriate to restrict the size of significant groundwater recharge areas in the final map to polygons of 0.01 km^2 or larger.

The final delineation of significant groundwater recharge areas (after removing these small polygons from the delineation shown in Figure 6.2-6) is shown on Map 6-4.

6.2.6 ASSIGNMENT OF VULNERABILITY SCORES

This section, including Map 6-5, was removed based on changes to the Technical Rules. Vulnerability scores are no longer assigned for Significant Groundwater Recharge Areas (2022). ~~The significant groundwater recharge areas were assigned vulnerability scores by overlaying the map of significant groundwater recharge areas with the map of regional groundwater vulnerability (see Section 6.1). In accordance with the *Technical Rules*, the significant groundwater recharge areas were assigned vulnerability scores of 6, 4, and, 2 where they were located in areas of high, medium, and low vulnerability, respectively. The significant groundwater recharge areas with assigned vulnerability scores are shown on Map 6-5.~~

6.2.7 UNCERTAINTY ANALYSIS

The uncertainty of the delineation ~~and vulnerability assessment~~ of significant groundwater recharge areas were evaluated, and a value of “high” or “low” uncertainty was determined for each of the following factors:

1. The distribution, variability, quality, and relevance of data used (Data)
2. The ability of the methods and models used to accurately reflect the flow processes in the system (Modeling)
3. The quality assurance and quality control procedures applied (QA/QC)
4. The extent and level of calibration and validation achieved for models used or calculations/assessments completed (Calibration and Validation).

An overall uncertainty rating was determined for the delineation ~~and vulnerability assessment~~ of significant groundwater recharge areas based on the highest uncertainty rating assigned to the factors listed above. ~~The uncertainty ratings assigned to the vulnerability assessment are similar to those assigned to the landscape-scale groundwater vulnerability assessment (see Section 6.1.3) because the vulnerability of significant groundwater recharge areas is determined by overlaying the landscape-scale vulnerability map on the delineated significant groundwater recharge areas.~~ Uncertainty ratings are given in Table 6.2-7.

Table 6.2-7: Uncertainty Ratings for Significant Groundwater Recharge Areas (SGRA)

Consideration Factor	Uncertainty Ratings	
	Delineation of SGRA	~~Vulnerability Assessment of SGRA[1]~~
Data	Low	~~High~~
Modeling	High	~~High~~
QA/QC	Low	~~Low~~
Calibration and Validation	High	~~High~~
Overall Uncertainty Rating	**High**	~~**High**~~

~~[1]Based on the uncertainty ratings assigned to the landscape-scale groundwater vulnerability assessment (see Section 6.1.3)~~

6.2.8 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Edge mapping

Methodologies for mapping significant groundwater recharge areas should be further evaluated considering differences between the Ganaraska Source Protection Area and the Central Lake Ontario Source Protection Area (see Chapter 9 for additional information).

6.2.9 REFERENCES

~~AECOM. (2009). *Groundwater Vulnerability Assessment – TCC Source Protection Region*. Guelph (ON).~~

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Thornthwaite, C.W. & Mather, J.R. (1957). Instructions and tables for computing potential evapotranspiration and the water balance. Drexel Institute of Technology, Laboratory of Climatology. *Publications in Climatology*, *10*(3), 145-311.

6.3 WATER QUALITY RISK ASSESSMENT

The vulnerability score of highly vulnerable aquifers ~~and significant groundwater recharge areas~~ cannot exceed 6.0. This means that no significant threats can occur in this~~ese~~ vulnerable area~~s~~. The requirements for the threats assessment for ~~the~~ highly vulnerable aquifers ~~and significant groundwater recharge areas as~~ set out in the *Technical Rules* are as follows:

1. Identification of the activities or conditions that are or would be drinking water threats
2. Listing of the circumstances under which each activity listed above makes or would make the activity a moderate or low drinking water threat. For conditions, information must be provided that confirms that there is a condition and the hazard rating for the condition.
3. Mapping of the areas within each vulnerable area and the relevant circumstances where an activity or condition is or would be a moderate or low drinking water threat.

The methods used to identify and map activities and circumstances are similar to the methods set out in Chapters 4 and 5 for municipal systems.

6.3.1 LISTING OF ACTIVITIES THAT ARE OR WOULD BE DRINKING WATER THREATS

The activities that are or would be drinking water threats in highly vulnerable aquifers ~~and significant groundwater recharge areas~~ include the following:

- Activities prescribed to be drinking water threats in paragraphs 19 and 20 of subsection 1.1(1) of *O. Reg. 287/07 (General)*
- ~~Activities identified as local threats by the Source Protection Committee~~
- Activities that contribute to drinking water issues.

Activities Prescribed to be Drinking Water Threats

The activities prescribed to be drinking water threats are listed in Table 6.3-1. These include 20~~19~~ water quality threats and 2 water quantity threats.

~~*Activities Identified by the Source Protection Committee*~~

~~No local threats have been added by the Source Protection Committee that apply to highly vulnerable aquifers and significant groundwater recharge areas.~~

Activities that Contribute to Drinking Water Issues

The *Technical Rules* allows for drinking water quality issues to be identified for drinking water systems across the Source Protection Area. However, there is no need to conduct an issues assessment for systems outside of the vulnerable areas because a vulnerability score is needed to calculate the risk score, and the *Technical Rules* specifies that threats can only be identified in vulnerable areas. The issues can include chemical and radiological parameters, but not pathogens.

An assessment of water quality for non-municipal systems has not been conducted. Therefore, no drinking water issues were identified in the highly vulnerable aquifers ~~and significant groundwater recharge areas~~.

Table 6.3-1: Activities Prescribed to be Drinking Water Threats

No.	Description of Activity
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage
3	The application of agricultural source material to land
4	The storage of agricultural source material
5	The management of agricultural source material
6	The application of non-agricultural source material to land
7	The handling and storage of non-agricultural source material
8	The application of commercial fertilizer to land
9	The handling and storage of commercial fertilizer
10	The application of pesticide to land
11	The handling and storage of pesticide
12	The application of road salt
13	The handling and storage of road salt
14	The storage of snow
15	The handling and storage of fuel
16	The handling and storage of a dense non-aqueous phase liquid
17	The handling and storage of an organic solvent
18	The management of runoff that contains chemicals used in the de-icing of aircraft
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body[1]
20	An activity that reduces the recharge of an aquifer[1]
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard
22	The establishment and operation of a liquid hydrocarbon pipeline

Source: Paragraphs 19 and 20 of subsection 1.1(1) of *O. Reg. 287/07 (General)*

[1]Activity is a water quantity threat (evaluated in the water budget and water quantity threats assessment)

6.3.2 LISTING OF CONDITIONS THAT ARE DRINKING WATER THREATS

Conditions that are or would be drinking water threats are documented conditions resulting from past activities. The assessment of conditions in highly vulnerable aquifers ~~and significant groundwater recharge areas~~ was limited to records in the Brownfields Registry (Records of Site Conditions) where the site was located in a highly vulnerable aquifer ~~or a significant groundwater recharge area~~ with a vulnerability score of 6. No conditions were identified as a result of this assessment.

6.3.3 CIRCUMSTANCES UNDER WHICH EACH ACTIVITY IS OR WOULD BE A MODERATE OR LOW DRINKING WATER THREAT

The circumstances under which activities prescribed to be drinking water threats are (or would be for future activities) moderate or low drinking water threats in highly vulnerable aquifers ~~and significant groundwater recharge areas~~ (with a vulnerability score of 6) are indicated on maps of these areas (see Section 6.3.4 below). The tables refer to the *Tables of Drinking Water Threats*, which list the activities and circumstances for all combinations of vulnerable area and vulnerability score to identify when an activity is or would be considered a moderate or low drinking water threat.

Circumstances for some of the activities listed in the *Tables of Drinking Water Threats* refer to values of percent managed lands, livestock density, and percent impervious surface area. These are intermediate calculations that support the assignment of threat levels for certain prescribed activities. (These calculations are discussed in Section 4.4.2.4.) Percent managed lands, livestock density, and percent impervious surface area in highly vulnerable aquifers are shown on Maps 6-6 through 6-8. ~~and significant groundwater recharge areas are shown on Maps 6-10 through 6-12.~~

6.3.4 MAPPING OF AREAS AND CIRCUMSTANCES WHERE AN ACTIVITY IS OR WOULD BE A MODERATE OR LOW DRINKING WATER THREAT

The areas that are or would be moderate or low chemical and pathogen threats in highly vulnerable aquifers are shown on Map 6-9. ~~The areas that are or would be moderate or low chemical and pathogen threats in significant groundwater recharge areas are shown on Map 6-13.~~ The index tables provided on these maps link the vulnerability score for each vulnerable area with tables that list the circumstances in which these activities would be moderate or low threats.

6.3.5 ISSUES RELATED TO SYSTEMS NOT IDENTIFIED AS PER CLAUSE 15(2)(E) OF THE *CLEAN WATER ACT, 2006*

Drinking water systems that are not identified per clause 15(2)(e) of the *Clean Water Act* include small and large municipal non-residential drinking water systems, small and large non-municipal non-residential drinking water systems, non-municipal year-round and seasonal residential drinking water systems, and private wells. These systems were subjected to a preliminary investigation for the evaluation of potential drinking water issues, but there was insufficient data to carry out an assessment of drinking water issues for these systems.

The Drinking Water Information System (DWIS) and the Sewage and Water Inspection Program (SWIP) databases were reviewed to identify the relevant systems and to determine the potential presence of any drinking water issues. This review revealed that the databases did not include all of the relevant systems and that they had limited water quality data useful for the evaluation of drinking water issues. Further, the funding or timing necessary to complete required technical studies such as source tracking and groundwater modelling to identify anthropogenic activities causing any issues or to delineate issue contributing areas was not available. Note also that per Technical Rule 134.1(2), activities that contribute to drinking water issues related to these systems are only considered as moderate threats.

The Source Protection Committee decided that, although these systems have tremendous importance to the region, the lack of sufficient data and information would make it difficult to complete the technical assessments needed to complete an assessment of drinking water issues for these systems. The Committee therefore passed a resolution (SPC 2010-10-15-07[a]) to not include an assessment of drinking water issues for "Other" drinking water systems.

[a] See Source Protection Committee minutes for October 15, 2010

CHAPTER 7: GREAT LAKES CONSIDERATIONS

The watersheds in the Ganaraska Region Source Protection Area drain to Lake Ontario. Additionally, 107 km^2 of land that flows to Rice Lake drains directly to the Trent River watershed that outlets to Lake Ontario in Trenton. This chapter addresses the requirements of the *Clean Water Act* that are applicable to source protection areas that drain into the Great Lakes.

7.1 CONSIDERATION OF GREAT LAKES AGREEMENTS

The *Clean Water Act* requires that the *Terms of Reference* − for the preparation of an Assessment Report and Source Protection Plan for source protection areas that contain water that flows into the Great Lakes or the St. Lawrence River − considers the following documents: the *Great Lakes Water Quality Agreement,* the *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem,* the *Great Lakes Charter*, and any other agreement to which the Government of Ontario or the Government of Canada is a party that relates to the Great Lakes Basin and that is prescribed by the regulations. (There are currently no other documents prescribed by the regulations.) Further, the *Technical Rules* indicates that a written description of how these agreements were considered in the work undertaken in accordance with the *Technical Rules* be included in the Assessment Report.

During the development of the work plan and preparation of the Assessment Report, organizations involved in the delivery of programs associated with these agreements were consulted through the following representatives:

- Canada-Ontario Agreement/Great Lakes Divisional Project Manager, Lake Ontario Lakewide Management Plan
- Port Hope Harbour Remedial Action Plan staff
- Port Hope Area Initiative staff
- LAMP (Lake Ontario Lakewide Management Plan) Coordinator, Environment Canada
- Remedial Action Plan Liaison, U.S. Environmental Protection Agency
- Remedial Action Plan Program Officer, Environment Canada.

Further, data made available through broader Great Lakes monitoring programs (e.g., MOECC Drinking Water Surveillance Program) were used in the development of this Assessment Report.

Although all three prescribed documents share common goals with the source protection process, the *Great Lakes Water Quality Agreement* is the only prescribed document that has specific links to the preparation of the Ganaraska Assessment Report. The following sections describe the prescribed documents and indicate how they were considered during the preparation of this Assessment Report.

7.1.1 GREAT LAKES WATER QUALITY AGREEMENT

The *Great Lakes Water Quality Agreement* is an agreement between the governments of Canada and the United States of America that expresses their commitment to restore and maintain the chemical, physical, and biological integrity of the Great Lakes Basin Ecosystem. It also reaffirms the rights and obligations of these two countries under the *Boundary Waters Treaty*. The Agreement outlines provisions for the development of cooperative programs and research and includes a number of objectives and guidelines to achieve its goals (Environment Canada, 2004a).

A provision of the Agreement that is specifically relevant to the Ganaraska Region Source Protection Area is the development and implementation of Remedial Action Plans. These are management plans that are designed to address environmental issues in areas around the Great Lakes that fail to meet the objectives set out in the Agreement (where such failure has caused or is likely to cause impairment of the beneficial use of these areas or their ability to support aquatic life). These problem areas are established by the Agreement as Areas of Concern. The Port Hope Harbour Area of Concern is located in the Ganaraska Region Source Protection Area and is described below.

The *Bay of Quinte Remedial Action Plan* endeavors to address specific impaired beneficial uses of the Bay of Quinte. The entire Trent River watershed is located in the Bay of Quinte Area of Concern, which includes the 107 km^2 of land that drains to Rice Lake in the Ganaraska Region Source Protection Area. For detail on the Rice Lake drainage area, please refer to Chapter 2. For information on the *Bay of Quinte Remedial Action Plan*, please refer to the Trent Assessment Report.

Port Hope Harbour Remedial Action Plan

The Port Hope Harbour is located on the west side of the mouth of the Ganaraska River, on the shore of Lake Ontario. In 1987, under the Canada-United States *Great Lakes Water Quality Agreement*, Port Hope Harbour was listed as an Area of Concern in terms of supporting aquatic life (Environment Canada, 1989). The sediments within the harbour, approximately 85,000 cubic meters, are contaminated by uranium and thorium series radionuclides, heavy metal, and PCBs caused by waste management practices associated with radium and uranium refining operations in the former Town of Port Hope (Ward 1, Municipality of Port Hope) (Environment Canada, 1989).

In addition to contamination in the harbour, which led to its listing as an Area of Concern, historic low-level radioactive waste contamination, associated with historic waste management practices, is present at major on-land areas (ravines, large open land areas, and the municipal landfill site) and small-scale sites (individual properties and public roadways) in and around the former Town of Port Hope. Major waste containment facilities also exist and are associated with historic low-level radioactive waste deposition. These facilities, licensed by the Canadian Nuclear Safety Commission, are located at the Welcome Waste Management Facility in Ward 2 of the Municipality of Port Hope and at the Port Granby Waste Management Facility in Ward 4 of the Municipality of Clarington.

Natural Resources Canada is leading the cleanup of these historic radioactive wastes found in the Municipality of Port Hope and the Municipality of Clarington, including those in the Port Hope Harbour, through a separately funded initiative, and is now working together with Environment Canada to ensure the stages of the Remedial

Action Plan are followed within the larger cleanup project framework. Please note that the cleanup associated with low-level radioactive waste is not associated with the *Great Lakes Water Quality Agreement*.

The Port Hope Harbour Remedial Action Plan was considered in the development of this Assessment Report. The document was considered in the following ways:

- During the preparation of technical studies and background reports that are components of this Assessment Report, data and reports associated with plans for the remediation of the Port Hope Harbour Area of Concern were reviewed, including the following:
    a. Aquatic Environment Baseline Characterization Study for the Port Hope Project (EcoMetrix Incorporated, 2005)
    b. Port Hope Harbour Remedial Action Plan: Stage 1 environmental conditions and problem definition, Draft (Environment Canada, 1989).

7.1.2 CANADA-ONTARIO AGREEMENT RESPECTING THE GREAT LAKES BASIN ECOSYSTEM

The *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem* is an agreement between the Government of Canada and the Province of Ontario that supports the restoration and protection of the Great Lakes basin ecosystem. It outlines how the two governments will cooperate and coordinate their efforts to restore, protect, and conserve the Great Lakes basin ecosystem, and it contributes to meeting Canada's obligations under the *Great Lakes Water Quality Agreement* (Environment Canada, 2004b). Although this agreement is geared toward the protection of water quality, it does not contain any specific technical information that was applicable to the preparation of this Assessment Report.

7.1.3 GREAT LAKES CHARTER

The *Great Lakes Charter* is a series of agreements between the Provinces of Ontario, Quebec, and the eight Great Lakes States that set out broad principles for the joint management of the Great Lakes (Environment Canada, 2005). The original Charter was developed in 1985 in response to the growing use of water and proposals to divert large quantities of water out of the Great Lakes Basin (Ministry of Natural Resources and Forestry, 2005). The purposes of the Charter are "*to conserve the levels and flows of the Great Lakes and their tributary and connecting waters; to protect and conserve the environmental balance of the Great Lakes Basin ecosystem; to provide for cooperative programs and management of the water resources of the Great Lakes Basin by the signatory States and Provinces; to make secure and protect present developments within the region; and to provide a secure foundation for future investment and development within the region*" (Council of Great Lakes Governors, 1985).

The *Great Lakes Charter* was supplemented in 2001 by the *Great Lakes Charter Annex*, which reaffirmed the principles of the Charter and committed the Governors and Premiers of the Great Lakes States and Provinces to "*developing an enhanced water management system that…protects, conserves, restores, and improves the Waters and Water-Dependent Natural Resources of the Great Lakes Basin*" (Council of Great Lakes Governors, 2001). The *Great Lakes Charter Annex* implementing agreements, including the *Great Lakes-St. Lawrence River*

Basin Sustainable Water Resources Agreement, attempt to provide this water management system (Environment Canada, 2005).

Although this charter is geared toward the protection of water quality and quantity, it does not contain any specific technical information that was applicable to the preparation of this Assessment Report.

7.1.4 GREAT LAKES TARGETS

The *Clean Water Act* allows for the Minister of the Environment and Climate Change to establish targets relating to the use of the Great Lakes as a source of drinking water for any of the source protection areas that contribute water to the Great Lakes. If targets are set, policies and steps would need to be established to achieve these targets. No targets have been set at this time.

7.1.5 LAKE ONTARIO WORKING GROUP

The source protection regions and areas draining into Lake Ontario (Niagara, Halton-Hamilton, CTC, Trent Conservation Coalition, Quinte, and Cataraqui) have formed a Lake Ontario Lake-by-Lake Working Group (comprised of Source Protection Committee Chairs and Project Managers) to discuss and address common issues, share knowledge, and engage in broader discussions on Great Lakes issues from a drinking water perspective.

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CHAPTER 8: POTENTIAL CLIMATE CHANGE IMPLICATIONS

Climate change is a long-term shift in climate measured by changes in temperature, precipitation, winds, and other indicators. It includes changes to average climatic conditions and to their variability. Since many aspects of this Assessment Report are related to climatic factors, climate change has the potential to impact some of the conclusions of the report. This section is a summary of the available climate change knowledge relevant to the Source Protection Region and a discussion of the potential impacts of climate change on the conclusions of this Assessment Report expected in the next 25 years.

8.1 CLIMATE TRENDS AND PROJECTIONS

There is a robust scientific consensus that the Earth's climate has changed and will continue to change as human activities increase the concentrations of greenhouse gases in the atmosphere. Climate change research at both North American and regional (Ontario and the Great Lakes) scales is summarized in the following sections.

8.1.1 NORTH AMERICA

It is very likely that climate change will cause North America to experience significant warming and changes to temporal and spatial patterns of precipitation over the next several decades. The following discussion is a summary of Warren & Egginton (2008), which provided an overview of various climate trends and projections for Canada, supplemented with additional references where indicated.

8.1.1.1 TEMPERATURE

On average, Canada has warmed by more than 1.3 ^{o}C from 1948 to 2006. The greatest temperature increases during this time period were observed in the Yukon and the Northwest Territories. On a seasonal basis, temperature increases have been greater during the winter and spring (Warren & Egginton, 2008; CCME, 2003). Of all the seasons, fall has warmed the least (CCME, 2003).

All of Canada is projected to warm during the next 80 years. The greatest increases are expected in the Arctic. Increases are also expected to be greater in the central portions of the country than along the east and west coasts. On a seasonal basis, warming is expected to be greatest during winter, and lower in summer and fall, and winter nights are expected to warm more than winter days.

8.1.1.2 PRECIPITATION

On average, Canada has become wetter during the past half century, with mean precipitation across the country increasing by about 12%. Annually averaged, the largest percentage increase in precipitation has occurred in the Arctic, and southern Canada has seen little change.

Future precipitation is difficult to project, and changes are of lower statistical significance than for changes in temperature. Annual total precipitation is projected to increase 0 to 10% in the far south and 40 to 50% in the Arctic by 2080. Due to enhanced evapotranspiration (driven by higher temperatures), many regions will experience a moisture deficit despite greater amounts of precipitation. Throughout most of southern Canada, precipitation increases are projected to be low during the summer and fall (0 to 10% by 2050). The extreme daily precipitation is also expected to increase.

The proportion of yearly precipitation falling as snow has also been changing (Warren & Egginton, 2008; CCME, 2003). The southern half of Canada generally has received a higher proportion of rain, and the North has received a higher proportion of snow (CCME, 2003).

The trend towards more precipitation is expected in a warming climate because higher temperatures cause more water to evaporate from the Earth's surface; since a warmer atmosphere can hold more water vapour, this makes more moisture available in the air to fall as precipitation (CCME, 2003).

8.1.1.3 EXTREME WEATHER EVENTS

There is scientific evidence that increased temperatures will be accompanied by changes in the intensity, duration, frequency, and geographic extent of weather and climate extremes (Warren & Egginton, 2008; CCSP, 2008a). The frequency of extreme warm summer temperatures (> 30 °C) is expected to increase across Canada and the frequency of extreme cold days are projected to decline significantly. Climate models indicate that many currently rare extreme events will become more commonplace. Some extreme events, such as heat waves, extreme precipitation events, and heavy downpours, are expected to occur more frequently, and others, such as cold snaps and frosts, are expected to occur less frequently (CCSP, 2008a).

For a mid-range scenario of future greenhouse gas emissions, a day that is so hot that it is currently experienced only once in every 20 years would occur every three years by the middle of the century over most of the continental US and every five years over most of Canada. By the end of the century, it would occur every other year or more (CCSP, 2008a).

8.1.2 ONTARIO AND THE GREAT LAKES REGION

8.1.2.1 TEMPERATURE

Average annual temperatures in Ontario have been increasing and are projected to continue to increase due to climate change. From 1948 to 2006, annual average temperatures across Ontario have increased between 0 and 1.4 °C (with larger increases observed in the spring). From 1950 to 2003, the north of the province has shown both the largest increase in the number of warm days and a significant decrease in the number of cold days (Chiotti & Lavender, 2008).

The Conservation Authorities Moraine Coalition used long-term (1971 to 2000) climate data (air temperature and precipitation) from selected Environment Canada climate stations to analyze climate trends in the Oak Ridges Moraine and surrounding area. Four of the ten stations included in the analysis are located in the Source Protection Region: Trenton Airport, Peterborough Airport, Cobourg Sewage Treatment Plant, and Lindsay Frost. The analysis indicated that yearly deviation of average annual temperature from the long-term annual mean did not show a significant trend, except for the Cobourg Sewage Treatment Plant station, which shows a significant warming trend. It also indicated that monthly deviation of average monthly temperature from the long-term monthly mean showed a significant warming trend (CAMC, 2008).

The trend of increasing average annual temperature is projected to continue, and the largest increases are expected in winter (Chiotti & Lavender, 2008). Annual average surface air temperature is anticipated to increase between 1.5 to 2.0 °C in the Great Lakes Region of Canada between 1990 and 2030 (CCSP, 2008b). Seasonal projections for Ontario indicate that the greatest warming will occur in the north during winter, and the number of days exceeding 30 ^{o}C in the south is projected to more than double by 2050 (Chiotti & Lavender, 2008). It is expected that changes in extreme warm temperatures will be greater than the changes in annual mean.

8.1.2.2 PRECIPITATION

There is greater variation in projections of precipitation than those of temperature. Climate simulations have shown that annual precipitation in Ontario is expected to increase within the next 20 to 50 years under most future emission scenarios (Chiotti & Lavender, 2008). The greatest precipitation increases are projected for northern Ontario (Chiotti & Lavender, 2008). However, some projections indicate a decrease in annual precipitation for most of the province in the next 50 years (Colombo et al., 2007). Further, analysis of Environment Canada precipitation data in the Oak Ridges Moraine area showed that the yearly deviation of average annual precipitation from the long-term annual mean and the monthly deviation of average monthly precipitation from the long-term monthly mean do not show any significant trend (CAMC, 2008).

Although annual precipitation totals are likely to increase, summer and fall decreases of up to 10% are projected for southern Ontario by 2050. Warmer temperatures and longer growing seasons will result in increasing evapotranspiration, which will decrease the net moisture availability. Winter projections show increases in precipitation, increasing from south to north and ranging from 10% to over 40% (Chiotti & Lavender, 2008).

Changes in the extreme daily precipitation amounts in Ontario are expected to be greater than the changes projected in the annual mean amounts. This means that these types of events will become more frequent and intense. It is likely that lake-effect snow will increase in the short to medium term as lake temperatures rise and winter air temperatures are still cool enough to produce snow. By the end of the 21st century however, snowfall may decrease and possibly be replaced by heavy lake-effect rainfall events (Chiotti & Lavender, 2008).

8.1.3 POTENTIAL IMPACTS ON WATER RESOURCES

Climate change has the potential to affect water resources at a national scale. Increasing temperatures increase the amount of evapotranspiration that occurs, which decreases soil moisture. Climate models indicate that North America may experience changes in annual runoff; this will increase in the eastern regions, change little in the midwest and south, and decrease substantially in the interior to the west. There is also a trend towards reduced snowpack and earlier snowmelt runoff peaks (spring freshet) (CCSP, 2008b). Several changes to water resources in the Great Lakes basin are illustrated in Table 8.1-1 (Chiotti & Lavender, 2008).

Table 8.1-1: Expected Changes to Water Resources in the Great Lakes Basin due to Climate Change

Hydrological Parameter	Expected Changes in the 21st Century
Runoff	Decreased annual runoff, but increased winter runoff Earlier and lower spring freshet Lower summer and fall low flows Longer duration low flow periods Increased frequency of high flows due to extreme precipitation events
Lake levels	Lower net basin supplies and declining levels due to increased evaporation Increased frequency of low water levels
Groundwater recharge	Decreased groundwater recharge, with shallow aquifers being especially sensitive
Groundwater discharge	Changes in amount and timing of baseflows to streams, lakes and wetlands
Snow Cover	Reduced snow cover (depth, areas, and duration) with resulting increase in evaporation
Water temperature	Increased water temperatures in surface water bodies
Soil moisture	May increase by as much as 80% during winter, but decrease by as much as 30% in the summer and fall.

Source: Chiotti & Lavender, 2008

8.1.4 WATER BUDGET ANALYSIS OF CLIMATE CHANGE EFFECTS IN THE GANARASKA REGION SOURCE PROTECTION AREA

A hydrologic numerical model, CANWET Version 3, was selected to quantify the water budget elements of 8 watersheds in the Ganaraska Region Source Protection Area and assess future climate change stresses for surface and groundwater (Ganaraska Region Conservation Authority, 2008). First, the CANWET model was set up and calibrated for three gauged watersheds and then the calibrated parameters were applied to the five ungauged watersheds. The models were then rerun for the future climate change scenario that considered the impacts on land use from urbanization, water requirements over the next 25 years, and the predicted weather from Canadian Global Climate Models (CGCM).

The water budget components were derived from long-term (2021 to 2040) simulation runs of calibrated CANWET models. The results were summarized and compared with other scenarios shown in Table 8.1-2. Stress analysis was conducted for surface and groundwater supplies for the climate change scenario. The water supply, water reserve, and water demand, together with percent water demand and stress level, are summarized in Tables 8.1-3 and 8.1-4. In general, the CGCM predicts a considerable increase in annual precipitation (about 40%) and as a result, the CANWET model simulates significant increases in stream flow.

The results show that the CGCM model simulations seem to overestimate precipitation for future years and that further investigation is needed. The simplistic modeling approach as used in the Tier 1 (Ganaraska Region Conservation Authority, 2008) study has been found to be limiting for handling groundwater flows under changed climatic conditions. This is because of some inherent limitations in the SCS-CN (Soil Conservation Service Curve Number) approach and the “single tank subsurface structure” of the CANWET model. Uncertainty in the stress assessment has been characterized as high. It is recommended that a more complex hydrologic model and groundwater model be developed to provide greater accuracy in the findings.

8.1.5 POTENTIAL IMPACTS ON ASSESSMENT REPORT FINDINGS

The projected changes in climate have the potential to impact some of the conclusions of this Assessment Report. In general, the anticipated changes in climate make historical climate and stream flow records unreliable for making projections about future conditions. Contents of this Assessment Report that include projections or analysis of these historical data have the potential to be affected by climate change. Further, secondary impacts are expected as a result of the changes in climate (e.g., a decrease in surplus water due to an increase in evapotranspiration). The potential impacts of climate change on the findings of this Assessment Report in the next 25 years are summarized in Table 8.1-5.

Table 8.1-2: Comparison of Water Budget Scenarios (mm/year)

Watershed	Precipitation		Evapotranspiration			Sub-surface Flow			Surface Runoff			Streamflow		
	E	Fcc	E	F	Fcc	E	F	Fcc	E	F	Fcc	E	F	Fcc
Wilmot Creek	894.3	1276.3	529.3	529.2	586.8	289.7	297.6	571.4	66.2	74.7	122.6	351.9	352.2	682.1
Ganaraska River	864.6	1276.3	498.4	498.4	601.7	353	352.1	616.7	50.5	51.3	100.7	402.8	402.6	716.9
Graham Creek	894.3	1276.3	529.4	529.4	586.8	311	310.8	603.6	52.7	52.9	90.3	363.8	363.8	693.7
Cobourg Creek	864.6	1276.3	479.1	479.5	564.4	423	414.9	680.8	76.9	84.7	150.4	497.4	497	829.1
Gage Creek	864.6	1276.3	479.8	479.6	564.6	420.9	414.3	675.5	78.4	85.1	155.9	486.1	485.9	818.1
West Lake Ontario	486.6	1276.3	498.4	497.1	601.4	339	312.7	553.2	64.7	92.7	165.1	397.8	399.4	712.3
East of Gage Creek	864.6	1276.3	479.7	459.4	536.5	290.2	293.1	546	90.1	107.5	193.8	380.3	400.6	740.2
East Lake Ontario	864.6	1276.3	479.6	479.3	564.4	425.9	408.9	671.4	73.4	90.9	160.2	497.8	498.4	830.3

E = Existing land use, F = Future land use, Fcc = Future land use under climate change

Table 8.1-3: Summary of Surface Water Stress Assessment for the Climate Change Scenario (mm/year)

Watershed	Annual Supply	Annual Reserve	Water Demand	Maximum Monthly Percent Water Demand	Stress Level
Wilmot Creek	645.1	375.6	2.3	3.2	Low
Ganaraska River	675.8	453.5	2.3	2.5	Low
Graham Creek	651.6	383.2	2.1	3.2	Low
Cobourg Creek	761.2	476.5	1.7	2.1	Low
Gage Creek	759.7	472.2	13.3	20.6	Moderate
West Lake Ontario	672.5	432.6	1.7	4.0	Low
East of Gage Creek	661.3	362.9	1.1	1.7	Low
East Lake Ontario	758.2	474.5	1.3	3.1	Low

Table 8.1-4: Summary of Groundwater Stress Assessment for the Climate Change Scenario (mm/year)

Watershed	Annual Supply	Annual Reserve	Water Demand	Percent Water Demand	Stress Level
Wilmot Creek	571.4	57.1	4.5	0.9	Low
Ganaraska River	616.7	61.7	3.2	0.6	Low
Graham Creek	603.6	60.4	0.7	0.1	Low
Cobourg Creek	680.8	68.1	2.3	0.4	Low
Gage Creek	675.5	67.6	2.1	0.3	Low
West Lake Ontario	553.2	55.3	1.6	0.3	Low
East of Gage Creek	546	54.6	0.5	0.1	Low
East Lake Ontario	671.4	67.1	1.1	0.2	Low

Table 8.1-5: Potential Impacts of Climate Change on Contents of the Ganaraska Assessment Report

Assessment Report Content	Effects of Climate Change		Potential Impact(s) on Assessment Report Content(s)
	Primary Impacts	Secondary Impacts	
Significant Groundwater Recharge Areas (SGRA)	• Increase in average annual precipitation • Increases in average annual evapotranspiration • Increase in evapotranspiration is greater than increase in precipitation	• Decrease in surplus (i.e., precipitation minus evapotranspiration) • Decrease in 55% of surplus • Decrease in Recharge Threshold used to identify SGRA	• Increase in SGRA
IPZ-2 and WHPA-E	• Increase in intensity of an event (flow) with a specified return period (i.e., 2-yr)	• Increase in stream flow velocity • Increase in travel distance corresponding to a specified time of travel (i.e., 2 hrs)	• Increase in IPZ-2 and WHPA-E and number of significant threats
WHPA-B, WHPA-C, and WHPA-D	• Increase in municipal water demand	• Increase in municipal water extraction rate • Increase in travel distance corresponding to a specified time of travel (i.e., 2 yrs, 5 yrs, and 25 yrs)	• Increase in WHPA-B to WHPA-D and number of significant threats
Subwatershed-based Water Quantity Stress	• Decrease in median stream flow • Increase in municipal water demand • Decrease in groundwater recharge	• Decrease in surface water supply • Increase in municipal water extraction rate • Decrease in groundwater supply	• Increase in Surface Water Quantity Stress • Increase in Groundwater Quantity Stress • Increase in the number of stressed subwatersheds
Components of hydrological cycle	• Increase in average annual precipitation • Increases in average annual evaporation and evapotranspiration • Decrease in median stream flow • Decrease in median runoff • Decrease in groundwater recharge • Decrease in groundwater discharge	• Decrease in surface water supply • Decrease in groundwater supply	
Wellhead Capture Area (total/at steady state)	• Decrease in groundwater recharge • Increase in municipal water demand	• Increase in municipal water extraction rate	• Increase in total capture area (based on mass balance)

Note: IPZ-3, WHPA-F, and IPZ-Q are dependent only upon subsurface and/or surface topography; IPZ-1 and WHPA-A are based on prescribed specifications; +Groundwater Vulnerabilities and HVA are based on subsurface topographic and geologic characteristics; Surface Water Vulnerabilities are based on intake characteristics and corresponding terrain characteristics such as topography, drainage, soil characteristics, geology, and land use.

8.1.6 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Continual improvements in climate change modeling should be carried out to capture potential variability between models and their results. In addition, consideration should be given to the effects of climate change on the quantity and quality of drinking water sources at a local level and within the Great Lakes Basin.

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CHAPTER 9: CROSS-BOUNDARY CONSIDERATIONS

The findings of this Assessment Report may affect source protection planning in neighbouring source protection areas and regions. Similarly, the Assessment Reports for neighbouring source protection areas and regions may affect source protection planning in the Trent Conservation Coalition Source Protection Region. The Source Protection Committee will need to work with the committees of neighbouring source protection regions to ensure a coordinated approach to communications, information management, and policy development for shared areas of concern. This will be of particular importance to municipalities that are located in two or more source protection regions. These cross-boundary considerations are discussed below. The neighbouring source protection areas and regions are shown on Figure 9-1.

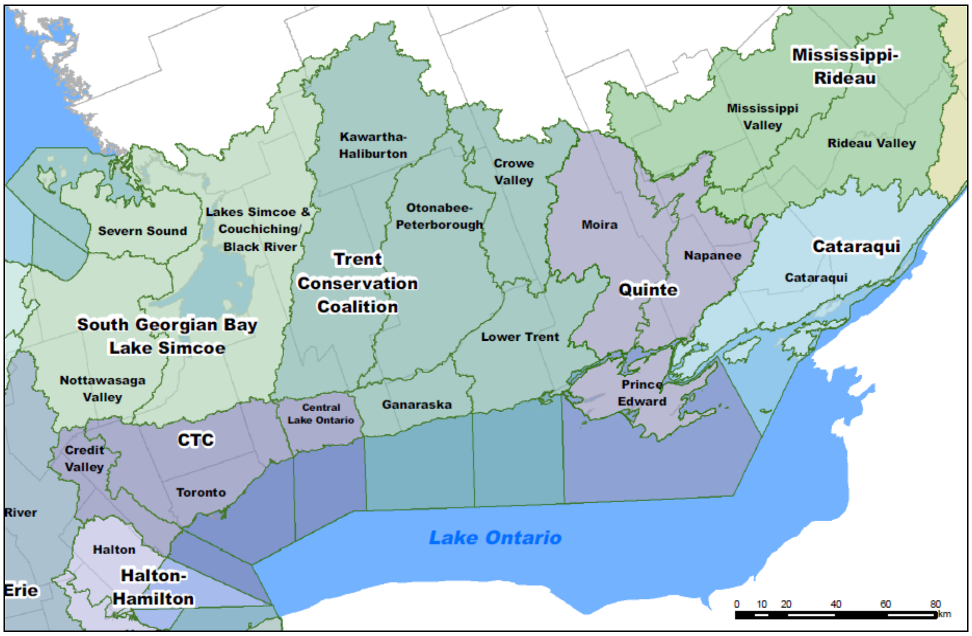

Figure 9-1: Neighbouring Source Protection Areas and Regions

9.1 TRENT CONSERVATION COALITION SOURCE PROTECTION AREAS

The Ganaraska Region Source Protection Area is a part of the Trent Conservation Coalition Source Protection Region. Matters that affect the other Trent Conservation Coalition Source Protection Areas and the ways that they have been addressed are listed below:

- Intake Protection Zone 3 for the Hastings Municipal Water System (located in the Otonabee-Peterborough Source Protection Area) extends into the Ganaraska Region Source Protection Area as shown in Figure 9-2. There are no circumstances in the IPZ-3 within the Ganaraska Region Source Protection Area that would make activities significant, moderate, or low drinking water threats.
- Significant groundwater recharge areas and highly vulnerable areas were delineated for the entire Trent Conservation Coalition. Some of these areas cross the boundary between the Ganaraska Region Source

- Protection Area and other Trent Conservation Coalition Source Protection Areas. The use of the same methods ensures constancy of results.
- The Trent River watershed extends into the Ganaraska Region Source Protection Area. The water budget for the entire Trent River (including the portion that extends into the Ganaraska Region Source Protection Area) is included in the Trent Assessment Report. The Ganaraska Assessment Report cross-references the Conceptual and Tier 1 water budget chapters and maps in this report. During the preparation of the water budgets, groundwater losses and gains across the surface water divides were considered.

9.2 OTHER SOURCE PROTECTION REGIONS

The Ganaraska Region Source Protection Area is bordered to the east and north by the Trent Conservation Coalition Source Protection Areas and bordered to the west by the CTC Source Protection Region (Credit Valley Toronto and Region, and Central Lake Ontario Source Protection Areas). The matters that affect the CTC Source Protection Region are listed in Table 9-1.

Where vulnerable areas cross source protection region boundaries, information was shared among the affected source protection regions to build upon knowledge and coordinate approaches. In these cases, consultation among the Source Protection Committees of the related source protection regions will be required to ensure that a common approach is taken at the source protection planning stage. Where drinking water threats are present in one of these overlapping areas, policies will need to be acceptable to both Source Protection Committees.

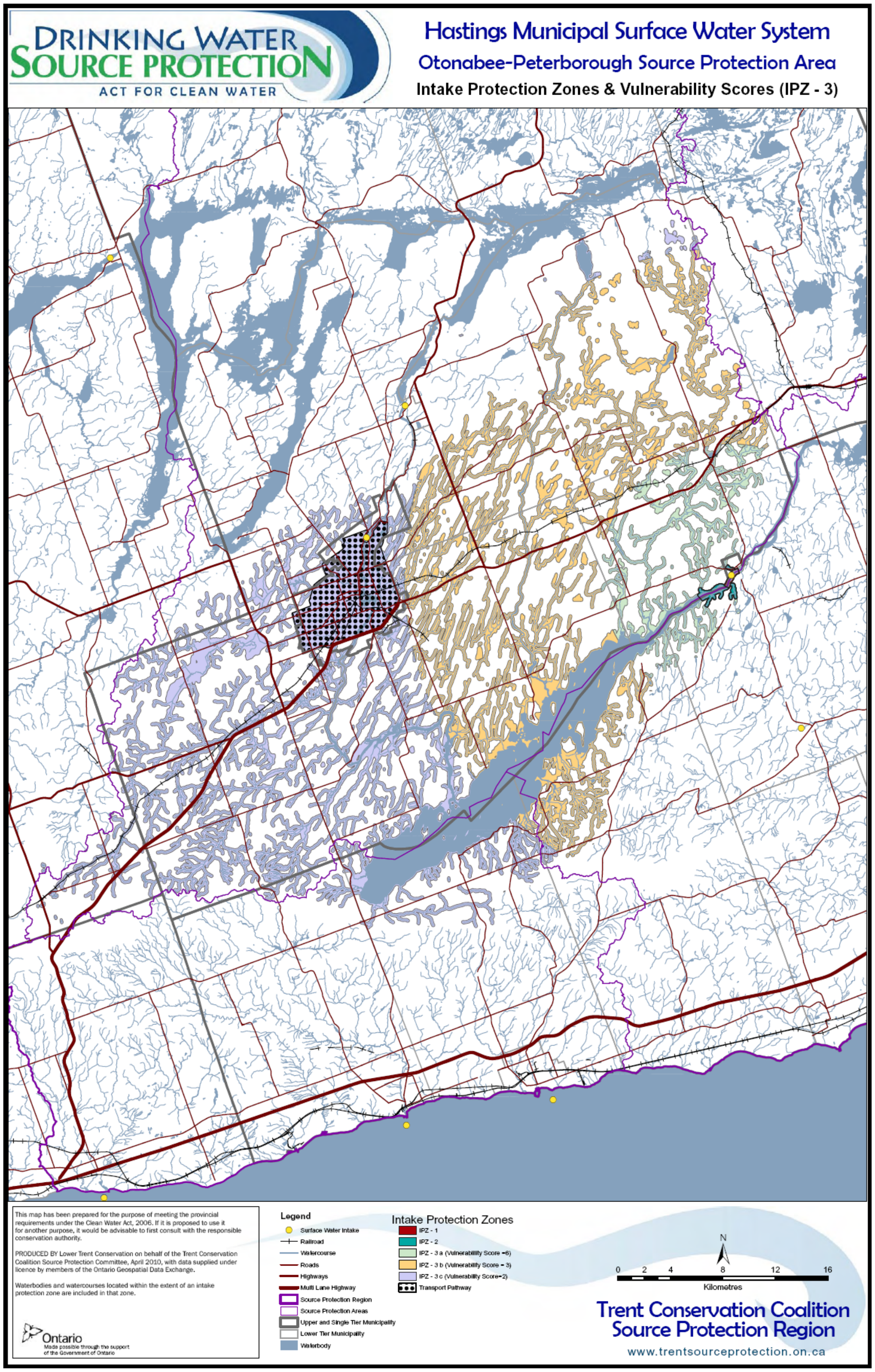

Figure 9-2: Hastings Municipal Water System Intake Protection Zone 3 Extent

Table 9-1: Cross-Boundary Considerations

Shared Concern	Description of the Matter	Steps Taken to Date / Notes
CTC Source Protection Region		
SGRA Edge Mapping	Significant Groundwater Recharge Areas are being identified as part of the Assessment Reports in each source protection region of Ontario. Methodologies for mapping Significant Recharge Areas has been, reviewed to ensure compatible, comparable products for all neighbouring Source Protection Regions (most specifically with the Central Lake Ontario Source Protection Area). Vulnerability assessments and issues-based evaluations within SGRAs will also need to align. In addition, further decisions regarding edge mapping should occur between the Central Lake Ontario Source Protection Area and the Ganaraska Region Source Protection Area (see Section 9.3).	• Trent Conservation Coalition Significant Groundwater Recharge Area report and mapping provided to CTC Source Protection Region. • Methodologies for mapping Significant Groundwater Recharge Areas should be further evaluated considering differences between the Ganaraska Source Protection Area and the Central Lake Ontario Source Protection Area.
HVA Edge Mapping	Highly Vulnerable Aquifers are being identified as part of the Assessment Reports in each source protection region of Ontario. Methodologies for mapping Highly Vulnerable Aquifers has been reviewed to ensure that the products are similar for all neighbouring Source Protection Regions (most specifically with the Central Lake Ontario Source Protection Area). Vulnerability assessments and issues-based evaluations within the HVAs will also need to align. In addition, further decisions regarding edge mapping should occur between the Central Lake Ontario Source Protection Area and the Ganaraska Region Source Protection Area (see Section 9.3).	• The Trent Conservation Coalition Groundwater Vulnerability and Highly Vulnerable Aquifers report and mapping were provided to the CTC Source Protection Region. • Methodologies for mapping Highly Vulnerable Aquifers should be further evaluated considering differences between the Ganaraska Source Protection Area and the Central Lake Ontario Source Protection Area.
Water Budgets	There may be a need to discuss technical findings related to water budgets/groundwater flow with neighbouring source protection committees. Groundwater may cross surface watersheds, impacting the quantity of water available in a neighbouring region.	• Conceptual and Tier 1 water budgets were provided to the CTC Source Protection Region.
Common Policy Development	The Trent Conservation Coalition Source Protection Committee will work with neighbouring committees to develop common approaches/policies to address similar threats and to assist municipalities that lie within two or more Source Protection Regions.	• To occur during planning phase

Shared Concern	Description of the Matter	Steps Taken to Date / Notes
Source Protection Regions located in Municipality of Durham (South Georgian Bay - Lake Simcoe and CTC)		
Peer Review of Groundwater Vulnerability Studies	Peer Review of Groundwater Vulnerability Studies for municipal systems should be coordinated between the three Source Protection Regions in Durham Region to ensure a consistent review and consistent products for the Municipality.	• Discussion took place between staff of the three Source Protection Regions and with the Regional Municipality of Durham re: methodology for peer review. A letter was received from Durham (see Appendix A) indicating that the municipality was satisfied with the approach.
Source Protection Regions that Drain to Lake Ontario (Niagara Region, Halton-Hamilton, CTC, Quinte, Cataraqui Source Protection Regions)		
Lake Ontario	The Trent Conservation Coalition Source Protection Region watersheds flow into Lake Ontario where there are several surface water intakes (from Niagara to Kingston). Three Lake Ontario intakes are located in the Ganaraska Region Source Protection Area. The source protection regions will need to continue to work together on the Lake Ontario Collaborative project and with Source Protection Regions/Areas not in the Collaborative to ensure a consistent approach to assessing the risks and developing policies to protect Lake Ontario. The regions will also need to consider any Provincial, Federal, International agreements/policies for the Great Lakes and any Remedial Action Plans, and consult with the responsible agencies/ministries. The committees should collectively develop policies to address Great Lakes agreements and targets.	• Ongoing involvement with Lake Ontario Collaborative and communications with Cataraqui Source Protection Area through development of the Assessment Report. • Intake Protection Zone 2 and 3 from the Ganaraska Region Source Protection Area and the Central Lake Ontario Source Protection Area intersect within the CTC Source Protection Region. • Future Intake Protection Zone 3 identified within the CTC Source Protection Region may affect the Ganaraska Region Source Protection Area. Updates to future Assessment Reports will occur in relation to IPZ -3 studies.

9.3 EDGE MATCHING

Highly vulnerable aquifers (HVA) and significant groundwater recharge areas (SGRA) have been identified as two of the four vulnerable areas under the *Clean Water Act, 2006*. Therefore, each source protection area is required to delineate these vulnerable areas for inclusion in their Assessment Reports. A number of methodologies and approaches are acceptable for the identification of these vulnerable areas; each source protection area has the flexibility to choose one methodology over another, depending on the availability of data and other information such as modeling results. Thus, constrained to a large extent by the availability of data and information coverage for their region, each of the four source protection regions that share a border with the Trent Conservation Coalition Source Protection Region adopted different methodologies to delineate highly vulnerable aquifers and significant groundwater recharge areas.

The Trent Conservation Coalition Source Protection Region (TCC) is bordered to the east by the Quinte Source Protection Region (Moira Source Protection Area). On its western boundary, the TCC lies adjacent to the South Georgian Bay-Lake Simcoe Source Protection Region (Lake Simcoe and Couchiching/Black River Source Protection Areas) and the Credit Valley-Toronto and Region-Central Lake Ontario Source Protection Region (Central Lake Ontario Source Protection Area). This configuration amounts to five contact boundaries, which are identified in Table 9-. A summary of the edge-matching review for the contact boundaries between the Ganaraska Region Source Protection Area and the Central Lake Ontario Source Protection Area is given below. The edge-matching review for the contact boundary between the Kawartha-Haliburton, Lower Trent, and Crowe Valley Source Protection Areas with neighboring Source Protection Areas outside of the Trent Conservation Coalition Source Protection Region is discussed in the Trent Assessment Report.

Table 9-2: Shared Boundaries with other Source Protection Regions and Source Protection Areas

TCC Source Protection Areas with Shared Boundary	Source Protection Areas with Shared Boundary with TCC Source Protection Area(s)	
	Source Protection Area	Source Protection Region
Kawartha-Haliburton	Lake Simcoe and Couchiching/Black River	South Georgian Bay Lake Simcoe
Kawartha-Haliburton	Central Lake Ontario	Credit Valley, Toronto & Region, Central Lake Ont.
Ganaraska Region	Central Lake Ontario	Credit Valley, Toronto & Region, Central Lake Ont.
Lower Trent	Moira Source Protection Area	Quinte
Crowe Valley	Moira Source Protection Area	Quinte

Genivar (2011) conducted a comparison of groundwater vulnerability mapping. The following represents findings from the study. Groundwater vulnerability is expected to be variable and reflective of the underlying geology. There are some inconsistencies in the groundwater vulnerability mapping along the contacts between the Central Lake Ontario Source Protection Area and the Ganaraska Region Source Protection Area. There also appears to be differences in the relative proportions of vulnerability determined in similar geological settings. The most significant difference is the area mapped as high vulnerability in the Central Lake Ontario Source Protection Area to the south of the Oak Ridges Moraine Area. In this area, many small areas are mapped as high vulnerability that may represent local occurrences where the groundwater vulnerability was determine to a shallow sand and gravel stratum that may not contain sufficient water to serve as an aquifer.

Revisions to the groundwater vulnerability in the CTC Source Protection Region and the Trent Conservation Coalition Source Protection Region would be required to prepare a consistent map of regional groundwater vulnerability in the Regional Municipality of Durham. The revisions should consider application of a filter to ensure that water is present in the uppermost layer to which the vulnerability rating is determined and to undertake the groundwater vulnerability analysis for the portion of Regional Municipality of Durham in the Trent Conservation Coalition Source Protection Region using the regional AVI methodology. This mapping will affect the delineation of highly vulnerable aquifers and the distribution of vulnerability scores within significant groundwater recharge areas.

In regards to significant groundwater recharge area delineations, two different methods were used by the three Source Protection Regions with in the Regional Municipality of Durham. Genivar (2011) concluded that the significant groundwater recharge areas within the Trent Conservation Coalition Source Protection Region portion of the Regional Municipality of Durham could theoretically be recalculated using the methodology applied in the South Georgian Bay Lake Simcoe and CTC Source Protection Regions to produce a more consistent product in the Regional Municipality of Durham.

9.4 REFERENCES

Technical Memorandum E – Durham Region Significant Groundwater Recharge Area Edge Matching Review dated (GENIVAR, Jan 14, 2011)

Technical Memorandum A – Durham Region Groundwater Vulnerability and Highly Vulnerable Aquifer Edge Matching Review (GENIVAR, Dec 14, 2010)

CHAPTER 10: CONCLUSIONS AND NEXT STEPS

10.1 SUMMARY

This Assessment Report is a summary of the results of technical studies undertaken to identify the threats to municipal drinking water sources for the Ganaraska Region Source Protection Area. There are six existing municipal drinking water systems in the Ganaraska Region Source Protection Area. Three of these systems draw their water from surface water sources and three draw their water from groundwater sources.

The surface water systems have their sources in Lake Ontario and serve the larger communities of Port Hope, Cobourg, and the Village of Newcastle. These systems are classified as Type A intakes since they draw water from a Great Lake source. Intake Protection Zones 1, 2 and 3 are delineated to protect these surface water sources. No drinking water quality issues, conditions, or threats were identified in the Intake Protection Zones 1 and 2 for the three surface water systems. The delineation of an Intake Protection Zone 3, associated with a spill from a fuel pipeline, produced a significant ~~(local)~~ drinking water threat. The fuel pipeline intersects 20 stream segments that would result in an impact to the Newcastle Drinking Water System and 10 stream segments that would result in an impact to the Cobourg Water Treatment Plant and Municipality of Port Hope Water Treatment Plant.

In 2013, additional event based modeling was undertaken which identified significant drinking water threats: marina gasoline storage tank ruptures (fuel spill) impacting the Cobourg and Newcastle surface water supplies; and wastewater treatment plant disinfection failures impacting the Cobourg, Newcastle, and Port Hope surface water supplies.

None of the groundwater systems are considered GUDI (Groundwater Under the Direct Influence of surface water). All three systems therefore have a Wellhead Protection Area A through D delineated to protect the groundwater sources. No drinking water quality issues were identified for these systems.

For the wellhead protection areas, 15 parcels associated with ~~24~~ 14 drinking water threats were identified. Approximately 73% of the parcels affected are residential, 7% are agricultural, 7% are industrial, and 13% are municipal (i.e., septic systems at water treatment plants).

The water budget analyses completed (Conceptual Water Budget, Tier 1 Water Budget and Water Quantity Stress Assessment) indicate low stress levels in all but two watersheds. The two moderately surface water stressed watersheds are not associated with municipal drinking water systems. As such, no further water quantity stress assessment is required and there are no water quantity stresses.

10.2 DATA GAPS

The requirements of the Assessment Report are set out by the *Clean Water Act* (including the *General Regulations* and *Technical Rules*). While additional information and data would contribute to the overall findings, a data gap is only identified when the lack of information or data prevented the Source Protection Committee from meeting the requirements of the Act. Information requirements that would support continual improvement are discussed throughout the report. No data gaps have occurred in the Ganaraska Assessment Report.

10.3 ANTICIPATED IMPROVEMENTS FOR FUTURE ASSESSMENT REPORTS

The following updates should be considered in future versions of the Ganaraska Assessment Report:

- Investigation into the possibility of modeling other extreme event situations should occur. These could include, but are not limited to spills from transportation corridors (road, rail and shipping lanes) and low level radioactive waste clean-up activities.
- Further evaluation of conditions for Lake Ontario sources.
- Improvements to wellhead protection areas based on refined geological models.
- Revised mapping for significant groundwater recharge areas and highly vulnerable aquifers, incorporating edge mapping efforts.
- Updated threats counts, if applicable.

10.4 PREPARATION OF SOURCE PROTECTION PLAN

The Ganaraska Assessment Report findings ~~will be~~are used to develop policies for the Ganaraska Source Protection Plan that will serve to protect the sources of drinking water for the municipal systems in the Ganaraska Region Source Protection Area and Trent Conservation Coalition Source Protection Region. Policies ~~will be~~are developed by the Source Protection Committee in consultation with municipalities, Conservation Authorities, property and business owners, farmers, industry, health officials, community groups, and others working together to create a fair, practical, and implementable Source Protection Plan. Public input and consultation ~~will~~ play a significant role throughout the process. Formal public consultation periods ~~will~~ were~~be~~ held on the draft and proposed Ganaraska Source Protection Plan before it ~~is~~ was finalized and submitted to the Minister of the Environment and Climate Change in ~~by August 20,~~ 2012. Additional pubic consultation will occur when required under a Section 36 or 34 amendment.

GLOSSARY

LIST OF ACRONYMS

ACRONYM	EXPLANATION
AVI	Aquifer Vulnerability Index
CAMC-YPDT	Conservation Authorities Moraine Coalition & York - Peel - Durham - Toronto
CCS	Census Consolidated Subdivision
DNAPL	Dense non-aqueous phase liquid
GIS	Geographic Information System
GUDI	Groundwater Under Direct Influence (of surface water)
HVA	Highly vulnerable aquifer
IPZ	Intake Protection Zone
ISI	Intrinsic Susceptibility Index
MAC	Maximum acceptable concentrations
MASL	Metres above sea level
MDL	Method detection limit
SAAT	Surface to Aquifer Advection Time
SGRA	Significant Groundwater Recharge Area
SPA	Source Protection Area
SWAT	Surface to Well Advection Time
THM	Trihalomethane
TOT	Time-of Travel
UZAT	Unsaturated Zone Advection Time
WHPA	Wellhead Protection Area
WWAT	Watertable to Well advection Time

DEFINITION OF TERMS

TERM	DEFINITION
Advection	Transport by horizontal movement, as in the transport of heat and water vapour from one location to another by the horizontal movement of air or water.
Aesthetic Objective	Objectives established for drinking water quality parameters that may impair the taste, odour, or colour of water or which may interfere with good water quality control practices.
Agricultural Source Material	Any material that is from an agricultural source and is capable of being applied to land as a nutrient including manure produced by farm animals, runoff from farm-animal yards and manure storages, washwaters from agricultural operations, and organic materials produced by intermediate agricultural operations.
Anaerobic	A life or process that occurs in, or is not destroyed by, the absence of oxygen.
Anaerobic Bacteria	An organism that can survive and grow in an unoxygenated environment.
Anoxic	Being depleted of dissolved oxygen. This condition is generally found in areas that have restricted water exchange.
Anthropogenic	Refers to an effect, process, or material that is derived from human activities, as opposed to those occurring in biophysical environments without human influence.
Aquifer	A subsurface area of porous, permeable soil or rock – almost like a sponge – that can store and transmit significant amounts of groundwater.
Aquifer Vulnerability Index (AVI)	The Aquifer Vulnerability Index is a numerical indicator of an aquifer's intrinsic or inherent vulnerability to contamination expressed as a function of the thickness and permeability of overlying layers.
Aquitard	A subsurface layer of rock or sediment that permits limited transmission of groundwater.
Baseflow	Water that flows into a stream through the subsurface. It is the sustained flow (amount of water) in a stream that comes from groundwater discharge or seepage. Groundwater flows underground until the water table intersects the land surface and the flowing water becomes surface water in the form of springs, streams/rivers, lakes, and wetlands. Baseflow is the continual contribution of groundwater to watercourses and is important for maintaining flow in streams and rivers between rainstorms and in winter conditions.
Bedrock	Solid or fractured rock usually underlying unconsolidated geologic materials; bedrock may be exposed at the land surface.

TERM	DEFINITION
Biodegradation	The composition of a substance into more elementary compounds by the action of microorganisms such as bacteria.
Biofilm	An aggregate of micro-organisms in which cells adhere to each other and/or to a surface.
Calcareous	Soil that is chalky in appearance, containing calcium carbonate or magnesium carbonate.
Coagulation	Clumping of particles in wastewater to settle out impurities, often induced by chemicals such as lime, alum, and iron salts.
Conservation Authorities Regulation Limit	The area delineated on a map or series of maps filed at the head office of a conservation authority in accordance with the *Development, Interference with Wetlands and Alterations to Shorelines and Watercourses* regulation made under the *Conservation Authorities Act*.
Conservation Authorities Moraine Coalition	The Conservation Authorities Moraine Coalition consists of the nine conservation authorities with jurisdiction on the Oak Ridges Moraine.
Cyanobacterial Toxins	Naturally produced poisons stored in the cells of certain species of cyanobacteria. These toxins fall into various categories. Some are known to attack the liver (hepatotoxins) or the nervous system (neurotoxins); others simply irritate the skin. These toxins are usually released into water when the cells rupture or die. Health Canada scientists are more concerned about hepatotoxins than neurotoxins, because neurotoxins are not considered to be as widespread as hepatotoxins in water supplies.
Drinking Water System	Drinking water system means a system of works, excluding plumbing, that is established for the purpose of providing users of the system with drinking water and that includes (a) Any thing used for the collection, production, treatment, storage, supply, or distribution of water (b) Any thing related to the management of residue from the treatment process or the management of the discharge of a substance into the natural environment from the treatment system (c) A well or intake that serves as the source or entry point of raw water supply for the system.
Drinking Water Threat	This refers to an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the *Clean Water Act* as a drinking water threat.

TERM	DEFINITION
Drought	Drought is a complex term that has various definitions, depending on individual An extended period of time when low water conditions occur in a region. This occurs when a region receives consistently below average precipitation. Drought can have impacts on aquatic life and on water supply for human use and consumption.
Drumlin	A drumlin is an elongated mound of glacial sediment deposited parallel to ice flow.
Effluent	The discharge of a pollutant in a liquid form, often from a pipe into a stream or river.
Eutrophication	A process where lakes, streams or other water bodies receive too many nutrients. The surplus of nutrients contributes to too much growth of algae, weeds or other nuisance plants. The growth of algae, or algal blooms, lowers dissolved oxygen in the water.
Evapotranspiration	Evapotranspiration is the combined loss of water from a given area and during a specific period of time by evaporation from the soil surface and by transpiration from plants.
Exceedance	Violation of the pollutant levels permitted by environmental protection standards.
Geographic Information System (GIS)	A computer based system that has the capability to input, store, retrieve, manipulate, analyse, and output geographically referenced data.
Glaciofluvial	Glaciofluvial pertains to rivers and streams flowing from, on, or under melting glacial ice, or to sediments deposited by such rivers and streams.
Groundwater	Subsurface water that occurs beneath the water table in soils and geological formations that are fully saturated.
Groundwater Discharge	The water in a river or stream that comes from groundwater.
Groundwater Recharge	The inflow of water to a groundwater reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge.
Groundwater Under the Direct Influence (GUDI)	GUDI is a commonly used acronym for Groundwater Under the Direct Influence of Surface Water. This term refers to groundwater sources (e.g., wells, springs, etc.) where microbial pathogens are able to travel from nearby surface water to the groundwater source.
Groundwater Vulnerability	A measure of how easy or difficult it is for a contaminant to move from the surface to an aquifer. It is a measure of the amount of protection afforded by the subsurface material above the aquifer to a surface-based contamination source.
Headwater	The small tributaries and seepage areas that are the initial source waters of a stream or river.

TERM	DEFINITION
Highly Vulnerable Aquifer (HVA)	An aquifer that is susceptible to contamination from the surface. The depth and type of subsurface material over the aquifer affect its vulnerability.
Hydraulic Conductivity	A measure of a material's (such as soils, sediments, or rocks) ability to transmit water when submitted to a hydraulic gradient.
Hydraulic Gradient	Hydraulic gradient is the rate of change of pressure head per unit of distance of flow at a given point and in a given direction.
Hydrogeology	The study of the interrelationships of geologic materials and hydraulic processes.
Hydrograph	A graph that shows water level as a function of time.
Hydrological	Of hydrology
Hydrology	The scientific study of the properties, distribution and effects of water on the Earth's surface, in the soil, underlying rocks and in the atmosphere.
Hydrometric Station	A location where systematic records of stage (water level) or stage and discharge (flow) are obtained.
Impervious	Surfaces that resist or prevent the infiltration of water.
Infiltration	The process by which water on the ground surface enters the soil.
Indicator Parameters	Values that reflect the range of issues in the watershed and are most useful in assessing relative watershed health.
Intake Protection Zone	An area that is related to a surface water intake and within which it is desirable to regulate or monitor drinking water threats.
Interpolation	A method of constructing new data points within the range of a discrete set of known data points.
Intrinsic Susceptibility Index (ISI)	A calculated value that estimates the susceptibility of a given groundwater aquifer to contamination by activity or water on the surface at a given point. It is a numerical indicator of an aquifer's intrinsic susceptibility to contamination expressed as a function of the thickness and permeability of layers overlying the aquifer.
Kriging	A group of geostatistical techniques to interpolate the value of a random field at an unobserved location from observations of its value at nearby locations.

TERM	DEFINITION
Livestock Density	Relates to the number of farm animals grown, produced or raised per square kilometre of an area and, under the *Clean Water Act*, is determined by dividing the nutrient units generated in each area by the number of acres of agricultural managed land in that area where agricultural source material is applied.
Macroinvertebrates	Animals lacking a spinal column that are visible with the unaided eye.
Managed Land	Lands to which agricultural source material, commercial fertilizer, or non-agricultural source material is applied.
MODFLOW (MODular FLOW)	A groundwater flow simulation model software developed by US Geological Survey.
Moraine	An accumulation of earth and stones carried by a glacier that is usually deposited into a high point like a ridge. The debris or rock fragments brought down with the movement of a glacier.
Municipal Drinking Water System	A water treatment facility that is either owned and or operated by the municipality to provide drinking water to residents in that community. This may be water from groundwater (wells) or surface water sources like rivers and lakes.
Municipal Drinking Water System	A water treatment facility that is either owned and or operated by the municipality to provide drinking water to residents in that community. This may be water from groundwater (wells) or surface water sources like rivers and lakes.
Non-Agricultural Source Material	Any material that is not from an agricultural source and is capable of being applied to land as a nutrient, such as pulp and paper biosolids, sewage biosolids, yard waste, fruit and vegetable peels, and food processing waste.
Overburden Wells	Groundwater wells tapping water from the unconsolidated geologic material above the bedrock.
Palaeozoic	The geologic era that lasted from about 540 to 250 million years ago. During the early Paleozoic, much of North America was covered by a warm, shallow sea with many coral reefs. During the late Paleozoic, huge, swampy forest regions covered much of the northern continents.
Percolation	The downward movement of water in the ground through porous soil and cracked or loosely-packed rock.
Permeability	A measure of the ability of a material (such as soils, sediments, or rocks) to transmit water through its pore spaces.
Permit to Take Water	Any person that takes more than 50,000 litres of water per day from any source requires a Permit to Take Water, issued by the Ontario Ministry of the Environment and Climate Change Director under the *Ontario Water Resources Act*, unless they meet the criteria for certain exempted water takings.

TERM	DEFINITION
Physiography	A science that deals wit the origins and development of landforms.
Runoff	Water that moves over land rather than being absorbed into the ground. Runoff is greatest after heavy rains or snowmelts, and can pick up and transport contaminants from landfills, farms, sewers, industrial or commercial operations, or other sources.
Safe Drinking Water Act	The legislation passed by the Ontario government, which recognizes that the people of Ontario are entitled to expect their drinking water to be safe and provides for the protection of human health and the prevention of drinking water health hazards through the control and regulation of drinking water systems and drinking water testing.
Significant Groundwater Recharge Area (SGRA)	An area within which it is desirable to regulate or monitor drinking water threats that may affect the recharge of an aquifer.
Source Protection Area (SPA)	The area over which a conservation authority has jurisdiction under the *Conservation Authorities Act* is established as a source protection area under the *Clean Water Act*. The Ministry of the Environment and Climate Change can expand or create a source protection area to include parts of Ontario that are not included in Conservation Authority jurisdiction. O. Reg. 284/07, made under the *Clean Water Act*, establishes source protection areas across Ontario.
Source Protection Authority	A conservation authority or other person or body that is required to exercise powers and duties under the *Clean Water Act, 2006*. Where a conservation authority exists, it becomes the source protection authority for the area. The source protection authority can include additional members to represent areas outside of Conservation Authority jurisdiction. O. Reg. 284/07, made under the *Clean Water Act*, establishes source protection authorities across Ontario.
Streamflow	The surface water discharge that occurs in a natural channel.
Subwatershed	An area that is drained by a tributary or some defined portion of a stream.
Surface Water	All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.).
Surface Water Intake	A structure that draws water from a surface water body (lake, river or stream) for a water supply system.
Threat	See Drinking Water Threat
Tier 1 Water Budget	A water budget developed using a geographical information system or equivalent to assess groundwater flows and levels, surface water flows and levels, and the interactions between them.

TERM	DEFINITION
Tier 2 Water Budget	A water budget developed using computer based, three-dimensional groundwater flow models and computer based, continuous surface water flow models to assess groundwater flows and levels, surface water flows and levels, and the interactions between them.
Till	An unsorted or very poorly sorted sediment deposited directly from glacial ice. Till composition is variable ranging from clays to mixtures of clay, sand, gravel and boulders.
Time of Travel (TOT)	With respect to groundwater, the length of time that is required for groundwater to travel a specified horizontal distance in the saturated zone. With respect to surface water, the length of time that is required for surface water to travel a specified distance within a surface water body.
Topography	The physical features, especially the relief and contours, of the land surface.
Transport Pathway	A conduit that provides a direct path to a groundwater aquifer or a surface water body that is used as a source of drinking water and increases the potential for contamination (e.g., abandoned wells, tile drainage, ditches, gravel pits, etc.)
Uncertainty Factor	A rating of "high" or "low" assigned to the vulnerability delineation and scoring. It is based on an assessment of the confidence the hydrologist or hydrogeologist had in the data, methods, models, calibration and/or the understanding of the hydrogeological/hydrological features.
VIEWLOG	A borehole data management and integration system software developed by EarthFX.
Vulnerable Areas	Under the *Clean Water Act*, includes: • significant groundwater recharge areas • highly vulnerable aquifers • surface water intake protection zones • wellhead protection areas
Vulnerability Scores	Scores assigned using a comparative scale to quantify the susceptibility to contamination within vulnerable areas. A higher score means a higher susceptibility to contamination.
Water Budget	An accounting of the inputs and outputs of water in a hydrologic system. A water budget quantifies the components of the hydrologic cycle and the human uses of water using the available data and a water balance equation based on the law of conservation of mass.
Watershed	An area of land that is drained by a watercourse and its tributaries into a particular body of water such as a lake, bay or large river.
Well Field	An area containing one or more wells that produce usable amounts of water.

TERM	DEFINITION
Wellhead Protection Area (WHPA)	The surface and subsurface area surrounding a well that supplies a drinking water system through which contaminants are reasonably likely to move so as to eventually reach the well.
Wetlands	An area, saturated by surface or groundwater, having vegetation adapted for life under those soil conditions (i.e., swamps, bogs, fens, marshes).